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Geothermal Energy Market Study on the Atlantic Coastal Plain

THE DEMAND SPECIFIED MODEL FOR DIRECT APPLICATIONS OF GEOTHERMAL ENERGY: A USER'S GUIDE

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This work was supported by the Department of Energy under Interagency agreements No. EX-76-A-36-1008 and DE-AI01-79-ET27025

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DISCLAIMER

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ABSTRACT

The Applied Physics Laboratory and the Center for Metropolitan Planning and Research of The Johns Hopkins University support the Department of Energy's Division of Geothermal Energy (DOE/DGE) in planning and assisting the development of geothermal energy in the eastern United States. This effort includes development scenarios, energy market surveys, development of tools to analyze and optimize the cost of geothermal energy, the methodology for prediction of market penetration technical assistance to states, groups, and individuals and general support to DOE/DGE. This report documents one of the economic tools developed under that program. Related reports are listed as references.

CONTENTS

	Preface	7
1.	Introduction	9
2.	Background of Demand-Specified Model	10
3.	Demand-Specified Model Features	11
4.	Running the Program	13
	Program Operating Options	15
	Resource Condition Options	18
	Demand Condition Options	19
	Financial Condition Options	20
5.	Summary	23
	References	24
	Appendix A: Options in DSM	25
	Appendix B: Sample DSM Output	27

PREFACE

The Applied Physics Laboratory (APL) and the Center for Metropolitan Planning and Research (Metro Center) of The Johns Hopkins University support the Department of Energy's Division of Geothermal Energy (DOE/DGE) in planning and assisting the development of geothermal energy in the eastern United States. This effort includes development scenarios, energy market surveys, development of tools to analyze and optimize the cost of geothermal energy, the methodology for prediction of market penetration, technical assistance to states, groups, and individuals, and general support to DOE. For information relating to the program, contact Sally Kane or Peter Kroll of the Metro Center or Kwang Yu at APL. This report documents one of the economic tools developed under that program. Related reports are listed as references.

1. INTRODUCTION

The Demand-Specified Model for Direct Applications of Geothermal Energy (DSM) is an interactive computer program that is used to simulate the performance of a low-to-moderate quality geothermal resource in commercial use over a period of time.

The program is run by entering commands at a standard interactive computer terminal. Resource, financial, and demand conditions are specified; results are reported via the terminal screen or printer. New parametric data can then be supplied to represent another set of conditions (a scenario). In this way, a rapid sensitivity analysis of the assumed geothermal resource can be performed.

The primary use of DSM is to size a geothermal system according to a specified demand rather than assuming that enough demand exists to consume the energy that a resource can supply.

The procedure for using DSM is described in this guide.

2. BACKGROUND OF DEMAND-SPECIFIED MODEL

DSM is one of a series of economic analysis programs designed by The Johns Hopkins University Center for Metropolitan Planning and Research (Metro Center) for the Johns Hopkins University Applied Physics Laboratory (JHU/APL) under contract to the U.S. Department of Energy (DOE).

These programs are used to analyze the economic feasibility of developing the low-to-moderate grade geothermal resources postulated to exist in a number of the eastern United States. Detailed economic analysis principles along with adequate engineering relationships are represented in the models to assure realistic cost estimates for such applications as space heating, sanitary water heating, and industrial process heating.

The assumptions, relationships, and equations that define these models are presented in two JHU/APL reports (Refs. 1 and 2). Reference 1 describes an early, static simulation; Ref. 2 describes the dynamic simulation, GRITS, which is currently in use.

DSM has been derived from the GRITS model, so Ref. 2 is appropriate for those interested in the details of the technical and economic relationships that are incorporated. The features that make DSM a separate program are listed below.

3. DEMAND-SPECIFIED MODEL FEATURES

The major feature of DSM is that it sizes a geothermal system according to user-specified demands, whereas the GRITS model assumes that enough demand for geothermal energy exists to consume that which the resource can supply.

The GRITS model includes routines for industrial process heating and for residential/commercial heating. In GRITS, the number of residential customers is calculated by (a) determining the maximum hourly net thermal output of a geothermal well from wellhead temperature, reject temperature, and maximum flow rate, (b) subtracting the commercial demand at the design temperature from the available energy, and (c) dividing the remaining energy by the space and sanitary hot water demand of a typical housing unit at the design temperature. Note that this approach assumes that the potential residential demand is at least sufficient to use the remaining energy.

Since this approach is not appropriate for some applications, DSM provides an alternate: the heating requirement to be satisfied by each geothermal well is specified and the flow rate to meet the demand at the design temperature is calculated.[1] For example, the energy from a well may be designated to heat a limited number of buildings on a university campus or an agricultural complex. The total demand is specified in terms of heating requirements per unit of floor space per degree day and the total floor space of the complex.[2] Heat load is calculated (as in GRITS) on the basis of average hourly temperature for the area under study.

The set of capital components modeled in DSM contains a user-specified retrofit cost that replaces GRITS' distribution system and hookup costs.

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[1]Although flow rates in GRITS vary with changes in outside temperature and, in heating requirements, the maximum flow rate is a user-specified independent variable. All flow rates are dependent variables in DSM.

[2]The same result could be achieved with GRITS but only by the awkward and time-consuming procedure of altering flow until only the commercial demand is satisfied.

The unique financial feature of DSM, compared to GRITS, is that the calculation of net present value of a geothermal project given a selling price for geothermal energy, is eliminated. DSM substitutes the financial measure of the payback period, i.e., the time when the initial capital investment is paid back by operating expense savings that result from conversion to the geothermal system.[3]

DSM is also much shorter and easier to run than GRITS, the parent model, but still retains its major features. Although some flexibility has been sacrificed, the basic structure of the calculations has been maintained.[4]

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[3]To compensate for the fact that calculations are made only in annual increments, the attainment of the payback period in DSM is assigned to the year during which 90% of payback is reached.

