RESERVOIR ENGINEERING MANAGEMENT PROGRAM

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The Reservoir Engineering Management Program being conducted at Lawrence Berkeley Laboratory includes two major tasks: 1) the continuation of support to geothermal reservoir engineering related work, started under the NSF-RANN program and transferred to ERDA at the time of its formation; 2) the development and subsequent implementation of a broad plan for support of research in topics related to the exploitation of geothermal reservoirs. This plan is now known as the GREMP plan.

The continuation of support of research to NSF-RANN contract recipients has been reasonably straightforward. All these groups were conducting research that could be related to an improved capability to exploit geothermal resources and, accordingly, all contracts were continued and are in force at this time. Included here are the contracts at institutions shown in Figure 1, which also indicates briefly the scope of work being done.

In FY '77, $515 K was spent in support of these programs. It is estimated that $400 K will be spent on these contracts in FY '78.

The "GREMP" Plan

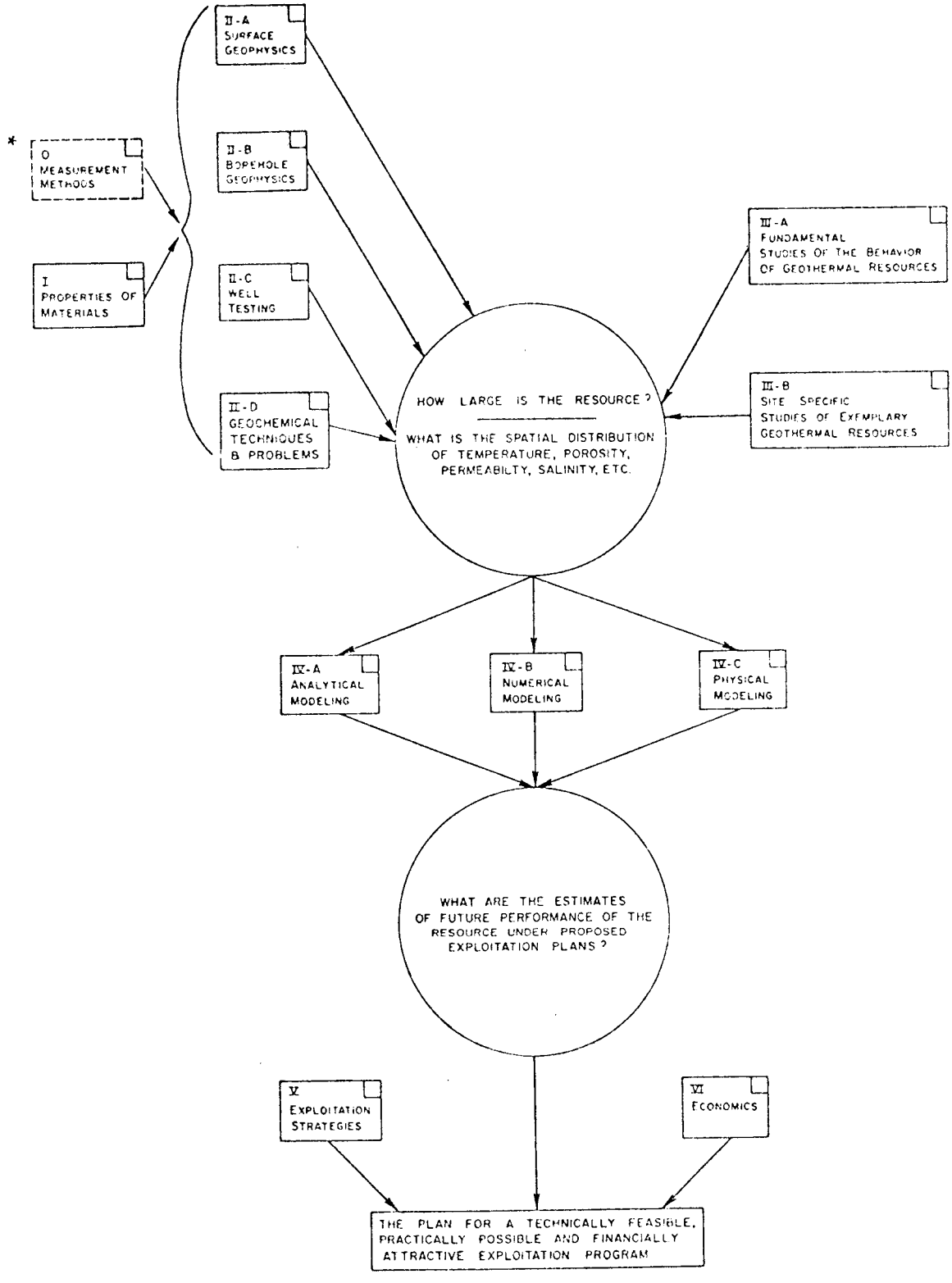
The acronym GREMP stands for "Geothermal Reservoir Engineering Management Plan" and is a misnomer. The plan addresses more than reservoir engineering and, in fact, touches on almost all technical areas involved in the exploitation of geothermal resources. The plan was deliberately made as broad as possible for several reasons: 1) in order to provide some written plan in areas for which no plan existed; 2) in order to perceive the interrelationship that exists among these technical areas, for instance physical properties of rocks and interpretive borehole geophysics; and 3) therefore, and in view of the total program and the interrelationships of the technical areas, to provide insight into how to implement the plan, e.g., what priorities should be assigned to the various tasks and what might the total cost of the program be.

