UT/CES-RR-10

RECEIVED BY TIC MAR 21 1979

OPERATIONS RESEARCH AND SYSTEMS ANALYSIS OF GEOTHERMAL/GEOPRESSURED RESOURCES IN TEXAS

C. Dale Zinn

December 1977

MASTER

Research Report No. 10

CENTER FOR ENERGY STUDIES

ces

THE UNIVERSITY OF TEXAS AT AUSTIN

DISTRIBUTION ... UNLIMITED

OPERATIONS RESEARCH AND SYSTEMS ANALYSIS
OF GEOTHERMAL/GEOPRESSURED
RESOURCES IN TEXAS

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or 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.

FINAL REPORT

December 1977

This study was funded in part by the Energy
Research and Development Administration
under contract No. EG-77-S-05-5443.

Principal Investigator:

C. Dale Zinn
Center for Energy Studies
The University of Texas at Austin

MASTER

TABLE OF CONTENTS

I. INTRODUCTION

The Center for Energy Studies at The University of Texas at Austin has contracted with the Energy Research and Development Administration (ERDA) to perform an operations research and systems analysis of the geothermal/geopressured resources in Texas. To the present time the planning support project has concentrated on the development of the geopressured resources located along the Texas Gulf Coast. A team at Louisiana State University is performing a similar service with regard to the geopressured resources of the Louisiana Gulf Coast.

The overall objective of these projects is the formulation of a coordinated regional plan for the development of the geothermal/geopressured energy resources in the Texas/Louisiana Region. The primary goal of this project is the preparation and analysis of preliminary geothermal/geopressured energy development scenarios for the state of Texas. A secondary goal of the first phase of the study is the establishment of a regional organization to continue the planning support activity so that more comprehensive development plans can be formulated and analyzed.

This report describes the status of the project and reflects the accomplishment of the goals of the project. Additionally, the report outlines the projected continuation of the present work and the work directed toward establishment of additional objectives.

The first portion of the report details the work that has been accomplished. The second portion sets forth the plans for the continuation of this planning support effort. A summary section containing general conclusions and recommendations is included. The appendices to the report yield additional detailed information related to the development scenarios that have been generated by the project.

II. RESEARCH ACCOMPLISHED

As discussed in the proposal for this research project, subtasks 1 through 6 of task 1 have been accomplished. Subtask 1 required a review of existing data pertinent to preliminary geopressured development scenarios. During the course of this review, the planning team discovered that there is a wide variance in the estimates of the amount and location of the Texas geopressured resources. The variance in these estimates is evidenced by the following ranges that were found for the geopressured resources of the Texas/Louisiana Gulf Coast:

Resource base	
Thermal	19.5-176,000 quads
Mechanical	1.2-693 quads
Gas	13.6-111,500 quads
Recoverable energy	
Thermal	19.5-2,058 quads
Gas	0.0001-52,000 quads
Electricity	0.1-110,000 megawatt-centuries

The reasons for these differences are demonstrated by comparing the various assumptions given in table 1. The ranges are as follows:

Area	29,000-154,000 square miles
Productive area	1-50 percent
Thickness	8,000-19,680 feet
Sandstone	5.4-60 percent

Table 1

ASSUMPTIONS FOR VARIOUS RESOURCE ASSESSMENTS

	Dorfman [1] Texas	Gould [2] Intercomp	Hawkins [3] LSU	Hise [4] LSU	House [5] Livermore	Jones [6] LSU	Myers [7] Livermore	Papadopulos [8] USGS	Schnadelbach [9] de Laureal
Area (sq mi)	100,000	60,000	42,000	100,000	30,600	154,000	29,000	55,970	
Area productive (%)		22.5			5		1-50		
Thickness (ft)	10,000	10,000	8,000	10,000	15,000	13,120-19,680	15,000	9,482-13,715	
Sandstone (%)	15	7.5	5.4	10	56	50	10-60	12-49	
Porosity (%)	22	20	20	20	20	25	15-35	18-22	
Dissolved natural gas (scf/bbl)	35	30-40	20.3	30	19-44	18.8-164	1-30	28.2-46.3	107
Water in place (trillion/bbl)	164	10	0.67	100	10.9	1,492	0.126-88.2	657	1,042
Gas in place (trillion ft^3)	5,735	>300	13.6	3,000	221.7	100,000	0.126-2,646	23,636	111,500
Recovery (%)	5	50		5	2-100	>1.1	0.1-70	0.12-3.3	
Recoverable water (trillion bbl)	8.2	5.0		5.0		>17.1	0.000126-61.7	0.79-21.7	
Recoverable gas content (scf/bbl)	30	30		25		30			
Recoverable gas (trillion ft^3)	256	150		125		>1,146	0.0001-1,000	768	

Porosity	15-35 percent
Dissolved natural gas	1-164 standard cubic feet per barrel
Recovery	0.1-100 percent

In addition to the assumption variations illustrated in table 1, implicit factors are significant in the resource assessment process. For example, resource assessment is closely linked to the development concept that is envisioned in making the resource assessment. If one perceives that development means the production of direct electrical energy as well as the production of methane, one probably restricts his assessment to the amount of resource that is likely to have a fluid temperature in excess of 300 degrees Fahrenheit. However, if one envisions that the geopressured resource will be developed primarily as a producer of methane, a restriction to an assessment of resources having temperatures in excess of 300 degrees Fahrenheit is not likely. This interaction between resource assessment and resource use is largely unstated but highly significant in understanding and describing the development process.

This variance has made the selection of assumptions for the resource base for the development scenarios somewhat difficult. The Texas research team decided to use the information that was available as a result of the resource assessment activity carried out by the Texas Bureau of Economic Geology (BEG) under the direction of Dr. Don Bebout.

Subtask 2 of task 1 required the formulation and review of assumptions for constructing development scenarios based upon high, nominal, and low energy development rates. Since the BEG resource data did not directly contain estimates of the amount of fluid that could be expected to be recovered, the research team decided to formulate a set of parameters that would represent these three levels of development. Specific values for these parameters are given in appendix A for each of the five identified Texas Frio formation fairways. The values given in appendix A were selected by using the resource assessment data and by consultation with experts, notably Drs. Bebout, Dorfman, and Knapp of The University of Texas Geothermal Research Group.

Subtask 3 of task 1 required the formulation of initial geothermal/ geopressured development scenarios. The Texas operations research team accomplished this subtask by using the results of subtasks 1 and 2 to establish a resource base for the development scenarios. This resource base information was then combined with information describing drilling time for production and disposal wells, construction time for power and fuel processing plants, the permitting process, and drilling rig availability to produce a set of initial development scenarios for the five identified fairways in Texas. These development scenarios, which take the form of logically constructed sequences of events that result in a time line for power on line and gas in production, are given in detail in appendix A.

Subtask 4 of task 1 required review of the initial development scenarios with representatives of local and state governments, industry, and community groups. This activity has been completed to the extent that officials of the electric utility industry along the Texas Gulf Coast--i.e., Gulf States Utilities, Central Power and Light Co., and Houston Lighting and Power Co.--and several agencies of the state of Texas have been contacted and have reviewed the initial scenarios.

Meaningful contact with local governmental agencies and community groups has been most difficult to establish. In fact, no review of the scenarios has been accomplished by any governmental entity below the state level. This is not to say that an effort has not been made by the operations research team to accomplish this task. In fact, a representative of the local council of governments in Brazoria County has been contacted, and Dr. Zinn has agreed to speak to the joint council meeting in order to describe the operations research project and to solicit local input to the planning process. Unfortunately, the council was extremely slow in setting up this meeting, and therefore no meaningful discussion has yet been held with this important group. The initial discussions are scheduled for the January 19, 1978, meeting of the Brazoria County Cities Association.

Subtask 5 of task 1 required revision of the preliminary scenarios to reflect substantive comments obtained in the review process. Since no substantive comments regarding these development plans were received from any of the reviewers, no revisions of the preliminary scenarios were made. This fact should not be construed to mean that the development plans should be accepted as the consensus plan for geopressured developments in the state of Texas. The most likely cause of the lack of comments is either that the reviewers did not fully understand what was involved in the planning process, or that they did not view the problem as being of enough immediate interest to warrant a great expenditure of time and effort on the part of their staff for analysis of the implications of these plans.

Subtask 6 of task 1 required a detailed analysis of the preliminary scenarios. The analysis is given in a later section of this report and thus completes the work described in task 1 of the proposal for this project.

Task 2 of the proposal deals with the establishment of a regional planning organization. Work on this project has revealed that this should be identified as a regional (or state) planning support activity.

Subtask 1 of task 2 required identification of organizations in the state of Texas that have an interest in and/or responsibility for geothermal/geopressured resources. This subtask has been substantially completed in that the Texas state agencies having responsibility for geothermal/geopressured resources have been identified. These agencies and their interaction with geopressured energy development are discussed in some detail in a later section of this report. In addition, several industrial organizations, notably the Texas Gulf Coast utilities, have been contacted by the project research group. Detailed contact with the oil and gas industry regarding this operations research project has recently been initiated and will be pursued more vigorously in the future.

Subtasks 2 and 3 of task 2 deal with the creation of a regional planning support organization. Several preliminary structures for this planning support activity have been proposed in meetings with representatives of the Division of Geothermal Energy (DGE) of the Department of Energy and in an advance copy of a proposal for continuation of this research project.
A variety of intrastate and interstate problems have made the accomplishment

of the task impossible at this time. It is hoped that the response by the Governor of Texas to DGE's request for designation of an official Texas representative for this matter will assist in clearing up these difficulties.

III. SUMMARY OF PRELIMINARY DEVELOPMENT SCENARIOS

Details of the preliminary development scenarios for the geopressured resources of the Frio formation in Texas are given in appendix A of this report. These scenarios were developed using a computer-oriented planning program that is code-named GEODEV. This program contains an algorithm for estimating resource capacity and reservoir performance based upon information obtained from geologic reports and reservoir simulation studies. GEODEV uses estimates of the following parameters to compute the total amount of recoverable energy from each fairway:

1. Fluid temperature
2. Thickness of formation
3. Porosity of formation
4. Permeability
5. Recoverability
6. Gas content of the fluid
7. Fairway area
8. Fraction of fairway producible

Estimates of these paramaters were obtained from the resource assessment data developed by the Bureau of Economic Geology and from consultation with the researchers involved. These estimates are combined with information obtained from drilling experts and from similar projects involved with developing California's hydrothermal resources to obtain a time-line for development of each of the five identified fairways in the Frio formation in Texas.

The lifetime over which the resource is to be produced is specified in order to balance well spacing with regional flow rate. The time required to drill a producing well, the time required to drill a dry well, and the success ratio combine to yield the total average time needed to establish a producing well. An estimate of the availability of drilling rigs is combined with this information to produce an estimate of the number of production wells that can be completed per year.

The number of desirable simultaneous construction projects and the time delay between the decision to undertake a project and the actual start of construction combine with the plant construction time to detail the time-line for production. An outline for a three-year development scenario for a geopressured power facility is given in appendix B.

The information described in the preceding paragraphs is processed by the computer-oriented planning program GEODEV to produce the development scenarios that are attached as appendix A. On the basis of optimistic estimates of the parameters used in GEODEV, the total equivalent recoverable energy in the Frio formation along the Texas Gulf Coast will support 2,575 megawatts by the year 2000. This total consists of 875 megawatts from thermal and hydraulic energy from the fluids and 1,701 megawatts supported by the methane produced from the resource. Total methane production from these Frio resources is approximately 4 trillion standard cubic feet by the year 2020. Details of the power and gas production are found in the production schedules given in appendix A.

One possible method for disposing of the geopressured fluid is to reinject it into the formation from which it was produced. This method is expensive in terms of the increased cost of the reinjection wells and in terms of the amount of energy required for reinjection. However, discussion with the reservoir modeling group, primarily Dr. Roy Knapp, at The University of Texas indicates that this method of disposal may be useful in enhancing the recovery of methane from the formations. Preliminary estimates are that deep reinjection may increase the lifetime of the reservoir by a factor of two and the total recovery by a factor of three. Another possible beneficial effect of this method is that subsidence may be minimized.

Because of these interesting possibilities, a set of development plans based upon optimistic estimates of the key parameters considering deep reinjection has been produced and is included in appendix A. The total gas production under this scenario is 5.89 trillion standard cubic feet by the year 2020. If the estimates of increased reservoir life and increased production are reasonably accurate, production would continue until approximately 2040 with a total recovery of approximately 12 trillion standard cubic feet of gas.

Returning to the optimistic development plans for the shallow reinjection scheme, the first plant will be completed in 1982 in the Brazoria fairway. Construction will continue throughout the Texas Gulf Coast until 2014 when the last plant will be completed in Hidalgo County. This program requires the construction of 59 plants and 276 production wells over a period of 35 years.

Pessimistic estimates of the parameters that affect geopressured development yield a highly negative preliminary evaluation of the resource based upon direct energy conversion alone. Even considering the potential gas content of the fluid, the amount of recoverable energy is relatively small (although it may be potentially significant for specific areas of the coast).

Details of production schedules based upon optimistic, nominal, and pessimistic estimates of the resource characteristics yield the scenarios given in appendix A.

Bar charts of events have been constructed for a single plant development and for exploitation of the entire Brazoria fairway. These constitute appendix B.

Economic Analysis

A cash flow model of the development scenarios for the Texas Gulf Coast has been constructed. This model uses continuous cash flows and continuous discounting methods to analyze the economics associated with the optimistic development scenarios for the Frio formation geopressured resources of the Texas Gulf Coast. The measures of economic performance are the present worth of the cash flows that describe the development scenarios or the discounted rate of return that these cash flows describe.

The optimistic development scenario for the Brazoria County geopressured resource is discussed in detail in the next section. Following that discussion is a summary of information for the optimistic scenarios of the other Texas Gulf Coast Frio formation fairways.

Two situations were examined for the Brazoria County fairway: the shallow and deep reinjection development plans. Shallow reinjection places the effluent from the power plant into saline aquifers at relatively shallow depths. The deep reinjection scenario places the effluent back

Table 2

DATA FOR BRAZORIA COUNTY FAIRWAY
SHALLOW REINJECTION SCENARIO

Parameter	Value (million $)
Capital cost (Fuel plant)	$ 10 per 70,000 bbl/day
Capital cost (Power plant)	$ 3 per 5-Mw capacity
Capital cost (Producing well)	$ 2.8
Capital cost (Disposal well)	$ 0.5
Number of producing wells per plant	3
Flow rate	94,270 bbl/day
Methane content	50 scf/bbl
Number of disposal wells per plant	6
Operating costs (fuel) as a fraction of capital cost:	
Operation and maintenance	0.0250
Overhead	0.0200
Insurance	0.0035
Property tax	0.0100
Operating costs (power) as a fraction of capital cost:	
Operation and maintenance	0.0620
Overhead	0.0200
Insurance	0.0035
Property tax	0.0100
Methane royalty rate	0.125
Geothermal royalty rate	0.125
Value of brine	$ 0.08 per bbl
Price of methane	$ 1.75 per thousand ft^3
Price of electricity	$ 0.042 per kwh
Generating capacity available for sale per plant	80% of 35 Mw
Natural gas severance tax rate	0.075
Electricity regulation tax rate	0.003
Corporate income tax rate	0.48
Depreciation method	Straight line, no salvage
Lifetime	30 years
Depletion allowance	0.10 of value of brine

into the producing reservoir, which varies in depth from 12,000 to 20,000 feet. Deep reinjection is much more expensive in terms of both initial cost and operation, but it may aid in maintaining reservoir pressure, increasing production of fluids, and minimizing surface subsidence problems.