[4]To reduce its number of available options, DSM assumes a minimum ambient temperature of 0°F and a boiler cost and capital equipment lifetimes as in GRITS' default scenario.

4. RUNNING THE PROGRAM

In this section, a brief description is presented of the program options available on the program DSM currently running on the time-sharing system of The Johns Hopkins University's DEC system-10 at the Baltimore campus. The program is accessible to low- or high-speed terminals over regular telephone lines from any location. The summary descriptions of the program options should be sufficient for the user with a knowledge of the modeling concepts used in DSM (refer to this document and Ref. 2) to operate the program immediately with no further instruction. Prompts by the program are intended to be self-explanatory, and an on-line help message system is available. In addition, the current status of the scenario is always available for display at the terminal.

The values of most system parameters can be changed by the user of the program; this capability permits the determination of the impact on average costs, specific annual costs, and system characteristics caused by changes in a certain parameter. If a parameter value is not specified by the user, the program uses the default value. The default values are shown in Appendix B.

DSM is accessed from a computer terminal[5] as follows:

1. Dial the computer in Baltimore at (301) 338-7222 for low-speed lines or (301) 338-8403 for 1200 baud transmission,

2. Place the telephone receiver in the acoustic coupler on the terminal, and

3. Press the RETURN key. The user must now enter[6] the account number to access the DEC system-10,

---

[5]The terminal must be set to full duplex mode, upper case lock (if available), and the proper speed.

[6]Characters typed by the user are indicated in this manual by underlining; the underlining is not actually typed by the user.

followed by the confidential password for that account which will not appear on the terminal.

.LOGIN a,b

Password: ________

A "." will then appear at the left of the screen (a welcome message may first appear on the terminal), which means that the computer is in "monitor mode." To run the program DSM, the user then types

.RUN DSM

The program is now waiting to accept the first option.

The user then selects any of the available program options and follows the prompts by the program. Options 1 to 9 are program operation commands, while options 10 to 33 are used to adjust scenario parameters. To change a parameter, the user simply types its option number and presses the RETURN key (all responses must be followed by pressing RETURN). The program will specify the unit of value to be used (e.g., cost in thousands of dollars per mile) and wait for input. For some parameters, a limited range of values is accepted by the program. If the user types in an unacceptable value, the value is requested again.[7]

For most options requiring a numeric input, if the user enters the option but then decides to leave it unchanged, he may exit from it by typing an asterisk (*). After all desired changes have been made, the user may then review the scenario or run the program. Once a scenario has been run, the program can immediately accept new parameters for the next run. <u>All parameters, once changed by the user, remain at those values until changed again.</u> Thus, if the well depth on the first run is changed from its default value of 5000 to 7000 ft, the well depth value will remain 7000 for subsequent runs, unless changed again by the user.

[7]Options requiring word responses, e.g., YES, NO, FINANCIAL, etc., should be typed in upper case characters.

The user can run as many simulation scenarios as he desires. When he has finished, he must exit from DSM first using its option 9. This places the terminal back into the computer's monitor mode. If the previous run has generated any detailed printout for the line printer, the following command must be typed:

.PRINT/DEL/FILE:FOR FILE1.A.FILE2.B.etc.

where FILE1.A,FILE2.B,etc. represent all files specified by the user in option 3. Finally, the user must log off from the system by typing the command

.K/F

A description of each option follows. (Users familiar with GRITS should be aware that the options have been assigned different numbers in DSM.)

PROGRAM OPERATING OPTIONS

Option H (HELP). By typing HELP, a list of all (or a selected subset) of the available options will be displayed.

Option 1. If option 1 is chosen, the program will display the current values of all scenario parameters specified to this point by the user. Since the user may only be interested in a particular set of parameters, he may choose to see either the program operating commands (options 1-9), resource, demand, or financial options, or all options.

Option 2. Option 2 tells DSM to simulate the current scenario. If an output file has been specified earlier in option 3, it is open, and will receive detailed results for each year simulated as well as record the scenario parameters and the summary results for the project. (If this is the case, DSM will also give the user the option of having only the listing of the scenario and a brief summary table of results in the final year go to the output file.) Also, if option 7 has been chosen to record annual data in the files for later input to a plotting program (see option 7 for further details), the chosen variables will be written out for each year of the simulation. In any case, DSM will request at what detail the results should be displayed on the user's terminal (note that the detail specified here will not affect what is sent to any output files that may be open).

Either of three choices may be made by typing the associated number:

1. Will print out only the summary results over the project lifetime, including initial capital investment, discounted average cost, and payback period.

2. Will print out an annual summary of the project for each year of the evaluation, including average costs, as well as the final summary as in 1.

3. Will print out detailed results of the scenario for each year of the evaluation, including each cost component and certain demand and operation statistics; a final summary of the project is also printed.

Option 3. Option 3 permits detailed resource, demand, and financial characteristics and simulation results generated by the model to be recorded for every year of the simulation in order to be printed later at the line printer. DEC-10 file names must be in the following format: 6 letters, period, 3-letter extension; e.g. ATLNTC.WDT. No blanks or special characters may be used in the file name. If the user simply presses the RETURN key without specifying a file name, data for the runs will not be stored for a hardcopy (if a file had been previously specified, this closes it).

Option 4. Option 4 allows the user to specify a descriptive title for the run that will be displayed on the terminal during output displays and will be recorded on the printout file if output has been requested. To replace an existing title, the option is simply called again, and the new title is typed in. To erase an existing title and replace it with nothing, simply press RETURN in response to this option's request for a title. (Note that this title is saved when a scenario is saved using option 5.)

