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Research Applied to National Needs (RANN)
Center for Engineering Research
University of Hawaii

Pele Energy Laboratory Experiments (PELE)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. ABSTRACT

There is currently a considerable interest developing in the nation regarding the search for new power sources which can satisfy high-quality environmental impact criteria. One which is receiving more and more attention involves the use of geothermal resources. If the concept of the goethermal resource (or underground steam) is expanded to include other inner-earth heat resources (such as those found in molten mantle materials or merely hot rock), one sees real promise for application of science and technology to meet this national energy need.

As in most major scientific and engineering efforts, in order to achieve success, it will be necessary to experiment. Ideally, an outdoor laboratory is needed where man may experiment with the extraction of the earth's interior heat. He must also have a place where he can experiment with the development of conversion and transmission systems that will produce and transmit power from this heat in a non-polluting manner under different conditions and for satisfactory distances. Hawaii may be that laboratory.

This proposal suggests a two-year RANN funding to enable a specific interdisciplinary group of researchers at the University of Hawaii, together with a group of distinguished advisors and consultants, to initiate feasibility studies and obtain data fundamental to a realization of the Hawaii laboratory concept.

The laboratory problem which serves as an application to motivate the researchers, is the need to determine the feasibility of providing non-polluting power for Hawaii from the extraction of lava energy. In the process of generating data of relevance to the solution of this problem, the laboratory characteristics will be documented. The program is named after the Hawaiian Goddess of Volcanoes, PELE. It is an acronym for Pele Energy Laboratory Experiments. This eventually may mean Power from the Extraction of Lava Energy, if sufficient private venture capital is identified for a development as an outgrowth of the RANN effort.

II. NARRATIVE

A. Introduction

1) Overview

The concept of using the State of Hawaii as an outdoor energy laboratory could have considerable advantages to the Nation in its quest for the development of systems for producing electrical energy from sources which have a low-pollution potential. Hawaii abounds in unexploited energy resources (such as winds, ocean waves, solar radiation, ocean thermal variations, and subsurface heat). Although each of these may have potential, the one unique resource which seems to have an excellent technology transfer capability, as far as Hawaii is concerned, is subsurface heat, or geothermal energy. The exceptional aspect of the Hawaiian geothermal resource, and in fact, one of the reasons that it is most interesting to scientists and engineers, is the potential variety of local characteristics. That is, the subsurface heat anomalies, which are manifested in Hawaii, may be present in a great variety of forms. Specifically, these forms include a hot water, cold water, hot porous rock, hot dense rock, geothermal steam, molten magma, and cold deep sea water.

When all of these variations are located and identified, they will be found within a relatively short distance from one another, thus adding greatly to the efficiency, versatility, and applicability of field laboratory development in Hawaii.

The program will result in the identification and development of the methodology for extraction of lava energy, briefly summarized in the title PELE (Power from the Extraction of Lava Energy). This program will have application in many geographic areas where it is possible to reach heat from the earth's interior, either by engineering operations or by natural processes. A useful local by-product of this program will be the production of electrical power for Hawaii from some of the resources which are discovered.

The concept of using the State of Hawaii as an outdoor laboratory encompasses facets and advantages beyond technological and scientific aspects related to the subsurface heat resource. In a socio-economic-environmental sense, Hawaii is also an excellent place to experiment and confirm modeling criteria. Here is found a virtually closed ecosystem which includes no identifiable fossil fuel resouces. This environment is not affected by continent-ocean interface problems, or variations caused by other population centers. Here, a distribution of people over 350 miles of ocean, is isolated from the other states of the Nation by over 2,000 miles of that same ocean. Within the 350 miles, these people are collected on five major islands, with 80% living in Honolulu, on the island of Oahu. Thus, the problems of an urban center are present, but they are isolated sufficiently from others to lend a quality of control to this study. To add interest, it is noted that the most obvious heat resources are located on the island of Hawaii, separated by some 200 miles of ocean from Oahu. Thus it is seen that a laboratory assignment of producing power from Hawaii's heat resources, also needs to address itself to ocean transmission of that power. The economic motivation exists to attempt a solution, in that power rates for single family dwellings in Hawaii are among the highest in the nation.

Out of the Hawaii effort could come the following:

1. Establishment of a laboratory where scientists and engineers could work to experiment with technological developments in power production from earth heat resources.
2. Development of efficient, environmentally clean systems for conversion of underground heat resources to useful energy.
3. Development of efficient ocean transmission systems to transverse the deep ocean with electrical energy.
4. Perfection of survey techniques for locating underground heat resources.
5. Experimentation with deep-drilling techniques for reaching molten rock.
6. Determination of the socio-economic-environmental effects of a non-polluting energy resource on a society.

The National Science Foundation RANN Program is not asked to fund the total effort, but only a two year "seed-money" type effort toward a three year program to establish feasibilities on a scientifically credible basis in order that public, private, and industrial venture capital may be attracted to bring the project to fruition.

These feasibility study efforts involve research in the technological, scientific, societal, economic and environmental areas. They are collected into areas of engineering feasibility, geophysical feasibility, socio-economic feasibility, and environmental feasibility to form an interdisciplinary effort under central management with replicable experience as a central goal.

In general, the first year will be spent surveying and assessing the true nature of the interdisciplinary problem, and in establishing communication links between researchers and advisors who, together, will build the composite team.

The second year will be spent probing in greater depth the technological and sociological aspects of the Hawaii laboratory. As the technological possibilities are surveyed and findings adduced are introduced, task assignments will be modified to conform and account for the more discrete aspects of the social interface.

The third year will be spent collecting and finalizing the various individual feasibility efforts into an interrelated package which will present in scientifically and technologically credible terms the probabilities of success of an environmentally clean power development effort in the Hawaii model. An appropriate focus will be maintained on predictions of useful transfer of the developing technology to the National and International prototypes. Local funding will cover this aspect.

Geophysical feasibility projects initiated the first year will consist largely of surface type surveys which will lead to the prediction of the most likely location to drill a deep exploratory research test hole. The surveys will be performed in the County of Hawaii and at minimum, will consist of photogeologic, geomagnetic, electrical resistivity, microseismic, magnetic induction, and ground heat types of surveys. The output of this first year's effort should be a recommendation as to the best possible site for a deep exploratory well, which is designed to expose as much information as possible about the nature and extent of variations in relevant underground resources that exist in the Hawaii laboratory.

Specifically, engineering feasibility efforts the first year will develop mathematical models and parametric projections useful to prediction of the scope of the natural heat reserve which is necessary to produce given quantities of power from certain assumed types of resources. These resources will include all those likely to be encountered in the Hawaii laboratory exploration.

This will initially require research into power generation systems design, heat transfer techniques, and materials. In addition, companion studies in ocean transmission and systems engineering will be initiated. The output of this first year's effort should be an increase in knowledge base of the investigators involved, and a report to other units on the physical requirements of the overall system, in parametric terms.

Socio-economic feasibility projects the first year will be cognizant of the following problems, or questions, and speak to their solutions:

1. Socio-economic – Specifically, what are the social and economic benefits, including impact on balance of trade, productivity and employment? What would be the distribution of benefits among different industries and areas of the county or area?
2. Public Impact – Can visible progress be shown within a reasonable period, including significant progress in planning and design to keep public interest at a positive level?
3. Budget Impact – What are estimated long-term costs and returns? Full systems costs and returns?
4. Non-Federal Support – What is the feasibility and likely maximum extent of cost-sharing by industry? Can the actual power production project be achieved through steps short of direct Federal funding, regulation, or standard setting?
5. Potential Problems – Are there potential institutional or economic barriers to implementation of the technology, and how can they be overcome? Are there any side-effects from the technology, and how are they to be dealt with or capitalized?
6. Organization and Management – Assuming several programs or projects positively survive the evaluation, what kind of organization (existing agencies, new agencies, or quasi-public corporations), if any should be created or redirected to carry out this program.

The output of the first year's effort will be a draft of material which provides answers, in part, to the above questions and prepares other groups to address a solution of the more serious of the problems identified.

The environmental feasibility study efforts the first year will be designed to create means or develop techniques to provide environmental cleanup to waste waters that may be used in power generation. This environmental control will be directed toward the development of processes in aquaculture, agriculture, and by-product recovery such as protein and chemicals. In this way, engineering of systems may proceed with the knowledge that environmental impact may be controlled to tolerable levels.

Environmental impact studies will be prepared during the first year to cover all proposed major laboratory development projects, including the drillings and deep wells of the second and third years of the geophysical feasibility efforts.

The output of these environmental efforts will also be published in environmental impact statements along with reports on the initial feasibility of using natural processes for environmental cleanup of nutrient-rich cooling waters. It is presently known that this resource is useful as a cold sink in a power system, but it is not known presently what technique will best remove the nutrients. The geophysical surveys for heat resources will somewhat solve the magnitude mystery in the equation by determining the extent and location of cooling water requirements.

Geophysical feasibility studies in the second year will involve a continuation of surface and airborne survey activity similar to that performed in year one, but at other locations around the State. Monitoring of the deep well, presently thought most likely to be drilled in the immediate vicinity of the active lava flows at Kilauea, close to Hawaii Volcanoes National Park, will be performed and suitable reports prepared for distribution to the other research teams and to the various advisory committees for their review and recommendations. Monitoring will include research on geochemical observations, generation of information on rock properties, and evaluation of geological findings. These reports are the expected major output of the second year's effort.

Engineering feasibility studies the second year will continue development of the mathematical models and parametric studies the first year, but with modifications and adjustments which may be imposed by socio-economic and environmental constraints, as indicated in the first year output from the latter groups.

As data are received on deep exploratory wells, and as the thermal resources are identified both qualitatively and quantitatively, the engineering studies will become more specifically related to precisely how each resource may be used in power generation within the necessary socio-economic and environmental constraints.

These studies will result in perturbation of the technology forecasting of year one, and appropriate inputs will then be provided to the socio-economic and environmental feasibility groups in order that the impact of these developments may be properly assessed. Feedback and interaction will be constantly in order throughout the program.

Socio-economic studies the second year will be based on the receipt of the technology forecasting data from the environmental feasibility study group. These data will be combined with societal data in order to assess the impact of the predicted technologies on the socio-economic aspects of the system. Output of this year's effort will be a set of constraints which are to be provided as inputs (and a form of feedback) to the engineering system design studies of year three; also as a set of indicators relevant to the magnitude of parameters that may have a subsequent effect on the environmental ecology such as land use, legislation, planning, and economic development. An economic model also will be forthcoming which will enable rapid assessment and prediction of the effects of adjustments in locally produced power on agriculture, aquaculture, and chemical by-products and other major factors in the economy. Gross effects on the economy will be more generally explored, as well.

The environmental feasibility research group will become involved the second year in the adjustment of impact statements in the light of inputs received from the other areas; engineering, geophysics, and socio-economics. Certain experiments in the growth of useful organisms from warmed nutrient-rich sea water will be performed. Also the agriculture and by-product recovery areas of research will become more specifically related to the developing projects as results from chemical and biological analyses of resource materials are reported. Output from this year's effort will be used primarily in the engineering system design efforts of year three.

Activity in year three of the geophysical feasibility study will probably include deep drilling of one other exploratory well, very likely at Hualalai in the northwest area of the County of Hawaii. This location is thought to be most likely to produce a geothermal deposit of note. It has the additional advantage of being close to cold deep ocean water. Should such a drilling be successful, power production for Hawaii would be assured at a relatively early date. This well is not a part of the budget involved in this proposal, and must wait to be proposed until such a time as survey activities assure its viability, feasibility, and advisability. It is expected that this assurance would be obtained toward the middle of the second year of the proposed three-year effort.

During year three, it is estimated that geophysical surveys will be conducted on each of the other islands of the State in order to locate possible future sites for power development. These results would be reported at the end of this period.

Year three of the engineering feasibility sub-program would see an assessment of the lava energy resources discovered by the deep drilling of the exploratory well in year two. This assessment would make use of the parametric studies performed earlier to propose an engineering development project for power production from the identified thermal resources. From this review, a system design would then be developed which includes not only the power production system but also the power distribution system for the State. This would be fed back to the socio-economic and environmental groups for consideration of feasibility and appropriateness in the light of the socio-economic-environmental constraints. The final output would be a conceptual, or preliminary design of a plausible system. This should provide the base for public or private venture capital to proceed in Hawaii; but, more importantly, this should provide example and experimental data having applicability in various other locations of the Nation and the World.

Year three of the socio-economic feasibility study area would involve a continuation of the types of activities of year two. That is, a receipt of outputs from the engineering and environmental groups, and a prediction of socio-economic effects subsequent to preparation of recommendations on constraints for the overall system which would produce outputs within acceptable socio-economic-environmental groups, and a prediction of socio-economic-environmental limits. In short, controlled technology.

Year three of the environmental feasibility area would provide a "last word" review to projected environmental impacts. It would see further developments of the specific possibilities of environmental control which are offered by aquaculture, agriculture, and by-produce recovery. It is anticipated that reports from this group this year would provide a basis for on-going environmental control efforts as the program continues under other sponsorship.

NOTE

In addition to portions of the previous material, Sections 2) through 7) which follow present answers to points raised as items 1 through 6 on page 5 of the RANN guidelines of September 1971.

2) Identification of National Need

In the earlier days of man's existence, in fact in the present century, the methods by which he met his needs for power and heat held no serious threats to his survival; therefore, little thought or concern was given to the associated environmental or ecological degradation. In recent times, however, the number of instances in which irreversible damage has been done to environments or ecological systems, because of a "business as usual" solution to the demands for increased supplies of energy, have become numerous.

Serious doubt is expressed by many of the nation's leading futurists that man, as we know him will survive this century; even counting on some change in his waste patterns. His insistence on more energy and power at the same time as he pollutes space ship earth with solid wastes (many of which were in part, at one time, a consumer of this power) may well destroy the life-sustaining potential of the earth's air, land and water. Even though the argument may be speculative, it is clear, at least that to survive indefinitely and live conveniently, man must alter his ways so far as energy conversion is concerned.

The magnitude of the need for energy on a national, and even international scale, is staggering in its immenseness and rate of growth. The emerging nations are impeded in their development by a shortage of available energy. The more developed nations are choking in their own effluents while they struggle with a critical shortage of available energy.

A recent report prepared by Resources for the Future, Inc.,[1] offered a most pertinent overview of the national problem, in context of a consideration of the prospect for a continued supply of economical electrical power

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[1] A Report to the National Science Foundation, "Energy Research Needs," October, 1971, pg. xi.

"The separate strands that enter into this concern include such factors as: (1) the recent growth of energy consumption at a rate faster than that of gross national product (contrary to the long-standing downward trend in the energy/GNP relationship); (2) the failure of proved reserves of crude oil and natural gas to increase at a rate consistent with the growth in consumption (a recent phenomenon in the case of natural gas); (3) the decline in the thermal efficiency of converting fossil fuels to electric energy (a recent reversal in a long-standing trend); (4) the deterioration of the natural environment, a situation whose amelioration appears to entail higher energy costs at almost every point in the energy supply chain from the extraction of mineral fuels all the way through to the facilities in which fuels are utilized to produce heat, electricity and motive power; (5) doubts that nuclear energy will ever be available at costs as low as had earlier been anticipated. And, if thought is given to imports as a possible answer to some of these problems, there are factors at work in international oil which seem to point to substantially higher prices than in the past, and a grave question concerning the reliability of imports, particularly from the Middle East and North Africa, the world's most prolific known oil-bearing regions"

3) Specification of Problem of Interest

Of all the problems associated with the satisfaction of the nation's requirement that its energy needs be met, the most critical seems to be the realization that it be met by non-polluting means. Many of the societal problems which have been caused by production of usable energy by polluting means could be greatly reduced if polluting by-products were eliminated or otherwise minimized. This is one of the reasons this research effort is aimed at the development of a system which will produce adequate quantities of energy in a sufficiently non-polluting manner to remain within an acceptable level of environmental impact.

4) Society and Resource Description

The primary society which will be directly involved in this study will be the people of the State of Hawaii. The secondary society will be the people of the Mainland states. The tertiary society will be the people of the world.

The primary society includes 769,000 people. These people live in essentially a closed ecosystem, being somewhat isolated from the other contiguous states by at least 2,000 miles of ocean surface.

When Captain Cook discovered the Sandwich Islands, the approximately 300,000 Hawaiians were burning kukui nuts for light. Successive generations of malahinis (strangers) have been frustrated in developing the power to meet requirements imposed by their brand of civilization. They have found no fossil fuels, and the short and mostly ephermeral streams offer little hydro-power potential. In later years, they have found supplemental power from boilers fired with cane waste, but this has been seasonal and uneconomical. To complicate matters, low-cost LPG is expensive when shipped long distances in American "bottoms" as required by the Jones Act. This has left fossil fuels, also imported, as the only energy source of sufficient magnitude. In recent times it was determined that nuclear power plants were much too large for the relatively small local demand.

Yet, Hawaii is literally bathed in natural energy. From the waves which erode the coastlines of each island, to the tradewinds which blow almost continuously on the windward exposures and the sun which so frequently shines, it is indeed uniquely blessed with unexploited natural energy assets. Beneath these surface manifestations, the heat from molten lava throbs below in active or geologically recently active but non-violent volcanic flows. Favorable thermal conditions (from surface manifestations) are found close to the shoreline at many points around the islands.

Neverthcless, with all of these natural resources, the State depends almost exclusively upon the conversion of energy through the burning of fossil fuels for all purposes. These fuels must be shipped to Hawaii over great distances by sea-going oil tankers, a highly dependent and vulnerable means of transportation.

5) Consequences of Research

The concept of the development of a National Laboratory for Volcanic Energy Research could be one of the most exciting consequences as far as the secondary and tertiary groups are concerned.

Potential economic and social benefits that will be provided by a successful solution of the problem of alternative energy production by non-polluting and economic means will also have great consequences in Hawaii.

Power rates in Hawaii are "pegged" to oil cost. The U.S. oil quota system and the environmental mandate to use "low sulfur" oil (in short supply), has escalated power costs. The fuel oil costs and impediments to many normal economic devices cause power rates on Oahu to be greater than most mainland rates, and the more serious impediments on the Island of Hawaii and other islands cause their rates to be even higher.

In order to develop the relative need more thoroughly, annual residential electrical use (Table 1) was determined for three time periods, 1958, 1964, and 1969 for a variety of locations. These data indicate a doubling of electrical power consumption in most cases over an eleven year period.

Table 2 looks at the effect of population size on yearly average power costs and the costs for the purchase of minimum power. In most cases, the cost of power decreased with increasing size of population. For cities reviewed in Tables 2 and 3, the average minimum power purchased was calculated to be 17 KWH at $1.18.

The average power costs for 1970 (the latest nationwide figures available) for regions in the United States was determined by breaking down the cities and states into regions and averaging the values found for 1000 KWH in Tables 2 and 3.

Region	Ave. $/1000 KWH
Northeast	15.00
East	25.00
Midwest	22.00
Southwest	18.00
Northwest	9.00
West	13.00
Honolulu (far West)	22.00

The average for these regions is approximately $18.00 per 1000 KWH, while Honolulu was (1970) $22.00 per 1000 KWH, or 22 percent above the estimated average for the United States. The following recent news release (Feb. 1, 1972) indicates present and prospective Honolulu rates.

The national average cost of residential power (see Table 4) has shown a steady increase over the past twenty years, especially in the low end of KWH (100-750) consumption rates.

In general, the cost of residential power has been increasing, per region, with time (approximately every ten years). With the present trend, the United States will have the need for more and cheaper power. This will certainly be true for Hawaii, which is already above the United States average by 22%.

A-24 Honolulu Star-Bulletin Tuesday, Feb. 1, 1972 ★

New Electric Rates to Hit Low Users

Under the new rates proposed by Hawaiian Electric Co., the biggest percentage increases are for families who consume 600 kilowatts or less each month.

The rates are now up for approval before the State Public Utilities Commission.

Hawaiian Electric Co. officials have pinpointed the "average" electric consumer as one who uses 700 kilowatts per month and whose appliances include an electric water heater.

Under the proposed new rates, this consumer would get a 9.6 per cent increase in his monthly bill.

Most people whose electric consumption falls below 700 kilowatts would get a bigger percentage increase than 9.6.

Kenneth F. Stretch, manager of Hawaiian Electric's customer service department, says such a disproportionate rate increase is necessary if the company is to recoup from its low electric consumers the basic fixed cost of delivering electricity.

The chart below shows the Hawaiian Electric rates:

Kwhr	Present Rate	Proposed Rate	Increase	
	$	$	$	%
		(Without Water Heater)		
15	1.43	2.00	0.57	39.9
50	3.11	3.45	0.34	10.9
100	4.95	5.45	0.50	10.1
150	6.40	6.95	0.55	8.6
200	7.83	8.45	0.62	7.9
300	9.92	11.45	1.53	15.4
400	12.00	13.35	1.35	11.3
500	14.08	15.25	1.17	8.3
600	16.17	17.15	0.98	6.1
700	18.25	19.35	1.10	6.0
800	20.34	21.55	1.21	5.9
900	22.42	23.75	1.33	5.9
1000	24.50	25.95	1.45	5.9
2000	45.34	47.95	2.61	5.8
3000	66.18	69.95	3.77	5.7
		(With Water Heater)		
200	7.83	8.45	0.62	7.9
300	9.72	11.45	1.73	17.8
400	11.60	13.35	1.75	15.1
500	13.48	15.25	1.77	13.1
600	15.57	17.15	1.58	10.1
700	17.65	19.35	1.70	9.6*
800	19.74	21.55	1.81	9.2
900	21.82	23.75	1.93	8.8
1000	23.90	25.95	2.05	8.6
2000	44.74	47.95	3.21	7.2
3000	65.58	69.95	4.37	6.7

Table 1

ANNUAL RESIDENTIAL ELECTRICAL ENERGY USE

City	State	kwh 1958	1964	1969
Hayward	California	2,747	3,827	4,877
San Francisco	California	1,719	2,310	3,993
Los Angeles	California	2,270	3,112	4,196
Atlanta	Georgia	2,751	3,915	5,450
Honolulu	Hawaii	4,392	5,802	7,222
Chicago	Illinois	2,089	2,717	3,658
Wichita	Kansas	3,451	4,996	6,796
New Orleans	Louisiana	3,194	5,140	7,659
Boston	Massachusetts	1,607	2,072	2,935
St. Louis	Missouri	2,365	3,132	4,447
Omaha	Nebraska	3,563	5,532	7,690
New York - Bronx	New York	1,426	1,742	2,275
- Queens	New York	1,826	2,355	3,295
- Richmond	New York	2,173	2,806	4,325
Seattle	Washington	8,063	10,288	12,346
Burlington	Vermont	2,993	4,817	7,168

Table 2

1970 YEARLY AVERAGE POWER COSTS FOR CITIES OF VARIOUS SIZES

			Minimum Bill		kwh				
State	City	Population	$	kwh	100	250	500	750	1000
Connecticut	Clinton	2,693	1.00	12	4.08*	8.13	12.38	16.13	19.88
	Greenwich	53,793	1.00	12	4.08	8.13	12.38	16.13	19.88
	No. Burchall	10,250	1.00	10	3.85	7.30	9.80	13.80	18.30
	Hartford	162,178	1.75	22	4.45	8.25	10.50	14.70	20.20
Arizona	El Mirage	3,258	1.11	12	3.85	7.29	11.38	15.60	22.28
	Chandler	12,181	1.13	13	3.88	7.94	11.49	15.75	18.19
	Tempe	45,919	1.11	12	3.85	7.87	11.38	15.60	18.01
	Phoenix[1]	505,666	1.14	12	3.91	7.90	12.10	15.36	17.66 21.35 w.
	Phoenix[2]	505,666	1.12	12	3.86	7.98	11.46	15.71	22.45
Missouri	Eldon	3,158	1.23	19	5.01	8.85	12.57	17.12	20.72
	Fulton	11,151	1.00	17	4.81	8.81	14.81	20.43	26.06
	Joplin	38,958	1.59	25	4.19	7.37	10.28	14.39	17.10
	Kansas City	475,539	1.06	22	4.02	8.15	11.24	16.04	20.85
	St. Louis	750,026	2.13	40	3.74	7.80	11.13	15.66	21.01
Washington	Burlington	2,968	1.14	30	3.14	6.55	6.93	9.12	11.31
	Ellensburg	10,044	1.00	50	2.00	3.50	5.50	7.38	9.25
	Everett	53,981	1.04	33	2.34	3.74	5.30	6.86	8.42
	Seattle	557,087	.75	25	2.52	4.40	5.00	6.40	8.15

*Dollars

[1]Salt River P&L

[2]ANIG P.S.

Table 3

1970 YEARLY AVERAGE POWER COSTS FOR VARIOUS CITIES

City	State	Minimum Bill $	Minimum Bill kwh	kwh 100	kwh 250	kwh 500	kwh 750	kwh 1000
Hayward	California	.65		4.32	7.41	10.61	13.81	17.01
San Francisco	California	.50		3.81	6.20	9.40	12.60	15.80
Los Angeles	California	.60		3.19	5.68	7.99	10.88	14.06
New York - Brooklyn	New York	1.72	10	5.70	10.09	14.82	18.69	24.27
- Manhattan	New York	1.72	10	5.70	10.09	14.82	18.69	24.27
- Queens	New York	1.72	10	5.70	10.09	14.82	18.69	24.27
- Bronx	New York	1.72	10	5.70	10.09	14.82	18.69	24.27
- Richmond	New York	1.72	10	5.70	10.09	14.82	18.69	24.27
Wichita	Kansas	1.00	10	3.75	5.25	7.75	11.00	14.75
Chicago	Illinois	1.03	10	4.16	7.66	10.18	13.88	18.22
Boston	Massachusetts	.75	12	4.67	9.35	12.63	18.42	26.20
Omaha	Nebraska	1.00	20	2.80	5.80	8.30	11.30	15.05
Dallas	Texas	1.20	24	3.96	7.44	9.46	13.25	17.62
Burlington	Vermont	1.00	17	3.37	6.70	8.80	11.88	14.97
Rutland	Vermont	2.00	20	4.00	7.00	10.38	14.73	19.73
New Orleans P&L	Louisiana	.90	10	3.72	6.98	10.18	12.87	17.57
New Orleans Public Service	Louisiana	.90	10	3.54	6.75	9.50	14.25	18.65
Miami	Florida	1.10	20	3.70	6.75	10.76	14.78	18.79
Honolulu	Hawaii	1.40	15	4.78	8.45	12.03	17.42	22.20
Atlanta	Georgia	1.02	23	3.57	6.14	9.02	11.61	14.44

Table 4

NATIONALLY AVERAGED BILL FOR RESIDENTIAL SERVICE

Year	Average Bill (kwh) 100	250	500	750	1000	Average Cost (kwh) 100	250	500	750	1000
1970	4.09*	7.51	10.51	14.22	18.31	4.09**	3.00	2.10	1.90	1.83
1969	4.05	7.40	10.32	13.97	18.03	4.05	2.96	2.06	1.86	1.80
1968	4.03	7.38	10.37	14.16	18.27	4.03	2.45	2.07	1.89	1.83
1967	4.03	7.37	10.37	14.21	18.32	4.03	2.45	2.07	1.89	1.83
1966	4.00	7.34	10.34	14.19	18.32	4.00	2.94	2.07	1.89	1.83
1958	3.93	7.30	10.47			3.93	2.92	2.09		
1950	3.76	6.98	10.11			3.76	2.79	2.02		

* Dollars.

** Cents/kwh.

Although many references were considered, the one which will be most useful in total data is "Typical Electric Bills 1970," Federal Power Commission, Washington, D.C.

Aside from the obvious economic advantages that the development of a non-polluting low-cost energy resource would have for Hawaii, it would enable the State to more reasonably realize a recent policy position (promoting population dispersion) through supplying a good power base on each of the islands in the State. This would enable the introduction of alternative transportation systems, such as electric automobiles and mass transit systems. By virtue of the cost and pollution-saving advantages of these solutions, Hawaii would realize a more desirable living environment.

Except for those businesses which directly handle fossil fuels, Federal, State, municipal and private agencies all feel the pinch of this exotic imported energy resource. Immediate implications of an alternative energy source, such as geothermal would not have severe consequences. Long-range implications would mean that there would be a general phasing out of dependency on fossil fuels, and a general conversion to the new resource, to a large extent on a replacement of equipment basis, as the older equipment ceased to function or compete.

6) User Interest

Although the business as usual means of electrical energy production has in the past appeared to have economic advantages, events are now at that point in time where an aggressive attempt must be made to identify and exploit new technological alternatives for energy generation or conversion on a credible scientific basis, particularly ways that minimize environmental impacts; as well as to find ways to more effectively utilize and conserve energy. The general problem is, of course, not exclusive or unique to Hawaii.

For some time, Hawaii has had more than a passing interest in the development of a new source or sources of energy for the State which would lessen the import costs and environmental impact of its conventional energy producing systems. Hawaiian Electric Company has financed studies in the feasibility of nuclear power systems, the development of a power transmission system between the islands, the application of the electric automobile toward the solution of air pollution and transportation problems, and the use of deep saline wells to avoid ocean discharge of cooling water to avoid thermal pollution effects of power plants. On March 2, 1972 Lewis Lengnick, President of Hawaiian Electric Company, officially announced a policy in which the company would purchase geothermal steam should such become available in sufficient quality and quantity to make it economically feasible for power generation. The following recent news release (Mar. 26, 1972) refers to this interest, and to that of the County of Hawaii, in the proposed RANN program.

In the early years of the past decade, drillings were made in the Puna Rift area of the island of Hawaii for the specific purpose of locating sites where geothermal steam from water intrusion might be used for power generation. The results were non-conclusive, and the project was abandoned before deep drillings were accomplished. This had a negative effect on further developments at that time, but in recent years the interest has again revived.

The high cost of power in Hawaii, the alleged adverse effects of "hot" effluents and the potential increase in air pollution or energy cost increases of large magnitude (when low sulfur fuel is no longer economically available), motivated the 1970 State Legislature to pass a resolution requesting the University of Hawaii to initiate studies of new sources of energy. This proved to be the origin of the Hawaii Energy Research Operation (HERO). In 1971, Hawaii County and the State provided $10,000 to the University for an energy-aquaculture study; and a small grant ($5,000) from the Atomic Energy Commission aided immeasurably in the assessment of the geothermal potential of the islands. These primary studies, or surveys, have been completed recently.

These studies disclosed that best potential of non-polluting power from Hawaii's resources is a system concept which may be referred to a geo-marine power. The system uses geothermal heat from an active or recently extinct volcano area, and cold (41°F) deep-ocean (-2,000 ft) water lying only a mile offshore. Use of the cold, deep-ocean water enchances generating efficiency; particularly if no steam, but only hot geothermal water, is found.

