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March 23, 1992

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DIV. OF WATER & LAND DEVELOPMENT

MEMORANDUM

TO: Members, Geothermal Technical Advisory Committee

FROM: Gerald O. Lesperance

SUBJECT: Scope of Work, DBED - GeothermEx Contract

As promised at the March 19, 1992 GEO-TAC meeting, attached is a copy of our scope of work with GeothermEx.

Gerald O Lesperance

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Attachment

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3.2 Proposed Work Plan

The general scope of work described in the Request for Proposal consists of providing assistance to DBED and DLNR for seven tasks:

1. establishing priorities for resource assessment methodologies;

2. planning the direction of the SOH program, with particular emphasis on the cost-effectiveness of various exploratory drilling methods;

3. planning appropriate well tests, surveys and mapping projects, including input on instrumentation, equipment, methods, procedures, personnel, and budgets;

4. providing technical guidance relative to the geothermal/cable project master plan and EIS;

5. providing technical guidance relative to the planning and design of the geothermal/cable project by the Consortium and HECO:

6. providing objective, scientifically supported conclusions about the extent and characteristics of geothermal resources in Hawaii for use in policy-making or investment decisions; and

7. providing geothermal well-field design and resource management expertise to avoid over-production and premature depletion of geothermal resources.

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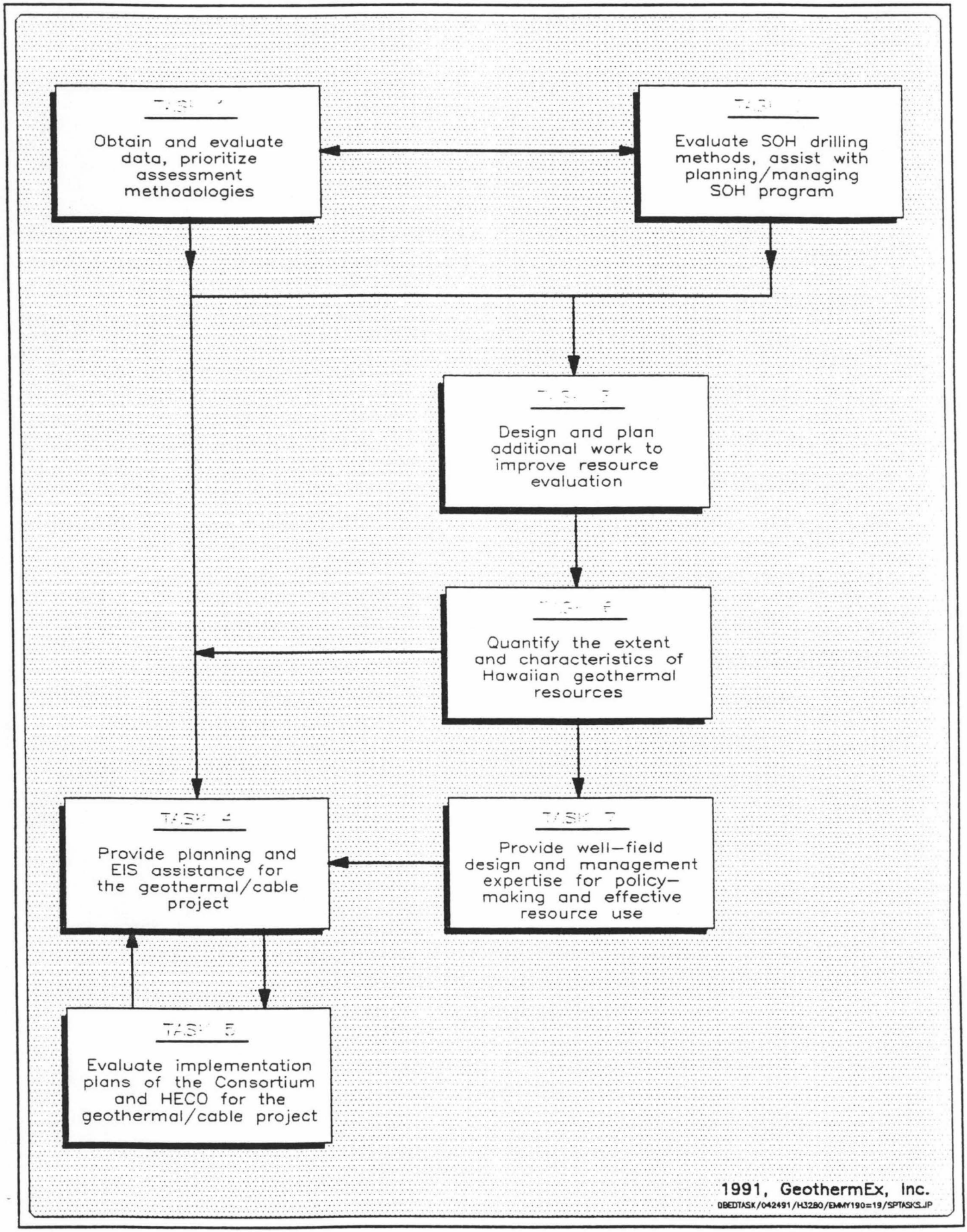
Our understanding of the relationships between these tasks is illustrated in figure 2.