Elements of GREMP

As conceived, there are 13 elements or technical areas to GREMP. These are shown in Figure 2. The elements can be grouped into seven super groups if one would want to simplify the program: 1) work related to measurement methods of use in the exploitation of geothermal resources; 2) studies of properties of materials of interest in the exploitation of geothermal resources; 3) work related to the definition, in the sense of

TITLE	CONTRACTOR
Data Compilation and Analysis From Italian Geothermal Field	Stanford-Italian
Modeling, Tracer, and Analytical Studies of Geothermal Resources	Stanford Ramey-Kruger
Wairakai Geothermal Reservoir Model	S^3
Mass and Heat Transport - Fractured Systems in Geothermal Reservoirs	Princeton
Modeling of East Mesa Geothermal Field	University of Colorado
Cerro Prieto Geothermal Modeling	UC/Riverside

Figure 1. Current NSF/RANN Legacies Contracts



*The element "Measurement Methods" is being handled outside GREMP at this time.

Figure 2. Overview of the Geothermal Reservoir Engineering Program.

describing, of reservoir characteristics; 4) studies of specific, generalized, and hypotherical geothermal resources; 5) modeling the behavior of geothermal systems; 6) exploitation strategies; and 7) economics. Details of what each of these elements involves can be found in the report entitled "Geothermal Reservoir Engineering Management Program Plan (GREMP Plan)," issued by the Lawrence Berkeley Laboratory (LBL-7000, UC-66a, TID-4500-R66, Oct. 1977). Detailing any element of the program is a difficult task, and, if described in excessive detail, one might as well have done the research. However, there is a need for some level of detail in explaining what sorts of things should be done within each element. To illustrate the detail sought for the GREMP document the element "Well Testing" will be used as an example. As shown in Figure 3, we were able to break out research projects as a subset of the elements and research tasks as a subset of the projects. Note, for example, the recognition of the need for new operational procedures to define mass flow and energy flow (i.e., power) characteristics of a reservoir and also the desire to support work in crude estimating of the capability of a well.

Another point is illustrated by Figure 2, namely that LBL and in fact DOE/DGE does not exist alone. The well testing work involving instruments will be coordinated with the programs at Sandia because of their ongoing program in instrument development and because of the innate strength of their staff in instrument development.

Interrelationship of the Elements of GREMP

Figure 2 also shows the interrelationships of the elements of GREMP and illustrates the questions that these capabilities seek to help answer. The purpose of the entire GREMP program is to establish a higher level of technical capability to exploit geothermal resources than now exist. The "bottom line" is to produce better plans than are now possible for technically feasible, practically possible, and financially attractive exploitation programs.

Of fundamental importance are the questions: How large is the resource? and, What is the spatial distribution of temperature porosity, permeability, and salinity? With answers to these questions one should be in a position to determine if the resource contains enough energy to support a power plant of given size, if the energy can be moved out to the surface of the earth where it can be converted to electricity, and if there are any special problems to anticipate. For instance, are dissolved silica and trace elements present in such amounts that scaling of surface equipment will be a problem? The elements borehole geophysics, well testing, site specific studies (as a guide to completing a picture), all contribute to the answer to these questions.

Once the "static" situation regarding a geothermal reservoir is known, emphasis changes to the question of how the reservoir will perform when produced. Various forms of modeling can be used to predict future performance. However, the exploiter of a geothermal reservoir still does not have the plan he needs inasmuch as he must also consider the economics of the exploitation venture and the various strategies for its development. Accordingly the GREMP plan calls for some support in these areas of work.