Studies to date show that thermal and chemical pollution control aspects of the geo-marine system also may yield valuable by-products. Thermal pollution control is inherent in the system. The water can be discharged from the condensers at virtual

Pele could furnish Hawaii's electricity

By KIT SMITH
Advertiser Financial Editor

All of a sudden, harnessing Madame Pele's hot lava as a source of electrical power in Hawaii doesn't seem such a far-out dream.

The outlook brightened when Hawaiian Electric Co. on March 1 committed itself to buying geothermal steam "if an adequate supply is developed at a reasonable cost."

That commitment is expected to smoke out venture capital to finance exploratory drilling and development.

HAWAIIAN ELECTRIC on its own can't provide venture capital, says Carl H. Williams, executive vice president. A speculative exploration venture would imply a greater potential payoff than a regulated utility is allowed, he explained.

Already, the University of Hawaii's Center for Engineering Research has done enough spade work to excite interest in Pele's commercial potential.

THIS MONTH, the University — through the Center for Engineering Research — applied to the National Science Foundation for a grant to fund a volcanic energy laboratory on the Big Island.

The proposed program — called PELE, for Power from Extraction of Lava Energy — recently won the endorsement of the Hawaii County Council's legislative committee.

FINDINGS OF the research — if a grant is obtained — will be freely available to any and all steam explorers, said Howard Harrenstien, director of the Center for Engineering Research.

Harrenstien looks for both speculative drillers and large energy companies, such as Union Oil and Phillips Petroleum, to join in the search.

"But don't panic," he said. "The State won't be over-run. That can't happen because of the required environmental impact studies."

ALSO, THERE is the memory of unsuccessful drilling on the Big Island a decade ago by Magma Power Co. of California. Five wells were drilled along the Puna rift zone before the effort was abandoned.

Under the PELE program, a test hole would be drilled near Kilauea, outside the National Park.

Kilauea is the area of greatest underground heat on the Big Island. But possible volcanic activity might argue against locating a power plant there, said Harrenstien.

HUALALAI'S northwest rift is a promising site for a commercial heat source, in Harrenstien's view. A production hole ideally would be close to the ocean, so the power plant could draw on 40-degree water from the ocean bottom to produce steam.

Problems of plant location are purely secondary to Hawaii's three-pronged need for a new energy source, said the University researcher:

- Electrical power produced by burning oil is expensive here and will become more so. The price of low-sulphur oil, in particular, is expected to climb steadily.

Harrenstien said that California's Imperial Valley, where electricity costs less than half as much as in Hawaii, is considering geothermal power.

- Oil-fired plants emit pollutants. If the Kona Coast should be developed extensively, stepped-up power generation could cause unsightly air pollution, due to eddying air currents, said Harrenstien. And tourism would suffer.

A geothermal plant on the Big Island would be a closed, environmentally clean system, with no discharge of salts to the atmosphere, he said.

- Hawaii is at the mercy of shipping lanes remaining open to bring oil for electricity production.

Should a strike or other emergency shut off that oil supply, "one can imagine being without power while watching a volcano erupting," said Harrenstien.

HOW CLOSE is geothermal power to being a commercial reality in Hawaii?

In Harrenstien's view, the absolute soonest is four years for small amounts of power and eight years for large amounts. There is no reason all of the Big Island's power requirements can't be met eventually by geothermal energy, he said.

Means already have been devised — on paper — to transmit power underwater between islands, he said. Or Oahu itself could have an underground heat source — possibly between Kailua and Waimanalo. But he conceded he is not a geologist.

EVEN TODAY, low-cost geothermal power is generated on the Mainland by Pacific Gas & Electric Co. in the geyser fields of Sonoma County in Northern California. Other countries having geothermal installations include Mexico, Japan, Russia, New Zealand and Italy.

Not only is geothermal energy stored in the earth in virtually endless supply — with its price not inflating — but geothermal plant costs are lower, too.

VERN CRONKHITE, manager of engineering design for Hawaiian Electric, said information for the PG&E facility in California indicates a geothermal plant would cost two-thirds to three-quarters as much as a conventional boiler-fired plant.

Also, for Hawaii, geothermal steam is a more realistic alternative to oil as an energy source than is nuclear power, said Cronkhite. The smallest nuclear plant being offered is 500 megawatts, he said, "and that's much too large for our system to absorb economically."

ambient ocean surface water temperature. Environmental control also is afforded by the chemical and biological processes which can be performed on the discharge waters.

The proposed research appears to offer great rewards for even limited success. A gross appraisal of geothermal power economics is very favorable. It is noted that geothermal power is competitive with conventional power systems in Japan and California; where there are locally-produced fossil fuels, hydro-power, nuclear power, and the advantages of interconnected systems. The potential commercially-desirable by-products from the Hawaii geo-marine power system further enhance the economic feasibility. The geo-marine power and by-product system also would have applications in many other locations where deep water is near shore. Benefits to less developed areas of the world are obvious, but are not yet quantifiably determined in this context.

In a recent article in "Engineering News Record" the potential significance of geothermal anomalies as natural low-pollution energy sources was considered in large perspective.

Joseph Barnea, head of the United Nations Resources and Transport Section, explains that if a geothermal field is properly exploited, produces a safe yield and is recharged, it can last indefinitely. In one form of recharging, the water brine are reintroduced into the reservoir. He estimates that the U.S. will need to spend from $1 billion to $2 billion to explore its geothermal reserves.

Even more enthusiastic is Bernardo Grossling, a research geophysicist for the U.S. Geological Survey (USGS), who tells us that until now most estimates of geothermal potential were based on known hot springs in volcanic regions. If we add the energy potential of the sedimentary basins of the world, man has an almost limitless source of energy. M. King Hubbert, another research geophysicist with the USGS, says that his estimate of a 60-million-kw capacity for 50 years is a "minimal figure subject to upward revision," He says he will not scale the figure upwards, "until I see some of the technological problems solved." Later in the same article, a most promising concept, considered in the instant proposal, was introduced.

"Geothermal resources have been put to some unusual and practical applications in the U.S. and abroad. The U.S.S.R. have an experimental plant that uses an input of geothermal water with a temperature of only 170° to 180°F. The plant uses freon, which has a low boiling point as an intermediate medium. This development may make economically feasible the production of electric power from relatively low temperature geothermal resources." Grossling continues and points out, "this could open vast areas of the U.S., including the Gulf states area and the Eastern seaboard to geothermal development."

The geo-marine system could be environmentally even more desirable than the system of note in the following glowing report from the same article. "Power produced from geothermal steam causes almost no air pollution. In wet steam fields, the main concern is how it dispose of the brine. Barnea says, process the brine to obtain valuable minerals. Other believe that the brine could be reinjected into the reservoir to recharge it. Most of the unsightly pipes can be buried underground and geothermal power plants are much smaller than the massive nuclear plants with their cooling towers." This advantage will be investigated thoroughly with a view to attainment of maximum feasible advantage in efficiency and environmental protection.

7) Policy Matters

Policy decisions or issues which might be influenced by this research involve the government's policy toward mineral rights and ownership of natural resources and orderly plans for economic development activities. For this research to succeed, it is necessary for the State (a major property owner) to lease its rights to developers, or for the State to become the steam or power producer with industry providing the distribution system or some other well planned system of development. In any event, needs for clear policies become evident, and appropriate controls are necessary to prevent destruction of the delicate balance of the island biome by "gold rush" type speculation ventures.

B. The Research Plan

1) Background

The Hawaiian Archipelago, entirely formed by volcanic action, is a group of islands, reefs, and shoals, stretching from southeast to northwest for 1,600 miles between 150°41′ and 175°75′ W. longitude. The inhabited islands of note to the State of Hawaii in present context involve those at the southeast end of the archipelago, and consist of Hawaii, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai and Niihau, taken generally in the southeast to northwest order. The map in Figure 1 shows the location of these islands. Data on area, altitude, maximum dimensions and population are listed in Table 5.

The geologic structures of the Islands are basaltic generally quite porous above sea level, and less porous to dense as deeper formations, below sea level, are encountered. Although confirmation of the latter concept must await deep drilling exploration, it is evident that the hydrostatic pressure of the surrounding sea would prevent highly porous magma formations. The lowered likelihood of gas expansion at these pressure during undersea buildup of the Islands would also support higher density theories.

Hawaiian magmas are highly fluid in nature, which gives rise to the formation of the shield type of volcanoes. Violent eruptions and steam explosions have not been frequent. Silica content in the melts is quite high, relatively.

The highly porous above-ocean strata supports authorities in the belief that, because ground water intrusion is so convenient, superheated steam domes similar to those found in geyser fields are not present in above-sea level locations in Hawaii. Except for steam vents connected with very recent lava flows (thought to be owing in rain and ground water intrusion of these flows), there are no geysers in Hawaii. Superheated steam is only evident at higher elevations on the Mauna Loa rift on the island of Hawaii. It is thought that the lack of large quantities of ground water at this elevation allows this steam to superheat.

Warm water in wells have been found at many locations in Hawaii. These include spots on the Puna rift at Kapoho, at South Kohala, West Molokai, Waimanalo (Oahu), and West Maui. The maximum temperature of these water wells was about 95°F. This again is thought to attest to the great porosity of the basaltic

Table 5

PHYSICAL CHARACTERISTICS OF THE ISLANDS, WITH POPULATIONS

Island	Area (sq. mi.)	Altitude (feet)	Maximum distance (miles)		Population	Principal City
			North-South	East-West		
Hawaii	4,030	13,784	87.3	75.3	63,468	Hilo
Maui	728	10,025	25.0	38.4	38,691	Wailuku
Oahu	604	4,025	40.0	26.0	630,528	Honolulu
Kauai	555	5,170	24.5	29.9	29,524	Lihue
Molokai	260	4,970	10.1	37.0	5,261	Kaunakakai
Lanai	141	3,370	13.3	13.0	2,204	Lanai City
Niihau	72	1,281	9.7	9.0	237	None
Kahoolawe	45	1,477	6.4	10.9	1	None
Total	6,435	...	...	...	769,913	...

(From Stearns, updated to 1970)

shield volcanoes. Figure 2 shows these locations more specifically.

At a few locations above sea level, where trapped and perched ground water has been discovered between the impermeable dikes on the rift zones, the collected water has been used successfully for irrigation and other domestic uses.

Generally, rain water and ground water seeps through the porous formation until it reaches a virtual sea level, where it meets the more dense sea water which has intruded through the porous rock under the islands. For some distance above this salt water table, the fresh water, being less dense, floats and forms what is called the Graven-Herzberg lens. This lens provides a source of fresh water for domestic use.

At some locations of recent volcanic activity, such as Kapoho at the southeast extremity of the island of Hawaii, salt water anomalies are found rather than the expected fresh water. It is speculated that these anomalies indicate a convective process of heat flow from a geothermal source which is relatively shallow and located directly beneath. Deeper drilling is needed to confirm this.

As increasing depths below sea level are reached, the possibilities increase for encountering geothermal steam which is trapped in so-called self-sealing gas tanks (as

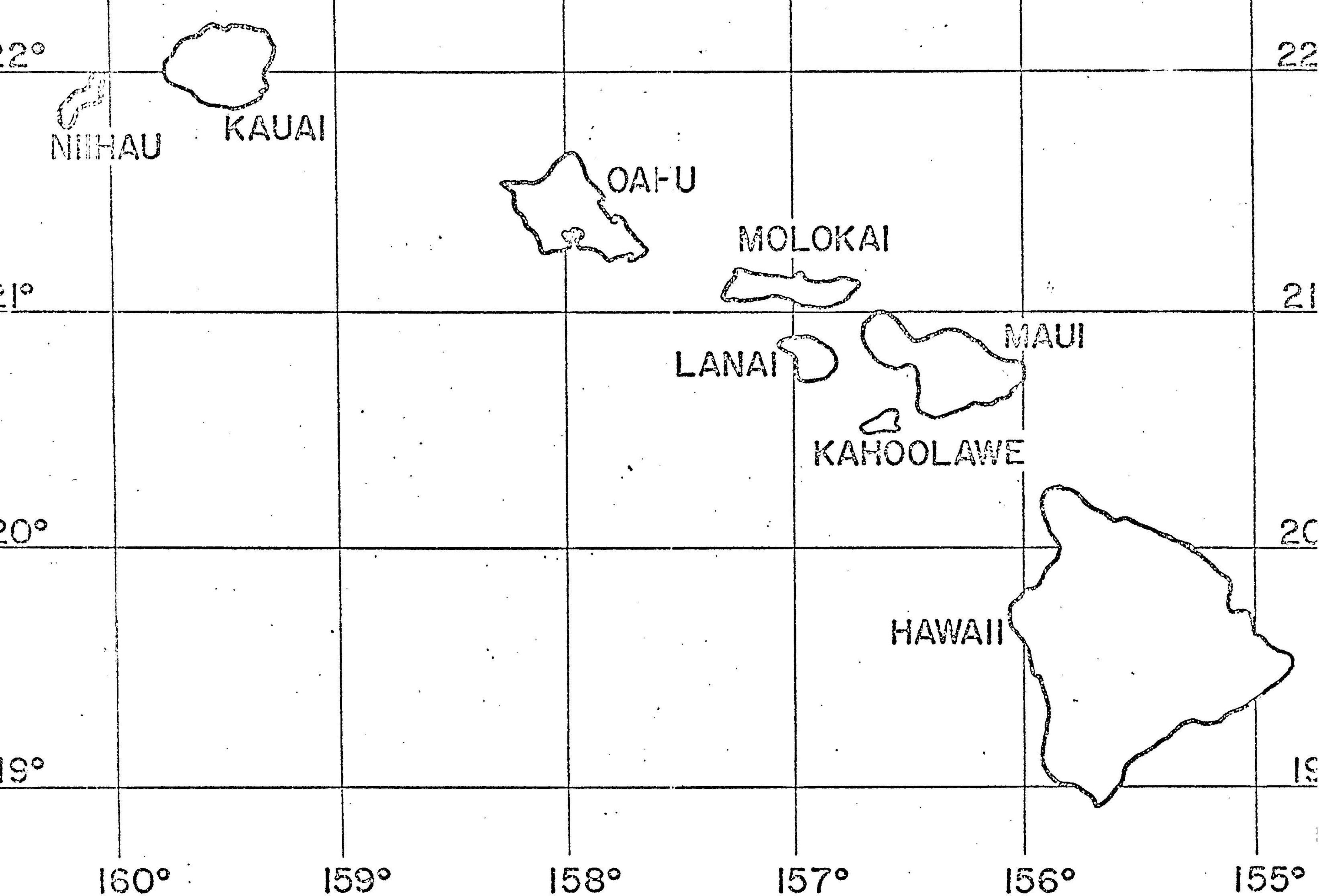


Figure 1. The inhabited islands in the Hawaii Archipelago of reference

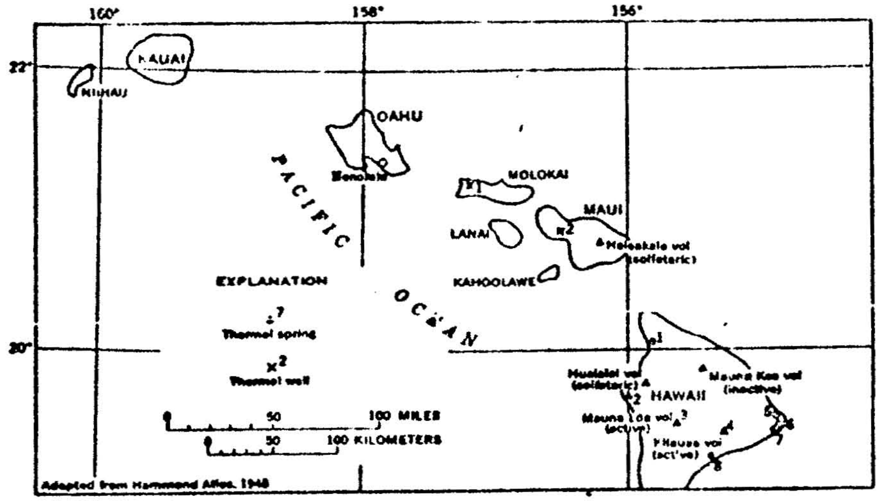


Figure 2 (From Waring, via Austin). Hawaii showing location of thermal springs and thermal wells. All sites are considered basaltic magma heat source type.

No. on figure	Name or location
	Maui County
1	West part of Molokai Island.
2	Mouth of Ukumehame Canyon on Maui Island.
	Hawaii County
1	On shore at Kawaihae....
2	Near shore at Kailua.....
3	In and near crater of Mauna Loa volcano.
4	Crater of Kilauea volcano.
5	0.5 mile northwest of Puu Kukae.
6	Near north base of Puu Kukae hill.
7	On shore 3 miles south of Kapoho.
8	Near Waiwelawela Point.

proposed separately by Facca and Kennedy). Furthermore, possibilities of encountering warmed sea water anomalies, which will flash to steam on exposure to atmospheric pressure, also become realities.

If, for some reason the hot rock is so dense that salt water, or ground water does not intrude, or when more heat transfer surface is required, then opportunities to engineer a geothermal through mechanical intrusion of water into a cavity created by fracturing techniques are anticipated.

If liquid magma is encountered, water may be mechanically introduced which will produce a geothermal of note because of the self-sealing characteristics of the phenomenon in consideration. This has been suggested by Dr. George Kennedy, Professor of Geochemistry and Geophysics at UCLA.

It would seem then that the most likely geothermal resource areas for power production in Hawaii would be those which are below sea level, as close to stabilized magma bodies, or recently reheated intrusion areas as possible.

As a matter of likely fact, some of the best locations may be offshore along extensions of recently active rift zones at depths where the hydrostatic pressure of the sea would prevent flashing of hot water steam. Deep drilling from stable floating platforms would be required to explore these possibilities, after sensitive seismic and thermal survey work.

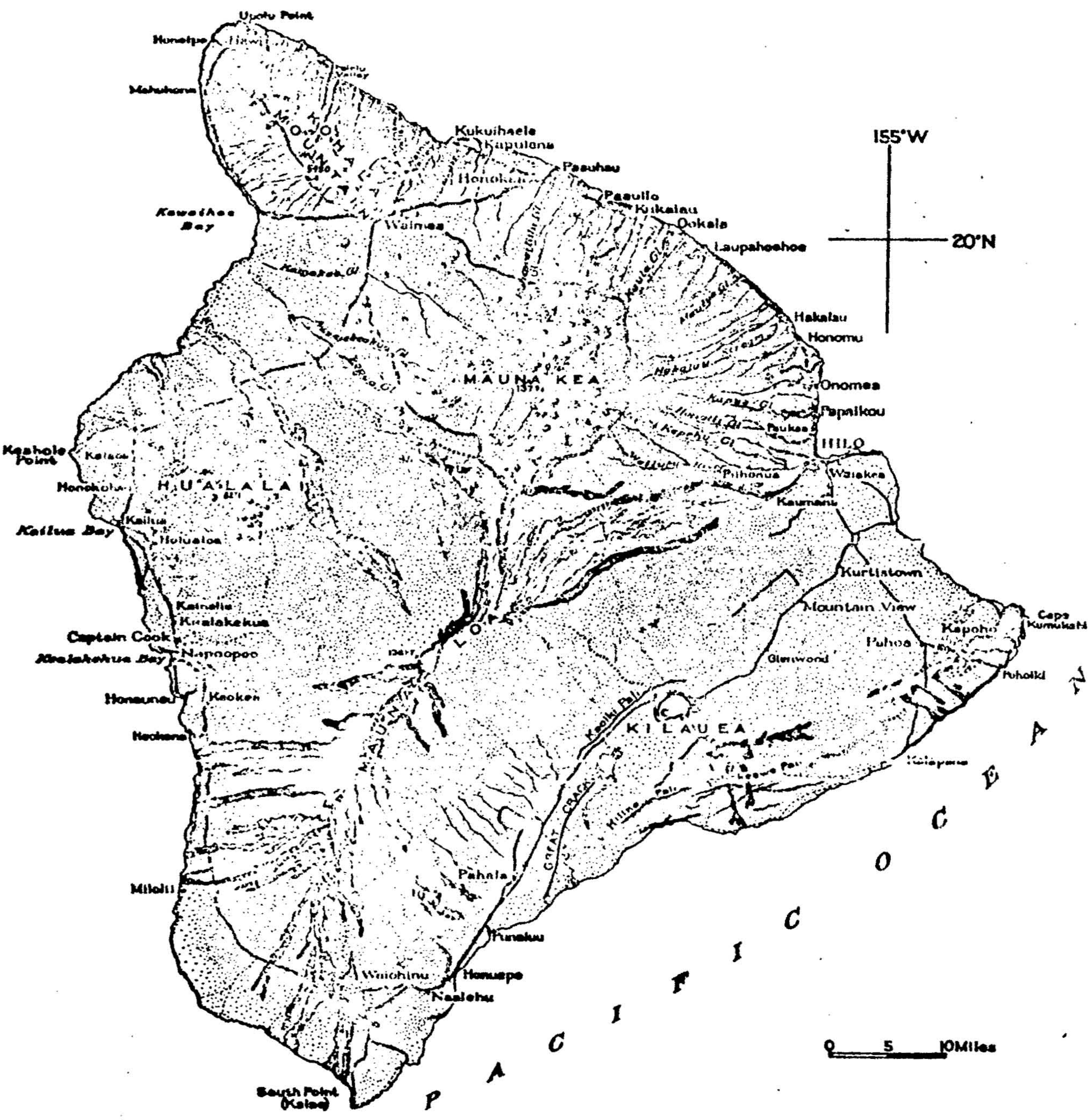


Figure 3. Geothermal Regions on the Island of Hawaii
(from MacDonald)

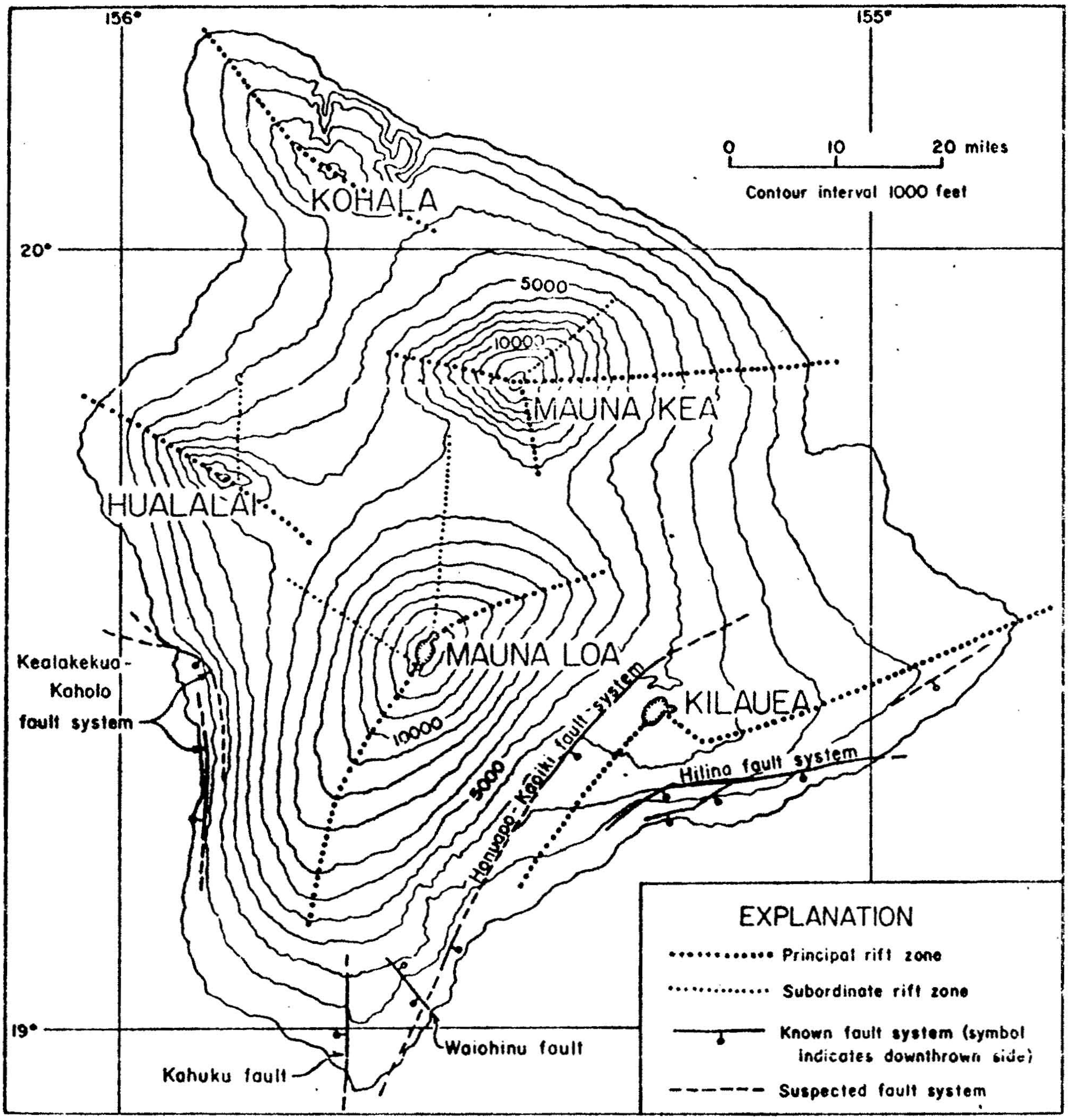


Figure 4. Rift Zones on the Island of Hawaii

(from MacDonald)

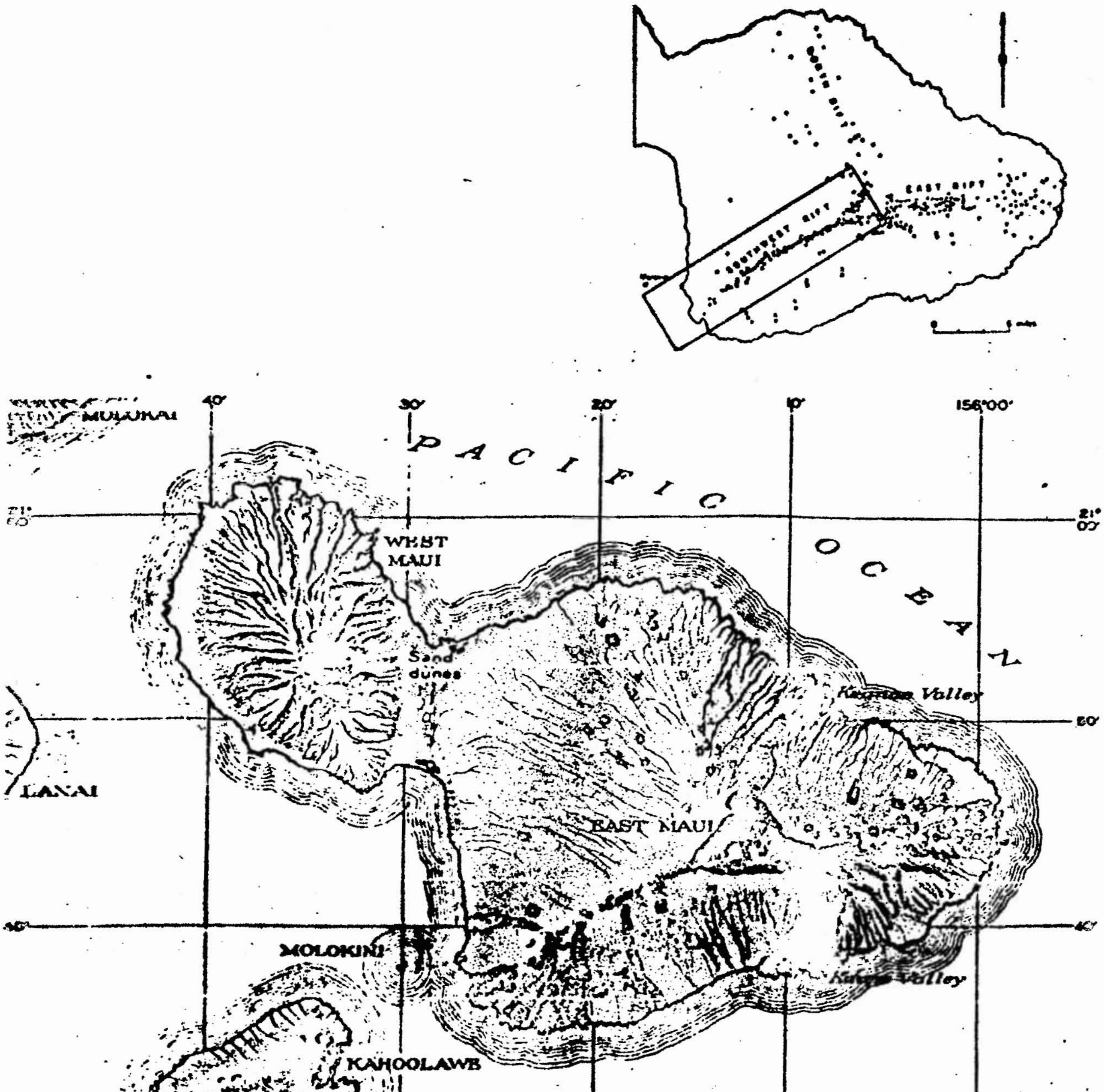


Figure 5. MAUI Geothermal Regions
(from MacDonald)

It is appropriate to identify another natural resource found in Hawaii, which is not geothermal, but when coupled with geothermal, will enable the most efficient production of power with little or no environmental impact. It is the almost infinite supply of cold, deep-ocean (2000-ft depths, 41°F.) sea water which surrounds the islands and which is thought to permeate much of them. In locations such as south and west Hawaii, for example Keahole Point, this water is less than a mile from shore. This cold water, after being brought to the surface and warmed as a heat sink in power production, could become a valuable source of nutrients for aquaculture production. On the sunny west shore of Hawaii, this resource could be a significant factor in industrial development of an aquaculture activity of note, while assisting in environmental cleansing of the warmed cooling water.

In the County of Hawaii, regions of Hawaii, regions of possible geothermal outside the National Park areas, including the Puna rift, Kilauea, Kapoho, the northwest rift of Hualalai, the southwest rift of Mauna Loa, and the east rift of Mauna Kea. Figure 3 shows these locations.

On the land-based geothermal resource areas in this county, the most likely for development seems to be the north slope of Kilauea and the west slope of Hualalai, since they are relatively quiet, but not so quiet as to indicate a lack of residual heat or even molten magma. Hualalai last erupted in 1801, but was the center of violent and frequent earthquakes in 1929, thus indicating the probable presence of magma activity. Kilauea is presently active on the south flank with 300-ft lava fountains at Mauna Ulu, and flows which are filling Alae and Aloi craters. Hualalai is situated close to deep ocean water and the sunny coast (see Figure 4).

On Maui, the southwest rift of Haleakala seems to be geologically similar to Hualalai. It therefore seems the most likely resource area in this county for consideration. Figure 5 indicates the location.

On Oahu, the county with the greatest population, and hence power demand, geomagnetic anomalies have located a possible geothermal under Kailua, on the eastern side of the island. Recent indications of warm water anomalies in the Herzberg lens near Waimanalo add to the speculation concerning available residual heat under Oahu.