Task 1 (Obtain and Evaluate Data, Prioritize Assessment Methodologies). Initially, GeothermEx proposes to rapidly and systematically review pertinent documents. This would not cover the same ground as the ENEL report, but would go forward to synthesize the results of the surveys. As discussed previously, GeothermEx has in its library most of the documents describing the results of the work carried out to date in the KERZ. This mature area of exploration should first be analyzed as completely as possible to determine which exploration methods have been most successful. In particular, the subsurface information from deep wells will be systematically analyzed and correlated to anomalies in geophysics and geochemistry. The State may be asked to obtain confidential releases of some additional deep well data from operators in order to complete the critical task of determining which methods of survey are useful for identifying geothermal reservoirs in Hawaii. The results of this task will provide input to Tasks 3 and 6.

Dr. Gardner will perform this task, with the assistance of Dr. McNitt and others.

Task 2 (Evaluate SOH Drilling Methods, Assist with Planning/ Managing SOH Program). While GeothermEx has been involved in the evaluation of data from the SOH drilling project, we have not been part of the process of making decisions on the drilling methods to be used. GeothermEx's experience in the design and drilling of core holes, temperature-gradient wells and geothermal production wells will be fully utilized in developing other cost-saving measures without compromising the quantity or quality of data obtained from the SOH wells or the

FIGURE 2.
INTER–RELATIONSHIPS BETWEEN TASKS



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evaluation of the geothermal resource. The RPA report and the drilling data from all slim holes will be reviewed in detail.

This tasks will be carried out principally by Mr. Granados, with contributions relative to geology from Dr. Gardner.

Task 3 (Design and Plan Additional Work to Improve Resource Evaluation). The results of the first two tasks will be critically evaluated by Dr. Gardner, with assistance from Dr. McNitt, Dr. Klein, Dr. Greensfelder and Dr. Sanyal. Dr. Gardner will evaluate drilling-related activities, and advise DBED if and where further drilling is warranted. Dr. McNitt, with input from Dr. Klein and Dr. Greensfelder, will provide support in evaluating potential new geological, geophysical and geochemical survey methods. Dr. Sanyal will evaluate well-test options for improving the understanding and quantification of Hawaii's geothermal resources.

Work programs for additional geological/geophysical/geochemical surveys will be devised including personnel, budget, instrumentation and procedures. Studies of chemistry of fluids will be part of the program. The work done by ENEL will be reviewed for completeness and the validity of the conclusions reached. Some additional plotting and simple analysis of the existing data is planned.

Any re-sampling of warm and cold water points for chemical and isotopic analysis, with certain field and laboratory analyses, chemical thermodynamic modeling of the various cool and warm groundwaters, to further determine or illustrate conditions of water-rock interaction, such as temperature and gas pressures, and possible mixing relationships would likely be deferred until priorities of exploration are discussed with DBED and DNLR. It is not yet certain whether new sampling and

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computer modeling have sufficient priority to be included in the overall program, relative to other activities and budget. The priority of this work will have to be judged in relation to possible acquisition of other kinds of data (drilling, temperature gradient, well test, reservoir modeling), which may be more useful in reaching conclusions about the size, location and extent of the resource.

Tasks 4 and 5 (Provide Technical Guidance Relative to the Geothermal/Cable Project). The engineering and economic feasibility of the 500 megawatt inter-island electric cable program have been demonstrated; however, the resources to supply the electricity have yet to be developed. Because geothermal is an indigenous energy source, it has high priority for development and ultimate transfer of electricity to the market in Oahu. Under Tasks 4 and 5, GeothermEx, The Ben Holt Company and Dames & Moore will correlate the issues described in the geothermal/cable master plan and EIS to actual and potential development plans of the existing operators, the Consortium and HECO. The precise scope and personnel assigned to these two tasks will be developed after discussions with DBED, DLNR, HECO, ERCE and the Consortium (KEP); Dr. Gardner, Mr. Brugman, and Mr. Everingham will participate in these tasks.

