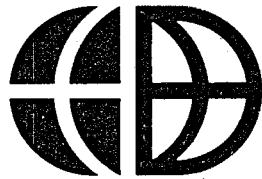


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# **Dillingham**

## **FINAL REPORT**

### **PAHOA GEOTHERMAL INDUSTRIAL PARK**

**ENGINEERING AND ECONOMIC ANALYSIS**

**FOR**

**DIRECT APPLICATIONS OF GEOTHERMAL ENERGY**

**IN AN**

**INDUSTRIAL PARK AT PAHOA, HAWAII**

**Prepared for:**

**U.S. Department of Energy  
Division of Geothermal Energy  
San Francisco Operations Office  
DOE Contract No. DE-AC03-79ET27233**

**Prepared by:**

**Advanced Projects Department  
Hawaiian Dredging & Construction Company  
A Dillingham Company**

**James W. Moreau - Principal Investigator**

**December 1980**

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## ABSTRACT

This engineering and economic study evaluated the potential for developing a geothermal industrial park in the Puna District near Pahoia on the Island of Hawaii. Direct heat industrial applications were analyzed from a marketing, engineering, economic, environmental, and sociological standpoint to determine the most viable industries for the park.

An extensive literature search produced 31 existing processes currently using geothermal heat. An additional list was compiled indicating industrial processes that require heat that could be provided by geothermal energy. From this information, 17 possible processes were selected for consideration. Careful scrutiny and analysis of these 17 processes revealed three that justified detailed economic workups.

The three processes chosen for detailed analysis were: an ethanol plant using bagasse and wood as feedstock; a cattle feed mill using sugar cane leaf trash as feedstock; and a papaya processing facility providing both fresh and processed fruit. In addition, a research facility to assess and develop other processes was treated as a concept.

Consideration was given to the impediments to development, the engineering process requirements and the governmental support for each process. The study describes the geothermal well site chosen, the pipe line to transmit the hydrothermal fluid, and the infrastructure required for the industrial park. A conceptual development plan for the ethanol plant, the feedmill and the papaya processing facility was prepared.

The study concluded that a direct heat industrial park in Pahoia, Hawaii, involves considerable risks. If a developer wishes to proceed, he should be assured of the viability of tenant processes. No processes were discovered which would obviously benefit by moving immediately to a geothermal industrial park near Pahoia.

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LIST OF ABBREVIATIONS

g	Acceleration Due to Gravity (32 ft. per second per second)
hz	Hertz
MBTU	Million BTU
BDT	Bone Dry Ton
ROI	Rate of Return on Investment
GPD	Gallons Per Day
M	Magnitude on the Richter Scale
MT	Metric Tons
MW	Megawatt
TPD	Tons Per Day
PPM	Parts Per Million

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## FOREWORD

Hawaiian Dredging and Construction Company, a Dillingham Company, completed this study in late 1980. The study was to examine the feasibility of an industrial park in Pahoehoe, Hawaii, utilizing the geothermal heat believed to be available in that area. The work was performed under a contract for the U.S. Department of Energy, Geothermal Energy Division, and was directed by Ms. Hilary Sullivan, Program Coordinator. Significant cost sharing in the study was contributed by Hawaiian Dredging and Construction Company, the County of Hawaii, Amfac, Inc. and GeoProducts, Inc.

The study was under the direction of Mr. Jim Moreau, Principal Investigator. He was assisted by the following staff: Ms. Jennifer Harris, Mr. Dien Truong, Mr. Russell Luke, Ms. Janice Kuwahara and Ms. Heather Garlutzo. The principal subcontractors were:

- Planning & Community: County of Hawaii; Mr. A. Nakaji, Mr. D. Black
- Agriculture: University of Hawaii, College of Tropical Agriculture; Dr. R. Stanley, Dr. J. Brewbaker, Mr. J. Maloney.
- Geothermal Engineering: W. A. Hirai & Associates; Mr. W. Hirai, Mr. Curt Beck
- Ethanol Production: GeoProducts, Inc.; Mr. K. Boren
- Animal Feedmill: Darrow Sawyer, Inc.; Mr. H. Sawyer
- Papaya Processing: University of Hawaii, Hilo; Dr. R. King
- Engineering Analysis: University of Hawaii, Hilo; Dr. W. Chen
- Ethanol Engineering: Parsons Hawaii; Mr. W. Siegrist
- Sugar & Papaya: Puna Sugar Company; Mr. J. Humme
- Direct Heat Applications: Oregon Institute of Technology; Dr. P. J. Lienau, Geoheat Utilization Center

As well as assisting in the study, appendices were prepared by the following:

- Resource: Hawaii Institute of Geophysics; Dr. C. Helsley
- Legal: Carlsmith, Carlsmith, Wichman & Case;  
Mr. S. Okura
- Social Impact: University of Hawaii, Department of Sociology;  
Dr. P. Canan
- Labor & Economic Impact: Puna Hui Ohana; Mr. E. Kinney
- Environmental: Ecotrophics; Dr. S. Siegel
- Financial: Bank of Montreal; Mr. K. McNerney  
Merrill Lynch; Mr. W. Laskey

An Advisory and Review Board representing a cross section of Hawaiian industry and community leadership concerned with the appropriate development of the Kilauea east rift geothermal resource was briefed twice during the study.

Finally, Mr. Lloyd Jones, Manager of the Hawaiian Dredging & Construction Company Advanced Projects Department, provided study participants guidance, counseling, insights and continuing support throughout the study period.

## EXECUTIVE SUMMARY

### Introduction

The increasing high cost of imported oil has created a favorable economic and political climate for geothermal development in Hawaii. Today, "energy self-sufficiency" is a major concern of Hawaii State and County governments and the business community.

The long term benefit of geothermal development as part of that energy self-sufficiency plan for Hawaii can be substantial. Geothermal electric power generation appears to be assured for at least the first 25 Mw of electric power. However, direct heat applications enjoy no similar assurance of success.

This study addresses the potential for success of the conceptual use of geothermal heat in an industrial park near Pahoehoe, Hawaii.

### MARKET IDENTIFICATION

A literature search of geothermal direct heat applications resulted in 31 processes. Separately and together, selected team members submitted their assessment for each process. Selection criteria dictated that potential processes:

- Be heat intensive.
- Relate to Hawaiian raw materials or low-cost imports.
- Be technologically proven.
- Be free from any known limiting barriers.
- Have a potential market.

The principle conclusions reached from these assessments were:

- No one process stood out as an assured success

- There would be problems associated with all developments
- It is difficult to penetrate complex Hawaiian markets
- Transportation to and from Pahoia is a critical factor
- Transfer of mainland technology to Hawaiian application must be done carefully.

Through repeated review with increasingly stringent criteria for inclusion in the industrial park, the list was narrowed to eight potentially promising industries. In addition, a research facility was conceived for the park with the intent to test and prove additional processes.

The eight potential processes selected for an initial economic viability analysis were:

- Aquaculture oriented to the production of tilapia (freshwater fish)
- Cement bonded wallboard
- Ethanol plant using a cellulose feedstock
- Cattle feedmill using sugar cane trash and/or bagasse
- Freeze drying of Kona coffee
- Koa lumber processing using a geothermal heated kiln
- Papaya processing
- Protein recovery plant
- Geothermal applications research laboratory (concept only)

#### SITE DEVELOPMENT

For the purpose of this study, a site located about 1 mile southwest of Pahoia in the Puna District on the Island of Hawaii was used. (See Figure 1.1.)

However, the actual implementation of the industrial park concept developed in this study may be equally feasible on other sites near the geothermal field.

## GEOHERMAL RESOURCE

The primary geothermal resource in the State of Hawaii is found in the Kilauea Volcano east rift zone that trends in a north easterly direction two miles south of Pahoa. The surface geological expressions suggest that geothermal resources are likely to be found more or less continuously through this zone. Thus, a proposed drilling site 2-1/2 miles south of the industrial park site has a good probability of success. The dry hole risk of drilling at the proposed well site is 3 in 10; the probability of attaining adequate resource for the industrial park is estimated at 70%.

Two geothermal resource development scenarios were originally developed to provide heat for the industrial park:

1. Development of geothermal wells as a primary energy source for a 25 MWe power plant, with the residual steam being used by the industrial park. The cost for hydrothermal fluid transmission and the cost for the well development would be apportioned between the electric application and the direct heat applications.
2. Development of geothermal wells and transmission facilities dedicated to the industrial park and thus independent of direct electric power generation.

Under either scenario, the hydrothermal fluid would be converted to steam at the wellhead and transported 2-1/2 miles to the 800 acre industrial site located at the edge of the rift zone. Geothermal brine would be re-injected at the well site.

Initially, a price of \$2.67/MBTU was calculated for geothermal steam based upon three producing wells assuming 1000 BTU is obtained per pound of steam. This price is comparable to fossil fuel steam costs at \$7.46/MBTU.

As the study progressed and the specific industrial processes and their associated geothermal requirements were known, the geothermal steam price was recomputed to \$5.934/MBTU if only one industry operates.

#### INITIAL TEST FOR ECONOMIC VIABILITY

An initial economic viability test assessed the differential costs of locating each of the eight potential industries in the industrial park at Pahoia versus the industry's current location. Freight, logistics, energy and distribution costs were found to be the primary variables.