Assuming later successful experience in exploring the island of Hawaii locations, it should be possible to deep drill on the other islands and find suitable resources as well.

Although the Hawaiian volcanic region is unique, in its uniqueness are found examples of a wide variety of thermodynamic conditions which add considerably to its use as a laboratory for experimentation with the development of non-polluting power from energy extraction mechanisms. This same variety offers much hope for a technology transfer type of activity which uses the Hawaiian Laboratory to develop systems for other environments and regions.

It is likely that at some point between the quiet surface of the Hawaiian landscape either above sea level or offshore on the sea bottom and a point beneath, where a magma body is located, one may encounter either geothermal steam, hot fresh water, hot sea water, or hot rock. It is also likely that at some other point nearby, cold fresh or sea water is available in abundant supply. Whether or not these resources may be efficiently converted into a power production system is a problem of engineering feasibility. For a project to be feasible from an engineering point of view requires studies in systems design, power production, heat exchanger mechanisms, material science, systems engineering and electrical transmission. These are not exclusive unto themselves, but are affected by environmental, societal, and economic constraints, after an assessment of the extent of the resources has been made.

2) Organization

The goals, objectives, and general relationships of the research plan were outlined in the overview section of this proposal, section IIA 1). In order to accomplish these purposes an interdisciplinary organization has been conceived, with the Center for Engineering Research as focal point, which will enable scientists, engineers, economists, business and government to work together to bring about the results sought.

The actual research is divided into four major disciplinary areas. These are geophysical, engineering, socio-economic, and environmental in nature. Within these sub-program areas, each of which is managed by a University of Hawaii faculty researcher, are various individual tasks. Each of these tasks is conducted by an individual who has experience, interest, and time allocated to the pursuit of the task.

Tasks are designed to provide interdisciplinary inputs to the sub-program areas, which in turn have established lateral communication links, each with the other, in order that rapid cross-flow of information may occur.

Management of the system is concentrated in the office of the Center for Engineering Research whose Director is the proposed Principal Investigator for the entire program. The Center is advised by local, national, and international advisory committees, in addition to receiving the usual RANN six month review commentary. Publication and dissemination of results of the program are a responsibility of this Center, as well as fiscal operations.

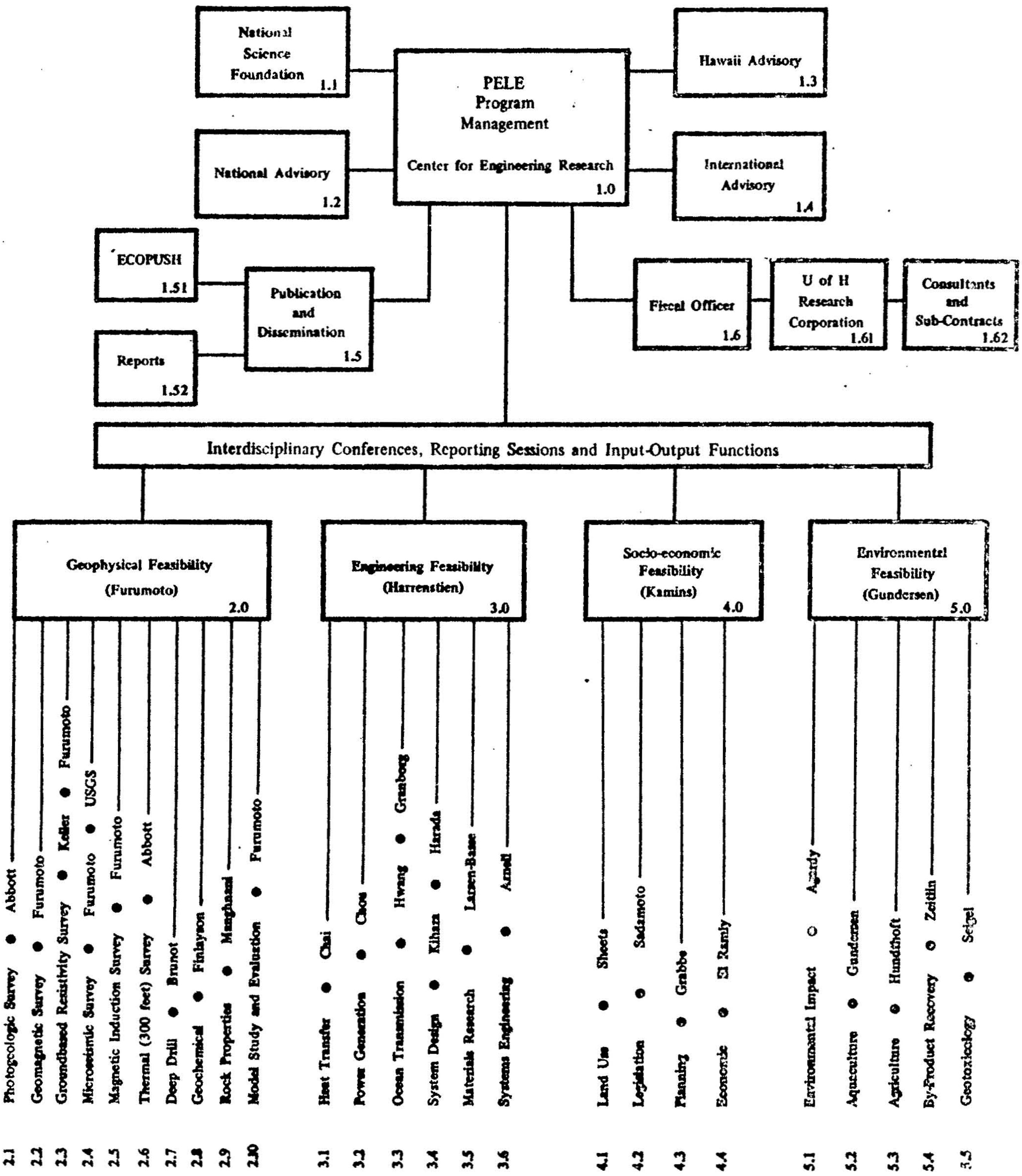
A diagram which shows the organizational structure just described is present as Figure 6 . On this diagram are listed the various tasks which have been identified as necessary components to the overall effort. Each task or organizational area has been assigned a numerical designation to aid in the identification of material which follows as far as assignment to task is concerned.

A time-line which shows the period after which each task is to be performed, along with the proposed budget level of support, is presented in Figure 7. Details of the tasks pertaining to this research plan are presented in arithmetic order of task identification numbers in Appendix A. Budget details are included in Appendix B.

Figure 6

PROGRAM ORGANIZATION

(See Appendix A for further detail)



PROGRAM AND EXPENDITURE SCHEDULE

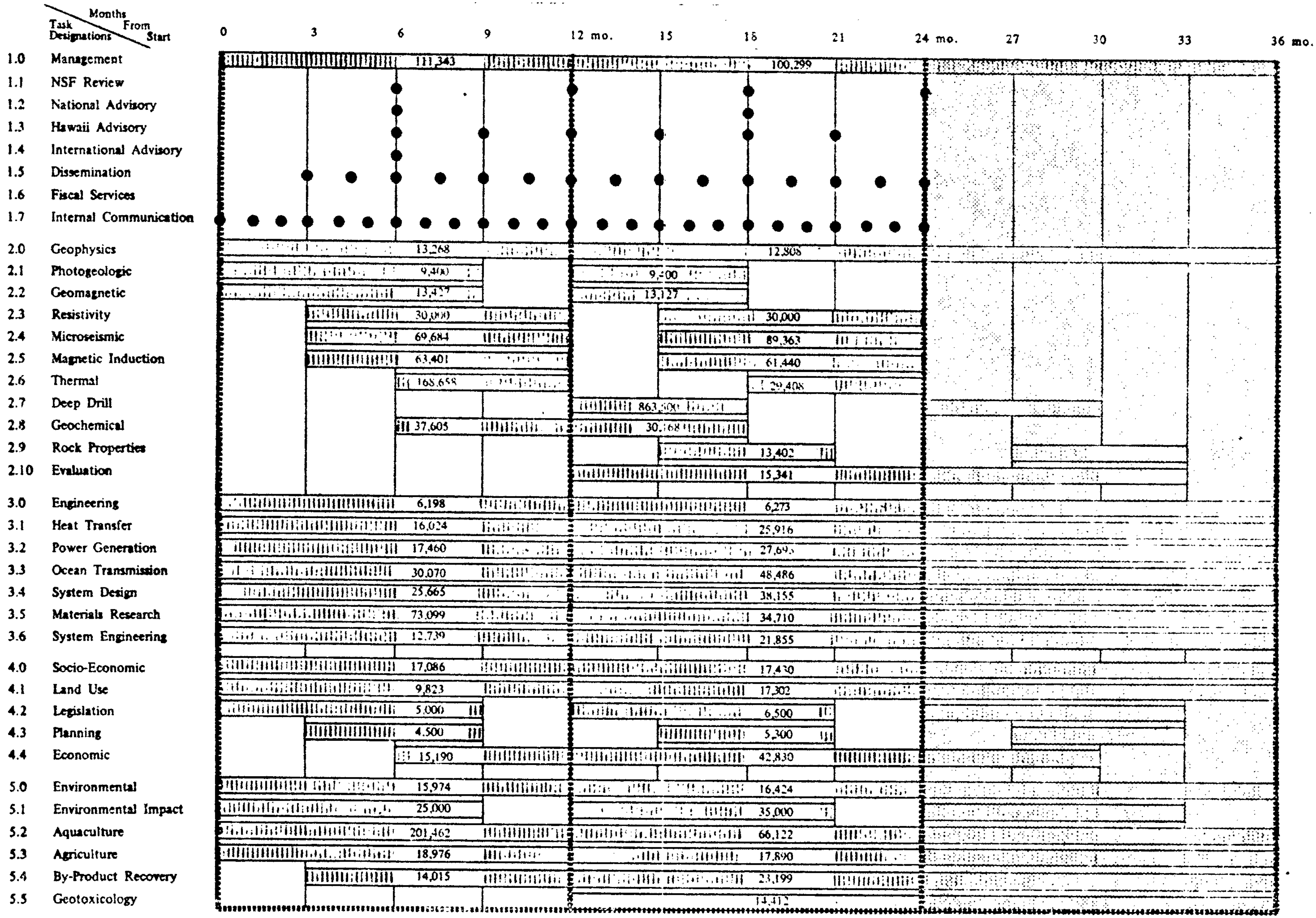


Figure 7 PROGRAM AND EXPENDITURE SCHEDULE (3rd Year Funding not requested; ● indicates meetings)

C. Management Plan

This interdisciplinary program is proposed to be managed by Center for Engineering Research (CER), University of Hawaii. The Center for Engineering Research coordinates all research activity in the College of Engineering at the University of Hawaii. In addition, it has responsibility for the continuing education program and for administering interdisciplinary projects with other research units both on and off campus.

The CER has, since 1968, presented over 39 seminars, each a minimum of two days, on subjects ranging from air pollution to new sources of energy. Over 3000 persons have attended these seminars. Six new conferences are being planned for 1972, one of which is on geothermal energy. Six additional ones are planned for 1973. The conferences provide and excellent medium for informing the public of how science and technology may be used in the solution of societal problems. This series would be used as an information outlet for many of the developments of the PELE Program.

The CER has an annual budget of approximately $140,000. It receives assistance from other units on campus which adds to the total University outlay for this function.

Principal Investigator will be Dr. Howard P. Harrenstien (Director, CER); he will devote 50% of his time to this effort, 25% being contributed by NSF. All aspects of, and tasks within, the program will be directed through CER for overall managing, coordinating, and supervising, and integrating purposes as well as fiscal control.

Tasks numerically designated as 1.0 to 2.0 in the Research Plan (Appendix A) are descriptive of overall as well as specific categories of activities called management functions. Figure 6 shows relationships of management task functions to technical task functions, and the method of integration and communication within the program.

Figure 7 in the Research Plan shows a schedule of NSF review sessions, advisory conferences, accomplishment milestones with associated time and cost frames of reference, and an overall view of the total program.

Those aspects of the program planned to be performed by investigators not in the employ of the University of Hawaii, will be contracted through established University of Hawaii business procedures. Satisfactory performance and supervisory decisions will be in the ultimate judgment of the CER Director, as overall program manager. Task investigators in the employ of the University of Hawaii, to the extent supported by the program will report to the program manager.

Legal fiscal agent for the program will be the Office of Research Administration of the University of Hawaii under the aegis of the President of the University. The University is ultimately governed for fiscal purposes by a Board of Regents, in the nature of trustees. NSF has previously made contracts with the University through established business practices.

D. Related Programs and Activities

1) University of Hawaii

This proposal has received enthusiastic encouragement and support from the following members of the University community:

John Farias, Jr., Chairman, Board of Regents
Harlan Cleveland, President
Wytze Gorter, Chancellor, Manoa Campus
Richard K.C. Lee, Director, University of Hawaii Research Corporation
John W. Shupe, Dean, College of Engineering
George Woollard, Director, Hawaii Institute for Geophysics

E. Related Programs in Other Organizations

The PELE Program described herein has stimulated activities and attention to volcanic energy resources in a number of other organizations within the State. Specifically, encouragement, endorsement or assistance have been offered from the following:

1. The County of Hawaii Office of Research and Development
2. The Bishop Estate
3. The State of Hawaii Department of Planning and Economic Development
4. The Hawaiian Electric Company
5. Pacific Resources, Inc.
6. The Mayor's Office, County of Hawaii
7. The Hawaii County Council
8. The Governor's Office of Environmental Quality Control
9. The State of Hawaii Senate Committee on Ecology and the Environment
10. The U.S. Geological Survey

Research organizations outside the State of Hawaii having expressed an interest in this program include representatives from Lawrence Radiation Laboratory, Los Alamos Scientific Laboratory, Battelle Northwest Laboratories, and Battelle Columbus Laboratories. University groups have included representatives from Stanford University, the University of California at Los Angeles, the University of California at Riverside, the Colorado School of Mines, and the University of Tokyo.

In the specific case of the Colorado School of Mines, Dr. George Keller, who is Professor of Geophysics, has proposed a RANN program to use the Kilauea volcano as a laboratory to evaluate mechanisms that may be important in hydrothermal systems. He has proposed to drill within the Hawaiian Volcanoes National Park in such a location so as to determine the nature of an assumed convective cell atop the magma chamber. This proposed project is complementary to the PELE program proposed here. The techniques proposed by Keller are also to be used by him in certain stages of the PELE exploratory program. The Kilauea drilling is of a type which is supportive to the PELE program.

Another program of relevance is the Subterrene, Hothead, and thermal cracking types of projects which are being performed and proposed by the Los Alamos Scientific Laboratory. Many aspects of these projects have a direct relevance to future engineering development activities of PELE. In addition, it would appear that the LASL researchers would have an interest in using the PELE laboratory for many of their experiments.

Another laboratory which has been and continues to pursue research of relevance to the PELE program is Battelle Northwest Laboratories. At Battelle, Geothermal studies have been performed of types which may offer benefit to the Hawaii program depending on the nature of the substrata. Recently, Battelle has shown an interest in developing a research program in material science for heat pipe technology. These heat pipes conceivably could be used directly in molten magma for purposes of energy extraction.

The Lawrence Radiation Laboratory has also indicated an interest in pursuing a program in heat pipe technology. This obviously has a relevance to PELE. If magma is reached at reasonable depths, field experiments using heat pipes could be a real possibility.

In order to assure proper coordination and collaboration, representatives from each of the above project areas and laboratories have been included in the National Advisory Committee for PELE. In addition, mutual visitations are scheduled with each of these programs for purposes of intimate coordination.

F. Dissemination of Research Results

Potential beneficiaries and users of the anticipated research results are identified earlier in the Narrative to this proposal. Tasks 1.5 and 1.7 (Dissemination and Internal Communication) include descriptions of the means by which research results will be disseminated. It is important in this regard that much of the mechanism for this transfer has been arranged or established prior to submitting the proposal.

Conferences previously held and conferences in arrangements stages have had this purpose as a central motivation. Communication with the large non-scientific audience has also been a fact in operation of Center for Engineering Research and is planned to be expanded through means of the Public Understanding of Science program called ECOPUSH.

G. Current Support

Activities of the principal investigator are not presently supported by other agencies of the Federal Government, although the ECOPUSH Conference Proposal is pending with NSF, Public Understanding of Science program.

The task investigators are available to the extent necessary to satisfy the level of program needs, as given in this proposal. However, it is suggested that the level of funding requested may justify a site visit. At the time of this visit matters of investigator availabilities (and level of participation and possible conflicting activities) can be considered in context and in person.

H. Application to Other Federal Agencies

This proposal has not been submitted to any other agencies for support. It has, however, received the endorsement of the State of Hawaii and the County of Hawaii, which have written it in as a part of the Capital Improvements Program (CIP) for the County 1972-73 budget period. The contemplated support available as matching funds from this source to the PELE program is $200,000.

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2. "Hawaii Revised Statutes," Sec. 182.1.

3. "California Laws for Conservation of Geothermal Resources," Resources Agency of California, Division of Oil and Gas, 1971.

4. "Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development, Imperial County," Imperial County Dept. of Public Works, Calif., May 1971.

5. "Basic Conditions, Procedures, and Performance Standards for Geothermal Regulation in a Rural County," Division of Oil and Gas, California.

6. "Basic Conditions, Procedures, and Performance Standards for Geothermal Regulation in an Urban County," Division of Oil and Gas, California.

7. "Procedure for Evaluating Environmental Impacts," Geological Circular 645, Department of the Interior, Washington, 1971.

APPENDIX A

Material in this appendix is offered as explanatory detail to the management and research plan. It is presented on individual task formats which relate directly to those tasks listed in Figure 6 of the the narrative portion of this proposal. Each task is budgeted separately. Budget breakdowns occur in Appendix B to this proposal.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	PELE Program Management		
Sub-program Manager	Howard Harrenstien		
Task Title	Program Management	Task No.	1.0
Investigator	Howard Harrenstien		
Department	Center for Engineering Research		

Budget	Year One	Year Two	Total
	61,074	62,935	124,009

Task Summary

Task Description

The Center for Engineering Research (CER) is the central focus for management responsibility of the proposed PELE Program. The flow of management responsibility is shown in the material which follows.

Project Need

There is a need for a focus of responsibility in management in order to assure rapid and prompt communication of information at all levels, and to assure adequate attention to the program proposed.

Anticipated Results

It is anticipated that by centralizing the management in the CER office, the program will have a high degree of probable success by virtue of its obvious recognition of importance by University, State, and County administrations, and by virtue of the resources which are available to the CER office.

Task Title	Program Management	Task No. 1.0

Task Details

The management center for the PELE Program is the Center for Engineering Research (CER) at the University of Hawaii. The Center was authorized by the Board of Regents in 1965, and has been in continuous operation since that time. The Director of the Center for Engineering Research, Dr. Howard Harrenstien, who also holds the title of Associate Dean of the College of Engineering, is the Principal Investigator for the PELE Program.

The Center for Engineering Research will draw on the services of the University Office of Research Administration and on the University of Hawaii Research Corporation for aid in processing the various requisitions, the writing of consulting contracts and sub-contracts, and other fiscal operations. The Fiscal Officer for the project, Mr. Wilfred Ii, however, will be housed in the CER office.

The "chain of command", in a management sense, is as shown on the organizational diagram (Fig. 1). Dr. Harrenstien will draw upon the advice and counsel of the various advisory committees shown, relative to administrative, technical, and management decisions. The structure of these committees is described in sections of this proposal which immediately follow. In addition to these committees, personal consultation with and between the various principal investigators of projects listed, as well as with the subprogram managers, will be held on a routine basis. These consultations will also provide input to management decisions and overall coordinative efforts. Meetings of the various advisory and review committees will be as scheduled in the timeline presented previously.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	PELE Program Management		
Sub-program Manager	Howard Harrenstien		
Task Title	National Science Foundation Review	Task No.	1.1
Investigator	RANN Representative		
Department	Advanced Technology Applications, NSF		

Budget	Year One	Year Two	Total

Task Summary

Task Description

Each six months the program will receive a review from the RANN Section of NSF. Although this review may be in Honolulu, Washington, D.C., or any other location specified by NSF, it is suggested that at least one meeting per year be held on site in Hawaii.

Project Need

There is a need for close liaison with the Federal Government in order that duplication of efforts be avoided, and that results receive rapid dissemination to appropriate national users.

Anticipated Results

Thorough cooperation between the local Hawaii research team, State and County agencies, and the Federal Government to assure valuable application of this research to National needs.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	PELE Program Management					
Sub-program Manager	Howard Harrenstien					
Task Title	National Advisory Committee				Task No.	1.2
Investigator	Howard Harrenstien					
Department	Center for Engineering Research					
Budget	Year One	6,000	Year Two	6,064	Total	12,064

Task Summary

Task Description

This Committee is comprised of persons who are known nationally for their experience and knowledge in matters related to the proposed effort. They will meet annually in Honolulu, or Hilo, to review the progress and advise on future directions.

Project Need

There is a critical need to communicate to others who have experience in such programs the progress of the Hawaii effort. Their advice and counsel will provide a valuable input to the direction of the activity.

Anticipated Results

It is anticipated that this Committee will provide the necessary guidance to assure that the program has a national relevance in a scientifically credible way. It is further anticipated that the results of the Hawaii effort will be more closely coordinated and communicated to other National Laboratories and Government through the functions of this Committee.

Task Title	National Advisory Committee	Task No. 1.2

Task Details

The following persons are recommended as possible members of this advisory committee. These persons have not been formally contacted to determine their willingness to serve in this capacity. Members may be added or deleted on recommendation from NSF.

Tentative membership includes the following:

Dr. Franklin Agardy
Vice-President, URS Research Company
155 Bovet Road
San Mateo, California 94402

Mr. David Anderson
Division of Oil and Gas
State of California

Dr. Ellis Armstrong
Bureau of Reclamation
Dept. of the Interior
Washington, D.C.

Mr. Glenn Coury
Distillation Division
Office of Saline Water
U.S. Dept. of the Interior
Washington, D. C. 20240

Mr. Anthony Ewing
Plowshare Division
Atomic Energy Commission
Washington, D. C. 20543

Dr. Giancarlo Facca
Inter-regional Technical Advisor
The United Nations
New York, New York

Mr. Milton Fisher
A. D. Gelhart Co., Inc.
295 Madison Avenue
New York, New York 10017

Dr. Richard Fiske
U.S. Geological Survey
Department of the Interior
Washington, D. C.

Mr. Hamilton Hess
President, Sierra Club
255 Ursuline Road
Santa Rosa, California 95401

Dr. Gary Higgins
Lawrence Radiation Laboratory
P. O. Box 808
Livermore, California 94550

Mr. S. Kaufman
Exploration and Production
Research Division
Shell Development Company
P. O. Box 481
Houston, Texas 77001

Dr. George Kennedy
Institute of Geophysics and
Planetary Physics
University of California
Los Angeles, California 90024

Dr. G. W. Leonard
Code 45
Naval Weapons Center
China Lake, California 93555

Mr. Al Lessin
Environmental Protection Agency
Washington, D. C.

Task Title	National Advisory Committee	Task No. 1.2

Task Details

Mr. Buster W. Miller
District Exploration Manager
Gulf Oil Company - U.S.
P. O. Box 1392
Bakersfield, California 93302

Mr. Carel Otte
Manager, Geothermal Division
Union Oil and Gas Division
Union Oil Company of California
Union Oil Center
Los Angeles, California 90017

Dr. Henry Ramey, Jr.
Professor of Petroleum Engineering
Stanford University
Stanford, California 94305

Representative from RANN Program
National Science Foundation

Representative from USGS
Menlo Park Office
Menlo Park, California

Dr. Robert Rex
Institute of Geophysics and
Planetary Physics
University of California
Riverside, California 92502

Dr. Eugene Robinson
CNC 4
Los Alamos National Laboratory
P. O. Box 1663
Los Alamos, New Mexico 87544

Mr. Herbert Rogers
President
Rogers Engineering Company
San Francisco, California

Mr. Don Stewart
Battelle Northwest Laboratories
Richland, Washington

Dr. Israel Warshaw
Engineering Division
National Science Foundation
Washington, D. C.

Mr. Dick Werner
Lawrence Radiation Laboratory
Livermore, California

Dr. Max Williams
Dean of Engineering
University of Utah
Salt Lake City, Utah

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	PELE Program Management		
Sub-program Manager	Howard Harrenstien		
Task Title	Hawaii Advisory Committee	Task No.	1.3
Investigator	John Shupe		
Department	College of Engineering		

Budget	Year One	Year Two	Total
	3,950	4,014	7,964

Task Summary

Task Description

This Committee of Hawaii residents will be comprised of key individuals from industry, government, and the scientific community. They will meet quarterly to review the progress of the program and offer advice and counsel.

Project Need

For such a program to result in the economical production of non-polluting power for Hawaii, it is essential to have a way of communicating its results to the business leaders, and receive early feedback and advice from them as to its progress and direction.

Anticipated Results

Anticipated results include the transfer of information to the business community, and the growing financial and legislative support of the programs objectives. At some point in time, a very large part of the support of the project by local government and industry is contemplated.

Task Title	Hawaii Advisory Committee	Task No. 1.3

Task Details

The following persons are recommended as possible members of this advisory committee. These persons have not been formally contacted to determine their willingness to serve in this capacity. Members may be added or deleted on recommendation from NSF.

Tentative membership includes the following:

President Harlan Cleveland
President
University of Hawaii

Dr. John Craven
Dean of Marine Programs
University of Hawaii

Mr. John Farias, Jr.
Director
County of Hawaii
Office of Research and Development

Dr. Howard Harrenstien
Director
Center for Engineering Research
University of Hawaii

Dr. Ralph Hook
Dean
College of Business Administration
University of Hawaii

Mr. Paul Joy
Vice-President
Pacific Resources

Dr. Wytze Gorter
Chancellor, Manoa Campus
University of Hawaii

Mr. Lewis Lengnick
President
Hawaiian Electric Company

Mr. Roy Leffingwell
President
Hawaii Manufacturers Association

Dr. Shelley Mark
Director
State of Hawaii Department of Planning and Economic Develop.

Dr. Richard Marland
Director
Governor's Office of Environmental Quality Control

Mr. Atherton Richards
Trustee
Bishop Estates

Dr. John Shupe, (Chairman)
Dean, College of Engineering
University of Hawaii

Dr. Peairs Wilson
Dean
College of Tropical Agriculture
University of Hawaii

Dr. George Woollard
Director
Hawaii Institute of Geophysics

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	PELE Program Management
Sub-program Manager	Howard Harrenstien
Task Title	International Advisory Committee — Task No. 1.4
Investigator	Augustine Furumoto
Department	Geophysics

Budget	Year One	Year Two	Total
	13,582	16,857	30,439

Task Summary

Task Description

There is a need for an opportunity to communicate the intent and results of the program on the international scene. Advice and counsel from these scientists who have participated in energy developments elsewhere will be invaluable.

Project Need

This Committee will be comprised of internationally known scholars, scientists, and engineers who will meet bi-annually in Hawaii to review and advise on the program. Their first meeting will be during the U.S.-Japan Seminar on Volcanic Energy in February, 1973, at Hilo, Hawaii.

Anticipated Results

It is anticipated that the establishment of this Committee will help assure that the program will have an international relevance. The development of the PELE Laboratory should be an attractive and useful adjunct to many of these scientists' programs.

Task Title	International Advisory Committee	Task No. 1.4

Task Details

The following persons are recommended as possible members of this advisory committee. These persons have not been formally contacted to determine their willingness to serve in this capacity. Members may be added or deleted on recommendation from NSF.

Tentative membership includes the following:

Mr. Arturo Alcaraz
Commission of Volcanology
Rizal, Philippines

Dr. Kenzo Baba
Geological Survey of Japan
135 Hisamoto-cho
Kawasaki, Japan

Dr. Joseph Barnea
Resources and Transportation Division
United Nations

Dr. A. J. Ellis
Director, Chemistry Division
D.S.I.R.
Petone, New Zealand

Dr. Giancarlo Facca
Inter-regional Technical Advisor
The United Nations
New York, New York

Mr. A.L.C. Fooks
c/o M.O.W., Private Bag
Taupo, New Zealand

Dr. Augustine Furumoto
Hawaii Institute for Geophysics
University of Hawaii

Mr. D. Hadikusumo
Direktorat Geologi, Diponegoro 57
Bandung, Indonesia

Mr. Jim Healy
N.Z. Geological Survey, D.S.I.R.
Rotorua, New Zealand

Dr. Manfred Hochstein
Geophysics Division, D.S.I.R.
Wellington, New Zealand

Dr. Hideo Iga
President
Geothermal Energy Association of Japan

Dr. George Kennedy
Institute of Geophysics and Planetary Physics
University of California
Los Angeles, California

Mr. W.A.J. Mahon
Chemistry Division, D.S.I.R.
Taupo, New Zealand

Dr. Takeshi Minakami
University of Tokyo
Tokyo, Japan

Dr. Yasue Oki
Director, Hot Spring Research Inst. of Kanagawa Prefecture
Yumoto, Hakone
Kanagawa Prefecture, Japan

Dr. Anthony M. Taylor
Bureau of Mineral Resources
Canberra, Australia

Dr. Izumi Yokoyama
Department of Geophysics
Hokkaido University
Sapporo, Japan

Dr. Kozo Yuhara
National Research Center for Disaster Prevention
6-15-1, Ginza, Chuo-ku
Tokyo, Japan

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	PELE Program Management		
Sub-program Manager	Howard Harrenstien		
Task Title	Publication and Dissemination	Task No.	1.5
Investigator	George Sheets		
Department	Center for Engineering Research		

Budget	Year One	Year Two	Total
	26,737	27,286	54,023

Task Summary

Task Description

Dissemination of research results through written publications, conference presentations, and seminars directed toward user groups interested in research results directly and indirectly.

Project Need

The research proposed in PELE will result in technological advances which will create major revisions in many aspects of societal organization and in economic life of important segments of the business community. Government operations will also require adjustment to account for these changes.

Anticipated Results

Through means of early dissemination of not only the raw technological information, but also the predicted implications of the new techniques, we may avoid a large part of the dislocations caused historically by introduction of new technology without preparation for the effects on the larger society and environmental systems.

Task Title	Publication and Dissemination	Task No. 1.5

Task Details

Three primary means are planned as vehicles through means of which a two-way information flow may be acquired and maintained.

1. A traditional system for publication of written technical bulletins and scholarly papers and reports. Editorial and clerical services will be provided to assist investigators on a continuing basis.

2. Ongoing seminar programs and continuing education systems within the Center for Engineering Research and the general University of Hawaii structure will be vehicles through which fundings will be made available and feedback received from the broadest community group. In particular, the existing NSF program, under the Public Understanding of Science auspices will be used to reach the general public.