Option 5. Option 5 permits use of a previously defined scenario. The user may want to return to the standard default scenario (the one existing when the session was started). Alternatively, the user may have his own default or standard scenario to capture a particular application or projected configuration. DSM handles this by saving such scenarios in a separate "scenario file".

Note that this type of file is distinct from other files mentioned in other program operating options. The user creates such a standard file by first changing all relevant resource, demand, and financial options (and a title if desired) in DSM, then choosing option 5 and using its suboption to specify a file name (using standard DEC-10 conventions as described above) to store the scenario. Once such a file has been specified, it is stored permanently and can be recalled at future sessions by selecting the relevant suboption of option 5. It is important to remember that this scenario (as stored) is not readable by eye and cannot be printed. To determine the contents of a scenario file, it should be recalled by using this option and its scenario listed by option 1 or by using the printout option 2 for a sample simulation run of the scenario. This scenario file is not to be confused with the printout file of option 2, and must have a unique file name, otherwise it is possible for the user to inadvertently destroy the file.

Option 6. When the user calls this option, the results of the last year of the last run simulation that was run will be displayed on the user's terminal. Note that a scenario is only run when option 2 has been executed. Even though the user may have changed some parameters, these will not be involved in the simulation until option 2 has been run.

Option 7. Option 7 allows the user to generate time series data from a simulation of a DSM scenario and record it in auxiliary files for later use in the Tektronix plotting program Plot-10 Easy Graphics, called EZPLOT on the Johns Hopkins computer.[8] A 4-character file name must be specified for each variable to be recorded by the program (press RETURN to skip a variable). These files then remain open so that the next time option 2 (a scenario run) is executed, the pertinent data are recorded in these specified files for each year of the simulation. The files are then closed; to record time series of several different runs, this option must be chosen each time in order to specify a new set of auxiliary files. Upon exiting the program, EZPLOT can then access the files, each containing one variable, using its "ATTACH" command. Thus, with this facility, illustrative displays of selected

---

[8]Note to programmers: this option is self-contained in a subroutine. The subroutine could be replaced by one that, for example, tabulates all selected variables for each year in a format suitable for presentation.

resource, demand, and financial conditions simulated by the program can be created. It is important to note that when such graphs are desired, the user will generally want to run the simulation at intervals of one year in order to record every data point.

Option 9. Option 9 will end execution of the program, including closing all open files, and will return the user to monitor mode, where he must print out any relevant files and log off from the system.

RESOURCE CONDITION OPTIONS

Option 10. Specify the number of production wells in the system.

Option 11. Specify the average depth of production wells (in feet).

Option 12. Specify the temperature of the geothermal water at the wellhead (in degrees Fahrenheit).

Option 13. Specify the reject temperature of the system (in degrees Fahrenheit). Note that this value must be less than the temperature at the wellhead.

Option 14. Specify the average depth of reinjection wells (in feet).

Option 15. Specify the number of reinjection wells.

Option 16. Specify the function[9] to approximate expected annual drawdown as linear, logarithmic, or annual compounded rate of increase.

[9]Often, the necessary resource parameters are lacking. This function would enable the user to study the sensitivity of the results to the resource assumptions. For cases where local aquifer parameters are better known, BIGMAC (Ref. 3) can be used. BIGMAC is a refinement of the DSM model that incorporates aquifer hydrologic characteristics to determine geothermal well drawdown and pumping energy requirements for a given prespecified demand. A user manual of this program is in preparation.

Option 17. Specify the total length of the transmission system between wellhead(s) and distribution system (in miles).

DEMAND CONDITION OPTIONS

Option 18. Option 18 allows the user to specify the location of the area being modeled. Associated with this area is the ambient air temperature distribution, which is used to determine the demand for space heating by the consumers served by the geothermal heating system. This "hourly weather data" is already incorporated into DSM for Atlantic City, NJ, Salisbury, MD, and Norfolk, VA. If the user wishes to run DSM for any of these areas, or for areas with similar temperature distributions, he should choose the relevant city from among the three, and DSM will then request the next input option.

If the user desires to model another location for the installation of a geothermal system, he should select the area chosen by the user (hourly weather data must then be input). The hourly weather data are the number of hours during a year in which the temperature falls within a 5°F range. DSM requires the hourly weather data for 20 5°F intervals, from [-30 to -26°F] to [+65 to +69°F]. If the user is simulating a geothermal system for a particular area for the first time, the chances are that the weather data for that area have not yet been used in either the DSM or GRITS programs. Therefore, the user must specify that the data will be entered from the TERMINAL, in response to DSM's query. Since entering the data from the terminal is a somewhat tedious process, DSM will save the data in a "weather data file," so that the user can later recall the data directly from the file in future runs without retyping the entries from the keyboard. In this way, a library of weather data for all locations of interest can be constructed for later use. In response to DSM's request for the name of the file in which the weather data will be stored, the user must enter a file name conforming to the standard DEC-10 file naming conventions of six letters followed by a period followed by three letters. Once all the data are entered from the terminal, a permanent record of the data exists. The data can be called in future runs of the model by specifying FILE instead of TERMINAL when choosing option 18, and then indicating the weather data file name declared previously, when it is requested by DSM.

Option 19. Option 19 specifies the design temperature of the system. The design temperature is that ambient air temperature above which geothermal energy supplies all heating requirements. (Any portion of demand not capable of being supplied by geothermal will be met by the fossil fuel boiler.) The design temperature must be below 65°F.

Option 20. Option 20 requests the total commercial floor area to be heated (in thousands of square feet).

Option 21. The user specifies two rates of heating demand for the commercial floor space. Space heating demand is requested in Btu's per square foot per degree-day, typically a value between 8 and 14. Sanitary hot water heating demand is entered as Btu's per square foot per day.

