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GEOTHERMAL ENERGY: TOMORROW'S ALTERNATIVE TODAY.

A Handbook for Geothermal-Energy Development in Delaware

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PREFACE

This publication was prepared under contract with the United States Department of Energy by the State of Delaware's Division of Facilities Management. The commercialization effort was established in the Summer of 1980 to help the State define and shape policies to enhance the prospect of geothermal energy development. This handbook is a general procedure guide to the various technical, economic, and institutional aspects of geothermal development in Delaware.

The Division of Facilities Management wishes to thank Dr. David B. Lombard, D.O.E., project manager, and Mr. Fletcher C. Paddison, of The John Hopkins University, Applied Physics Laboratory, for their assistance and support throughout the course of this project.

Geothermal Energy: Tomorrow's Alternative Today is built largely from the conclusion of other researchers. Any distortions of presentation, errors of interpretation, or opinions expressed in the report are, however, solely the authors' responsibility.

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INTRODUCTION

Continued political instability in major oil-exporting countries, the United States' dependence on conventional fuels and increasing energy needs define the bleak reality of our "energy future".

One readily recognizes that the achievement of energy independence and long-term security of energy sources and supplies are essential to the health of the national economy, the well-being of our citizens, and the maintenance of national security.

Specifically, Delaware is faced with a finite and diminishing resource base of native fuels and, as a consequence, must develop as quickly as possible a diversified pluralistic energy capability. These aforementioned conditions have caused attention to turn to less conventional energy sources. One promising alternative is geothermal energy.

Given this climate, the State has adopted a policy to foster the prudent research, development and use of a diverse array of energy resources. This report is a result of that effort.

GEOHERMAL AS AN ALTERNATIVE

Geothermal energy is energy in the form of heat trapped in the earth's crust. There are three main types of geothermal energy. They are grouped by characteristics such as presence or absence of water, temperature of water, and additionally, whether or not gases are dissolved in water under pressure.

A brief description follows.

Hot Dry Rock (HDR) is characterized by the near absence of water in any form. Geothermal energy is obtained by pumping water down by means of an injection well into hot basement rock which has been fractured. The water is then heated by the surrounding rock in situ and is removed via the production well. The heat is then extracted from the water at the surface. Research in HDR is primarily done at Los Alamos Scientific Laboratory, New Mexico.

Geopressured geothermal resources are found in thick wedges of Gulf Coast sedimentary rocks. These resources contain methane dissolved in moderately hot water under high pressure. In addition to thermal energy, extraction of methane gas from the fluid is another viable energy source.

Hydrothermal energy is the third type of geothermal energy. Water which is present in rock below the earth's surface is pumped to the surface. The water serves as a convenient transfer medium to bring heat from within the earth's crust to the surface. Dependent upon temperature, the water will be used

directly as in space conditioning or indirectly to produce electricity. Moderate temperature hydrothermal energy with direct-use applications is the type of resource which is expected to be present in Delaware.

RESOURCE CHARACTERISTICS

In an area where the subsurface geology has been explored, many of the resource characteristics determined by the geology may already be known. To date, the total depth of the deepest well in Delaware is 918 meters (3,012 feet). Geology beyond this point is surmised by way of geophysical investigations, such as seismics and stratigraphic correlation. Listed below are the resource characteristics which determine the feasibility of a geothermal project.

- Source
- Occurrence
- Temperature
- Reservoir Rock Type
- Chemical Composition
- Quantity
- Flow Rate

Source

Areas of increased crystal temperatures are observed through heat flow and temperature gradient measurements. The source of heat anomalies in the earth's crust is probably due to the decay of radioactive elements in common silicic rocks, such as granite (Samuel, 1978). Generally, there is more heat trapped in reservoir rocks than in the fluid (Kunze, et al., 1979). This makes it possible to return the fluid to the reservoir through a reinjection well and remove additional heat via the original production well.

Occurrence

Hydrothermal resources are found in rock bodies which have sufficient permeability and porosity to allow for fluid movement. In Delaware, these resources would most likely be in the Atlantic Coastal Plain sediments. See section on Geology for a more complete discussion.

Temperature/Depth

The value of a geothermal resource increases as the temperature increases. Higher temperatures are associated with increased depth. Drilling costs are increased as it becomes necessary to drill deeper for a resource. Economics largely determine at what point it is no longer profitable to drill deeper for the higher temperature resource.

The temperature range of hydrothermal resources is great (Table 1). Temperatures greater than or equal to 150°C (302°F) are hot enough to produce electricity. This is presently being done in California at the Geyser, a steam field that produces much of the electricity for San Francisco. Low to moderate temperatures, 27°-150°C (80°-302°F), cannot be used to generate electricity; however, at the present time, the heat can be used directly as is explained in the section on Direct Heat Utilization. There is a general rule that temperature increases proportionately with depth with the average thermal gradient of 25°C/Km (1.5°F every 100 feet). Variations in the geothermal gradient observed result from the heat flow through rocks and their thermal conductivity (Costain, 1980).

Reservoir Rock Type

The type of rock drilled through significantly affects the drilling costs and time. The drill bit has to be replaced more often when drilling through highly compacted, chemically altered and metamorphosed sediments.

Chemical Composition

Chemical composition of a resource determines the amount of fouling and scaling of pipes and whether treatment is necessary before utilizing, discharging or reinjecting the spent fluid.

Quantity

The quantity of the resource determines the life of the project. The Geothermal Resource Interactive Temporal Simulation computer model in Appendix E indicates how sensitive project success is to certain resource characteristics.

Flow Rate

A sufficient flow rate is necessary to make the project economically feasible. Five hundred (500) gallons per minute (gpm) is a good flow rate for deep geothermal wells (Kunze, et al., 1979).

GEOLOGY

The Atlantic Coastal Plain is a major geological physiographic province throughout the eastern coast of the United States. It is characterized by a blanket of low thermal conductive sediments which thicken seaward to form a wedge-shaped feature. Beneath these sediments is believed to be the

Table 1. Temperature range of hydrothermal resources (Source: The Johns Hopkins University/Applied Physics Laboratory).

heat-releasing rocks (granitic plutons) which have a relatively high content of radioactive elements. The radioactive decay of the radioactive elements produces heat which is trapped by the low thermal conductivity of the water saturated Coastal Plain sediments which act as an insulator. The heat from the underlying rocks (the crystalline basement rocks beneath the sediments of the Atlantic Coastal Plain) can accumulate in the sediment layer and become a hydrothermal resource if recoverable fluid is present (Figure 1). Figure 2 depicts potential areas of geothermal resources in the Atlantic Coastal Plain. Most of Delaware lies in this region.

The Department of Energy has funded geothermal explorations in the Atlantic Coastal Plain states. In Delaware, this work was performed by the Virginia Polytechnic Institute, and State University, the Delaware Geological Survey and the United States Geological Survey. Five 1000 foot holes were drilled throughout lower Delaware, and temperature gradient measurements were taken. The results indicate a higher than normal temperature gradient for each hole. Geological and geophysical data was used to predict "depth to basement" (the lowest extent of the sedimentary rocks) since the maximum depth drilled to in Delaware is only 918 meters (3,012 feet). Calculations using the temperature gradient measured, an average surface temperature of 12.8°C (55°F) and estimates of depth to basement were used to predict the maximum temperature obtainable at each site. Table 2 lists the results. As explained in the preceding section, higher

temperatures are usually associated with increased depth. Therefore, although the test hole in Dover had a higher temperature gradient than the Lewes hole, higher temperatures should be attainable in the Lewes hole because the sediment layer is thicker (Figure 3).

Attempts to correlate high temperature gradients with geophysical data, such as gravity and magnetic lows, were not conclusive (Woodruff, 1980). It was anticipated that high temperature gradients would indicate massive buried granitic rock as the source of heat. These granitic intrusions, in turn, would be detected as geophysical anomalies. More data is necessary to complete this relationship.

WELL MECHANICS AND PUMPING SYSTEMS

Various industrial processes require different temperatures; consequently, the first step in determining the utilization potential of geothermal energy is to define the physical characteristics required for the application. Physical characteristics generally include temperature, flow rate, water quality and location. Once these requirements are determined, an exploration program can be developed (Combs, et al., 1979).

Exploration

After a thorough literature search and consultation with the Delaware Geological Survey (located in Penny Hall on the University of Delaware's campus) is completed, then a decision can be made as to whether or not a given site displays

Figure 1. Schematic model of a geothermal reservoir in sedimentary rocks of low thermal conductivity overlying basement plutonic rocks (radiogenic deposit) enriched in uranium and thorium (Source: The Johns Hopkins University/Applied Physics Laboratory).

Figure 2. Potential areas of geothermal resources in the Atlantic Coastal Plain (Source: The Johns Hopkins University/Applied Physics Laboratory).

AREA	DEPTH TO BASEMENT FEET	MAX TEMP EXPECTED	
		°C	°F
Dover	3600	53	127
Greenwood	4100	56	133
Lewes	6000	65	149
Georgetown	4450	58	136
Fenwick Island	6950	75	167
Seaford/Salisbury	4780	56	133

TABLE 2. ESTIMATED MAXIMUM TEMPERATURE AT THE
DEPARTMENT OF ENERGY'S THERMAL GRADIENT
TEST HOLES IN DELAWARE (Source: The Johns
Hopkins University/Applied Physics Laboratory)

after Woodruff, 1979; and Benson, 1979.

Figure 3. Diagrammatic cross section through hinge zone of the Baltimore Canyon Trough, Delaware (Source: Ebasco Services, Inc.).

sufficient potential to warrant detailed exploration. Since each site is unique, one exploration method or series of methods will not work in all circumstances. Those exploration methods used to assess a site's characteristics include geological exploration techniques, geochemical investigations, geophysical exploration, drilling and geophysical logging. Exploration methods must be viewed in terms of the value of the information they produce relative to the resource for they are costly, and final verification of a resource must be based on drilling (Combs, et al., 1979).

Development

The drilling of a well represents the greatest expense and the greatest risk in geothermal energy utilization (Kunze, et al., 1979). Geothermal well costs are on an average 30% to 50% more expensive than the same depth oil and gas or water wells because of the regulations governing construction, environmental constraints, and larger hole size (Prestwich, 1980).

Once the exploration phase of development is complete, the geologist/geophysicist can designate the site and specify the theoretical depth estimate for the resource. The theoretical depth estimate will be sufficient to meet the needs of the application and allows for a contingency of 25-50% to be added to ensure adequate productivity (Kunze, et al., 1979). After the depth estimate has been established and the flow rate and temperature predicted, the well size and the diameter of the well hole in the production section (the deepest part of the well) can be

determined. In addition to providing for a casing size sufficient to meet the application needs (flow rate and temperature) and depending upon well depth and the transmissibility of the aquifer, the production section of the casing string might have to house the pump and motor required to realize the desired production (APL/JHU QM-79-114, 1979). A 9 5/8" diameter casing is sufficient to conduct flows as large as 1000 gallons per minute (gpm). The determination of well design, selection of drilling equipment, supervision of the drilling operation, and the "development" and testing of the well are the province of the drilling engineer. By contrast, the drilling contractor is charged with the competent, safe, and cost effective operation of the drilling rig (Kunze, et al., 1980).

Drilling

Conventional drilling methods from both the oil and gas and water well industries apply to geothermal drilling. However, certain aspects make geothermal drilling unique. They are temperature, fracture dominated reservoirs (not anticipated in Delaware), and to some degree, the volume of flow (Prestwich, 1980).

The next phase after site selection/well design and the review of applicable regulations and the obtaining of the necessary permits, licenses, etc. is site preparation. Site preparation depends upon the location and regulations, but generally consists of the following: an access road, construction of the well pad,

construction of a reserve mud pit, installation of drilling rig stabilization anchors, installation of conductor casing, completing the mouse and rat holes and the construction of the cellar.

The installation of the conductor casing is often accomplished by a local water well driller, whereas the drilling of the well is left to an adequately sized drilling rig. The well casing is installed in steps with each successive string being of a narrower diameter in order to allow it to pass through the previous casing string, Figure 4. Before a casing string is hung and cemented in place, a geophysical log is run in the well. These logs indicate the production zone or zones and, therefore, aid in the determination of when to stop drilling. Drilling through the area "predetermined" to contain the production zone(s) is most critical for the drilling fluid can mask, damage or cause the loss of a good production zone (Prestwich, 1980). Equally important is the selection of the completion technique; it is recommended that the production wells (in the Atlantic Coastal Plain) be completed with screen and gravel over an adequate section of the aquifer in order to minimize the head loss and to ensure adequate productivity (Yu, 1979).

Pumps

Two types of pumps are utilized in geothermal wells, Figure 5. They are the vertical-shaft turbine pump with the motor located at the well head and the submersible down-hole pump which has the motor located below the

pumps within the well's casing. Currently vertical-shaft pumps are being utilized at a depth of 305 meters (1000 feet) in East Mesa, California, and are capable of performing at depths of 457 meters (1500 feet) (D. Payne, personal communication, 1982). Depth is not a limiting factor with submersible pumps, but temperature is; current technology limits temperatures to less than 180°C (365°F) (Centrilift-Hughes, Inc., 1981). Vertical-shaft pumps are preferable since annual maintenance is limited to inspection, and historically their life expectancy is greater than down-hole systems. The life expectancy of the pump motor and variable speed drive is estimated to be greater than 20 years (Paddison, et al., 1979). The lifetime of submersible pumps for geothermal uses is not firmly established but will probably average two years. Thus, provisions must be made at the well head to pull and rebuild the pump (APL/JHU QM-79-145, 1979).

Reinjection Well

A nearby reinjection well may affect the thermal quality of the production well. In order to avoid premature thermal dilution, it appears prudent to follow the French experience by separating the reinjection well from the production well by some one or two kilometers. Travel time, assuming uniform aquifer parameters, for the water would then be 15 to 30 years. As a further precaution, one can reinject at a shallower depth. Then, even if the aquifer is not truly confining, the thermal dilution times will be substantially larger than those estimated here (Yu, 1979). Geothermal fluid disposal is discussed in a subsequent section.

Figure 4. Typical design for a low-to-moderate-temperature geothermal well (Source: The Johns Hopkins University/Applied Physics Laboratory).

Figure 5. Types of pumps used to withdraw geothermal water (Source: The Johns Hopkins University/Applied Physics Laboratory).

System Design

Figure 6 illustrates a geothermal heating system. The geothermal water goes through a central heat exchanger and then, depending on the quality of the water and the location of the system, to some form of disposal system. The geothermal water gives off its heat to fluid (water) in the heat exchanger thereby limiting the exposure of the total system to the corrosive properties of the geothermal water; this is referred to as a closed loop system. The fluid, which is heated in the heat exchanger, is the fluid that will serve the needs of the application. Some applications will need the "working" fluid to be increased in temperature to serve the needs of the application; this is accomplished by a topping system (a boiler or heat pump which increases the temperature of the "working" fluid), (APL/JHU QM-79-114, 1979).

Heat Exchangers

The following types of heat exchangers are presently being utilized in geothermal systems: the down-hole heat exchanger, the shell-and-tube heat exchanger, the plate heat exchanger, the fluidized-bed heat exchanger, the direct heat exchanger, and the plastic-tube heat exchanger (Lienau, et al., 1979).

Heat Pumps

Heat pumps using water as an energy medium are referred to as water source or water referenced heat pumps. Heat pumps, like refrigerators, utilize temperature

differentials. As the refrigerant absorbs heat from "low"-temperature water, it changes (boils) from a liquid to a gas. The gas is then pressurized by a compressor to raise its temperature even further. The thermal energy is then transferred by means of a heat exchanger. The refrigerant then condenses and is recycled, and the process repeats itself. Some types of heat pumps can be reversed and perform a cooling function (Fahys-Smith, et al., 1981). Currently, non-reversible heat pumps can amplify 10-60°C (50-140°F) water to temperatures up to 60-140°C (140-220°F) (Neiss, 1980). Direct heat activated cooling equipment needs a temperature of 82°C (180°F) for operation, thus precluding its use in Delaware until new technologies are further developed (G. Culver, personal communication, 1982).

FLUID DISPOSAL

There are several methods used to dispose of geothermal fluid after the heat has been extracted. The fluid can be reinjected into the ground, discharged into nearby surface waters or evaporated from a holding pond. Ponding is not a reasonable alternative in Delaware because the area needed is large (i.e., 8 km² in Cerro Prieto, Mexico). Ponding is often used during well-testing. The decision whether to reinject or discharge is more easily made after the resource characteristics are determined. Table 3 lists characteristics of reinjection and discharge.

Reinjection

It may be advantageous to

Figure 6. Illustration of industrial use-hydrothermal system
(Source: The Johns Hopkins University/Applied Physics
Laboratory).

TABLE 3. CHARACTERISTICS OF FLUID DISPOSAL METHODS

	Reinjection	Discharge
Permits	Water Well EPA Underground Injection	National Pollutant Discharge Elimination System (NPDES) Access for pipes
Pro	Maintains pressure May prolong life of aquifer	Low cost function of (pipe and distance) Need not drill and main- tain additional well
Con	High Cost Drill and maintain additional well	May lose well pressure
Environmental Concerns	Will not affect surface Careful not to contaminate ground water May help prevent land subsidence	Will affect surface Careful not to thermally or chemically pollute water to which fluid is discharged

reinject the fluid in order to maintain pressure in the well. In this way, the life of the aquifer may be prolonged. Care must be taken not to reinject the "cooled" fluid where it may mix with the production waters being extracted - possibly and significantly lowering the temperature at the wellhead. Generally, one (1) km is used as the minimum distance to separate the production and reinjection wells. The distance is dependent on the local hydrology and geology. Most geothermal projects use 10-25% of the heat in the fluid (Kunze, et al., 1979). Some of the lost heat can be recaptured by returning the fluid to the reservoir. If the fluid is reinjected at a distance from the production well, it will become "warmed" by the reservoir rocks as it approaches the well.

Contamination of the ground water must be avoided. Delaware law dictates that the spent fluid must be returned to the same aquifer or one with similar properties.

The primary disadvantages of reinjection are the cost of drilling and maintaining a second well, scale deposition and formation plugging. The cost of drilling and maintaining a reinjection well is less expensive than a production well. This is because reinjection wells are generally shallower with smaller casing diameters and a smaller pump. Nonetheless, a reinjection well will significantly raise project costs.

Scale deposition and formation plugging may be encountered when reinjecting. Likely causes of this fouling are precipitation of silica/calcite, collection of

suspended particles or chemical alteration of minerals (Defferding, et al., 1978).

Environmentally, a reinjection well should decrease the chance of land subsidence and should not have any ill effects in the area. An underground reinjection permit must be obtained from the Water Supply Branch of the Water Resources Section of the Department of Natural Resources and Environmental Control (DNREC).

Discharge to Surface Waters

Discharging the spent fluid to surface waters is less costly than reinjection - how much less depends on the distance the fluid must be piped from the wellhead to the point of discharge. Fledgling geothermal projects would be inclined to use this method of disposal because of economics. In the long-term, discharging may seem impractical for an area with many wells because of strict environmental regulations, land subsidence and the quantity of fluid that surface waters can ultimately accept. A National Pollutant Discharge Elimination System (NPDES) permit is required in order to discharge into surface waters. The Water Pollution Branch of the Water Resources Section of the Department of Natural Resources and Environmental Control is the issuing agency.

DIRECT HEAT UTILIZATION-FEASIBILITY

Many conventional heating systems can be retrofitted to utilize direct heat from a moderate-temperature geothermal fluid. More than 7,000 megawatts thermal (MWt) come from direct heat applications

in residential/commercial space conditioning, industry, agriculture and aquaculture throughout the world (Lund, 1979). Table 4 summarizes the worldwide direct heat use of geothermal energy.

A comprehensive market study regarding geothermal energy was done by The Johns Hopkins University, Applied Physics Laboratory (Toth, 1980). The study defined potential users of low to moderate temperature geothermal energy in southeastern New Jersey, Delaware, Maryland, Norfolk, Virginia and eastern North Carolina.

A temperature of 121°C (250°F) is considered the maximum temperature for geothermal resources for the northern region of the Atlantic Coastal Plain (Toth, 1980). Direct heat uses such as heating water, space conditioning and industrial processes were defined in each area. The pros and cons for each area are listed in Table 5. The results indicate that Delaware and Maryland were the most promising areas for low to moderate temperature geothermal development.

Feasibility

A preliminary step when developing a commercial geothermal project is to determine the heat requirements of the proposed user(s). Answering the questions below can begin to determine this. They are designed to assess the efficiency of using geothermal resources to meet the user's heat requirements. A brief discussion follows each question.

- How many uses for moderate heat are there?