3. The regular meetings of advisory boards will serve as dissemination media as well as feedback and counsel to the program.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Publications and Dissemination		
Sub-program Manager	George Sheets		
Task Title	ECOPUSH Conferences	Task No. 1.51	
Investigator	Joy MacQuiddy		
Department	Center for Engineering Research		
Budget	Year One	Year Two	Total

Task Summary

Task Description A projected schedule of seminars addressed to the general public in order to disseminate the science and technology advances adduced and derived in project PELE. ECOPUSH derives its name from Environmental Conferences on the Public Understanding of Science for Hawaii.

The seminar form for dissemination of PELE technology will be expedited by use of this existing program supported by NSF through the Public Understanding of Science program. Six seminars are planned in each of two years. It is anticipated that already planned programs will require only slight modification to permit concurrent consideration of currently available knowledge of PELE findings and their direct and indirect effects on the social, economic, and environmental systems.

Project Need

The need is for a two-way information flow between the scientists and the user public sectors. Continual contacts must be initiated and maintained in order to anticipate effects and overcome potential misconceptions.

Anticipated Results

From relatively long experience in public dissemination of technological information, it is expected that the overall program will be benefitted by public participation from inception. At minimum, it will be possible to create more positive public attitudes toward this technology by removing the mystery and consequent doubt which arises from ignorance.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Publications		
Sub-program Manager	George Sheets		
Task Title	Reports	Task No.	1.52
Investigator	Sue Perry		
Department	Center for Engineering Research		

Budget	Year One	Year Two	Total

Task Summary

Task Description

Produce permanent written and other documentation of PELE findings in forms suitable to widely inform not only the scientific but also the more general public. Maintain library of internal and external publications as necessary to inform project investigators and all other interested agencies.

Project Need

The technology of geothermal is in a fast growth infancy stage. Information dissemination and exchange is of cultural importance to a wide variety of persons, agencies, and organizations. PELE must be part of a two-way communication effort at all stages of operations.

Anticipated Results

The widest reasonably possible dissemination of PELE findings and results as well as receipt of pertinent feedback and results from persons, agencies, and organizations effected by or interested in the same or similar information and effects.

Task Title	Publications	Task No. 1.52

Task Details

In this project it is envisioned as a particular charge that not only the usual and traditional scholarly presentations be made of research results, but that the need of the larger non-scientific community be served. This latter need will require particular efforts toward contact with specialized public media, toward cooperation with popular writers, and contact with other disseminating methods reaching the even more general public.

Mechanical systems and personnel will be employed appropriately and in consonance with appropriate need. In order to expedite, in advance of formal presentations, findings will be reproduced in sufficient form and number for use of advisory panels and RANN management personnel.

Periodic bulletins and other appropriate forms will be created and distributed to all reasonably affected persons, agencies, and organizations.

A library system will be initiated as a first order of business in order to inform investigators and as a residuary for projects as well as a general reference system relating to externally as well as internally pertinent, significant information sources.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	PELE Program Management		
Sub-program Manager	Howard Harrenstien		
Task Title	Fiscal Service	Task No.	1.6
Investigator	Wilfred Ii		
Department	Office of Research Administration		

Budget	Year One	Year Two	Total

Task Summary

Task Description

All purchasing, personnel hiring, and accounting will initiate within the CER and be transmitted to the University Office of Research Administration and the University of Hawaii Research Corporation, as appropriate.

Project Need

There is a need to maintain close fiscal control and supervision as close to the CER as possible. There is an additional need to provide rapid service to principal investigators who need fiscal assistance.

Anticipated Results

A smooth flow of information on fiscal matters, a thorough and accurate account of the fiscal status of the program, and timely cash flow consistent with the level of effort realized.

Task Title	Fiscal	Task No. 1.6

Task Details

The University of Hawaii Research Corporation, separate from the Office of Research Administration at the University, was established for purposes of providing administrative service to research programs through channels which were more independent of restrictive State regulations and policies.

In programs of the PELE type, where consultant agreements and contracts for field services are involved, it is appropriate to use the Corporation because of its unique organization which allows it to consummate such arrangements with ease. The University Office of Research Administration will initiate the necessary Research Corporation activity where needed.

The involvement of the Research Corporation will provide an official unit for receiving monetary support from various sources, and a convenient mechanism for distributing these to contracting and consulting personnel and organizations in ways which will enable the successful completion of the stated objectives within the required time frame.

Although the University of Hawaii faculty, their graduate and undergraduate students, and University technicians, are competent and capable, it is essential that certain activities which involve either large expenditures of time and manpower or highly experienced technique and special equipment be contracted out.

Various consultants and sub-contractors will be hired to complete work described. Specifically, some of this work consists of environmental impact statements, defrayment of portions of costs of travel for advisory committee members, portions of the photogeologic surveys, resistivity surveys, microseismic surveys, thermal surveys, and deep drilling, as well as certain legal consultations.

Use of consultants and sub-contracts should assure that the highest level of expertise and the most economical and experienced field work is used. This should have a markedly positive effect on the project results.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	PELE Program Management
Sub-program Manager	Howard Harrenstien
Task Title	Conferences, Reporting Sessions, Input-Output Feed-back — Task No. 1.7
Investigator	Harrenstien, Furumoto, Kamins, Gundersen
Department	Engineering, Geophysics, Economics, Microbiology

Budget	Year One	Year Two	Total

Task Summary

Task Description

At approximately two-week intervals, the various sub-program managers will meet and discuss problems, progress, needs, outputs and projections for each of the program areas.

Project Need

There is a need for communication amongst sub-program managers in order that the entire interdisciplinary program proceeds smoothly and cooperatively.

Anticipated Results

A better quality overall program, with more interdisciplinary publications and rapid feedback to all investigators.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility				
Sub-program Manager	Augustine Furumoto				
Task Title	Geophysical Feasibility Management			Task No.	2.0
Investigator	Augustine Furumoto				
Department	Hawaii Institute for Geophysics				
Budget	Year One 13,268	Year Two 12,808	Total 26,076		

Task Summary

Task Description

All types of geological, geophysical and geochemical surveys that we think are relevant to Project PELE will be carried out. Data from surveys will be correlated to subsurface conditions as we know from drill hole specimens.

Project Need

Geophysical surveys are necessary to locate geothermal fields and to estimate the size of fields. We must know also what geophysical parameters mean in terms of subsurface properties.

Anticipated Results

The meaning of geophysical parameters will be very relevant. For example, we will know what the profile of electrical conductivity with depth means in terms of ground water distribution, heat flow pattern, etc. We will be able to interpret geophysical data in terms of subsurface geology accurately.

Task Title	Geophysical Feasibility Management	Task No. 2.0

Task Details

Introduction

By the Geophysical Program is meant the various geological, geophysical and geochemical studies that will be integrated into Project PELE. It is called the Geophysical Program simply because geophysical studies will occupy a large part of the time, effort and funds. The studies will include field surveys, laboratory analysis of samples, processing and interpretation of the collected data. At the later stages of the Project, there will be theoretical studies, numerical model studies using computers and small scale laboratory model studies.

In line with the general outline of the Project, the studies will for the first and second year be concentrated in the selected test area in the island of Hawaii. In the test area exploratory holes will be drilled to locate possible geothermal fields. Obviously, to increase the chances of success of the holes, data from geophysical surveys must be examined to determine the best sites for the holes.

In addition to serving as a site selection tool, we have basic scientific objectives for geophysical studies, as this is a research proposal. Geophysical surveys will give you the distribution of certain physical parameters with depth, such as, electrical resistivity, magnetic induction, susceptibility, velocity of P waves. But we desire the knowledge of other properties of the subsurface material -- density, temperature, thermal conductivity, mineralogical and chemical composition. We attempt the correlation of the measured set of parameters with the desired set of obtaining subsurface samples from exploratory core drilling and correlating the properties of the samples with the measured parameters. Hence, if we can study the test area thoroughly by a dense set of surveys coupled to appropriately placed deep exploratory holes, we can infer the subsurface properties of other areas with only geophysical surveys.

The geophysical program then broadly aims at the understanding of the geologic setting of the Hawaiian Islands with an eye to geothermal power or volcano power development.

In this section of the proposal, we shall list the specific objectives of the geophysical program, the kinds of studies we have in mind and their schedule. Then we shall take up somewhat in detail each type of study and present a proposed budget for each.

Specific Objectives of the Geophysical Program

In the preceding we have given the broad objective of the geophysical program. Coming down to a more practical level, we wish to propose the following three specific objectives:

1. To carry out careful site selection survey over the test area for exploratory drill holes. All relevant types of surveys will be brought into play.

Task Title	Geophysical Feasibility Management	Task No. 2.0

Task Details

2. To correlate the physical parameters from the surveys with properties of the subsurface samples obtained from the drill holes.

3. To carry out surveys in other areas in search of geothermal fields and volcano energy sources.

4. To carry out model studies on geothermal fields and volcano energy sources.

Types of Geological, Geophysical and Geochemical Studies

Below we have listed the types of studies we propose to do and the names of investigators who will be responsible for each.

1.	Photogeologic survey	A. T. Abbott
2.	Geomagnetic survey	A. S. Furumoto
3.	Electrical resistivity survey	G. Keller
4.	Micro seismic survey	A. S. Furumoto
5.	Electromagnetic survey	D. Klein
6.	Thermal survey in wells	A. T. Abbott
7.	Deep well logging	K. Brunot
8.	Geochemical survey	B. Finlayson
9.	Rock properties	M. Manghnani
10.	Model studies and evaluation	A. S. Furumoto and G. MacDonald

Schedule of Various Studies

The various studies will be staggered according to the role each will play. The photogeologic and magnetic surveys will start off as these are essentially reconnaissance type surveys. Futhermore, equipment for them are available, including an airplane, at the University of Hawaii, and mobilization time is minimal.

An outline of the schedule is given in Table 1. We are able to project our geophysical program three years ahead, but beyond that we feel the program will depend very much on the results we have obtained in the first three years. RANN support is only sought for the first two years at this time, however.

Task Title	Geophysical Feasibility Management	Task No. 2.0

Task Details

TABLE 1
Schedule of Surveys for the Geophysical Program

Survey	Investigator	Year ONE		Year TWO		Year THREE	
Photogeologic	Abbott	Hawaii	and Maui	Oahu, Molokai, Lanai			
Magnetic	Furumoto	Hawaii	and Maui	Hawaii	Oahu	Supplementary	
Electrical Resistivity	Keller		Hawaii		Maui		Oahu
Seismic Survey	Furumoto		Hawaii	Hawaii	Hawaii	Maui	Oahu
Electromagnetic	Klein		Hawaii	Hawaii	Hawaii	Maui	Oahu
Thermal Survey Using Wells	Abbott			Hawaii	Hawaii	Maui	
Deep Well	Brunot				Hawaii		
Geochemical	Finlayson		Hawaii	Hawaii	Hawaii	Hawaii	Hawaii
Rock Properties	Manghnani					Maui	
Model Studies & Evaluation	Furumoto & MacDonald		RANN Program			Hawaii	

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility				
Sub-program Manager	Augustine Furumoto				
Task Title	Photogeologic Surveys			Task No. 2.1	
Investigator	Agatin T. Abbott				
Department	Geology				
Budget	Year One 9,400	Year Two 9,400		Total 18,800	

Task Summary

Task Description

To search for areas in the Hawaiian Islands which show unusual surface heat radiation and other visible signs of thermal anomalies. This project will be accomplished by aerial photographic reconnaissance covering those parts of the islands first that are considered the most plausible for temperature anomalies to occur. These will first be on the islands of Hawaii and Maui. On Hawaii the areas to be surveyed will include on Kilauea, the summit area, the southwest rift, the southeast rift; on Mauna Loa the southwest rift and northeast rift; Hualalai, the northwest rift. Mauna Kea and Kohala shields are less likely candidates but some areas will be checked. On Maui the most favorable areas would include the southwest rift and the east rift on Haleakala.

Project Need

An airplane and suitable photographic equipment with both color and special heat sensitive film is required. Suitable laboratory processing is also required. This may be done by the present staff or may be contracted to a professional air survey company.

Anticipated Results

It is expected from the photos to be able to delineate certain favorable areas for further investigation by drilling and surface temperature measurements.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility
Sub-program Manager	Augustine Furumoto
Task Title	Geomagnetic Surveys — Task No. 2.2
Investigator	Augustine Furumoto, A. Malahoff
Department	Hawaii Institute for Geophysics

Budget	Year One	Year Two	Total
	13,427	13,127	26,554

Task Summary

Task Description

First, geomagnetic survey data that have been published or are available will be examined as to their value for Project PELE. Then aeromagnetic surveys and surface surveys will be carried out to supplement available data.

Project Need

Proper interpretation of data from magnetic exploration surveys will yield the areas at depth where the rocks are less magnetized. This can mean that rocks have lost their magnetization because the temperature of the rocks are above the Curie point. In other words, magnetic survey data can lead to location of hot spots.

Anticipated Results

From the data, we hope to locate hot areas at depth. As we already have published data, we do not need a large amount of field data to supplement what we have. Concentration of effort will be made more along interpretation than field work.

As geomagnetic data can be closely related to electromagnetic data, the personnel carrying out the electromagnetic surveys will also carry out the geomagnetic surveys. Hence, the proposed budget for geomagnetic surveys does not include salaries.

Task Title	Geomagnetic Surveys	Task No. 2.2

Task Details

Aeromagnetic surveys to outline the gross structure of the crust in the Hawaiian Islands have already been carried out and the results have been published (Malahoff and Woollard, 1968). Besides the published magnetic anomaly maps, there are much more data on file at the Hawaii Institute of Geophysics.

These surveys were done by traverses one mile apart. One feels that these traverses are sufficient for one purpose. But we want to be sure that the surveys were adequate for one purpose of locating heat sources. So we propose a detailed aeromagnetic survey over the test area so that the traverses will be done in a grid pattern rather than only in parallel line patterns. We propose that the lines be only 1/2 mile apart rather than the 1 mile spacing of the former surveys.

The surveys by Malahoff were done in 1965. It may turn out that the proposed surveys will turn out very different results. For the Kilauea Volcano has been very active in the past few years and this could cause changes in magnetic patterns of the subsurface material.

The equipment to be used in the survey are available at the Hawaii Institute of Geophysics. The airplane used in the 1963 surveys is still in good flying condition and has been in intermittent use since then in other projects. The mobilization time, including dusting off the equipment from the shelves and training new technicians to carry out the survey is expected to be about a month.

The personnel to be involved in the electromagnetic surveys will also be involved in the magnetic surveys. The magnetic surveys should be well completed before the electromagnetic surveys start.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility				
Sub-program Manager	Augustine Furumoto				
Task Title	Ground Based Resistivity			Task No.	2.3
Investigator	George Keller				
Department	Colorado School of Mines				
Budget	Year One	30,000	Year Two 30,000	Total	60,000

Task Summary

Task Description

Electrical resistivity surveys using the dipole method will be carried out over the selected area for intense study and areas surrounding it. In the later phases of the project, electrical resistivity surveys will be carried out to locate geothermal fields.

Project Need

Variations in resistivity depth profile of subsurface materials is about the best method for locating hot areas at depth. However, resistivity results must be correlated to actual drilling data to see how resistivity is a good indicator of temperature at depth.

Anticipated Results

Previous electrical resistivity surveys by Keller have shown upwelling of the fresh water-salt water interface under the Herzberg lens. This upwelling is due to convection by heating from below. We anticipate similar upwelling of the salt water to be found by resistivity surveys.

Task Title	Ground Based Resistivity	Task No. 2.3

Task Details

The Geological Problem

The basaltic rocks of the Hawaiian Islands are so porous that water seeps through them rather easily. This gives rise to the popular notion that there are no geothermal fields in Hawaii because the lateral flow of water carries the heat away.

The porosity of the island makes possible the existence of the Ghyben-Herzberg lens. This is an underground lens of fresh water that sits on top of a salt water table. Salt water from the ocean penetrates horizontally deep into the interior of the island mass to form a salt water table. On the other hand, fresh water from rainfall on the island percolates downward until the fresh water reaches the salt water table. The downward flow of the fresh water, is of course, slow and upon contact with the salt water, the fresh water rests gently atop the salt water table because fresh water is less dense. The cumulative effect is a lens of fresh water sitting atop the salt water table, if the system is left undisturbed.

Now, if there is a source of heat down deep in the salt water regime, a convection motion will be started. If the convection is vigorous enough, it can penetrate the Ghyben-Herzberg lens and produce a column of brackish water. The fresh water-salt water interface will be disturbed and there will be an upwelling of the interface.

The fresh water-salt water interface is also a good discontinuity in electrical resistivity. To map the undulations of this interface, an electrical resistivity survey is most appropriate. In fact, such a survey has been carried out near Kilauea Volcano, and an area of upwelling of the discontinuity in electrical resistivity has been detected. It is inferred that this upwelling is due to penetrative convective motions of the salt water.

The area selected for our intense study will be surveyed carefully by electrical methods to see if there are any undulations of the resistivity discontinuity. If such should prove to be the case, we will propose drilling at the upwelling areas.

As mentioned, George Keller of the Colorado School of Mines has completed surveys near Kilauea Volcano. As he has indicated interest in participating in the program, we have invited him to manage the electrical resistivity for surveys.

The budget for the electrical resistivity survey is given as a total figure, as George Keller will bring his own staff to carry out the survey. There will be close liason with the University of Hawaii so that the electrical resistivity survey will fit into the Geophysical Program. Should Dr. Keller's RANN proposal to drill Kilauea be funded, these two efforts are designed for complete compatibility and avoidance of overlap.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility				
Sub-program Manager	Augustine Furumoto				
Task Title	Microseismic Surveys			Task No. 2.4	
Investigator	Augustine Furumoto (USGS Menlo Park as consultants)				
Department	Hawaii Institute for Geophysics				
Budget	Year One	69,684	Year Two 89,363	Total	159,047

Task Summary

Task Description

Portable seismograph stations with sensitive instruments will be deployed over the area where resistivity surveys indicate likely hot areas. Microearthquakes will be recorded and their epicenters determined. With portable instruments designed for microseism study, the ground noise will be recorded and the amplitude spectra of the noise will be obtained.

Project Need

Microseismic surveys are needed to further identify those areas where likely geothermal activity and high heat flow is occuring.

If small earthquakes occur in the area where resistivity surveys show likely hot areas, then seismic data constitute added evidence for hot areas.

Anticipated Results

From seismic evidence we can increase the probability of locating geothermal areas or unknown magmatic reservoirs. Also by noting the amplitude decay of transverse waves along different paths, we can also find other unknown hot areas at depth.

Task Title	Microseismic Surveys	Task No.	2.4

Task Details

The seismic surveys will consist of two distinct parts: 1) seismicity study of microearthquakes 2) seismic noise survey and 3) seismic observations using an array of stations.

Seismicity of Microearthquakes

By microearthquakes, we mean earthquakes with a magnitude of less than 2. It seems natural that if there is thermal activity at a certain spot 2km below the surface of the earth, there would be very small earthquakes caused by fracturing and warping of the rocks. These earthquakes can be detected by high gain seismographs. The recordings must be filtered as ground noise may obscure these small seismic events.

For observations of microearthquakes, we shall use portable seismographs. Such seismographs, very well adapted for our program, have been developed commercially and are available. A single package consists of a vertical 1 cps geophone, amplifier with filters, a crystal chronometer and a visual recorder. The visual recorder can use pen and ink type of recordings for the old fashioned stylus on smoked paper recording. We have tested this seismograph package and found out that for microearthquake recordings, smoked paper recording is far superior to other types of visual recording, because of the fine resolution of the lines. Especially in rugged field recording, which we anticipate in our program, smoked paper recording is the most versatile and convenient.

We have considered and experimented with tape recording, but we have concluded that it is inefficient. For, the tape must be taken back to a central office for playback in order to judge that quality of recording. In our case, we wish to judge the results of our recording in the field. In fact, we plan to make the rounds of the temporary seismograph stations every 48 hours.

We plan to have the results of the electrical resistivity surveys before the seismicity study begins. We have to know the locations of expected thermal activity in order to locate our temporary stations. We plan to install six stations at the beginning.

After several weeks of recording, depending on the quality of the records, we should be able to locate the epicenters of the earthquakes and see whether they originate from the suspected areas of thermal activity. The seismographs will be properly calibrated so that we can obtain the compression-rarefaction distribution of the initial phase of the P wave for source motion study. Now, if we notice that the epicenters are concentrated in a given area and also that the compression rarefaction distribution shows a consistent pattern for a large number of earthquakes, we will proceed to source motion study using S waves. For this we shall take three

Task Title	Microseismic Surveys	Task No. 2.4
Task Details		

seismographs and put them together to form a single 3-component station. Two of the vertical geophones will be replaced by horizontal geophones. We can have only two such stations, but if these two are properly distributed, we can obtain sufficient data for source motion studies.

If the seismic survey shows a concentration of epicenters in the same area where electrical resistivity shows an upwelling of the fresh water-salt water interface, we have added evidence for thermal activity. At this stage, we proceed to seismic noise survey.

Seismic Noise Survey

If there is thermal activity in any spot, in addition to microearthquakes, we can expect microseisms, or ground noise, to be produced. These can be produced by convective motion of the ground water, boiling of the water and flexure of the rocks.

We do not know the spectral distribution of microseism due to thermal activity. As the initial stage of this survey, we shall take measurements at known areas of thermal activity near Kilauea Volcano. We shall make frequency analysis of these records to get a "signature" of the ground noise.

For the seismic noise survey, the instruments will be quite different from the seismicity study. We propose to use tape recordings, and the recording will be done in FM format. The instrument package will consist of a geophone, amplifier, a frequency modulator and a tape recorder. The prototype of this package is being built at the Hawaii Institute for Geophysics and will be tested in a few weeks.

For the spectrum analysis, the tapes will be played back through a frequency analyzer resulting in a "sonogram" which gives time in the abscissa, frequency in the ordinate and relative amplitudes in various shades of contours. Such equipment is available at the Hawaii Institute for Geophysics.

Once the "signature" of thermal activity is known, we can seek similar signatures in the suspected thermal area. This will be another added evidence in search of thermal activity.

Seismic Observations by Arraip

In the program for hat flow measurements, 40 holes 300 feet deep will be drilled. Thermistors will be placed at the bottom of the holes and also at 100 feet intervals to measure the heat flow. Six of these holes will be selected in order to put geophones into them in addition to the thermistors.

Task Title	Microseismic Surveys	Task No. 2.4

Task Details

As the diameter of the holes are not too large, we can put only 4 cps geophones into them. We propose to put three components down the hole, one vertical and two horizontal, and have the package oriented so that the horizontal geophones are in north-south and east-west direction.

Signals from the geophones will be channeled to a central recording office. The data will be processed with the aim of seeing the behavior of the seismic pattern as the nearby area is disturbed by drilling and extraction of steam and water.

This part of the geophysical program will not start until the holes are drilled and cased. Hence, we are requesting funding for this in the second year of the project.

This type of seismic observation proposes to investigate the deeper parts of the island. We want to know especially the thermal state of the material. This can be best estimated by observing the decay of S waves from various azimuths. In areas of hot material, we expect the S wave traveling through it to decay much more rapidly than going through a relatively cold area. From such data we expect to outline pockets of hot material under the island.

We do realize that the Hawaii Volcano Observatory maintains a network of stations around the island. We hope to have the cooperation of the Hawaii Volcano Observatory so that we could consult their data to help our analysis. This assurance has been verbally provided by the Director, Dr. Donald Peterson.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility					
Sub-program Manager	Augustine Furumoto					
Task Title	Magnetic Induction Surveys				Task No.	2.5
Investigator	Augustine Furumoto, D. Klein					
Department	Hawaii Insitute for Geophysics					
Budget	Year One	63,401	Year Two	61,440	Total	124,841

Task Summary

Task Description

Loop to loop audio magnetotelluric methods will be used to find resistivity-depth profiles where the dipole method may not work. The personnel of this survey also carry out the magnetic survey.

Project Need

The dipole electrical resistivity method is not very efficient where the surface soil is a very poor conductor. In such places we hope to use electromagnetic methods, specifically, the loop to loop audio magnetotelluric method.

Anticipated Results

From analyzing short time variations in the natural geomagnetic field, Klein has obtained the gross structure of the crust and upper mantle in Hawaii, in terms of resistivity-depth profile. The electromagnetic surveys as proposed here will have finer resolution and this should locate the vents through which the hot mantle material comes up into the crust and onto the surface.

Loop to loop audio magnetotelluric method should give us the resistivity-depth profiles in areas where the dipole method is not efficient.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility				
Sub-program Manager	Augustine Furumoto				
Task Title	Thermal Well Survey			Task No.	2.6
Investigator	Agatin T. Abbott				
Department	Geology				
Budget	Year One 168,658	Year Two 29,408		Total 198,066	

Task Summary

Task Description

An array of 40 holes, each 300 feet deep, will be drilled over the test areas near Kilauea and Hualalai to measure heat flow. There will be three thermistors in every hole. Of these holes, six will have three component seismometers at the bottom to also use the holes as a seismic array.

Project Need

The pattern of heat flow is not known and we must investigate. We are seeking areas where heat flows are high.

It is thought that seismometers are more efficient at depth, because ground noise will be attenuated. The depth also permits more reliable thermal records by virtue of the elimination of surface thermal anomolies.

Anticipated Results

After knowing the heat flow pattern, we will be able to determine what type of surface geophysical surveys can give us a good picture of the heat flow pattern.

Also, the seismic array will give us a picture of the deep hot area pattern.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility		
Sub-program Manager	Augustine Furumoto		
Task Title	Deep Drill	Task No.	2.7
Investigator	Kenneth Brunot		
Department	Consultant		

Budget	Year One	Year Two	Total
		863,500	863,500

Task Summary

Task Description

A first hole as deep as 12,000 feet will be drilled the second year at a site selected for most advantageous geophysical and geological data and proximity to the most productive natural conditions to support laboratory efforts. The drilling will recover oriented core samples which can be used for petrologic, paleomagnetic, hydrologic and physical property studies.

Project Need

Geophysical data from future surveys will have more reliable meaning if they are correlated to actual samples from depths in areas similar to future development prospects.

Anticipated Results

Correlation of geophysical data with core samples will tell us the meaning of data in terms of actual geology. Henceforth, then, reconnaissance surveys will be more meaningful.

A major item in the PELE laboratory effort is an exploration well. It is predicated upon a number of scientific premises and needs. The primary need is to know the precise nature of deep geologic structures underlying

Task Title	Deep Drill	Task No. 2.7

Task Details

relatively new volcanic areas. This need is great and is not satisfied by any previous investigation. In the Hawaiian Archipelago, previous drilling has been confined to shallow investigations to prove water resources, and one previous shallow drilling venture purporting to investigate possibilities of geothermal steam in an area of quite recent volcanic intrusion. Some data from these experiences are superficially useful. However, they do not provide the kind of controlled and deliberately-recorded facts necessary to support scientifically credible conclusions. In summary, the requirement that a sufficiently deep section be explored is in no way addressed by existing experience.

The decision to drill a deep well has been the result of extensive consultation with local, national, and international authorities. The correlative value of the deep well as a base line data against which to compare surface and shallower tests also will have immense significance.

From this consultation experience it is credible to assume that the findings and facts available from drilling records and rational deductions therefrom will constitute a quite attractive scientific base from which a broad spectrum of conceivable peripheral scientific efforts may be initiated. These would be possible in addition to the pragmatic solutions to the existing mysteries and conflicting scientific opinion about the nature and potential of newly formed volcanic areas vis-a-vis energy resources.

The most recent, and presently active, volcano in the Hawaiian Archipelago is Kilauea, within which is a large subsidence crater containing a smaller subsidence crater called Halemaumau which is the center surface manifestation of the most recent very large-magnitude magma intrusion indicating long-term thermal recharge of the underlying geological structures.

A drill hole within the National Park has been proposed by one investigator to a depth of 3,000 feet (Dr. George Keller, Colorado School of Mines). Input from this investigation would also be used to determine location of this deeper drilling, as well as technique detail.

Extensive consultations have resulted in a tentative choice of drilling technology and specifications relating to minimizing cost while achieving the greatest return within environmental and scientific result constraints.

If the Kilauea location is chosen, the well would be located at an elevation of 4,000 feet above sea level and would be programmed to penetrate the lava beds to a true vertical depth of 6,000 feet sub sea. Some 2,000 feet of directional drilling is envisioned which would constitute a total drilled depth of 12,000 feet. However, all considerations of depth, location, and other drilling parameters will be finalized after extensive surface and shallow drilling tests are performed and findings evaluated. If the location were at a lower elevation, drilling depths would be reduced accordingly.

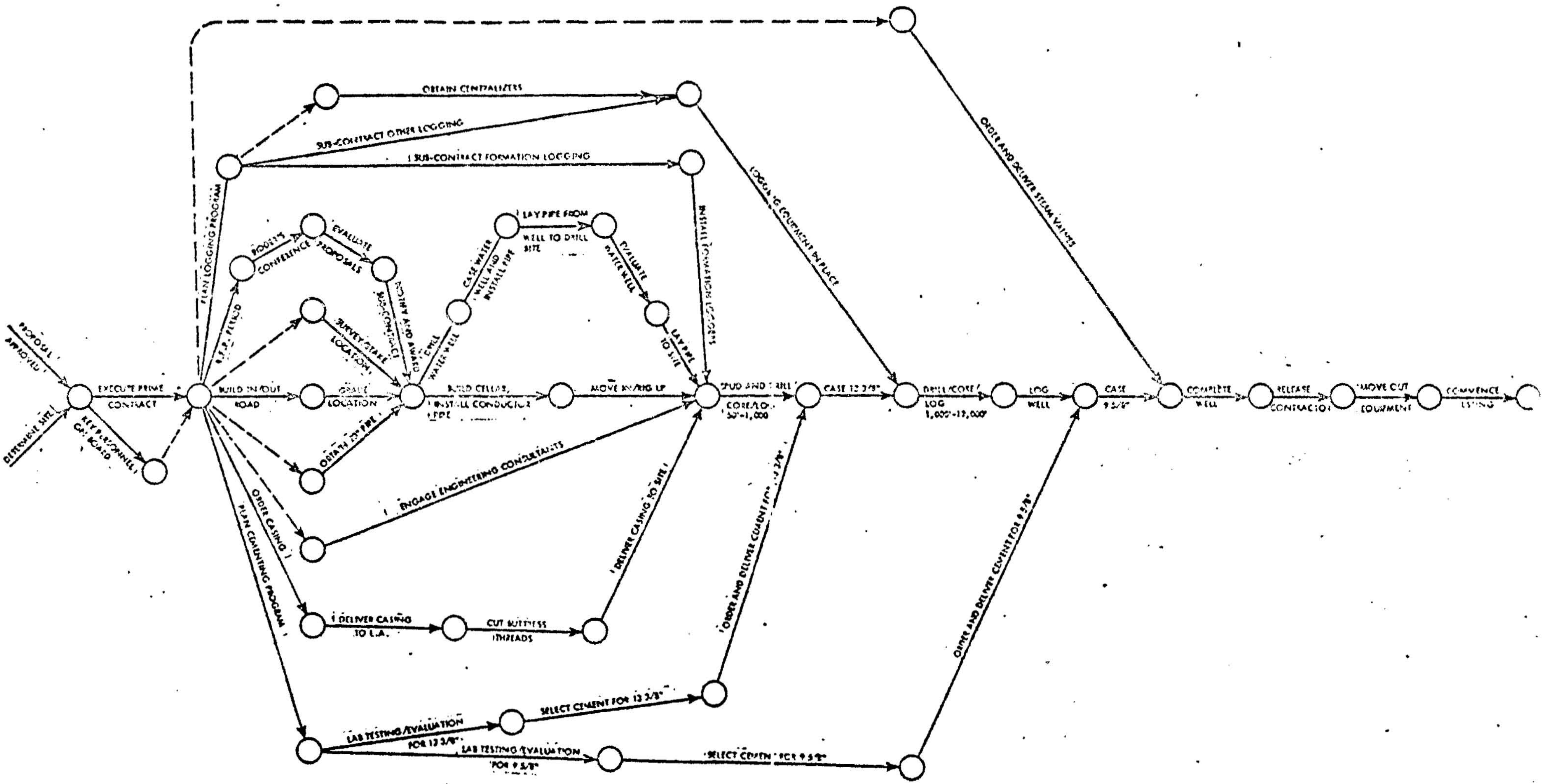
Task Title	Deep Drill	Task No. 2.7

Task Details

A surface 13-3/8 in. casing string will allow for drilling a 12-1/4 in. hole to a total depth and completing with a 9-5/8 in. string, if required, and completing the well with 8-3/4 in. hole and 6-5/8 in. casing.
12 in. series 900 bag and Double-Rams blow out preventors will be utilized during the drilling operations.