Option 22. Option 22 allows the user to enter the total cost to retrofit all buildings (in dollars). Note that entries as a general rule cannot include commas, so a retrofit fit cost of $250 thousand would have to be entered into the computer as 250000.

FINANCIAL CONDITION OPTIONS

Option 23. In option 23, the user can declare the length of the period during which all capital costs are amortized, which is assumed to be equal to the project evaluation (i.e., the study) period). The simulation model runs over this span of years at intervals also specified in this option. By selecting an interval of 1 year and a lifetime of 20 years, the next run of DSM's simulation would iterate calculations for each of 20 years, from year 0 to year 19 inclusive. If an interval greater than 1 is specified, for example, at the default of 5 years, then detailed calculations will be made for years 0, 5, 10, 15, and (in all cases) the final year, year 19. These detailed calculations will be recorded in any output files that were opened using options 3 or 7, and/or on the terminal if the request for execution (option 2) chose that detailed results be printed at the terminal. Calculations for discounted average cost and the payback period are made for intermediate years (i.e., those years not simulated) by a linear interpolation, so that to assure full accuracy in determining these values, annual calculations (interval=1 year) should be chosen. On the other hand, for exploratory analysis, simulations using greater increments (and therefore requiring fewer iterations by the model) may provide sufficient accuracy (and less voluminous computer printout if it is requested).

The study period cannot be greater than 30 years.

Option 24. Option 24 allows the specification of a resource assessment period at the beginning of the project. The number of years and the annual cost in thousands of dollars specified here defines the period before system construction begins. It includes such costs as exploration, feasibility studies, and so forth.

The resource assessment period is considered part of the financial lifetime of the project (for example, if a project is specified in option 23 as having a life of 20 years and in option 24 is declared to have a one year resource assessment phase, then year zero consists solely of the resource assessment phase, while the remaining 19 years, 1 to 19 represent the actual operational geothermal system in place).

Option 25. Because of factors unique to a particular location, the equation internal to DSM that estimates well cost may be adjusted by the user if he is better able to estimate the cost of a well. This option shows the user the estimated total cost of all production and reinjection wells and allows him to adjust the estimate by a scalar factor. (To leave the basic estimate of DSM unchanged, a factor of 1 should be typed.) If the factor is adjusted, the new well cost is printed and can be adjusted again or left unchanged. As with all DSM options, once a value has been changed by the user, it remains at that new value until changed again, so a well cost adjustment factor changed for one scenario will carry over into subsequent ones unless changed.

Option 26. The storage tank is designed according to the hours of flow from the wells that it can hold in reserve. For instance, if a user specifies that the storage tank should be able to hold 2 hours of flow, and the total flow from the wells is 100 gal/min, the tank will be sized to a capacity of 12,000 gallons, since 100 gal/min is equivalent to 6000 gal/h.

Option 27. The annual discount rate (in percent) is input in this option. It reflects time preference only. (For a fuller explanation of the discount rate as used in this series of programs, see Ref. 2.)

Option 28. The annual interest rate (in percent) is input in this option. (For a fuller explanation of the interest rate as used in this series of programs, see Ref. 2.)

Option 29. The simulation may be run in either real (constant) or nominal (current) dollars. The base year of dollar values is indicated when DSM is run. This option allows the user to choose whether values are to be reported in real or nominal dollars, and what inflation rate is to be used.

If real dollar calculations are to be performed (the default), the cost and price values reported are in constant dollars, and the only effect of the inflation rate is to decrease real costs of delayed capital investments.

If nominal dollar calculations are to be performed, the cost and price values reported are in current dollars, and the effect of the inflation rate is to increase the nominal dollar value of future costs and prices.

It is important to note that electricity and fossil fuel prices (options 31 and 32) are assumed to be in whatever (real or nominal) prices are specified by option 29, so if a previous scenario declared the energy prices as real (the default) and option 29 was then changed to nominal dollars, it is the user's responsibility to change the energy prices to nominal (current) dollars, and vice versa. (For a fuller explanation of real versus nominal dollars and the inflation rate as used in this series of programs, see Ref. 2.)

Option 30. The option for taxes is not yet implemented.

Option 31. The cost of electricity is input (in real or nominal dollars, whatever was specified in option 29) in cents per killowatt-hour. The initial value in year zero is entered first. DSM then requests the annual (compounded) percentage increase expected.

Option 32. The cost of fossil fuel is used by DSM to determine the costs of operating the peaking boiler and to determine the payback period of the geothermal system. The fossil fuel cost is input (in real or nominal dollars, whatever was specified in option 29) in dollars per million Btu. The initial value in year zero is entered first. DSM then requests the annual (compounded) percentage increase expected.

Option 33. The cost of operation and maintenance of the capital equipment of the system is determined as a fixed fraction of original capital cost. The user inputs the operation and maintenance cost fraction as a percentage.

5. SUMMARY

The DSM model is a flexible tool for the study of the economics of direct application of geothermal energy. The large number of options allow examination of a wide range of relationships. Once the user becomes familiar with the model's operation and selects the desired basecase parameter values, extensive sensitivity analysis may be conducted easily and inexpensively.

The insights gained in developing the DSM model have proven analytically valuable. For this reason, its unique features are presently being incorporated into the larger GRITS program to permit more detail and useful analyses.

Persons interested in using the program should contact the authors through The Johns Hopkins University Applied Physics Laboratory or the Center for Metropolitan Planning and Research.