"Well Testing" - Categories, Projects and Tasks

RESEARCH CATEGORY	RESEARCH PROJECT*	RESEARCH TASK
Well Testing	1. Assess conditions in geothermal reservoirs that affect tool and analysis requirements.	
	2. Improved data gathering systems.	a. Develop improved pressure tool capable of 650°F, 0-5000 psi pressure, 0.0. accuracy, one second minimum readout interval.
		b. Develop improved temperature tool capable of 650°F, accuracy of 1°F, continuous operating up to 90 days.
		c. Develop reliable downhole flow meter for geothermal applications.
		d. Develop automated multi-well data gathering system.
		e. Develop improved calorimetry systems.
		f. Develop improved mass flow rate measuring systems, particularly for two-phase flow.
		g. Develop packing and isolation apparatus for downhole applications such as drill stem testing.
	3. Develop new testing techniques and procedures.	a. Techniques for simultaneous analysis of mass and heat movement.
		b. New techniques for crude estimates of well capability (cf. James Method).
	4. Development of interpretation and analysis methods for hydraulic well testing and for temporary completion testing.	a. Improve and extend the analytical capability for pressure and temperature analysis for uninvestigated initial, boundary, and internal conditions of the reservoir.
		b. Perfect the use of well head values instead of sand face values in analyses.
	5. Development of methods of analysis of data from passive reservoir response.	a. Analysis of earth tides.
		b. Analysis of response to microseisms.
		c. Decline curve analysis.

*All projects and tasks involving tool, hardware and material development will be coordinated with the Geothermal Logging Development Program at Sandia Laboratories, Albuquerque, NM.

Figure 3

Use of GREMP

The GREMP program was reviewed twice by members of a so-called Review Task Force consisting of members of industry, government and the academic community. This group assigned priorities to the elements of the program. These priorities are shown in Figure 4. Highest priority was assigned to well testing, then to interpretive borehole geophysics, then to geochemical techniques and problems, and so on. The responsibility to develop a plan for geothermal log interpretation has been transferred to Los Alamos Scientific Laboratory. The balance of the program is currently being implemented by LBL; however, various considerations may possibly lead to parts of the program being revised and implemented elsewhere.

In any event, implementation of the program calls for the procedure outlined in Figure 5. The key developments are: 1) writing of a request for proposal to conduct research in the subject area, and 2) receipt and review of proposals and award of contracts in such a way as to achieve greater technical capability for the geothermal community in a particular technical area.

At the present time elements 1, 3, and 4, namely well testing, geochemical techniques and problems, and properties of materials, have been announced in the Commerce Business Daily. Over 80 requests for each category have been received to date. The RFP package for well testing is being mailed to requestors this week.

Anticipated Expenditures for GREMP in FY '78

The total currently authorized budget for supporting both the continuation of the NSF-RANN research and the initiation of new projects as a consequence of GREMP is $1 M. Of this amount, an estimated $400 K will be spent on the former NSF-RANN contractors. The balance of $600 K will be spent on new projects. At one time in development of the GREMP plan we estimated if all things we thought should be done were done, the cost would run over $2 M annually, not including the NSF-RANN contractees. Based on our experience to date with groups such as the NSF-RANN contractors, in view of expressions of interest to date, and in view of what in principle we would like to achieve, we anticipate that we can effectively spend $1.5 M in FY '78. This support would go to continuation of support to NSF-RANN contractors and to support work in well testing, geochemical techniques and problems, properties of materials, numerical modeling, analytical modeling, site specific studies, and socalled fundamental studies. Probably we will not be able to initiate any work from the GREMP program in physical modeling exploitation strategy and economics this fiscal year.

Looking at the Output of the GREMP Program

A question that can be fairly asked of those responsible for a research program is "What good have you done?" In order to have a measure of the results of a research program, one must have an objective toward

TABLE OF PRIORITIES

RESERVOIR ENGINEERING MANAGEMENT PROGRAM

Priority Number		Element/Category	Priority Scale *
1	II.C.	Well testing	9.9
2	II.B.	Interpretive borehole geophysics	8.8
3	II.D.	Geochemical techniques and problems	7.6
3	I.	Properties of materials	7.6
4	IV.B.	Numerical modeling	7.4
5	III.B.	Site specific studies	6.3
6	II.A.	Fundamental studies	5.9
7	IV.A.	Analytical modeling	5.4
8	II.A.	Surface geophysics	3.9
9	IV.C.	Physical modeling	3.4
10	VI.	Economics	1.6
11	V.	Exploitation strategy	1.5

* On a scale of 0 - 10.

Figure 4.