Current shallower drilling practices in the islands utilize compressed air. Since the stratigraphic section to be penetrated is not expected to sustain a hydrostatic column of water, air drilling will be programmed with a standby liquid mud system made up and ready for use in the event the need arises.

Order and relative nature of items of work priorities and constraints are illustrated in the following critical path drawing.


PROPOSAL APPROVED
DETERMINE SITE
EXECUTE PRIME CONTRACT
KEY PERSONNEL ON BOARD
PLAN LOGGING PROGRAM
OBTAIN CENTRALIZERS
SUB-CONTRACT OTHER LOGGING
SUB-CONTRACT FORMATION LOGGING
R.F.P. PERIOD
BIDDERS CONFERENCE
EVALUATE PROPOSALS
NOTIFY AND AWARD SUB-CONTRACT
SURVEY STAKE LOCATION
BUILD IN/OUT ROAD
GRADE LOCATION
DRILL WATER WELL
CASE WATER WELL AND INSTALL PIPE
LAY PIPE FROM WELL TO DRILL SITE
EVALUATE WATER WELL
LAY PIPE TO SITE
INSTALL FORMATION LOGGERS
BUILD CELLAR, INSTALL CONDUCTOR PIPE
MOVE IN/RIG UP
ENGAGE ENGINEERING CONSULTANTS
ORDER CASING
DELIVER CASING TO L.A.
CUT BUTTRESS THREADS
DELIVER CASING TO SITE
PLAN CEMENTING PROGRAM
LAB TESTING/EVALUATION FOR 13 3/8"
LAB TESTING/EVALUATION FOR 9 5/8"
SELECT CEMENT FOR 13 3/8"
SELECT CEMENT FOR 9 5/8"
ORDER AND DELIVER CEMENT FOR 13 3/8"
ORDER AND DELIVER CEMENT FOR 9 5/8"
LOGGING EQUIPMENT IN PLACE
ORDER AND DELIVER STEAM VALVES
SPUD AND DRILL CORE/LOG 50'-1,000'
CASE 13 3/8"
DRILL/CORE/LOG 1,000'-12,000'
LOG WELL
CASE 9 5/8"
COMPLETE WELL
RELEASE CONTRACTOR
MOVE OUT EQUIPMENT
COMMENCE TESTING

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility				
Sub-program Manager	Augustine Furumoto				
Task Title	Geochemical Analyses			Task No.	2.8
Investigator	Bruce Finlayson				
Department	Chemistry, University of Hawaii at Hilo				
Budget	Year One 37,605	Year Two 30,168		Total 67,773	

Task Summary

Task Description

When drilling has started, chemical analyses will be made of hot fluids (gas, steam and water) discharged from boreholes and correlated with geological and geophysical data obtained from these wells with regard to source of the fluids, size of the source and power potential of the source. Materials from the boreholes will also be analyzed with regard to corrosion effects on various alloys.

Project Need

Trace elements give a qualitative idea of the thermal state of the region from which the gases came. Important, quantitative information regarding underground conditions will require collection and study of data from several sources; particularly important will be chemical analysis of borehole discharges. Power plant design will require chemical data on discharges; e.g., amount of gas present affects size of gas extractors for systems making direct use of geothermal steam.

Anticipated Results

Inference from geological study, combined with geological and geophysical data will give us a picture of the subsurface thermal state with respect to temperatures, pressure and power potential from geothermal reservoirs. discovered. Engineering feasibility will use this data to determine design parameters for the power plant. From corrosion studies, we can determine the materials needed for power development and maintenance costs of power plants.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility
Sub-program Manager	Augustine Furumoto
Task Title	Rock Properties — Task No. 2.9
Investigator	Murli Manghnani
Department	Hawaii Institute for Geophysics

Budget	Year One	Year Two	Total
	-	13,402	13,402

Task Summary

Task Description

The goals of the project are to make laboratory measurements of the physical properties, such as porosity, density, thermal conductivity, electrical resistivity, seismic velocities and magnetic susceptibility of the rock samples collected in the field. Effect of porosity on these properties will be investigated.

Project Need

Necessary equipment for carrying out most of the proposed measurements is available. However, some electronic equipment is needed for investigating the thermal conductivity and electrical resistivity of rock specimens.

Anticipated Results

The results will enable us to understand the relationships among the measured physical parameters for several rock types, and the effects of porosity on the physical properties. The results will be most useful in interpreting the field geophysical data, and will aid in locating the dense subsurface rock.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Geophysical Feasibility				
Sub-program Manager	Augustine Furumoto				
Task Title	Model Study and Evaluation			Task No.	2.10
Investigator	Augustine Furumoto, Gordon MacDonald				
Department	Geophysics/Geology				
Budget	Year One	-	Year Two 15,341		Total 15,341

Task Summary

Task Description

After all geophysical data are in concerning Kilauea and Mauna Loa volcanoes, model studies on heat dissipation on the volcanoes will be done. The models will be mostly numerical ones using computers. In the case that is intractable, we shall attempt scale models in the laboratory.

Project Need

The heat budget of the geothermal and volcanic system must be figured out, so that we can estimate the amount of heat that can be exploited and how.

Anticipated Results

We expect to have the answers to the questions posed in Project Need. The answers will be the quantitative part for the Evaluation Project.

From the geophysical field data, we should have a pattern of heat flow. By numerical methods we shall trace down the heat flow pattern to see the energy distribution at depth.

Task Title	Model Study and Evaluation	Task No. 2.10
Task Details		

For years, the staff of the Hawaii Volcano Observatory at Kilauea have kept tilt data and have made some analyses of them. We shall include these data and reports in our study to obtain the energy pattern at depth.

The analysis of heat flow pattern at depth may be intractable numerically. Even if the problem is tractable, a better insight can be obtained by examining a scale model in the laboratory. Hence, some sort of scale model study will be done. The question of displaying the results will be important and for this the Audio-Visual Services will be contracted on a consulting basis.

The model study, both by numerical method and by scale model method, should yield quantitative results so that judgments can be made on geothermal development. The results should indicate the rate at which heat can be extracted from the volcanic system. Environmental impact will also be considered.

The study is primarily designed to answer the questions that the national advisory board and the international advisory board might raise. The study should indicate, after two years, in which directions basic research in volcano energy development should proceed.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Engineering Feasibility				
Sub-program Manager	Howard Harrenstien				
Task Title	Engineering Feasibility Management			Task No.	3.0
Investigator	Howard Harrenstien				
Department	Center for Engineering Research				
Budget	Year One 6,198	Year Two 6,273		Total	12,471

Task Summary

Task Description

This portion of the program considers the engineering and technological feasibility of turning the thermal anomalies of the earth into power producing systems by environmentally nondegrading means.

Project Need

Low-density energy resources, such as are found in regions of geothermal highs, are required as alternatives to other more common energy producing systems involving fossil and nuclear fuels, because of apparent and assumed environmental constraints.

Anticipated Results

It is anticipated that power production systems will be conceptually designed which will produce minimum environmental impact at an acceptable rate of economic benefit, through the conversion of thermal anomalies into electrical power.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Engineering Feasibility		
Sub-program Manager	Howard Harrenstien		
Task Title	Power Generation Systems	Task No. 3.2	
Investigator	James Chou		
Department	Mechanical Engineering		
Budget	Year One 17,460	Year Two 27,693	Total 45,153

Task Summary

Task Description The project will require the principal investigator to study types of power generation systems which might have application to the types of resources that may be encountered in the geophysical exploration.

After familiarization of the critical problems, efforts shall be made to determine the improved designs of the plant and its components in reference to its environmental impact and the cost of power production. In the end, procedures and guidelines shall be established for the design of conventional geothermal power plants under the various conditions which may exist in the United States. The second part is to study unconventional methods of harnessing and utilizing geothermal energy, such as combining the power plant with a sea-water desalting plant and directly converting geothermal heat to energy.

Project Need

There is a need for the development of a local expertise in an understanding of the various possible systems of power production from geothermal and other thermal resources.

Anticipated Results

This project will provide input to projects of system design, systems engineering, material science, heat transfer, and ocean transmission.

Results from this study will lead to the improved design of future plants in this nation as well as many developing countries of the world. A reliable evaluation of economic feasibilities of developing geothermal energy depends upon the engineering analyses to be carried out in this study.

Task Title	Power Generation Systems	Task No. 3.2

Task Details

The technological and economic feasibility of producing electricity from geothermal energy is a proven fact in Italy, the United States and New Zealand. The fields in Italy and the United States produce dry steam which is then used in conventional power plants. The field at New Zealand is a wet field, the hot water must be flashed before it can be used in the plant. The development in Hawaii (assuming Hawaii has one or the other field) should follow along similar lines.

Another type of field that has potential for development is the hot water field. In these fields the temperature of chemical composition of the water is not suited for flashing. These fields require the use of binary-fluid power cycles. The "Magnamax" designed by Rogers Engineering Company in the United States, and a flurocarbon turbine (presently on line) built by Ishikawa-Harima Heavy Industrial Company of Japan, are designed or can be adapted for this kind of field.

The fourth type of field is the dry hot rock field that to date has received only limited attention. In this field the rock must be fractured either by explosives or hydraulically, and water injected to produce steam or hot water. The American Oil Shale Corporation and the U.S. Atomic Energy Commission, in a joint venture, proposed this system using nuclear explosives for fracturing the rock. Other rock fracturing methods should also be investigated and experimental work should be performed to determine the technical feasibility of producing steam from hot fractural rock injected with water.

The proximity to deep ocean cold water at 41° suggests that studies be made combining this resource with the geothermal resource for increased efficiency. Preliminary calculation of Carnot efficiency shows that for the low temperature field, this process is not effective, however.

The engineering task of PELE will be to become familiar with all of the geothermal power production processes. An additional task that is mandatory is that all of the processes be designed for zero environmental impact. This means that <u>before any equipment is installed, the design must show minimal environmental degradation</u>.

The engineering task will be carried out by establishing a central information center for all types of power production processes and techniques. Where needed, on-site inspection of plant operation will be made and conferences with other experts held.

TABLE 3.2.1

Carnot Efficiency of Some ΔT (η)

$$\eta = \left[1 - \frac{TL}{TH}\right] \times 100\%$$

TH °F/°R	η_I TL_C = 80°F/540°R	η_I TL_A = 45°F/505°R	Δη
1000/1460	63%	65.4%	2.4%
900/1360	60.3%	63%	2.7%
800/1260	57.2%	60%	2.8%
700/1160	53.5%	56.5%	3.0%
600/1060	49%	52.4%	3.4%
500/960	43.7%	47.4%	3.7%
400/860	37.2%	41.2%	4.0%
300/760	29%	33.5%	4.5%
200/660	18.1%	23.5%	5.4%
100/560	3.5%	10%	6.5%

The Carnot cycle is the maximum efficiency cycle between TH and TL.

TL_C ≡ Conventional surface water
= 80°F

TL_A ≡ Deep cold water
= 45°F

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Engineering Feasibility				
Sub-program Manager	Howard Harrenstien				
Task Title	Ocean Transmission			Task No.	3.3
Investigator	Henry Hwang, Bertil Granborg				
Department	Electrical Engineering				
Budget	Year One 30,070	Year Two 48,486		Total 78,556	

Task Summary

Task Description

To develop an effective system for transmitting electric energy across channels from the Island of Hawaii to Maui, Molokai, Oahu, and Kauai.

After analytical study, a laboratory model system will be set up to simulate the practical situation. Results of experimental study will be analyzed and used for designing the practical transmission system linking the five islands of Hawaii across separate channels.

Project Need

Geothermal potential of certain islands may be lacking or insufficient for demands. A network of inter-tied transmission links would provide a means of distribution in the deficient island or islands.

Anticipated Results

Experimental and analytical studies will provide the following information:

1. The feasibility of a transmission system linking the five islands across the Pacific Ocean.
2. The effectiveness of the system.
3. The technical know-how of the system operation.
4. The design of the system.
5. Relevant problems and possible solutions pertaining to the system operation.

Task Title	Ocean Transmission	Task No. 3.3

Task Details

The present state-of-the-art of high voltage DC underwater transmission can be advanced to suit the requirements of power transmission between the Hawaiian Islands. For instance, five different installations around the world are presently in operation with 100-250 kv voltage, 30-600 mw power and underwater cable distances of 25 to 60 miles. Most of these transmission systems containing mercury are rectifier-inverter arrangements with sufficient reactive power generation. The control of power flow and reversible power flow is maintained without interruption of service. Recent solid state rectifier-inverter techniques have resulted in thyristor developments where one single unit may carry as much as 3,000 A and 150,000 volts. This would be 450 mw power or the present generating capacity of the Island of Oahu. The use of thyristors would be advantageous for the Hawaii development because solid state devices are simpler to control and maintain than the mercury arc rectifiers. Estimated transmission distances under water for the Hawaii system are:

Oahu-Molokai	20 miles
Molokai-Maui	7 miles
Maui-Hawaii	25 miles
Oahu-Kauai	65 miles

It would be desirable to create a transmission model of the Hawaii system to study the system. Several different choices exist concerning DC underwater and overhead transmissions mixed with AC land transmissions. The control of power flow and the communication links of the control system should be subject to specific research because of the unique features of the system. Also, stability problems of a mixed DC-AC system must be subject to research.

A parallel development should use digital or analog/hybrid computer models for the study. The model systems should be studied by experiments. The results of the experiments will be analyzed and used to design a best system for practical use.

Task Title	Ocean Transmission	Task No. 3.3
Task Details		

Selected References:

1. CLIFFORD, J.F. and SCHMIDT, "Digital Representation of DC Transmission System and its Controls", IEEE Trans. on Power and Systems, 80, January, 1970, pp. 97-105.

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9. LARU, A.U., "High Voltage DC Transmission General Background and Present Technical Status", IEEE Trans. on Power Apparatus and Systems, January, 1964, p. 62.

10. PETERSON, H.A., PADKE, A.G. and RETAIN, D.K., "Transient in EHVDC Power Systems", Part I - Rectifier Fault Currents, IEEE Trans. on Power Apparatus and Systems, 88, July, 1969, p. 981.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Engineering Feasibility		
Sub-program Manager	Howard Harrenstien		
Task Title	Engineering Design	Task No. 3.4	
Investigator	Deane Kihara, David Harada		
Department	Mechanical Engineering		
Budget	Year One 25,665	Year Two 38,155	Total 63,820

Task Summary

Task Description

Parametric study of power plant cycles which are designed to utilize low temperature heat sources, such as those encountered in geothermal fields, and other volcanic thermal anomalies. Technology forecasting in the way of plausible engineering designs which meet all known scientific and socio-economic-environmental constraints.

Project Need

Engineering feasibility studies to parallel efforts in the geothermal exploration area should be initiated now in order that the results of these efforts can be meshed and evaluated as soon as they become available. There is a need by all groups for a series of engineering design possibilities in order that their effect on societal, economic, and environmental models might be assessed.

Anticipated Results

A computer simulation model which can be used to predict engineering and operating characteristics of a desired design and its compatibility with available geothermal heat source. The ultimate production of a conceptual design for a power plant utilizing the better qualities of the discovered resource in a way which would not produce undesirable side effects on the socio-economic-environmental system.

One example of the type of parametric study possible is that performed on the dry hot basalt field. The generation of power from a dry hot basalt field requires that the rock be fractured and that a fluid be injected to generate superheated vapor. Preliminary calculations made show that by fixing certain parameters the volume of fractured region can be calculated, assuming the field can be uniformly cooled a certain increment, ΔT in these calculations. The following assumptions were made to simplify the calculations:

1. Average specific heat, 0.20 BTU/lb - ^{o}F;

2. Average usable heat 25 percent, i.e., only 1/4 of the heat can be used in power production;

3. Average density, 184 lb/cu ft;

4. The field has a life of 20 years;

5. Generation of 10 megawatts (M.W.) of electricity.

The fractured region is assumed to be insulated from the surrounding medium. This is justified by considering the low thermal conductivity (k) of basalt.

T (^{o}F)	k(B/ft - ^{o}F)
212	1.73
930	1.33
1652	0.87

Table 3.1, Temperature vs Thermal Conductivity

The 20-year life of the field is an economic consideration and is necessary in determining economic feasibility. 10 M.W. at a 25 percent efficiency for 20 years requires a total of 23.9 x 10^{12} BTU of heat. The results of calculations shown in Fig. 3.1 show the volume of fractured rock required for different temperature increments.

Two physical configurations, the sphere (Fig. 3.1) and the cylinder (Table 3.2), show the dimensions of the fractured volume required. The configuration is determined by the fracturing technique used, i.e., explosives for the sphere, hydraulic cracking for the cylinder.

Task Title	Engineering Design	Task No. 3.4

Task Details

These preliminary calculations suggest that a family of curves can be generated varying the other parameters, assumed constant in these calculations. A computer program would best carry the task out varying properties of basait and other mediums. Given certain conditions the amount of fractured volume needed would be given in table or graph form.

L, ft	$\Delta T=1000^{o}F$ $V=6.5x10^8$ $Rx10^3$, ft	$\Delta T=750^{o}F$ $V=8.66x10^8$ $Rx10^3$, ft	$\Delta T=500^{o}F$ $V=13x10^8$ $Rx10^3$,ft	$\Delta T=250^{o}F$ $V=26x10^8$ $Rx10^3$,ft
100	1.44	1.66	2.03	2.83
200	1.02	1.16	1.44	2.03
300	.88	.96	1.28	1.66
400	.72	.88	1.02	1.44
500	.65	.74	.91	1.28

Cylinder Length, Radius for Various ΔT

Table 3.2

10 M.W. Plant
25% Total Efficiency
0.20 Specific Heat Basalt
184 lb/c.f. Density

ΔT °F	$V \times 10^8$ c.f.
1000	6.5
750	8.66
500	13.0
250	26.0

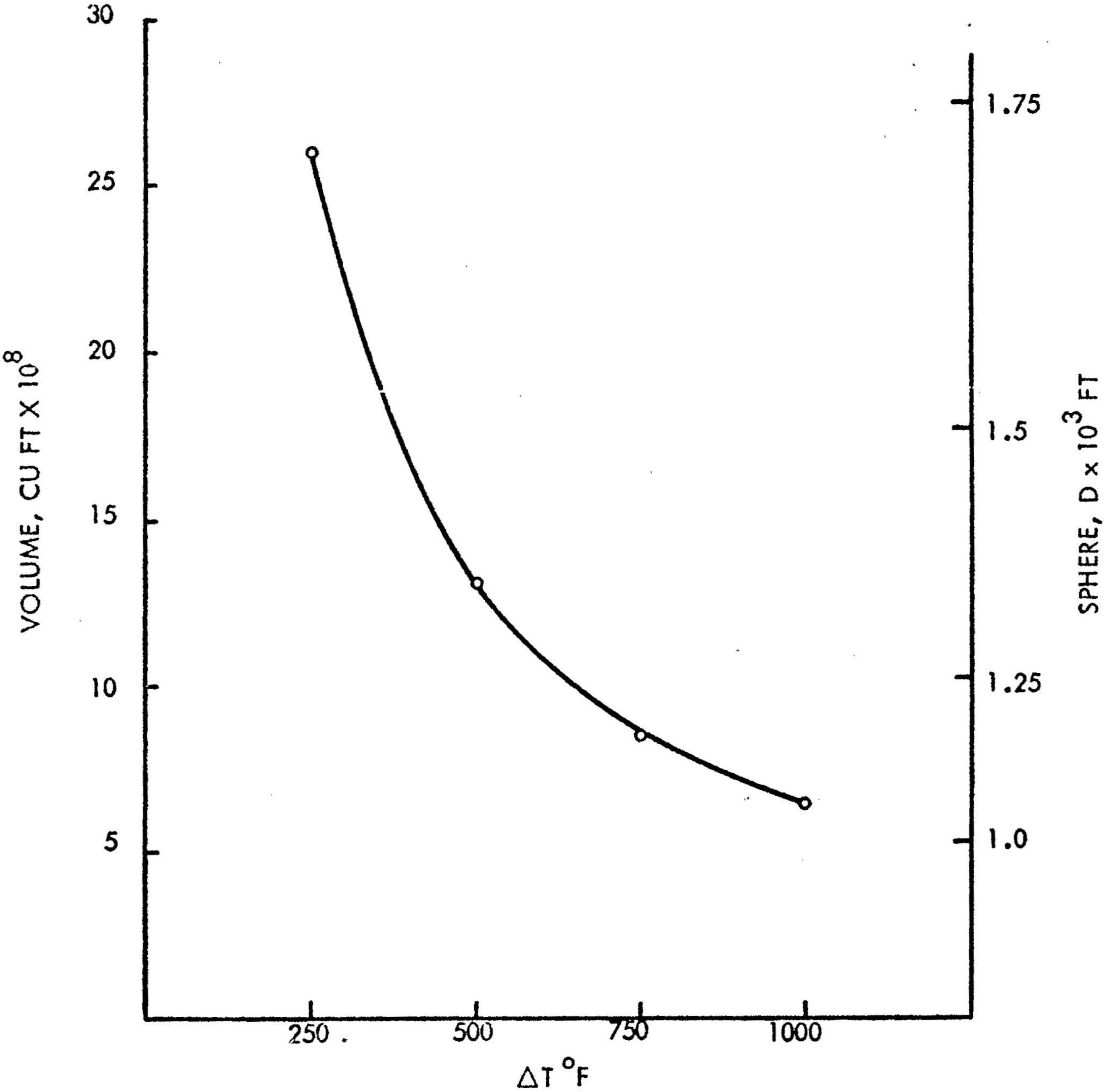

Figure 3.1

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Engineering Feasibility				
Sub-program Manager	Howard Harrenstien				
Task Title	Materials Research			Task No.	3.5
Investigator	Jorn Larsen-Basse				
Department	Mechanical Engineering				
Budget	Year One 73,099	Year Two 34,710	Total 107,809		

Task Summary

Task Description

Empirical studies of hot corrosion, erosion, and mechanical properties of candidate materials will be undertaken in typical lava melt composition.

Project Need

A comprehensive knowledge of the properties of candidate materials for use in working in semi-solidified or liquid lava is necessary if these geothermal fields are to be considered for power production.

Anticipated Results

Research will show what state-of-the-art materials can be used effectively when working in the high temperature and the highly corrosive gases encountered in lava pools and reservoirs. Criteria for the development of new materials, more capable of functioning in the geothermal environment will be presented.

Task Title	Materials Research	Task No. 3.5
Task Details		

The purpose of this part of the program is to make a preliminary study of the compatibility of various candidate materials for heat exchange applications with flowing liquid lava. It is intended to initially concentrate on corrosion and especially on erosion of materials, in order to capitalize on the principal investigator's rather extensive background in wear phenomena and behavior of surfaces of materials. M.S. degree in mechanical engineering within this program could, for example, fall into the following areas:

- influence of composition and microstructure on rates of solution of high temperature in silicate melts;
- relationship between creep parameters and high temperature erosion;
- relationship between parameters of the liquid-temperature, viscosity density, velocity, etc., and high-temperature erosion;
- influence of temperature and composition on the viscosity of lavas; and
- creep behavior of solid lava at high temperature.

Proposed Experimentation

Initial studies will be based on weight-loss determinations and optical microscopy of materials immersed for various times and at various temperatures in crucibles containing liquid lava. Secondly, dishes of materials showing initial corrosion resistance will be spun at various velocities in liquid lava. The rate of corrosion-erosion will be determined by weight-loss measurements and the nature of the attack by optical microscopy. Auxiliary investigations include the hardness and creep of the metals used, viscosity and composition of the lavas, and composition of the corrosion products.

Initial materials groups for testing include austenitic stainless steel, nickel alloys, some cobalt superalloys, poly-crystalline SiC and refractory metals such as W, Mo and Ti.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Engineering Feasibility		
Sub-program Manager	Howard Harrenstien		
Task Title	Systems Engineering	**Task No.** 3.6	
Investigator	Walter Arnell, Anthony Yen		
Department	Center for Engineering Research, Electrical Engineering		
Budget	**Year One** 12,739	**Year Two** 21,855	**Total** 34,594

Task Summary

Task Description System analysis of the many aspects of a complete power production and by-product recovery system, including distributary networks.

Initially in the first year this position will assist in identifying, defining, and coordinating technological areas necessary as part of assessing feasibility for the systems integrative process for obtaining power from the extraction of energy from volcanic lava.

As the program matures regular reports of technological progress from the various specialties will be assessed, forwarded in toto or in summary to those areas where communication is mandatory for response to the needs of PELE's goal.

Project Need

There is a need for a continuous evaluation and methodology developing process which will allow tradeoffs of a technological nature to be considered.

The project requires monitoring of the various technical specialties involved in order to constantly re-evaluate systems integration and optimization within the time frame of the project. Such a requirement must obviously be accomplished within the framework of the uniqueness that the Hawaiian geothermal environment has to offer.

Anticipated Results Advice and counsel on which alternatives seem most feasible as technological solutions to the problem of generating power and by-products in non-polluting fashion.

It is anticipated that specific areas of technological research and design will be defined which are necessary for the extraction of power from the geothermal sources unique to the Hawaiian environment. At the same time priorities will be given for research in these areas which when optimized will produce an operable power system for the use of geothermal heat in conjunction with cold deep-ocean nutrient rich sea water at the earliest possible time. This information will be presented in a series of reports and will also indicate budget needs to pursue PELE to its earliest conclusion.

Task Title	Systems Engineering	Task No. 3.6

Task Details

An example of a sub-system within the Systems Engineering Task would be incorporation of an evaluation technique called the "Simplex Method". Use of the simplex method to assist in determining high heat areas for purpose of drilling locations may be described as follows.

Let us introduce the following notation, where f is temperature; x location axes:

1) x_h is the vertex which corresponds to $f(x_h) = \max_i f(x_i)$, where $i = 1,2,\ldots,n + 1$.

2) x_s is the vertex which corresponds to $f(x_s) = \max_i f(x_i)$, $i \neq h$.

3) x_l is the vertex corresponding to $f(x_l) = \min_i f(x_i)$, where $i = 1,2,\ldots,n + 1$.

4) x_0 is the centroid of all $x_i, i \neq h$ and is given by

$$x_0 = \frac{1}{n} \sum_{\substack{i=1 \\ i\neq h}}^{n+1} x_i .$$

We now define the three basic operations used in the method:

1) Reflection, where x_h is replaced by

$$x_r = (1 + \alpha)x_0 - \alpha x_h,$$

where the reflection coefficient $\alpha > 0$ is equal to the ratio of the distance $[x_r x_0]$ to $[x_h x_0]$.

2) Expansion, where x_r is expanded in the direction along which further improvement of the function value is expected. We use the relation

$$x_e = \gamma x_r + (1 - \gamma)x_0,$$

where the expansion coefficient $\gamma > 1$ is the ratio of the distance $[x_e x_0]$ to $[x_r x_0]$.

3) <u>Contraction</u>, by which we contract the simplex,

$$x_c = \beta x_h + (1 - \beta)x_0,$$

where the contraction coefficient β is the ratio of the distance $[x_c x_0]$ to $[x_h x_0]$ and satisfies $0 < \beta < 1$.

As we have mentioned, the method can be viewed as the moving, shrinking, and expanding progress of the simplex method toward the minimum. This motion is accomplished in the following way.

i) An initial simplex is formed, and the function is evaluated at each of the vertices in order to determine x_h, x_s, x_l, and x_0.

ii) We first try reflection and evaluate the function at the reflected point x_r.

iii) If $f(x_s) \geqq f(x_r) \geqq f(x_l)$, then we replace x_h by x_r and restart the process with the newly formed simplex.

iv) However, if $f(x_r) < f(x_l)$, we may expect that the direction $x_r - x_0$ could give us an even lower value of the function if we move further. Therefore we expand our new simplex in this direction. The expansion succeeds if $f(x_l) > f(x_e)$, and in this case x_h is replaced by x_e. In the case of failure x_h is replaced by x_r, and in either case we restart the process from our new simplex.

v) If the reflection move (ii) yields x_r, such that $f(x_h) > f(x_r) > f(x_s)$, we replace x_h by x_r and make the contracting move. (This replacement is not executed when $f(x_r) > f(x_h)$.) After the contracting move we compare $f(x_h)$ and $f(x_c)$.

If $f(x_h) > f(x_c)$, we consider that the contraction is successful, x_h is replaced by x_c, and we start from the new simplex.

In a case of failure, i.e., $f(x_h) \leq f(x_c)$, the last simplex is shrunk about the point of the lowest function value x_l by the relation

$$x_i := \frac{1}{2}(x_i + x_l),$$

and we begin from (i).

To demonstrate the simplex technique for selecting drill locations, consider the thermal area of Wairakei in New Zealand where thirty-six holes were drilled and temperature profiles were prepared from these data. Locations of the drilled holes and temperature section are shown in Figs. 1 and 2. The high temperature center (A) is indicated in Fig. 2.

To find the high temperature center, assuming the simplex method is used, suppose that the first three holes drilled are nos. 15, 16, and 17; then the next choice by "Reflection" is hole no. 21. By comparing temperature at no. 21 and the previous three holes, the method indicates "Expansion" and would indicate a location between hole nos. 8 and 20, or close to the Center of (A).