Task 6 (Quantify the Extent and Characteristics of Hawaiian Geothermal Resources). The objective of this task is a familiar one to GeothermEx because it is the objective of most reservoir assessment activities that we perform. Our judgements on reservoir capacity are often the basis of investment and/or policy-making decisions.

The first step in this task is to develop a conceptual hydrogeologic model of the Hawaiian geothermal reservoir(s) from all available geoscientific and well test data. This model will be a

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written and graphical description of fluid sources, location of upflow and outflow zones, fluid flow paths, structure and lithology (including the locations of faults and hydrologic discontinuities), chemical evolution along the fluid flow paths, and the distributions of temperature, pressure, enthalpy and chemical characteristics within the geothermal systems. This task will allow the boundaries of the exploitable reservoir(s) to be defined.

The second step of this task normally is to volumetrically estimate the reserves available within the boundaries of the exploitable reservoir. We have developed an improved version of the volumetric method, originally developed by the U.S. Geological Survey, for this purpose when sufficient data exists. Our improved methodology also takes into account the probabilities associated with the reserve estimate. It should be noted that this technique estimates reserves; it cannot address the number of wells required or potential operational problems with delivering those reserves to the wellhead.

If the resource is too deep or has unsolvable drilling problems or corrosion or scaling problems, it cannot be exploited commercially, no matter how great the reserves. If the reservoir rock has such a limited transmissivity that an inordinately large number of wells will be required to supply a power plant, no project can be developed even if the reserves exist. If the production comes solely from a fault, the development prospects may be limited by the difficulty of injection outside the fault zone because injection within the fault zone may cool down production while injection outside the fault zone may not provide sufficient pressure support to the production wells. If the reservoir transmissivity and/or storativity is small, the wells may have to be spaced so far from each other to avoid severe interference that the available leasehold cannot accommodate all the wells. If there is

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strong natural recharge, the initial wells may be sufficient for the life of a project, if not, make-up wells will need to be drilled.

Therefore, the practicability of any level of development needs to be verified by forecasting well productivity and injectivity under various plausible operating scenarios. This is the goal of numerical modeling. Numerical reservoir modeling follows conceptual modeling and is a task which GeothermEx frequently accomplishes (see Appendix B). It consists of mathematically simulating the heat transfer, fluid flow, thermodynamic behavior of the system based upon exploration, drilling and production/injection data. The model is then used to forecast reservoir and well behavior. Numerical modeling is not part of the initial proposed technical advisory consulting program but should be recognized as a future goal and task. For the KERZ, a useful model would cost at least $30,000 and at present would only include a relatively small area.

Dr. Sanyal, Dr. McNitt, Dr. Klein, Dr. Gardner and Mr. Menzies will be responsible for this task.

Task 7 (Provide Geothermal Well-Field Design and Resource Management Expertise). The results of Task 6 will be used as a basis for developing well-field design and management policies for the high enthalpy Hawaiian geothermal resources. These policies will be used to ensure that yield can be sustained once the resource is developed. For this, we would provide the State with technical advice on the appropriate spacing of well and maintenance of offset distances. We have participated with several companies during negotiations for inclusion of leases into Federal Unit areas; were GeothermEx to be selected by DBED as consultants, we would work closely with DBED and State regulators to examine unitization as one possible method of

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assuring orderly and sustained yield from geothermal resources in Hawaii.

Under unitization regulations, the owners of leases in a participating area agree to appoint one of themselves as operator for all. Generally the owner with the largest interest (acreage) within a geologically defined reservoir area is appointed operator. The operator is responsible for planning well spacing, drilling, production and injection and so forth. Unitization has been used at Roosevelt Hot Springs and Cove Fort, Utah, and Medicine Lake, California and is one management concept worth investigating.

Another critical aspect of well-field design and resource management will be to assess the injection programs proposed by developers. Considering the need for protecting the environment, a sound injection program must be developed. The current plan at Puna calls for injecting the waste water along with the gases. Similar injection of gases at another U.S. geothermal field has caused breakthrough of gases into production wells, reducing plant efficiency and requiring unplanned discharge of gases into the atmosphere. At least five commercial geothermal projects in the U.S. are suffering from cooling due to improper injection strategy. At least one geothermal project in the U.S. has been accused of causing pollution of the groundwater aquifers with arsenic. If injection takes place into the producing reservoir, there is a risk of cooling or gas breakthrough at the production wells (if gas is being injected). If injection takes place outside the reservoir, it provides no pressure support to the production wells and may incur the risk of groundwater pollution and excessive pressure buildup; even increased seismicity is possible. We have developed optimum injection schemes for many geothermal projects.

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Dr. Gardner, assisted by Dr. Sanyal will work with DBED and DLNR on this important task.