#### ENGINEERING AND ECONOMIC ANALYSIS

Three industries appeared to be economically viable when located at the park after this initial analysis. These were the ethanol plant, the cattle feed mill and the papaya processing plant. Each industry was then subjected to detailed engineering and economic analyses.

#### BARRIERS AND CONCERNS

Potential barriers to and concerns about developing a geothermal industrial park at Pahoia, Hawaii were evaluated.

These issues involved the major social, environmental and legal matters impacting on the proposed conceptual park development. Permitting procedures were addressed.

#### FINAL CONCEPT

From the foregoing, a most feasible concept for the park was developed. This is:

1. The anchor industry would be a commercial ethanol plant designed to produce 20,000 gpd of fuel-grade ethanol and other energy



products. Initial feedstock would be bagasse and wood from ohia forests and wastes from lumber operations. In the future, eucalyptus and leucaena trees would be considered for nearby energy tree farms to serve as feedstock.

2. A cattle feedmill would produce a roughage component for cattle feed using sugar cane leaves (trash) which would be combined with a binder and then cubed and dehydrated. The primary market for this product would be in Japan.
3. A papaya processing facility would include a refrigeration cooled warehouse for fresh fruit, a puree production line, and a vacuum dehydration process for making papaya snacks. Papaya is currently the mainstay industry in the lower Puna District, and such a plant could offer an opportunity for cooperative ownership by the local Hawaiian farmers.
4. A research facility to test the feasibility of other direct heat applications and develop additional promising processes including small scale low temperature applications would also be considered.

#### FINANCING PLANS

At such time a developer and/or investor becomes interested in commercialization of geothermal energy based on the final park concept, lending institutions actively involved in geothermal development will develop financing plans and sponsor a credit facility to finance 75% of the estimated project costs based on the Federal Government's geothermal loan guarantee program.

## CONCLUSIONS

The establishment of an industrial park utilizing geothermal heat is possible but involves considerable risk. This industrial park concept requires a developer willing and capable of assuming those risks. Such a developer should be fully satisfied that the anchor industry and the other proposed park industries are technically and economically viable with assured markets. In this study no processes were discovered which would either significantly benefit by relocation or would be guaranteed reasonable success if initiated as a new industry.

## CHAPTER 1

### BACKGROUND AND INTRODUCTION

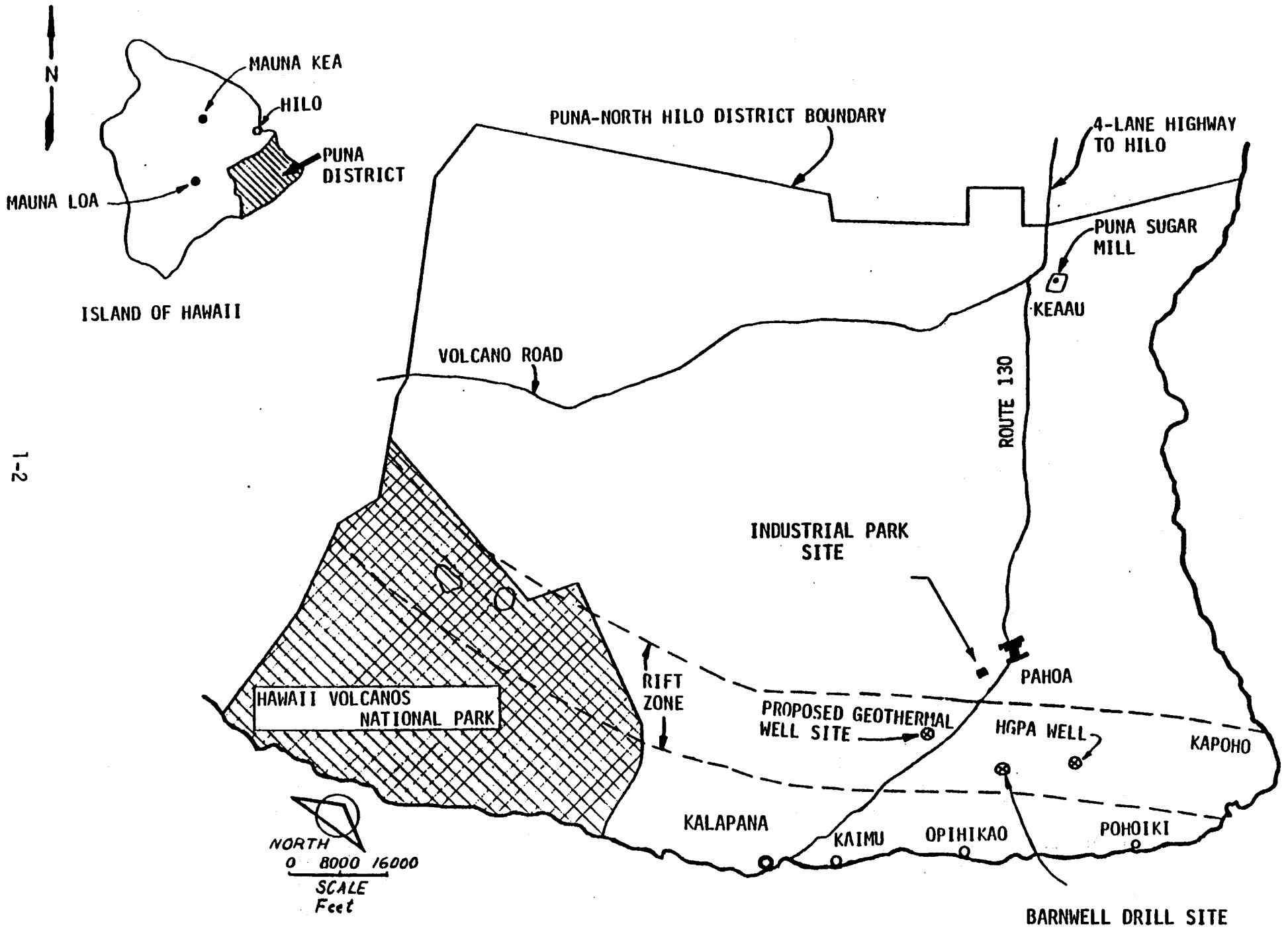
#### Introduction

The Big Island of Hawaii has been described as a sleeping giant, an island with a challenge and an island in trouble. None of these brief descriptions adequately describe the island of Hawaii in relation to the development of a geothermal industrial park near Pahoa in the lower Puna district. However, in a sense, the district's Kapoho geothermal resource is a "sleeping giant" and a "challenge" that can help in the realization of some of the island's goals relating to economic development and energy self-sufficiency.

This chapter provides a community profile of the Puna district together with its history, its people, and its climate. A summary of recent business development experience along with Hawaii County's goals for energy self-sufficiency are included.

#### Community Profile

The island of Hawaii lies 180 miles southeast of Oahu, the State's population and commercial activity center. The Puna district, shown on Figure 1.1, stretches southward from the suburbs of the city of Hilo to the Black Sands seashore at Kalapana. The area is generally rural and agricultural with local farmers producing the bulk of the county's papaya, anthuriums and orchids, worth nearly \$13,000,000 in annual sales. In addition, the illegal marijuana crop figures prominently in the economy of Lower Puna and the County.



1-2

Figure 1.1 Boundary Map of Puna District

### Puna: A Rural Community in Transition

An examination of Pahoā, Lower Puna's largest community, indicates a fairly recent history. Ancient Hawaiians in the area had generally settled in coastal communities extending up the rugged Ka'u/Puna coastline to Hilo. Kalapana, Kapoho, Opihikao, Kilohana and Pohoiki were thriving fishing communities trading dried fish with upper Hilo/ Hamakua villages for dried meat, vegetables, taro, potatoes, or tapa cloth.

In the late 1800's, the Ola'a Sugar Company, later to become the Puna Sugar Company, replanted its acreage from coffee and rubber to sugar and expanded its acreage southward establishing the town of Pahoā. The original town site which was near the present Yamaguchi Service Station was later moved to a nearby site near the Akebono Theatre when the Pahoā Lumber Company established a sawmill to cut ohia timber to manufacture railroad ties for the westward moving Union and Southern Pacific Railroads. In 1903, the Ola'a Sugar Company opened a new plantation store and built new plantation houses on the hill next to the church.

Pahoā's population at that time consisted of recent imported Chinese, Filipino and Japanese laborers in addition to a large Hawaiian community.

Change came slowly to this community until the 1960's, at which time, some exploratory drilling for geothermal took place and new residents arrived.

Heavy in-migration has occurred from large continental U.S. urban centers, mostly from the West Coast. A significant number, mostly

Filipinos, arrived to work on the various farms. On the other hand, early mainland newcomers generally were retirees settling on lands purchased years ahead in any of the several large pre-1956 subdivisions (Figure 1.2) which were without electricity, water, drainage, sewage and adequate roads. Recently, many younger Caucasians came in large numbers, seeking a self-sufficient lifestyle. Many are involved in pakalolo (marijuana) cultivation, purchasing more lands with the profits.

Overall, the Puna district population increased over 147% since the last census with Lower Puna receiving the greatest portion of the increases for a total population of nearly 5,000.