In this process only five holes are needed to locate the area of (A).

Suppose the starting point is far from (A) such as hole nos. 1, 2, and 33 (or 34), then the simplex method will indicate no. 14 (or 19) as optimal choice by "Reflection"; one more stage of search will probably indicate a location near center of area (A). The above two procedures were shown in dotted lines.

Task Details

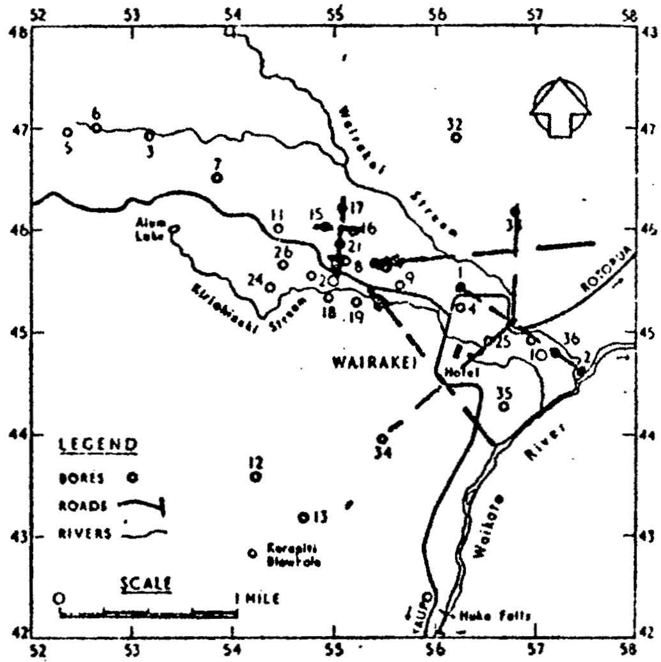

Figure 1

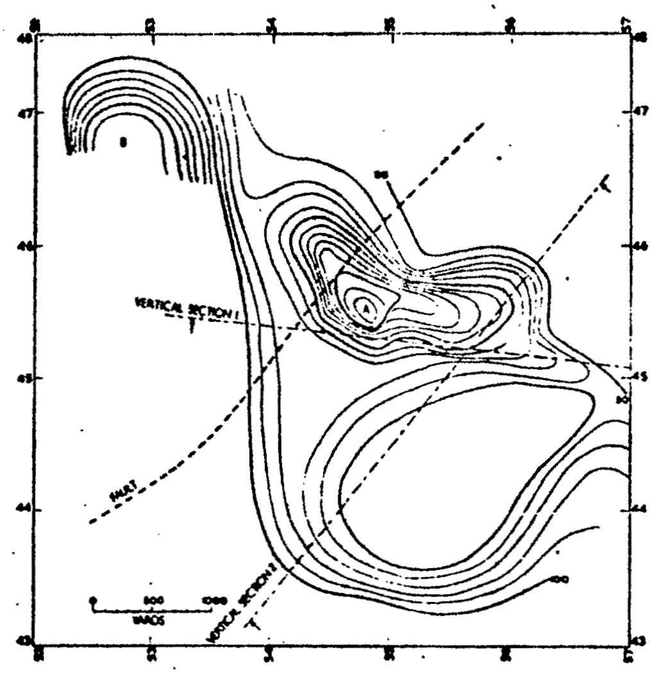

Figure 2

(from Banwell and Hutt, ASME Transaction, Jan., 1957, p. 260)

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Socio-Economic Feasibility				
Sub-program Manager	Robert M. Kamins				
Task Title	Socio-Economic Feasibility			Task No. 4.0	
Investigator	Robert M. Kamins				
Department	Economics				
Budget	Year One 17,086		Year Two 17,430		Total 34,516

Task Summary

Task Description

Study and identify societally oriented elements predictably affected by technological results of PELE, or controlling PELE operations, or indirectly involved in either a controlling or effective role so as to constitute an important societal or project impingement.

Project Need

In past, technologically oriented work has taken little account of more than the bare scientific possibility. PELE intends to address the need to account in advance for the implications to societal organization, of the changes and other effects and controls implicit in use of new technologies developed in the course of investigations.

Anticipated Results

The result should include more ready public understanding so as to receive the benefit of guidance arising out of public interest. By predictive and early understanding of probable socio-economically controlling elements, early adjudgment of project operations will be possible to provide more appropriate overall results.

Task Title	Socio-Economic Feasibility	Task No. 4.0

Task Details

Socio-economic effects and controls will be evaluated through four general study categories:

1. Land use will encompass societal impingements, legal and environmental factors as well as economic feasibilities effected by use of land and restraints imposed through societal considerations. (Project 4.1)

2. Legislation requirements will be definitively determined and a specific code recommended. Throughout this process the public will be directly and indirectly involved. (Project 4.2)

3. Planning will encompass study of societal needs predicted and existing in order to bring about orderly realization of the benefits of technological findings. (Project 4.3)

4. Economic factors effecting the society from employment of technological findings in PELE and controlling economic elements operations and later feasibility of PELE findings, will be evaluated through predictive models. Ancillary effects and controlling elements will be evaluated on a reactive basis throughout the life of the program. (Project 4.4)

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Socio-Economic Feasibility				
Sub-program Manager	Robert M. Kamins				
Task Title	Land Use Ramifications			**Task No.** 4.1	
Investigator	George Sheets				
Department	Center for Engineering Research				
Budget	**Year One** 9,823	**Year Two** 17,302	**Total** 27,125		

Task Summary

Task Description

To study, identify, and correlate relationship between the State of Hawaii laws and the counties of Hawaii laws and regulations vis a vis the development of geothermal energy in the State of Hawaii; to also evaluate the land use requirements of the proposed project and make necessary arrangements.

Project Need

At present the State of Hawaii has no specific laws relative to geothermal (or oil and gas) technology. Existing laws which are relevant relate to mining. The state-wide land use law together with the mandatory reservation of mineral rights on State-land conveyances, creates unique legal posture which will require unique solutions. These solutions will be assisted by experience from other jurisdictions which will be useful both in recommending regulations and in defining project land requirements.

Anticipated Results

This effort should result in more orderly exploration and development of geothermal technology for the benefit of the people of Hawaii, and on a National level, through means of a more definitive body of law and regulations developed, and recommended as far as possible before, rather than after the fact, of operational exigencies. Arrangement activities relating to use of land for Project PELE will offer operational activities from which specific opportunities will arise to exercise items of regulatory device.

Task Title Land Use Ramifications	Task No. 4.1

Task Details

Local and National Regulation

The State of Hawaii enjoys land use laws unique in the United States. The statewide land use law is seen as a model by many states, and even the Federal Government, in pending legislation. However, this body of law makes no specific provision for geothermal technology. The Hawaii code relating to mineral rights, while broad enough to embrace the area, would create an atmosphere of doubt leading to delay and undue litigation in any future in any future climate of geothermal development interest. Nationally the problems are solved by relating oil and gas legislation to geothermal technology. Even this means has been fraught with inadequacies.

Coming at a time of environmental awareness, and possibly because of same, the most carefully couched and complete regulation of operations and business relations relevant to geothermal technology, and land use techniques and effects, must be researched and regulations recommended. These regulations must have the advantage of all existing legal precedent and technological feasibilities as well as operational exercise.

Through consultation with national and regional experts with the best present legal experience in the field, and close touch with the technology of project PELE in Hawaii and other world wide technological projects, a valuable interrelated body of knowledge can be assembled and recommended, the usefulness of which will be felt in all jurisdictions following the common law system of jurisprudence.

Recent contacts with representatives of the California Oil and Gas Commission, and familiarity with their experience in regulating geothermal operations, has tended to give focus to the Hawaii and the national problem. All indications are that the study described herein should be initiated as early as possible, as a national need.

Project Land Use

Hawaii may be generally characterized, relatively, as having very little federal land not under military control, a large proportion of state land, and a quite large proportion of ownership of large blocks of land in private hands such as eleemosynary and other private trust devices. The largest of the latter form is the Bernice P. Bishop Estate. This estate owns the land not only in the area of prime interest to initial PELE operations; but also the area of secondary timeliness is quite nearby to a large parcel of B.P. Bishop estate. Contacts have been initiated with the trustees and their agents to the purpose of acquiring consent to enter and use these locations. Early indications are quite positive to the point of arranging further conferences with current lessee occupiers, who are expected to also react positively

Early contacts with state and county officials are also positive, but hearings on use permit applications will be necessary in all cases before appropriate local regulating authorities. These responsibilities are also included within the scope of this task proposal.

Task Title	Land Use Ramifications	Task No. 4.1

Task Details

The interesting historical-legal question remains as to the status of private ownership of mineral rights in the state (in view of the mandatory reservation required in Hawaii statutes) is raised by reason of the fact that Hawaii monarchs all claimed complete title to all Hawaii land. This plus the fact that all private Hawaii land holdings (including the estates) derive from the monarchs and/or from the state, raises the need to consider the Organic Act making Hawaii part of the United States and other relevant historical/legal materials. These studies will result in suggested legislation and ordinances in Hawaii, as well as guidance and recommendations for operations and regulation on a national basis.

The following letter indicates the attitude of the largest private land owner in the State.

OFFICE OF THE TRUSTEES
519 Halekauwila Street
P. O. Box 3466
Honolulu, Hawaii 96801
Telephone 531-1684
Cable: PAUAHI

KAMEHAMEHA SCHOOLS / BERNICE PAUAHI BISHOP ESTATE

March 24, 1972

Mr. George M. Sheets
Land Use Coordinator
Center for Engineering Research
University of Hawaii
2565 The Mall
Honolulu, Hawaii 96822

Dear Mr. Sheets:

Request for Easement re Geothermal Power, Lease 11,777, Keauhou, Kau, Hawaii

The Trustees, at their meeting held March 23, 1972, noted with considerable interest your request as it relates to an easement for investigation of geothermal potentials on the island of Hawaii. The Trustees voted to cooperate with you to the extent allowable under Bishop Estate Lease No. 11,777 as long as your contemplated use is compatible with the use of adjoining Bishop Estate lands.

As you are aware, the area in which you request an easement, is presently leased to Hawaiian Ranch Company under Lease No. 11,777. The ranch has been expediting the development of these lands so that they will eventually carry many more head of cattle than now possible. As a consequence, they are reluctant at this time to give you a blanket easement for an area of 100 to 300 acres; however, they recognize the importance of your project.

Mr. Carlson of the Kona Office has discussed this with Mr. Joe Serrao, Ranch Manager, Hawaiian Ranch Company, and asked that he consider your request and the opportunities which might be forthcoming from this venture.

The Trustees also request that you discuss your request for an easement of the area needed with Mr. John Anderson, C. Brewer and Company, Honolulu, who is overall Manager of Hawaiian Ranch Company.

As it pertains to your request for a future easement in North Kona on the northwest rift of Hualalai, the Trustees would accord you their cooperation in securing the necessary easement; noting that in this area it would be necessary to coordinate this with their lessee, Signal Oil Company.

In order to lend our support to your efforts, we would appreciate being invited to any conferences arranged with our lessees.

Maps and other data are available at the Bishop Estate Office in Honolulu and any questions, requests, etc., should be channeled through Mr Lawrence Cunha of the Trustees' Staff (Area Development Manager, Neighbor Islands).

Very truly yours,

Lawrence Cunha
For Secretary

NKC bp

cc Mr. Norman K. Carlson

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Socio-Economic Feasibility				
Sub-program Manager	Robert M. Kamins				
Task Title	Legislation			**Task No.** 4.2	
Investigator	Lloyd Sadamoto				
Department	Hawaii County Office of Research and Development				
Budget	**Year One** 5,000		**Year Two** 6,500		**Total** 11,500

Task Summary

Task Description

To study and present the need for legislation together with appropriate examples to public agencies in order to properly supervise and regulate development of the technologies, involved in PELE, in the public interest.

Project Need

At present the State of Hawaii, and most of the other states have no legislation relating to the supervision and regulation of geothermal technology. The national need will be commensurate to the predictable rush to this technology as means of exploitation are discovered.

Anticipated Results

Through means of this effort a body of suggested legislation will be promulgated and considered by appropriate agencies and jurisdictions to the end that development will be orderly and within bounds of reasonably minimum environmental impact.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Socio-Economic Feasibility				
Sub-program Manager	Robert M. Kamins				
Task Title	Planning			Task No. 4.3	
Investigator	Eugene Grabbe				
Department	State of Hawaii Department of Planning and Economic Development				
Budget	Year One 4,500		Year Two 5,300		Total 9,800

Task Summary

Task Description

In recognition of the multi-faceted effects on the social and economic systems as well as the technologies of energy generation and use, this project will predict and identify need for planning on an interdisciplinary basis for technological as well as societal purposes.

Project Need

To realize the best potential of geothermal technology on the broadest base of scientific planning consideration in order to minimize environmental and societal dislocations while realizing the greatest economic advantage to the society.

Anticipated Results

A program or detailed plan by which geothermal technology may be exploited and resources allocated in a manner acceptable most reasonably by all affected sectors of the society. As an instance the present state administration contemplates population dispersal as an official policy. A new source of energy may well provide impetus to this policy if adequately planned in early stages of development.

Task Title	Planning	Task No. 4.3
Task Details		

Any major technological project such as PELE will have effects on the economy, society, and the environment. As a result part of the program must be devoted to the assessment of and planning for such consequences -- be they positive or negative. The initial impact of Project PELE will be on the County of Hawaii, but the full impact will eventually be felt by the State as a whole. The County of Hawaii, Research and Development will play a major role in initial planning with the support of the State Department of Planning and Economic Development (DPED), the University of Hawaii, and other State and County agencies.

For the planning subprogram, inputs will be obtained from the Environmental Feasibility Program on aquaculture, agriculture, by-product recovery and environmental impact and from other parts of the project as appropriate. It will also seek inputs from other parts of the project as appropriate. It will also seek inputs from other State organizations active in sociotechnical assessments such as the Governor's Advisory Committees on:

-- Science and Technology
-- The Year 2000
-- New Communities

Commissions such as:

-- Population Stabilization
-- Land Use

and University Research and Development Centers.

Many new methods are available today for forecasting and assessment of new technology. Some of these have been used successfully by the Planning Department of DPED in defining problems, in forecasting of events and for policy formulation. It is anticipated that the programs will be developed for assessment of selected sociotechnical issues not covered elsewhere. Emphasis will be on multidisciplinary issues.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Socio-Economic Feasibility				
Sub-program Manager	Robert M. Kamins				
Task Title	Economic Feasibility Considerations			**Task No.** 4.4	
Investigator	Nabil A. El-Ramly				
Department	Business Economics and Quantitative Methods				
Budget	**Year One** 15,190	**Year Two** 42,830		**Total** 58,020	

Task Summary

Task Description

The project will identify concepts pertinent to PELE and investigate their relative significance in order to provide actual examples necessary to develop procedures and methodologies needed to evaluate and plan geothermal developments. Apply these concepts and methodologies to actual cases as technologies are developed.

Project Need

Because of uniqueness of geothermal technology existing methods of evaluation of only partially adequate. Establishment of precise state-of-the-art criteria will require use of system methods to a greater degree than in traditional power generation technology.

Anticipated Results

Explanations of value of the new technology relative to traditional and alternative methods and analysis of feasibility of geothermal energy as part of a total economic scheme including value of economic development made possible and on an expanded basis to societal benefit in present and future contexts.

Task Title	Economic Feasibility Considerations	Task No. 4.4

Task Details

Project Description

1. Identify and analyze important economic concepts pertinent to (a) the evaluation of alternative schemes for developing geothermal resources; (b) the comparison of geothermal sources with other power sources; (c) the optimization of total power supply systems in which geothermal energy may play a role; and (d) the development of geothermal potentials as a multi-purpose project.

2. Investigate the significance of the concepts developed to the interrelated decision problems of when, to what extent, and how to develop geothermal sources.

3. Provide realistic and/or actual examples to clarify the importance of considering the formulated concepts in the economic evaluation of geothermal projects.

4. Establish procedures and methodologies indicating the manner in which such economic concepts may be considered (individually and collectively) in the planning and evaluation of geothermal developments.

5. Explain the nature and type of information needed in order to apply the procedures and directions developed to specific cases.

Project Need

Although the economic evaluation of geothermal developments is conceptually identical to those of many other developments, nevertheless, there are a number of important aspects of geothermal systems that require special considerations in economic analysis. On the one hand, the technology of developing geothermal resources is new, and the state-of-the-art is not well established. As such geothermal technology is subject to rapid change and improvements, necessitating consideration of many short run effects and highly unpredictable long run results. Thus, special attention to the time perspective is needed on the economic comparison of geothermal developments with other sources of power. On the other hand, geothermal resources is further characterized due to its potential role in power supply developments and in multi-purpose projects. Thus it is essential to evaluate geothermal developments according to the objectives of the total system of which it will only be a component.

Because of the newness of geothermal technology and the necessity of considering a geothermal development as a system component rather than independent component, an approach is needed for establishing comparability with other development projects. This requires a precise differentiation between long-range and short-range investment decisions, an examination of the factors affecting the economics of geothermal systems, a method for assessing costs and benefits for technological development, and a new means for planning for growth.

Task Title	Economic Feasibility Considerations	Task No. 4.4

Task Details

Such distinguishing features of new technologies of which geothermal is a good example have largely been neglected, or subjectively accounted for, in the traditional approaches to economic analysis. The purpose of this proposed study is to analyze objectively certain economic considerations (see below) which could lead to a better understanding and evaluation of investment in geothermal developments.

Anticipated Results

1. Technological Advances

(a) Explain the nature of technological advances as it relates to geothermal systems and the problems of measuring the rate of technological progress.

(b) Distinguish between the manifestations of progress as represented by changing physical engineering parameters and the measure of progress in terms of economic consequences.

(c) Identify the economic concepts required (e.g., "opportunity cost of technological advances," and "uncertainty cost of new systems") to explain the influence of technological progress on investment timing (whether to build now or wait for future equipment) and on the staging of construction.

2. Development of Geothermal Expertise and Its Role in Economic Evaluations

(a) Explaining the difference between the cost of acquiring geothermal expertise and the benefits that could be realized from its utilization.

(b) Establish the basis on which part of the costs of early geothermal developments may be shifted to subsequent projects, and provide the justification for considering long-range benefits in evaluating present investments.

(c) Construct an analytical framework for estimating the value of expertise.

3. Planning for Growth

(a) Analyze the ways for expansion of power supply systems based on or incorporating geothermal plants.

(b) Discuss the question of capital allocation over time (depreciation and depletion accounting) and its relationship to the principle of marginal cost pricing as it applies to geothermal power.

Task Title	Economic Feasibility Considerations	Task No. 4.4

Task Details

4. Externalities and Systems Approach to Economic Evaluation

(a) Identify the economic externalities associated with geothermal developments, and establish means for evaluating the intangible factors concerned.

(b) Examine the significance of including a geothermal plant as a power system component rather than an independent component.

(c) Analyze the various possibilities for using geothermal sources, both conjunctive in space and in time, with other power supply systems.

5. Planning Horizon and Benefit/Cost Analysis

(a) Identify the concept of a "planning horizon" especially as it relates to power projects in general and geothermal projects in particular.

(b) Discuss the influence of prediction intervals and the accuracy of estimated benefit/cost streams upon the length of a planning horizon.

(c) Discuss the relationship between geothermal plant life and the planning horizon and explain the effects of pre-horizon investment in a geothermal project upon the post-horizon goals of a total power supply system.

(d) Elaborate on the methodology of comparing alternatives with different lives and explain the underlying assumptions behind present methods of evaluation.

6. Economic Analysis and Its Relationship to Financial Feasibility

(a) Explain the difference between an economic and financial analysis.

(b) Discuss the constraints imposed by financing consideration upon the planning for geothermal developments.

(c) Explain the significance and sensitivity of discount rates in economic evaluations of geothermal and other power supply alternatives.

(d) Explain the role of inflation as it relates to geothermal projects and alternative power sources.

7. Economics of Multi-Purpose Projects (by-product recovery)

(a) Investigate some general economic considerations relating to the problem of cost and benefit allocation among products.

(b) Elaborate on some of the decision problems concerning the development of multi-purpose projects such as siting, marketing, and interface problems.

Task Title	Economic Feasibility Considerations	Task No. 4.4

Task Details

(c) Explain the economic consequences of suboptimizations based upon the individual objectives of each partner in multi-purpose project upon the performance of the total system.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Environmental Feasibility				
Sub-program Manager	K. Gundersen				
Task Title	Environmental Feasibility			Task No.	5.0
Investigator	K. Gundersen				
Department	Microbiology				
Budget	Year One	15,974	Year Two 16,424	Total	32,398

Task Summary

Task Description

To predict environmental impact and positive productive facets of PELE in order to prevent negative environmental results and realize, in advance, areas of preparatory research.

Project Need

The most immediately predictable needs are to prepare means by which effluent waters may be transformed to a non-polluting condition prior to return to the natural systems. A general environmental impact study is also required in this context to prepare for hearing before governmental agencies.

Anticipated Results

The goals within this part of PELE will be to approach as nearly as possible to zero negative environmental impact on existing ecologies and environmental conservation requirements. Perhaps, in part, this result will offer aid in seeking a solution to "Energy: The Ultimate Environmental Problem" as presented in the February 1972 issue of Professional Engineer.

Task Title	Environmental Feasibility	Task No. 5.0

Task Details

The environmental feasibility sub-program will consist of at least five general task categories:

1. The aquaculture task will consider, study, and identify the appropriate form of primary growth for the purpose of removing nutrients from the deep, cold sea water brought up for use in making more efficient the condenser side of warm-water power generation systems.

2. Agriculture studies will consider means by which products of the geothermal technology will or can be made to benefit island food production.

3. By-product recovery projects envision chemical and rare metal recovery as well as ways and means of removing or making less harmful the undesirable elements from system effluents.

4. Environmental impact statements will be prepared in all cases of physical operations from initial exploratory well drilling to final production operations and as part of all phases of planning. It is felt that this phase of operation will also be closely tied to land use and legislative efforts in the socio-economic sub-programs.

5. Geotoxicology studies will consider the impacts caused by releasing chemical products from deep geological structures into the atmosphere, with particular regard to the effect on living things and ecologies.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Environmental Feasibility				
Sub-program Manager	K. Gundersen				
Task Title	Environmental Impact			**Task No.**	5.1
Investigator	Franklin J. Agardy				
Department	URS Research Corporation				
Budget	**Year One** 25,000	**Year Two**	35,000	**Total**	60,000

Task Summary

Task Description

Study and identify environmental effects and controlling elements to the purpose of advising project investigators in devising impact statements. These statements will be needed to conform to regulatory requirements of local and federal governments.

Project Need

To carefully analyze environmental impacts of project operations and project future environmental impact of geothermal technology.

Anticipated Results

Standard operating procedures and regulations as necessary to produce minimal negative environmental effects resulting from introduction of geothermal technology.

Task Title	Environmental Impact	Task No. 5.1

Task Details

Operations of PELE will involve physical events on land, and may therefore affect the environment within the definitions of environmental impact. Environmental impact statements will therefore be an early necessity vis a vis program projects and tasks.

Environmental impact statements currently are required for a wide variety of activities, usually bearing some relationship to construction activities and operations. The impacts that must be considered are delineated in a general way in various official acts, guidelines prepared by local and federal agencies. A wide variety of environmental elements and impacts must be considered, such as:

Pollution	Economics
Air	Taxation
Water	Supply
Land	Demand
Noise	Urban Development
Thermal	

Land Use	Social
Aesthetics	Dislocation
Recreation	Employment
Health	Travel Effects
Safety	Relative Cost of Living Effects
Politics	Demographic
Public Works	Cultural

Ideally, preliminary environmental impact assessment should begin as soon as task or project planning is initiated so as to consider alternative plans with respect to relative environmental impacts.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Environmental Feasibility					
Sub-program Manager	K. Gundersen					
Task Title	Aquaculture				Task No.	5.2
Investigator	K. Gundersen					
Department	Microbiology					
Budget	Year One	201,462	Year Two	66,122	Total	267,584

Task Summary

Task Description

Model and applied research on phytoplankton productivity in nutrient-rich deep-ocean water under surface light and temperature conditions. Phytoplankton production in ponds of up to 600 m^3 volume. Harvesting and processing research.

Project Need

The fundamental need for the project is in its demonstration that deep cold ocean water, which is readily and abundantly available in the Hawaiian Islands, can safely be used as an optimal heat sink in the geothermal power producing system.

Anticipated Results The "biological filtration" by phytoplankton of plant nutrients contained in deep-ocean water serves two major purposes: 1) Permits the use of cold ocean water as an optimal heat sink in an electricity producing system without the risk of producing thermal and chemical pollution of the ocean surface environment, 2) Permits the production of potentially valuable organic material(algae) under controlled conditions from abundantly available solar energy and deep-water plant nutrients.

Successful results of the project will benefit several new practical-economical developments in the State of Hawaii and the Nation as well as being of considerable scientific and technological significance at an international level.

Task Title	Aquaculture	Task No. 5.2

Task Details

Outline of Proposed Research

1. Site of Pilot Plant

A State-County supported survey of coastal areas on the island of Hawaii has resulted in the selection of Keahole Pt. (see Fig. 5.1-1) as the potentially most suitable site for a deep-ocean water pilot plant. Factors which were considered, included coastal bathymetry and horizontal distance to deep water, suitability of adjacent coastal land for building of laboratory and production ponds, ownership of land and likely availability, stability of climatic conditions with maximum of yearly sunshine hours, closeness to transportation and a lodging center, and location of likely geothermal areas. Of eight sites considered, the Keahole Pt. site was found by far the most suitable. The land here is owned by the State of Hawaii and consists of about 160 acres, fairly level lava-covered coast land between the new Kona Airport and the U.S. Coastguard Lighthouse. A depth of 700 meters is reached 1.6 km off-shore. Commercial flights to and from the airport will connect the pilot project with Honolulu and Hilo within 40 minutes. Kailua town, with hotels, service facilities and a harbor is located three miles south on the sunny, low-precipitation Kona Coast. Being on the leeward side of the island, the coastal waters are fairly calm and will offer maximum stability during the installation of the deep-water pipes and pumps.

The State Department of Transportation has responded favorably to making the site available for the project and action has already been taken by the County of Hawaii for its release to the project.

2. Deep-Water Recovery

The deep-ocean, 1-1/2" diameter, water supply system will comprise an armored pipe through the surf, a junction box and pump housing at about 10 m below sea level and the deep-ocean line extending from the junction box to 700 m below sea level about 1.6 km offshore. The pipeline through the surf will be a double steel pipe conduit armored with heavy stone. A submersible electric pump will be installed in the junction box where the depth would preclude cavitation at the required rates of flow of about 20 liters per minute. The 1-1/2" deep-ocean pipeline would be either Genline or Ortac rubber hose, laid directly on the bottom.

During the third year the deep-ocean water supply system will be expanded to an 8" diameter pipeline.

3. Laboratory Facilities

A one-story, approximately 20 x 40 ft, shelter and laboratory building will be constructed during the first year. Due to the dry and calm climate on the Kona Coast a minimum of physical structures for weather protection is required. The building will consist of a biological-chemical laboratory, a small machine shop, a minimal office and lounge, a kitchenette and a small sleeping quarter for two with a toilet-shower.

Task Title	Aquaculture	Task No. 5.2

Task Details

4. Production Ponds and Water Flow Systems

During the first two years, with only the 1-1/2 inch pipe available for deep-water supply, the experimental work will be confined to small volume cultures in carboys and aquaria and to two approximately 6m^3 outdoor ponds (A-ponds).

During the third year, following the installation of the 8 inch deep-water pipe, six additional A-ponds will be constructed. In addition, we will build four 60m^3 ponds (B-ponds) and two 600m^3 ponds (C-ponds). The ponds will be made circular with inwardly sloping sides to permit rotational, or fountain-like stirring and mixing. The C-ponds will be about 5m deep to permit the determination of organism density-production-light intensity relationships. It is assumed that the high light intensities prevailing at this latitude (>100,000 lux at the peak of the day) may have a negative effect on photosynthetic production unless high cell densities is maintained and the water is kept continuously circulating in a vertical direction. The proposed design of ponds, with a 1:10:100 volume relationship between the A, B, and C ponds, should provide considerable flexibility in optimizing the system. The design permits the operation of a continuous-flow system as well as batch production and permits the use of as much as 40% inoculum in seeding the C-ponds. If necessary, shading can be provided in smaller and shallower A-ponds during critical periods.

The ponds will be furnished with an aeration system which will increase the mixing efficiency and also provide constant carbon dioxide and oxygen levels. It has been calculated that a flow of 200m^3 of air per minute will be adequate to preserve the about two moles of total CO_2 contained in 1m^3 of seawater in the C-ponds.

All ponds will be interconnected through PVC piping and the flow produced by means of suitable pumps. Sub-project 5.4 (By-product recovery) will make use of deep water at any point within the system. All waste water and overflow will be discharged through a pipe extended to about 10m depth off-shore.

5. Harvesting and Processing Methods

Already early in the project we will investigate various techniques for harvesting and processing phytoplankton. The most feasible harvesting method for small culture volumes will presumably be centrifugation using a Sharpless centrifuge or a milk or yeast separator. An interesting and economically attractive harvesting method which may prove applicable to large culture volumes is ground gravity filtration. The porous lava rock making up the underground at Keahole Pt. should permit easy filtrations after draining of ponds onto large sand beds. Experiments along this line will be initiated early in the project.

The harvested cell paste will be further processed by various methods (sun drying, freeze drying, etc.) and the suitability and economics of each method. Considerable effort will be made during the first year of this project to collect information on harvesting and processing techniques and equipment suitable for the algal product.

Task Title	Aquaculture	Task No. 5.2

Task Details

6. Chemical Operation Control

It will be necessary to maintain a strict monitoring scheme for the deep-water quality at all times to ensure that no foreign water enters the system (e.g. through leaks in the deep-water pipe) and no significant amounts of nutrients are discharged and returned to the sea environment. The organisms which are being raised are to be regarded as a biological filter and a basic requirement of the operation will be to ensure that this filter efficiently "cleans up" the deep-water throughout the operation.

Preliminary experiments done in this laboratory (Gundersen and Bienfang, 1970) have shown that the phytoflagellate, Dunaliella tertiolecta, during growth in deep-water culture in the laboratory will reduce the nitrate content from 320 to 10.5 µg N/1 and the phosphate content from 52.5 to 4.5 µg P/1. The State of Hawaii water quality standards for Class AA coastal water sets the upper limit for total nitrogen at 100 µg/1 and total phosphorus at 20 µg/1. Although open ocean surface water contains only about 3.7 µg NO_3-N/1 and 3 µg PO_4-P/1 (Gundersen et al., 1972) it is believed that the levels expected to exist in exit-water from the production ponds will be sufficiently low to justify its discharge into surface ocean water. If organisms other than diatoms are raised it will, of course, be unavoidable that considerable amounts of silicate from the deep water will be discharged but it is believed that this kind of "pollution" will have little effect on the environment as long as nitrogen and phosphorus are practically absent. The State standards do not specify any limits for silicates.