Table 2 shows the data used for the economic analysis of the shallow reinjection scenario. A computer-oriented economic model entitled GEOCON was used to analyze these data to determine the discounted cash flow rate of return. The rate of return obtained by this method is 15.5 percent.

Taking into consideration that this economic model is simplified and that economic considerations of utility and fuel-producing companies are different, the conclusion is that this rate is at a level that appears interesting. More detailed modeling needs to be done to investigate the effects of separating fuel producers from utility companies and to better represent economic details such as the handling of intangible drilling costs, production tax credits, and depletion allowance based upon energy values. Preliminary investigations of some of these factors are given in a later section of this report.

An important use of the economic model is the investigation of which parameters have a significant impact on the rate of return. The investigation is accomplished by a form of sensitivity analysis in which the measure of sensitivity that is used is

$$S = \frac{\Delta\%\ \text{Rate of return}}{\Delta\%\ \text{Parameter}}$$

If S = 0, a change in the parameter has no effect on the rate of return. S<0 implies that the rate of return decreases as the parameter increases, and S>0 implies that the rate of return increases as the parameter increases. Increasing values of |S| indicate increasing sensitivity. The parameters considered for sensitivity analysis are those that are subject to government regulation or those that could be affected by improved technology resulting from government-funded research and development activities. Table 3 summarizes these results.

Examination of the information presented in table 3 reveals that for this scenario the parameter that has the greatest effect on the rate of return is the price of electricity. In most cases, this parameter is not directly controlled by the producers but is regulated in a somewhat complex manner by state public utility commissions. The parameters that rank second and third for this scenario are of interest since they may be affected by research and development activities. As an illustration, a 10 percent reduction in the capital cost of a fuel plant will result in an increase of 0.6 percent in the rate of return. A 10 percent reduction in the capital cost of a power plant will result in an increase of 0.5 percent in the rate of return.

This information gives some insight into what parameters are important to consider in the economic sense and can aid in establishing some limits on the amount of research and development money that can reasonably be spent on these efforts. Quantification of this information will be done in the course of more detailed economic analyses.

Table 3

RESULTS FOR BRAZORIA SHALLOW REINJECTION SCENARIO

Parameter	Sensitivity	Rank
Gas price	0.324	4
Capital cost (power)	-0.339	3
Capital cost (fuel)	-0.413	2
Capital cost (wells)	-0.084	5
Electricity price	0.729	1
Depletion allowance	0.033	6

Rate of Return for this scenario is 15.5%.

Although the price of gas produced from the resource ranks fourth for this scenario, it is worthy of serious consideration. For example, an increase in gas price from $1.75 per thousand cubic feet to $2.00 per thousand cubic feet--an estimate of the unregulated price since this is the approximate price of new intrastate gas--will yield an increase in the rate of return of approximately 0.675 percent. Because this factor is a policy item that is influenced by governmental action, this information should prove valuable to the decision-making process.

Consideration of the deep reinjection scenario for the Brazoria fairway yields some extensive changes in the development of the geopressured energy resource. A power plant will probably still be constructed to recover the thermal and hydraulic energy in the fluid; however, instead of being sold as electrical energy, a significant portion of this energy will be used to reinject the used fluid into the producing reservoir. Since the reinjection wells are likely to be located at some distance from the fuel plant, the energy required for reinjection will probably be converted to electrical energy and used to drive electrical pumps at the reinjection wellhead.

The changes that occur in the input parameters when the deep reinjection method is used are outlined in table 4. Using these data, the rate of return for the deep reinjection scenario is approximately 7 percent. The sensitivity of the parameters for the deep reinjection scenario is given in table 5.

Analysis of this information reveals that the rate of return for the deep reinjection scenario is most sensitive to the price of the gas that is extracted. In fact, in order to achieve a rate of return of the

Table 4

DATA FOR BRAZORIA COUNTY FAIRWAY DEEP REINJECTION SCENARIO

Parameter	Value
Capital cost (disposal well)	$ 2.5 million
Flow rate	128,000 bbl/day
Generating capacity available for sale	0% of 50 Mw
Lifetime	60 years

Table 5

RESULTS FOR BRAZORIA DEEP REINJECTION SCENARIO

Parameter	Sensitivity	Rank
Gas price	1.367	1
Capital cost (power plant)	-0.204	3
Capital cost (fuel plant)	-0.649	2
Capital cost (wells)	-0.149	4
Depletion allowance	0.028	5

Rate of Return for this scenario $\approx$ 7%.

approximate magnitude of that obtained by the shallow reinjection scenario, it is necessary to increase the price of gas to $4.00 per thousand cubic feet. At this point a 10 percent increase in the price of gas will result in a 2 percent increase in the rate of return, from 15 percent to 17 percent.

Another parameter that is not explicitly stated in the deep reinjection scenario warrants consideration. Although the amount of energy that will be needed for deep reinjection has not been accurately calculated at this time, preliminary results indicate that practically all of the thermal and hydraulic energy will be required for reinjection. This finding will be investigated in greater detail; however, in the meantime it is instructive to examine the effect of variation in the amount of electrical energy available for sale on the rate of return for this scenario. Table 6 summarizes this investigation.

The results of economic investigation of the optimistic development scenarios for the Texas Gulf Coast Frio formation fairways are summarized in tables 7 through 9. For each fairway, the following information is given:

1. Rate of return for the shallow reinjection scenario
2. Parameter sensitivity for the shallow reinjection scenario

In each case the parameters that are different from those of the Brazoria fairway shallow reinjection scenario are listed, along with their new values.

The Armstrong fairway, located in Kenedy County, does not show a positive rate of return; therefore, no sensitivity analysis for this

Table 6

EFFECT OF VARIATION IN NET ELECTRICAL OUTPUT

Fraction of electrical capacity available for sale	Rate of return
0	14.69
0.15	15.76
0.30	16.79
0.45	17.80
0.60	18.78

The sensitivity of this parameter is 0.126.

Table 7

ECONOMIC ANALYSIS: DATA AND RESULTS FOR
MATAGORDA FAIRWAY

Parameter	Value
Number of production wells per plant	6
Flow rate	10,690 bbl/day
Generating capacity available for sale per plant	80% of 8 Mw

Parameter	Sensitivity	Rank
Gas price	0.6203	3
Capital cost (power plant)	-0.4345	4
Capital cost (fuel plant)	-0.3765	5
Capital cost (wells)	-0.6324	2
Electricity price	1.1239	1
Depletion allowance	0.0648	6

Rate of return for this scenario is 7.25%.

Table 8

ECONOMIC ANALYSIS: DATA AND RESULTS FOR
CORPUS CHRISTI FAIRWAY

Parameter	Value
Number of production wells per plant	3
Flow rate	22,853 bbl/day
Generating capacity available for sale per plant	80% of 8.5 Mw

Parameter	Sensitivity	Rank
Gas price	0.4949	2
Capital cost (power plant)	-0.3594	4
Capital cost (fuel plant)	-0.3631	3
Capital cost (wells)	-0.3091	5
Electricity price	1.0997	1
Depletion allowance	0.0454	6

Rate of return for this scenario is 10.36%.

Table 9

ECONOMIC ANALYSIS: DATA AND RESULTS FOR HIDALGO FAIRWAY

Parameter	Value
Number of production wells per plant	6
Flow rate per well	18,718 bbl/day
Generating capacity available for sale per plant	80% of 14 Mw

Parameter	Sensitivity	Rank
Gas price	0.4643	2
Capital cost (power plant)	-0.3490	5
Capital cost (fuel plant)	-0.3652	3
Electricity price	1.0196	1
Depletion allowance	0.0425	6

Rate of return for this scenario is 10.6%

fairway was developed. The overall impact of not developing this fairway is minimal since it is a small project in terms of usable resources.

This preliminary economic analysis of the development scenarios for the Texas Gulf Coast Frio formation geopressured resources indicates that the development plan using shallow reinjection for disposal of the fluids is economically interesting with gas and electricity priced at or near current price levels. Analysis of the deep reinjection plan, a method which may be required because of subsidence problems, indicates that gas prices will have to increase significantly from current levels before this plan becomes attractive.

As previously mentioned, the economic model with which these investigations were made is relatively simple. For example, all capital costs such as the installed cost of power plants, fuel plants, and the cost of drilling wells are handled as depreciable costs. This method makes more difficult the investigation of items such as the effect of allowing intangible drilling costs to be claimed as expense items rather than depreciable assets. However, the impact of this factor can be estimated using the results of the model. The oil and gas industry has traditionally classified between 50 percent and 75 percent of the cost of drilling a well as intangible expenses. The effect of this procedure on a geopressured well is to lower the effective drilling cost by 25 percent to 37.5 percent.

The impact of this method on the Brazoria fairway optimistic scenario is to increase the rate of return by 0.2 percent to 0.3 percent, not a dramatic change. The reason is probably the mix of capital involved in the development plan since the cost of drilling wells is approximately 25 percent of the total investment in the plant. Therefore, if a different scheme of development is envisioned, such as that proposed in [10], the impact of allowing intangible drilling costs to be treated as expenses may be considerably more significant.

Another factor that deserves some comment is the treatment of depletion allowance. The current investigations used a depletion allowance based upon 10 percent of the value of the brine in the geothermal fluids. The value of this brine was estimated to be $0.08 per barrel. This value was selected since it is the basis for the depletion allowance currently in existence. An interesting question to entertain is what would be the effect of a depletion allowance based upon the energy value of the fluid. If gas is valued at $2.00 per thousand cubic feet, the value of the gas is approximately $0.10 per barrel. The thermal and hydraulic energy value of the fluid is approximately $0.05 based upon its energy equivalent in relation to natural gas priced at $2.00 per thousand cubic feet. This analysis yields a total energy value of $0.15 per barrel. Even though this value is nearly double the brine value that was used, it does not appear that this fact would have a great effect on the rate of return of the scenarios since the sensitivity of all scenarios to the depletion allowance was considerably less than to the other parameters.

The effect of unregulated prices for gas produced from geopressured fluids is indicated by the sensitivity coefficients given earlier in this report. The importance of this factor is dramatically illustrated by considering the deep reinjection scenario where a gas price of $4.00 per thousand cubic feet is required to produce a rate of return of approximately 15 percent.

An item of particular interest is the allowance of a tax credit based on the production of gas from the geopressured resources. A tax credit of $0.50 per thousand cubic feet of gas produced from these resources was proposed by the United States Senate in its version of the energy legislation that is currently under consideration by the U.S. Congress. This credit could have a profound effect upon the development of geopressured energy resources. Investigations with the economic model GEOCON indicate that interesting rates of return for the development scenarios can be achieved with reasonably low gas prices. The internal rate of return considering this tax credit is given in the following table:

Gas price per thousand cubic feet (dollars)	Rate of return (percent)
1.00	15.69
1.25	16.39
1.50	17.08
1.75	17.78

The effect of this tax credit on the economics of geopressured resource development can be illustrated by considering a simple cash flow analysis. For notational convenience let

R = Revenue

E = Expenses

TI = Taxable income

ATE = After tax earnings

T = Taxes

t = Tax rate

q = Quantity of gas sold in thousand cubic feet

p = Price of gas per thousand cubic foot

k = Tax credit per thousand cubic foot

Now, ATE = R - E - T, and T = (R-E)t - kq. Since R = pq,

$$T = (pq - E)t - kq$$

and

$$ATE = pq - E - [(pq - E)t - kq]$$

$$ATE = pq - pqt + kq - E + Et$$

$$ATE = pq(1 - t) + kq - E(1 - t)$$

$$ATE = [p(1 - t) + k]q - E(1 - t).$$

Therefore, the contribution to aftertax earnings of the production and sale of one thousand cubic feet of gas is $[p(1 - t) + k]$. If the tax rate is 48 percent (that is, $t = 0.48$) and the price of gas is $1.75 per thousand cubic feet, the contribution to aftertax earnings is 1.41 per thousand cubic feet. However, if there is no production tax credit, this contribution must be provided by the price of gas alone, which requires a price of $2.71 per thousand cubic feet. This discussion illustrates the impact that a governmental decision concerning tax credits can have on the development of the geopressured resources.

The results reported in this paper are by no means the last word on the economics of developing the Texas geopressured resources. As previously mentioned, refinements of the economic model, changes in the input parameters, research and development activities, governmental actions, and other development alternatives may have a significant effect on the economics of developing these geopressured resources. A primary function of future operations research work will be to analyze the results of these factors, particularly as they influence the planned development of the resource.

IV. REVIEW OF SCENARIOS

State Agencies

A program of interaction with governmental agencies, industry, and the general public is under way. In particular, communication has been established with a number of state agencies, of which the following are most directly involved with the development of geothermal/geopressured resources.

1. Texas Railroad Commission

The Texas Railroad Commission has been charged by the state legislature to regulate the exploration, development, and production of geothermal energy and associated resources in Texas, on both public and private land. Current regulations cover three basic operations: well drilling, production of geothermal fluids, and disposal of spent fluids. This discussion deals primarily with applications which must be filed and permits which must be obtained, and the amount of time necessary to complete those actions.

Obtaining permits for drilling geothermal development and production wells should not present any great difficulties unless there are significant changes in the current procedures. Drilling permits are issued by the regional offices of the Railroad Commission, where processing will normally require four or five days. A separate application must be filed for each well that is to be drilled; however, this requirement should not cause any problems because of the speed with which permits can be obtained. Statewide rules establish minimum acreage and spacing requirements to control well densities. Where no special field rule is applicable, the general requirement is for 40 acres as the minimum acreage per well. Special field rules generally require 640 acres for a gas well. There are not as yet any special field rules for a geothermal resource well. Should there be a request for an exception to an applicable density rule, the Railroad Commission staff must study the application at greater length, resulting in a delay of approximately 45 days. Should some outside interest protest such a permit, public hearings would be required with delays as long as 120 days. It seems doubtful that requests for density rule exceptions would be made for geothermal resource wells. Some cities in Texas have ordinances restricting drilling activities inside the city limits, but this fact probably does not affect the development plants. County governments will probably not be involved in the drilling/permitting process. Monthly production reports must be filed with the commission, but this requirement is a routine one that should not cause any difficulty in geopressured development.

The Railroad Commission may regulate the production of fluids from geothermal resource wells. The commission classifies all production wells under its jurisdiction as either oil, gas, or geothermal resource wells. Geothermal resource ownership disputes may arise in Texas between surface rights owners and mineral rights owners of land. These disputes would likely delay development by significantly lengthening the time required to obtain a valid lease for the drilling operations. Litigation will probably be required to solve disputes of this kind. If such disputes are litigated, a completed legal study indicates that the courts will probably rule that geothermal resources are minerals.