An industry with several uses for moderate heat can effectively use the resource by replacing conventional fuel sources with geothermal heat wherever possible. The practice of utilizing all the available heat from a geothermal source by passing the fluid through one system and extracting the required heat and then sending the lowered temperature fluid to another area to extract additional residual heat and so on is known as cascading.

- How many BTU's (British Thermal Units) are consumed?

The quantity of heat used must be determined to size a geothermal project to the needs and anticipated demand of the user. For example, if a business operates at a process heat of 41°C (100°F), a lower temperature would be deficient and a much higher temperature would be excessive. Naturally, the latter case is preferred as the excess heat could be utilized in several areas in most businesses and communities. A deficient heat source may be cost-effective if a heat pump is used to boost the temperature (Neiss, 1980). Otherwise, drilling deeper, modifying heat use or abandonment of the project may be warranted.

- Are the heat requirements time-constant? That is, does the number of BTU's used vary from season to season? Is the utilization of the heat constant throughout the day or are there large daily fluctuations in heat requirements?

An industry or community that has little variation in heat requirements both daily and annually would optimize the resource. For example, businesses that provide

TABLE 4. WORLDWIDE DIRECT USE OF GEOTHERMAL ENERGY IN 1979
(Source: Lund, 1979)

<u>Country</u>	<u>Space Heating/ Cooling (Mwt)</u>	<u>Agriculture/ Aquaculture (Mwt)</u>	<u>Industrial Processes (Mwt)</u>
Iceland	680	40	50
New Zealand	50	10	150
Japan	10	30	5
USSR	120	5100	---
Hungary	300	370	---
Italy	50	5	20
France	10	---	---
Others	10	10	5
USA	<u>75</u>	<u>5</u>	<u>5</u>
TOTAL	1245	5570	235

TABLE 5. FACTORS THAT INFLUENCE THE MARKETABILITY OF
GEOTHERMAL ENERGY IN EACH RESOURCE AREA
(Source: Toth, 1980)

Resource Area	Pros	Cons
Southeastern New Jersey	<ol style="list-style-type: none"> 1. Large residential/ commercial market 2. Ample groundwater for industrial expansion 3. Moderate markets in other sectors 	<ol style="list-style-type: none"> 1. Old economically depressed metropolitan areas 2. Pine Barrens to be environ- mentally guarded area 3. Current industries are lo- cated in areas of less favorable resource potential
Delmarva Peninsula	<ol style="list-style-type: none"> 1. Large industrial market-well suited to potential resource conditions 2. Large agricultural market 3. Moderate residential/ commercial market 4. Thick sedimentary sections and poten- tially attractive resources 5. Ample groundwater supplies 	<ol style="list-style-type: none"> 1. Markets distributed over a large area
Norfolk, VA. area	<ol style="list-style-type: none"> 1. Very large military market 2. Large residential/ commercial market 3. Moderate industrial market 	<ol style="list-style-type: none"> 1. Reinjection prohibited 2. Thin sedimentary sections, indicating lower potential resource conditions 3. Critical groundwater area, which would limit indus- trial expansion
Eastern North Carolina	<ol style="list-style-type: none"> 1. Thick sedimentary sections and higher potential resource conditions 2. Ample surface and groundwater supplies 3. Moderate industrial markets 	<ol style="list-style-type: none"> 1. Large swamp and water areas 2. Best markets are located in areas of lower potential resource temperatures

community services such as hospitals, restaurants and gift shops in a resort town would have seasonal fluctuations in energy demand. This would not be cost-effective unless accounted for when planning to use the resource.

- Can an increase in heat consumption be anticipated?

A company that is flourishing may expand their production, thereby, energy needs. Increases in production are usually accompanied by increased employment of personnel who need homes which are run by energy. Careful planning is necessary to insure the prudent use of the resource.

- What is the user's present heat source? What is the anticipated stability of the supply and cost of this resource?

With increased costs of conventional fuels, it would be wise to plan alternative sources of energy, particularly those whose supply and cost are not limited by politics and natural abundance.

ENVIRONMENTAL AND LEGAL ISSUES

Many environmental problems are associated with the process of producing, harnessing and utilizing energy. Geothermal projects cause few deleterious effects on the environment. Serious environmental problems such as airborne toxic and noxious emissions and high noise levels are the result of steam venting associated with high temperature (vapor-dominated) geothermal energy. Delaware has a moderate temperature (liquid-dominated) resource. Moderate temperature geothermal energy does not have the extreme heat and intense corrosion

problems associated with steam; therefore, the handling and disposal of the fluid is not as critical to the environment.

The environmental issues pertaining to moderate-temperature geothermal energy are addressed below:

Noise

Noise associated with developing a moderate temperature geothermal resource is considered minimal. The degree of noise disturbance depends on the density of the population and its proximity to the well. Sources of noise are increased vehicular traffic and the movement of heavy equipment, site preparation, drilling and operation of diesel engines and compressors.

Increased vehicular traffic and the movement of heavy equipment may be more readily noticed in a rural area more so than an urbanized area, particularly during the evening hours and on weekends.

Noise associated with preparing the site for drilling (i.e., leveling the site, removing vegetation) would be temporary and not unlike familiar road planing.

Drilling would also be temporary but is a constant 24 hour/day operation. Mud drilling can be heard at 80-90 decibels at 50 feet (Leitner, 1978). This is equivalent to the degree of noise experienced when a hair dryer is held near the ear. Compressed air drilling is louder (100 decibels at 50 feet) than mud drilling but is used primarily in drilling through zones of steam

not present in Delaware. Drilling noise increases when the drill string is raised or lowered.

Operation of diesel engines and compressors is a constant, round-the-clock noise. These can be muffled with various devices.

Noise levels are generally regulated by local government. The Air Resources Section of the Department of Natural Resources and Environmental Control regulations specify that a noise disturbance in a Class A residential area must be less than ten decibels over the ambient noise level. In the case of pure tones (low level incessant noise like a humming or buzzing sound), noise levels cannot exceed five decibels over the ambient noise level (C. Wilkens, personal communication, 1982).

Air Quality

Preservation of air quality becomes an environmental concern in high temperature (vapor-dominated) geothermal projects. Venting of steam can increase the concentration of pollutants (i.e., sulfide, boron, arsenic) in the air and cause local atmospheric changes such as fogging and enhanced precipitation.

Moderate temperature (liquid-dominated) geothermal projects, however, have a negligible effect on air quality. The only true culprit is fumes from diesel engines associated with drilling and trucking.

Water Quality

Geothermal fluids are thermally

and chemically different from surface and ground waters. Geothermal fluids are much warmer than the average ground water temperature of 12.8-14.5°C (55-58°F). Therefore, it is necessary to regulate instances where geothermal fluids may mix with surface and ground waters whether it be by accident or by design in order to preserve ground water quality. An accident such as spillage of geothermal fluid at the wellhead can result in pollution of both surface and ground water. Leakage of fluid from a well can be caused by improper well construction, casing corrosion, cement failure and geological events causing casing movement or shearing, i.e., slope failure at the Geysers (Weiss, 1978). This leakage could result in the contamination of ground water. The boundary between ground water and more saline subsurface water in Delaware is approximately 500 feet. Migration of the geothermal fluid upward into the ground water would be controlled by the point of failure and the porosity and permeability of the formation.

The disposal of spent fluid is regulated by federal, state and local laws. Discharged spent fluid must be made compatible with the host body of water to prevent thermal pollution. Often, treatment of the water to remove impurities is necessary. Diluting the geothermal fluid with surface water should increase thermal and chemical similarities. However, the possibility of pollution can still occur by other means such as percolation from evaporation ponds and hydraulic fracturing of formation when reinjecting (Weiss, 1978).

Solid Waste

The bulk of solid waste comes from well drilling, scale deposition and treatment of reinjection fluids (Layton, 1980).

Disposal of solid waste is regulated by the Department of Natural Resources and Environmental Control (DNREC) and the Solid Waste Authority. The Delaware Environmental Protection Act (7 Delaware Code, Chapter 60, Subchapter II, Section 6025) states "(b) No person shall dispose or discharge solid waste anywhere in the State including any surface or ground water, except (1) through municipal or private solid waste collection systems which have received a permit from the Department (DNREC), or (2) in solid waste disposal facilities which have received a permit from the Department, or (3) in containers specially provided for solid waste collection by any state or municipal agency or company which has received a permit from the Department."

Subsidence and Seismicity

Land subsidence may occur in moderate temperature (liquid-dominated) geothermal systems where fluid is removed but not reinjected. As fluid is removed via the production well, compaction of buried sediments may occur causing overall land subsidence. Subsidence has been observed at Wairakei, New Zealand, where waste fluid from the geothermal project is discharged into a stream rather than reinjected (Bouwer, 1978).

The reinjection of fluid may increase seismicity of the area.

Reinjection of pressurized fluid may fracture surrounding rocks (hydraulic fracturing). Lubrication by pressurized fluid may cause slippage between stressed rocks (Crow, 1980). This occurred in Denver, Colorado, where earthquake activity and pressure of injected fluid were found to be directly proportional (Pickett, 1968). By lowering the pressure, seismicity could be lowered and controlled.

Delaware is a relatively inactive seismic zone. If reinjection fluid pressures are kept beneath the fracture pressure of surrounding rocks, increases in seismicity are not expected.

Legal

At present, Delaware has no laws specifically designed to regulate a geothermal industry. Questions, such as the following, have been raised but not yet answered.

- What is the definition of a geothermal resource?
- Are geothermal resources distinct from ground water (i.e., temperature, depth, chemical composition)?
- Who owns the resource?
- Should there be a royalty? What percentage?
- Is there a need for new legislation concerning geothermal leasing?

For a discussion of geothermal issues, refer to the National Council of State Legislators Geothermal Policy Report:

"Legislative Issues and Recommendations".

Cases can be built for both sides of most of the questions above. There is a general agreement, however, that Delaware does need some type of legislation not only to regulate the resource but to promote its development and simultaneously protect the rights of all parties involved.

To date, attempts to enact geothermal legislation remain unsuccessful. In 1981, Senate Bill No. 469 with Senate Amendment No. 3 made its way to the Governor's desk, but was vetoed. Senate Substitute 1 to Senate Bill No. 203 met the same fate in 1982.

A copy of Senate Substitute No. 1 to Senate Bill No. 203 and its veto message are contained in Appendix C.

PERMITS AND REGULATIONS

Geothermal activities such as siting, drilling, heavy equipment transport, construction and fluid disposal are regulated by federal, state and local laws to preserve and improve the quality of the environment. Below is listed permits and regulations which may govern geothermal development in Delaware. It is necessary to obtain these permits, wherever necessary, before geothermal activities can begin. Samples of the permit applications are contained in Appendix D.

Coastal Zone Status Decision/Coastal Zone Permit

The Coastal Zone Act is intended to monitor the types of industry

located in coastal areas, thereby protecting and preserving the coastal environment. If a geothermal site is located within the Coastal Zone (Figure 7), it is necessary to apply for a "status decision" from the Projects and Planning Section of the Division of Environmental Control of the Department of Natural Resources and Environmental Control. The "status decision" is based on classifying project characteristics which will determine whether the activity is:

- a prohibited use, such as heavy industry,
- a manufacturing industry, which requires a Coastal Zone permit, or
- not regulated by the Coastal Zone Act.

Moderate temperature geothermal development is generally not considered to be a heavy or manufacturing industry; however, a "status decision" application must still be submitted if the project is located within the Coastal Zone.

Driller's License

The drilling company and drillers must be licensed in the State of Delaware. They must also meet the insurance requirements. Applications are made to the Water Resources Section, Water Supply Branch of the Department of Natural Resources and Environmental Control (DNREC).

Wetlands Permit/Subaqueous Lands Permit/Beach Permit

Wetlands, subaqueous lands and the beach are changing; these

Figure 7. Coastal Zone Map (Source: Department of Natural Resources and Environmental Control).

corrosive environments generally are not conducive to geothermal development. These permits would probably not be applicable except when transporting geothermal fluid via pipelines in or through coastal areas.

Water Well Construction Permit

Well information such as location, drilling method, approximate depth, casing material and diameters, capacity and screen parameters is necessary for completion of the water well construction permit application. This application is to be completed by a Delaware licensed water well driller and submitted to the Water Resources Section, Water Supply Branch of the Department of Natural Resources and Environmental Control (DNREC).

Water Allocation Permit

The Water Allocation permit is issued by the Water Supply Branch of the Water Resources Section of DNREC and must be obtained if the well capacity exceeds 50,000 gallons per day (gpd). An additional permit from the Delaware River and Basin Commission (DRBC) must be obtained if the project is located within the Delaware River Basin and has a flow greater than 100,000 gallons per day (gpd), which is less than a modest 70 gpm. Both permits will be necessary if the well site is within the Delaware River Basin (W. Osburn, personal communication, 1982).

Solid Waste Permit/Waste Hauling Permit

These permits are issued by the Solid Waste Management Branch of the Water Resources Section of the

Department of Natural Resources and Environmental Control. Drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of geothermal energy are defined by regulation as solid wastes which are not hazardous wastes. Therefore, these wastes can be disposed of at any permitted sanitary landfill in the state without the necessity of permits. Depending upon the site, a drilling sump or pit may be permissible. Care must be taken not to contaminate drinking water supplies when using this method (M. Nair, personal communication, 1982).

Archaeological, Cultural and Historical Sites

The National Historic Preservation Act of 1966 provides for the protection of properties included in or eligible for inclusion in the National Register of Historic Places. This protection is afforded through review and comment by the Advisory Council on Historic Preservation on Federal undertakings that affect such properties. The regulations provide for the resolution of conflicts between undertakings and the Register properties in a manner that best serves the public interest, which is not always the ideal preservation interest. Private undertakings are not currently regulated by the National Historic Preservation Act or state law. Consultation with the Department of State's Bureau of Archaeology and Historical Preservation is advised during the earliest stages of project planning (F. Stocum, personal communication, 1982).

National Pollutant Discharge Elimination System (NPDES) Permit

An NPDES permit is required when disposal of the spent fluid is by discharge to surface waters. The permit application is reviewed by the Water Pollution Branch of the Water Resources Section of DNREC. The discharged fluid must be compatible (naturally or by treatment) with the host water. The physical and chemical properties of the fluid and its discharge rate must fall within strict standards. Because of the ease of pollution when discharging into open waters, the information required for this permit must be detailed and often necessitates several professional reports.

Transportation Regulations

A permit from the Division of Highways of the Department of Transportation (DOT) is necessary for vehicles which exceed specified weights and size standards.

Rights-of-way and construction permits for pipelines adjacent, above and beneath public roads are issued by the Utilities Section (DOT), (Division of Economic Development, 1980).

Local Laws and Regulations

Local laws and regulations include the licensing of contractors, construction permits (i.e., wellhead and pumping station structures), zoning and noise regulations.

Table 6 lists permits, agency in charge, process time and cost.

FINANCE AND TAXATION

Finance

Direct use of geothermal energy (the type of use envisioned in Delaware) can be accomplished either by retrofitting an existing facility or utilized as the energy source for a new business. The principle question that must be answered satisfactorily for a geothermal project is "Will the annual savings justify the capital investment?" (Higbee, 1980). For a new business venture, geothermal energy is but one component in a processed product and, consequently, one additional variable which has to be assessed with all other variables. Remember, in a new plant if the resource fails, the option to convert to a conventional fuel may be viable (Rodzianko, 1980). But, since both the production and utilization phases of a geothermal development are so inextricably tied together on a site specific basis, it is imperative that the resource on which the facility is built last as long as it takes to recover the investment (Rodzianko, 1978). Given the above, one can readily understand why sound financial planning from the earliest stages of conceptual development is essential.

Direct use projects require \$250,000 to \$6 million of risk capital (the most expensive type of money available) from the exploration through development stage (Rodzianko, 1978, 1980). Consequently, potential investors must understand all of the risks and mitigating measures attendant to geothermal development. Despite the cost structure of geothermal energy, which requires a relatively large

**Environmental Permit Review—
Division of Environmental Control**

	Issuing Agency	Review Agency	Fee	Time Required	Possible Appeal	Appeal Agency
Wetlands Permit	DNREC Wetlands Section	Numerous State & Federal Agencies	250 min. 500 max.	45 days	Yes	Wetlands Board Appeal
Subaqueous Lands Permit	DNREC Wetlands Section	Numerous State & Federal Agencies	\$50 plus	45 days	No	—
Subaqueous Lands Lease	DNREC Wetlands Section	Numerous State & Federal Agencies	\$50 plus	60-90 days	No	—
Coastal Zone Permit	DNREC—EC	None	\$75 for legal notices	90 days	Yes	CZM + Coastal Zone Ind. Control Board
Beach Permit	DNREC—Div. of Soil & Water Conservation	None	0-\$150	Approval 1-7 days Permit 20 days min. generally 30-90 days	Yes	Dept. Secretary Superior Court
Ground & Surface Water Appropriation of Over 100,000 G.P.D.	DRBC via Water Supply Branch	None	\$100 min	6 weeks or less	Yes	To court of proper jurisdiction
Water Allocation	DNREC Water Supply Branch	Only on large capacity wells	None	30 days to 1 year	Yes	Environmental Appeals Board
Well Permits	DNREC Water Supply Branch	Only on large capacity wells	None	1-30 days	Yes	Environmental Appeals Board
Solid Waste Permit	DNREC Solid Waste Branch	Solid Waste Branch	No	Min. 15 days Max. 60 days	Yes	Environmental Appeals Board
Waste Hauling Permit	DNREC Water Pollution Branch	In-House	None	21 days plus	Yes	Environmental Appeals Board
National Pollutant Discharge Elimination System	DNREC Water Resources Section	U.S. EPA, Region III	No	180 days Max.	Yes	Environmental Appeals Board

Table 6. Permits applicable to geothermal development in Delaware (Source: Delaware Development Office).

capital investment at the beginning of a project, it is offset by the small annual operating costs occurring throughout the project's life (Higbee, 1980). Annual operating and maintenance expenses are generally less than 2% of the capital cost of a project.

It is envisioned that as the costs of conventional fuels continue to accelerate at a rate greater than inflation, more small companies will become involved in direct use projects. Direct use projects are attractive to many companies, for the BTU production can be used by any industry requiring process heat. Additionally, it is generally easier to finance a small project with a quick turnaround time to cash flow as opposed to a large project with a long lead time to cash flow where delay and environmental hazards are inherently much greater (Rodzianko, 1980).

Recent federal budget cuts have changed the scenario for financing a geothermal project. No longer available are such sources as the U.S. Department of Energy's (DOE) Geothermal Loan Guarantee Program and the DOE's User-Coupled Confirmation Drilling Program. Both of these programs minimized the financial risk of the geothermal entrepreneur. The Delaware Development Office can assist developers in determining if their project can be partially financed through government sources and whether or not the project is eligible for Industrial Revenue Bond (IRB) financing. Innovative financing from public and private lenders may be necessary.

The four types of investment funds available to corporations are:

1. Venture Capital
2. Corporate Internal Capital
3. Debt Financing
4. Miscellaneous Funds
(Generally government or public sector financing)
(Long, 1980)

Remember, in order for geothermal energy to be economically feasible, it must be the cheapest energy alternative (Higbee, 1980). The economic analysis of a project's viability is, therefore, crucial. Computer models have, therefore, been developed to perform the economic evaluations of direct use applications of geothermal energy. The Geothermal Resource Interactive Temporal Simulation (GRITS) model (developed by the Applied Physics Laboratory and the Center for Metropolitan Planning and Research of The Johns Hopkins University and funded by DOE's Division of Geothermal Energy) calculates the cost and revenue streams for the lifetime of a project that utilizes low to moderate temperature geothermal resources (Kroll, et al., 1982). A description of the GRITS model and examples are contained in Appendix E.

Taxation

Beginning with the Energy Tax Act of 1978, the federal government has sought to define and clarify those tax incentives which are available to geothermal energy investors (Georing, et al., 1979). Before 1978, the federal tax treatment of geothermal resources was based on judicial decisions, not

statutory authority (Higbee, et al., 1979). Legislation has provided for tax consideration in three principle areas. They are: (1) intangible drilling deductions, (2) tax credit, and (3) depletion allowances (Georing, et al., 1979). However, tax advantages are only available to those taxable entities that have a tax liability in excess of the tax benefits (Higbee, 1980).

● Intangible Drilling Costs. Intangible drilling and development costs may be chargeable to capital or to expense. "This option applies to all expenditures made by an operator for wages, fuel, repairs, hauling, supplies, etc. incident to and necessary for the drilling of wells and the preparation of wells for the production of steam or hot water." (U.S. Treasury Regulation §5a.612-1). Intangible drilling and development costs amount to approximately 75% of a finished well's cost (Goering, et al., 1979).