The Keahole laboratory will be equipped to handle nitrate and phosphate analyses of water taken at frequent intervals within the water system as well as several other chemical components, such as organic nitrogen and phosphorus, ammonium, plant pigments, vitamins, oxygen, total carbon dioxide, and pH. Equipment for continuous recording of temperature, pH, oxygen, and carbon dioxide will be installed in the larger ponds. Light measurements will also be made continuously.

7. Previous Work

Chemical and productivity studies of deep-ocean water have already been in progress for some years in the laboratory of the P.I. The major findings and results are discussed in a paper, "Thermal pollution: use of deep, cold, nutrient rich sea water for power plant cooling and subsequent aquaculture in Hawaii" (Gundersen and Bienfang, 1970). Other aspects of deep water chemistry and microbiology of the Pacific Ocean off Hawaii are discussed in a recent paper (Gundersen et al, 1972).

8. Projected Production

The following estimation of the optimum production which is expected in this pilot study is based on actual carbon-fixation data and deep-water nutrient analyses taken from the papers cited in Section 7 above, and other sources.

Task Title	Aquaculture	Task No. 5.2

Task Details

a. Composition of Phytoplankton

1 gram dry weight (dw) of algae contains (Oswald and Golueke, 1967):

Carbon	0.4g
Nitrogen	0.1g
Phosphorus	0.01g

b. Nutrient Content of Deep-Ocean Water at 700 m:

Carbon as carbon dioxide	24g per m^3
Nitrogen as nitrate	0.56g per m^3
Phosphorus as phosphate	0.08g per m^3

c. Production of Phytoplankton (<u>Dunaliella tertiolecta</u>):

In deep ocean water: 0.25gC, or 0.625g algae dw per m^3 per hour. Assuming a daily light period of 10 hours, the daily production amounts to 6.25g algae. The nutrients required for this production is 0.625g nitrogen and 0.06g phosphorus. This is approximately the amounts available in $1m^3$ of deep-ocean water.

d. Pilot Scale Production in C-Ponds ($600m^3$):

With a water residence time of one day, each pond should produce 6.25 x 600 = 3,750g algae dw per day. Assuming 200 days of operation of each pond per year, the yearly production should amount to 3,750 x 200 = 750,000g per year, or approximately 1500 lbs of dry weight algae.

e. Production Per Acre:

A $600m^3$ C-pond, 5m deep, has a surface area of about $175m^2$ (about 1/23 acre). Assuming the same water depth, the culture volume per acre amounts to 600 x 23 = $13,800m^3$ of water. With a magnitude of production as above, one acre could produce 13,800 x 6.25 x 200 = 17,250,000g dw algal material per year, or about 17 metric tons. It is admitted that a crop of this size will probably never be obtained, but the calculation has nevertheless been included for completeness.

9. Product Utilization

At the present time, algae per se are not marketable and their potential uses, therefore, need to be investigated. Below are listed some of the more obvious potentials of an algal concentrate which we will explore in cooperation with industrial and academic expertise. PELE Sub-project 5.3, Agriculture, has as one of its major objectives to investigate the potential agricultural uses of algal concentrates.

Task Title	Aquaculture	Task No. 5.2
Task Details		

a. Direct Utilization

- Food for filter feeding and herbivorous aquaculture organisms (processed or unprocessed product)

- Food supplement for cattle, swine, and poultry

- Human food

b. Uses After Extraction

- Polysaccharides (alginates, etc.)

- Oils and fats

- Proteins

- Biochemicals

- Vitamins

- Antibiotics

- Other pharmaceuticals

- Minerals

c. Transformation Products

- Hydrocarbons

- Chemicals and biochemicals produced from natural precursors

One can also visualize phytoplankton used as agents for the biosynthesis of specific products much in the same way as bacteria and other microorganisms are now used for a variety of industrial fermentations.

10. Work Plan, Summary

<u>Year 01</u>

- Planning, building, and organizing the Keahole laboratory
- Study tour to U.S. Mainland and to Columbia University's deep-water pilot plant in St. Croix, Virgin Islands
- Selection of potential producer-organisms (phytoplankton)
- Propagation and preliminary growth studies of producer strains
- Selection and purchase of equipment and supplies
- Installation of 1-1/2" deep-water pipeline

Task Title	Aquaculture	Task No. 5.2

Task Details

Year 02

- Productivity research in controlled laboratory cultures and in two outdoor A-ponds ($6m^3$)
- Determination of optimal light and nutrient ranges for various primary producer organisms
- Preliminary study of harvesting and processing method

Year 03

- Installation of 8" deep-water pipeline and large pump
- Construction of six A-ponds ($6m^3$), four B-ponds ($60m^3$) and two C-ponds ($600m^3$)
- Full scale production
- Continued research on plankton productivity and growth dynamics
- Harvesting and processing methods
- Nutritional and other evaluation of plankton products

Year 04

- Production research
- Processing research

Years 05-06

- Production, refinements of methods, improvements of pond design, harvesting and processing techniques
- Merging with geothermal pilot plant
- Development of commercial scale production system

11. References

Gundersen, K., C. W. Mountain, Diane Taylor, R. Ohye and J. Shen, "Some Chemical and Microbiological Observations in the Pacific Ocean off the Hawaiian Islands", Limol. Oceanogr. in press.

Oswald, W. J. and C. G. Golveke, "Large Scale Production of Algae", Paper presented before the International Conference of Single-Cell Protein at MIT, Mass., 1967.

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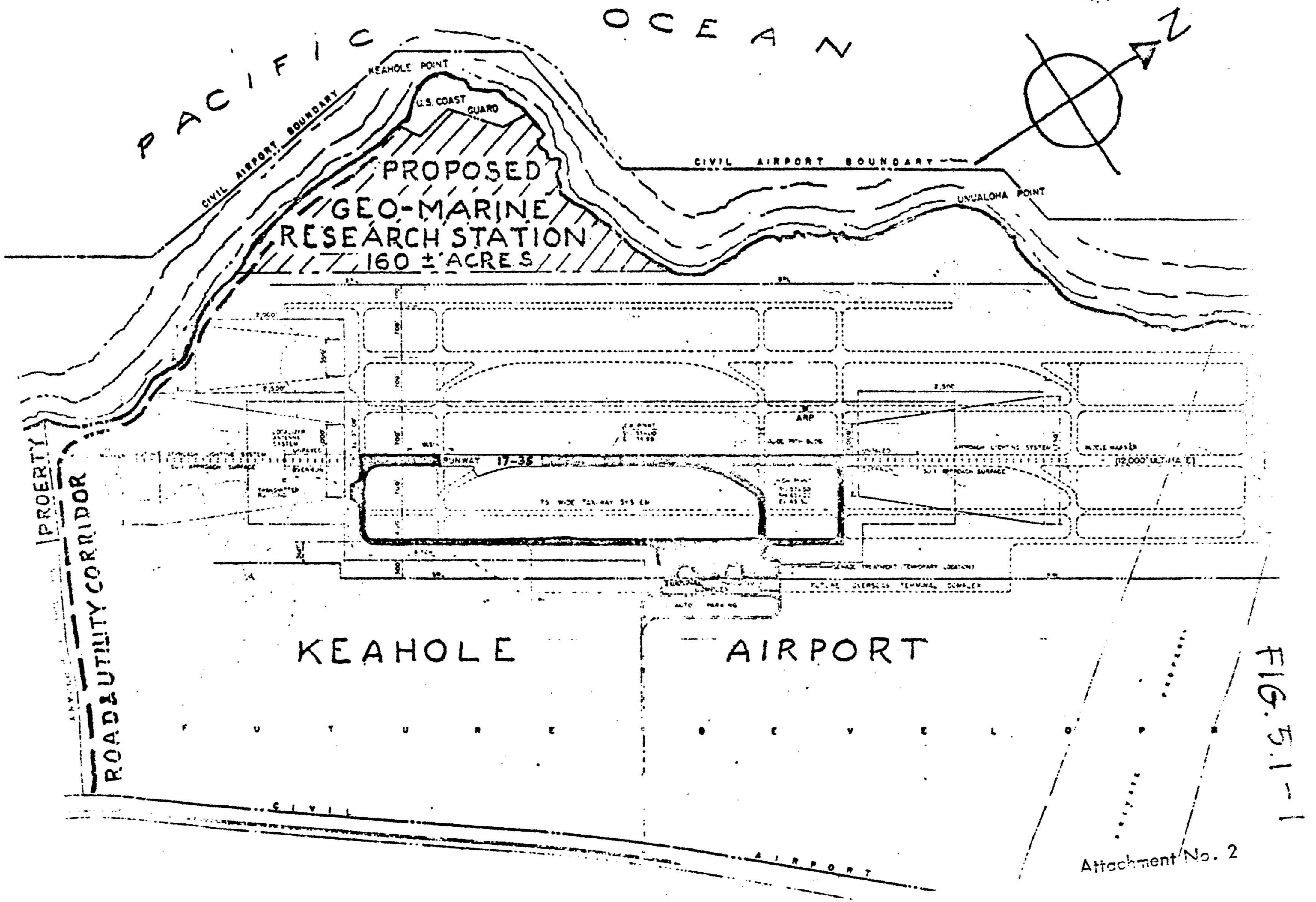
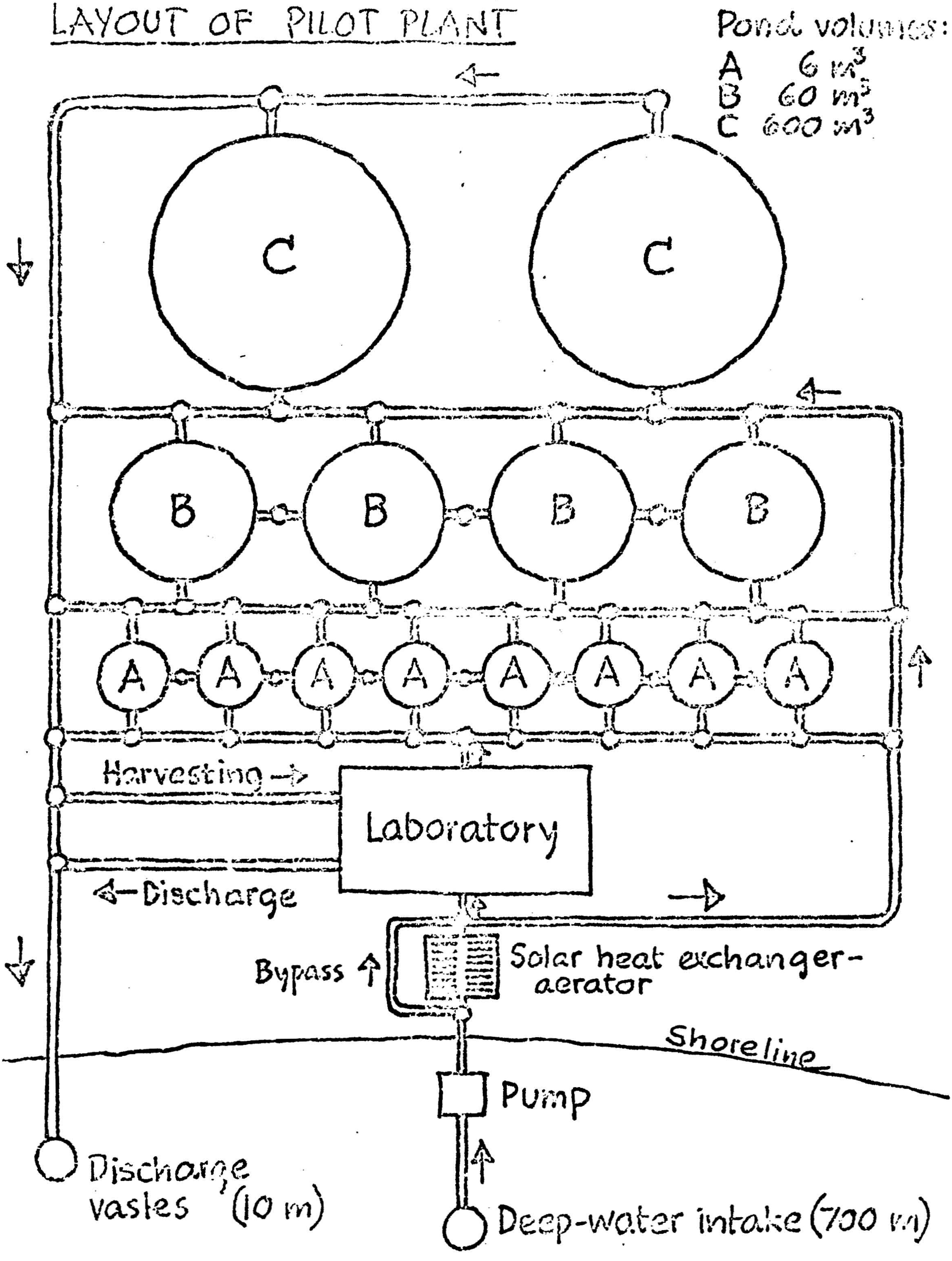


FIG. 5.1-1

Attachment No. 2

PELE Project 5.1: Aquaculture FIG. 5.1-[illegible]

LAYOUT OF PILOT PLANT



Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Environmental Feasibility				
Sub-program Manager	Kaare Gundersen				
Task Title	Agriculture			Task No.	5.3
Investigator	Elgin B. Hundtoft				
Department	Agricultural Engineering				
Budget	Year One 18,976		Year Two 17,890		Total 36,866

Task Summary

Task Description

Apply agricultural technology to the possibility of using increased electrification and other by-product resources to improve Hawaii agriculture.

Project Need

There is a need in Hawaii for the improved agricultural production, which will yield an independency from shipments of foodstuffs to the State, and even provide an export commodity.

Anticipated Results

Recommendations and improved understanding on the ways in which agriculture in Hawaii may become a part of an overall system of the production of electrical power and by-products in an environmentally acceptable manner.

Task Title	Agricultural Engineering	Task No. 5.3

Task Details

Task Description

- Conduct economic feasibility studies relative to new or increased usage of electrical energy in food production, to include the following:

  1. Environmental Control

     a. for crop production
     b. for product storage

  2. Central Processing of Agricultural Commodities

     a. location and layout of production units
     b. location and layout of processing plant

  3. Central, Regional Irrigation Systems for Crop Production

  4. Alternatives in Agricultural Waste Disposal Made Feasible Through Low Cost Electrical Power

  5. Mechanized and/or Automated Production of Foods

- Assist aquacultural specialists in the mechanization of aquacultural production systems

- Promote the development of an Agricultural Electrification Educational Program

Project Need

- Potentials to Agriculture with Low-Cost Electrical Power

Complete environmental control in the production of fresh market produce could have far-reaching effects on the entire agricultural-ecological system, effects for which agricultural production units are being watched more and more closely. A "closed" system could exclude diseases, insects, weeds and other pests without ecological influence. With less costly sources for both energy and fresh water, environmentally-controlled production may be feasible.

Markets for many of Hawaii's unique tropical commodities could be increased by many times if methods for preservation in the "fresh" state would be developed and put into use. Controlled atmospheric storage permits planned production, costs, prices, and returns. The feasibility of CA storages could more meaningfully be studied with knowledge that a low-cost power supply will ultimately become available to the agricultural industries of Hawaii.

Task Title	Agricultural Engineering	Task No. 5.3

Task Details

Hawaii's agriculture lags in knowledge of what could be accomplished with the availability of low-cost power and low-cost fresh water for irrigation. This lag is the direct result of the price tag associated with more modern alternatives. Among the categories where studies are needed are: 1) central irrigation systems for crop production, 2) utilization and disposal of agricultural wastes, 3) improved methods for processing fruits and vegetables, and 4) automated production systems (especially in livestock production).

Electrical power is hardly used by the State's agricultural production industry. Nor is its use available as an alternative to the decreasing and ever more costly farm labor force -- a force that each year relishes less the backbreaking work they are asked to perform. Mainland farmers enjoy the conveniences of electrical farmsteads for just pennies per hour. Such an alternative would be a boon to Hawaii's agriculture as well.

- Engineering Aquaculture

Aquaculture is in a state of existence somewhat like land culture hundreds of year ago. Major research emphasis for coming years will undoubtedly be to ascertain optimum cultural conditions for production. Eventually, however, the development of acceptable production systems will be in order. Early integration of the engineering aspects with the cultural aspects will result in earlier realization of stable aquacultural industries.

- Education on Agricultural Applications of Electrical Power

Hawaii is the only state in the United States where rural electrification is not actively promoted by industry and university personnel hired and trained specifically to serve the needs of agriculture. With the development of a geothermal electric power facility, an educational program will necessarily evolve. Presently, the costs of installing and maintaining the necessary rural transmission systems coupled with the high cost of generating power, economically prohibit intensive agricultural use. With changes in availability, much information on potential and recommended uses will be needed.

Anticipated Results

Within two years, these exploratory efforts would provide the following results:

- Recommendations for future agricultural production systems based on:
  1) economic studies and projections
  2) preliminary feasibility research with respect to environmental control on the production and storage of selected commodities,
  3) assimilated information from agricultural regions presently committed to intensive electrical usage.

Task Title	Agricultural Engineering	Task No.	5.3

Task Details

- An improved understanding of aquaculture and the potential mechanization of aquaculture systems
- A base of information for initiating the development of an educational program in agricultural electrification

Pele Energy Laboratory Experiments (PELE)

University of Hawaii
Proposed RANN Program

Center for Engineering Research
September 1, 1972 - August 31, 1974

Sub-program Title	Environmental Feasibility				
Sub-program Manager	Kaare Gundersen				
Task Title	By-Product Recovery			Task No.	5.4
Investigator	H. Zeitlin				
Department	Chemistry				
Budget	Year One 14,015	Year Two 23,199	Total 37,214		

Task Summary

Task Description

The ocean waters in the vicinity of the geothermal project will be studied as a source of economically important trace metals through application of a novel adsorbing colloid flotation process developed at the University of Hawaii. A detailed study of the concentration levels and distribution of the trace metals in the deep and overlying waters will also be carried out.

Project Need

The ocean is the source of virtually limitless quantities of many metals of industrial importance present as trace constituents in the dissolved state. There is need for exploratory studies leading to the separation and eventual recovery of a number of these metals notably uranium. For maximum utilization of seawater from which the trace metals have been stripped, the process of separation should be followed by one of desalinization. There also is a related need for information on the trace metal concentration and distribution in the waters to be examined for geothermal energy.

Anticipated Results

Based on the results obtained thus far with the model trace metals separated by colloid flotation on a laboratory scale, and assuming that the technique can be extended to other metals and separation achieved successfully on a large scale unit, it is anticipated that seawater might eventually provide the source, economically, of a number of valuable trace metals.

The trace metal distribution data should shed light on the role and effect of dissolved metallic micro constituents on aquaculture studies.

Task Title	By-Product Recovery	Task No. 5.4
Task Details		

Summary

The chemical phase is concerned with: (1) the utilization of seawater as a source of trace elements through the application of adsorbing colloid flotation for the separation of various economically important trace metals from seawater, (2) a detailed study of the concentration levels and distribution of trace metals in deep and overlying seawater. The elements to be examined include uranium, molybdenum, manganese, cobalt, nickel, copper, chromium, vanadium, and zinc.

The major objective of the research is the application of a novel foam separation technique developed recently at the University of Hawaii for the removal of a number of model metals present in seawater as cations and anions (2-6). The separation based on adsorbing colloid flotation is believed to be the first applied to seawater. A collector-surfactant-air system which is comprised of a negatively charged surfactant, a positively charged collector, and air is used for the removal of metallic anions and a positively charged surfactant, a negatively charged collector, and air to remove cations in seawater. As an example, in the case of molybdenum which exists in seawater as anionic molybdate, an anionic surfactant (dodecyl sodium sulfate), ferric chloride which forms a positively charged iron (III) hydroxide colloid, and air are added to seawater at a low pH to the flotation cell (see Figure 5.4-1). Upon addition of the surfactant and bubbling of air through the seawater, the positively charged surfaces of the molybdenum enriched iron hydroxide particles are attracted to the surfactant ions. These are concentrated and oriented in the air-water interphase in such a manner that the hydrophobic portion points to the air phase and the charged portion remains in the aqueous phase. A stable froth floats to the surface from which it is easily removed and analyzed. The work carried out on a laboratory scale has the advantage of simplicity of equipment, essentially quantitative recovery of the model cations and anions studied, and rapidity. The separation is achieved in 2-3 minutes. Results obtained are summarized in the table.

It is believed that the technique can be applied to a wide variety of trace cations and anions in seawater by judicious selection of surfactant, collector, and pH. Although studies have been confined to laboratory scale the work done so far warrants a more detailed investigation of the separation on a pilot scale of selected trace elements of economic importance, e.g., uranium.

It is also proposed to study the trace metal levels and distribution in the deep waters near the island of Hawaii. Data concerning trace metals in deep waters are exceedingly scarce, unreliable, and difficult to interpret. This is attributed to the excessive costs associated with the distances involved and the infrequent sampling. An added problem is the stabilization of the original trace metal concentrations. In most cases, the trace metals cannot be analyzed on board ship and several weeks or months must elapse before they can be brought in and analyzed on

Summary of Results of the Separation of Trace Ions by Colloidal Flotation (2)

Metal	Ionic Species	Surfactant	pH	Ionic Conc. in Seawater ($\mu g l^{-1}$)	Recovery (%)	Method of Determination
Molybdenum	MoO_4^{-2}	Sodium dodecyl sulphate	4.0±0.1	11.4	95.3	Spectrophotometric (as Mo-CNS complex)
Uranium	$[UO_2(CO_3)_3]^{4-}$	Sodium dodecyl sulphate	5.7±0.1	3.2	82.0[a]	Spectrophotometric (as Rhodamine-B complex)
Zinc	Zn^{2+}	Dodecyl-amine	7.6±0.1	3.2	94.0	Atomic Absorption
Copper	Cu^{2+}	Dodecyl-amine	7.6±0.1	0.8	95.0	Spectrophotometric (as dibenzyl-dithiocarbamate complex)

[a]A recovery of 90% has been achieved by a thorium hydroxide-sodium dodecanoate-air system (6).

Task Title	By-Product Recovery	Task No. 5.4

Task Details

land based laboratories thus necessitating storage and increasing possibilities for both contamination and changes due to bacterial and chemical activity. The deep sea sites in the proposed study are located within easy reach of Oahu, thus permitting an unusually favorable opportunity for a detailed and sustained study at minimal cost with maximal reliability and integrity of data.

Research Plan

The flotation technique that has been worked out on a laboratory scale on uranium, molybdenum, copper, and zinc will be extended to cobalt, nickel, chromium, vanadium, and manganese and then to other precious metals such as gold and silver. There is good reason to believe that the latter two metals are separable by flotation. Previous work suggests that a low pH is required for the separation of anions and a pH on the basic side but less than 10 is used to remove cations. The method will be applied on a larger scale by construction of a flotation unit which can accommodate up to 100 gallons of sea water and more. It is believed that by means of large scale flotation followed by a desalinization process, seawater could conceivably provide economically both a source of trace metals and fresh usable water.* It should be pointed out that the flotation process results only in a separation of trace metals in seawater. Additional work is required for the separation of the individual elements and their eventual recovery.

Vertical profiles of the trace elements in the areas of interest will be obtained. The data will be analyzed statistically in order to determine whether differences exist in the deep and overlying waters. Sampling for the chemical analysis will be carried out simultaneously with that for bacterial, biological, and other studies. The water will be collected in pre-conditioned, all plastic containers with proper safeguards taken to prevent metallic and other forms of contamination. The samples will be frozen immediately following collection and brought to the laboratory for analysis.

The trace elements in the seawater samples will be separated either by flotation or by standard solvent extraction procedures. Analysis will be carried out by established spectrophotometric and/or atomic absorption procedures.

All equipment required for the analysis is available at the Department of Chemistry or the Hawaii Institute for Geophysics.

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*If the results obtained from this flotation unit are satisfactory, it is proposed to design, construct, and operate on a pilot scale a larger unit made of metal. Funds for this purpose are requested in the budget for the third year.

Pele Energy Laboratory Experiments (PELE)

University of Hawaii Proposed RANN Program	Center for Engineering Research September 1, 1972 - August 31, 1974

Sub-program Title	Environmental Feasibility		
Sub-program Manager	Kaare Gundersen		
Task Title	Geotoxicology of Thermal Areas	Task No. 5.5	
Investigator	Sanford Siegel		
Department	Botany		
Budget	Year One	Year Two 14,412	Total 14,412

Task Summary

Task Description

Monitor particulate and gaseous effluents released from subsurface drilling operations into thermal structures. Toxic metals indicating presence of mercury, selenium, thallium, plus halogens will be of most concern. Local changes in the content of these substances in soil, plants, and waters (including rainfall) will be followed up after baseline data are established.

Project Need

Adverse changes in local environmental chemistry could arise from introduction of subsurface effluents and alter biota relations and create human hazards.

Anticipated Results

Toxicants will be found. These will be identified quantitatively and guidance as to location of drill site and techniques will be forthcoming to prevent potential development of health hazards and ecosystem alterations.

APPENDIX B

This appendix presents individual budgets for all tasks which comprise the management and research plan. In addition, a summary is included which provides an overview to the total budget. The proposed time-flow is as presented in Figure 7 of the narrative.

BUDGET COMMENTARY

NSF RANN support is sought for the first two years of the three year budget presented here. No attempt has been made to list equivalent matching funds for land leases, local industry contributions, and private donations, which are substantial. A major item in the matching fund category, which is included, is a $200,000 appropriation the first year from the Capital Improvements Program of Hawaii County. These funds are to be allocated as follows:

	$ 50,000	Geophysical surveys (Tasks 2.3, 2.4, 2.8)
	150,000	Deep ocean pipe installation (Task 5.2)
Total	$200,000	

It is proposed that full matching fund details be presented at the time of the site visit, should this proposal receive favorable review.

A summary of budget detail is given as the last page of this appendix.

PELE PROGRAM
RANN PROPOSAL BUDGET

1.2 -NATIONAL ADVISORY

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
H. Harrenstien			
2. Other Personnel			
a. Secretary (6 months @ 25%)	987	1,026	1,067
Total Salaries and Wages	987	1,026	1,067
B. FRINGE BENEFITS	266	273	281
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	1,253	1,299	1,348
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	100	100	100
F. TRAVEL			
1. Domestic (six trips)	4,200	4,200	4,200
2. Foreign			
G. PUBLICATION COSTS			
H. COMPUTER COSTS			
I. OTHER COSTS			
1. Communications			
2. Postage			
J. TOTAL DIRECT COSTS	5,553	5,599	5,648
K. INDIRECT COSTS (45.3% of Salaries and Wages)	447	465	483
L. TOTAL PROJECT COSTS	6,000	6,064	6,131

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

1.3 -HAWAII ADVISORY

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
J. Shupe			
2. Other Personnel			
a. Secretary (6 months @ 25%)	987	1,026	1,067
Total Salaries and Wages	987	1,026	1,067
B. FRINGE BENEFITS	266	273	281
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	1,253	1,299	1,348
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	100	100	100
F. TRAVEL			
1. Domestic (Two trips x 10 persons to Hilo)	2,000	2,000	2,000
2. Foreign			
G. PUBLICATION COSTS			
H. COMPUTER COSTS			
I. OTHER COSTS			
1. Communications	100	100	100
2. Postage	50	50	50
J. TOTAL DIRECT COSTS	3,503	3,549	3,598
K. INDIRECT COSTS (45.3% of Salaries & Wages)	447	465	483
L. TOTAL PROJECT COSTS	3,950	4,014	4,081

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

1.4 INTERNATIONAL ADVISORY

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigators			
H. Harrenstien			
A. Furumoto			
2. Other Personnel			
a. Secretary			
6 months @ 50%	1,974		2,052
6 months @ 25%	987		1,026
Total Salaries and Wages	2,961		3,078
B. FRINGE BENEFITS	850		875
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	3,811		3,953
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES			
F. TRAVEL			
1. Domestic			1,400
2. Foreign			
New Zealand-Hawaii	1,130		1,130
Australia-Hawaii	1,130		1,130
Philippines-Hawaii	1,040		1,040
Indonesia-Hawaii	1,130		1,130
Tokyo-Hawaii (2)	*		1,680
G. PUBLICATION COSTS			
H. COMPUTER COSTS			
I. OTHER COSTS			
1. Consultants	4,000		4,000
J. TOTAL DIRECT COSTS	12,241		15,463
K. INDIRECT COSTS (45.3% of Salaries and Wages)	1,341		1,394
L. TOTAL DIRECT COSTS	13,582		16,857

* Provided by U.S.-Japan Seminar

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

1.5 - DISSEMINATION

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
G. Sheets - 25%	4,317	4,491	4,671
2. Other Personnel			
a. J. MacQuiddy			
b. S. Perry - 50%	4,266	4,434	4,614
c. Student Help (Hourly) 30 hrs/week @ $2.15/hr	3,354	3,354	3,354
Total Salaries and Wages	11,937	12,279	12,585
B. FRINGE BENEFITS	1,890	1,942	2,013
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	13,827	14,221	14,598
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	2,000	2,000	2,000
F. TRAVEL			
1. Domestic			
2. Foreign			
G. PUBLICATION COSTS	2,000	2,000	2,000
H. COMPUTER COSTS			
I. OTHER COSTS			
1. IBM MTST Rental	1,500	1,500	1,500
2. Xerox and Photocopy	2,003	2,003	2,003
J. TOTAL DIRECT COSTS	21,330	21,724	22,101
K. INDIRECT COSTS (45.3% of Salaries and Wages)	5,407	5,562	5,701
L. TOTAL PROJECT COSTS	26,737	27,286	27,802

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

2.0 GEOPHYSICS

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
A. Furumoto			
2. Other Personnel			
a. Stenographer - 50%	3,378	3,516	3,654
b. Student Help 1800 hrs. @ $1.95/hr	3,510	3,510	3,510
Total Salaries and Wages	6,888	7,026	7,164
B. FRINGE BENEFITS	845	874	903
C. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS	7,733	7,900	8,067
D. PERMANENT EQUIPMENT			
1. Typewriter	600		
2. File Cabinets (2)	240		
E. EXPENDABLE EQUIPMENT AND SUPPLIES	500	650	650
F. TRAVEL			
1. Domestic Interisland (2 trips)	400	400	400
2. Foreign			
G. PUBLICATION COSTS	400	400	400
H. COMPUTER COSTS	225	225	225
I. OTHER COSTS			
1. Typewriter Maintenance	50	50	50
J. TOTAL DIRECT COSTS	10,148	9,625	9,792
K. INDIRECT COSTS (45.3% of Salaries and Wages)	3,120	3,183	3,245
L. TOTAL COSTS	13,268	12,808	13,037