According to local and Hilo realtors, large numbers of these newcomers, in all ethnic groups, have migrated from Honolulu, Maui and Kona where heavy tourist, condominium and industrial development are drastically altering the cultural landscape.

Most of the residents have a variety of jobs outside of Lower Puna, mostly in Hilo. Unemployment averages 9.2% in the Lower Puna District. Part of this high rate can be attributed to the seasonal nature of the farm work and a large number of itinerants; but the primary cause is the limited local employment opportunities coupled with the reluctance by certain residents to commute beyond the district.

In the early 1970's, in response to growth and changes, several new businesses moved into Pahoehoe including Magoo's Pizza House, a natural food store, another laundromat, a savings and commercial bank, a bakery/coffee house, a Chinese restaurant, a used appliance store, and an electronic games center. A small medical center attends to the health needs of many in the community.

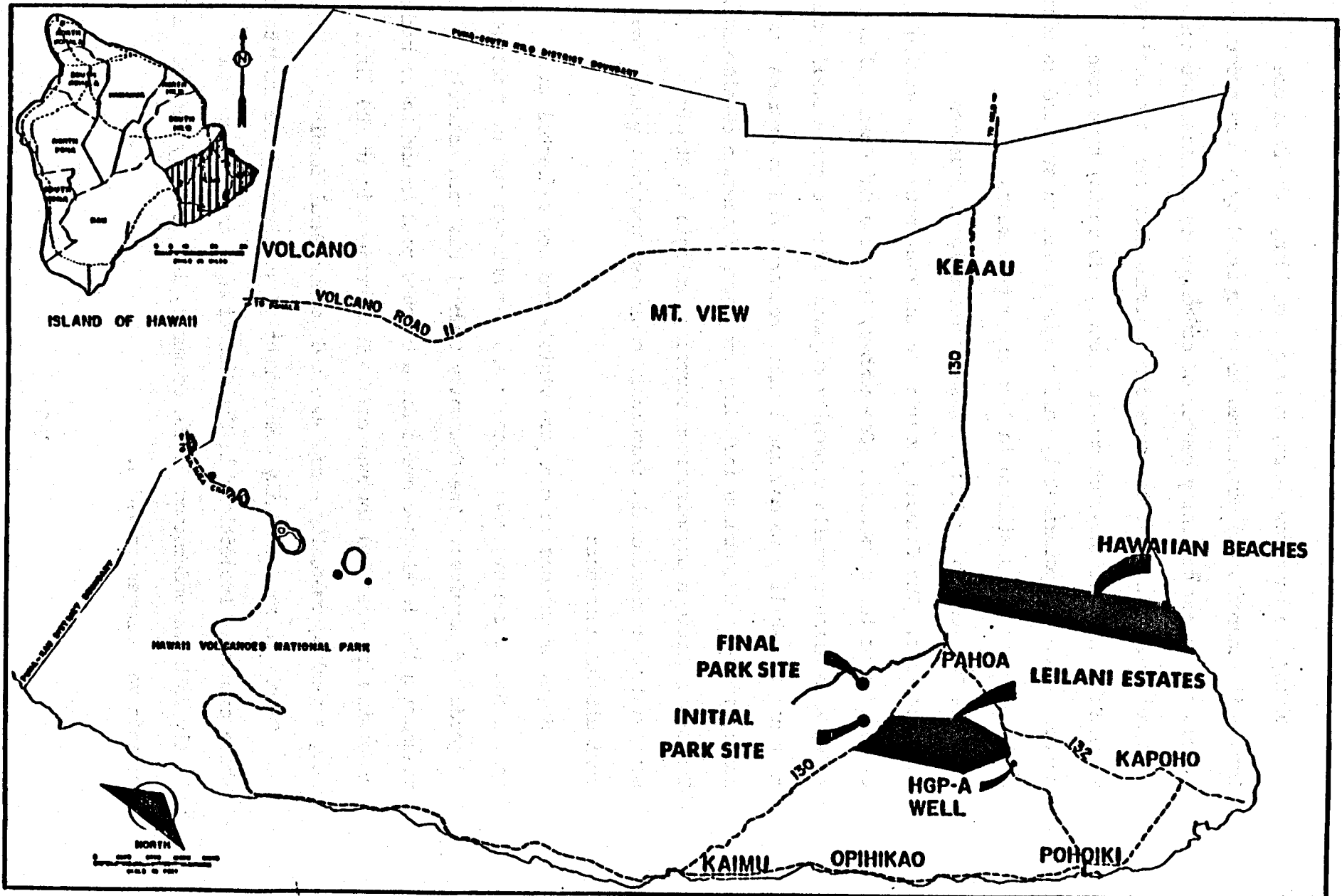


Figure 1.2 Alternative Park Site Locations

During the past few years, only one building, the Japanese Hongwanji (church), was demolished to be replaced by a more modern structure. A new community center of contemporary architecture has been built on a short street extending outward from the main road on which Pahoehoe's first low-cost public housing (50 units) have been built. Pahoehoe is approximately half a square mile in size and is estimated to be worth \$9 million in land and improvements.

The Puna Community Council has a membership of fourteen organizations. The Council provides an informal network promoting betterment of the community. One member, the Puna Hui Chana, claims to be a Hawaiian umbrella community organization; it has a small staff that has the ability to conduct limited research and to express community issues and concerns including geothermal/economic development. The other thirteen organizations represent religious, ethnic subdivision, recreational, fraternal, business, parents, youth, and agricultural interests.

Signs of changes to come are visible and are reflected in congestion of the highways, schools and restaurants and in shortages of goods and services. The Community Council has been actively pressuring the local government for a by-pass road around Pahoehoe rather than widening the road through town. This project is in the final stages pending community acceptance and governmental funding.

People in the community are currently experiencing the impacts of these changes. Projections in the direction of these changes are likely to be misunderstood if the community is not fully informed and mitigative measures provided.

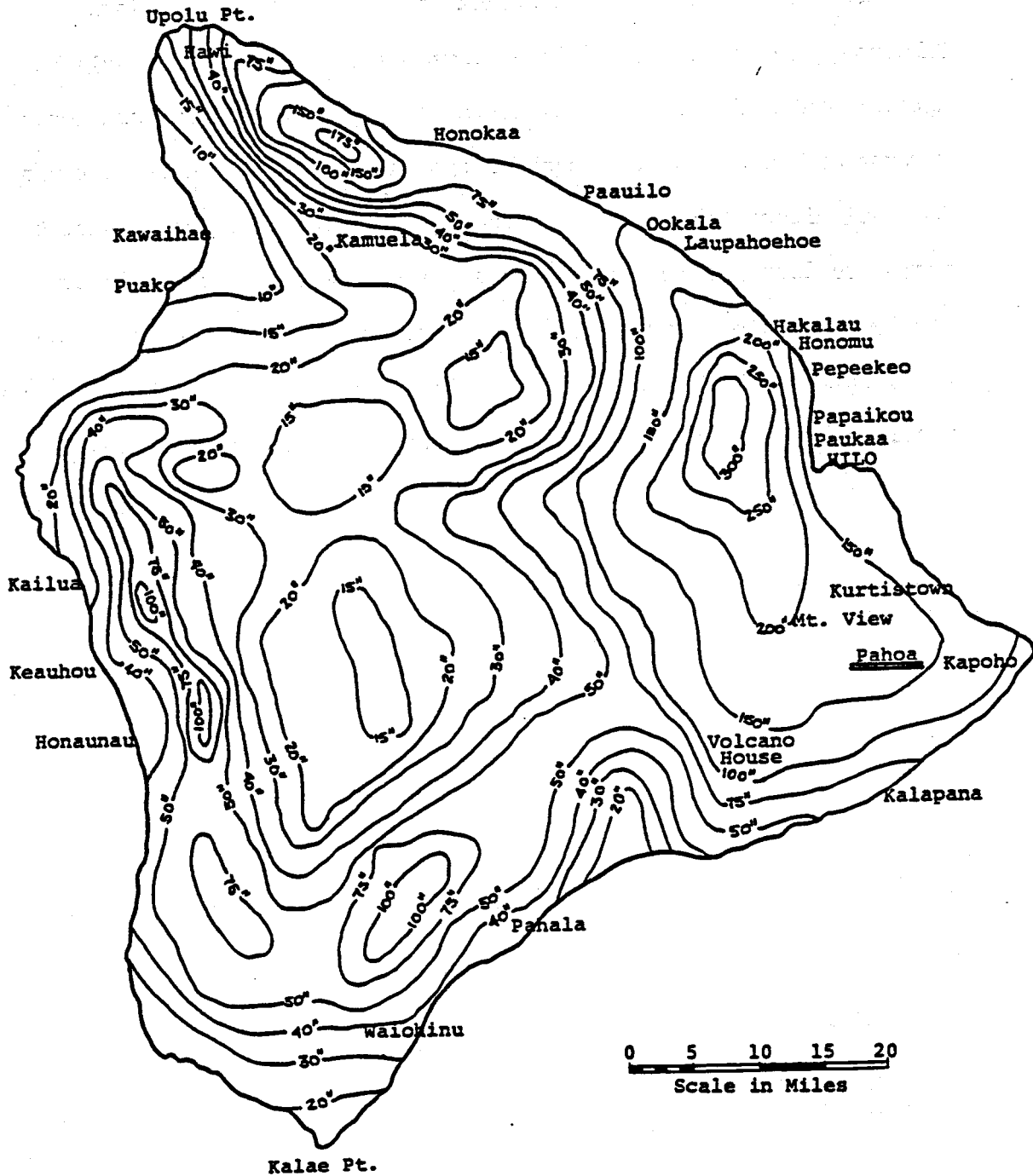


### Climate and Topography

Pahoia is located on the windward, rainy side of the island, at an elevation of 650 feet. The annual rainfall varies from about 150 inches to 200 inches. (Figure 1.3)

Much of the lower Puna district has been overrun with lava. Pahoehoe lava and recent aa lava flows are considered unsuitable for agriculture production. However, the old aa flows can support dense vegetation, papaya, and through weathering, the soil can be suitable for agriculture production. In the western portion of the district there are large stands of ohia forests; the central portion is primarily devoted to the production of sugar cane and anthuriums. The air is clear and the noise level is low. Both of these factors play a prominent role in the environmental impact of geothermal development.