● Tax Credits. An additional 15% energy property tax credit is provided for alternative energy property (geothermal equipment) (IRC §46). The credit applies only to alternative energy property as defined by U.S. Treasury Regulations §1.48-9 (c) (10), and are derived from a geothermal deposit as defined by U.S. Treasury Regulations §1.44 C-2 (h), which states in part that the resource temperature must exceed 50°C (122°F) at wellhead. The investment credit expires on December 31, 1982 (IRC §46). The residential energy credit U.S. Treasury Regulations §1.44 C-1 is not addressed.

● Percentage Depletion. Percentage depletion is a statutory

concept that provides for a deduction of specified percentages of the gross income from the property (Higbee, et al., 1979). The deduction, however, cannot exceed 50% of the taxpayer's taxable income from the property (computed without allowance for depletion) (IRC § 613 (a)). Cost depletion provides for a deduction for the taxpayer's basis (cost) in the property in the relation to the production and sale of minerals from the property (Higbee, et al., 1979). The taxpayer is required to compute depletion by both the cost and percentage method and to claim the larger of the two amounts (Higbee, et al., 1979, IRC § 613 (a)). The applicable percentage depletion is listed below:

In the Case of	
Taxable Years	
Beginning in	The Applicable
Calendar Year -	Percentage is -

1982	18
1983	16
1984 and thereafter	15

(IRC § 613 (e) (2)).

Other tax-oriented incentives are applicable to geothermal energy development and are most helpful in attracting equity capital and in maximizing project profitability. Additional tax incentives that may be employed are the basic tax credit, the credit for increasing research activities, the new job credit, and the accelerated cost recovery system. Proper guidance from the appropriate professionals is essential in order to assemble the best possible business plan (Rodzianko, et al., 1979).

STEPS NECESSARY FOR GEOTHERMAL DEVELOPMENT

Steps followed in preparation for drilling a geothermal well are similar from project to project. Table 7 lists the types of activities necessary and approximates their chronology.

TABLE 7. GENERAL PROCEDURE

- Determine project feasibility
- Check resource characteristics (temperature gradient, sediment type, life of aquifer - if known) determined by geology and hydrology
- Size reasonable project
- Finance and Insure
- Prepare project management plan
- Choose site/acquire land (lease/buy)
- Apply for permits, investigate state, local and federal regulations/environmental, legal and institutional impediments
- Prepare Environmental Evaluation
- Prepare drilling specifications
- Let bid package for drilling company. Check availability of rig
- Prepare site
- Bring in shallow rig
- Move in larger rig
- Pump test and incorporate user
- Dispose of spent fluid

REFERENCES

1. "A Prospectus for the Development of Geothermal Energy on the Delmarva Peninsula", Applied Physics Laboratory/The Johns Hopkins University QM-79-114, 22 May 1979.
2. "A Framework for a Site Prospectus for Geothermal Energy Development: Delmarva Peninsula", Applied Physics Laboratory/The Johns Hopkins University QM-79-145, June 1979.
3. H. Bouwer, Groundwater Hydrology. Hightown, New Jersey: McGraw Hill, Inc., pp. 378-391, 1978.
4. "The System and the Proof", Centrilift-Hughes, Inc., 1981.
5. J. Combs, et al., "Exploration, Confirmation and Evaluation of the Resource", Chapter 2 in Geothermal Resources Council Special Report No. 7, Direct Utilization of Geothermal Energy: A Technical Handbook, pp. 3-16, 1979.
6. J.K. Costain, "Geothermal Exploration Methodology in the Eastern U.S. and Results of First Deep Test on the Atlantic Coastal Plain at Crisfield, Maryland", Geothermal Resources Council Special Report No. 9, Commercial Uses of Geothermal Heat, pp. 33-38, 1980.
7. N. Crow, "Outline of Tutorial on Induced Subsidence and Seismicity in Geothermal Areas", Geothermal Resources Council Management Survey Course No. 3, Geothermal Environmental Problems, Control Technology and Mitigation Measures, 1980.
8. Personal communication with G. Culver, Geo-Heat Center, Oregon Institute of Technology, 1982.
9. L.J. Defferding, et al., "Disposal of Liquid Effluents from Geothermal Installations", Geothermal Resources Council, Transitions, Vol. 2, pp. 141-144, 1978.
10. "A Guide to Permit Regulations for Business Locations: State of Delaware", Division of Economic Development, 1980.
11. S.W. Goering, et al., "An Analysis of the Design, Economics, and Federal Tax Impacts of Proposed Geothermal Greenhouse Operations Near the Baca Grande Development, San Luis Valley, Colorado", Geothermal Resources, Transitions, Vol. 3, pp. 253-256, 1979.
12. C. Higbee, et al., "Economics of Direct-Use Development", Chapter 5 in Geothermal Resources Council Special Report No. 7, Direct Utilization of Geothermal Energy: A Technical Handbook, pp. 3-47, 1979.

13. C. Higbee, "Economic Factors of Direct Use Project", Geothermal Resources Council Technical Training Course No. 4, Economic Assessment and Financing of Geothermal Projects, 1980.
14. P. Kroll, et al., "GRITS (Version 9): Model Description and User's Guide", The Johns Hopkins University/Applied Physics Laboratory QM-81-112/MCGER-81-002, April, 1982.
15. J.F. Kunze, et al., "Reservoir Development and Management", Chapter 3 in Geothermal Resources Council Special Report No. 7, Direct Utilization of Geothermal Energy: A Technical Handbook, pp. 3-21, 1979.
16. J.F. Kunze, et al., "The Economics of Drilling for Direct Heat", Geothermal Resources Council Special Report No. 9, Commercial Uses of Geothermal Heat, pp. 71-74, 1980.
17. D.W. Layton, "Water Quality Considerations in Geothermal Development", Geothermal Resources Council Management Survey Course No. 3, Geothermal Environmental Problems, Control Technology and Mitigation Measures, 1980.
18. P. Leitner, "An Environmental Overview of Geothermal Development: The Geysers-Calistoga KGRA/Vol. 3, Noise", Lawrence Livermore Laboratory, University of California, pp. 1-8, August 16, 1978.
19. P.J. Lienau, et al., "Utilization" Chapter 4 in Geothermal Resources Council Special Report No. 7, Direct Utilization of Geothermal Energy: A Technical Handbook, pp. 5-84, 1979.
20. W.P. Long, "Corporate Investment Sources", Geothermal Resources Council Technical Training Course No. 4, Economic Assessment and Financing of Geothermal Projects, 1980.
21. J.W. Lund, "Worldwide Direct Application Review", Geothermal Resources Council Special Report No. 5, A Symposium of Geothermal Energy and its Direct Uses in the Eastern United States, pp. 49-53, 1979.
22. Personal communication with M. Nair, Department of Natural Resources and Environmental Control - Solid Waste Management Branch, 1982.
23. R.C. Neiss, "High Temperature Heat Pumps Can Accelerate the Use of Geothermal Energy", Geothermal Resources Council Report No. 9, Commercial Uses of Geothermal Heat, pp. 89-95, 1980.
24. Personal communication with W. Osburn, Department of Natural Resources and Environmental Control - Water Supply Branch, 1982.
25. F.C. Paddison, et al., "Analysis of the Use of Geothermal Energy at Crisfield, Maryland" Quarterly Report, Energy Programs at The Johns Hopkins University Applied Physics Laboratory, EQR/79-4, pp. 21-25, October-December, 1979.

26. Personal communication with D. Payne, Peerless Pump, 1982.
27. G.R. Pickett, "Properties of the Rocky Mountain Arsenal Disposal Reservoir and Their Relation to Nearby Earthquake", Quarterly of the Colorado School of Mines, Vol. 63: Golden, Colorado, pp. 73-100, 1968.
28. P. Rodzianko, "Overview of an Introduction to Geothermal Power Plant Financing Options", Commercialization of Geothermal Resources, Geothermal Resources Council, Davis, California, pp. 35-38, November, 1978.
29. P. Rodzianko, et al., "Financing Direct-Use Projects", Chapter 6 in Geothermal Resources Council Special Report No. 7, Direct Utilization of Geothermal Energy: A Technical Handbook, pp. 3-18, 1979.
30. P. Rodzianko, "Financing Geothermal Development", Geothermal Resources Council Special Short Course No. 9, An Introduction to the Exploration and Development of Geothermal Resources, 1980.
31. P. Rodzianko, "Financing", Geothermal Resources Council Technical Training Course No. 4, Economic Assessment and Financing of Geothermal Projects, 1980.
32. S.M. Prestwich, "Low Temperature Drilling Techniques for Direct Applications", Geothermal Resources Council Special Report No. 9, Commercial Uses of Geothermal Heat, pp. 97-98, 1980.
33. E.A. Samuel, "Occurrence of Low-Temperature Geothermal Waters in the United States", Assessment of Geothermal Resources of the United States - 1978, U.S. Geological Survey Circular 790, pp. 86-100, 1978.
34. Personal communication with F. Stocum, Department of State's Bureau of Archaeology and Historic Preservation, 1982.
35. W.J. Toth, "Definition of Markets for Geothermal Energy in the Northern Atlantic Coastal Plain", The Johns Hopkins University/Applied Physics Laboratory GEMS-002/QM-80-075, p. 221, May, 1980.
36. R. Weiss, "Ground Water Monitoring Methodology for Geothermal Development", Geothermal Resources Council, Transitions, Vol. 2, pp. 709-712, 1978.
37. Personal communications with C. Wilkins, Department of Natural Resources and Environmental Control - Air Resources Section, 1982.
38. K. Woodruff, Preliminary Targeting of Geothermal Resources in Delaware, Progress Report for July 15, 1979 - May 30, 1980, U.S. Department of Energy, DOE/ET/28416-2, p. 17, August, 1980.
39. K. Yu, "Analysis of Effects of Well Completion on Drawdown", Quarterly Report, Energy Programs at The John Hopkins University Applied Physics Laboratory, EQR/79-2, p. 25, April-June, 1979.

GLOSSARY

Annual Cash Flow - Annual surplus or definite cash after accounting for all revenue (or savings) and disbursements including taxes.

Aquifer - An underground water bearing layer of rock, sand or gravel.

Basement Rock - A term referring to crystalline rock beneath sedimentary feature.

BTU - British Thermal Unit. A unit of heat equal to about 252 calories; quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Capital Investment - Investments made before production starts.

Cascading - The practice of recycling geothermal fluid until all the extractable heat is used.

Casing - The pipe which supports the well, prevents contamination of ground water, and through which the fluid is transported to the surface.

Cost of Capital - The weighted average after-tax cost of raising funds.

Crust - The outer part of the lithospheric plate-approximately 32 kilometers thick.

Decibel - A numerical expression of the relative loudness of a sound; the difference in decibels between two sounds is ten times the common logarithm of the ratio of their power levels.

Direct Use - The non-electric use of moderate-temperature geothermal fluid in space conditioning, agriculture or aquaculture.

Drill Bit - An implement attached at the end of the drill string used for boring (drilling).

Drilling Consultant - A person with expertise in the field of drilling (geothermal) wells, who is capable of providing technical advice to the participant.

Efficiency (of well) - The ratio of theoretical well drawdown to actual well drawdown.

End Use - The economic utilization of the hydrothermal resource as an alternate energy; i.e., space heat, process heat, etc.

Fluid Disposal - The removal of hydrothermal fluids produced from the well for purposes of well tests, drilling, and production.

Geopressured - A type of geothermal energy. The resource is deeply buried under great pressure. Methane is often present. Found primarily in Gulf Coast states.

Geothermal Energy - Energy in the form of heat trapped in the earth's crust.

Geothermal Gradient - The rate of regular increase of temperature with depth, (i.e., $1.5^{\circ}\text{F}/100\text{ ft.}$).

Heat Exchanger - A mechanism for transferring heat energy from one medium to another (i.e., water to air, water to a heat transfer fluid (water)).

Heat Flow - A geophysical measurement, sometimes used to detect geothermal resources.

Heat Pump - A method of moving, concentrating or removing heat through the use of a compressor (i.e., a reversible refrigerator capable of heating or cooling).

Hot Dry Rock (HDR) - A type of geothermal energy characterized by the near absence of water.

Hydrology - The study of ground and surface waters, their chemical and physical properties, location, flow and geologic environment.

Hydrothermal - 1. A type of geothermal energy. The resource is primarily in the liquid phase. 2. Of or pertaining to hot water.

In Situ - "in place".

Interest Rate - Annual interest rate paid on outstanding debt.

KGRA - Known Geothermal Resource Area.

Liners - Casing used to maintain wellbore stability where that casing is hung in the wellbore and does not extend to the surface.

Lithology - The physical character of a rock; generally determined megascopically or with the aid of a low-power magnifier.

Logs - Geophysical borehole logs used to interpret lithology, porosity, wellbore temperatures, fluid conductivity and resistivity, radioactivity and other physical and chemical characteristics of the rocks and fluids adjacent to the wellbore.

Lost Circulation - The loss of fluids to the formation.

Metamorphosed - A change resulting from heat, pressure and/or chemical solutions.

Normal Temperature Gradient - A general rule that temperature increases proportionately with depth approximately 1.5°F for every 100 feet of depth.

Permeability - The rate of diffusion of a fluid through a porous body under standard conditions of area, thickness and pressure.

Porosity - The ratio of the volume of a material's pores to its total volume.

Pure Tone - Low level incessant noises like a humming or a buzzing sound.

Reservoir Rock - Stores fluid, whether it be gas, oil or water.

Sedimentary - A type of rock composed of consolidated particles weathered or eroded from a pre-existing rock.

Seismicity - Refers to earthquake activity.

Silicic Rocks - Containing minerals with a high silica content. Very abundant.

Site Preparation - Well site construction necessary for drilling a well, which includes access roads, drill pad, reserve pits, support power and water, cellar and conductor pipe setting.

Space Conditioning - Heating or cooling of residential or commercial buildings for human comfort, including the production of domestic hot water.

Stratigraphic Correlation - The comparison of various layers of similar vertical sequences of sedimentary rock from separate locations (wells).

Subsidence - The sinking or settling of land due to compaction.

Transmissibility - The performance of any aquifer, defined by the thickness of the aquifer times the permeability of the aquifer.

Well Cuttings - Rock chip samples brought to the surface with the drilling fluid.

Well Development or Completion - All procedures and equipment for well cleanout-stimulation, production zone liners, and wellhead equipment to meet production requirements.

Well Testing - Those tests conducted during drilling, prior to rig demobilization, to provide lithologic and hydrologic data, and short or long term tests such as pump or flow tests and pressure recordings taken to define well producibility after rig demobilization.

Utilization Factor - The amount of power used on an annual basis by the system, divided by the maximum power that can potentially be used by the system on an annual basis (8760 hr/yr). This is analogous to be the equivalent percentage of time that the system will operate at peak power on an annual basis.

APPENDIX A
TECHNICAL ASSISTANCE

Certain information is available to prospective developers from various governmental and private sources. The following institutions and agencies should prove helpful.

1. Applied Physics Laboratory
The Johns Hopkins University
John Hopkins Road
Laurel, Maryland 20707
Phone: (301) 953-7100
Contact: Fletcher C. Paddison
Areas of Expertise: Engineering, Reservoir Management, Economics, Design
2. Virginia Polytechnic Institute and State University
Department of Geological Sciences
Blacksburg, Virginia 24061
Phone: (703) 961-6521
Contact: Dr. John K. Costain
Areas of Expertise: Heat Flow, Geophysics, Conducted the Atlantic Coastal Plain Exploration Program
3. Geothermal Resources Council
P.O. Box 98
Davis, California 95616
Phone: (916) 758-2360
Contact: David N. Anderson
Area of Expertise: Utilization
4. Geo-Heat Utilization Center
Oregon Institute of Technology
Klamath Falls, Oregon 97601
Phone: (503) 882-6321
Contact: Gene Culver
Areas of Expertise: Engineering, Reservoir Management, Economics, Design
5. National Water Well Association
500 West Wilson Bridge Road
Worthington, Ohio 43085
Phone: (614) 846-9355
Areas of Expertise: Water-well Drilling, Heat Pumps
6. Delaware Geological Survey
University of Delaware
Penny Hall
Newark, Delaware 19711
Phone: (302) 738-2833
Contact: Kenneth D. Woodruff
Areas of Expertise: Ground Water Hydrology, Stratigraphy

7. Center for Metropolitan Planning and Research
The John Hopkins University
Baltimore, Maryland 21218
Phone: (301) 338-7180
Contact: Sally Kane or Peter Kroll
Areas of Expertise: Economics, operation of GRITS model
8. U.S. Department of Energy
Division of Geothermal Energy
MS-6B-025
Washington, DC 20585
Phone: (202) 252-8070
Contact: Dr. David B. Lombard
Areas of Expertise: Eastern U.S. Geothermal Program

APPENDIX B
RESPONSIBLE STATE OFFICE OR AGENCY

Delaware has no geothermal law. Consequently, geothermal development would be regulated as a water well. The following State agencies are responsible for administering regulations and issuing permits.

1. Department of Natural Resources and Environmental Control
King's Highway
P.O. Box 1401
Dover, Delaware 19901
 - a. Division of Environmental Control
Projects and Planning Section
Phone: (302) 736-5409
Permit: Coastal Zone Status Decision
 - b. Division of Environmental Control
Water Resources Section
Water Supply Branch
Phone: (302) 736-4761
Permits: Water Well Driller; Water Well Driver, Pump Installer, Application for Water Well Contractors License; Application for Permit to Appropriate the Waters of the State of Delaware; Application for a Permit to Drill a Well; Delaware River Basin Commission, (1) Application for Approval of a Proposed Ground Water Withdrawal, (2) Environmental Form, (3) Applicant's Statement - Project Review Fee
 - c. Division of Environmental Control
Water Resources Section
Water Pollution Branch
Phone: (302) 736-4761
Permit: National Pollutant Discharge Elimination System
 - d. Division of Environmental Control
Water Resources Section
Solid Waste Management Branch
Phone: (302) 736-4781
Permit: Solid Waste
 - e. Division of Environmental Control
Wetlands Section
Phone: (302) 736-4691
Permits: Wetlands Permit; Subaqueous Lands Permit; Subaqueous Lands Lease
2. Department of State
Bureau of Archaeology and Historic Preservation
Old State House
P.O. Box 1401
Dover, Delaware 19901
Phone: (302) 736-5685
Permit: Compliance with National Historic Preservation Act of 1966

3. Department of Transportation
Administration Center
P.O. Box 778
Dover, Delaware 19901
 - a. Division of Highways
Permits Section
Phone: (302) 736-4374
Permits: Special permits for vehicles in excessive size and weight classes
 - b. Division of Highways
Utilities Section
Phone: (302) 736-4334
Permits: Rights-of-way along, above, beneath public roads for pipelines
4. Delaware Development Office
Townsend Building
P.O. Box 1401
Dover, Delaware 19901
Phone: (302) 736-4271
Permits: Determination of eligibility for: Industrial Revenue Bond financing and/or Federal financing

APPENDIX C
DELAWARE'S GEOTHERMAL LEGISLATIVE HISTORY

Delaware has no geothermal law at present. Additionally, under present Delaware case law, geothermal resources would probably be considered underground water and would be regulated as such. The thermal properties of water being regarded as only one of its characteristics.

Attached are copies of Senate Substitute No. 1 to Senate Bill No. 203, the Geothermal Resources Act, which passed the legislature but was vetoed by the Governor. The veto message is also attached.

A discussion of Delaware's present laws regulating the resource is contained in Geothermal Policy Report: Legislative Issues and Recommendations which was prepared for the Delaware Legislature in 1979. A copy can be obtained from the National Conference of State Legislatures, 1125 Seventeenth Street, Suite 1500, Denver, Colorado 80202, (303) 623-6600.

SPONSOR: Sens. McDowell, Zimmerman,
Arnold, Bair, Berndt, Cook,
Connor, Marshall, Martin,
Murphy, Neal and Reps. Smith,
Barnes, Bennett, Campanelli,
Free, Gilligan, Minner, Oberle,
Plant

DELAWARE STATE SENATE
131ST GENERAL ASSEMBLY

SENATE SUBSTITUTE NO. 1

JUN 23 1981

TO

SENATE BILL NO. 203

AN ACT TO AMEND TITLE 7, DELAWARE CODE, RELATING TO THE ESTABLISHMENT
OF PUBLIC POLICY IN PROMOTING THE DISCOVERY, DEVELOPMENT, PRODUCTION
AND REGULATION OF GEOTHERMAL RESOURCES IN THE STATE OF DELAWARE.