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

2.1 PHOTOGEOLOGIC

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
A. Abbott			
B. FRINGE BENEFITS			
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS			
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT & SUPPLIES			
F. TRAVEL			
G. PUBLICATION COSTS			
H. COMPUTER COSTS			
I. OTHER COSTS			
1. Aircraft Rental	4,800	4,800	
2. Photos	2,600	2,600	
3. Consultant	2,000	2,000	
J. TOTAL DIRECT COSTS	9,400	9,400	
K. INDIRECT COSTS			
L. TOTAL COSTS	9,400	9,400	

NOTE: THIS PROPOSAL FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

2.2 GEOMAGNETIC

		01 YEAR	02 YEAR	03 YEAR
A.	SALARIES AND WAGES			
	1. Senior Personnel			
	a. Investigator			
	A. Furumoto			
	A. Malahoff			
	2. Other Personnel			
	a. Graduate Student	6,702	6,702	
B.	FRINGE BENEFITS	264	264	
C.	TOTAL SALARIES AND WAGES AND FRINGE BENEFITS	6,966	6,966	
D.	PERMANENT EQUIPMENT			
E.	EXPENDABLE EQUIPMENT AND SUPPLIES	500	500	
F.	TRAVEL			
	1. Domestic Interisland (2 trips)	400	400	
G.	PUBLICATION COSTS	400	400	
H.	COMPUTER COSTS	225	225	
I.	OTHER COSTS			
	1. Equipment Restoration	600		
	2. Equipment Maintenance		300	
	3. Aircraft Rental (20 hrs)	700	700	
	4. Field Work per diem (30 man days @ $20/day)	600	600	
J.	TOTAL DIRECT COSTS	10,391	10,091	
K.	INDIRECT COSTS (45.3% of Salaries and Wages)	3,036	3,036	
L.	TOTAL COSTS	13,427	13,127	

NOTE: THIS PROPOSAL FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

2.3 - RESISTIVITY

	01 YEAR	02 YEAR
Subcontract *	30,000**	30,000

* This project will be subcontracted to: Dr. George Keller
Colorado School of Mines
Golden, Colorado 80401

** $15,000 County of Hawaii Capital Improvement Program

PELE PROGRAM
RANN PROPOSAL BUDGET

2.4 MICROSEISMIC

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
A. Furumoto			
2. Other Personnel			
a. Graduate Student	11,070	16,605	
b. Student Help	2,480	3,150	
c. Field Assistant	1,800	3,600	
Total Salaries and Wages	15,350	23,355	
B. FRINGE BENEFITS	540	811	
C. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS	15,890	24,166	
D. PERMANENT EQUIPMENT			
1. Microearthquake System (6 @ $4200 ea)	25,200		
2. Field Equipment and Housing for Equip.	1,800		
3. Other	1,860		
4. 24-channel Film Recorder		10,000	
5. 3-component Down Hole Seismometer (6 @ $800 ea)		4,800	
6. Clock and Radio System		2,200	
7. Amplifiers		9,000	
8. Accessories		2,000	
Total	* 28,860	29,000	
E. EXPENDABLE EQUIPMENT AND SUPPLIES	1,030	1,600	
F. TRAVEL			
1. Domestic (Interisland, 2 trips)	400	400	
G. PUBLICATION COSTS	800	800	
H. COMPUTER COSTS	450	450	
I. OTHER COSTS			
1. Seismic Analyzer Rental	400		
2. Array Building		6,000	
3. Other Array Expenses		1,000	
4. Field work per diem (240 man days @ $20/day)	4,800	4,800	
5. Equipment Transportation	100	200	
6. U.S.G.S. Consultant	10,000	10,000	
J. TOTAL DIRECT COSTS	62,730	78,416	
K. INDIRECT COSTS (45.3% of Salaries & Wages)	6,954	10,947	
L. TOTAL COSTS	69,684	89,363	

* $25,200 County of Hawaii Capital Improvement Program for Equipment

PELE PROGRAM
RANN PROPOSAL BUDGET

2.5 MAGNETIC INDUCTION

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
A. Furumoto			
b. Co-Investigator			
D. Klein	9,984	10,380	
2. Other Personnel			
a. Graduate Student	11,070	13,409	
b. Student Help	3,354	3,354	
c. Field Assistant	3,600	3,600	
Total Salaries and Wages	28,008	30,738	
B. FRINGE BENEFITS	2,830	2,903	
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	30,838	33,641	
D. PERMANENT EQUIPMENT			
1. Digital Voltmeter	900		
2. Oscillator and Power Amplifier	800		
3. Null Meter (2 @ $300 ea)	600		
4. Cables and Accessories	600		
5. Generator 5 KVA	900		
	3,800		
E. EXPENDABLE EQUIPMENT AND SUPPLIES			
1. Field	800	400	
2. Office	300	300	
F. TRAVEL			
1. Domestic			
a. Interisland	600	400	
b. Mainland	1,400	700	
G. PUBLICATION COSTS	1,600	1,600	
H. COMPUTER COSTS ($225/hr)	675	675	
I. OTHER COSTS			
1. Communications	300	200	
2. Rental Analysis Equipment	400	500	
3. Equipment Maintenance		800	
4. Field Work per diem (420 man days @ $20/day)	8,200	8,200	
5. Equipment Transportation	200	100	
6. Audio-Magneto Telleric Equip. Fabrication	1,600		
J. TOTAL DIRECT COSTS	50,713	47,516	
K. INDIRECT COSTS (45.3% of Salaries & Wages)	12,688	13,924	
L. TOTAL COSTS	63,401	61,440	

NOTE: THIS PROPOSAL IS FOR YEARS 01 & 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

2.6 THERMAL

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
A. Abbott			
2. Other Personnel			
a. Graduate Student	13,404	13,404	
b. Student Help	2,025	2,025	
Total Salaries and Wages	15,429	15,429	
B. FRINGE BENEFITS	540	540	
C. TOTAL SALARIES AND WAGES AND FRINGE BENEFITS	15,969	15,969	
D. PERMANENT EQUIPMENT			
1. Thermal Survey Recorders	2,000		
2. Thermistors ($20 ea)	2,400	500	
3. Cables and Accessories	1,000		
E. EXPENDABLE EQUIPMENT AND SUPPLIES	3,000	1,000	
F. TRAVEL			
1. Domestic			
a. Interisland	400	400	
b. Mainland		700	
G. PUBLICATION COSTS		800	
H. COMPUTER COSTS		450	
I. OTHER COSTS			
1. Drilling Contract	130,000		
2. Communication	500	200	
3. Consultants	4,000		
4. Field Work per diem (120 man days @ $20/day)	2,400	2,400	
J. TOTAL DIRECT COSTS	161,669	22,419	
K. INDIRECT COSTS (45.3% of Salaries & Wages)	6,989	6,989	
L. TOTAL COSTS	168,658	29,408	

NOTE: THIS PROPOSAL IS FOR YEARS 01 & 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

2.7 DEEP DRILL

	01 YEAR	02 YEAR	03 YEAR
A. MOBILIZE RIG		100,000	25,000
B. LOCATION COST		20,000	20,000
C. DRILLING (100 days @ $2400/day)		240,000	240,000
D. DIRECTIONAL SERVICE		35,000	35,000
E. LOGGING		40,000	40,000
F. BITS (17-1/2 & 12-1/4 inches)		58,000	58,000
G. CASING (20 in., 13-3/8 in., 9-5/8 in.)		85,000	85,000
H. CEMENTING		75,000	75,000
I. AIR COMPRESSORS		55,000	
J. FIXED COST		77,000	77,000
DRILLING COST		785,000	655,000
K. ENVIRONMENTAL PROTECTION (10%)		78,500	65,500
L. TOTAL COSTS		863,500	720,500

ESTIMATE BY K. BRUNOT
14162 HALF MOON BAY RD.
DEL MAR, CALIFORNIA 92014

NOTE: THIS PROPOSAL FOR YEAR 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

2.8 GEOCHEMICAL

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator B. Finlayson (2 months)	2,768	2,878	
2. Other Personnel			
a. Student Help	3,354	3,354	
b. Graduate Student		6,702	
Total Salaries and Wages	6,122	12,934	
B. FRINGE BENEFITS	35	300	
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	6,157	13,234	
D. PERMANENT EQUIPMENT			
1. Stationary pH meter and Accessories	1,000		
2. Portable pH Meter	350		
3. Specific Ion Electrodes	500		
4. UV-Visible Spectrophotometer	6,000		
5. Accessories	950		
6. Atomic Absorption Spectrophotometer	8,000		
7. Accessories	1,000		
8. Small Equipment Items (stirrers, hot plates)	2,000		
9. Field Equipment	200		
	* 20,000		
E. EXPENDABLE EQUIPMENT AND SUPPLIES			
1. Chemicals	4,000	4,400	
2. Office Supplies	250	250	
F. TRAVEL			
1. Interisland	400	400	
2. Mainland	700	700	
G. PUBLICATION COSTS	600	600	
H. COMPUTER COSTS	225	225	
I. OTHER COSTS			
1. Communications	100	100	
2. Field Work per diem (120 man days @ $20/day)	2,400	2,400	
3. Equipment Repair and Maintenance		2,000	
J. TOTAL DIRECT COSTS	34,832	24,309	
K. INDIRECT COSTS (45.3% of Salaries & Wages)	2,773	5,859	
L. TOTAL COSTS	37,605	30,168	

* $9,800 County of Hawaii Capital Improvement Money

PELE PROGRAM
RANN PROPOSAL BUDGET

2.9 ROCK PROPERTIES

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
M. Maghnani			
2. Other Personnel			
a. Graduate Student		6,702	6,702
B. FRINGE BENEFITS		264	264
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS		6,966	6,966
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES		3,200	6,600
F. TRAVEL			
1. Interisland		200	400
2. Mainland			700
G. PUBLICATIONS			500
H. COMPUTER COSTS			450
I. OTHER COSTS			
J. TOTAL DIRECT COSTS		10,366	15,616
K. INDIRECT COSTS (45.3% of Salaries & Wages)		3,036	3,036
L. TOTAL COSTS		13,402	18,652

NOTE: THIS PROPOSAL IS FOR YEARS 02 & 03 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

2.10 EVALUATION

		01 YEAR	02 YEAR	03 YEAR
A.	SALARIES AND WAGES			
	1. Senior Personnel			
	a. Investigators			
	A. Furumoto			
	G. MacDonald			
	2. Other Personnel			
	a. Graduate Student		5,010	
B.	FRINGE BENEFITS		254	
C.	TOTAL SALARIES, WAGES AND FRINGE BENEFITS		5,264	
D.	EQUIPMENT		3,000	
E.	EXPENDABLE EQUIPMENT AND SUPPLIES			
	1. Laboratory		250	250
	2. Office		150	150
F.	TRAVEL			
	1. Interisland $200/trip		600	400
	2. Mainland $700/trip		2,100	2,100
G.	PUBLICATION COSTS		500	500
H.	COMPUTER COSTS		225	225
I.	OTHER COSTS			
	1. Consulting		800	800
	2. Communication		200	200
J.	TOTAL DIRECT COSTS		13,071	4,625
K.	INDIRECT COSTS (45.3% of Salaries & Wages)		2,270	
L.	TOTAL COSTS		15,341	4,625

NOTE: THIS PROPOSAL IS FOR YEARS 02 & 03 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

3.0 - ENGINEERING FEASIBILITY

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
H. Harrenstien			
2. Other Personnel			
a. Secretary 25%	987	1,026	1,067
b. Student Help (Hourly) 520 hours @ $2.15/hour	1,118	1,118	1,118
c. Graduate Student			4,896
Total Salaries and Wages	2,105	2,144	7,081
B. FRINGE BENEFITS	265	273	556
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	2,370	2,417	7,637
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	500	500	500
F. TRAVEL			
1. Domestic			
a. Interisland	1,200	1,200	1,200
b. Mainland	700	700	700
G. PUBLICATION COSTS			
H. COMPUTER COSTS	225	225	225
I. OTHER COSTS			
1. Communication	200	200	200
2. Postage	50	50	50
J. TOTAL DIRECT COST	5,245	5,292	10,512
K. INDIRECT COST (45.3% of Salaries and Wages)	953	971	
L. TOTAL PROJECT COSTS	6,198	6,273	13,720

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

3.1 - HEAT TRANSFER

		01 YEAR	02 YEAR	03 YEAR
A.	SALARIES AND WAGES			
	1. Investigator			
	H.C. Chai (2 months)	4,670	4,856	5,050
	2. Graduate Student	4,635	9,450	9,450
	Total Salaries and Wages	9,305	14,406	14,500
B.	FRINGE BENEFITS	279	534	535
C.	TOTAL SALARIES, WAGES AND FRINGE BENEFITS	9,584	14,940	15,035
D.	PERMANENT EQUIPMENT			
E.	EXPENDABLE EQUIPMENT AND SUPPLIES	500	500	500
F.	TRAVEL			
	1. Domestic			
	a. Interisland	600	1,200	1,200
	b. Mainland	700	1,400	1,400
G.	PUBLICATION COST	200	400	400
H.	COMPUTER COST	225	450	450
I.	OTHER COSTS			
J.	TOTAL DIRECT COST	11,809	19,390	19,485
K.	INDIRECT COST (45.3% of Salaries and Wages)	4,215	6,526	6,568
L.	TOTAL PROJECT COSTS	16,024	25,916	26,053

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

3.2 - POWER PLANT

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Investigator			
J. Chou (2 months)	4,317	4,670	4,856
2. Graduate Student	4,944	10,080	10,080
Total Salaries and Wages	9,261	14,750	14,936
B. FRINGE BENEFITS	279	536	537
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	9,540	15,286	15,473
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	500	1,000	1,000
F. TRAVEL			
1. Domestic			
a. Interisland	600	1,200	1,200
b. Mainland	700	1,400	1,400
2. Foreign (New Zealand-Japan)	1,500	1,500	1,500
G. PUBLICATION COST	200	400	400
H. COMPUTER COST	225	225	225
I. OTHER COSTS			
J. TOTAL DIRECT COST	13,265	21,011	21,198
K. INDIRECT COST (45.3% of Salaries and Wages)	4,195	6,682	6,766
L. TOTAL PROJECT COSTS	17,460	27,693	27,964

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

3.3 - OCEAN TRANSMISSION

		01 YEAR	02 YEAR	03 YEAR
A.	SALARIES AND WAGES			
	1. Investigators			
	H. Hwang	3,992	4,152	4,316
	B. Granborg	3,992	4,152	4,316
	2. Graduate Student	9,270	18,900	18,900
	Total Salaries and Wages	17,254	27,204	27,532
B.	FRINGE BENEFITS	550	1,059	1,060
C.	TOTAL SALARIES, WAGES AND FRINGE BENEFITS	17,804	28,263	28,592
D.	PERMANENT EQUIPMENT			
E.	EXPENDABLE EQUIPMENT AND SUPPLIES	1,000	1,000	1,000
F.	TRAVEL			
	1. Domestic			
	a. Interisland ($200/trip)	1,200	2,400	2,400
	b. Mainland East Coast ($700/trip)	1,400	2,800	2,800
G.	PUBLICATION COST	400	800	800
H.	COMPUTER COST	450	900	900
I.	OTHER COSTS			
J.	TOTAL DIRECT COST	22,254	36,163	36,492
K.	INDIRECT COST (45.3% of Salaries and Wages)	7,816	12,323	12,472
L.	TOTAL PROJECT COSTS	30,070	48,486	48,964

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

3.4 - SYSTEMS DESIGN

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
D. Kihara (2 mos.)	3,550	3,690	3,837
2. Other Personnel			
a. Associate Researcher			
D. Harada - 50%	4,800	4,992	5,190
b. Graduate Students	4,944	10,080	10,080
Total Salaries and Wages	13,294	18,762	19,107
B. FRINGE BENEFITS	1,399	1,694	1,738
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	14,693	20,456	20,845
D. PERMANENT EQUIPMENT	-	-	-
E. EXPENDABLE EQUIPMENT AND SUPPLIES	500	1,000	1,000
F. TRAVEL			
1. Domestic			
a. Interisland	600	1,200	1,200
b. Mainland	1,400	2,100	2,100
G. PUBLICATION COSTS	200	400	400
H. COMPUTER COSTS	2,250	4,500	4,500
I. OTHER COSTS	-	-	-
J. TOTAL DIRECT COST	19,643	29,656	30,045
K. INDIRECT COST (45.3% of Salaries and Wages)	6,022	8,499	8,655
L. TOTAL PROJECT COSTS	25,665	38,155	38,700

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

3.5 - MATERIALS RESEARCH

			01 YEAR	02 YEAR	03 YEAR
A.	SALARIES AND WAGES				
	1. Senior Personnel				
	a. Investigator				
	J. Larsen-Basse (2 mos.)		4,152	4,316	4,490
	2. Other Personnel				
	a. Graduate Students		9,270	13,621	13,621
	b. Student Help		2,000	2,000	2,000
	Total Salaries and Wages		15,422	19,937	20,111
B.	FRINGE BENEFITS		766	792	793
C.	TOTAL SALARIES, WAGES AND FRINGE BENEFITS		16,188	20,729	20,904
D.	PERMANENT EQUIPMENT				
	Hot hardness tester	4,000			
	Creep furnace and controller	2,000			
	Gas fired furnace and controller	7,000			
	Misc. accessories - crudibles, pumps, motors	3,000			
	Recorder to thermocouples	2,200	42,200	-	-
E.	EXPENDABLE EQUIPMENT AND SUPPLIES		5,000	2,000	2,000
F.	TRAVEL				
	1. Domestic				
	a. Interisland		600	600	600
	b. Mainland		1,400	1,400	1,400
G.	PUBLICATION COSTS		500	500	500
H.	COMPUTER COSTS		225	450	450
I.	OTHER COSTS		-	-	-
J.	TOTAL DIRECT COST		66,113	25,697	25,854
K.	INDIRECT COST (45.3% of Salaries and Wages)		6,986	9,031	9,110
L.	TOTAL PROJECT COSTS		73,099	34,710	34,964

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

3.6 - SYSTEMS ENGINEERING

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Investigator			
W. Arnell	2,417	2,515	2,615
2. Graduate Student	4,635	9,450	9,450
Total Salaries and Wages	7,052	11,965	12,065
B. FRINGE BENEFITS	266	520	521
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	7,318	12,485	12,586
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	500	500	500
F. TRAVEL			
1. Domestic			
a. Interisland ($200/trip)	600	1,200	1,200
b. Mainland ($700/trip)	700	1,400	1,400
G. PUBLICATION COST	200	400	400
H. COMPUTER COST	225	450	450
I. OTHER COSTS			
J. TOTAL DIRECT COST	9,543	16,435	16,536
K. INDIRECT COST (45.3% of Salaries and Wages)	3,196	5,420	5,465
L. TOTAL PROJECT COSTS	12,739	21,855	22,001

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

4.0 - SOCIO-ECONOMIC FEASIBILITY

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
R. Kamins (Summer-one month)	2,600	2,600	2,600
2. Other Personnel			
a. Graduate Student 25%	4,704	4,896	4,896
b. Secretary 25%	987	1,026	1,067
c. Student Help (Hourly) 520 hours @ $2.15/hour	1,118	1,118	1,118
Total Salaries and Wages	9,409	9,640	9,681
B. FRINGE BENEFITS	540	548	550
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	9,949	10,188	10,231
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	500	500	500
F. TRAVEL			
1. Domestic			
a. Interisland ($200/trip)	1,200	1,200	1,200
b. Mainland ($700/trip)	700	700	700
G. PUBLICATION COST			
H. COMPUTER COST	225	225	225
I. OTHER COSTS			
1. Communications	200	200	200
2. Postage	50	50	50
J. TOTAL DIRECT COST	12,824	13,063	13,106
K. INDIRECT COST (45.3% of Salaries and Wages)	4,262	4,367	4,385
L. TOTAL PROJECT COSTS	17,086	17,430	17,491

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

4.1 LAND USE

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
G. Sheets (25%)	4,317	4,491	4,671
B. FRINGE BENEFITS	850	877	905
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	5,167	5,368	5,576
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	500	500	500
F. TRAVEL			
1. Interisland $200/trip	600	1,200	1,200
2. Mainland $700/trip	1,400	2,800	2,800
G. PUBLICATION COSTS	200	400	400
H. COMPUTER COSTS			
I. OTHER COSTS			
1. Consultant		5,000	10,000
J. TOTAL DIRECT COSTS	7,867	15,268	20,476
K. INDIRECT COSTS (45.3% of Salaries & Wages)	1,956	2,034	2,116
L. TOTAL PROJECT COSTS	9,823	17,302	22,592

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

4.2 LEGISLATION

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator			
L. Sadamoto			
B. FRINGE BENEFITS			
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS			
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	400	400	300
F. TRAVEL			
1. Interisland $200/trip	1,000	1,000	600
2. Mainland $700/trip	1,400	1,400	700
G. PUBLICATION COSTS	200	200	200
H. COMPUTER COSTS			
I. OTHER COSTS			
1. Consultant	2,000	3,500	1,200
J. INDIRECT COSTS			
K. TOTAL PROJECT COSTS	5,000	6,500	3,000

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

4.3 PLANNING

		01 YEAR	02 YEAR	03 YEAR
A.	SALARIES AND WAGES			
	1. Senior Personnel			
	a. Investigator			
	E. Grabbe			
B.	FRINGE BENEFITS			
C.	TOTAL SALARIES, WAGES AND FRINGE BENEFITS			
D.	PERMANENT EQUIPMENT			
E.	EXPENDABLE EQUIPMENT AND SUPPLIES	400	400	500
F.	TRAVEL			
	1. Interisland $200/trip	600	1,200	1,600
	2. Mainland $700/trip	1,400	1,400	1,400
G.	PUBLICATION COSTS	100	300	400
H.	COMPUTER COSTS			
I.	OTHER COSTS			
	1. Consultant	2,000	2,000	3,000
J.	TOTAL DIRECT COSTS	4,500	5,300	6,900
K.	INDIRECT COSTS			
L.	TOTAL PROJECT COSTS	4,500	5,300	6,900

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

4.4 - ECONOMIC FEASIBILITY

		01 YEAR	02 YEAR	03 YEAR
A.	SALARIES AND WAGES			
	1. Investigator			
	N. El Ramly (2 months)	3,550	3,690	3,837
	2. Graduate Student	4,635	14,175	9,270
	3. Student Help	——	3,354	3,354
	Total Salaries and Wages	8,185	21,219	16,461
B.	FRINGE BENEFITS	272	799	546
C.	TOTAL SALARIES, WAGES AND FRINGE BENEFITS	8,457	22,018	17,007
D.	PERMANENT EQUIPMENT	——	5,000	2,000
E.	EXPENDABLE EQUIPMENT AND SUPPLIES	500	1,000	1,000
F.	TRAVEL			
	a. Interisland ($200/trip)	600	1,200	1,200
	b. Mainland ($700/trip)	1,400	2,800	2,800
G.	PUBLICATION COST	300	300	300
H.	COMPUTER COST	225	900	450
I.	OTHER COSTS			
J.	TOTAL DIRECT COST	11,482	32,218	24,757
K.	INDIRECT COSTS (45.3% of Salaries and Wages)	3,708	9,612	7,457
L.	TOTAL PROJECT COST	15,190	42,830	32,214

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

5.0 - ENVIRONMENTAL FEASIBILITY

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
Investigator			
K. Gundersen (Summer-one month)	1,837	1,910	1,986
2. Other Personnel			
a. Graduate Student 50%	4,704	4,896	4,896
b. Secretary 25%	987	1,026	1,067
c. Student Help (Hourly) 520 hours @ $2.15/hour)	1,118	1,118	1,118
Total Salaries and Wages	8,646	8,950	9,067
B. FRINGE BENEFITS	536	545	553
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	9,182	9,495	9,620
D. PERMANENT EQUIPMENT			
E. EXPENDABLE EQUIPMENT AND SUPPLIES	500	500	500
F. TRAVEL			
1. Domestic			
a. Interisland ($200/trip)	1,200	1,200	1,200
b. Mainland ($700/trip)	700	700	700
G. PUBLICATION COST			
H. COMPUTER COST	225	225	225
I. OTHER COSTS			
1. Communications	200	200	200
2. Postage	50	50	50
J. TOTAL DIRECT COST	12,057	12,370	12,495
K. INDIRECT COST (45.3% of Salaries and Wages)	3,917	4,054	4,107
L. TOTAL PROJECT COST	15,974	16,424	16,602

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

5.1 - ENVIRONMENTAL IMPACT

	01 YEAR	02 YEAR
Subcontract *	25,000	35,000

Consultant

* This project will be subcontracted to: Dr. Franklin Agardy
URS Research Company
155 Bovet Road
San Mateo, California 94402

PELE PROGRAM
RANN PROPOSAL BUDGET

5.2 - AQUACULTURE

		01 YEAR	02 YEAR	03 YEAR
A.	SALARIES AND WAGES			
	1. Investigator K. Gundersen	1,837	1,910	1,986
	2. Graduate Student	—	8,160	8,160
	3. Technicians (Hourly)	8,598	17,970	26,184
	4. Student Help	645	1,075	1,075
	Total Salaries and Wages	11,080	29,115	37,405
B.	FRINGE BENEFITS	63	618	665
C.	TOTAL SALARIES, WAGES AND FRINGE BENEFITS	11,143	29,733	38,070
D.	PERMANENT EQUIPMENT	150,000*	—	—
E.	EXPENDABLE EQUIPMENT AND SUPPLIES	22,000	9,000	25,000
F.	TRAVEL			
	1. Interisland	1,000	2,000	2,000
	2. Mainland	2,100	2,100	2,100
G.	PUBLICATION COST	500	500	500
H.	COMPUTER COST			
I.	OTHER COSTS			
	1. Communications	200	400	400
	2. Freight	1,000	200	1,000
	3. Utilities	5,000	5,000	5,000
	4. Vehicle Lease	3,500	3,500	3,500
	5. Repair and Maintenance	—	500	1,000
	Total I	9,700	9,600	10,900
J.	TOTAL DIRECT COST	196,443	52,933	78,570
K.	INDIRECT COSTS (45.3% of Salaries and Wages)	5,019	13,189	16,945
L.	TOTAL PROJECT COST	201,462	66,122	95,515

*Provided by the County of Hawaii Capital Improvement Program

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

5.3 - AGRICULTURE

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Investigator			
E.B. Hundtoft			
2. Research Assistant 25%	4,857	5,052	5,052
3. Student Help	2,150	2,150	2,150
Total Salaries and Wages	7,007	7,202	7,202
B. FRINGE BENEFITS	945	975	975
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	7,952	8,177	8,177
D. PERMANENT EQUIPMENT	2,300	2,300	—
E. EXPENDABLE EQUIPMENT AND SUPPLIES	1,000	500	1,000
F. TRAVEL			
1. Interisland	600	600	600
2. Mainland	1,400	700	700
G. PUBLICATION COST	700	500	500
H. COMPUTER COST	450	450	450
I. OTHER COSTS			
1. Reefer Lease	1,400	1,400	—
J. TOTAL DIRECT COST	15,802	14,627	11,427
K. INDIRECT COST (45.3% of Salaries and Wages)	3,174	3,263	3,263
L. TOTAL PROJECT COST	18,976	17,890	14,690

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

5.4 BY-PRODUCT RECOVERY

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator H. Zeitlin	2,332	4,664	4,850
2. Other Personnel			
a. Graduate Student	4,008	4,008	4,152
b. Graduate Student		4,152	4,308
c. Student Help	645	645	645
Total Salaries & Wages	6,985	13,469	13,955
B. FRINGE BENEFITS	266	529	532
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS	7,251	13,998	14,487
D. PERMANENT EQUIPMENT	2,000	500	500
E. EXPENDABLE EQUIPMENT AND SUPPLIES	1,000	1,000	1,000
F. TRAVEL			
1. Interisland	600		600
2. Mainland		1,400	
G. PUBLICATION COSTS		200	200
H. COMPUTER COSTS			
I. OTHER COSTS			
J. TOTAL DIRECT COSTS	10,851	17,098	16,787
K. INDIRECT COSTS (45.3% of Salaries & Wages)	3,164	6,101	6,322
L. TOTAL PROJECT COSTS	14,015	23,199	23,109

NOTE: THIS PROPOSAL IS FOR YEARS 01 AND 02 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

5.5 GEOTOXICOLOGY

	01 YEAR	02 YEAR	03 YEAR
A. SALARIES AND WAGES			
1. Senior Personnel			
a. Investigator S. Seigel			
2. Other Personnel			
a. Graduate Student		5,346	5,535
b. Student Help		1,500	1,500
Total Salaries & Wages		6,846	7,035
B. FRINGE BENEFITS		265	266
C. TOTAL SALARIES, WAGES AND FRINGE BENEFITS		7,111	7,301
D. PERMANENT EQUIPMENT		1,500	500
E. EXPENDABLE EQUIPMENT AND SUPPLIES		500	500
F. TRAVEL			
1. Interisland		1,600	1,600
G. PUBLICATION COSTS		600	600
H. COMPUTER COSTS			
I. OTHER COSTS			
J. TOTAL DIRECT COSTS		11,311	10,501
K. INDIRECT COSTS (45.3% of Salaries & Wages)		3,101	3,186
L. TOTAL PROJECT COSTS		14,412	13,687

NOTE: THIS PROPOSAL IS FOR YEARS 02 AND 03 ONLY.

PELE PROGRAM
RANN PROPOSAL BUDGET

BUDGET SUMMARY

		01 YEAR	02 YEAR
A.	SALARIES AND WAGES	256,820	366,489
B.	FRINGE BENEFITS	21,895	26,307
C.	TOTAL SALARIES, WAGES AND FRINGE BENEFITS	278,715	392,796
D.	PERMANENT EQUIPMENT	* 255,400	41,800
E.	EXPENDABLE EQUIPMENT AND SUPPLIES	49,880	37,800
F.	TRAVEL		
	1. Domestic		
	a. Interisland	18,600	26,600
	b. Mainland	26,600	36,400
	2. Foreign	5,930	1,500
G.	PUBLICATION COSTS	9,500	13,000
H.	COMPUTER COSTS	7,650	12,375
I.	OTHER COSTS	** 256,453	1,006,553
J.	TOTAL DIRECT COSTS	908,728	1,568,824
K.	INDIRECT COSTS	116,339	164,929
L.	TOTAL PROJECT COSTS	1,025,067	1,733,753

* Of this total, $185,000 is provided by County of Hawaii, Capital Improvement Program

** Of this total, $15,000 is provided by County of Hawaii, Capital Improvement Program

TOTAL PROGRAM COSTS, YEAR ONE	1,025,067
TOTAL PROGRAM COSTS, YEAR TWO	1,733,753
TOTAL PROGRAM COSTS	2,758,820

NSF portion	2,558,820
Hawaii portion	200,000
Total	2,758,820

APPENDIX C

Bibliographic information is contained in this appendix to indicate competence and experience of principal and senior investigators.