Among other responsibilities, the Railroad Commission must approve any agreement for voluntary unitization of an oil or gas field in the state of Texas. However, Texas does not have a compulsory, or majority consent, unitization law despite numerous legislative proposals for one. The present law applies only to oil or gas fields and would have to be amended to embrace geothermal resources, if that becomes desirable. Since the development scenarios described in this report require relatively large drainage areas for geopressured resource development, unitized operations of the resource field might be necessary for economy, and to protect the correlative rights of all property owners in the field. A legal study of this matter has been initiated, and consideration will be given to the need for additional legislation.

The problem of disposing of geothermal effluent in an environmentally permissible manner is a significant one, as some facilities for electricity generation may be discharging hot saline fluids at rates as high as 400,000 barrels per day. The two methods under consideration for disposing of these wastes are surface discharge and reinjection. It is probable that both methods of disposing of geothermal fluids will be regulated to some degree by the Railroad Commission. Surface discharge, however, must meet the standards of the former Texas Water Quality Board (TWQB). Because of federal requirements, surface discharge of fluids involves a lengthy process which includes public hearings and the possible preparation of detailed environmental impact statements if federal action is involved. The General Land Office, the Parks and Wildlife Department, the US Coast Guard, and the US Army Corps of Engineers are all likely to be involved in the process. Obtaining a permit could easily take a year or more.

Disposal by subsurface injection, as currently regulated by the Railroad Commission, is relatively simple. Under the State Drinking Water Act of 1974 (SDWA), the EPA is currently considering the promulgation of regulations and procedures for subsurface disposal of waste. Under expected rules, the reinjection of geothermal fluids will probably require a permitting process which is both expensive and more time consuming. The time to obtain a permit for a reinjection well may be extended to a year or more, and this may delay the development plans that are given in appendix A.

2. General Land Office

The General Land Office will be concerned only if state lands are involved. The involvement might include direct development on state lands or the need to build pipelines across state lands. If any type of disposal of the fluids into the Gulf of Mexico or adjacent estuarine areas is contemplated, the General Land Office will become involved in the permitting process since permits must be obtained for any facilities crossing the mean high water level along the coastal beaches.

The amount of state-owned land located within the potential development area is relatively small. Therefore, it is expected that the General Land Office will not be involved in a major way in the permitting processes that relate to the development plans.

3. Public Utilities Commission

The Public Utilities Commission (PUC) is a relatively new agency in the state of Texas, having been in existence for approximately two years. The PUC has regulatory responsibility over public utilities that operate in the state of Texas outside municipalities. The impact of the PUC with respect to the geopressured energy development scenarios is most likely to come by means of the rate regulation authority that the PUC has over electric utility rates. A certificate of public convenience and necessity for construction of a power plant is issued by the PUC. This certification process does not prohibit the building of a plant but has an economic effect on the decision to build since it is unlikely that the expense of a plant constructed without this certificate would be allowed to be included in the rate base of the utility. The PUC would view the expense incurred in the drilling of geopressured wells and the construction of a fuel plant as not includable in the rate base of an electric utility. This decision could have a significant impact on the economics of development by the electric utility industry.

4. Texas Department of Water Resources

In September, 1977, three independent state water agencies were merged into a single Department of Water Resources. The general responsibility of this agency is the freshwater resources of the state of Texas. For the reinjection disposal methods that are used in the development scenarios, the new department will have little direct responsibility under existing procedures. In the current mode of operation, the department ascertains that any subsurface disposal that is being proposed will not affect the freshwater resources of the state of Texas; the department maintains a cooperative working relationship with the Railroad Commission. This arrangement has worked well to the present time; however, depending upon the outcome of the Environmental Protection Agency's decisions regarding the Safe Drinking Water Act, the Texas Department of Water Resources may become more heavily involved in the permitting process for subsurface disposal. This possibility is discussed further in the section on federal agencies.

5. Texas Parks and Wildlife Department

The Texas Parks and Wildlife Department has no direct permitting or regulatory authority over the drilling of geopressured wells or the construction of power plants. This department is ordinarily consulted by the Railroad Commission to ensure that drilling activities will not be hazardous to the wildlife of the area. If surface disposal is contemplated, this agency could play a major role as a result of its responsibility for protection of the fish and wildlife of the state of Texas.

Federal Agencies

Communication with several federal agencies has also been established. Of those agencies contacted (EPA, US Army Corps of Engineers, FPC, US Coast Guard), the one to be most closely involved in the permitting policies for and the regulation of geothermal/geopressured resources is the EPA. The Dallas office of the EPA is not sure of the agency's present jurisdiction. If disposal of the effluent is by surface methods, permits must be acquired under the guidelines of EPA as regulated under the Federal Water Pollution Control Act Amendments (FWPCAA). If disposal is by means of subsurface injection, proper procedure is less clear. The EPA has litigated some aspects of controlling such injections under the FWPCAA with mixed results in the federal courts. In view of the specific authority over subsurface disposal of waste under the Safe

Drinking Water Act, this former ambiguous authority may never be resolved. However, the EPA has had a policy in Texas of noninterference with underground waste disposal that does not involve any related surface discharge The new regulations under the SDWA, when promulgated, will probably change this policy. Under regulations proposed in 1976, geothermal wells were not grouped as oil and gas wells with respect to part c of the SDWA. This situation will probably complicate the process of obtaining permits for subsurface disposal of geopressured fluids and thus delay the development scenarios discussed in this report. The situation regarding these rules has been discussed in detail in a previous report of the Center for Energy Studies [11].

Projected Research

The development scenarios described in this report are a result of considering only a limited number of issues associated with the geopressured energy resource. These issues exist in all fields ranging from strictly technological considerations to social problems. For example, the resolution of the legal issues of ownership, leasing, and unitization could delay the resource development, or reservoir performance might require a completely different type of development

Many of these issues are totally unresolved, while others can be characterized only by varying degrees of uncertainty. An important activity for future work is the identification and characterization of these issues.

Another important activity is the continuation and expansion of the effort to involve in the planning activity all parties interested in geopressured energy development. This process has been initiated in that the current development scenarios and the objectives of the planning project have been discussed with representatives of the electric utilities that serve the Texas Gulf Coast and with representatives of several key agencies of the state of Texas. Unfortunately, very little detailed feedback regarding the resource development planning has been received from these parties. The contact with state and federal organizations and industrial participants needs to be expanded to ensure a smooth flow of information and to promote greater involvement of these entities in the planning process.

Interaction with the oil and gas industry and with local governmental agencies relative to the planning process has been initiated. This process needs to be expanded to involve these important entities actively in the planning process.

The discussions with the electric utilities that serve the Texas Gulf Coast revealed that the utilities are interested in the development of the geopressured energy resources. The major question that needs to be resolved in order to obtain more definite commitments from the utilities is that of the economics of producing power with the resource. This is a complex question that is impacted by a variety of factors ranging from reservoir characteristics to the cost and efficiency of power conversion equipment. Economic investigations such as the one discussed in this report can aid in the resolution of this question.

Additionally, the construction and operation of a demonstration plant should be quite beneficial in stimulating the interest of the utilities in developing the geothermal/geopressured resources. The utilities will probably be interested in participating in a joint venture for a demonstration plant if they can find a way to share the risks involved and recover their capital expenditures. An arrangement similar to that involving San Diego Gas and Electric, EPRI, and DOE for a demonstration plant near Heber, California, would probably be desirable. Since the first demonstration well is scheduled to be started in early 1978 in Brazoria County, arrangements for constructing this demonstration power plant should begin immediately in order for the construction of plants as envisioned in the development scenarios to proceed on schedule.

V. CONCLUSIONS AND RECOMMENDATIONS

The conclusions that can be drawn at this time are somewhat limited in scope; however, they are sufficient to give an indication of what needs to be considered for development of the resource to occur. The following four major categories are considered:

1. Technological feasibility
2. Government regulations
3. Industry support
4. Resource base

The technological areas that are required are drilling and operation of production and disposal wells, efficient energy conversion equipment, and gas separation equipment. In a general sense these technologies that are required for the geopressured resources of the Texas Gulf Coast are currently well developed.

However, some modifications may be either required for or beneficial in stimulating the development. As an example, one of the most critical factors involved in well operation is most likely to be the ability to produce the fluids at high flow rates without having sand carry-over. Even very small amounts of sand in the fluid can create severe problems for the equipment used in fuel processing and energy conversion. Current technology available for completing wells will probably be sufficient to eliminate the problem; however, until a demonstration well has been drilled and flow tests have been conducted the results will not be known with certainty. The situation should be closely monitored so that research on this potential problem can be initiated if the flow test results so indicate.

Another item that should be noted is that the development scenarios given in appendix A operate with wells that are producing two to three times the flow rates of the projected Brazoria test well. Wells of this size may be either technically or economically infeasible. This fact does not mean that the scenarios could not take place. More wells could be drilled to produce the desired flows. The economic investigations presented earlier indicate that although the cost of wells is important, this factor is probably not critical in the development plans. Thus, research and development activity in this area is probably not warranted at this time.

The equipment required to extract the methane from the geopressured fluid should not be a problem to obtain. The technology for these kinds of devices exists today with the possible exception of systems designed to operate at higher pressures. Consultation with informed sources indicates that the design and fabrication of this equipment does not constitute a problem.

Several preliminary design studies for energy conversion systems have been performed, and no great technological difficulties have been predicted. The energy conversion efficiency of these devices is not too high, approximately 10 percent as compared to approximately 40 percent for modern fossil-fueled equipment. This area is one in which technological improvements could make the development of the resource more attractive. Several equipment manufacturers--including General Electric, Pacific

Pump, Rotoflow, and the Elliott Company--have indicated a willingness to supply equipment of the type that is likely to be needed for the development scenarios. The equipment could be supplied in a timely manner and at a cost compatible with that used in the economic evaluation of the scenarios.

The process of obtaining the necessary permits for development of a geothermal reservoir can be completed in a matter of days. The Texas Railroad Commission regulates geothermal production and reinjection in Texas. The commission has imposed only a few regulations for geothermal and brine-disposal wells. However, the federal Environmental Protection Agency, acting under the Safe Drinking Water Act, has proposed stringent regulations concerning reinjection which could easily extend to a year or more the time needed to obtain a permit.

The electric utility companies that serve the Texas Gulf Coast have indicated an interest in the development of the geopressured energy resources. These companies have different ideas about the mode of operation that would be best for their purposes. While one company would prefer to control the entire process and market both electricity and natural gas, another would prefer simply to purchase hot water from a separate methane producer.

Each of these companies has had the opportunity to review the development scenarios presented in this report. Unfortunately, none of these companies have made any specific comments about their willingness to support these plans or to propose any alternative plans of their own.

In addition to the electric utilities, contact has been established with one company that is primarily interested in the methane that may be obtained from the resource. This company has not had time to give detailed consideration to the development scenarios. However, one point that has emerged from the discussions with industry is worthy of note: Industry is not too comfortable in working on a development program that has direct input from the federal government. Industry would prefer a situation in which the rules of operation--the permitting process, leasing process, resource usage restrictions and so forth--are established, and indirect incentives, such as tax credits and depletion allowances, are used to promote the development of the resource. As indicated in the economic discussion in this report, unregulated gas prices, production tax credits, and intangible drilling expense allowances are likely to be most effective in stimulating the interest of private industry in the development of geopressured resources.

The development scenarios that are given in appendix A have been constructed for the resources in the currently defined prospect areas in the Frio formation of the Texas Gulf Coast. Recent resource investigations indicate that significant geopressured resources probably exist in the Wilcox and Vicksburg formations in the Gulf Coastal area. In fact, preliminary estimates are that the Wilcox formations may contain six to ten times as much resource as the Brazoria fairway of the Frio formation. In time, the result would be a most significant increase (that is, 830 billion cubic feet per year by the year 2000) in the energy that could be obtained from this resource. The critical factor in recovering energy from these formations appears to be the formation permeability. If the permeability is as high as that in the Brazoria Frio formation, the prospects are extremely good; however, if the permeability is as low as in the Hidalgo formation, the prospects are not so bright. Planning for development of these resources is heavily dependent upon how much resource can be recovered. Accordingly, an assessment of the producibility of the Wilcox and Vicksburg formations is vital in order to stimulate the interest of industry and to provide an input to the planning process. A program of searching out existing information such as well logs and core data should be instituted immediately if the Wilcox and Vicksburg formation resources are to produce significant amounts of energy by the year 2000. It is understood that a proposal for this work has been submitted to DOE by the Texas Bureau of Economic Geology.

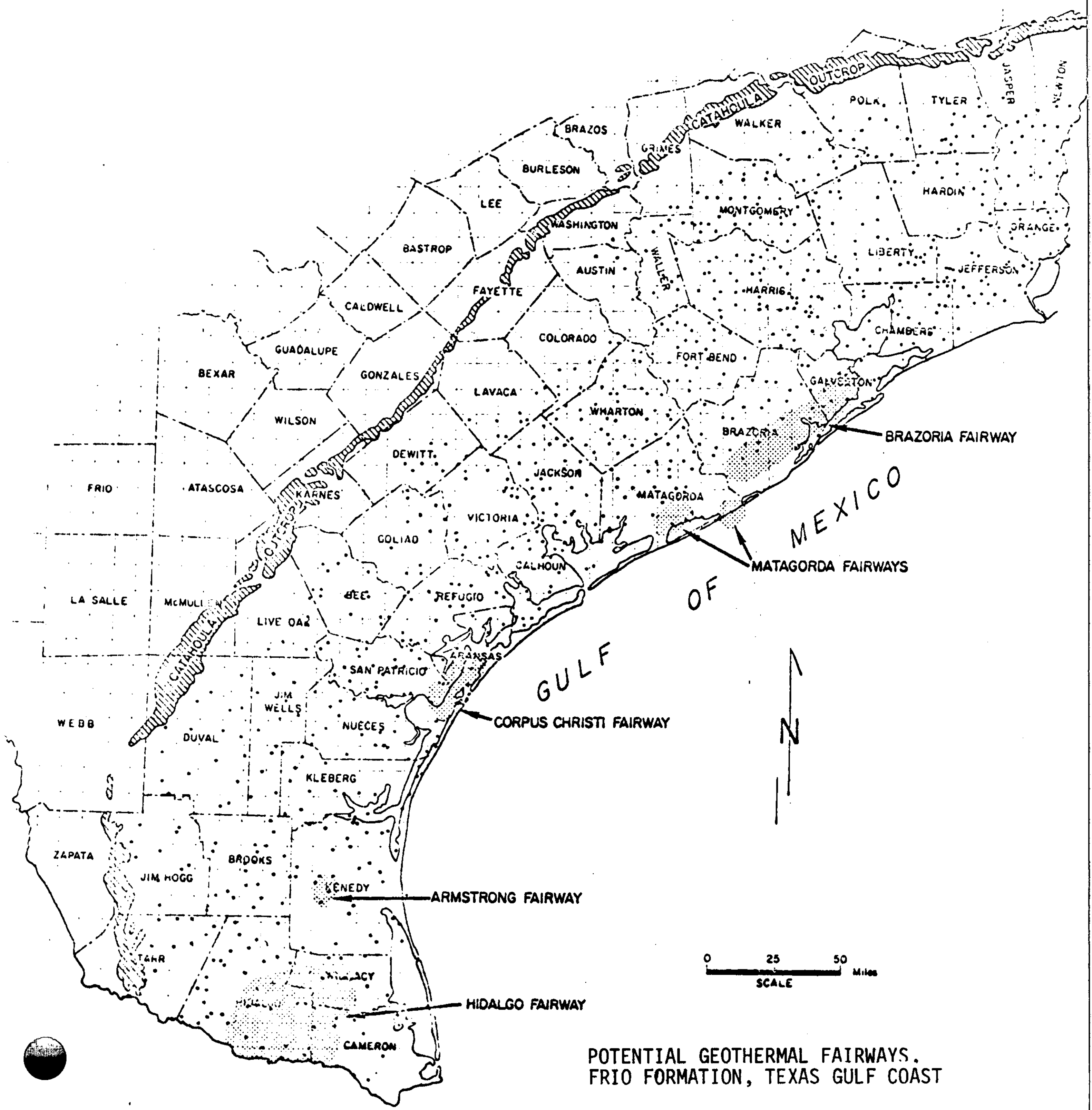
Appendix A

PRELIMINARY DEVELOPMENT SCENARIOS

This is a preliminary scenario for the development of the five regions of the Texas Gulf Coast which appear favorable for the utilization of geopressured/geothermal resources to be found within the Frio formation. The map on the next page gives the geographical location of these five regions. It should be stressed that the following analysis deals only with the Frio formation.