BE IT ENACTED BY THE GENERAL ASSEMBLY OF THE STATE OF DELAWARE
(Three-fifths of all members elected to each House thereof concurring therein):

1 Section 1. Amend Title 7, Delaware Code, by adding thereto a new Chapter to be designated as
2 Chapter 72 to read as follows:

3 "CHAPTER 72. GEOTHERMAL RESOURCES ACT

4 §7201. Findings; Policy; Purpose

5 It is declared to be in the public interest to foster and promote the discovery, development,
6 production, primary and cascaded utilization, and disposal of geothermal resources in the State of
7 Delaware in such a manner so as will prevent waste, provide for maximum economic recovery, and
8 safeguard the natural environment and the public welfare.

9 §7202. Definitions

10 As used in this Chapter the term:

11 (a) 'Department' means the Department of Natural Resources and Environmental Control.

12 (b) 'Secretary' means the Secretary of the Department of Natural Resources and
13 Environmental Control.

14 (c) 'Geothermal resources' means the natural heat of the earth at temperatures greater
15 than 32 degrees Celsius and includes:

16 (1) the energy, including pressure, in whatever form present in, resulting from,
17 created by, or that may be extracted from that natural heat;

18 (2) the material medium, including the brines, water and steam naturally present as
19 well as any substance artificially introduced to serve as a heat transfer medium; and

1 (3) all dissolved or entrained minerals and gases that may be obtained from the
2 material medium, but excluding hydrocarbon substances and helium.

3 (d) 'Geothermal area' means the same general land area which, in its subsurface, is
4 underlaid or reasonably appears to be underlaid by geothermal resources from or in a single
5 reservoir, pool, or other source or interrelated sources as such area or areas may be from time
6 to time designated by the Secretary after consultation with the Delaware Geological Survey.

7 (e) 'Permit' means a permit issued pursuant to this Act for the construction and operation
8 of any well or injection well.

9 (f) 'Person' means any individual natural person, general or limited partnership, joint
10 venture, association, cooperative organization, corporation whether domestic or foreign, agency
11 or subdivision of this or any other state, or any municipal or quasi-municipal entity whether or
12 not it is incorporated.

13 (g) 'Waste' means any physical waste including, but not limited to:

14 (1) Underground waste resulting from the inefficient, excessive or improper use of
15 dissipation of geothermal energy in or of any geothermal resource pool, reservoir, or other
16 source; or the locating, spacing, construction, equipping, operating, or producing of any
17 well in a manner which results, or tends to result, in reducing the quantity of geothermal
18 energy to be recovered from any geothermal area in this State;

19 (2) The inefficient above-ground transporting and storage of geothermal energy; and
20 the locating, spacing, equipping, operating, or producing of any well or injection well in a
21 manner causing, or tending to cause, unnecessary or excessive surface loss or destruction
22 of geothermal energy;

23 (3) The escape into the open air, from a well, of steam or hot water in excess of what
24 is reasonably necessary in the efficient development or production of a well.

25 (h) 'Well' means any excavation or other alteration in the earth's surface or crust by means
26 of which the energy of any geothermal resource and/or its material medium is sought or
27 obtained.

28 (i) 'Injection well' means any special well, converted producing well or reactivated or
29 converted abandoned well employed for injecting material into a geothermal area to maintain
30 pressures in a geothermal reservoir, pool, or other source, or to provide new material or to
31 serve as a material medium therein, or for reinjecting any material medium or the residue
32 thereof or any by-product of geothermal resource exploration or development into the earth.

33 (j) 'Board' means the Environmental Appeals Board.

1 S7203. Permits; Application; Fee; Exceptions

2 (a) Any person who, as owner or operator, proposes to construct a well or to alter a well or to
3 construct or to alter an injection well shall first apply to the Secretary for a geothermal resource
4 well permit. Such application shall set out the following information on a form or forms prescribed
5 by the Department:

6 (1) The name of any person making the application; if such person is a partnership, joint
7 venture, association, or other unincorporated group of corporate or natural persons, the names
8 and places of domicile of each of the constituent persons who have general partnership
9 responsibility and authority for and in such unincorporated group or persons; if any person
10 named on a permit application is a corporation, its place of domicile, the names and places of
11 domicile of its principal executive officers, and the names and places of domicile of any person
12 or persons owning a thirty percentum (30%) or greater interest, whether legal, beneficial, or a
13 combined legal and beneficial interest, in such corporate person; if the applicant is making an
14 application as an agent for any other person, it shall be clearly so stated and any person who is
15 the applicant's principal shall be subject to each and all of the disclosure requirements of this
16 subdivision; for purposes of this subdivision, the domicile of a corporation is at all of the
17 following:

18 (A) the place of incorporation,

19 (B) the principal place of business,

20 (C) the place, by city and state, of the home office, and in any instance where the
21 domicile is required to be disclosed all of these places shall be specified.

22 (2) The location of the proposed well or the injection well described particularly by a legal
23 description sufficient to show the location of the proposed well, such description to be approved
24 by the Secretary.

25 (3) The length, size, type and thickness of casing proposed to be used in such well or such
26 injection well and any other devices or techniques to be used in the drilling, operation, and
27 maintenance of such well or injection well for the purpose of conserving geothermal resources
28 and their availability, avoiding waste and for the protection of other subsurface natural
29 resources.

30 (4) The character and composition of the material expected to be derived from such well.

31 (5) The means proposed to be used to contain and manage the material expected to be
32 derived from such well or injected into such injection well in order to avoid unreasonable
33 damage to life, property, or surface and atmospheric natural resources.

34 (6) Whether such well or such injection well is proposed to be constructed as a part of a
35 program for exploration or for development of an already explored geothermal resource area.

1 (7) Such other information as the Secretary may determine to be necessary for the
2 administration of this Act.

3 (b) Any application for a permit to construct a well made pursuant to this section shall be
4 accompanied by an application pursuant to 7 Delaware Code, Chapter 60 if such well will involve the
5 use of groundwater other than as a mineral source or as a material medium to transfer geothermal
6 energy to the surface.

7 (c) Any application for a permit made pursuant to this Section shall be accompanied by a filing
8 fee of:

9 (1) One Hundred Dollars (\$100) if for a well, or

10 (2) Fifty Dollars (\$50) for an injection well, and no application shall be accepted and filed
11 by the Secretary until such filing fee has been deposited with him. All monies received under
12 provisions of this Act shall be deposited to the General Fund of the State of Delaware.

13 (d) No person shall construct or alter a well or an injection well without having first secured a
14 permit therefor; provided however, that the Secretary may, by general rule or regulation adopted
15 pursuant to this Chapter, exempt specific categories of wells or injection wells otherwise embraced
16 by this Act upon a finding that the purposes of this Act do not require that such wells be subject to
17 the permit requirement of this Section.

18 (e) Nothing in this Act shall be construed as affecting any valid, vested water rights for water
19 in use on or before the effective date of the Act.

20 (f) The Secretary after consultation with the Delaware Geological Survey shall have the
21 authority to and may designate any area of the State a 'geothermal area' when the Secretary finds or
22 has reason to believe that such designation is necessary to protect the geothermal resource from
23 waste and to protect other resources of the State from contamination or waste.

24 (g) No person shall drill a well for any purpose to a depth of nine hundred (900) meters or more
25 below land surface in a designated 'geothermal area' without first obtaining a permit under the
26 provisions of this Section. Such permit shall be in addition to any permit required by other
27 provisions of law.

28 (h) The owner or operator of any well constructed or being constructed pursuant to 7 Delaware
29 Code, Chapter 60, which encounters a geothermal resource, shall report such finding to the
30 Secretary. In the event the owner or operator intends or desires to utilize such resource, such owner
31 or operator shall make application for a geothermal permit as required under this Section.

32 (i) Any application for a permit made pursuant to this section shall be duplicated by the
33 Department and sent to any State Agency which requests it for review and comments.

1 §7204. Applications; Investigations; Notices; Hearings; Decisions

2 (a) Upon receipt and acceptance of a proper application, the Secretary shall undertake such
3 investigations as necessary to determine that the construction or alteration of the proposed well or
4 injection well will be in the public interest. The Secretary shall consider:

5 (1) The financial resources of the applicant, his principal, or other person who may be
6 legally responsible for the subject well or injection well, and the probability that such person
7 will be financially able to bear all costs for which he might be responsible which may be
8 incident to the construction, operation, and maintenance of the well or injection well proposed
9 to be constructed or altered.

10 (2) The adequacy of measures proposed to safeguard land, water and air resources from
11 unreasonable degradation, and especially to protect groundwater aquifers and surface-water
12 sources from contamination which would render such water of lesser quantity or quality.

13 (3) The possibility that the construction and maintenance of the proposed well will cause
14 waste or will damage any geothermal resource, reservoir, or other source, by unreasonable
15 reduction of pressures or unreasonable reduction of any geothermal resource material medium
16 or in any other manner, so as to render any geothermal resource of unreasonably less value.

17 (4) The rights of existing geothermal users.

18 (5) Any possible interdependence between any geothermal resource, reservoir, pool, or
19 other source expected to be affected under the permit and any aquifers or other sources of
20 ground waters used for beneficial uses other than uses as a material medium or a mineral
21 source, and the probability that such interdependence may cause such groundwater sources to
22 be inadequate to meet demands on them under existing water rights.

23 (6) The extent to which the applicant is capable of utilizing the resource as a renewable
24 resource.

25 (7) The priority in time in which competing applications are received.

26 (b) Notice and public hearing on an application under this Chapter shall be in accordance with
27 the provisions of 7 Delaware Code §6004(b) and 7 Delaware Code §6006 (3) and (4).

28 §7205. Permit; Issuance; Bond; Appeal

29 (a) If the Secretary finds that the well or the injection well as it is proposed to be constructed
30 or altered will be in the public interest, he may issue a permit therefor. The Secretary may issue a
31 permit substantially in accordance with the specifications on the application, may limit the scope of
32 the permit granted, or may issue a permit subject to conditions.

1 (b) If the Secretary finds that the well or injection well as it is proposed to be constructed or
2 altered in the application will not be in the public interest he shall refuse to issue a permit.

3 (c) The Secretary shall require, as a condition of every permit, every person who engages in the
4 construction, alteration, testing, or operation of a well to file with the Secretary, on a form
5 prescribed by the Secretary, a bond indemnifying the State of Delaware and any other party or
6 parties specified by the Secretary, providing good and sufficient security, conditioned upon the
7 performance of the duties required by this Act and covering any risks of damage or loss resulting
8 from operations under the permit. Such bond shall be in an amount to be determined by the
9 Secretary and may be filed as an individual bond for a single well or as a blanket bond for a group of
10 wells.

11 \$7206. Permit Applications; Consolidation

12 The Department may, by regulation, provide for the consolidation of permit applications where
13 several wells are proposed to be constructed in a geothermal area either for exploration or for
14 development. Such regulations shall be promulgated according to the provisions of 7 Delaware
15 Code, §6010(a).

16 \$7207. Well Abandonment or Discontinuance of Operation; Notice

17 At least five (5) days before any operation to abandon any well or injection well is commenced,
18 the owner or operator thereof shall submit in writing a notification of intention to abandon to the
19 Secretary for approval. Such notification shall clearly state the condition of the well or injection
20 well, and the proposed method of abandonment. No person shall commence any operation to
21 abandon a well or an injection well without approval by the Secretary.

22 \$7208. Well Abandonment; Order of Approval or Disapproval

23 The Secretary may, before the proposed date for commencing any abandonment operation,
24 approve by order in writing, or disapprove by order in writing, any proposed abandonment. An order
25 may be made conditional or limited and may specify tests or other practices required for approval.

26 \$7209. Well Abandonment; Report; Action by Secretary

27 (a) Within five (5) days after the completion of the abandonment of any well or injection well,
28 the owner or operator of the abandoned well or injection well shall report, in writing to the
29 Secretary on such form as may be prescribed by the Secretary on all work done with respect to the
30 abandonment.

31 (b) If the Secretary finds that the owner or operator failed to comply with the Secretary's
32 approval order, the Secretary may issue an order requiring corrective action.

1 §7210. Powers and Duties; Penalties

2 (a) The Secretary may adopt, amend, or rescind reasonable rules, regulations, and construction
3 standards necessary to the administration of this Act in accordance with the procedure set forth in 7
4 Delaware Code, §6006(2) and (4). Regulations adopted pursuant hereto may be interpretative of
5 provisions of this Act. In the absence of regulations, permit applications shall be reviewed in
6 accordance with the provisions of this Act.

7 (b) The Secretary may require that owners or operators of wells or injection wells keep or
8 cause to be kept well logs, core records, and drilling histories of such wells or injection wells. He
9 may require that copies of such logs, records, or histories be filed with the Secretary within a
10 reasonable time after well completion. The Secretary may further require such other geologic,
11 geochemical, or engineering plans, reports, or records as necessary for the administration of this
12 Act. Any reports, logs, records, or histories filed with the Secretary shall not be available for public
13 inspection and shall be kept as confidential by the Secretary for a period of one (1) year from well
14 completion, provided, however, that the Secretary may use any such reports, logs, records, or
15 histories in any action in any court to enforce the provisions of this Act or any order or regulation
16 adopted hereunder.

17 (c) The Secretary or his duly authorized designees and employees of the Delaware Geological
18 Survey, in regulating any activity over which he has jurisdiction pursuant to this Chapter, may enter,
19 at reasonable times, upon private or public property to inspect any well or geothermal resource
20 development project to determine if such well or project is being constructed, operated, or
21 maintained according to any applicable permits or to determine if the construction, operation, or
22 maintenance of such well or project may involve a threat to life or property or an unreasonable risk
23 to land, water or air resources. Upon request official identification shall be provided to the owner,
24 occupant, custodian or agent of said property.

25 (d) If the Secretary finds that any person is constructing, operating or maintaining any well or
26 injection well not in accordance with any applicable permit, regulation, order, or provision of this
27 act, or any other law, regulation or ordinance, the Secretary may issue an order to such person to
28 correct or to stop such practices as are found to be improper and to mitigate any injury of any sort
29 caused by such practices.

30 (e) The Secretary may enforce any provision of this Act or any order or regulation issued or
31 adopted pursuant hereto or any permit condition by bringing action in accordance with the provisions
32 of 7 Delaware Code §§6005 and 6013. Nothing contained herein shall prevent the Secretary from
33 seeking voluntary compliance in accordance with the provisions of 7 Delaware Code, §6019.

1 (f) The Secretary may undertake such studies, investigations, or research programs as
2 necessary for the proper administration of this Act and in order to develop experience in and
3 understanding of the entire field of geothermal resource exploration and development in both its
4 technical and regulatory aspects. The Secretary may cooperate with other State agencies, the State
5 institutions of higher learning, agencies of other states, and agencies of the federal government in
6 the preparation of such investigations, studies, or research projects.

7 (g) The Secretary may enter into cooperative agreements and memoranda of understanding
8 with agencies of other states for the purpose of the administration of geothermal areas which are
9 partially in Delaware and partially in one or more other states.

10 §7211. Name of Owner on Permit; Transfers Restricted; Permit Amendment; Fee; Resident Agent

11 (a) No well may be owned or operated by any person whose name does not appear on the permit
12 or permit application therefor, nor may any well be transferred to any new owner or operator unless
13 such transfer has been approved by the Secretary. All notices, orders, permit conditions,
14 regulations, and provisions of this Act shall be binding upon transferees, successors, and assigns of
15 permit holders.

16 (b) No changes in or departure from the procedures, locations, or data, contained in a permit
17 shall be permitted under this Act until an amendment to such permit is approved by the Secretary.
18 The Department may specify forms upon which applications for amendments to permits may be filed
19 with the Secretary. Any application to amend a permit shall be accompanied by a filing fee of Fifty
20 Dollars (\$50), and the Secretary shall not accept an amendment application which is not
21 accompanied by such filing fee.

22 (c) The Secretary shall approve any application to amend a permit unless he finds that such
23 amendment will not be in the public interest. If the Secretary refuses to approve such amendment,
24 he shall serve on the applicant, by certified mail, an order disapproving the amendment and setting
25 out the reasons for disapproving the amendment.

26 (d) Every permit holder, shall designate to the Secretary an agent who resides in this State
27 upon whom may be served all orders, notices, or permits issued by the Secretary.

28 §7212. Appeals

29 (a) Any person whose interest is substantially affected by any action of the Secretary may
30 appeal to the Delaware Environmental Appeals Board pursuant to the provisions of 7 Delaware Code,
31 §6008 and all proceeding under such appeal shall be in accordance with the provisions of 7 Delaware
32 Code, Chapter 60.

33 (b) Any person whose interest is substantially affected by any decision of the Environmental
34 Appeals Board may appeal such decision to the Superior Court in accordance with the provisions of 7
35 Delaware Code, §6009.

1 §7213. Ownership; Leasing; Access

2 (a) Geothermal Resources are found and are hereby declared to be sui generis and to be held and
3 owned by the State as a public trust for the people of Delaware.

4 (b) The Governor and the Secretary may lease development rights to geothermal resources
5 underlying surface and subaqueous lands owned by the State. The Secretary shall promulgate
6 regulations regarding method of lease acquisition, lease terms and conditions, and royalties due to
7 the State under lease operations.

8 (c) Where geothermal resources underlie surface lands in private ownership, subject to
9 development of geothermal resources under the provisions of this Act, the State shall have an
10 overriding royalty of 3% of the gross value of such geothermal resource production.

11 (d) Where a geothermal resource operation would be otherwise uneconomical, the Secretary
12 may reduce, suspend or waive the royalty due on a State lease or the overriding royalty due on
13 private lands.

14 §7214. Liberal Construction

15 This Chapter, being necessary for the welfare of the State and its inhabitants, shall be liberally
16 construed in order to serve its purposes and policy.

17 §7215. Severability

18 If any section, subsection, clause or provision of this Act shall be adjudged unconstitutional or
19 to be ineffective in whole or in part, to the extent that it is not adjudged unconstitutional or is not
20 ineffective it shall be valid and effective and no other section, subsection, clause or provisions of
21 this Act shall on account thereof be deemed invalid or ineffective, and the inapplicability or
22 invalidity of any section, subsection, clause or provisions of this Act in any one or more instances or
23 under any one or more circumstances shall not be taken to affect or prejudice in anyway its
24 applicability or validity in any other instance or under any other circumstances.

SYNOPSIS

This legislation establishes a geothermal policy for the State of Delaware. The bill defines geothermal energy, who owns it, how it shall be regulated and controlled so as to be beneficial to the general public as an alternative energy source as well as to assure environmental safeguards. The Department of Natural Resources and Environmental Control has the responsibility of granting permits for the development and production of such energy.

Authors - Rod Thompson, Deputy Attorney General assigned to the Department of Natural Resources and Environmental Control; Michael F. Parkowski, Parkowski, Noble & Guerke; George William Sherk, National Conference of State Legislatures

Senator McDowell wishes to thank the following institutions, organizations, and agencies without whose cooperation the drafting of this legislation would not have been possible. They are:

1. The National Conference of State Legislatures, Geothermal Policy Project
2. Parkowski, Noble and Guerke
3. The Johns Hopkins University, Applied Physics Laboratory
4. The Johns Hopkins University, Center for Metropolitan Planning and Research
5. Delaware Geological Survey
6. Department of Natural Resources and Environmental Control; and
7. Delaware Energy Office.

STATE OF DELAWARE
EXECUTIVE DEPARTMENT

PIERRE S. DU PONT
GOVERNOR

DOVER

July 2, 1982

To the Senate of the 131st
General Assembly of the
State of Delaware

I am returning without my signature Senate Substitute No. 1
for Senate Bill No. 203 which I received on June 23, 1982 and which
is entitled:

"AN ACT TO AMEND TITLE 7, DELAWARE CODE
RELATING TO THE ESTABLISHMENT OF PUBLIC POLICY
IN PROMOTING THE DISCOVERY, DEVELOPMENT, PRODUCTION
AND REGULATION OF GEOTHERMAL RESOURCES IN THE STATE
OF DELAWARE."

This bill would create an extensive licensing and regulatory
system in the Department of Natural Resources and Environmental
Control which would govern the commercial development of geothermal
energy resources in Delaware.

Although a worthy objective of the bill is to clarify Delaware
law regarding commercial rights in a potential natural resource, I am
returning the bill unsigned because I believe it may well inadvertently
impede commercial development of a potential energy resource which
could benefit all Delawareans. The regulatory framework and
licensing scheme required by this bill would likely create disincentives
for small developers interested in exploring for alternative energy
sources in Delaware. We need to reduce bureaucratic barriers to
the entry of new commercial ventures in the Delaware economy, partic-
ularly with regard to the energy market.