Figure 1.3 --MAP OF THE ISLAND OF HAWAII SHOWING THE DISTRIBUTION OF RAINFALL



SOURCE: County of Hawaii, Department of Water Supply, 1972-1973 Annual Report, Table No. 7.

## Big Island Business Experience

Observations and experience concerning business development in the County of Hawaii indicate that the marketing of products has been the greatest single impediment to the economic viability of a new venture. Rarely have land, building permits, technical production, financing or other considerations been a limiting factor.

As a background to market identification, businesses which had failed within the last 10 years on the Big Island were examined. The evaluation was limited to growing, manufacturing and processing operations. Retail stores, visitor industry facilities, and other low energy users were excluded. It was concluded that approximately 55% of new ventures failed due to market factors, another 30% failed because of management factors and 15% because of capital problems. It is highly improbable that the cost of energy was the deciding factor in any failure. Seven case studies were evaluated. The principal findings are summarized below:

Case #1: The combination of poor productivity coupled with market pricing problems created a situation where management could no longer defend operating a business with returns on investment below those expected by the company shareholders.

Case #2: An agricultural product operation failed because of a shortage of cash. They also had a marketing problem in that while a local outlet was found, markets outside of the limited Hawaiian market could not be penetrated.

Case #3: Management did not seem to have control of operating cost, nor could they penetrate the market. These factors, coupled with increased inventory led to a cash shortage and then collapse.

- Case #4: A Midwestern operator attempted to establish an operation on the Island of Hawaii using mainland techniques with little adaptive research information. A large capital investment was made in equipment where more economical alternates would have probably worked as well or better.
- Case #5: The developer created an operation that was too labor intensive and subsequently ran into cash problems. The management also did not understand how to market a new product, and had no staff available to handle the marketing function. This resulted in excess cash being tied up in inventory.
- Case #6: This operation was designed to dry, process and ship an agricultural product. The market was good, however, the operator could not meet market obligations with regard to quality and quantity. Lacking proper management, a quality control program was not instituted, which resulted in negative responses from the marketplace. The resulting cash flow problems impacted the funds available for fertilization, which in turn resulted in low yields per acre and eventual failure.
- Case #7: Management was apparently unable to determine the future requirements of certain products resulting in large inventories of unusable manufactured components.

The cases reviewed contain a common thread of marketing problems, difficulties of cash flow, and weak management. In contrast, examination of the ongoing businesses on the Island of Hawaii indicated that many of these have survived because they are small and easy to control.

## Energy Self-Sufficiency

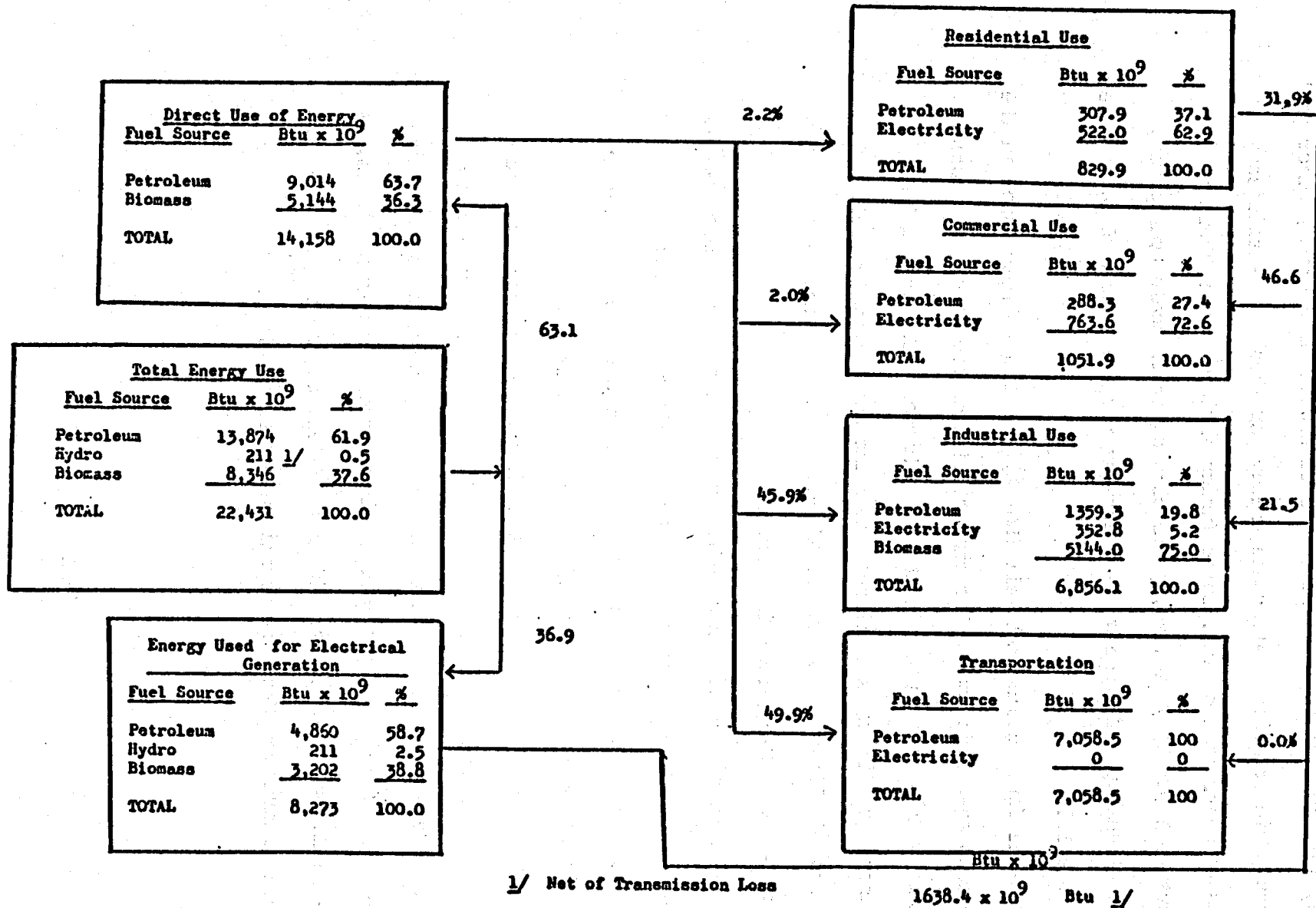
Energy self-sufficiency for the Island of Hawaii has become a major goal of the State administration. Alternate energy for this self-sufficiency program has concentrated on wind, solar (which includes Ocean Thermal Energy Conversion (OTEC)), biomass, photovoltaic, small scale hydropower, and geothermal energy. The energy use patterns for the island of Hawaii are shown in Table 1.1.

In 1976 the first geothermal well (HGP-A) was drilled near Pahoa in the Kilauea volcano east rift zone. The characteristics and other information covering this well are contained in the next Chapter. In 1981, a 3 MW wellhead generator will be operational using the steam from the well.

Additional drilling nearby in the Kilauea east rift zone is ongoing at this time by Barnwell Geothermal Corporation.

The local electric utility has indicated a willingness to purchase up to approximately 25 MW of power from geothermal sources. Additional electricity for the Island of Hawaii will not be required in the near or foreseeable future without a substantial increase in demand.

The possibility of an underwater cable that would connect the Island of Hawaii with Oahu could increase the demand for geothermally produced electricity. Oahu has a total electrical generating capacity of approximately 1200 MW; 98% of which is provided by fossil fuel generation plants. A cable carrying an estimated 200 to 400 MW of Island of Hawaii power to Oahu would do much to make the State of Hawaii energy self-sufficient.



Source: SRI International, Energy Self-Sufficiency for the Big Island of Hawaii (Final Report, January 1980)

Table 1.1 Energy Use for Hawaii County, 1977

## CHAPTER 2

### GEOHERMAL RESOURCE DEVELOPMENT

#### Introduction

A proposed site for the industrial park lies west of the Pahoa-Kaimu Road and just north of the Kilauea east rift zone at an elevation of approximately 750 feet above sea level. A well site (at an elevation of 1100 feet) was selected in a geothermal anomaly on the east rift zone nearest to the industrial park. The difference in elevation will eliminate the need for pumping the hydrothermal fluid to the park (Figure 2.1). In this chapter, the geothermal resource, the well site, the pipeline and the industrial park heat requirements are discussed. Costs and resource development assumptions and development timetables for two scenarios are included.