There are several other formations, including the Wilcox and Vicksburg, which hold similar or better potential for development of geopressured/ geothermal resources. Since reasonable estimates of the amount of recoverable resources in these formations were not available at the time of this study, no valid estimates of the type presented here were made for those formations. However, such studies are in progress at this time. There is also a large potential for development in offshore reservoirs which have not been considered here.

Through geological studies, five fairways within the Frio formation of the Texas Gulf Coast were delineated as having potential fluids under high pressures at temperatures above 300°F and as having permeabilities sufficiently high to allow sustained flow. The temperature involved a range between 225°F and 375°F throughout the coastal region. The formation temperature tends to increase as one progresses from the northeast (Brazoria fairway) to the southwest (Hidalgo fairway). Formation permeabilities tend to work in the opposite direction, with low permeabilities (<1 millidarcy) occurring more often in the southwest and high permeabilities (20 to >100 millidarcies) occurring more frequently in the northeast reservoirs. The porosity of the formations may generally be assumed to



POTENTIAL GEOTHERMAL FAIRWAYS,
FRIO FORMATION, TEXAS GULF COAST

be around 20 percent although it does vary from 10 to 25 percent and shows an increasing trend as one moves from southwest to northeast. The formation thickness ranges from 125 feet (Armstrong) to over 700 feet (Hidalgo). Formation thickness by definition means a series of sandstone deposits at varying depths separated by shale beds. It is not, as is commonly assumed, one continuous block of porous sandstone. The gas content of the fluids, although not known precisely, will range from 20 to 60 standard cubic feet per barrel of effluent as the temperature of the brine varies from 300°F to 375°F, respectively. The salinity of the fluids did not enter into the calculations explicitly. However, it was implicitly assumed to lie between 20,000 and 80,000 parts per million. The depths of these reservoirs are between 10,000 and 15,000 feet. The areal extent of the fairways range from a low of 100 square miles (Armstrong) to 1,300 square miles (Hidalgo).

We have assumed that 75, 60, and 40 percent of the toal areal extent of each fairway is producible for the optimistic, nominal, and pessimistic scenarios, respectively. Our recoverability factor for this "producible" resource ranges from 1 to 15 percent if one does not consider deep reinjection of the waste effluent into the original reservoir.

During the course of this project, discussions with various experts indicated that the technology for drilling the wells, constructing the plants, and establishing production is available. Further, given the limitation of plant construction time, we have estimates that there will be an ample supply of drilling rigs of the sizes needed to ensure the completion of the necessary number of wells to allow production to begin. Implicit in this estimate is a projected 50 percent success ratio in drilling producible wells. Thus the critical time parameter throughout these scenarios is the three years assumed necessary for construction of a single production plant. The validity of this assumption has been checked with several companies that have had experience with similar projects, and it has been found to be a reasonably good estimate. Simultaneous construction of plants has been allowed to the extent of one plant completion per year in the optimistic scenarios. Each of the scenarios without deep reinjection is based upon a 30-year life for each production well. The actual well drainage area may vary, and each plant is assumed to cover approximately 36 square miles. However, the total production for each region is believed accurate for the assumed parameters.

In the optimistic scenarios it has been assumed that there will be no problems--legal, social, environmental, or otherwise. Also assumed is a lack of technical problems such as material shortages, strikes, power failures, equipment breakdown, etc. The nominal scenarios assume that some complications of the sort mentioned above occur, while in the pessimistic scenarios many things go wrong.

We have also considered the alternative of using deep reinjection of the waste effluent into the original reservoir to extend the lifetime of the reservoir and increase the recoverability of the resource, particularly the gas content. We have estimates from the reservoir modeling project that deep reinjection will likely essentially triple the recoverability factor, hence extending the lifetime of each well while increasing its yearly production. For simplicity we have assumed that the increased production will be evident from the start and that tripling total recoverability will double the lifetime. Therefore, the scenarios with deep reinjection are based on a lifetime of 60 years.

Throughout this development we have ignored the effect of reservoir depletion with time on the flow rate and total production. The pessimistic scenarios, for all but Brazoria fairway, have been omitted for the present since they essentially show no potential for economically favorable production of the resource.

Estimated Resource Characteristics for Brazoria Fairway

I. Optimistic Scenario

Formation Thickness	500 feet
Temperature	350°F
Porosity	22%
Permeability	50 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	15%
b) With Deep Reinjection	45%
Gas Content	50 scf/bbl
Fairway Extent	784 mi^2
Fraction of Fairway Producible	0.75
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

II. Nominal Scenario

Formation Thickness	350 feet
Temperature	325°F
Porosity	20%
Permeability	35 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	10%
b) With Deep Reinjection	30%
Gas Content	40 scf/bbl
Fairway Extent	784 mi^2
Fraction of Fairway Producible	0.60
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

III. Pessimistic Scenario

Formation Thickness	250 feet
Temperature	300°F
Porosity	20%
Permeability	20 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	5%
b) With Deep Reinjection	15%
Gas Content	20 scf/bbl
Fairway Extent	784 mi^2
Fraction of Fairway Producible	0.40
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

Estimated Resource Characteristics for Matagorda Fairway

I. Optimistic Scenario

Formation Thickness	400 feet
Temperature	350°F
Porosity	20%
Permeability	5 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	5%
b) With Deep Reinjection	15%
Gas Content	50 scf/bbl
Fairway Extent	300 mi^2
Fraction of Fairway Producible	0.75
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

II. Nominal Scenario

Formation Thickness	300 feet
Temperature	325°F
Porosity	20%
Permeability	3 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	3%
b) With Deep Reinjection	9%
Gas Content	40 scf/bbl
Fairway Extent	300 mi^2
Fraction of Fairway Producible	0.60
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

Estimated Resource Characteristics for Corpus Christi Fairway

I. Optimistic Scenario

Formation Thickness	400 feet
Temperature	350°F
Porosity	20%
Permeability	5 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	5%
b) With Deep Reinjection	15%
Gas Content	50 scf/bbl
Fairway Extent	400 mi^2
Fraction of Fairway Producible	0.75
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

II. Nominal Scenario

Formation Thickness	300 feet
Temperature	325°F
Porosity	20%
Permeability	3 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	3%
b) With Deep Reinjection	9%
Gas Content	40 scf/bbl
Fairway Extent	400 mi^2
Fraction of Fairway Producible	0.60
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

Estimated Resource Characteristics for Armstrong Fairway

I. Optimistic Scenario

Formation Thickness	125 feet
Temperature	300°F
Porosity	20%
Permeability	30 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	10%
b) With Deep Reinjection	30%
Gas Content	40 scf/bbl
Fairway Extent	100 mi^2
Fraction of Fairway Producible	0.75
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

II. Nominal Scenario

Formation Thickness	100 feet
Temperature	275°F
Porosity	20%
Permeability	20 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	5%
b) With Deep Reinjection	15%
Gas Content	20 scf/bbl
Fairway Extent	100 mi^2
Fraction of Fairway Producible	0.60
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

Note: This scenario has been excluded from this report since it appears infeasible for development at this time.

Estimated Resource Characteristics for Hidalgo Fairway

I. Optimistic Scenario

Formation Thickness	700 feet
Temperature	350°F
Porosity	20%
Permeability	5 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	5%
b) With Deep Reinjection	15%
Gas Content	50 scf/bbl
Fairway Extent	1300 mi^2
Fraction of Fairway Producible	0.75
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

II. Nominal Scenario

Formation Thickness	500 feet
Temperature	325°F
Porosity	20%
Permeability	2 millidarcies
Fluid Recovery	
a) W/O Deep Reinjection	2%
b) With Deep Reinjection	6%
Gas Content	40 scf/bbl
Fairway Extent	1300 mi^2
Fraction of Fairway Producible	0.60
Life of Facilities	
a) W/O Deep Reinjection	30 years
b) With Deep Reinjection	60 years

BRAZORIA FAIRWAY -- OPTIMISTIC W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	94267.	BARRELS PER DAY
SUPPORT AREA	12.57	SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	3	
ELEC GEN CAPACITY	35.35	MEGAWATTS
GAS FLOW CAPACITY	5.16E+09	SCF PER YEAR
LIFETIME	30.	YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	16	
ELEC GEN CAPACITY	565.60	MEGAWATTS
GAS FLOW CAPACITY	8.26E+10	SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1960.	0	0	0	0	0
1961.	0	0	0	0	0
1982.	1.	35.	5.16E+09	69.	104.
1983.	1.	35.	5.16E+09	69.	104.
1984.	2.	71.	1.03E+10	138.	208.
1985.	3.	106.	1.55E+10	207.	313.
1986.	4.	141.	2.06E+10	276.	417.
1987.	5.	177.	2.58E+10	344.	521.
1988.	6.	212.	3.10E+10	413.	625.
1989.	7.	247.	3.61E+10	482.	730.
1990.	8.	283.	4.13E+10	551.	834.
1991.	9.	318.	4.65E+10	620.	938.
1992.	10.	354.	5.16E+10	689.	1042.
1993.	11.	389.	5.68E+10	758.	1147.
1994.	12.	424.	6.19E+10	827.	1251.
1995.	13.	460.	6.71E+10	896.	1355.
1996.	14.	495.	7.23E+10	964.	1459.
1997.	15.	530.	7.74E+10	1033.	1564.
1998.	16.	566.	8.26E+10	1102.	1668.
1999.	16.	566.	8.26E+10	1102.	1668.
2000.	16.	566.	8.26E+10	1102.	1668.
2001.	16.	566.	8.26E+10	1102.	1668.
2002.	16.	566.	8.26E+10	1102.	1668.
2003.	16.	566.	8.26E+10	1102.	1668.
2004.	16.	566.	8.26E+10	1102.	1668.
2005.	16.	566.	8.26E+10	1102.	1668.
2006.	16.	566.	8.26E+10	1102.	1668.
2007.	16.	566.	8.26E+10	1102.	1668.
2008.	16.	566.	8.26E+10	1102.	1668.
2009.	16.	566.	8.26E+10	1102.	1668.
2010.	16.	566.	8.26E+10	1102.	1668.
2011.	16.	566.	8.26E+10	1102.	1668.
2012.	15.	530.	7.74E+10	1033.	1564.
2013.	15.	530.	7.74E+10	1033.	1564.
2014.	14.	495.	7.23E+10	964.	1459.
2015.	13.	460.	6.71E+10	896.	1355.
2016.	12.	424.	6.19E+10	827.	1251.
2017.	11.	389.	5.68E+10	758.	1147.
2018.	10.	354.	5.16E+10	689.	1042.
2019.	9.	318.	4.65E+10	620.	938.
2020.	8.	283.	4.13E+10	551.	834.

BRAZORIA FAIRWAY -- OPTIMISTIC WITH DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	128838. BARRELS PER DAY
SUPPORT AREA	11.45 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	3
ELEC GEN CAPACITY	48.31 MEGAWATTS
GAS FLOW CAPACITY	7.05E+09 SCF PER YEAR
LIFETIME	60. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	16
ELEC GEN CAPACITY	773.03 MEGAWATTS
GAS FLOW CAPACITY	1.13E+11 SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	1.	48.	7.05E+09	94.	142.
1983.	1.	48.	7.05E+09	94.	142.
1984.	2.	97.	1.41E+10	188.	285.
1985.	2.	97.	1.41E+10	188.	285.
1986.	3.	145.	2.12E+10	282.	427.
1987.	4.	193.	2.82E+10	377.	570.
1988.	5.	242.	3.53E+10	471.	712.
1989.	6.	290.	4.23E+10	565.	855.
1990.	7.	338.	4.94E+10	659.	997.
1991.	8.	387.	5.64E+10	753.	1140.
1992.	9.	435.	6.35E+10	847.	1282.
1993.	10.	483.	7.05E+10	942.	1425.
1994.	11.	531.	7.76E+10	1036.	1567.
1995.	12.	580.	8.46E+10	1130.	1710.
1996.	13.	628.	9.17E+10	1224.	1852.
1997.	14.	676.	9.88E+10	1318.	1995.
1998.	15.	725.	1.06E+11	1412.	2137.
1999.	16.	773.	1.13E+11	1506.	2280.
2000.	16.	773.	1.13E+11	1506.	2280.
2001.	16.	773.	1.13E+11	1506.	2280.
2002.	16.	773.	1.13E+11	1506.	2280.
2003.	16.	773.	1.13E+11	1506.	2280.
2004.	16.	773.	1.13E+11	1506.	2280.
2005.	16.	773.	1.13E+11	1506.	2280.
2006.	16.	773.	1.13E+11	1506.	2280.
2007.	16.	773.	1.13E+11	1506.	2280.
2008.	16.	773.	1.13E+11	1506.	2280.
2009.	16.	773.	1.13E+11	1506.	2280.
2010.	16.	773.	1.13E+11	1506.	2280.
2011.	16.	773.	1.13E+11	1506.	2280.
2012.	16.	773.	1.13E+11	1506.	2280.
2013.	16.	773.	1.13E+11	1506.	2280.
2014.	16.	773.	1.13E+11	1506.	2280.
2015.	16.	773.	1.13E+11	1506.	2280.
2016.	16.	773.	1.13E+11	1506.	2280.
2017.	16.	773.	1.13E+11	1506.	2280.
2018.	16.	773.	1.13E+11	1506.	2280.
2019.	16.	773.	1.13E+11	1506.	2280.
2020.	16.	773.	1.13E+11	1506.	2280.