Finally, I note that the bill would declare all geothermal
resources under lands in Delaware to be owned in trust by the State;
furthermore, it grants the State automatic royalty rights of three
percent of the gross value of any geothermal resource production.
This aspect of the bill seriously jeopardizes legitimate property
rights of Delaware landowners, depriving them of existing ownership
rights to resources underneath, as well as on, the surface of land.

To the Senate of the
131st General Assembly
of the State of Delaware

- 2 -

July 2, 1982

Moreover, I understand that this aspect of the bill would probably require certifications of title and title insurance policies issued in Delaware to except subsurface geothermal resources. Such an exception might well be unattractive to commercial lenders and might impede real estate transactions or force title insurance companies to accept the risk of removing such an exception, with attendant higher title insurance fees. I believe that Delaware landowners would be understandably upset over the contraction of their property rights and the potential title certification problems which would accompany enactment of this bill into law.

For these reasons, I return Senate Substitute No. 1 for Senate Bill No. 203 unsigned.

Respectfully submitted

Pierre S. du Pont, IV
Governor

PSduP/wcj

APPENDIX D
SAMPLE PERMITS

Attached are sample copies of the following forms required in the State of Delaware.

1. Coastal Zone Permit
2. Application for License:
 - a) Water Well Driller
 - b) Water Well Driver
 - c) Pump Installer
3. Application for Water Well Contractors License
4. Application for a Permit to Drill a Well
5. Application for Permit to Appropriate the Waters of the State of Delaware
6. Delaware River Basin Commission:
 - a) Application for Approval of a Proposed Groundwater Withdrawal
 - b) Environmental Form
 - c) Applicant's Statement - Project Review Fee
7. Authorization to Discharge Under the National Pollutant Discharge Elimination System and the Laws of the State of Delaware

DELAWARE
COASTAL ZONE PERMIT

DATE OF ISSUANCE: _____

NUMBER: _____

ISSUED TO: _____

TO PERMIT: _____

SITE LOCATION: _____

CONDITIONS Incorporated And Made Part Of This Permit:

1. This permit is conditional upon the permittee's compliance with all other applicable permit requirements of the State of Delaware.
2. Issuance of this permit does not relieve the permittee of the Legal obligation of complying with all building permit, subdivision, and other applicable code requirements of the county and municipality wherein the permitted project is located.
3. If there are significant deviations from the plan and operations approved by the Secretary the permittee shall notify the Secretary as soon as possible. This permit may be revoked and a new permit application required if the Secretary deems the deviations to substantially change the nature or scale of the project and to be of actual or probable harm to the purposes of the Coastal Zone Act.

SIGNATURE _____

(Secretary, Department of Natural Resources
and Environmental Control)

State of Vermont

Department of Natural Resources
and
Environmental Control

APPLICATION FOR LICENSE

Category: Water Well Driller____, Water Well Driver____, Pump Installer____

Name of Applicant: _____

Address: _____

Home Telephone: _____

Name of Company Employed by: _____

Company Address: _____

Company Telephone Number: _____

Previous Employment in Water Well Industry:

1. _____
2. _____
3. _____

Number of years experience in constructing water wells or installing pumping equipment _____.

List any other licenses you currently hold and give expiration date.

1. _____ Expires _____
2. _____ Expires _____
3. _____ Expires _____

I certify that the information contained herein is true, factual and complete, and I understand that fraudulent, erroneous or incomplete information shall render any license issued as a result of this application void.

Witnessed _____

Date _____

This application must be accompanied by a fee of ten (\$10.00) dollars.

Authorized signature of applicant

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
Application for Water Well Contractors License

1. Name of Applicant _____
2. State of Incorporation _____
3. Name and Address of resident agent in Delaware _____

4. Name and Address of chief executive officer _____

5. Address and telephone number of main office in Delaware _____

6. Name and Address of person to contact in case of emergency _____

7. List on back the address of all offices from which you conduct your business of constructing water wells and/or installing pumping equipment in the State of Delaware.
8. Number of years experience in constructing water wells and/or installing pumping equipment _____. List this information on back for branches and/or affiliates.
9. Who will be the individual(s) responsible for the on-site supervision of your water well construction and/or installing of pumping equipment in the State of Delaware? List on back.
10. List on back any permits or licenses that are currently in force between your company and any other agency in the State of Delaware. These may include state or municipal general contractor's permits, or the like. Indicate the expiration date of each.

11. List below any permits or licenses that are currently in force between your company and any agency in any state that borders Delaware (Pa., Md., N.J.). Indicate state and local permits and the expiration of each.
12. Proof of insurance must accompany this application as set forth in Section 12 of the Regulations For Licensing Water Well Contractors adopted December 15, 1981. Attach a copy of the required insurance policy or certificate of insurance and proof that the policy is currently in effect.
13. This application must be accompanied by a fee of Ten (\$10.00) Dollars, checks payable to: State of Delaware.
14. I certify that the information contained herein is true, factual, and complete and I understand that fraudulent, erroneous or incomplete information shall render any permit issued as a result of this application void from the date of this application.

APPLICANT

DATE

WITNESS

DATE

Press Hard - Write Clearly - Use Ball-Point Pen or Typewriter - Press Hard

Mail To:
Water Supply Section
Division of Environmental Control
Tatnall Building P.O. Box 1401
Dover, Delaware 19901
PLEASE PRINT

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
AND ENVIRONMENTAL CONTROL
APPLICATION FOR A PERMIT TO DRILL A WELL
(To be completed by a licensed water well driller)

APPLICATION MUST BE
SUBMITTED AND PERMIT
RECEIVED BEFORE DRILLING
IS STARTED.

Owner: _____
Telephone Number: _____
Mailing Address: _____
County _____ Zip _____

Date of Application: _____ Mon. _____ Day _____ Year
Estimated Date of Construction: _____
Driller: _____ License No. _____
Pump Installer: _____ License No. _____

WELL INFORMATION (circle one)

Purpose: Test Well - Permanent Well - Option to convert
Use: Domestic - Public - Commercial
Industrial - Agriculture - Other

Describe Other: _____

Is this a replacement well? yes no

Reason for replacement: _____

Date abandoned well is to be sealed: _____

How _____

Has an application been made for an approved sewage
disposal system? yes - no

Permit Number: _____

LOCATION MAPS

Road Map

PROPOSED WELL CONSTRUCTION

Method of drilling: _____

Approximate total depth of well: _____ ft.

Name of aquifer: _____

Casing diameter (s)
inner to outer (in.)

--	--	--

Casing Material: _____

Screen Material: _____

Tentative Screen Setting: between _____ and _____ ft.

Estimated length of screen: _____ ft.

Will the well be gravel packed? yes - no

Type of grout: _____ From: _____ ft. to _____ ft.

Desired capacity of the well: _____ gpm

Maximum daily use: _____ gpd

I hereby affirm the information I have furnished
is accurate and correct

Applicant (circle)
Representative _____

Site Plan (include suitable plot plan if available)

Permit No. _____

For Official Use Only. -- Do Not Write Below This Line.

Pursuant to provisions of 7 Delaware Code, Chapter 60, permission is hereby granted to construct and use a well as described above. All current regulations governing well construction and water resource use must be followed. The following conditions must be observed: ()

This permit expires: _____

SIGNED: _____

A completion report must be filed with the Division of Environmental
Control within twenty-one (21) days after completion of this well.
Failure to do so may result in license suspension.

Permit Number: _____
Report filed _____

APPLICATION FOR PERMIT TO
APPROPRIATE THE WATERS
OF THE STATE OF DELAWARE

Date Received _____ Point or points of diversion _____

Applicant's Name _____

Mailing Address _____

City and State _____ Zip _____

Use of Water

Public _____ Municipal _____ Industrial _____ Irrigation _____

Commercial _____ Agricultural _____

Location of point or points of diversion

Quantity of water to be appropriated and beneficially used:

Gallons per minute _____

Gallons per day _____

Signature of Applicant

TYPE OF APPLICATION

(a) Addition to Comprehensive Plan

Federal, State, and local agencies are required to plan all projects (related to powers delegated to the Commission by the Delaware River Basin Compact) in consultation with the Commission. (For private project sponsors, cooperative planning and inclusion of a project in the Comprehensive Plan, where warranted, are optional.) Upon completion of the planning phase, but prior to actual design, application should be made for inclusion in the Comprehensive Plan. If, however, actual designs are completed and construction scheduled within 3 years, application should be made concurrently for inclusion in the Comprehensive Plan and approval under Section 3.8 of the Compact. Information to accompany this type of application is described in Section 2-1.4 of the Commission's Rules of Practice and Procedure.

(b) Change in a Comprehensive Plan Project

Proposals for changes and additions to a Comprehensive Plan Project may be submitted by any party of interest. Information to accompany this type of application is described in Section 2-1.4 of the Commission's Rules of Practice and Procedure.

(c) Approval Under Section 3.8 of the Compact

Application for approval under Section 3.8 of the Compact should be made for any project, public or private, which may have a substantial effect on the water resources of the Basin. This includes projects or components of projects previously included in the Comprehensive Plan, when final plans are formulated. The Commission's Rules of Practice and Procedure classify such projects in Section 2-3.5 and describe exhibits to accompany the application in Section 2-3.8.

(d) Inclusion in "A-List" of the Water Resources Program

Upon completion of design and scheduling of construction, application may be made by sponsors of public projects for review and inclusion of such projects in the "A-List" of the Water Resources Program. If the project is not already a part of the Comprehensive Plan, application for inclusion therein is to be filed concurrently. (This program is considered for adoption by the Commission annually during the month of February.) Inclusion in such list is also deemed approval for purposes of section 3.8 of the Compact. Section 2-2.3 of the Commission's Rules of Practice and Procedure describes the information that must accompany an application of this type.

DELAWARE RIVER BASIN COMMISSION

● Type of Application: (Check one or more - see reverse side)

- (a) Addition to the Comprehensive Plan..... ()
- (b) Change in a Comprehensive Plan Project..... ()
- (c) Approval under Section 3.8 of the Compact..... ()
- (d) Inclusion in "A-List" of the Water Resources Program..... ()

Pursuant to the Delaware River Basin Compact and the Rules of Practice and Procedure of the Delaware River Basin Commission, application is hereby made for review of the project described below:

(A) Application From:
 Name _____

 Mailing Address _____

 Telephone _____
 Name of Counsel _____

 Name of Engineer _____

For Use of Commission
 Docket No. _____
 Date Received _____
 Action by Commission

- (B) Type of Project: (Check)
(1) Impoundment..... ()	(4) Stream Encroachment..... ()
(2) Withdrawal of Water..... ()	(5) Well..... ()
(3) Disposal of Wastes..... ()	(6) Other..... ()

(C) Description of Project:

Signature of Authorized Person _____

Name _____

Title _____

Date _____

DELAWARE RIVER BASIN COMMISSION

Application for Approval of a Proposed Ground Water Withdrawal

1. Applicant's name _____
2. Mailing address _____
- _____ 3. Telephone _____

4. Affidavit:

State or Commonwealth of _____,

County of _____. I, _____

being duly sworn, according to law, depose and say that I (am the applicant) (am an official or officer of the applicant) (have the authority to make this application) and that the plans, reports and documents submitted as part of the application are true and correct to the best of my knowledge and belief.

Sworn and subscribed to before me this _____ day of _____ 19____,

Notary Public*

Signature of responsible official

* Applications for withdrawal for irrigation are not required to be notarized.

6. Name of Engineer (or Geologist) and Firm _____
7. Mailing address _____
- _____ 8. Telephone _____
9. Signature of consultant _____

Engineer's
Seal

10. Project location:

a. State _____

b. County _____

c. Municipality _____

11. Attach map (preferably USGS Quadrangle) indicating location of project

12. a. Latitude (each withdrawal)

b. Longitude (each withdrawal)

13. Physical description of location--tying into landmarks such as roads:

14. Proposed use

Proposed average daily use

a. Domestic water supply

b. Industrial process water

c. Industrial cooling water

d. Irrigation

e. Other _____

15. Establish the need for additional water demand (applicants for irrigation wells shall include the Agriculture Extension Service recommendation as to rates of application total quantities of water required by crops, and the soil types to which water is to be applied).

16. Description of Well:

a. Depth

b. Diameter

c. Casing diameter

d. Casing length

e. Type of pump

f. Size of pump

g. Length of screen

h. Location of screen

i. Pump intake setting

17. Results of Pumping Test - attach data sheet showing:

a. Date and time of start of pumping test

b. Date and time of end of pumping test

c. Hourly pump rates

d. Hourly water levels

e. Static water level at start (distance below surface)

f. Level at end of pumping test (distance below surface)

18. Location of nearby wells

a. Locate all nearby wells on map, as required by item 11 (if none are nearby, give approximate distance to nearest one)

b. Repeat 16a. -- h. for each nearby well and 17d. -- f. for representative wells monitored during pump test.

Delaware River Basin Commission

ENVIRONMENTAL FORM

Applicant _____
Title of Project _____
Location _____

Date _____

DRBC Docket No. _____

1. List any significant environmental impacts, beneficial and adverse, caused by the proposed action.

2. What mitigating measures will be used to reduce or alleviate the adverse environmental impacts?

3. Summarize the alternatives considered.

4. List any known objectors to the proposed action.

Delaware River Basin Commission

Nº 1745

APPLICANT'S STATEMENT — PROJECT REVIEW FEE
(See Reverse Side For Additional Information)

1. Name and Address of Applicant

2. Name of Project

Docket #

3. Type of Project

Check Applicable Item(s)

-(a) impoundments
.....(b) diversions of water into or out of the Delaware River Basin
.....(c) industrial water use and waste treatment facilities
.....(d) electric generating and transmission facilities
.....(e) petroleum product pipelines
.....(f) stream encroachments; and
.....(g) withdrawal of ground water

4. Project Cost Factors (Complete all lines using Zero where applicable)

Item	Estimated Cost
a. Design	\$
b. Supervision of Construction	\$
c. Legal Services	\$
d. Contract Administration	\$
e. Land	\$
f. Materials	\$
g. Construction and Fabrication	\$
TOTAL ESTIMATED PROJECT COST	\$

Footnotes/Remarks

5. Filing Fee Schedule (Check applicable item(s))

(The filing fee is the greater of (a) or (b))

Computation:

-(a) minimum fee: \$100. for any project; or (a) \$ 100.
.....(b) alternative fee: (b)
.....(1) 1/10 of 1% of estimated project cost up to \$1,000,000. (1) \$
.....(2) 1/50 of 1% of remaining cost above \$1,000,000; but not (2) \$
to exceed a maximum fee of \$50,000 as to any one project,
exclusive of added environmental fees.

Total \$*

6. Filing Fee Required with Application

*Please enclose check in this amount with application. Check should be made payable to Delaware River Basin Commission.

NOTE: Should this project require an Environmental Impact Statement or an Environmental Assessment, you will be notified at a later date and an Applicant's Statement-Environmental Review Fee will be forwarded for completion and payment of applicable fee.

Signature of Certifying Official

Date

Title

ACKNOWLEDGMENT BY DRBC OF FEE PAYMENT

Received Check No., dated, Bank No.
in amount of

- COPIES: (1) Administrative Division Copy — white
(2) APPLICANT — Retain This Copy — pink
(3) Applicant — DRBC Receipted Copy — yellow
(4) Project Review Copy — blue

Signature

A RESOLUTION requiring the payment of fees for Commission review of certain water resources projects.

WHEREAS, review of proposed water resources projects pursuant to Section 3.8 of the Delaware River Basin Compact has become a substantial program activity representing a major public cost; and

WHEREAS, certain categories of project review cases demand extended staff analysis and the use of expert consultants, the cost of which cannot always be forecast within the Commission's budget; and

WHEREAS, it is timely and in the public interest to initiate a program of allocating a portion of the costs of reviewing water resources projects to the applicant or project sponsor; now therefore

BE IT RESOLVED by the Delaware River Basin Commission:

1. A filing fee shall be paid to the Commission, according to the schedule herein, at the time of filing each application for project review, described in paragraph 2 hereof, pursuant to Section 3.8 of the Delaware River Basin Compact. Government agencies shall be exempt from such filing fee.

2. Project review fees under this regulation shall be required for the following categories of projects, subject to provisions of Section 2-3.5(a) of the Rules of Practice and Procedure:

- (a) impoundments;
- (b) diversions of water into or out of the Delaware River Basin;
- (c) industrial water use and waste treatment facilities;
- (d) electric generating and transmission facilities;
- (e) petroleum product pipelines;
- (f) stream encroachments; and
- (g) withdrawal of ground water.

3. The project review filing fee is the greater of (a) and (b) as follows:

- (a) minimum fee: \$100 for any project;
- (b) alternative fee:
 - (1) 1/10 of 1% of project cost to \$1,000,000;
 - (2) 1/50 of 1% of remaining cost above \$1,000,000 but not to exceed a maximum fee of \$50,000 as to any one project, exclusive of added environmental fees;
 - (3) environmental report fee: \$1,500 for any project; and
 - (4) environmental impact statement fee: \$30,000 for any project.

4. The project cost shall include the estimated costs of design, supervision of construction, legal services, contract administration, land, materials, equipment, construction and fabrication.

5. Not more than one project review filing fee shall be paid to the Commission as to any one project. Phased review by the Commission of stages in the development of a project shall be considered a single filing for purposes of this regulation. Revision of projects previously approved by the Commission shall be exempt from the requirements of this regulation.

6. Estimated capital costs of electric transmission lines, petroleum product pipelines and stream encroachment shall be calculated for that portion of the project subject to Commission review and the filing fee shall be limited in its application to the cost so calculated.

7. Revenues received pursuant to this regulation shall be covered into the Commission's general fund and be subject to specific appropriation by the Commission.

ADOPTED: June 28, 1972

Amended April 23, 1975 (Res. 75-3)

State Permit Number WPCC
NPDES Permit Number DE
Effective Date
Expiration Date

AUTHORIZATION TO DISCHARGE UNDER THE
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
AND THE LAWS OF THE
STATE OF DELAWARE

In compliance with the provisions of the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977 (33 U.S.C. 1251 et seq.) (hereinafter referred to as "the Act"), and pursuant to the provisions of 7 Del. C., §6003

is authorized to discharge from the facility
(Point Sources) located at

to receiving waters named

The effluent limitations, monitoring requirements and other permit conditions are set forth in Part I, II and III hereof.

Robert J. Touhey, P.E., Manager
Division of Environmental Control
Department of Natural Resources
and Environmental Control

Date Signed

A. General Description of Discharges and Facilities

73

Such discharge(s) shall be monitored by the permittee as specified below:

Sample
Type

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location:

C. MONITORING REQUIREMENTS

During the period beginning and lasting through

Effluent Parameter

Monitoring Requirement

Measurement
Frequency

Sample
Type

D. SCHEDULE OF COMPLIANCE

1. The permittee shall achieve compliance with the effluent limitations specified for discharges in accordance with the following schedule:

2. No later than 14 calendar days following a date identified in the above schedule of compliance, the permittee shall submit either a report of progress or, in the case of specific actions being required by identified dates, a written notice of compliance or non-compliance. In the latter case, the notice shall include the cause of noncompliance, any remedial actions taken, and the probability of meeting the next scheduled requirement.

E. Monitoring and Reporting

- ## 1. Representative Sampling

Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge.

- ## 2. Reporting

Monitoring results obtained during the previous one (1) month shall be summarized for each month and reported on a Discharge Monitoring Report Form (EPA No. 3320-1), postmarked no later than the 28th day of the month following the completed reporting period. The first report is due on . Signed copies of these, and all other reports required herein, shall be submitted to the State at the following address:

DELAWARE DEPT. OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL, DIVISION
OF ENVIRONMENTAL CONTROL, TATNALL BUILDING, P. O. BOX 1401, DOVER, DELA-
WARE 19901 TELEPHONE: 302/736-4761

3. Definitions

- a. The daily average discharge - The total discharge by weight during a calendar month divided by the number of days in the month that the production or commercial facility was operating. Where less than daily sampling is required by this permit, the daily average discharge shall be determined by the summation of all the measured daily discharges by weight divided by the number of days during the calendar month when the measurements were made.
- b. The daily maximum discharge - The total discharge by weight during any calendar day.
- c. Maximum instantaneous concentration - The concentration of a pollutant in terms of milligrams per liter which represents the value obtained from a grab sample of an effluent. The maximum instantaneous concentration shall be based on a review of the degree of fluctuation experienced in comparable systems. For purposes of compliance, the maximum instantaneous concentration shall be based on the actual analysis of the grab sample.
- d. Bypass - The intentional diversion of wastes from any portion of a treatment facility.
- e. Upset - An exceptional incident in which there is unintentional and temporary noncompliance with technology-based permit effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facility, inadequate treatment facilities, lack of preventive maintenance or careless or improper operation.
- f. Composite sample - A combination of individual samples obtained at intervals over a time period. Either the volume of each individual sample is proportional to discharge flow rates or the sampling interval (for constant volume samples) is proportional to the flow rates over the time period used to produce the composite. For a continuous discharge, a minimum of 24 individual grab samples shall be collected and combined to constitute a 24 hour composite sample. For intermittent discharges of 4-8 hours duration, a minimum of 12 grab samples shall be collected and combined to constitute the composite sample for the discharge. For intermittent discharges of less than 4 hours, a minimum of individual grab samples shall be collected and combined to constitute the composite sample equal to the duration of the discharge in hours times 3 but not less than 3 samples.
- g. Grab sample - An individual sample collected in less than 15 minutes.