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APPENDIX A

OPTIONS IN DSM

Program Operating Commands

H This help routine
1. Type out the current scenario parameters
2. Run the current scenario
3. Specify a file to record run in detail
4. Specify scenario title
5. Specify, or return to, a default scenario
6. Reprint results of the most recent run of DSM
7. Record data in output files for later graphing
8. (Not used)
9. End execution of DSM

Resource Condition Options

10. Number of wells
11. Average production well depth
12. Temperature of water at wellhead
13. Reject temperature
14. Average reinjection well depth
15. Number of reinjection wells
16. Average annual drawdown per well
17. Length of transport system

Demand Condition Options

18. Heating load (location of demand site)
19. Design temperature
20. Floor area of buildings
21. Heating requirements of buildings
22. Retrofit cost for buildings

Financial Condition Options

23. Length of evaluation period
24. Resource assessment period and cost
25. Well cost modification
26. Storage tank sizing
27. Discount rate
28. Interest rate
29. Real/nominal dollars and inflation rate
30. Taxes (not implemented)
31. Cost of electricity
32. Cost of fossil fuel for peaking boiler and payback
33. Cost of operation and maintenance

APPENDIX B

SAMPLE DSM OUTPUT

DSM: DEMAND-SPECIFIED MODEL FOR DIRECT APPLICATIONS OF GEOTHERMAL ENERGY
CENTER FOR METROPOLITAN PLANNING & RESEARCH, THE JOHNS HOPKINS UNIVERSITY

DSM SAMPLE OUTPUT--DEFAULT SCENARIO

```
              DSM SAMPLE OUTPUT--DEFAULT SCENARIO
            (BASE PERIOD FOR COSTS IS SPRING, 1980)

                     SCENARIO PARAMETERS

PROGRAM OPERATING CONDITIONS
-----------------------------
#  3   OUTPUT FILE NAME:                           DSM.SMP
#  4   TITLE OF SCENARIO:  (DISPLAYED ABOVE, IF ANY)
#  7   DATA FILES WILL NOT BE GENERATED.

RESOURCE CONDITION PARAMETERS
-----------------------------
# 10   NUMBER OF PRODUCTION WELLS:                       1
# 11   DEPTH OF UPWELL (FEET):                       5000.
# 12   WELLHEAD WATER TEMP.(DEG. FAHR.)
          CONSTANT FUNCTION USED WITH:
          CONSTANT WATER TEMP.=     130.0
# 13   REJECT TEMPERATURE (DEG.FAHR.):                85.0
# 14   DEPTH OF REINJECTION WELL (FEET):             5000.
# 15   NUMBER OF REINJECTION WELLS:                      1
# 16   DRAWDOWN OF UPWELL (PERCENT)
          LINEAR FUNCTION USED WITH:
          INITIAL DRAWDOWN= 20.00
          ANNUAL CHANGE=     0.00
# 17   TRANSPORT DISTANCE (MILES)  :                  0.25

DEMAND CONDITION PARAMETERS
-----------------------------
# 18   AREA UNDER CONSIDERATION:      SALISBURY,MD
# 19   SYSTEM DESIGN TEMP.(DEG. FAHR.):                 30
# 20   TOTAL FLOOR AREA(THOUSAND SQ FT):            50.000
# 21   AVG HEAT DEMAND(BTU/SQ.FT./DEG-DAY):           9.00
       AVG HOT WATER DEMAND(BTU/SQFT/DAY):            0.00
# 22   RETROFIT COST(THOUSANDS): $                  30.000
```

FINANCIAL CONDITION PARAMETERS

```
# 23    STUDY PERIOD: 20 YEARS; INTERVALS OF  5 YRS
# 24    RESOURCE ASSESSMENT PERIOD (YEARS):  0
        ANNUAL RESOURCE ASSESSMENT COST: $          0. THOUSAND
# 25    WELL COST ADJUSTMENT FACTOR:            1.000
        ADJ. TOTAL COST OF WELLS ($THOUS): 329.159
# 26    STORAGE TANK CAPACITY:   1.0 HOURS OF FLOW
# 27    DISCOUNT RATE (PERCENT):                 2.00
# 28    INTEREST RATE (PERCENT):                14.00
# 29    COST CALCULATIONS ARE IN REAL DOLLARS
        INFLATION RATE (PERCENT):                9.00
# 30    TAXES:
# 31    COST OF ELECTRICITY (CTS/KWH)
           COMPOUNDING FUNCTION USED WITH:
           1-INITIAL ELEC. PRICE=     5.50
           2-PERCENT ANNUAL CHANGE=  1.50
# 32    FOSSIL FUEL COST ($/MIL. BTU)
           COMPOUNDING FUNCTION USED WITH:
           INITIAL FOSS. FUEL PRICE=   6.000
           PERCENT ANNUAL CHANGE=      3.500
# 33    OPER. & MAINT. COST (% OF CAPITAL):    1.00%
```

* * COST OF INITIAL CAPITAL EQUIPMENT * *

WELLS:	$	329.159	THOUSAND
HEAT EXCHANGERS:	$	5.029	THOUSAND
PUMPS:	$	9.697	THOUSAND
RETROFIT:	$	30.000	THOUSAND
PEAKING BOILER:	$	8.438	THOUSAND
TRANSPORT SYSTEM:	$	76.662	THOUSAND
STORAGE TANK:	$	52.934	THOUSAND
* TOTAL *	$	511.918	THOUSAND