BRAZORIA FAIRWAY -- NOMINAL W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	39992. BARRELS PER DAY
SUPPORT AREA	12.57 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	3
ELEC GEN CAPACITY	13.64 MEGAWATTS
GAS FLOW CAPACITY	1.75E+09 SCF PER YEAR
LIFETIME	30. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	13
ELEC GEN CAPACITY	177.30 MEGAWATTS
GAS FLOW CAPACITY	2.28E+10 SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	1.	14.	1.75E+09	23.	37.
1986.	1.	14.	1.75E+09	23.	37.
1987.	1.	14.	1.75E+09	23.	37.
1988.	2.	27.	3.50E+09	47.	74.
1989.	2.	27.	3.50E+09	47.	74.
1990.	3.	41.	5.25E+09	70.	111.
1991.	3.	41.	5.25E+09	70.	111.
1992.	4.	55.	7.01E+09	94.	148.
1993.	4.	55.	7.01E+09	94.	148.
1994.	5.	68.	8.76E+09	117.	185.
1995.	5.	68.	8.76E+09	117.	185.
1996.	6.	82.	1.05E+10	140.	222.
1997.	6.	82.	1.05E+10	140.	222.
1998.	7.	95.	1.23E+10	164.	259.
1999.	7.	95.	1.23E+10	164.	259.
2000.	8.	109.	1.40E+10	187.	296.
2001.	8.	109.	1.40E+10	187.	296.
2002.	9.	123.	1.58E+10	210.	333.
2003.	9.	123.	1.58E+10	210.	333.
2004.	10.	136.	1.75E+10	234.	370.
2005.	10.	136.	1.75E+10	234.	370.
2006.	11.	150.	1.93E+10	257.	407.
2007.	11.	150.	1.93E+10	257.	407.
2008.	12.	164.	2.10E+10	281.	444.
2009.	12.	164.	2.10E+10	281.	444.
2010.	13.	177.	2.28E+10	304.	481.
2011.	13.	177.	2.28E+10	304.	481.
2012.	13.	177.	2.28E+10	304.	481.
2013.	13.	177.	2.28E+10	304.	481.
2014.	13.	177.	2.28E+10	304.	481.
2015.	12.	164.	2.10E+10	281.	444.
2016.	12.	164.	2.10E+10	281.	444.
2017.	12.	164.	2.10E+10	281.	444.
2018.	11.	152.	1.93E+10	257.	407.
2019.	11.	153.	1.93E+10	257.	407.
2020.	10.	136.	1.75E+10	234.	370.

BRAZORIA FAIRWAY -- PESSIMISTIC W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE 14283. BARRELS PER DAY
SUPPORT AREA 12.57 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS 3
ELEC GEN CAPACITY 4.39 MEGAWATTS
GAS FLOW CAPACITY 3.13E+08 SCF PER YEAR
LIFETIME 30. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS 8
ELEC GEN CAPACITY 35.09 MEGAWATTS
GAS FLOW CAPACITY 2.50E+09 SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	0	0	0	0	0
1987.	0	0	0	0	0
1988.	1.	4.	3.13E+08	4.	9.
1989.	1.	4.	3.13E+08	4.	9.
1990.	1.	4.	3.13E+08	4.	9.
1991.	1.	4.	3.13E+08	4.	9.
1992.	1.	4.	3.13E+08	4.	9.
1993.	1.	4.	3.13E+08	4.	9.
1994.	2.	9.	6.26E+08	8.	17.
1995.	2.	9.	6.26E+08	8.	17.
1996.	2.	9.	6.26E+08	8.	17.
1997.	2.	9.	6.26E+08	8.	17.
1998.	3.	13.	9.38E+08	13.	26.
1999.	3.	13.	9.38E+08	13.	26.
2000.	4.	18.	1.25E+09	17.	34.
2001.	4.	18.	1.25E+09	17.	34.
2002.	4.	18.	1.25E+09	17.	34.
2003.	5.	22.	1.56E+09	21.	43.
2004.	5.	22.	1.56E+09	21.	43.
2005.	6.	26.	1.88E+09	25.	51.
2006.	6.	26.	1.88E+09	25.	51.
2007.	6.	26.	1.88E+09	25.	51.
2008.	7.	31.	2.19E+09	29.	60.
2009.	7.	31.	2.19E+09	29.	60.
2010.	8.	35.	2.50E+09	33.	68.
2011.	8.	35.	2.50E+09	33.	68.
2012.	8.	35.	2.50E+09	33.	68.
2013.	8.	35.	2.50E+09	33.	68.
2014.	8.	35.	2.50E+09	33.	68.
2015.	8.	35.	2.50E+09	33.	68.
2015.	8.	35.	2.50E+09	33.	68.
2016.	8.	35.	2.50E+09	33.	68.
2017.	8.	35.	2.50E+09	33.	68.
2018.	7.	31.	2.19E+09	29.	60.
2019.	7.	31.	2.19E+09	29.	60.
2020.	7.	31.	2.19E+09	29.	60.

MATAGORDA FAIRWAY -- OPTIMISTIC W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	10694.	BARRELS PER DAY
SUPPORT AREA	5.88	SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	6	
ELEC GEN CAPACITY	8.02	MEGAWATTS
GAS FLOW CAPACITY	1.17E+09	SCF PER YEAR
LIFETIME	30.	YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	6	
ELEC GEN CAPACITY	48.12	MEGAWATTS
GAS FLOW CAPACITY	7.03E+09	SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	1.	8.	1.17E+09	16.	24.
1987.	1.	8.	1.17E+09	16.	24.
1988.	2.	16.	2.34E+09	31.	47.
1989.	3.	24.	3.51E+09	47.	71.
1990.	4.	32.	4.68E+09	63.	95.
1991.	5.	40.	5.85E+09	78.	118.
1992.	6.	48.	7.03E+09	94.	142.
1993.	6.	48.	7.03E+09	94.	142.
1994.	6.	48.	7.03E+09	94.	142.
1995.	6.	48.	7.03E+09	94.	142.
1996.	6.	48.	7.03E+09	94.	142.
1997.	6.	48.	7.03E+09	94.	142.
1998.	6.	48.	7.03E+09	94.	142.
1999.	6.	48.	7.03E+09	94.	142.
2000.	6.	48.	7.03E+09	94.	142.
2001.	6.	48.	7.03E+09	94.	142.
2002.	6.	48.	7.03E+09	94.	142.
2003.	6.	48.	7.03E+09	94.	142.
2004.	6.	48.	7.03E+09	94.	142.
2005.	6.	48.	7.03E+09	94.	142.
2006.	6.	48.	7.03E+09	94.	142.
2007.	6.	48.	7.03E+09	94.	142.
2008.	6.	48.	7.03E+09	94.	142.
2009.	6.	48.	7.03E+09	94.	142.
2010.	6.	48.	7.03E+09	94.	142.
2011.	6.	48.	7.03E+09	94.	142.
2012.	6.	48.	7.03E+09	94.	142.
2013.	6.	48.	7.03E+09	94.	142.
2014.	6.	48.	7.03E+09	94.	142.
2015.	6.	48.	7.03E+09	94.	142.
2016.	5.	40.	5.85E+09	78.	118.
2017.	5.	40.	5.85E+09	78.	118.
2018.	4.	32.	4.68E+09	63.	95.
2019.	3.	24.	3.51E+09	47.	71.
2020.	2.	16.	2.34E+09	31.	47.

MATAGORDA FAIRWAY -- OPTIMISTIC WITH DEEP REINJECTION

WELL PARAMETERS

FLOW RATE 10931. BARRELS PER DAY
SUPPORT AREA 4.01 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS 9
ELEC GEN CAPACITY 12.30 MEGAWATTS
GAS FLOW CAPACITY 1.80E+09 SCF PER YEAR
LIFETIME 60. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS 6
ELEC GEN CAPACITY 73.78 MEGAWATTS
GAS FLOW CAPACITY 1.08E+10 SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	1.	12.	1.80E+09	24.	36.
1987.	1.	12.	1.80E+09	24.	36.
1988.	2.	25.	3.59E+09	48.	73.
1989.	3.	37.	5.39E+09	72.	109.
1990.	4.	49.	7.18E+09	96.	145.
1991.	5.	61.	8.98E+09	120.	181.
1992.	6.	74.	1.08E+10	144.	218.
1993.	6.	74.	1.08E+10	144.	218.
1994.	6.	74.	1.08E+10	144.	218.
1995.	6.	74.	1.08E+10	144.	218.
1996.	6.	74.	1.08E+10	144.	218.
1997.	6.	74.	1.08E+10	144.	218.
1998.	6.	74.	1.08E+10	144.	218.
1999.	6.	74.	1.08E+10	144.	218.
2000.	6.	74.	1.08E+10	144.	218.
2001.	6.	74.	1.08E+10	144.	218.
2002.	6.	74.	1.08E+10	144.	218.
2003.	6.	74.	1.08E+10	144.	218.
2004.	6.	74.	1.08E+10	144.	218.
2005.	6.	74.	1.08E+10	144.	218.
2006.	6.	74.	1.08E+10	144.	218.
2007.	6.	74.	1.08E+10	144.	218.
2008.	6.	74.	1.08E+10	144.	218.
2009.	6.	74.	1.08E+10	144.	218.
2010.	6.	74.	1.08E+10	144.	218.
2011.	6.	74.	1.08E+10	144.	218.
2012.	6.	74.	1.08E+10	144.	218.
2013.	6.	74.	1.08E+10	144.	218.
2014.	6.	74.	1.08E+10	144.	218.
2015.	6.	74.	1.08E+10	144.	218.
2016.	6.	74.	1.08E+10	144.	218.
2017.	6.	74.	1.08E+10	144.	218.
2018.	6.	74.	1.08E+10	144.	218.
2019.	6.	74.	1.08E+10	144.	218.
2020.	6.	74.	1.08E+10	144.	218.

MATAGORDA FAIRWAY -- NOMINAL W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE 4813. BARRELS PER DAY
SUPPORT AREA 5.88 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS 6
ELEC GEN CAPACITY 3.28 MEGAWATTS
GAS FLOW CAPACITY 4.22E+08 SCF PER YEAR
LIFETIME 30. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS 5
ELEC GEN CAPACITY 16.41 MEGAWATTS
GAS FLOW CAPACITY 2.11E+09 SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	0	0	0	0	0
1987.	0	0	0	0	0
1988.	0	0	0	0	0
1989.	0	0	0	0	0
1990.	1.	3.	4.22E+08	6.	9.
1991.	1.	3.	4.22E+08	6.	9.
1992.	1.	3.	4.22E+08	6.	9.
1993.	2.	7.	8.43E+08	11.	18.
1994.	2.	7.	8.43E+08	11.	18.
1995.	3.	10.	1.26E+09	17.	27.
1996.	3.	10.	1.26E+09	17.	27.
1997.	4.	13.	1.69E+09	23.	36.
1998.	4.	13.	1.69E+09	23.	36.
1999.	5.	16.	2.11E+09	28.	45.
2000.	5.	16.	2.11E+09	28.	45.
2001.	5.	16.	2.11E+09	28.	45.
2002.	5.	16.	2.11E+09	28.	45.
2003.	5.	16.	2.11E+09	28.	45.
2004.	5.	16.	2.11E+09	28.	45.
2005.	5.	16.	2.11E+09	28.	45.
2006.	5.	16.	2.11E+09	28.	45.
2007.	5.	16.	2.11E+09	28.	45.
2008.	5.	16.	2.11E+09	28.	45.
2009.	5.	16.	2.11E+09	28.	45.
2010.	5.	16.	2.11E+09	28.	45.
2011.	5.	16.	2.11E+09	28.	45.
2012.	5.	16.	2.11E+09	28.	45.
2013.	5.	16.	2.11E+09	28.	45.
2014.	5.	16.	2.11E+09	28.	45.
2015.	5.	16.	2.11E+09	28.	45.
2016.	5.	16.	2.11E+09	28.	45.
2017.	5.	16.	2.11E+09	28.	45.
2018.	5.	16.	2.11E+09	28.	45.
2019.	5.	16.	2.11E+09	28.	45.
2020.	4.	13.	1.69E+09	23.	36.

CORPUS CHRISTI FAIRWAY -- OPTIMISTIC W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	22853. BARRELS PER DAY
SUPPORT AREA	12.57 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	3
ELEC GEN CAPACITY	8.57 MEGAWATTS
GAS FLOW CAPACITY	1.25E+09 SCF PER YEAR
LIFETIME	30. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	8
ELEC GEN CAPACITY	68.56 MEGAWATTS
GAS FLOW CAPACITY	1.00E+10 SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	1.	9.	1.25E+09	17.	25.
1987.	1.	9.	1.25E+09	17.	25.
1988.	2.	17.	2.50E+09	33.	51.
1989.	3.	26.	3.75E+09	50.	76.
1990.	4.	34.	5.00E+09	67.	101.
1991.	5.	43.	6.26E+09	84.	126.
1992.	6.	51.	7.51E+09	100.	152.
1993.	7.	60.	8.76E+09	117.	177.
1994.	8.	69.	1.00E+10	134.	202.
1995.	8.	69.	1.00E+10	134.	202.
1996.	8.	69.	1.00E+10	134.	202.
1997.	8.	69.	1.00E+10	134.	202.
1998.	8.	69.	1.00E+10	134.	202.
1999.	8.	69.	1.00E+10	134.	202.
2000.	8.	69.	1.00E+10	134.	202.
2001.	8.	69.	1.00E+10	134.	202.
2002.	8.	69.	1.00E+10	134.	202.
2003.	8.	69.	1.00E+10	134.	202.
2004.	8.	69.	1.00E+10	134.	202.
2005.	8.	69.	1.00E+10	134.	202.
2006.	8.	69.	1.00E+10	134.	202.
2007.	8.	69.	1.00E+10	134.	202.
2008.	8.	69.	1.00E+10	134.	202.
2009.	8.	69.	1.00E+10	134.	202.
2010.	8.	69.	1.00E+10	134.	202.
2011.	8.	69.	1.00E+10	134.	202.
2012.	8.	69.	1.00E+10	134.	202.
2013.	8.	69.	1.00E+10	134.	202.
2014.	8.	69.	1.00E+10	134.	202.
2015.	8.	69.	1.00E+10	134.	202.
2016.	7.	60.	8.76E+09	117.	177.
2017.	7.	60.	8.76E+09	117.	177.
2018.	6.	51.	7.51E+09	100.	152.
2019.	5.	43.	6.26E+09	84.	126.
2020.	4.	34.	5.00E+09	67.	101.

CORPUS CHRISTI FAIRWAY -- OPTIMISTIC WITH DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	10931.	BARRELS PER DAY
SUPPORT AREA	4.01	SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	9	
ELEC GEN CAPACITY	12.30	MEGAWATTS
GAS FLOW CAPACITY	1.80E+09	SCF PER YEAR
LIFETIME	60.	YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	8	
ELEC GEN CAPACITY	98.38	MEGAWATTS
GAS FLOW CAPACITY	1.44E+10	SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	1.	12.	1.80E+09	24.	36.
1987.	1.	12.	1.80E+09	24.	36.
1988.	2.	25.	3.59E+09	48.	73.
1989.	2.	25.	3.59E+09	48.	73.
1990.	3.	37.	5.39E+09	72.	109.
1991.	4.	49.	7.18E+09	96.	145.
1992.	5.	61.	8.98E+09	120.	181.
1993.	6.	74.	1.08E+10	144.	218.
1994.	7.	86.	1.26E+10	168.	254.
1995.	8.	98.	1.44E+10	192.	290.
1996.	8.	98.	1.44E+10	192.	290.
1997.	8.	98.	1.44E+10	192.	290.
1998.	8.	98.	1.44E+10	192.	290.
1999.	8.	98.	1.44E+10	192.	290.
2000.	8.	98.	1.44E+10	192.	290.
2001.	8.	98.	1.44E+10	192.	290.
2002.	8.	98.	1.44E+10	192.	290.
2003.	8.	98.	1.44E+10	192.	290.
2004.	8.	98.	1.44E+10	192.	290.
2005.	8.	98.	1.44E+10	192.	290.
2006.	8.	98.	1.44E+10	192.	290.
2007.	8.	98.	1.44E+10	192.	290.
2008.	8.	98.	1.44E+10	192.	290.
2009.	8.	98.	1.44E+10	192.	290.
2010.	8.	98.	1.44E+10	192.	290.
2011.	8.	98.	1.44E+10	192.	290.
2012.	8.	98.	1.44E+10	192.	290.
2013.	8.	98.	1.44E+10	192.	290.
2014.	8.	98.	1.44E+10	192.	290.
2015.	8.	98.	1.44E+10	192.	290.
2016.	8.	98.	1.44E+10	192.	290.
2017.	8.	98.	1.44E+10	192.	290.
2018.	8.	98.	1.44E+10	192.	290.
2019.	8.	98.	1.44E+10	192.	290.
2020.	8.	98.	1.44E+10	192.	290.