Development and use of low temperature (below 200°F) geothermal wells and waste heat from the geothermal brine at the HGP-A or other wells was considered outside of the scope of this contract with the Department of Energy. This contract was limited to the consideration of an industrial park off the rift zone. This park then will require transportation of the geothermal heat at a significant distance (1 to 3 miles) from the wells to the park. It is not technically desirable nor economically practical to transport low quality geothermal fluid over these distances.

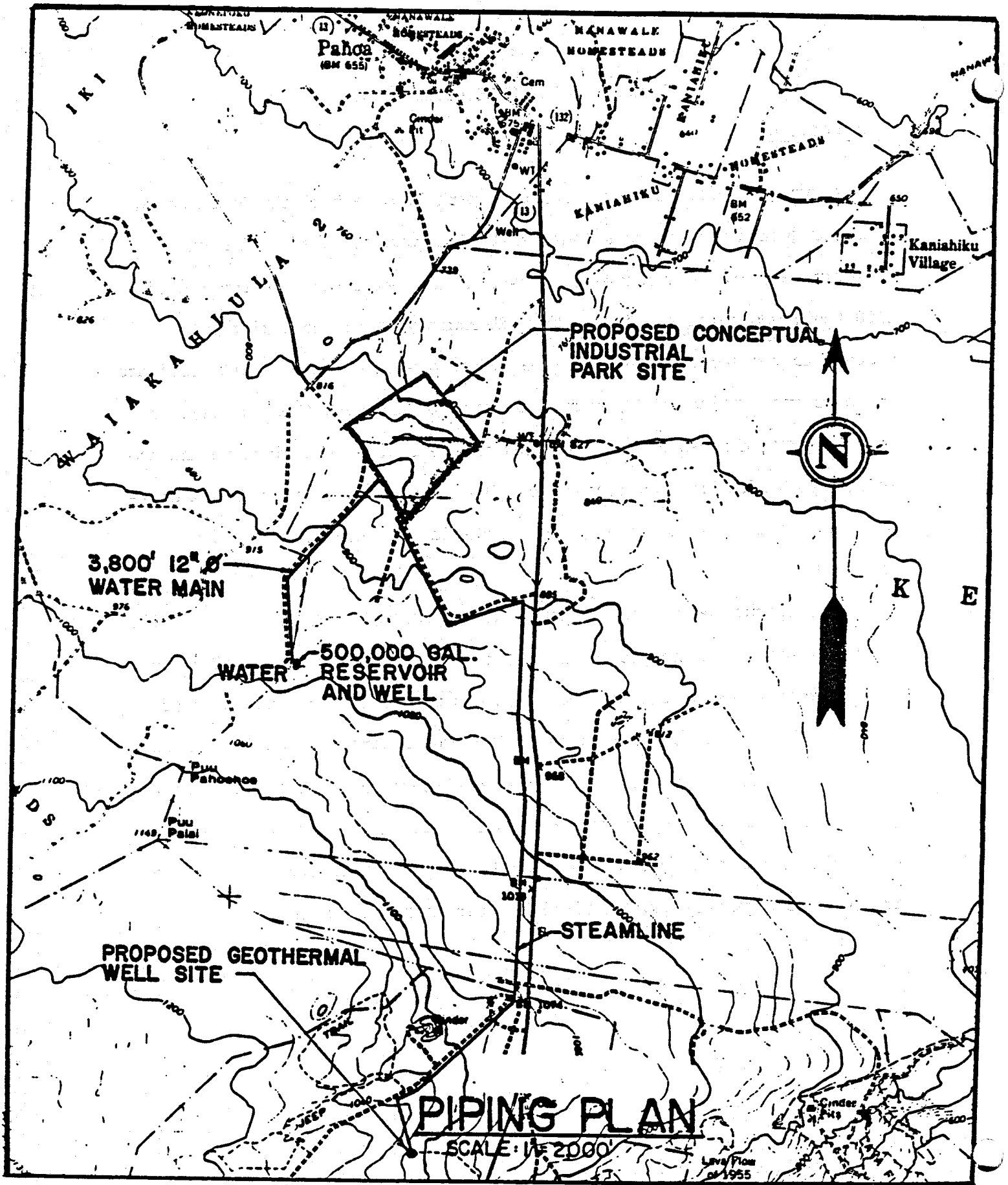


Figure 2.1  
HYDROTHERMAL FLUID TRANSMISSION PIPELINE PLAN



### The Geothermal Resource\*

The only proven geothermal resource in the State of Hawaii is in the eastern portion of the Puna District, about 25 miles from the summit of the Kilauea volcano. The magma (molten rock) entering the Kilauea volcano comes from deep within the earth and collects in a shallow storage reservoir beneath the summit caldera. Most of this stored magma leaves the summit region via subsurface conduits and shows up again as lava flows emerging to the surface along the rift zones.

The southeast rift zone of Kilauea commences at the Kilauea crater and extends in a southeasterly direction for about 4-1/2 miles where it makes an abrupt bend and continues on a trend of about N65E to Cape Kumukahi (Figure 2.2). The rift zone is marked by a series of eruptive vents, fault scars, and historic and prehistoric cinder cones indicating the presence of deep volcanic activity. The zone varies in width from 2 to 4 miles with the most active part apparently being confined to a zone approximately 2 miles wide. From geologic considerations, it is conceivable that much of this region's subsurface is at elevated temperature.

The rift zone consists of dike complexes which vary in thickness from 1 to 5 feet averaging between 2 and 3 feet. These dikes trend in various directions but generally have an average trend within about 20 degrees of the trend of the rift zone as a whole. The dikes probably comprise some 25 percent or more of the total volume of the rift zone. Thus, it can be estimated that the east Puna rift zone may contain 1,000 to 2,000 dikes in a generally fractured zone into which new lava can move.

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\*This section is a condensation of a more complete discussion as contained in Appendix A.

Each of these numerous dikes are intruded at temperatures in the vicinity of 1,100 degrees centigrade. However, it is calculated that the temperature within the rift zone, at a depth significantly below sea level where water circulation has not been great, should be about 300 degrees centigrade. This inferred subsurface geology was confirmed by the drilling of the HGP-A well in 1976.



## Geologic Hazards

The island of Hawaii is very young, with the oldest rocks now exposed to the surface being less than 500,000 years old. The Kilauea volcano is even younger and few of the surface rocks on Kilauea are older than 2,000 years. Any area with young geologic features has concomittant geologic hazards and Kilauea volcano is no exception. The primary hazards along the rift zone consists of earthquakes, lava flows, eruptions, and sudden ground movement associated with faulting. Although these hazards are present, the economic risk is probably small.

The largest earthquake in the recent past was the Kalapana earthquake of 1975 (M=7.2). Smaller earthquakes occurred in 1954 (M=6.5), in 1951 (M=6.5 and M=6.9), in 1929 (M=6.5), and in 1868 (large but magnitude unknown). Despite the size of these earthquakes, little structural damage occurred and accelerations rarely exceed 0.4g. These accelerations have a peak amplitude response primarily in the vertical direction. In a risk analysis for the current well site (Rogers Engineering, 1978), it was recommended that the design criteria for primary components (components whose failure involves severe economic loss or possible loss of life or severe injury) be adequate to withstand a ground acceleration of 0.41g with a response spectrum peaking at approximately 4 hz. These characteristics were recommended on the basis of a 30-year design life and an assumption that it was acceptable for the ground acceleration to exceed 0.41g with a probability of 10 percent in the 30-year period.

Volcanic hazards within the rift zone can be divided into 2 categories: Those due to events taking place in the immediate vicinity of an eruption and those that are associated with the downslope movement of lava issuing

from a vent. The best, and perhaps only, way of mitigating the first hazard is to locate the physical facilities outside the zone of potential active eruptive activity. The industrial park site being considered is outside the rift zone.

According to the Rogers Engineering report, 3 to 8 percent of the land area within the rift zone is likely to be buried by lava flows in any given 20 year period, while only 0.5 to 3 percent of the area outside the rift zone would be covered during the same period. Thus, location of the major physical facilities outside the rift zone, particularly if the location is in an area of high ground, should provide an adequately low risk for a major investment.

Ground subsidence has historically been limited to the rift zone itself or to areas to the south of the rift zone. Subsidence occurred within the rift zone in 1924 and again in 1955 in association with eruptive activity and also occurred south of the rift zone in 1975 at the time of the 1975 earthquake. There is no historic record of subsidence taking place north of the rift zone. Thus, subsidence should not be a significant hazard to a plant site located north of the rift zone.