SCENARIO IN YEAR 0

OPTION		VALUE
RESOURCE CONDITIONS		
10	NUMBER OF PRODUCTION WELLS:	1
11	DEPTH OF UPWELL (FEET):	5000.
12	WELLHEAD WATER TEMP.(DEG. FAHR.):	130.0
13	REJECT TEMPERATURE (DEG.FAHR.):	85.0
14	DEPTH OF REINJECTION WELL (FEET):	5000.
15	NUMBER OF REINJECTION WELLS:	1
16	DRAWDOWN OF UPWELL (PERCENT):	20.00
17	TRANSPORT DISTANCE (MILES):	0.250
DEMAND CONDITIONS		
18	AREA UNDER CONSIDERATION:	SALISBURY,MD
19	SYSTEM DESIGN TEMP.(DEG. FAHR.):	30
20	FLOORSPACE ON LINE (THOU.SQ FT):	50.000
21	BTU/SQFT/DAY- SP.HT: 9.0/DEG; H2O HT:	0.0
22	RETROFIT COST: $	30000.
FINANCIAL CONDITIONS		
23	STUDY PERIOD: 20 YRS; INTERVALS OF 5 YRS	
24	RESOURCE ASSESSMENT: 0 YRS @ $THOU	0./YR
25	WELL COST ADJUSTMENT FACTOR:	1.000
26	STORAGE TANK CAPACITY (GALLONS):	1750.
27	DISCOUNT RATE (IN PERCENT):	2.00
28	INTEREST RATE (PERCENT):	14.00
29	REAL/NOMINAL$:R; INFLATION RATE(%):	9.00
30	TAXES:	
31	COST OF ELECTRICITY (CTS/KWH):	5.500
32	FOSSIL FUEL COST ($/MIL. BTU):	6.00
33	OPER. & MAINT. COST (% OF CAPITAL):	1.00%

RESULTS OF MODEL FOR YEAR 0

FLOW FROM EACH WELL (GAL. PER MIN.):		29.17
TOTAL GEOTHERMAL BTU'S (MILLIONS):		1817.67
TOTAL SYSTEM BTU'S (MILLIONS):		1880.18
COEFFICIENT OF PERFORMANCE:		8.742
PERCENTAGE GEOTHERMAL UTILIZATION:		31.62
PERCENTAGE SERVICE GEOTHERMAL:		96.68
PUMPING ENERGY:		0.061 MILLION KWH
ANNUALIZED COSTS		(THOUSANDS OF DOLLARS)
WELL COSTS:	49.698	
HEAT EXCHANGER COSTS:	0.964	
ORIGINAL PUMP COSTS:	1.859	
RETROFIT COSTS:	4.530	
PUMP OVERHAUL COSTS:	0.811	
PUMPING COSTS:	3.352	
PEAKING BOILER COSTS:	1.274	
FOSSIL FUEL COSTS:	0.499	
TRANSPORT COST:	11.575	
STORAGE TANK COST:	7.992	
OPERATION AND MAINTENANCE COSTS:	5.119	
RESOURCE ASSESSMENT COSTS:	0.000	
TOTAL ANNUAL WELLHEAD COSTS:	59.230	
TOTAL ANNUAL SYSTEM COSTS:	87.673	
WELLHEAD COST PER GEO MIL. BTU($):	32.59	
SYSTEM COST PER MIL. BTU($):	46.63	
NET ANNUAL PAYBACK($ THOUSANDS):	6.034	
TOTAL PAYBACK SO FAR ($ THOU.):	6.034	

*(BASE PERIOD FOR COSTS IS SPRING, 1980)

SCENARIO IN YEAR 5

OPTION		VALUE
RESOURCE CONDITIONS		
10	NUMBER OF PRODUCTION WELLS:	1
11	DEPTH OF UPWELL (FEET):	5000.
12	WELLHEAD WATER TEMP.(DEG. FAHR.):	130.0
13	REJECT TEMPERATURE (DEG.FAHR.):	85.0
14	DEPTH OF REINJECTION WELL (FEET):	5000.
15	NUMBER OF REINJECTION WELLS:	1
16	DRAWDOWN OF UPWELL (PERCENT):	20.00
17	TRANSPORT DISTANCE (MILES):	0.250
DEMAND CONDITIONS		
18	AREA UNDER CONSIDERATION:	SALISBURY,MD
19	SYSTEM DESIGN TEMP.(DEG. FAHR.):	30
20	FLOORSPACE ON LINE (THOU.SQ FT):	50.000
21	BTU/SQFT/DAY- SP.HT: 9.0/DEG; H2O HT:	0.0
22	RETROFIT COST: $	30000.
FINANCIAL CONDITIONS		
23	STUDY PERIOD: 20 YRS; INTERVALS OF	5 YRS
24	RESOURCE ASSESSMENT: 0 YRS @ $THOU	0./YR
25	WELL COST ADJUSTMENT FACTOR:	1.000
26	STORAGE TANK CAPACITY (GALLONS):	1750.
27	DISCOUNT RATE (IN PERCENT):	2.00
28	INTEREST RATE (PERCENT):	14.00
29	REAL/NOMINAL$:R; INFLATION RATE(%):	9.00
30	TAXES:	
31	COST OF ELECTRICITY (CTS/KWH):	5.925
32	FOSSIL FUEL COST ($/MIL. BTU):	7.13
33	OPER. & MAINT. COST (% OF CAPITAL):	1.00%

RESULTS OF MODEL FOR YEAR 5

FLOW FROM EACH WELL (GAL. PER MIN.):	29.17
TOTAL GEOTHERMAL BTU'S (MILLIONS):	1817.67
TOTAL SYSTEM BTU'S (MILLIONS):	1880.18
COEFFICIENT OF PERFORMANCE:	8.742
PERCENTAGE GEOTHERMAL UTILIZATION:	31.62
PERCENTAGE SERVICE GEOTHERMAL:	96.68
PUMPING ENERGY:	0.061 MILLION KWH
ANNUALIZED COSTS	(THOUSANDS OF DOLLARS)
WELL COSTS:	32.301
HEAT EXCHANGER COSTS:	0.627
ORIGINAL PUMP COSTS:	1.208
RETROFIT COSTS:	2.944
PUMP OVERHAUL COSTS:	0.811
PUMPING COSTS:	3.611
PEAKING BOILER COSTS:	0.828
FOSSIL FUEL COSTS:	0.592
TRANSPORT COST:	7.523
STORAGE TANK COST:	5.194
OPERATION AND MAINTENANCE COSTS:	5.119
RESOURCE ASSESSMENT COSTS:	0.000
TOTAL ANNUAL WELLHEAD COSTS:	41.220
TOTAL ANNUAL SYSTEM COSTS:	60.758
WELLHEAD COST PER GEO MIL. BTU($):	22.68
SYSTEM COST PER MIL. BTU($):	32.31
NET ANNUAL PAYBACK($ THOUSANDS):	8.497
TOTAL PAYBACK SO FAR ($ THOU.):	43.595