CORPUS CHRISTI FAIRWAY -- NOMINAL W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	4813. BARRELS PER DAY
SUPPORT AREA	5.88 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	6
ELEC GEN CAPACITY	3.28 MEGAWATTS
GAS FLOW CAPACITY	4.22E+08 SCF PER YEAR
LIFETIME	30. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	6
ELEC GEN CAPACITY	19.70 MEGAWATTS
GAS FLOW CAPACITY	2.53E+09 SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	0	0	0	0	0
1987.	0	0	0	0	0
1988.	0	0	0	0	0
1989.	0	0	0	0	0
1990.	1.	3.	4.22E+08	6.	9.
1991.	1.	3.	4.22E+08	6.	9.
1992.	1.	3.	4.22E+08	6.	9.
1993.	2.	7.	8.43E+08	11.	18.
1994.	2.	7.	8.43E+08	11.	18.
1995.	3.	10.	1.26E+09	17.	27.
1996.	3.	10.	1.26E+09	17.	27.
1997.	4.	13.	1.69E+09	23.	36.
1998.	4.	13.	1.69E+09	23.	36.
1999.	5.	16.	2.11E+09	28.	45.
2000.	5.	16.	2.11E+09	28.	45.
2001.	6.	20.	2.53E+09	34.	53.
2002.	6.	20.	2.53E+09	34.	53.
2003.	6.	20.	2.53E+09	34.	53.
2004.	6.	20.	2.53E+09	34.	53.
2005.	6.	20.	2.53E+09	34.	53.
2006.	6.	20.	2.53E+09	34.	53.
2007.	6.	20.	2.53E+09	34.	53.
2008.	6.	20.	2.53E+09	34.	53.
2009.	6.	20.	2.53E+09	34.	53.
2010.	6.	20.	2.53E+09	34.	53.
2011.	6.	20.	2.53E+09	34.	53.
2012.	6.	20.	2.53E+09	34.	53.
2013.	6.	20.	2.53E+09	34.	53.
2014.	6.	20.	2.53E+09	34.	53.
2015.	6.	20.	2.53E+09	34.	53.
2016.	6.	20.	2.53E+09	34.	53.
2017.	6.	20.	2.53E+09	34.	53.
2018.	6.	20.	2.53E+09	34.	53.
2019.	6.	20.	2.53E+09	34.	53.
2020.	5.	16.	2.11E+09	28.	45.

ARMSTRONG FAIRWAY -- OPTIMISTIC W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	14283.	BARRELS PER DAY
SUPPORT AREA	12.57	SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	3	
ELEC GEN CAPACITY	4.39	MEGAWATTS
GAS FLOW CAPACITY	6.26E+08	SCF PER YEAR
LIFETIME	30.	YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	2	
ELEC GEN CAPACITY	8.77	MEGAWATTS
GAS FLOW CAPACITY	1.25E+09	SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	1.	4.	6.26E+08	8.	13.
1987.	1.	4.	6.26E+08	8.	13.
1988.	2.	9.	1.25E+09	17.	25.
1989.	2.	9.	1.25E+09	17.	25.
1990.	2.	9.	1.25E+09	17.	25.
1991.	2.	9.	1.25E+09	17.	25.
1992.	2.	9.	1.25E+09	17.	25.
1993.	2.	9.	1.25E+09	17.	25.
1994.	2.	9.	1.25E+09	17.	25.
1995.	2.	9.	1.25E+09	17.	25.
1996.	2.	9.	1.25E+09	17.	25.
1997.	2.	9.	1.25E+09	17.	25.
1998.	2.	9.	1.25E+09	17.	25.
1999.	2.	9.	1.25E+09	17.	25.
2000.	2.	9.	1.25E+09	17.	25.
2001.	2.	9.	1.25E+09	17.	25.
2002.	2.	9.	1.25E+09	17.	25.
2003.	2.	9.	1.25E+09	17.	25.
2004.	2.	9.	1.25E+09	17.	25.
2005.	2.	9.	1.25E+09	17.	25.
2006.	2.	9.	1.25E+09	17.	25.
2007.	2.	9.	1.25E+09	17.	25.
2008.	2.	9.	1.25E+09	17.	25.
2009.	2.	9.	1.25E+09	17.	25.
2010.	2.	9.	1.25E+09	17.	25.
2011.	2.	9.	1.25E+09	17.	25.
2012.	2.	9.	1.25E+09	17.	25.
2013.	2.	9.	1.25E+09	17.	25.
2014.	2.	9.	1.25E+09	17.	25.
2015.	2.	9.	1.25E+09	17.	25.
2016.	1.	4.	6.26E+08	8.	13.
2017.	1.	4.	6.26E+08	8.	13.
2018.	0	0	0	0	0
2019.	0	0	0	0	0
2020.	0	0	0	0	0

ARMSTONG FAIRWAY -- OPTIMISTIC WITH DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	19336.	BARRELS PER DAY
SUPPORT AREA	11.34	SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	3	
ELEC GEN CAPACITY	5.94	MEGAWATTS
GAS FLOW CAPACITY	8.47E+08	SCF PER YEAR
LIFETIME	60.	YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	2	
ELEC GEN CAPACITY	11.87	MEGAWATTS
GAS FLOW CAPACITY	1.69E+09	SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	1.	6.	8.47E+08	11.	17.
1987.	1.	6.	8.47E+08	11.	17.
1988.	2.	12.	1.69E+09	23.	34.
1989.	2.	12.	1.69E+09	23.	34.
1990.	2.	12.	1.69E+09	23.	34.
1991.	2.	12.	1.69E+09	23.	34.
1992.	2.	12.	1.69E+09	23.	34.
1993.	2.	12.	1.69E+09	23.	34.
1994.	2.	12.	1.69E+09	23.	34.
1995.	2.	12.	1.69E+09	23.	34.
1996.	2.	12.	1.69E+09	23.	34.
1997.	2.	12.	1.69E+09	23.	34.
1998.	2.	12.	1.69E+09	23.	34.
1999.	2.	12.	1.69E+09	23.	34.
2000.	2.	12.	1.69E+09	23.	34.
2001.	2.	12.	1.69E+09	23.	34.
2002.	2.	12.	1.69E+09	23.	34.
2003.	2.	12.	1.69E+09	23.	34.
2004.	2.	12.	1.69E+09	23.	34.
2005.	2.	12.	1.69E+09	23.	34.
2006.	2.	12.	1.69E+09	23.	34.
2007.	2.	12.	1.69E+09	23.	34.
2008.	2.	12.	1.69E+09	23.	34.
2009.	2.	12.	1.69E+09	23.	34.
2010.	2.	12.	1.69E+09	23.	34.
2011.	2.	12.	1.69E+09	23.	34.
2012.	2.	12.	1.69E+09	23.	34.
2013.	2.	12.	1.69E+09	23.	34.
2014.	2.	12.	1.69E+09	23.	34.
2015.	2.	12.	1.69E+09	23.	34.
2016.	2.	12.	1.69E+09	23.	34.
2017.	2.	12.	1.69E+09	23.	34.
2018.	2.	12.	1.69E+09	23.	34.
2019.	2.	12.	1.69E+09	23.	34.
2020.	2.	12.	1.69E+09	23.	34.

HIDALGO FAIRWAY -- OPTIMISTIC W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE	18718.	BARRELS PER DAY
SUPPORT AREA	5.88	SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS	6	
ELEC GEN CAPACITY	14.04	MEGAWATTS
GAS FLOW CAPACITY	2.05E+09	SCF PER YEAR
LIFETIME	30.	YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS	27	
ELEC GEN CAPACITY	379.04	MEGAWATTS
GAS FLOW CAPACITY	5.53E+10	SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	1.	14.	2.05E+09	27.	41.
1987.	1.	14.	2.05E+09	27.	41.
1988.	2.	28.	4.10E+09	55.	83.
1989.	2.	28.	4.10E+09	55.	83.
1990.	3.	42.	6.15E+09	82.	124.
1991.	4.	56.	8.20E+09	109.	166.
1992.	5.	70.	1.02E+10	137.	207.
1993.	6.	84.	1.23E+10	164.	248.
1994.	7.	98.	1.43E+10	192.	290.
1995.	8.	112.	1.64E+10	219.	331.
1996.	9.	126.	1.84E+10	246.	373.
1997.	10.	140.	2.05E+10	274.	414.
1998.	11.	154.	2.25E+10	301.	455.
1999.	12.	168.	2.46E+10	328.	497.
2000.	13.	182.	2.66E+10	356.	538.
2001.	14.	197.	2.87E+10	383.	580.
2002.	15.	211.	3.07E+10	410.	621.
2003.	16.	225.	3.28E+10	438.	662.
2004.	17.	239.	3.48E+10	465.	704.
2005.	18.	253.	3.69E+10	492.	745.
2006.	19.	267.	3.89E+10	520.	787.
2007.	20.	281.	4.10E+10	547.	828.
2008.	21.	295.	4.30E+10	575.	869.
2009.	22.	309.	4.51E+10	602.	911.
2010.	23.	323.	4.71E+10	629.	952.
2011.	24.	337.	4.92E+10	657.	994.
2012.	25.	351.	5.12E+10	684.	1035.
2013.	26.	365.	5.33E+10	711.	1076.
2014.	27.	379.	5.53E+10	739.	1118.
2015.	27.	379.	5.53E+10	739.	1118.
2016.	26.	365.	5.33E+10	711.	1076.
2017.	26.	365.	5.33E+10	711.	1076.
2018.	25.	351.	5.12E+10	684.	1035.
2019.	25.	351.	5.12E+10	684.	1035.
2020.	24.	337.	4.92E+10	657.	994.

HIDALGO FAIRWAY -- OPTIMISTIC WITH DEEP REINJECTION

WELL PARAMETERS

FLOW RATE 19134. BARRELS PER DAY
SUPPORT AREA 4.01 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS 9
ELEC GEN CAPACITY 21.53 MEGAWATTS
GAS FLOW CAPACITY 3.14E+09 SCF PER YEAR
LIFETIME 60. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS 27
ELEC GEN CAPACITY 581.18 MEGAWATTS
GAS FLOW CAPACITY 8.49E+10 SCF PER YEAR

PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	1.	22.	3.14E+09	42.	63.
1987.	1.	22.	3.14E+09	42.	63.
1988.	2.	43.	6.29E+09	84.	127.
1989.	2.	43.	6.29E+09	84.	127.
1990.	3.	65.	9.43E+09	126.	190.
1991.	4.	86.	1.26E+10	168.	254.
1992.	5.	108.	1.57E+10	210.	317.
1993.	6.	129.	1.89E+10	252.	381.
1994.	7.	151.	2.20E+10	294.	444.
1995.	8.	172.	2.51E+10	336.	508.
1996.	9.	194.	2.83E+10	378.	571.
1997.	10.	215.	3.14E+10	419.	635.
1998.	11.	237.	3.46E+10	461.	698.
1999.	12.	258.	3.77E+10	503.	762.
2000.	13.	280.	4.09E+10	545.	825.
2001.	14.	301.	4.40E+10	587.	889.
2002.	15.	323.	4.71E+10	629.	952.
2003.	16.	344.	5.03E+10	671.	1016.
2004.	17.	366.	5.34E+10	713.	1079.
2005.	18.	387.	5.66E+10	755.	1143.
2006.	19.	409.	5.97E+10	797.	1206.
2007.	20.	431.	6.29E+10	839.	1269.
2008.	21.	452.	6.60E+10	881.	1333.
2009.	22.	474.	6.91E+10	923.	1396.
2010.	23.	495.	7.23E+10	965.	1460.
2011.	24.	517.	7.54E+10	1007.	1523.
2012.	25.	538.	7.86E+10	1049.	1587.
2013.	26.	560.	8.17E+10	1091.	1650.
2014.	27.	581.	8.49E+10	1133.	1714.
2015.	27.	581.	8.49E+10	1133.	1714.
2016.	27.	581.	8.49E+10	1133.	1714.
2017.	27.	581.	8.49E+10	1133.	1714.
2018.	27.	581.	8.49E+10	1133.	1714.
2019.	27.	581.	8.49E+10	1133.	1714.
2020.	27.	581.	8.49E+10	1133.	1714.