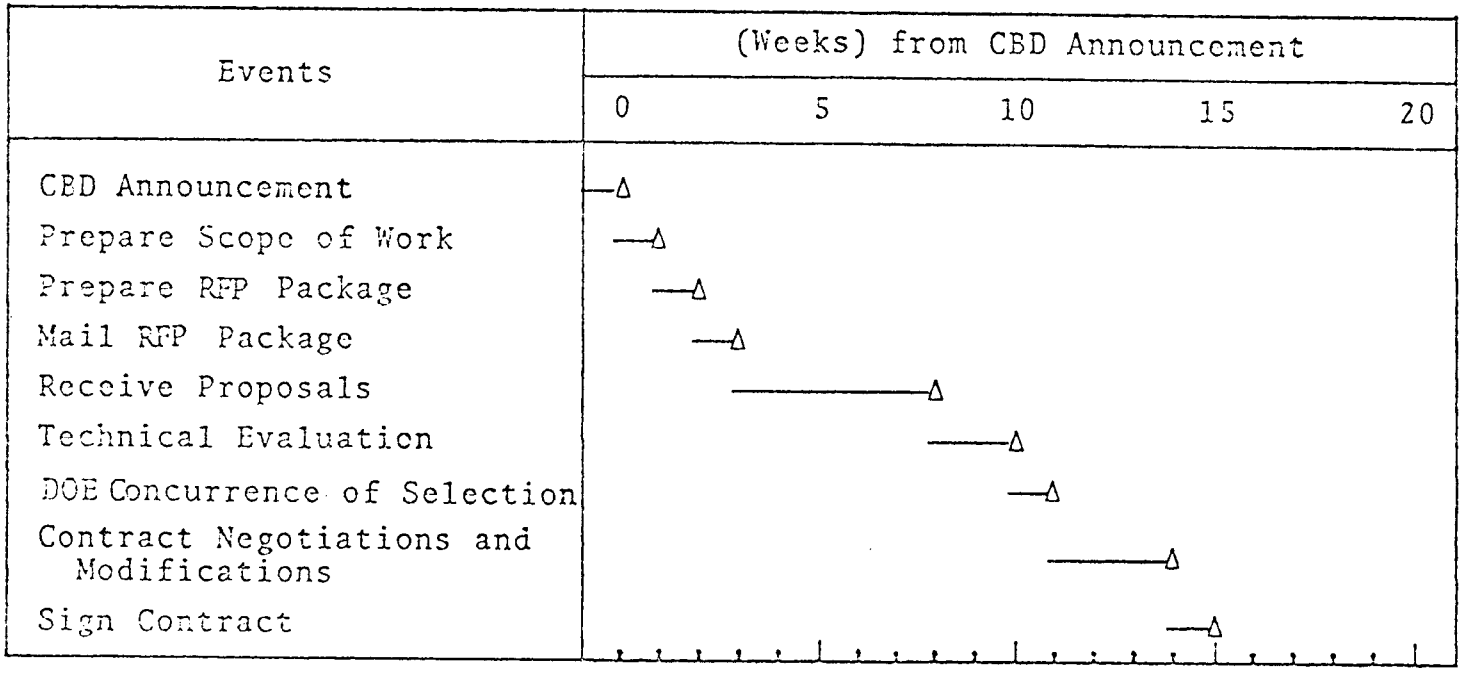


Figure 5. The competitive procurement planning schedule for GREMP.

which the research contributes. DOE/DGE has such an objective. The primary objective is to accelerate the commercial development of the nation's accessible geothermal resources.

Accordingly, research projects undertaking to solve or successfully solving or contributing to the solution of technical problems in acceleration of near-term commercialization of geothermal reservoirs should be favored. For example, work to solve the problem of successful reinjection of spent brine at a specific site should be favored through such a policy. On the other hand, many kinds of "research" are being carried out within the geothermal program; many do not meet the clearcut criteria of solving a technical impediment tomorrow. However, it is not valid to conclude that therefore this work is of no use. Research that is potentially applicable and clearly relating to the successful exploitation of geothermal resources needs to be supported, even if it is not directed at today's crisis. There are several reasons for this view. First, research done in conjunction with persons in training (usually students) broadens the education of these persons in respect to existing knowledge. In this way they are better trained to work in the geothermal industry. Second, support of basic or fundamental research invariably leads to the strengthening of the scientific basis from which technology arises. The establishment of such a scientific basis does not guarantee the development of an applicable technology but, in the hands of a practice-oriented person, can lead to the solutions needed for acceleration of commercial development. Persons with such expertise therefore turn out to be critical. Third, support for basic research usually attracts people who can generate an atmosphere of vitality and enthusiasm that is a healthy positive force for attack on both technological and scientific problems. The entropy they create is valuable and again, the use of their associated energy is focused by these alert, practice-oriented persons. Such people are critical to the success of a geothermal industry.

Conclusion and Summary

Both the NSF-RANN legacies and GREMP are in direct support of the DOE/DGE mission in general and the goals of the Resource and Technology/ Resource Exploitation and Assessment Branch in particular.

These goals are to determine the magnitude and distribution of geothermal resources and reduce risk in their exploitation through improved understanding of generically different reservoir types. These goals are to be accomplished by: 1) the creation of a large data base about geothermal reservoirs, 2) improved tools and methods for gathering data on geothermal reservoirs, and 3) modeling of reservoirs and utilization options.

The NSF legacies are more research and training oriented, and the GREMP is geared primarily to the practical development of the geothermal reservoirs.