- h. I/S (immersion stabilization) - A calibrated device is immersed in the effluent stream until the reading is stabilized.
- i. The monthly average temperature - The arithmetic mean of temperature measurements made on an hourly basis, or the mean value plot of the record of a continuous automated temperature recording instrument, either during a calendar month, or during the operating month if flows are of shorter duration.
- j. The daily maximum temperature - The highest arithmetic mean of the temperature observed for any two (2) consecutive hours during a 24-hour day, or during the operating day if flows are of shorter duration.
- k. Measured flow - Any method of liquid volume measurement the accuracy of which has been previously demonstrated in engineering practice, or for which a relationship to absolute volume has been obtained.
- l. Estimate - To be based on a technical evaluation of the sources contributing to the discharge including, but not limited to, pump capabilities, water meters and batch discharge volumes.
- m. Non-contact cooling water - The water that is contained in a leak-free system, i.e., no contact with any gas, liquid, or solid other than the container for transport; the water shall have no net poundage addition of any pollutant over intake water levels.

4. Test Procedures

Test procedures for the analysis of pollutants shall conform to the applicable test procedures identified in 40 C.F.R., Part 136, unless otherwise specified in this permit.

5. Quality Assurance Practices

The permittee is required to show the validity of all data by requiring its laboratory to adhere to the following minimum quality assurance practices:

- a. Duplicate ⁽¹⁾ and spiked ⁽²⁾ samples must be run for each constituent in the permit on 5% of the samples, or at least on one sample per month, whichever is greater. If the analysis frequency is less than one sample per month, duplicate and/or spiked samples must be run for each analysis.
- b. For spiked samples, a known amount of each constituent is to be added to the discharge sample. The amount of constituent added should be approximately the same amount present in the unspiked sample, or must be approximately that stated as maximum or average in the discharge permit.

(1) Duplicate samples are not required for the following parameters: Color, Temperature, Turbidity.

(2) Spiked samples are not required for the following parameters: Acidity, Alkalinity, Bacteriological, Benzidine, Chlorine, Color, Dissolved Oxygen, Hardness, pH, Oil & Grease, Radiological, Residues, Temperature, Turbidity, BOD₅ and Total Suspended Solids. Procedures for spiking samples are available through the Regional Quality Assurance Coordinator.

- c. The data obtained in a and b shall be summarized in an annual report submitted at the end of the fourth quarter of reporting in terms of precision, percent recovery, and the number of duplicate and spiked samples run, date and laboratory log no. of samples run and name of analyst.
- d. Precision shall be calculated by the formula, standard deviation $s = (\sum d^2/k)^{1/2}$, where d is the difference between duplicate results, and k is the number of duplicate pairs used in the calculations.
- e. Percent recovery shall be reported on the basis of the formula $R = 100 (F-I)/A$, where F is the analytical result of the spiked sample, I is the result before spiking of the sample, and A is the amount of constituent added to the sample.
- f. The percent recovery, R, in e above shall be summarized yearly in terms of mean recovery and standard deviation from the mean. The formula, $s = (\sum (x-\bar{x})^2 / (n-1))^{1/2}$, where s is the standard deviation around the mean $\bar{x}$, x is an individual recovery value, and n is the number of data points, shall be applied.
- g. The permittee or his contract laboratory is required to annually analyze an external quality control reference sample for each pollutant. These are available through the EPA regional quality assurance coordinator. Results shall be included in the annual report, c above.
- h. The permittee and/or his contract laboratory is required to maintain an up-to-date and continuous record of the method used, of any deviations from the method or options employed in the reference method, of reagent standardization, of equipment calibration and of the data obtained in a, b and f above.
- i. If a contract laboratory is utilized, the permittee shall report the name and address of the laboratory and the parameters analyzed together with the monitoring data required.

6. Records

- a. For each measurement or sample taken pursuant to the requirements of this permit, the permittee shall record the following information:
 - (1) The date, exact place and time of sampling or measurements;
 - (2) The person(s) who performed the sampling or measurements;

- (3) The dates analyses were performed;
- (4) The person(s) who performed each analysis;
- (5) The analytical techniques or methods used;
- (6) The results of each analyses; and
- (7) The quality assurance information as stated above.

b. An operator log must be kept on site at all times. This log should include time spent at the treatment facility on any date, and the nature of operation and maintenance performed.

7. Additional Monitoring by Permittee

If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved analytical methods as specified above, the results of such monitoring shall be included in the calculation and reporting of the values required in the Discharge Monitoring Report form (EPA No. 3320-1). Such increased frequency shall also be indicated.

8. Records Retention

All records and information resulting from the monitoring activities required by this permit including all records of analyses performed and calibration and maintenance of instrumentation and recording from continuous monitoring instrumentation shall be retained for three (3) years. This period of retention shall be extended automatically during the course of any unresolved litigation regarding the regulated activity or regarding control standards applicable to the permittee, or as requested by the Department.

A. MANAGEMENT REQUIREMENTS

1. Change in Discharge

All discharges authorized herein shall be consistent with the terms and conditions of this permit. The discharge of any pollutant identified in this permit at a level in excess of that authorized shall constitute a violation of the permit. Any anticipated facility expansions, production increase, or process modifications which will result in new, different or increased discharge of pollutants must be reported by submission of a new NPDES application at least 180 days prior to commencement of the changed discharge. Any other activity which would constitute cause for modification or revocation and reissuance of this permit, as described in Part II, B-5 of this permit, shall be reported to the Department. Following such notice, the permit may be modified to specify and limit any pollutants not previously limited.

2. Noncompliance Notification

- a. If, for any reason, the permittee does not comply with or will be unable to comply with any daily maximum effluent limitations or maximum instantaneous concentration specified in this permit, the permittee shall provide the Department with the following information, in writing, within five (5) days of becoming aware of such conditions:
 - (1) A description of the discharge and cause of noncompliance;
 - (2) The period of noncompliance, including exact dates and times and the anticipated time when the discharge will return to compliance;
 - (3) Steps being taken to reduce, eliminate and prevent recurrence of the noncomplying discharge.
- b. In the case of any upset or discharge subject to any toxic pollutant effluent standard under Section 307(a) of the Act, the Department shall be notified within 24 hours of the time the permittee becomes aware of the noncomplying discharge. Notification shall include information as described in paragraph 2(a) above. If such notification is made orally, a written submission must follow within five (5) days of the time the permittee becomes aware of the noncomplying discharge.

3. Facilities Operation

The permittee shall at all times maintain in good working order and operate as efficiently as possible all collection and treatment facilities and systems (and related appurtenances) installed or used by the permittee to achieve compliance with the terms and conditions of this permit. Proper operation and maintenance includes, but is not limited to, effective performance based on designed facility removals,

adequate funding, effective management, adequate operator staffing and training and adequate laboratory and process controls including appropriate quality assurance procedures.

4. Adverse Impact

The permittee shall take all reasonable steps to minimize any adverse impact to the waters of the State or the United States resulting from noncompliance with this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge.

5. Bypassing

Any bypass of treatment facilities necessary to maintain compliance with the terms and conditions of this permit is prohibited unless:

- a. The bypass is unavoidable to prevent loss of life, personal injury or severe property damage; and
- b. There are no alternatives; and
- c. The Department is notified within 24 hours (if orally notified, then followed by a written submission, within five (5) days of the permittee's becoming aware of the bypass. Where the need for a bypass is known (or should have been known) in advance, this notification shall be submitted to the Department for approval at least ten (10) days before the date of bypass; and
- d. The bypass is allowed under conditions determined by the Department to be necessary to minimize adverse effect as provided under 7 Del. C., Chapter 60, §6011.

6. Conditions Necessary for Demonstration of an Upset

An upset shall constitute an affirmative defense to an action brought for noncompliance with technology-based effluent limitations only if the permittee demonstrates, through properly signed contemporaneous operating logs, or other relevant evidence, that:

- a. An upset occurred and that the permittee can identify the specific cause(s) of the upset; and
- b. The permitted facility was at the time being operated in a prudent and workman-like manner and in compliance with proper operation and maintenance procedures; and
- c. The permittee submitted a notification of noncompliance as required by Part II, A.2.b.
- d. The permittee has taken all remedial measures required to minimize adverse impact.

7. Removed Substances

Solids, sludges, filter backwash, or other pollutants removed in the course of collection or treatment of wastewaters shall be disposed of in a manner such as to prevent any pollutant from such materials from entering surface waters or groundwaters.

8. Failure

The permittee, in order to maintain compliance with its permit, shall control production and all discharges upon reduction, loss or failure of the treatment facility until the facility is restored or an alternative method of treatment is provided.

9. Alternative Power Source

In order to insure compliance with the effluent limitations and all other terms and conditions of this permit, the Department may require that the permittee shall provide an alternative power sufficient to operate the wastewater collection and treatment facilities in accordance with the Schedule of Compliance contained in Part I of this permit.

B. RESPONSIBILITY

1. Right of Entry

The permittee shall allow the Secretary of the Department of Natural Resources and Environmental Control, the Regional Administrator, and their authorized representatives, jointly and severally, upon the presentation of credentials and such other documents as may be required by law:

- a. To enter upon the permittee's premises where a point source is located or where any records are required to be kept under the terms and conditions of this permit; and
- b. At reasonable times to have access to and copy any records required to be kept under the terms and conditions of this permit; to inspect any monitoring equipment or monitoring method required in this permit; to inspect any collection, treatment, pollution management, or discharge facilities required under this permit; and to sample any discharge of pollutants.

2. Transfer of Ownership and Control

In the event of any change in ownership or control of facilities from which the authorized discharge emanates, the permit may be transferred to another person if the permittee:

- a. Notifies the Department, in writing, of the proposed transfer; and

- b. A written agreement between the transferrer and the transferee, indicating the specific date of proposed transfer of permit coverage and acknowledging responsibilities of current and new permittees for compliance with and liability for the terms and conditions of this permit, is submitted to the Department; and
- c. The Department within thirty (30) days of receipt of the notification of the proposed transfer does not notify the current permittee and the new permittee of intent to modify, revoke and reissue, or terminate the permit and require that a new application be submitted.

3. Reapplication for a Permit

At least 180 days before the expiration date of this permit, the permittee shall submit a new application for a permit or notify the Department of the intent to cease discharging by the expiration date. In the event that a timely and sufficient reapplication has been submitted and the Department is unable, through no fault of the permittee, to issue a new permit before the expiration date of this permit, the terms and conditions of this permit are automatically continued and remain fully effective and enforceable.

4. Availability of Reports

Except for data determined to be confidential under Section 308 of the Act, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the Department of Natural Resources and Environmental Control. As required by the Act, effluent data shall not be considered confidential. Knowingly making any false statement on any such report may result in the imposition of criminal penalties as provided for under 7 Del. C., §6013.

5. Permit Modification, revocation and Reissuance and Termination

- a. After notice and opportunity for a hearing, this permit may be modified, terminated, or revoked and reissued in whole or in part during its term for cause including, but not limited to, the following:
 - (1) Violation of any terms or conditions of this permit;
 - (2) Obtaining this permit by misrepresentation or failure to disclose fully all relevant facts;
 - (3) A change in any condition that requires either a temporary or permanent reduction or elimination of the authorized discharge; or
 - (4) Information that the permitted discharge poses a threat to human health or welfare.

- b. In addition to the provisions of paragraph 5.a. above, this permit may be modified, revoked and reissued in whole or in part, but not terminated, after notice and opportunity for a hearing, for cause including, but not limited to, the following:
- (1) Material and substantial alterations or additions to the discharger's operation which were not covered in the effective permit provided that such alterations do not constitute total replacement of the process or production equipment causing the discharge which converts it into a new source;
 - (2) The existence of a factor or factors which, if properly and timely brought to the attention of the Department, would have justified the application of limitations or other requirements different from those required by applicable standards or limitations but only if the requestor shows that such factor or factors arose after the final permit was issued;
 - (3) Revision, withdrawal or modification of State water quality standards or Environmental Protection Agency promulgated effluent limitations guidelines, but only when:
 - (a) The permit term or condition requested to be modified or revoked was based on a promulgated effluent limitations guideline or an Environmental Protection Agency approved State water quality standards.
 - (b) The U.S. Environmental Protection Agency has:
 - (i) Revised, withdrawn or modified that portion of the effluent limitations guidelines on which the permit term or condition was based; or
 - (ii) Approved a State action with regard to a water quality standard on which the permit term or condition was based; and
 - (c) A request for modification or revocation and reissuance is filed within ninety (90) days after Federal Register notice of:
 - (i) Revision, withdrawal or modification of that portion of the effluent limitations guidelines; or
 - (ii) The U.S. Environmental Protection Agency approval of State action regarding a water quality standard;
 - (4) Judicial remand of Environmental Protection Agency promulgated effluent limitations guidelines, if the remand concerns that portion of the guidelines on which the permit term or condition was based and the request is filed within ninety (90) days of the judicial remand;

- (5) Any modification or revocation and reissuance of permits specifically authorized by the Act;
- (6) To comply with any applicable standard or limitation promulgated or approved under sections 301(b) (2) (C) and (D), 304 (b) (2) and 307(a) (2) of the Clean Water Act, if the effluent standard or limitation so issued or approved:
 - (a) Contains different conditions or is otherwise more stringent than any effluent limitations in the permit; or
 - (b) Controls any pollutant not limited in the permit.

The permit as modified or reissued under this paragraph shall also contain any other requirements of the Act then applicable.

- (7) To contain a schedule of compliance leading to termination of the direct discharge by a date which is no later than the statutory deadline;
- (8) To modify a schedule of compliance in an issued permit for good and valid cause by a date which is no later than the statutory deadline.
- (9) To modify a schedule of compliance of a POTW which has received a grant, under section 202(a) (3) of the Act, to reflect the amount of time lost during construction of the innovative and alternative facilities by a date which is no later than the statutory deadline.

6. Oil and Hazardous Substance Liability

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under 7 Del. C., Chapter 60.

7. State Laws

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable State law or regulation.

8. Discharge of Pollutants

Any person who causes or contributes to the discharge of a pollutant into waters of the State or the United States either in excess of any conditions specified in this permit or in absence of a specific permit condition shall report such an incident to the Department as required under 7 Del. C., §6028.

9. Property Rights

The issuance of this permit neither conveys any property rights in either real or personal property, or any exclusive privileges, nor authorizes any injury to private property or any invasion of personal rights, or any infringement of Federal, State or local laws or regulations.

10. Construction Authorizations

This permit does not authorize or approve the construction of any onshore or offshore physical structures or facilities or the undertaking of any work in any navigable waters.

11. Severability

The provisions of this permit are severable. If any provision of this permit is held invalid, the remainder of this permit shall not be affected. If the application of any provision of this permit to any circumstance is held invalid, its application to other circumstances shall not be affected.

Special Conditions

- A. The permittee, a publicly owned treatment plant (hereinafter referred to as POTW), shall:
1. Provide adequate notice to the Department of the following:
 - a. Any new introduction of pollutants into that POTW from an indirect discharger which would be subject to sections 301 or 306 of the Act if it were directly discharging those pollutants; and
 - b. Any substantial change in the volume or character of pollutants being introduced into that POTW by a source introducing pollutants into the POTW at the time of issuance of the permit.
 2. Identify, in terms of character and volume of pollutants, any significant indirect dischargers into the POTW subject to pretreatment standards under section 307(b) of the Act and 40 CFR, Part 403.
 3. Establish a local program, when required by the Department, in accordance with 40 CFR, Part 403 and applicable State laws and regulation to assure compliance with pretreatment standards to the extent applicable under section 307(b) of that Act. The local program shall be incorporated into the permit as described in 40 CFR, Part 403.
 4. Require any indirect discharger to such POTW to comply with the reporting requirements of sections 204(b), 307 and 308 of the Act, including any requirements established under 40 CFR, Part 403.

A. Special Conditions

APPENDIX E
GEOTHERMAL RESOURCE INTERACTIVE TEMPORAL
SIMULATION MODEL

This appendix was prepared by Ms. Sally M. Kane and Mr. Peter Kroll of the Center for Metropolitan Planning and Research, the Johns Hopkins University, Baltimore, Maryland.

* * * * *

The Geothermal Resource Interactive Temporal Simulation (GRITS) model was developed to calculate both the cost and revenue streams for each year of a project directly utilizing the heat of low to moderate temperature geothermal resources. GRITS is an interactive computer program that allows the user to vary a wide range of resource, demand, and financial parameters in order to observe their effect on the delivered costs of geothermal energy.

This model differs from many other models in that it is a temporal simulation program that produces a series of annual cost and revenue estimates for the entire life of the project. Through this feature, the model is capable of demonstrating the effects of various parameters whose values may change over the course of the project; examples are resource temperature, flow rate, cost of purchased energy, etc.

With the model, a user may take preliminary economic evaluations of process heating applications or community heating systems. In addition GRITS has two main operating modes from which to choose representing the different situations facing a potential geothermal developer; the system can be sized according to either the productivity of the geothermal resource (assuming demand is unlimited) or to meet only a specified demand.

The user of the model defines a project by specifying values for a wide range of resource conditions (for example, number of production and reinjection wells, well depth, water temperature, pumping requirements, maximum flow rate), demand conditions (such as industrial process heat demand and utilization factor), and financial conditions (for example, interest rate, inflation rate, project lifetime, cost of purchased energy). The large number of options provides considerable flexibility to study specific situations.

The model computes the annual energy production and costs in addition to several summary economic accounting measures. The two principal measures are (a) the discounted average cost i.e. the price that equates the discounted cost and revenue streams and (b) the net present value, the sum of the discounted cost and revenue streams. When the user specifies a selling price for the energy produced that differs from the discounted average cost of producing the energy, the net present value differs from zero. The discounted average cost indicates the value of the goods and services required to bring a unit of energy to a customer, and can roughly be compared with the market price of conventional fuels (once converted to \$/MBtu). The net present value takes into account projected market conditions through the specified selling price (or price trend) for the energy produced, and indicates the attractiveness of the investment to developers and financiers.

The remaining summary measures include initial capital costs, payback period, and break-even point. Initial capital costs reflect the sum of the unamortized outlays for initial system components, exclusive of replacement costs; initial capital costs are reported since a very high proportion of total capital costs is incurred in the first year of operation, and is an indicator of the size of the initial investment required to utilize geothermal energy. Payback period is said to occur when the cumulative savings in operating costs (due to use of geothermal energy instead of fossil fuel) exceeds the initial capital investment. The break-even point occurs in the first year in which net present value becomes positive, that is when revenues exceed costs.

Various industrial process heat scenarios (with specified industrial demands) were run using the GRITS model to explore the responsiveness of costs of supplying geothermal energy and the attractiveness of the potential investments to changes in heating demand (billion Btu per year), temperature (degrees Fahrenheit), production well depth (feet), and interest rates (percent). Initially all conditions in the model were assigned a basecase value. This basecase simulates the costs of developing a resource targeted to supply a company using 40 billion Btu of energy per year as process heat. Assumptions underlying this basecase as well as the summary measures can be found below in the reproductions of the computer print-out.

The values for heating demand, temperature, production well depth, and interest rates were varied one at a time (holding all other values constant). The results of these tests are presented in the accompanying tables. Based on the information displayed in the tables a few pertinent trends can be noted:

- 1) 1 Billion Btu per year and 10 billion Btu per year operations (given the resource characteristics) seem to be prohibitively expensive.
- 2) As interest rates increase from 10 to 18 percent, the DAC increases proportionately as heating demand increases from 1 to 50 billion Btu per year) and the NPV decreases.
- 3) Costs increase quickly with increases in depth of the production well (production well depths of 7000 and 8000 feet seem prohibitively expensive in each case given other resource conditions).
- 4) The break-even point seems to be achieved consistently with
50 billion Btu per year at 4000 feet with 120-180°F
50 billion Btu per year at 5000 feet with 160°F and 180°F
40 billion Btu per year at 4000 feet with 160°F and 180°F.