HIDALGO FAIRWAY -- NOMINAL W/O DEEP REINJECTION

WELL PARAMETERS

FLOW RATE 5348. BARRELS PER DAY
SUPPORT AREA 5.88 SQUARE MILES

PLANT PARAMETERS

NUMBER OF WELLS 6
ELEC GEN CAPACITY 3.65 MEGAWATTS
GAS FLOW CAPACITY 4.68E+08 SCF PER YEAR
LIFETIME 30. YEARS

FAIRWAY PARAMETERS

NUMBER OF PLANTS 21
ELEC GEN CAPACITY 76.60 MEGAWATTS
GAS FLOW CAPACITY 9.84E+09 SCF PER YEAR

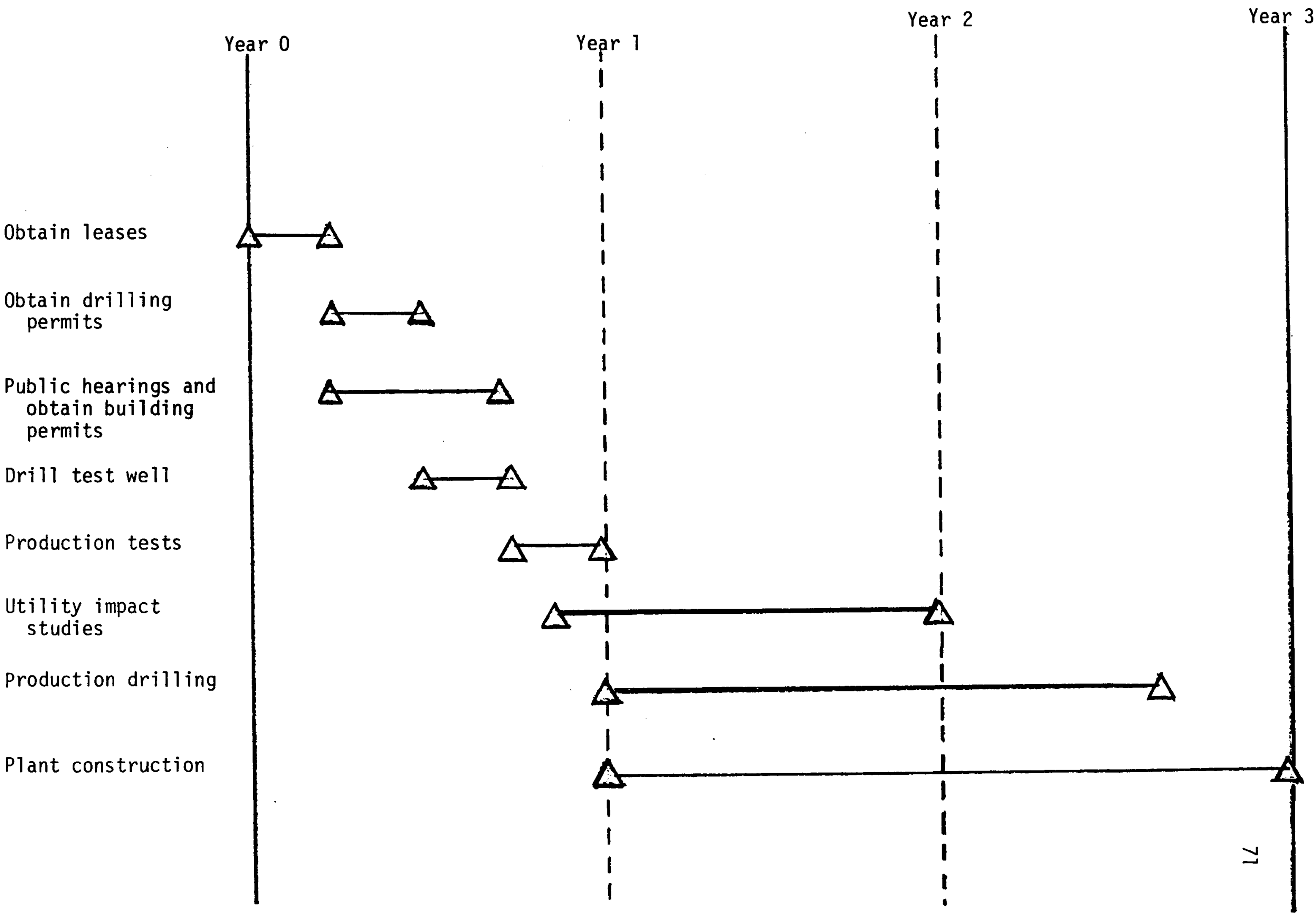
PRODUCTION SCHEDULE

YEAR	PLANTS	ELEC MW	GAS SCF	GAS MW	TOTAL MW
1980.	0	0	0	0	0
1981.	0	0	0	0	0
1982.	0	0	0	0	0
1983.	0	0	0	0	0
1984.	0	0	0	0	0
1985.	0	0	0	0	0
1986.	0	0	0	0	0
1987.	0	0	0	0	0
1988.	0	0	0	0	0
1989.	0	0	0	0	0
1990.	1.	4.	4.68E+08	6.	10.
1991.	1.	4.	4.68E+08	6.	10.
1992.	1.	4.	4.68E+08	6.	10.
1993.	2.	7.	9.37E+08	13.	20.
1994.	2.	7.	9.37E+08	13.	20.
1995.	3.	11.	1.41E+09	19.	30.
1996.	3.	11.	1.41E+09	19.	30.
1997.	4.	15.	1.87E+09	25.	40.
1998.	4.	15.	1.87E+09	25.	40.
1999.	5.	18.	2.34E+09	31.	50.
2000.	5.	18.	2.34E+09	31.	50.
2001.	6.	22.	2.81E+09	38.	59.
2002.	6.	22.	2.81E+09	38.	59.
2003.	7.	26.	3.28E+09	44.	69.
2004.	7.	26.	3.28E+09	44.	69.
2005.	8.	29.	3.75E+09	50.	79.
2006.	8.	29.	3.75E+09	50.	79.
2007.	9.	33.	4.22E+09	56.	89.
2008.	9.	33.	4.22E+09	56.	89.
2009.	10.	36.	4.68E+09	63.	99.
2010.	10.	36.	4.68E+09	63.	99.
2011.	11.	40.	5.15E+09	69.	109.
2012.	11.	40.	5.15E+09	69.	109.
2013.	12.	44.	5.62E+09	75.	119.
2014.	12.	44.	5.62E+09	75.	119.
2015.	13.	47.	6.09E+09	81.	129.
2016.	13.	47.	6.09E+09	81.	129.
2017.	14.	51.	6.56E+09	88.	139.
2018.	14.	51.	6.56E+09	88.	139.
2019.	15.	55.	7.03E+09	94.	149.
2020.	14.	51.	6.56E+09	88.	139.

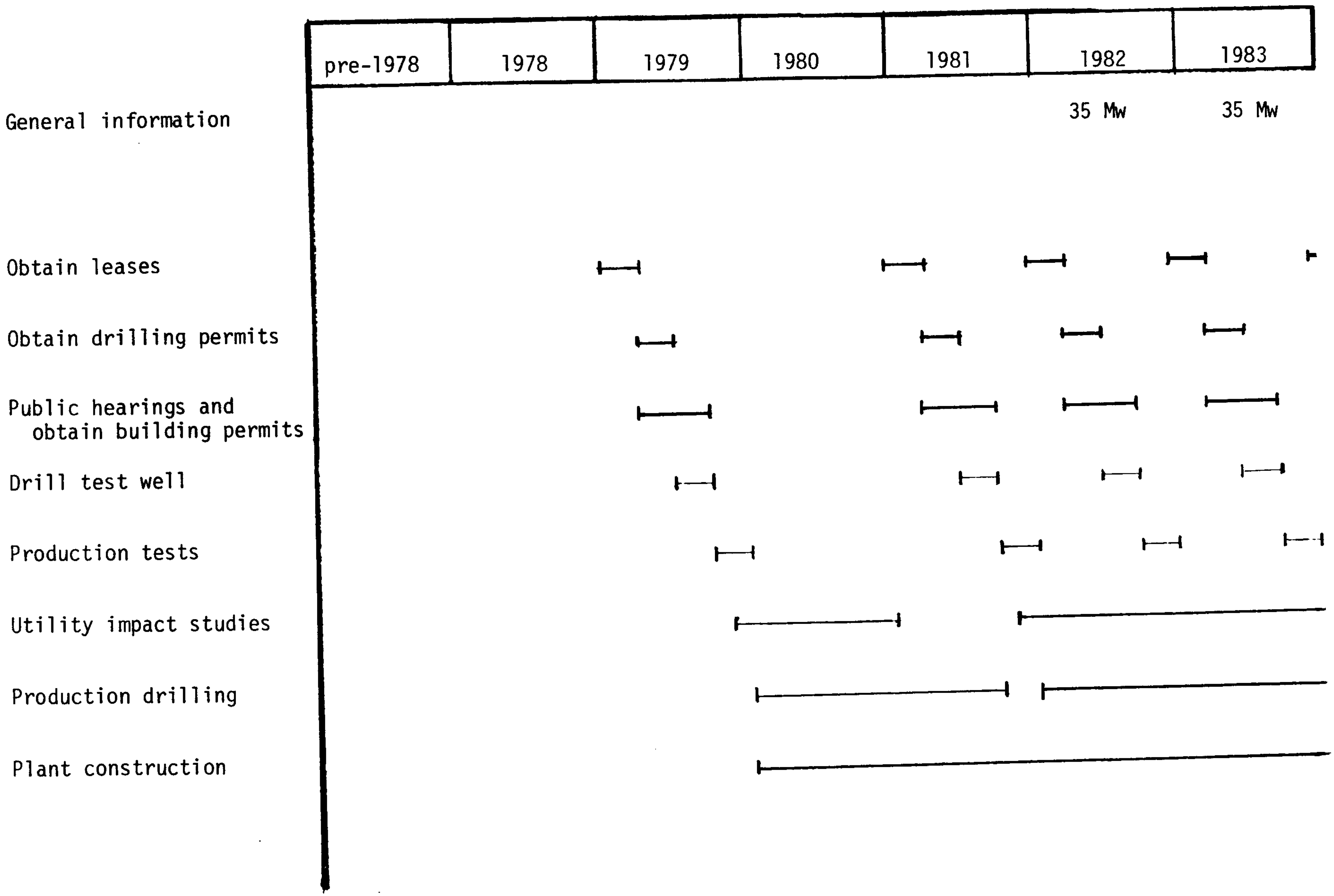
Appendix B

DEVELOPMENT SCHEDULES

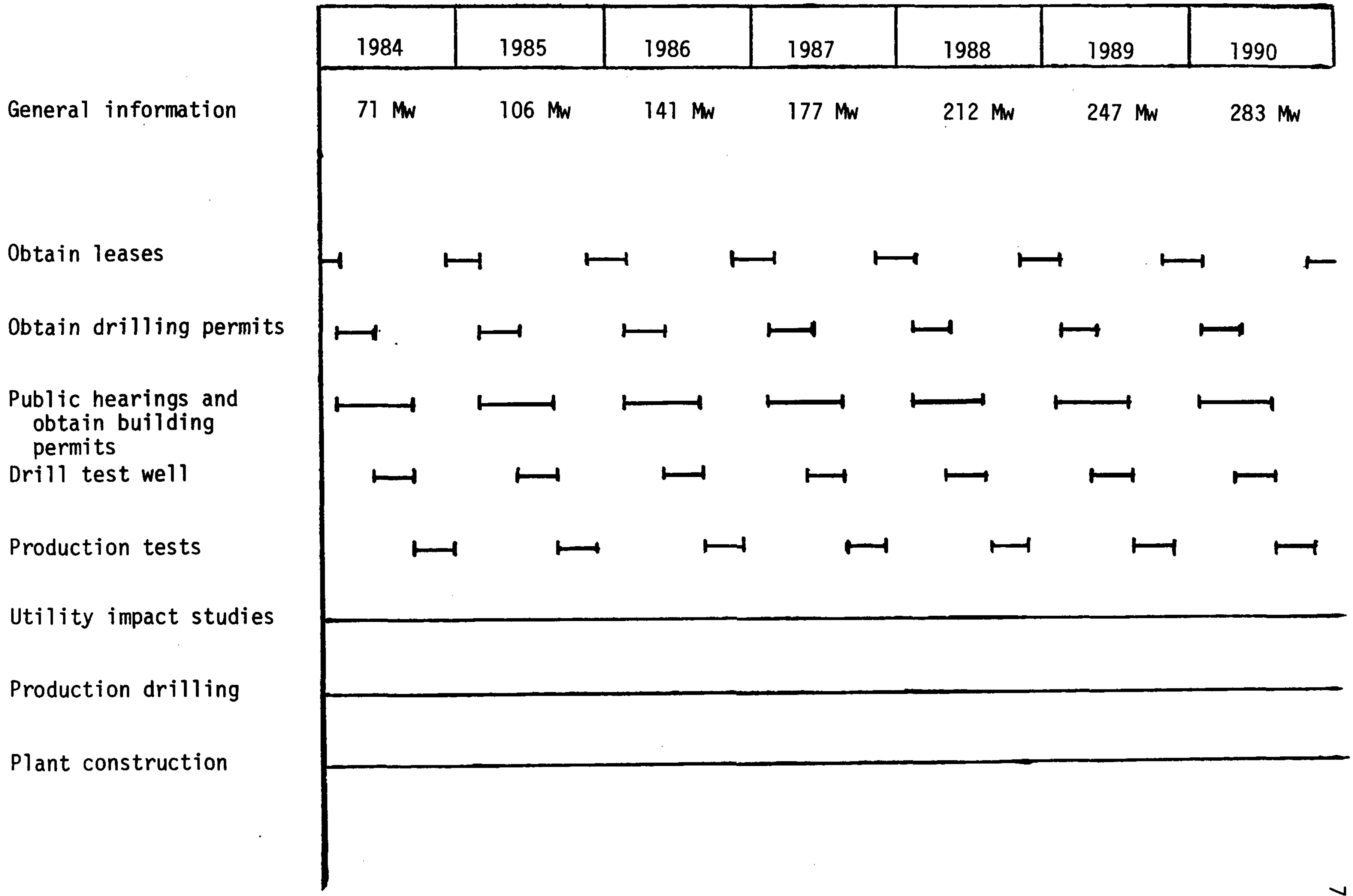
DEVELOPMENT SCENARIO FOR A SINGLE GEOPRESSURED GEOTHERMAL POWER FACILITY



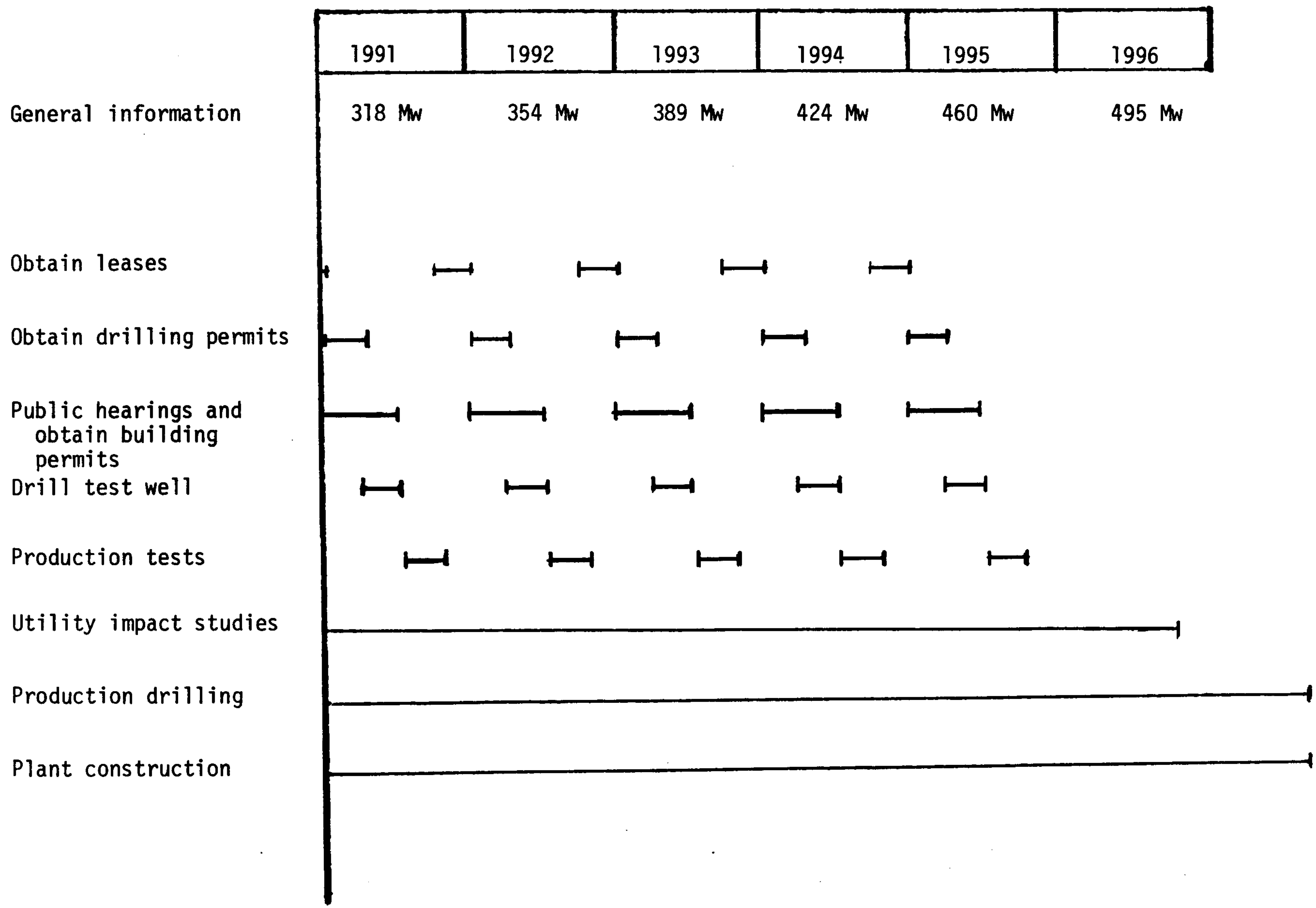
OPTIMISTIC DEVELOPMENT SCHEDULE FOR BRAZORIA FAIRWAY 1979-1996



OPTIMISTIC DEVELOPMENT SCHEDULE FOR BRAZORIA FAIRWAY 1979-1996 (Continued)



OPTIMISTIC DEVELOPMENT SCHEDULE FOR BRAZORIA FAIRWAY 1979-1996 (Continued)



Appendix C

DETAILED SCENARIO LAYOUTS

This appendix displays and discusses two possible formats for more detailed scenario layouts. The first format is shaped around the idea of "what has to be done." The second format is shaped around the idea of "who has to do things." Each form has advantages. The first makes it easier to analyze the process as a series of events. The second is useful if one is trying to institute changes, particularly within government, in order to simplify the procedures required to build and operate a geopressured plant.