*(BASE PERIOD FOR COSTS IS SPRING, 1980)

SCENARIO IN YEAR 10

OPTION		VALUE
RESOURCE CONDITIONS		
10	NUMBER OF PRODUCTION WELLS:	1
11	DEPTH OF UPWELL (FEET):	5000.
12	WELLHEAD WATER TEMP.(DEG. FAHR.):	130.0
13	REJECT TEMPERATURE (DEG.FAHR.):	85.0
14	DEPTH OF REINJECTION WELL (FEET):	5000.
15	NUMBER OF REINJECTION WELLS:	1
16	DRAWDOWN OF UPWELL (PERCENT):	20.00
17	TRANSPORT DISTANCE (MILES):	0.250
DEMAND CONDITIONS		
18	AREA UNDER CONSIDERATION:	SALISBURY,MD
19	SYSTEM DESIGN TEMP.(DEG. FAHR.):	30
20	FLOORSPACE ON LINE (THOU.SQ FT):	50.000
21	BTU/SQFT/DAY- SP.HT: 9.0/DEG; H20 HT:	0.0
22	RETROFIT COST: $	30000.
FINANCIAL CONDITIONS		
23	STUDY PERIOD: 20 YRS; INTERVALS OF	5 YRS
24	RESOURCE ASSESSMENT: 0 YRS @ $THOU	0./YR
25	WELL COST ADJUSTMENT FACTOR:	1.000
26	STORAGE TANK CAPACITY (GALLONS):	1750.
27	DISCOUNT RATE (IN PERCENT):	2.00
28	INTEREST RATE (PERCENT):	14.00
29	REAL/NOMINAL$:R; INFLATION RATE(%):	9.00
30	TAXES:	
31	COST OF ELECTRICITY (CTS/KWH):	6.383
32	FOSSIL FUEL COST ($/MIL. BTU):	8.46
33	OPER. & MAINT. COST (% OF CAPITAL):	1.00%

RESULTS OF MODEL FOR YEAR 10

FLOW FROM EACH WELL (GAL. PER MIN.):	29.17
TOTAL GEOTHERMAL BTU'S (MILLIONS):	1817.67
TOTAL SYSTEM BTU'S (MILLIONS):	1880.18
COEFFICIENT OF PERFORMANCE:	8.742
PERCENTAGE GEOTHERMAL UTILIZATION:	31.62
PERCENTAGE SERVICE GEOTHERMAL:	96.68
PUMPING ENERGY:	0.061 MILLION KWH
ANNUALIZED COSTS	(THOUSANDS OF DOLLARS)
. WELL COSTS:	20.993
HEAT EXCHANGER COSTS:	0.964
ORIGINAL PUMP COSTS:	1.859
RETROFIT COSTS:	1.913
PUMP OVERHAUL COSTS:	0.811
PUMPING COSTS:	3.890
PEAKING BOILER COSTS:	0.538
FOSSIL FUEL COSTS:	0.704
TRANSPORT COST:	4.889
STORAGE TANK COST:	3.376
OPERATION AND MAINTENANCE COSTS:	5.119
RESOURCE ASSESSMENT COSTS:	0.000
TOTAL ANNUAL WELLHEAD COSTS:	30.994
TOTAL ANNUAL SYSTEM COSTS:	45.056
WELLHEAD COST PER GEO MIL. BTU($):	17.05
SYSTEM COST PER MIL. BTU($):	23.96
NET ANNUAL PAYBACK($ THOUSANDS):	11.452
TOTAL PAYBACK SO FAR ($ THOU.):	94.945

*(BASE PERIOD FOR COSTS IS SPRING, 1980)

SCENARIO IN YEAR 15

OPTION		VALUE
RESOURCE CONDITIONS		
10	NUMBER OF PRODUCTION WELLS:	1
11	DEPTH OF UPWELL (FEET):	5000.
12	WELLHEAD WATER TEMP.(DEG. FAHR.):	130.0
13	REJECT TEMPERATURE (DEG.FAHR.):	85.0
14	DEPTH OF REINJECTION WELL (FEET):	5000.
15	NUMBER OF REINJECTION WELLS:	1
16	DRAWDOWN OF UPWELL (PERCENT):	20.00
17	TRANSPORT DISTANCE (MILES):	0.250
DEMAND CONDITIONS		
18	AREA UNDER CONSIDERATION:	SALISBURY,MD
19	SYSTEM DESIGN TEMP.(DEG. FAHR.):	30
20	FLOORSPACE ON LINE (THOU.SQ FT):	50.000
21	BTU/SQFT/DAY- SP.HT: 9.0/DEG; H20 HT:	0.0
22	RETROFIT COST: $	30000.
FINANCIAL CONDITIONS		
23	STUDY PERIOD: 20 YRS; INTERVALS OF	5 YRS
24	RESOURCE ASSESSMENT: 0 YRS @ $THOU	0./YR
25	WELL COST ADJUSTMENT FACTOR:	1.000
26	STORAGE TANK CAPACITY (GALLONS):	1750.
27	DISCOUNT RATE (IN PERCENT):	2.00
28	INTEREST RATE (PERCENT):	14.00
29	REAL/NOMINAL$:R; INFLATION RATE(%):	9.00
30	TAXES:	
31	COST OF ELECTRICITY (CTS/KWH):	6.876
32	FOSSIL FUEL COST ($/MIL. BTU):	10.05
33	OPER. & MAINT. COST (% OF CAPITAL):	1.00%