The above analysis has primarily dealt with the hazard at the proposed industrial park site. The producing wells and the pipeline are subjected to all the hazards of the rift zone by necessity, for that is where the resource is located. Earthquakes will probably not result in damage to either installation, with the possible exception that the well bore could be disrupted should a fracture intersect the well bore. This is an unlikely possibility and can be best mitigated by having several producing wells separated from each other by some distance. The pipeline itself should not

be injured by earthquakes, nor should eruptive activity disturb it as long as steam continues to flow within the pipeline for it is then essentially self-cooling. Lava flows, on the other hand, could disrupt the pipeline if very viscous or blocky. Little disruption is likely to occur if the pipeline is on the surface and is overrun by very fluid flow. Hazard to the pipeline can probably be minimized by shallow burial or by surface installation with downslope support structures. Since the pipeline must be designed with numerous expansion joints in order to accommodate thermal expansion and contraction, ground subsidence or extension should have little effect on its operation.

The geologic hazard inherent in the east Puna region can be greatly minimized by careful selection of industrial park site and by awareness of the natural hazard of the region during design and construction of all surface facilities. Although it is difficult to estimate the extent of economic loss that might result from the natural hazards of the area, the risk of significant economic loss should be considerably less than 5 percent during the useful life of the installation (estimated as 30 years) if care is used in the choice of site and proper engineering design and construction techniques are used.

#### Well Site Considerations

The major resources within the region are likely to be found in association with the 2 mile wide east rift zone. The exact location of geothermal resources along this trend is unknown. Little geophysical data is available to pinpoint detailed targets. However, the surface geological expressions suggest that resources are likely to be found more or less continuously throughout this zone, rather than in only a few isolated spots.

Thus, the well site selected for this study seems appropriate. When and if development does occur for this specific site, it may be possible to identify a resource within a mile and a half of the site where the 1840 vent line appears to provide evidence of a potential resource.

It is expected that future development in the southeast rift of Kilauea will result in a series of drilling sites separated by one to three miles, thus the industrial park concept need not be confined to a specific site. The existence of the current HGP-A well would suggest that one such site might be due north of the HGP-A well. However, the site under study is suited for the drilling similar to that which was recently completed by Barnwell at their Opihikao location. The Barnwell site is approximately 3 miles SSE of the proposed site adjacent to the easternmost vent of the western zone of the 1955 eruptive activity.

#### Park Heat Requirements

Initially it was anticipated that five or six processes requiring a total of 150 to 200 MBTU/hr. would be considered suitable for the industrial park. Development of the geothermal resource was evaluated under two scenarios. One scenario develops the resource solely for direct heat applications; the other is coupled with a 25 MW electric generating power plant.

#### Scenario 1 - Develop Resource Solely for Direct Heat Application

According to the HGP-A production data of January 1977, the well is capable of producing 79,000 lbs./hr. of two phase flow at 320 psig of which 41,000 lbs./hr. is steam. However, this production capacity is justifiably low due to erosion of the well's side walls which occurred during a five

week duration between completion of the drilling and lining of the well. This problem was a result of the delay in obtaining the lining material and not part of the procedures outlined for the project. Subsequent to completion of the HGP-A project, it was determined by the research team that HGP-A's production is approximately 30% low. With the assumption that new wells drilled will have comparable production characteristics with timely well lining and completion methods, the production of the new wells can be expected to be 30% higher than HGP-A. Therefore, the expected production of each well is:

Total flow-2 phase (320 psig, 438°F)	103,000 lbs./hr.
Steam	53,500 lbs./hr.

Three production wells, one standby well, and one injection well will be required. With the three production wells, 309,000 lbs./hr. of two phase flow or 160,500 lbs./hr. of steam will be produced. The proposed wellsite and transmission schematic to develop the geothermal resource and to deliver the energy to the park site is shown in Figure 2.1. The cost of the well development and well site equipment is presented below.

The well development costs are based on a preliminary cost estimate quoted by a firm actively drilling in Puna on the Island of Hawaii. The following breaks down the total cost of drilling a well:



Mobilization/Demobilization	\$ 165,000
Drilling 80 days @ \$7,500/day	600,000
Drilling Bits	126,000
Rental & Miscellaneous	57,500
Casing	156,730
Cement & Outside Services	324,000
Production Equipment	35,350
Supervision	24,000
Completion	<u>20,000</u>
Subtotal	1,509,000
Contingency	<u>100,000</u>
TOTAL	Approx. \$ 1,600,000

<u>Well Development Cost:</u>	<u>1980 Dollars</u>
Production wells (3)	\$ 4,800,000
Injection wells (1)	1,600,000
Standby well (1)	<u>1,600,000</u>
	<u>\$ 8,000,000</u>

The well site equipment costs were estimated based on the cost incurred on the HGP-A project adjusted for inflation.

Well Site Equipment:

Site Preparation	\$ 300,000
Two Phase Separator	70,000
Evaporators	700,000
H <sub>2</sub> S Abatement System	600,000
Site Utility, Roads, etc.	<u>530,000</u>
	<u>\$ 2,200,000</u>

The transmission pipeline will be 14,000 feet of 20 inch diameter insulated pipe. The estimated construction cost of the pipeline is \$2,700,000. Other costs, including administrative, legal, Environmental Impact Statement (EIS), etc. are estimated to be \$450,000. Table 2.1 shows the development timetable for Scenario 1.

Cost Summary

(1980 Dollars)

Construction Costs

Wells (5 x \$1,600,000)	\$ 8,000,000
Well Site Equipment	2,200,000
Pipeline	2,700,000
Administrative, Legal, EIS, etc.	450,000
	<hr/>
TOTAL	<u><u>\$13,350,000</u></u>

The required selling price of the steam to yield a reasonable rate of return was calculated to be \$0.00267/lb. What follows are the calculations that confirm that this selling price gives a reasonable rate of return.

	Year 1			Year 2			Year 3		
Permitting, EIS	██████████								
Well Drilling									
1st well			██████████						
other wells				████████████████████					
Well Testing			██████████	████████████████████					
Well Site Design					██████████				
Well Site Construction							████████████████████		
Pipeline Design					██████████				
Pipeline Construction							████████████████████		
Capital Investment	\$2,000,000			\$5,700,000			\$5,700,000		

Table 2.1 Scenario 1 - Development Timetable

Each pound of steam has an absolute heat value of approximately 1200 BTU. It is assumed for study purposes that only 1000 BTU is recovered per pound of steam. However, a more accurate figure can be confirmed once engineering drawings and specific equipment are identified.

The \$0.00267/lb. price for steam was confirmed utilizing the following assumptions:

Geothermal Resource Development  
Assumptions

Construction Costs

The total construction cost of \$13,350,000 is spread over three years according to the development timetable presented in Table 2.1.

Escalation

Construction cost escalation at 8% a year.

Revenue

A steam load factor of 90% was assumed. The amount of annual saleable steam was calculated as follows:

$$\begin{aligned} \text{Annual Saleable Steam} &= 157,500 \text{ lbs./hr.} \times 24 \text{ hrs.} \times 365 \text{ days} \\ &\quad \times .90 \\ &= 1,224,720,000 \text{ lbs./yr.} \end{aligned}$$

Revenues equal the annual steam sales times the selling price.

The required selling price was derived through computer iteration.

Operating Expenses

Field Operation & Maintenance - calculated as 7% of gross revenues.

Other Operating Expenses - calculated as 1% of gross revenues.

### Intangible Drilling Costs (IDC)

Consistent with current practice, 80% of total well costs (includes well equipment and associated permitting, lease, legal and administrative expenses) were designated as IDC and expensed in the year incurred.

### Depreciation

All capitalized construction costs were depreciated using accelerated depreciation over the allowable tax life:

Wells	20 years
Pipeline	30 years
Other Equipment	22.5 years

Depreciation of wells and other equipment begins upon operation.

### Royalties

In Hawaii, the State has indicated it would charge a royalty fee of 10% for geothermal hot water and steam or 5% for substances extracted from geothermal fluids in cases where it claims the minerals. When the minerals are not claimed by the State, the royalty rate is negotiable with the owner. An override of approximately 2% may be paid to the surface owner. In the analysis, the base case royalty assumption is 10% of gross revenues (Option 1). Sensitivity analyses were included in the model with royalty rates of 12% (Option 2) and 15% (Option 3) representing the basic state royalty plus an assumed 2% override and a 5% negotiated rate with a private owner respectively. All percentages are based on gross revenue of steam.

### Depletion Allowances

A depletion allowance totaling 15% of net revenue (gross revenue less royalties) was deducted from net revenue to arrive at taxable income.

### Income Tax Rate

The statutory combined State and Federal tax rate was assumed to be 50%.

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**Method of Financial Analysis:** Throughout this study, the method of financial analysis has been to prepare a financial model based on assumptions which are shown prior to the model. The model computes costs, revenues, taxes, depreciation, depletion, etc. to generate an after tax cash flow, typically for 25 years. From this after tax cash flow, an internal rate of return and a payback period is computed. Then a decision is made whether this return is reasonable for the risks involved.



FINANCIAL SUMMARY

	<u>Option 1</u> <u>10% Royalty</u>	<u>Option 2</u> <u>12% Royalty</u>	<u>Option 3</u> <u>15% Royalty</u>
<b>Present Value at Following Discount Rates:</b>			
15%	\$ 10,335	\$ 9,929	\$ 9,322
20%	4,400	4,145	3,764
25%	1,368	1,194	934
 <b>After-Tax Discounted Cash Flow Rate of:</b>			
Return	28.9%	28.4%	27.7%
Payback	5.8 years	5.9 years	6.0 years

Conclusion: The computed after tax discounted cash flow rates of return ranging from 28.9% to 27.7% reflect reasonable, risk adjusted, rates of return for a major corporation.