The second format appears to be more detailed than the first, but the appearance is misleading. In particular, some of the agencies listed under the state government will have a role only under certain circumstances. The General Land Office is not involved unless the construction or operation of the plant directly affects state-owned lands. The Texas Department of Water Resources at present, is active in the case of surface disposal of effluent, but not in the case of reinjection except to ensure the integrity of freshwater sources. The Parks and Wildlife Department has no direct role in the development of geopressured resources, but can become involved, through public hearings and court cases, if disposal methods threaten state parks, refuges, or fish and wildlife. The Air Control Board is involved only if there is a discharge of pollutants into the atmosphere.

These formats were loosely adapted from a form issued by ERDA. Since that form was based on the political situation relating to California's hydrothermal resource, some categories are not directly applicable to the geopressured resource in Texas. Texas does not require the extensive environmental impact studies needed in California, and most of the "geological studies" have been performed in the course of oil and gas exploration. These forms will, of course, continue to be modified as more detailed information becomes available.

Site Characteristics

Thickness -
Areal extent -
Porosity -
Permeability -
Temperature -
Gas content -
Recoverability -
Lifetime -

Summary of Major Events of Resource Development	
Procurement of leases Permitting activities Impact studies Exploration and assessment Development and construction Power on-line	
Detailed Project Schedule	
Procurement of leases 1. Land 2. Mineral rights	
Permitting activities 1. Drilling 2. Reinjection 3. Air pollution 4. Construction 5. Production	
Impact studies 1. Environmental 2. Social 3. Economic 4. Public hearings	
Exploration and assessment 1. Geological studies 2. Operations analysis 3. Exploratory drilling 4. Reservoir evaluation 5. Evaluation of reinjection techniques	

Development and construction 1. Permitting activities 2. Design and procurement 3. Construction 4. Testing	
Power on-line	

DETAILED SCENARIO LAYOUT #2

Site Characteristics

Thickness -
Areal extent -
Porosity -
Permeability -
Temperature -
Gas content -
Recoverability -
Lifetime -

Summary of Major Events of Resource Development	
Procurement of leases Permitting activities Impact studies Exploration and assessment Development and construction Power on-line	
Detailed Project Schedule	
Owner 1. Land leases 2. Mineral leases	
County/City 1. Public hearings 2. Building permits 3. Drilling permits	
State A. Texas Railroad Commission 1. Drilling permits 2. Production permits 3. Disposal permits 4. Monitor activities B. General Land Office 1. Leasing of state lands 2. Building permits on state lands 3. EIS - public hearings 4. Easements as needed	

C. Texas Water Department
   1. Public hearings
   2. Thorough investigation
   3. EPA approval
   4. Issue permits for surface disposal

D. Public Utilities Commission
   1. Issue certificate for construction
   2. Rate regulation policies

E. Parks and Wildlife Department

F. Air Control Board
   1. Administer standards
   2. Issue air pollution permits

Developer
1. Preliminary exploration
2. Exploratory drilling
3. Reservoir evaluation
4. Commitment to development
5. Prepare master development plan
6. Design - preliminary and final
7. Production drilling
8. Construction of plant
9. Power on-line

Federal Government

A. Energy Research and Development Administration
   1. Engineering research and development
   2. Resource exploration and assessment
   3. Geopressured/geothermal technology applications
   4. Advanced technology applications
   5. Utilization experiments
   6. Environmental control and institutional studies
   7. Loan guarantee program

B. Environmental Protection Agency
   1. Resolution of FWPCAA conflict
   2. Regulations under SDWA

REFERENCES

1. Myron H. Dorfman, "Natural Gas from Geopressured Zones in the U.S. Gulf Coast Basin," Gas Supply Review, Vol. 5, No. 6, American Gas Association, March 1977.

2. T. L. Gould and A. Spivak, "Production Economics of a Geopressured Geothermal Prospect," American Institute of Chemical Engineers, Paper No. 27E, March 1977.

3. Murray F. Hawkins, Jr., "Final Report -- Investigations of the Geopressure Energy Resource of Southern Louisiana," Louisiana State University Petroleum Engineering Department, ERDA Contract No. EY-76-S-05-4889, April 15, 1977.

4. Bill R. Hise, "Natural Gas from Geopressured Aquifers," in Natural Gas from Unconventional Geologic Sources, Board on Mineral Resources (Washington, D.C.: National Academy of Sciences, 1976).

5. P. A. House, P. M. Johnson, and D. F. Towse, "Potential Power Generation and Gas Production from Gulf Coast Geopressured Reservoirs," Lawrence Livermore Report UCRL-51813, 1975.

6. Paul H. Jones, "Natural Gas Resources of the Geopressured Zones in the Northern Gulf of Mexico Basin," in Natural Gas from Unconventional Geologic Sources, Board on Mineral Resources (Washington, D.C.: National Academy of Sciences, 1976).

7. B. Myers, R. Nelson, J. Howard, and R. Austin, "Some Elements of the Northern Gulf of Mexico Basin Geopressure Energy Resource," presented to American Association of Petroleum Geologists, UCRL-74807, Rev. 1, San Antonio, Texas, April 2, 1974.

8. S. S. Papadopulos, R. H. Wallace, Jr., J. B. Wesselman, and R. E. Taylor, "Assessment of Onshore Geopressured-Geothermal Resources in the Northern Gulf of Mexico Basin," Assessment of Geothermal Resources of the United States--1975, D. E. White and D. L. Williams, editors, U.S. Geological Survey Circular 726, 1975.

9. T. W. Schnadelbach, Jr., Inventory and Case Studies of Louisiana, Non-Electrical Industrial Applications of Geopressured Geothermal Resources, ERDA Contract No. EG-77-C-07-1629, Quarterly Progress Report (New Orleans: de Laureal Engineers, February 28, 1977).

10. C. Cronquist, J. P. Malott, N. H. Olsen, P. E. Purser, and F. W. Zimmerman, "Potential Producibility and Recovery of Natural Gas from Geopressured Aquifers of the Cenzoic Sediments of the Gulf Coast Basin," Gulf Universities Research Consortium, Bellaire, Texas, October 30, 1977.

11. K. E. Rogers 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, July 1977.

BIBLIOGRAPHY

Bebout, D. G.; Agagu, O. K.; and Dorfman, M. H. Geothermal Resources, Frio Formation, Middle Texas Gulf Coast. Geological Circular 75-8, Bureau of Economic Geology. Austin: The University of Texas at Austin, 1975.

Bebout, D. G.; Agagu, O. K.; and Dorfman, M. H. Geothermal Resources--Frio Formation, South Texas. Geological Circular 75-1, Bureau of Economic Geology. Austin: The University of Texas at Austin, 1975.

Bebout, D.G.; Loucks, R. G.; Bosch, S. C.; and Dorfman, M. H. Geothermal Resources--Frio Formation, Upper Texas Gulf Coast. Geological Circular 76-3, Bureau of Economic Geology. Austin: The University of Texas at Austin, 1976.

Bebout, D. G.; Loucks, R. G.; and Gregory, A. R. Frio Sandstone Reservoirs in the Deep Subsurface along the Texas Gulf Coast, Their Potential for the Production of Geopressured Geothermal Energy. Report of Investigation 91, Bureau of Economic Geology. Austin: The University of Texas at Austin, in press.

Bechtel Corporation. "Conceptual Design of Commercial 50 Mwe (Net) Geothermal Power Plants at Heber and Niland, California." San Francisco, California, October 1976.

Beck, Gary. Elliott, Division of Carrier Corporation, Jeannette, Pennsylvania. Personal communication, summer 1977.

Bloomster, C. H. "Economic Analysis of Geothermal Energy." Chemical Engineering Progress, July 1976, pp. 89-95.

Bloomster, C. H., and Knutsen, C. A. An Analysis of Electricity Production Costs from the Geopressured Geothermal Resource. BNWL-2192. Richland, Washington: Battelle, Pacific Northwest Laboratories, 1977.

Boyd, W. E. Completion Techniques for Geothermal-Geopressured Wells. Center for Energy Studies. Austin: The University of Texas at Austin, 1977.

Boyd, W. E. Testing and Sampling Procedures for Geothermal-Geopressured Wells. Center for Energy Studies. Austin: The University of Texas at Austin, 1977.

Comfort, W. J. Interim Report on Performance Tests of a Total Flow Impulse Turbine for Geothermal Application. UCID-17411. Livermore, California: Lawrence Livermore Laboratory, March 1977.

Cronquist, C.; Malott, J. P.; Olsen, N. H.; Purser, P. E.; and Zimmerman, F. W. Potential Producibility and Recovery of Natural Gas from Geopressured Aquifers of the Cenozoic Sediments of the Gulf Coast Basin. Bellaire, Texas: Gulf Universities Research Consortium, October 30, 1977.

Dorfman, M. H. Drilling and Production Techniques in Geothermal Reservoirs. Petroleum Extension Service, Division of Extension. Austin: The University of Texas at Austin, 1973.

Dorfman, M. H. "Natural Gas from Geopressured Zones in the U.S. Gulf Coast Basin." Gas Supply Review (American Gas Association) 5, March 1977.

Dorfman, M. H., and Deller, R. W., eds. Proceedings of the First Geopressured Geothermal Energy Conference. Center for Energy Studies. Austin: The University of Texas at Austin, June 1975.

Dorfman, M. H., and Deller, R. W., eds. Proceedings of the Second Geopressured Geothermal Energy Conference, vols. 1-5. Center for Energy Studies. Austin: The University of Texas at Austin, February 1976.

Electric Reliability Council of Texas. "Responses to Federal Power Commission Order No. 383-4 (Docket No. R-362)." San Antonio, April 1, 1977.

Gould, T. L., and Spivak, A. "Production Economics of a Geopressured Geothermal Prospect." Paper No. 27E. American Institute of Chemical Engineers, March 1977.

Gustavson, T. C., and Kreitler, C. W. 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. Austin: The University of Texas at Austin, 1976.

Hawkins, Murray F., Jr. Final Report--Investigations of the Geopressure Energy Resource of Southern Louisiana. ERDA Contract No. EY-76-S-05-4889, Petroleum Engineering Department. Baton Rouge: Louisiana State University, April 1977.

Hise, Bill R. "Natural Gas from Geopressured Aquifers." In Natural Gas from Unconventional Sources. Board on Mineral Resources. Washington, D.C.: National Academy of Sciences, 1976.

House, P. A.; Johnson, P. M.; and Towse, D. F. Potential Power Generation and Gas Production from Gulf Coast Geopressure Reservoirs. UCRL 51813. Livermore, California: Lawrence Livermore Laboratory, May 1975.

Jones, Paul H. "Natural Gas Resources of the Geopressured Zones in the Northern Gulf of Mexico Basin." In Natural Gas from Unconventional Geologic Sources. Board on Mineral Resources. Washington, D.C.: National Academy of Sciences, 1976.

Lopreato, S. C., and Blissett, M. An Attitudinal Survey of Citizens in a Potential Gulf Coast Geopressured-Geothermal Test Well Locality. Center for Energy Studies. Austin: The University of Texas at Austin, May 1977.

Louisiana Office of Conservation, R. T. Sutton, Commissioner. "Louisiana Gepressured/Geothermal Energy Resources, Resume of Activity." June 1977.

Lundquist, Art, and Bracker, William. Pacific Pumps Division, Dressler Industries, Inc., Huntington Park, California. Telephone interviews, summer 1977.

Morphis, John. Rotoflow Corporation, Los Angeles, California. Telephone interviews, summer 1977.

Myers, B.; Nelson, R.; Howard, J.; and Austin, R. "Some Elements of the Northern Gulf of Mexico Basin Geopressure Energy Resource." Presented to the American Association of Petroleum Geologists (UCRL-74807, Rev. 1). San Antonio, Texas, April 1974.

Oberbeck, A. W. The Geopressured Geothermal Resources of Texas: A Report on Legal Ownership and Royalty Issues. Center for Energy Studies. Austin: The University of Texas at Austin, January 1977.

Papadopulous, S. S.; Wallace, R. H., Jr.; Wesselman, J. B.; and Taylor, R. E. Assessment of Onshore Geopressured Resources in the Northern Gulf of Mexico Basin. U.S. Geological Survey Circular 726, Department of the Interior. Washington, D.C.: U.S. Government Printing office.

Railroad Commission of Texas. "Rules Having Statewide General Application to Oil, Gas, and Geothermal Resource Operations within the State of Texas." Austin, November 24, 1975.

Rogers, K. E., and Oberbeck, A. W. The Geopressured Geotermal Resources of Texas: Regulatory Controls over Water Pollution. Center for Energy Studies. Austin: The University of Texas at Austin, July 1977.

Schnadelbach, T. W., Jr. Inventory and Case Studies of Louisiana, Non-Electric Industrial Applications of Geopressured Geothermal Resources. ERDA Contract No. EG-77-C-07-1629, Quarterly Progress Report. New Orleans: de Laureal Engineers, February 28, 1977.

Swanson, R. K.; Oetking, P.; Osaba, J. S.; and Hagens, R. C. Development of an Assessment Methodology for Geopressured Zones of the Upper Gulf Coast Based on a Study of Abnormally Pressured Gas Fields in South Texas. San Antonio: Southwest Research Institute.

United States Geological Survey Facilities. "Working Papers of the MOPPS Oil and Gas Workshop," (draft). Reston, Virginia, May 24-26, 1977.

Wilson, J. S.; Hamilton, J. R.; Manning, J. A.; and Muehlberg, P. E. Environmental Assessment of Geopressured Waters and Their Projected Uses. Freeport, Texas: Texas Division, Dow Chemical, USA, April 1977.