For a detailed description of the model, please refer to the technical report, GRITS (Version 9): Model Description and User's Guide, QM-82-112, April 1982, available from the Metro Center or the Applied Physics

Laboratory. The program will continue to be available either in the form of computer tape and/or listing; one can also contact the Johns Hopkins University Computing Center to establish a computer account. Technical assistance for running the computer program and performing analyses can be obtained through a contract with Sally M. Kane or Peter Kroll at the Center for Metropolitan Planning and Research (Metro Center) at the Johns Hopkins University, Baltimore, Maryland. For other information, contact F.C. Paddison at the Applied Physics Laboratory of the Johns Hopkins University, Laurel, Maryland.

Annual Heating Demand = 1 Billion Btu/Year

Temperature=120 deg. F.
(Flow=7.26 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	461	747	1114	1682	2559
Net Present Value (Thous. \$)	-1124	-1799	-2664	-3997	-6053
Disc. Avg. Cost (\$/MMBtu)	145	228	335	499	752
Breakeven Year	--	--	--	--	--
Payback Year	--	--	--	--	--

Temperature=140 deg. F.
(Flow=4.62 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	460	745	1113	1680	2557
Net Present Value (Thous. \$)	-1107	-1778	-2641	-3972	-6025
Disc. Avg. Cost (\$/MMBtu)	143	226	332	496	749
Breakeven Year	--	--	--	--	--
Payback Year	--	--	--	--	--

Temperature=160 deg. F.
(Flow=3.39 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	459	745	1112	1679	2556
Net Present Value (Thous. \$)	-1098	-1768	-2630	-3959	-6011
Disc. Avg. Cost (\$/MMBtu)	142	224	331	494	747
Breakeven Year	--	--	--	--	--
Payback Year	--	--	--	--	--

Temperature=180 deg. F.
(Flow=2.67 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	459	744	1111	1678	2556
Net Present Value (Thous. \$)	-1092	-1762	-2623	-3951	-6002
Disc. Avg. Cost (\$/MMBtu)	141	224	330	493	746
Breakeven Year	--	--	--	--	--
Payback Year	--	--	--	--	--

Annual Heating Demand = 10 Billion Btu/Year

Temperature=120 deg. F.
(Flow=73 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	485	773	1142	1711	2590
Net Present Value (Thous. \$)	-955	-1682	-2599	-3982	-6087
Disc. Avg. Cost (\$/MMBtu)	18.51	27.47	38.75	55.79	81.71
Breakeven Year	--	--	--	--	--
Payback Year	--	--	--	--	--

Temperature=140 deg. F.
(Flow=46 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	480	766	1135	1704	2582
Net Present Value (Thous. \$)	-842	-1549	-2446	-3810	-5897
Disc. Avg. Cost (\$/MMBtu)	17.11	25.82	36.87	53.67	79.36
Breakeven Year	--	--	--	--	--
Payback Year	10	--	--	--	--

Temperature=160 deg. F.
(Flow=34 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	476	763	1131	1700	2578
Net Present Value (Thous. \$)	-785	-1483	-2371	-3726	-5803
Disc. Avg. Cost (\$/MMBtu)	16.42	25.01	35.94	52.63	78.20
Breakeven Year	--	--	--	--	--
Payback Year	10	--	--	--	--

Temperature=180 deg. F.
(Flow=27 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	475	761	1129	1698	2575
Net Present Value (Thous. \$)	-751	-1443	-2325	-3675	-5746
Disc. Avg. Cost (\$/MMBtu)	16.00	24.52	35.38	52.00	77.51
Breakeven Year	--	--	--	--	--
Payback Year	9	--	--	--	--

Annual Heating Demand = 25 Billion Btu/Year

Temperature=120 deg. F.
(Flow=182 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	512	801	1173	1744	2625
Net Present Value (Thous. \$)	-580	-1383	-2375	-3832	-6010
Disc. Avg. Cost (\$/MMBtu)	9.60	13.55	18.43	25.59	36.30
Breakeven Year	--	--	--	--	--
Payback Year	3	6	--	--	--

Temperature=140 deg. F.
(Flow=115 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	502	790	1161	1731	2611
Net Present Value (Thous. \$)	-327	-1085	-2032	-3445	-5579
Disc. Avg. Cost (\$/MMBtu)	8.36	12.09	16.74	23.69	34.19
Breakeven Year	--	--	--	--	--
Payback Year	3	5	10	--	--

Temperature=160 deg. F.
(Flow=85 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	497	784	1154	1724	2603
Net Present Value (Thous. \$)	-203	-939	-1864	-3256	-5370
Disc. Avg. Cost (\$/MMBtu)	7.75	11.37	15.92	22.76	33.16
Breakeven Year	--	--	--	--	--
Payback Year	3	5	10	--	--

Temperature=180 deg. F.
(Flow=67 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	493	781	1150	1719	2598
Net Present Value (Thous. \$)	-129	-852	-1764	-3143	-5245
Disc. Avg. Cost (\$/MMBtu)	7.38	10.94	15.43	22.21	32.54
Breakeven Year	--	--	--	--	--
Payback Year	3	5	9	--	--

Annual Heating Demand = 40 Billion Btu/Year

Temperature=120 deg. F.
(Flow=290 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	534	825	1199	1772	2654
Net Present Value (Thous. \$)	-177	-1052	-2114	-3640	-5886
Disc. Avg. Cost (\$/MMBtu)	7.30	10.00	13.27	17.98	24.91
Breakeven Year	--	--	--	--	--
Payback Year	2	3	6	--	--

Temperature=140 deg. F.
(Flow=184 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	520	810	1182	1753	2634
Net Present Value (Thous. \$)	207	-599	-1592	-3050	-5230
Disc. Avg. Cost (\$/MMBtu)	6.11	8.60	11.66	16.16	22.88
Breakeven Year	--	--	--	--	--
Payback Year	2	3	5	10	--

Temperature=160 deg. F.
(Flow=135 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	513	802	1173	1743	2623
Net Present Value (Thous. \$)	393	-378	-1339	-2765	-4912
Disc. Avg. Cost (\$/MMBtu)	5.54	7.92	10.88	15.28	21.90
Breakeven Year	3	--	--	--	--
Payback Year	2	3	5	9	--

Temperature=180 deg. F.
(Flow=107 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	509	797	1167	1737	2617
Net Present Value (Thous. \$)	505	-247	-1188	-2594	-4723
Disc. Avg. Cost (\$/MMBtu)	5.19	7.51	10.41	14.75	21.32
Breakeven Year	2	--	--	--	--
Payback Year	2	3	5	8	--

Annual Heating Demand = 50 Billion Btu/Year

Temperature=120 deg. F.
(Flow=363 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	548	840	1215	1789	2672
Net Present Value (Thous. \$)	104	-818	-1926	-3498	-5789
Disc. Avg. Cost (\$/MMBtu)	6.49	8.77	11.49	15.36	21.01
Breakeven Year	8	--	--	--	--
Payback Year	2	3	4	8	--

Temperature=140 deg. F.
(Flow=231 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	532	822	1195	1767	2649
Net Present Value (Thous. \$)	575	-261	-1285	-2774	-4983
Disc. Avg. Cost (\$/MMBtu)	5.34	7.40	9.92	13.58	19.02
Breakeven Year	2	--	--	--	--
Payback Year	2	2	4	7	--

Temperature=160 deg. F.
(Flow=169 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	524	813	1184	1756	2636
Net Present Value (Thous. \$)	803	8	-975	-2424	-4594
Disc. Avg. Cost (\$/MMBtu)	4.77	6.73	9.15	12.72	18.06
Breakeven Year	1	10	--	--	--
Payback Year	2	2	4	6	--

Temperature=180 deg. F.
(Flow=134 gpm)

	Depth				
	4000'	5000'	6000'	7000'	8000'
Capital Cost (Thous. \$)	518	807	1178	1748	2628
Net Present Value (Thous. \$)	939	169	-791	-2216	-4362
Disc. Avg. Cost (\$/MMBtu)	4.44	6.34	8.70	12.21	17.49
Breakeven Year	1	7	--	--	--
Payback Year	2	2	3	6	--

Annual Heating Demand = 1 Billion Btu/Year

	Interest Rate			
	10%	13%	15%	18%
Capital Cost (Thous. \$)	460	460	460	460
Net Present Value (Thous. \$)	-1005	-1065	-1107	-1172
Discounted Avg. Cost (\$/MMBtu)	131	138	143	151
Breakeven Year	---	---	---	---
Payback Year	---	---	---	---

Annual Heating Demand = 10 Billion Btu/Year

	Interest Rate			
	10%	13%	15%	18%
Capital Cost (Thous. \$)	480	480	480	480
Net Present Value (Thous. \$)	-734	-797	-842	-910
Discounted Avg. Cost (\$/MMBtu)	15.79	16.57	17.11	17.96
Breakeven Year	---	---	---	---
Payback Year	10	10	10	10

Annual Heating Demand = 25 Billion Btu/Year

	Interest Rate			
	10%	13%	15%	18%
Capital Cost (Thous. \$)	502	502	502	502
Net Present Value (Thous. \$)	-212	-280	-327	-400
Discounted Avg. Cost (\$/MMBtu)	7.79	8.13	8.36	8.72
Breakeven Year	--	--	--	--
Payback Year	3	3	3	3

Annual Heating Demand = 40 Billion Btu/Year

	Interest Rate			
	10%	13%	15%	18%
Capital Cost (Thous. \$)	502	502	502	502
Net Present Value (Thous. \$)	327	256	207	131
Discount Avg. Cost (\$/MMBtu)	5.74	5.96	6.11	6.35
Breakeven Year	3	4	5	7
Payback Year	2	2	2	2

Annual Heating Demand = 50 Billion Btu/Year

	Interest Rate			
	10%	13%	15%	18%
Capital Cost (Thous. \$)	532	532	532	532
Net Present Value (Thous. \$)	699	626	575	497
Discounted Avg. Cost (\$/MMBtu)	5.03	5.21	5.34	5.53
Breakeven Year	1	2	2	2
Payback Year	2	2	2	2

* * G R I T S * *

Geothermal Resource Interactive Temporal Simulation

Version 9A

Designed by Bill Barron, Peter Kroll, & Sally Kane

Written by Peter Kroll

Center for Metropolitan Planning & Research
The Johns Hopkins University
Baltimore, Maryland 21218

April 1982

Basecase for Delaware Geothermal Energy Feasibility Report

(Base period for costs is 2nd Quarter, 1981)

Industrial Scenario Parameters

Program Operating Conditions

0 Standard geothermal system
2 Output file name: DEO.OUT
4 Title of scenario: (displayed above, if any)
5 Industrial service chosen.
8 Data files will not be generated.
9 System will be sized according to DEMAND conditions.

Resource Condition Parameters

42 Number of production wells: 1
12 Depth of upwell (feet): 4000.
11 Wellhead water temp.(deg. Fahr.)
linear function used with:
initial water temp.= 140.0
annual drop in temp.= 0.0
21 Reject temperature (deg. Fahr.): 85.0
43 Number of reinjection wells: 1
23 Depth of reinjection well (feet): 1500.
26 Drawdown of upwell (percent)
log function used with:
initial drawdown= 14.89
drawdown in final year= 25.60
32 Maximum flow per well (gpm)
linear function used with:
initial flow= 282.00
annual change= 0.00
38 Transport distance (miles) carrying flow of...
1 wells' flow to distn. system: 0.019

Industrial Demand Condition Parameters

53 Indus. ht demand(million Btu/hr): 5.07
31 Industrial utilization factor (%): 90.00

(Listing continued on next page)

(cont'd) Basecase for Delaware Geothermal Energy Feasibility Report

Financial Condition Parameters

```

# 40 Economic accounting method: NPV & Disc Avg Cost
# 36 System selling price ($/mil. Btu):
      selling price is a multiple of:
      fossil fuel price, factor=      0.70
# 33 Study period: 11 years; Intervals of 1 year
# 41 Resource assessment period      1 yrs
      Ann'l resource assess. cost($thous): 50.
# 16 Well cost adjustment factor: 1.000
# 17 Heat exch. cost adjustment factor: 1.000
# 24 Storage tank capacity: 0.0 hours of flow
# 15 Capital Equipment Amort. Per. Phys. Life
      Wells      30. yrs*      30. yrs
      Piping system 30. yrs*      30. yrs
      Heat exchanger 10. yrs*      10. yrs
      In-well pumps 1. yrs*      1. yrs
      Storage tank 30. yrs*      30. yrs
      *(reduced as needed to end in study period)
# 37 Discount rate (percent): 4.00
# 27 Interest rate (percent): 15.00
# 25 Cost calculations are in REAL dollars
      Inflation rate (percent): 8.00
# 20 Cost of electricity (cts/kwh)
      compounding function used with:
      initial elec. price= 7.58
      percent annual change= 1.00
# 29 Fossil fuel cost ($/mil. Btu)
      compounding function used with:
      initial foss. fuel price= 8.690
      percent annual change= 2.000
# 44 Oper. & maint. cost (% of capital): 14.00%
  
```

* * Cost of Initial Capital Equipment * *

```

-----
Wells:      $      454.090 thousand
Heat exchangers: $      25.584 thousand
Pumps:      $      32.680 thousand
Transport system: $      8.019 thousand
Storage tank: $      0.000 thousand
-----
* Total *      $      520.373 thousand
  
```

(Base period for costs is 2nd Quarter, 1981)

12-Jul-82

Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 0

Option	Value
0 Standard Geothermal System	
9 System sized to meet the specified demand.	
10 Area under consideration: Lewes, Delaware	
11 Wellhead water temp.(deg. Fahr.): 140.0	
12 Depth of upwell (feet): 4000.	
15 Capital Equipment Amort. Per. Phys. Life	
Wells 30. yrs* 30. yrs	
Piping system 30. yrs* 30. yrs	
Heat exchanger 10. yrs* 10. yrs	
In-well pumps 1. yrs* 1. yrs	
Storage tank 30. yrs* 30. yrs	
16 Well cost adjustment factor: 1.000	
17 Heat exch. cost adjustment factor: 1.000	
20 Cost of electricity (cts/kwh): 7.580	
21 Reject temperature (deg.Fahr.): 85.0	
23 Depth of reinjection well (feet): 1500.	
24 Storage tank capacity (gallons): 0.	
25 Real/Nominal\$:R; Inflation rate(%): 8.00	
26 Drawdown of upwell (percent): 0.00	
27 Interest rate (percent): 15.00	
29 Fossil fuel cost (\$/mil. Btu): 8.69	
31 Industrial utilization factor (%): 90.00	
32 Maximum flow per well (gal/min): 0.00	
33 Study period: 11 yrs; Intervals of 1 year	
36 System selling price (\$/mil. Btu): 6.08	
37 Discount rate (in percent): 4.00	
38 Transport distance (miles): 0.019	
40 Economic accounting method: NPV & Disc. Avg. Cost	
41 Resource assessment: 1 yrs @ \$thou 50./yr	
42 Number of production wells: 1	
43 Number of reinjection wells: 1	
44 Oper. & maint. cost (% of capital): 14.00%	
53 Indus. ht demand(million Btu/hr): 5.07	

Results of Industrial Model for Year 0

Peak total flow (gpm):	0.00
Total system Btu's (millions):	0.00
Pumping energy:	0.000 million kwh
Coefficient of performance:	0.00
Annualized Costs (thousands of dollars):	
Well costs:	0.000
Heat exchanger costs:	0.000
Original pump costs:	0.000
Pump overhaul costs:	0.000
Annual pumping costs:	0.000
Transport costs:	0.000
Storage tank costs:	0.000
Operation and maintenance costs:	0.000
Resource assessment costs:	50.000
Total annual wellhead costs:	50.000
Total annual system costs:	50.000
Wellhead cost per geo mil. Btu(\$):*****	
System cost per mil. Btu(\$):*****	
Revenue (\$ thousands):	0.000
Net revenue (\$ thousands):	-50.000
Oper cost saved this yr(\$thou):	0.000
Tot. oper. cost savings(\$thou):	0.000

*Amort. per. reduced as needed to end in study period.

(Base period for costs is 2nd Quarter, 1981)

12-Jul-82

Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 1

Option	Value
0 Standard Geothermal System	
9 System sized to meet the specified demand.	
10 Area under consideration: Lewes, Delaware	
11 Wellhead water temp.(deg. Fahr.):	140.0
12 Depth of upwell (feet):	4000.
15 Capital Equipment Amort. Per. Phys. Life	
Wells	30. yrs* 30. yrs
Piping system	30. yrs* 30. yrs
Heat exchanger	10. yrs* 10. yrs
In-well pumps	1. yrs* 1. yrs
Storage tank	30. yrs* 30. yrs
16 Well cost adjustment factor:	1.000
17 Heat exch. cost adjustment factor:	1.000
20 Cost of electricity (cts/kwh):	7.656
21 Reject temperature (deg.Fahr.):	85.0
23 Depth of reinjection well (feet):	1500.
24 Storage tank capacity (gallons):	0.
25 Real/Nominal\$;R; Inflation rate(%):	8.00
26 Drawdown of upwell (percent):	20.00
27 Interest rate (percent):	15.00
29 Fossil fuel cost (\$/mil. Btu):	8.86
31 Industrial utilization factor (%):	90.00
32 Maximum flow per well (gal/min):	184.36
33 Study period: 11 yrs; Intervals of	1 year
36 System selling price (\$/mil. Btu):	6.20
37 Discount rate (in percent):	4.00
38 Transport distance (miles):	0.019
40 Economic accounting method: NPV & Disc. Avg. Cost	
41 Resource assessment: 1 yrs @ \$thou	50./yr
42 Number of production wells:	1
43 Number of reinjection wells:	1
44 Oper. & maint. cost (% of capital):	14.00%
53 Indus. ht demand(million Btu/hr):	5.07

*Amort. per. reduced as needed to end in study period.

Results of Industrial Model for Year 1

Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.526 million kwh
Coefficient of performance:	22.27
Annualized Costs (thousands of dollars):	
Well costs:	90.478
Heat exchanger costs:	5.098
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	40.269
Transport costs:	1.598
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	245.973
Total annual system costs:	253.377
Wellhead cost per geo mil. Btu(\$):	6.15
System cost per mil. Btu(\$):	6.34
Revenue (\$ thousands):	248.012
Net revenue (\$ thousands):	-5.365
Oper cost saved this yr(\$thou):	358.101
Tot. oper. cost savings(\$thou):	358.101

(Base period for costs is 2nd Quarter,1981)

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Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 2

Option	Value
0 Standard Geothermal System	
9 System sized to meet the specified demand.	
10 Area under consideration: Lewes, Delaware	
11 Wellhead water temp.(deg. Fahr.): 140.0	
12 Depth of upwell (feet): 4000.	
15 Capital Equipment Amort. Per. Phys. Life	
Wells 30. yrs* 30. yrs	
Piping system 30. yrs* 30. yrs	
Heat exchanger 10. yrs* 10. yrs	
In-well pumps 1. yrs* 1. yrs	
Storage tank 30. yrs* 30. yrs	
16 Well cost adjustment factor: 1.000	
17 Heat exch. cost adjustment factor: 1.000	
20 Cost of electricity (cts/kwh): 7.732	
21 Reject temperature (deg.Fahr.): 85.0	
23 Depth of reinjection well (feet): 1500.	
24 Storage tank capacity (gallons): 0.	
25 Real/Nominal\$:R; Inflation rate(%): 8.00	
26 Drawdown of upwell (percent): 21.34	
27 Interest rate (percent): 15.00	
29 Fossil fuel cost (\$/mil. Btu): 9.04	
31 Industrial utilization factor (%): 90.00	
32 Maximum flow per well (gal/min): 184.36	
33 Study period: 11 yrs; Intervals of 1 year	
36 System selling price (\$/mil. Btu): 6.33	
37 Discount rate (in percent): 4.00	
38 Transport distance (miles): 0.019	
40 Economic accounting method: NPV & Disc. Avg. Cost	
41 Resource assessment: 1 yrs @ \$thou 50./yr	
42 Number of production wells: 1	
43 Number of reinjection wells: 1	
44 Oper. & maint. cost (% of capital): 14.00%	
53 Indus. ht demand(million Btu/hr): 5.07	

Results of Industrial Model for Year 2

Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.563 million kwh
Coefficient of performance:	20.82
Annualized Costs (thousands of dollars):	
Well costs:	83.776
Heat exchanger costs:	4.720
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	43.511
Transport costs:	1.479
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	242.130
Total annual system costs:	249.419
Wellhead cost per geo mil. Btu(\$):	6.06
System cost per mil. Btu(\$):	6.24
Revenue (\$ thousands):	252.972
Net revenue (\$ thousands):	3.553
Oper cost saved this yr(\$thou):	364.284
Tot. oper. cost savings(\$thou):	722.385
(Payback completed in this year)	

*Amort. per. reduced as needed to end in study period.