## Scenario 2 - Develop Resource Coupled With a 25 MW Power Plant

It was originally assumed that the industrial park could utilize waste heat from a 25 MW power plant. Analysis concentrated on estimating costs for the geothermal field development and construction of the power plant. Based upon an after-tax discounted cash flow analysis various investment cost apportionments were made to derive the charges for electricity and steam.

The initial temperature requirement for industries in the industrial park was increased to the 400°F range to provide and accommodate a wider selection of industrial processes. This high temperature preference invalidated the assumed use of the brine portion of the two-phase power plant output and it was clear that separate wells would have to be drilled for both the power plant and direct heat users. However, a certain amount of cost-sharing of the well-site equipment, transmission pipeline and legal/environmental costs could be realized.

The costs assuming field development and construction of a 25 MW power plant and development of geothermal resources for direct heat application are presented in Table 2.3. The development timetable is shown in Table 2.4. The direct heat resource requirements are the same as in Scenario 1, but certain costs are lower reflecting the sharing of expenses with the power plant.

Consideration of the development time required for a co-located power plant/direct heat application with only a 5% cost savings reduced the attractiveness of this proposal. The price of the geothermal steam would not differ significantly from that calculated in Scenario 1. Therefore, this scenario was not developed further.

	<u>25 MW Power Plant</u>	<u>Direct Heat Applications</u>	<u>Total</u>
Well Requirements	6 wells 2 standby 2 injection	3 wells 1 standby 1 injection	9 wells 3 standby 3 injection
Field Development Costs			
Production Wells	\$ 9,600,000	\$ 4,800,000	\$ 4,400,000
Injection Wells	3,200,000	1,600,000	4,800,000
Standby Wells	<u>3,200,000</u>	<u>1,600,000</u>	<u>4,800,000</u>
	\$ <u>16,000,000</u>	<u>8,000,000</u>	<u>14,000,000</u>
Well Site Equipment Costs			
Site Preparation	\$ 400,000	\$ 200,000	\$ 600,000
Separator	140,000	70,000	210,000
Evaporator	—	700,000	700,000
H <sub>2</sub> S Abatement	800,000	400,000	1,200,000
Site Utilities, Road	560,000	330,000	890,000
	\$ <u>1,900,000</u>	<u>1,700,000</u>	<u>3,600,000</u>
Transmission Pipeline	—	\$2,700,000	\$2,700,000
Power Plant			
Equipment	\$ 10,000,000		\$ 10,000,000
Construction	12,500,000		12,500,000
Engineering	2,500,000		2,500,000
	\$ <u>25,000,000</u>		<u>25,000,000</u>
Legal, Environmental, Administrative	\$ <u>600,000</u>	\$ <u>300,000</u>	\$ <u>900,000</u>
Total Costs	\$ <u>43,500,000</u>	\$ <u>12,700,000</u>	\$ <u>46,200,000</u>
Percentage of Total	77.4%	22.6%	100%

TABLE 2.3

Costs of Direct Heat Application Coupled with 25 MW Power Plant

2-21

	Year 1	Year 2	Year 3	Year 4	Year 5
Permitting, EIS	█				
Well Drilling					
1st well		█			
other wells		█			
Well Testing		█	█		
Well Site Design			█		
Well Site Construction				█	
Pipeline Design				█	
Pipeline Construction				█	
Power Plant Design			█		
Power Plant Construction				█	
Capital Investment	\$2,000,000	\$8,500,000	\$10,000,000	\$20,000,000	\$15,700,000

Table 2.4 Scenario 2 - Development Timetable

## Steam Transmission Pipeline to Park

Clean steam is produced in a heat exchanger at the well site in a manner similar to that developed by M. Tanaka in the 1979 Puna Sugar study.\* The conceptual design was based on a minimum of 175,000 lbs./hr. of 403°F, 240 psig steam entering the pipeline at the wellsite end. The diameter of the proposed pipeline is 20 inches; the design length is 14,000 feet. The pipe material is steel of standard wall thickness, and insulated with 5 inches of calcium silicate insulation. Pressure losses were estimated from Unwin's formula assuming uniform average conditions along the length of the pipeline equal to the initial conditions. This estimate is 0.075 psi per 100 feet of pipeline. However, this method slightly underestimates the pressure loss, so the estimate was increased to obtain 6 psi per mile of pipeline. Thus, for the design length of 14,000 feet, total pressure loss is 16 psi. Steam condensation was determined from the results of heat transfer studies performed by M. Tanaka in the Puna Sugar geothermal study. These results showed steam losses of 880 pounds per hour per mile of pipeline, or total losses of about 2300 pounds over the design length of 14,000 feet. Thus, a maximum of 172,700 lbs./hr. of 395°F, 220 psig steam would be available at the parksite.

The assumed route of the pipeline is shown in Figure 2.1.

The total cost of the pipeline is estimated at \$2.7 million.

## Low Grade Heat

In both scenarios, there is resultant low grade heat from the separator which could be utilized. The amount of this geothermal resource normally reinjected, is as follows:

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\* Engineering and Economic Analysis for the Utilization of Geothermal Fluids in a Cane Sugar Processing Plant. Final Report - Puna Sugar Co., Ltd., July 1979.

Direct Heat Scenario: 148,500 lbs./hr. of 428°F water

25 MW Power Plant Scenario: 408,000 lbs./hr. of 373°F water

Converting this geothermal brine to process hot water would require two to three million dollars for heat exchangers, a second transmission pipeline and the drilling of fresh water wells at the well site.

Due to the uncertainties associated with the ultimate number of geothermal production wells to be used, the relatively low heat carrying capacity of hot water and the uncertainty in selecting a low temperature process, further study of low grade heat available from the hot water was terminated.

#### Comparison with Conventional Steam Plant

An attempt was made to compare the cost of providing geothermal steam with steam from a conventional oil-fired generating plant. The cost summary and assumptions in Table 2.5 were used to arrive at the cash flow for a steam boiler plant in Table 2.6. The resultant price of \$7.46/lb. compared to the geothermal steam price of \$2.67 confirms the cost-savings derived from using geothermal.

TABLE 2.5

Steam Boiler Assumptions

Construction Costs:

2 - 800 hp Cleaver Brooks boiler	162,000
Transportation - Pahoa	33,600
Additional Supporting Equipment	70,800
Transportation	5,000
Installation (1600 hrs @ 35/hr.)	56,000
Land Purchase (\$12,000/acre)	24,000
Building	75,000
Permitting	50,000
Testing	30,000
Site Preparation	10,000
Site Utility, Roads, etc.	<u>156,284</u>
Subtotal	672,684
Contingency - 20%	<u>134,537</u>
TOTAL	<u><u>807,221</u></u>

Revenue:

Based on annual steam capacity calculated as follows:

$$55,000/\text{lbs.}/\text{hr.} \times 20 \text{ hrs.} \times 365 \text{ days} \times .9 \\ = 361,350,000 \text{ lbs.}/\text{year}$$

Required selling price to obtain 20% after tax yield derived through computer iteration.

O & M:

Estimated at \$47,088 in 1980 dollars  
Escalated at 8% a year.

Fuel:

Estimated at \$2,512,368 in 1980 dollars  
based on 478 GPH @ \$.72/gallon.  
Escalated at 8% a year.

Depreciation:

Plant depreciated over 22.5 years using accelerated rate.

TABLE 2.5 (continued)

Tax:

Combined statutory State and Federal tax rate of 50%.

Investment Tax Credit (ITC):

ITC of 10% on capital costs.

Escalation:

8% per year.