RESULTS OF MODEL FOR YEAR 15

FLOW FROM EACH WELL (GAL. PER MIN.):	29.17
TOTAL GEOTHERMAL BTU'S (MILLIONS):	1817.67
TOTAL SYSTEM BTU'S (MILLIONS):	1880.18
COEFFICIENT OF PERFORMANCE:	8.742
PERCENTAGE GEOTHERMAL UTILIZATION:	31.62
PERCENTAGE SERVICE GEOTHERMAL:	96.68
PUMPING ENERGY:	0.061 MILLION KWH
ANNUALIZED COSTS	(THOUSANDS OF DOLLARS)
WELL COSTS:	13.644
HEAT EXCHANGER COSTS:	0.627
ORIGINAL PUMP COSTS:	1.208
RETROFIT COSTS:	1.244
PUMP OVERHAUL COSTS:	0.811
PUMPING COSTS:	4.190
PEAKING BOILER COSTS:	0.350
FOSSIL FUEL COSTS:	0.836
TRANSPORT COST:	3.178
STORAGE TANK COST:	2.194
OPERATION AND MAINTENANCE COSTS:	5.119
RESOURCE ASSESSMENT COSTS:	0.000
TOTAL ANNUAL WELLHEAD COSTS:	23.069
TOTAL ANNUAL SYSTEM COSTS:	33.400
WELLHEAD COST PER GEO MIL. BTU($):	12.69
SYSTEM COST PER MIL. BTU($):	17.76
NET ANNUAL PAYBACK($ THOUSANDS):	14.991
TOTAL PAYBACK SO FAR ($ THOU.):	162.822

*(BASE PERIOD FOR COSTS IS SPRING, 1980)

SCENARIO IN YEAR 19

OPTION		VALUE
RESOURCE CONDITIONS		
10	NUMBER OF PRODUCTION WELLS:	1
11	DEPTH OF UPWELL (FEET):	5000.
12	WELLHEAD WATER TEMP.(DEG. FAHR.):	130.0
13	REJECT TEMPERATURE (DEG.FAHR.):	85.0
14	DEPTH OF REINJECTION WELL (FEET):	5000.
15	NUMBER OF REINJECTION WELLS:	1
16	DRAWDOWN OF UPWELL (PERCENT):	20.00
17	TRANSPORT DISTANCE (MILES):	0.250
DEMAND CONDITIONS		
18	AREA UNDER CONSIDERATION:	SALISBURY,MD
19	SYSTEM DESIGN TEMP.(DEG. FAHR.):	30
20	FLOORSPACE ON LINE (THOU.SQ FT):	50.000
21	BTU/SQFT/DAY- SP.HT: 9.0/DEG; H20 HT:	0.0
22	RETROFIT COST: $	30000.
FINANCIAL CONDITIONS		
23	STUDY PERIOD: 20 YRS; INTERVALS OF	5 YRS
24	RESOURCE ASSESSMENT: 0 YRS @ $THOU	0./YR
25	WELL COST ADJUSTMENT FACTOR:	1.000
26	STORAGE TANK CAPACITY (GALLONS):	1750.
27	DISCOUNT RATE (IN PERCENT):	2.00
28	INTEREST RATE (PERCENT):	14.00
29	REAL/NOMINAL$:R; INFLATION RATE(%):	9.00
30	TAXES:	
31	COST OF ELECTRICITY (CTS/KWH):	7.298
32	FOSSIL FUEL COST ($/MIL. BTU):	11.54
33	OPER. & MAINT. COST (% OF CAPITAL):	1.00%

RESULTS OF MODEL FOR YEAR 19

FLOW FROM EACH WELL (GAL. PER MIN.):	29.17
TOTAL GEOTHERMAL BTU'S (MILLIONS):	1817.67
TOTAL SYSTEM BTU'S (MILLIONS):	1880.18
COEFFICIENT OF PERFORMANCE:	8.742
PERCENTAGE GEOTHERMAL UTILIZATION:	31.62
PERCENTAGE SERVICE GEOTHERMAL:	96.68
PUMPING ENERGY:	0.061 MILLION KWH
ANNUALIZED COSTS	(THOUSANDS OF DOLLARS)
WELL COSTS:	9.666
HEAT EXCHANGER COSTS:	0.444
ORIGINAL PUMP COSTS:	0.856
RETROFIT COSTS:	0.881
PUMP OVERHAUL COSTS:	0.811
PUMPING COSTS:	4.448
PEAKING BOILER COSTS:	0.248
FOSSIL FUEL COSTS:	0.959
TRANSPORT COST:	2.251
STORAGE TANK COST:	1.554
OPERATION AND MAINTENANCE COSTS:	5.119
RESOURCE ASSESSMENT COSTS:	0.000
TOTAL ANNUAL WELLHEAD COSTS:	18.861
TOTAL ANNUAL SYSTEM COSTS:	27.236
WELLHEAD COST PER GEO MIL. BTU($):	10.38
SYSTEM COST PER MIL. BTU($):	14.49
NET ANNUAL PAYBACK($ THOUSANDS):	18.319
TOTAL PAYBACK SO FAR ($ THOU.):	231.107

*** INITIAL CAPITAL COST: 511.918 THOUSAND DOLLARS ***
*** DISCOUNTED AVERAGE COST: 27.958 DOLLARS/MILLION BTU ***
*** DISC. AVG WELLHEAD COST: 19.721 DOLLARS/MILLION BTU ***
*** TOTAL NET PAYBACK: 231.107 THOUSAND DOLLARS ***
*** PAYBACK PERIOD NOT ACHIEVED ***

*(BASE PERIOD FOR COSTS IS SPRING, 1980)