(Base period for costs is 2nd Quarter, 1981)

12-Jul-82

Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 3			
Option	Value		
0	Standard Geothermal System		
9	System sized to meet the specified demand.		
10	Area under consideration:	Lewes, Delaware	
11	Wellhead water temp.(deg. Fahr.):	140.0	
12	Depth of upwell (feet):	4000.	
15	Capital Equipment	Amort. Per.	Phys. Life
	Wells	30. yrs*	30. yrs
	Piping system	30. yrs*	30. yrs
	Heat exchanger	10. yrs*	10. yrs
	In-well pumps	1. yrs*	1. yrs
	Storage tank	30. yrs*	30. yrs
16	Well cost adjustment factor:	1.000	
17	Heat exch. cost adjustment factor:	1.000	
20	Cost of electricity (cts/kwh):	7.810	
21	Reject temperature (deg.Fahr.):	85.0	
23	Depth of reinjection well (feet):	1500.	
24	Storage tank capacity (gallons):	0.	
25	Real/Nominal\$:R; Inflation rate(%):	8.00	
26	Drawdown of upwell (percent):	22.38	
27	Interest rate (percent):	15.00	
29	Fossil fuel cost (\$/mil. Btu):	9.22	
31	Industrial utilization factor (%):	90.00	
32	Maximum flow per well (gal/min):	184.36	
33	Study period: 11 yrs; Intervals of	1 year	
36	System selling price (\$/mil. Btu):	6.46	
37	Discount rate (in percent):	4.00	
38	Transport distance (miles):	0.019	
40	Economic accounting method:	NPV & Disc. Avg. Cost	
41	Resource assessment: 1 yrs @ \$thou	50./yr	
42	Number of production wells:	1	
43	Number of reinjection wells:	1	
44	Oper. & maint. cost (% of capital):	14.00%	
53	Indus. ht demand(million Btu/hr):	5.07	

*Amort. per. reduced as needed to end in study period.

Results of Industrial Model for Year 3	
Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.591 million kwh
Coefficient of performance:	19.82
Annualized Costs	(thousands of dollars):
Well costs:	77.571
Heat exchanger costs:	4.370
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	46.169
Transport costs:	1.370
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	238.229
Total annual system costs:	245.413
Wellhead cost per geo mil. Btu(\$):	5.96
System cost per mil. Btu(\$):	6.14
Revenue (\$ thousands):	258.032
Net revenue (\$ thousands):	12.618
Oper cost saved this yr(\$thou):	371.239
Tot. oper. cost savings(\$thou):	1093.624

(Base period for costs is 2nd Quarter, 1981)

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Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 4

Option	Value
0 Standard Geothermal System	
9 System sized to meet the specified demand.	
10 Area under consideration: Lewes, Delaware	
11 Wellhead water temp.(deg. Fahr.): 140.0	
12 Depth of upwell (feet): 4000.	
15 Capital Equipment Amort. Per. Phys. Life	
Wells 30. yrs* 30. yrs	
Piping system 30. yrs* 30. yrs	
Heat exchanger 10. yrs* 10. yrs	
In-well pumps 1. yrs* 1. yrs	
Storage tank 30. yrs* 30. yrs	
16 Well cost adjustment factor: 1.000	
17 Heat exch. cost adjustment factor: 1.000	
20 Cost of electricity (cts/kwh): 7.888	
21 Reject temperature (deg.Fahr.): 85.0	
23 Depth of reinjection well (feet): 1500.	
24 Storage tank capacity (gallons): 0.	
25 Real/Nominal\$:R; Inflation rate(%): 8.00	
26 Drawdown of upwell (percent): 23.22	
27 Interest rate (percent): 15.00	
29 Fossil fuel cost (\$/mil. Btu): 9.41	
31 Industrial utilization factor (%): 90.00	
32 Maximum flow per well (gal/min): 184.36	
33 Study period: 11 yrs; Intervals of 1 year	
36 System selling price (\$/mil. Btu): 6.58	
37 Discount rate (in percent): 4.00	
38 Transport distance (miles): 0.019	
40 Economic accounting method: NPV & Disc. Avg. Cost	
41 Resource assessment: 1 yrs @ \$thou 50./yr	
42 Number of production wells: 1	
43 Number of reinjection wells: 1	
44 Oper. & maint. cost (% of capital): 14.00%	
53 Indus. ht demand(million Btu/hr): 5.07	

Results of Industrial Model for Year 4

Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.614 million kwh
Coefficient of performance:	19.07
Annualized Costs (thousands of dollars):	
Well costs:	71.825
Heat exchanger costs:	4.047
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	48.466
Transport costs:	1.268
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	234.451
Total annual system costs:	241.539
Wellhead cost per geo mil. Btu(\$):	5.87
System cost per mil. Btu(\$):	6.04
Revenue (\$ thousands):	263.192
Net revenue (\$ thousands):	21.653
Oper cost saved this yr(\$thou):	378.747
Tot. oper. cost savings(\$thou):	1472.371

*Amort. per. reduced as needed to end in study period.

(Base period for costs is 2nd Quarter, 1981)

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Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 5

Option	Value
0 Standard Geothermal System	
9 System sized to meet the specified demand.	
10 Area under consideration: Lewes, Delaware	
11 Wellhead water temp.(deg. Fahr.): 140.0	
12 Depth of upwell (feet): 4000.	
15 Capital Equipment Amort. Per. Phys. Life	
Wells 30. yrs* 30. yrs	
Piping system 30. yrs* 30. yrs	
Heat exchanger 10. yrs* 10. yrs	
In-well pumps 1. yrs* 1. yrs	
Storage tank 30. yrs* 30. yrs	
16 Well cost adjustment factor: 1.000	
17 Heat exch. cost adjustment factor: 1.000	
20 Cost of electricity (cts/kwh): 7.967	
21 Reject temperature (deg.Fahr.): 85.0	
23 Depth of reinjection well (feet): 1500.	
24 Storage tank capacity (gallons): 0.	
25 Real/Nominal\$:R; Inflation rate(%): 8.00	
26 Drawdown of upwell (percent): 23.94	
27 Interest rate (percent): 15.00	
29 Fossil fuel cost (\$/mil. Btu): 9.59	
31 Industrial utilization factor (%): 90.00	
32 Maximum flow per well (gal/min): 184.36	
33 Study period: 11 yrs; Intervals of 1 year	
36 System selling price (\$/mil. Btu): 6.72	
37 Discount rate (in percent): 4.00	
38 Transport distance (miles): 0.019	
40 Economic accounting method: NPV & Disc. Avg. Cost	
41 Resource assessment: 1 yrs @ \$thou 50./yr	
42 Number of production wells: 1	
43 Number of reinjection wells: 1	
44 Oper. & maint. cost (% of capital): 14.00%	
53 Indus. ht demand(million Btu/hr): 5.07	

Results of Industrial Model for Year 5

Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.634 million kwh
Coefficient of performance:	18.47
Annualized Costs (thousands of dollars):	
Well costs:	66.504
Heat exchanger costs:	3.747
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	50.518
Transport costs:	1.174
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	230.878
Total annual system costs:	237.876
Wellhead cost per geo mil. Btu(\$):	5.78
System cost per mil. Btu(\$):	5.95
Revenue (\$ thousands):	268.456
Net revenue (\$ thousands):	30.580
(Breakeven point achieved in this year)	
Oper cost saved this yr(\$thou):	386.697
Tot. oper. cost savings(\$thou):	1859.068

*Amort. per. reduced as needed to end in study period.

(Base period for costs is 2nd Quarter, 1981)

12-Jul-82

Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 6

Option	Value
0 Standard Geothermal System	
9 System sized to meet the specified demand.	
10 Area under consideration: Lewes, Delaware	
11 Wellhead water temp.(deg. Fahr.): 140.0	
12 Depth of upwell (feet): 4000.	
15 Capital Equipment Amort. Per. Phys. Life	
Wells 30. yrs* 30. yrs	
Piping system 30. yrs* 30. yrs	
Heat exchanger 10. yrs* 10. yrs	
In-well pumps 1. yrs* 1. yrs	
Storage tank 30. yrs* 30. yrs	
16 Well cost adjustment factor: 1.000	
17 Heat exch. cost adjustment factor: 1.000	
20 Cost of electricity (cts/kwh): 8.046	
21 Reject temperature (deg.Fahr.): 85.0	
23 Depth of reinjection well (feet): 1500.	
24 Storage tank capacity (gallons): 0.	
25 Real/Nominal\$:R; Inflation rate(%): 8.00	
26 Drawdown of upwell (percent): 24.56	
27 Interest rate (percent): 15.00	
29 Fossil fuel cost (\$/mil. Btu): 9.79	
31 Industrial utilization factor (%): 90.00	
32 Maximum flow per well (gal/min): 184.36	
33 Study period: 11 yrs; Intervals of 1 year	
36 System selling price (\$/mil. Btu): 6.85	
37 Discount rate (in percent): 4.00	
38 Transport distance (miles): 0.019	
40 Economic accounting method: NPV & Disc. Avg. Cost	
41 Resource assessment: 1 yrs @ \$thou 50./yr	
42 Number of production wells: 1	
43 Number of reinjection wells: 1	
44 Oper. & maint. cost (% of capital): 14.00%	
53 Indus. ht demand(million Btu/hr): 5.07	

*Amort. per. reduced as needed to end in study period.

Results of Industrial Model for Year 6

Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.651 million kwh
Coefficient of performance:	17.99
Annualized Costs (thousands of dollars):	
Well costs:	61.578
Heat exchanger costs:	3.469
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	52.394
Transport costs:	1.087
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	227.545
Total annual system costs:	234.462
Wellhead cost per geo mil. Btu(\$):	5.69
System cost per mil. Btu(\$):	5.87
Revenue (\$ thousands):	273.825
Net revenue (\$ thousands):	39.363
Oper cost saved this yr(\$thou):	395.022
Tot. oper. cost savings(\$thou):	2254.090

(Base period for costs is 2nd Quarter, 1981)

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Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 7

Option	Value
0 Standard Geothermal System	
9 System sized to meet the specified demand.	
10 Area under consideration: Lewes, Delaware	
11 Wellhead water temp.(deg. Fahr.): 140.0	
12 Depth of upwell (feet): 4000.	
15 Capital Equipment Amort. Per. Phys. Life	
Wells 30. yrs* 30. yrs	
Piping system 30. yrs* 30. yrs	
Heat exchanger 10. yrs* 10. yrs	
In-well pumps 1. yrs* 1. yrs	
Storage tank 30. yrs* 30. yrs	
16 Well cost adjustment factor: 1.000	
17 Heat exch. cost adjustment factor: 1.000	
20 Cost of electricity (cts/kwh): 8.127	
21 Reject temperature (deg.Fahr.): 85.0	
23 Depth of reinjection well (feet): 1500.	
24 Storage tank capacity (gallons): 0.	
25 Real/Nominal\$:R; Inflation rate(%): 8.00	
26 Drawdown of upwell (percent): 25.11	
27 Interest rate (percent): 15.00	
29 Fossil fuel cost (\$/mil. Btu): 9.98	
31 Industrial utilization factor (%): 90.00	
32 Maximum flow per well (gal/min): 184.36	
33 Study period: 11 yrs; Intervals of 1 year	
36 System selling price (\$/mil. Btu): 6.99	
37 Discount rate (in percent): 4.00	
38 Transport distance (miles): 0.019	
40 Economic accounting method: NPV & Disc. Avg. Cost	
41 Resource assessment: 1 yrs @ \$thou 50./yr	
42 Number of production wells: 1	
43 Number of reinjection wells: 1	
44 Oper. & maint. cost (% of capital): 14.00%	
53 Indus. ht demand(million Btu/hr): 5.07	

*Amort. per. reduced as needed to end in study period.

Results of Industrial Model for Year 7

Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.666 million kwh
Coefficient of performance:	17.59
Annualized Costs (thousands of dollars):	
Well costs:	57.017
Heat exchanger costs:	3.212
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	54.139
Transport costs:	1.007
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	224.467
Total annual system costs:	231.308
Wellhead cost per geo mil. Btu(\$):	5.62
System cost per mil. Btu(\$):	5.79
Revenue (\$ thousands):	279.302
Net revenue (\$ thousands):	47.993
Oper cost saved this yr(\$thou):	403.682
Tot. oper. cost savings(\$thou):	2657.772

(Base period for costs is 2nd Quarter, 1981)

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Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 8			
Option		Value	
0	Standard Geothermal System		
9	System sized to meet the specified demand.		
10	Area under consideration: Lewes, Delaware		
11	Wellhead water temp.(deg. Fahr.):	140.0	
12	Depth of upwell (feet):	4000.	
15	Capital Equipment	Amort. Per.	Phys. Life
	Wells	30. yrs*	30. yrs
	Piping system	30. yrs*	30. yrs
	Heat exchanger	10. yrs*	10. yrs
	In-well pumps	1. yrs*	1. yrs
	Storage tank	30. yrs*	30. yrs
16	Well cost adjustment factor:	1.000	
17	Heat exch. cost adjustment factor:	1.000	
20	Cost of electricity (cts/kwh):	8.208	
21	Reject temperature (deg.Fahr.):	85.0	
23	Depth of reinjection well (feet):	1500.	
24	Storage tank capacity (gallons):	0.	
25	Real/Nominal\$:R; Inflation rate(%):	8.00	
26	Drawdown of upwell (percent):	25.60	
27	Interest rate (percent):	15.00	
29	Fossil fuel cost (\$/mil. Btu):	10.18	
31	Industrial utilization factor (%):	90.00	
32	Maximum flow per well (gal/min):	184.36	
33	Study period: 11 yrs; Intervals of	1 year	
36	System selling price (\$/mil. Btu):	7.13	
37	Discount rate (in percent):	4.00	
38	Transport distance (miles):	0.019	
40	Economic accounting method: NPV & Disc. Avg. Cost		
41	Resource assessment: 1 yrs @ \$thou	50./yr	
42	Number of production wells:	1	
43	Number of reinjection wells:	1	
44	Oper. & maint. cost (% of capital):	14.00%	
53	Indus. ht demand(million Btu/hr):	5.07	

Results of Industrial Model for Year 8	
Peak total flow (gpm):	184.36
Total system \$tu's (millions):	39971.88
Pumping energy:	0.680 million kwh
Coefficient of performance:	17.24
Annualized Costs	(thousands of dollars):
Well costs:	52.793
Heat exchanger costs:	2.974
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	55.784
Transport costs:	0.932
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	221.646
Total annual system costs:	228.417
Wellhead cost per geo mil. Btu(\$):	5.55
System cost per mil. Btu(\$):	5.71
Revenue (\$ thousands):	284.888
Net revenue (\$ thousands):	56.471
Oper cost saved this yr(\$thou):	412.651
Tot. oper. cost savings(\$thou):	3070.422

*Amort. per. reduced as needed to end in study period.

(Base period for costs is 2nd Quarter, 1981)

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Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 9			
Option	Value		
0	Standard Geothermal System		
9	System sized to meet the specified demand.		
10	Area under consideration: Lewes, Delaware		
11	Wellhead water temp.(deg. Fahr.):	140.0	
12	Depth of upwell (feet):	4000.	
15	Capital Equipment	Amort. Per.	Phys. Life
	Wells	30. yrs*	30. yrs
	Piping system	30. yrs*	30. yrs
	Heat exchanger	10. yrs*	10. yrs
	In-well pumps	1. yrs*	1. yrs
	Storage tank	30. yrs*	30. yrs
16	Well cost adjustment factor:	1.000	
17	Heat exch. cost adjustment factor:	1.000	
20	Cost of electricity (cts/kwh):	8.290	
21	Reject temperature (deg.Fahr.):	85.0	
23	Depth of reinjection well (feet):	1500.	
24	Storage tank capacity (gallons):	0.	
25	Real/Nominal\$:R; Inflation rate(%):	8.00	
26	Drawdown of upwell (percent):	26.04	
27	Interest rate (percent):	15.00	
29	Fossil fuel cost (\$/mil. Btu):	10.39	
31	Industrial utilization factor (%):	90.00	
32	Maximum flow per well (gal/min):	184.36	
33	Study period: 11 yrs; Intervals of	1 year	
36	System selling price (\$/mil. Btu):	7.27	
37	Discount rate (in percent):	4.00	
38	Transport distance (miles):	0.019	
40	Economic accounting method: NPV & Disc. Avg. Cost		
41	Resource assessment: 1 yrs @ \$thou	50./yr	
42	Number of production wells:	1	
43	Number of reinjection wells:	1	
44	Oper. & maint. cost (% of capital):	14.00%	
53	Indus. ht demand(million Btu/hr):	5.07	

*Amort. per. reduced as needed to end in study period.

Results of Industrial Model for Year 9	
Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.692 million kwh
Coefficient of performance:	16.93
Annualized Costs	(thousands of dollars):
Well costs:	48.883
Heat exchanger costs:	2.754
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	57.350
Transport costs:	0.863
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	219.076
Total annual system costs:	225.783
Wellhead cost per geo mil. Btu(\$):	5.48
System cost per mil. Btu(\$):	5.65
Revenue (\$ thousands):	290.585
Net revenue (\$ thousands):	64.802
Oper cost saved this yr(\$thou):	421.910
Tot. oper. cost savings(\$thou):	3492.333

(Base period for costs is 2nd Quarter, 1981)

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Basecase for Delaware Geothermal Energy Feasibility Report

Industrial Scenario in Year 10

Option	Value
0 Standard Geothermal System	
9 System sized to meet the specified demand.	
10 Area under consideration: Lewes, Delaware	
11 Wellhead water temp.(deg. Fahr.): 140.0	
12 Depth of upwell (feet): 4000.	
15 Capital Equipment Amort. Per. Phys. Life	
Wells 30. yrs* 30. yrs	
Piping system 30. yrs* 30. yrs	
Heat exchanger 10. yrs* 10. yrs	
In-well pumps 1. yrs* 1. yrs	
Storage tank 30. yrs* 30. yrs	
16 Well cost adjustment factor: 1.000	
17 Heat exch. cost adjustment factor: 1.000	
20 Cost of electricity (cts/kwh): 8.373	
21 Reject temperature (deg.Fahr.): 85.0	
23 Depth of reinjection well (feet): 1500.	
24 Storage tank capacity (gallons): 0.	
25 Real/Nominal\$:R; Inflation rate(%): 8.00	
26 Drawdown of upwell (percent): 26.45	
27 Interest rate (percent): 15.00	
29 Fossil fuel cost (\$/mil. Btu): 10.59	
31 Industrial utilization factor (%): 90.00	
32 Maximum flow per well (gal/min): 184.36	
33 Study period: 11 yrs; Intervals of 1 year	
36 System selling price (\$/mil. Btu): 7.42	
37 Discount rate (in percent): 4.00	
38 Transport distance (miles): 0.019	
40 Economic accounting method: NPV & Disc. Avg. Cost	
41 Resource assessment: 1 yrs @ \$thou 50./yr	
42 Number of production wells: 1	
43 Number of reinjection wells: 1	
44 Oper. & maint. cost (% of capital): 14.00%	
53 Indus. ht demand(million Btu/hr): 5.07	

Results of Industrial Model for Year 10

Peak total flow (gpm):	184.36
Total system Btu's (millions):	39971.88
Pumping energy:	0.703 million kwh
Coefficient of performance:	16.67
Annualized Costs (thousands of dollars):	
Well costs:	45.262
Heat exchanger costs:	2.550
Original pump costs:	37.582
Pump overhaul costs:	5.499
Annual pumping costs:	58.853
Transport costs:	0.799
Storage tank costs:	0.000
Operation and maintenance costs:	72.852
Resource assessment costs:	0.000
Total annual wellhead costs:	216.749
Total annual system costs:	223.397
Wellhead cost per geo mil. Btu(\$):	5.42
System cost per mil. Btu(\$):	5.59
Revenue (\$ thousands):	296.397
Net revenue (\$ thousands):	73.000
Oper cost saved this yr(\$thou):	431.449
Tot. oper. cost savings(\$thou):	3923.782

*****Totals Over Project Life*****
 *** Initial Capital Cost: 520.373 thousand dollars ***
 *** Net Present Value: 206.676 thousand dollars ***
 *** Discounted Average Cost: 6.113 dollars/million Btu ***
 *** Disc. Avg Wellhead Cost: 5.938 dollars/million Btu ***
 *** Break-even point achieved in year 5 ***
 *** Tot. Oper. Cost Saved: 3923.782 thousand dollars ***
 *** Payback completed in year 2 ***

*Amort. per. reduced as needed to end in study period.

(Base period for costs is 2nd Quarter, 1981)