STEAM BOILER ANALYSIS

STEAM BOILER ANALYSIS

STEAM BOILER ANALYSIS

DESCRIPTION	PERIOD-YEARS											PERIOD-YEARS											PERIOD-YEARS						
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
BOILERS	-162000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUPPORT EQUIP	-70000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INSTALLATION	-56000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LAND	-24000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BUILDING	-75000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PERMITTING	-50000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TESTING	-30000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SITE PREP	-10000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SITE FACILITIES	-156284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EQUIP TRANSPORT TO PAHOA	-38600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>SUBTOTAL</b>	<b>-672684</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
CONTINGENCY	-134537	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>TOTAL</b>	<b>-807221</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
INFLATION RATE	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800	.0800
SELLING RATE	.0075	.0081	.0087	.0094	.0101	.0110	.0118	.0128	.0139	.0149	.0161	.0174	.0189	.0203	.0219	.0237	.0256	.0276	.0298	.0322	.0348	.0376	.0406	.0438	.0473	.0511	.0552	.0596	
REVENUE	0	2911325	3144231	3395769	3667431	3960825	4277691	4619906	4989499	5388659	5819751	6285332	6788158	7331211	7917700	8511124	9235214	9974031	10771954	11633710	12564407	13569559	14655124	15827534	17093737	18461236	19938134	21533185	
O & M	0	50855	54923	59317	64063	69188	74723	80701	87157	94129	101659	109792	118576	128062	138307	149371	161321	174226	188165	203218	219475	237033	255996	276475	298594	322481	348279	376142	
FUEL	0	2713357	2930426	3164860	3418049	3691493	3986812	4305757	4650218	5022235	5424014	5857935	6326570	6832696	7379311	7969656	8607229	9295807	10039471	10842629	11710039	12646843	13658590	14751277	15931379	17205890	18592361	20068950	
DEPRECIATION	0	65375	59564	54269	49445	45050	41046	37397	34073	31044	28285	25771	25157	25157	25157	25157	25157	25157	25157	25157	25157	25157	12579	0	0	0	0	0	
<b>OPERATING PROFIT</b>	<b>0</b>	<b>81737</b>	<b>99317</b>	<b>117322</b>	<b>135874</b>	<b>155094</b>	<b>175110</b>	<b>196051</b>	<b>218051</b>	<b>241250</b>	<b>265793</b>	<b>291834</b>	<b>317856</b>	<b>345297</b>	<b>374933</b>	<b>406940</b>	<b>441500</b>	<b>478941</b>	<b>519161</b>	<b>562706</b>	<b>609735</b>	<b>660527</b>	<b>727960</b>	<b>799781</b>	<b>863764</b>	<b>932865</b>	<b>1007494</b>	<b>1088094</b>	
TAX	0	40869	49659	58661	67937	77547	87555	98026	109026	120625	132897	145917	158928	172648	187466	203470	220754	239420	259500	281353	304060	330263	363900	399891	431882	466433	503747	544047	
<b>NET EARNINGS</b>	<b>0</b>	<b>40869</b>	<b>49659</b>	<b>58661</b>	<b>67937</b>	<b>77547</b>	<b>87555</b>	<b>98026</b>	<b>109026</b>	<b>120625</b>	<b>132897</b>	<b>145917</b>	<b>158928</b>	<b>172648</b>	<b>187466</b>	<b>203470</b>	<b>220754</b>	<b>239420</b>	<b>259500</b>	<b>281353</b>	<b>304060</b>	<b>330263</b>	<b>363900</b>	<b>399891</b>	<b>431882</b>	<b>466433</b>	<b>503747</b>	<b>544047</b>	
NET EARNINGS	0	40869	49659	58661	67937	77547	87555	98026	109026	120625	132897	145917	158928	172648	187466	203470	220754	239420	259500	281353	304060	330263	363900	399891	431882	466433	503747	544047	
DEPRECIATION	0	65375	59564	54269	49445	45050	41046	37397	34073	31044	28285	25771	25157	25157	25157	25157	25157	25157	25157	25157	25157	25157	12579	0	0	0	0	0	
INV TAX CREDIT	807221	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAP EXP	-807221	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>CASHFLOW</b>	<b>-726499</b>	<b>106244</b>	<b>109223</b>	<b>112930</b>	<b>117382</b>	<b>122597</b>	<b>128601</b>	<b>135423</b>	<b>143099</b>	<b>151669</b>	<b>161181</b>	<b>171687</b>	<b>184085</b>	<b>197805</b>	<b>212623</b>	<b>228627</b>	<b>245911</b>	<b>264577</b>	<b>284737</b>	<b>306510</b>	<b>330025</b>	<b>355420</b>	<b>376550</b>	<b>399891</b>	<b>431882</b>	<b>466433</b>	<b>503747</b>	<b>544047</b>	

Table 2.6

Steam Boiler Analysis



**Steam Boiler  
Financial Summary**

	<u>Discount Rate</u>		
	10%	15%	20%
<b>Net Present Value</b>	<b>889,508</b>	<b>271,624</b>	<b>&lt;34,284&gt;</b>
<b>After Tax Discounted Cash Flow Rate of Return</b>	<b>19.3%</b>		
<b>Payback</b>	<b>6.2 Years</b>		

### Summary

It is reasonable to expect that a geothermal resource similar to that found in the existing HGP-A well could be found about 2-1/2 miles from the proposed industrial park site. It would be practical to pipe clean steam produced from this resource to the park. The proposed price of steam is about \$2.76/MBTU based on initial assumptions that five or six industrial processes would fully utilize the production from 3 geothermal wells. This compares to steam generated by a package oil fired boiler costing \$7.46/MBTU.

## CHAPTER 3

### DIRECT HEAT APPLICATIONS AND MARKET IDENTIFICATION

#### Introduction

This chapter discusses the surveys made to find candidate processes for the industrial park, and then summarizes those that were not discarded for obvious shortcomings.

#### Approach

A literature search identified existing processes proposed or now using direct geothermal heat. These are summarized in Table 3.1. Space heating and cooling were excluded because these were considered to be a service application rather than an industrial process.

A second table, Table 3.2, was prepared listing standard industrial processes requiring large amounts of heat at temperatures 300° and below and which could possibly be adapted to geothermal energy.

The initial list contained a wide range of applications varying from milk pasteurization to manganese nodule processing. Agricultural applications included poultry raising, animal husbandry, soil warming, soil sterilization and crop drying. Industrial applications for pulp processing, sulfur extraction, vegetable dehydration and lumber kiln operations had been proven successful. Aquaculture applications included raising of eels, catfish and prawns.

Study participants reviewed the processes obtained from the literature search listed in Tables 3.1 and 3.2. The processes were reviewed in light of engineering, economic and financial factors which enabled a comprehensive evaluation. The candidate processes were either discarded due to obvious

foreseeable shortcomings or retained for further investigation. The criteria employed were:

- Potential process must be heat intensive.
- Related to Hawaiian raw products or low cost imports.
- Technically sound.
- The temperature requirements of the processes involved should be within those anticipated from the geothermal resource.

APPLICATIONS	NATURE OR STATUS	DESCRIPTION	RESOURCE CHARACTERISTICS	LOCATION	REF	FEASIBILITY EVALUATION
Agribusiness	Proposed study	A proposed 5-year program involving greenhouses, fish farming, & biogas.	Geysers area	Lake County, CA	7 p.193	The concept of combined thermodynamics & biologic cycles should apply.
Agribusiness	Engineering & Economic Analysis	Analysis of geothermal potential for onion dehydration, alfalfa drying & greenhouses.	60°F +	Klamath & Snake River Basin, Oregon	8 p.17	Crops similar to onions & alfalfa are not available in the Puna District; greenhouses for growing 8 vegetables appears attractive.
Agricultural Chemical Plant	Economic Study & Engineering	A study to determine the feasibility of utilizing geothermal heat for industrial processing at an agricultural chemical plant.	Heber KGRA	EI Centro, Calif.	p.97	No similar chemical fertilizer plant is located nearby.
Alcohol Production (corn, wheat, sugar beet)	analysis	Determine incremental cost for converting a 20,000 gpd plant over to using geothermal energy.	req: 350°F (corn or wheat) 275°F (sugar beets)		2 p.241	Using a similar alcohol geothermal process, a centralized molasses feedstock ethanol plant should be economically attractive for the industrial park.
Alcohol Production	experiment completed 8/79	DOE's Idaho Nat'l Eng. Lab is experimenting with ethanol production utilizing used beet sugar syrup and ligno-cellulosic material as feedstock & geothermal energy for fermenting & distillation.	240°F Raft River KGRA		4,5	Laboratory results are relevant to planning for the Pahoia industrial park.
Alfalfa drying	existing	Geothermal heat is utilized for drying alfalfa (80% water) and formed into pellets.	1150 m deep 270°C	Broad Lands NZ	12 p.308	A similar drying process can be applied to convert sugar cane trash to cattle feed.
Alfalfa drying	study completed	Utilizes 200°F air temp. for a triple pass dryer. The study shows a savings of \$100,000 annually for a 30,000 ton/yr facility.	220°F	Klamath Oregon	8 p.23	A similar drying process can be applied to convert sugar cane trash to cattle feed.
Aluminum Reduction	study	\$150,000 funded by DOE to Battelle NW for 15 mo. study which began 7/78.	Not specified	--	1	Although the processing of bauxite ore to alumina may not be realistic for Puna, an aluminum industry on the Big Island is considered attractive for future economic development.
Aquaculture	existing	Freshwater prawns, crayfish & mosquito fish are bred.	57°C 200-250 gal/ min	Klamath Falls, Ore.	10	Aquaculture is a growing Hawaii industry and should be a prime candidate for direct heat applications.

Table 3.1

Summary of Literature Search for Geothermal Direct Heat Processes

APPLICATIONS	NATURE OR STATUS	DESCRIPTION	RESOURCE CHARACTERISTICS	LOCATION	REF	FEASIBILITY EVALUATION
Aquaculture	environmental report submitted	Utilize geothermal water to raise Malaysian prawns year-rd. on 246 acres of desert land.	84-87°F 300 gpm/well 3 wells, 100' deep	Mecca, CA.	3 p.11	Aquaculture is a growing Hawaii industry & should be a prime candidate for direct heat applications.
Beet Sugar Processing	drilling 10/79	3 phase program to use geothermal energy in a beet sugar processing plant presently using fossil fuel.	350°F 8000' deep	Brawley, CA	3 p.24	Although there are no sugar beets grown in Hawaii, the cane sugar industry is well established with fully amortized sugar processing mills.
Beet Sugar Refining	analysis	Utilizing geothermal brine for refining beet sugar is expected to reduce energy cost by 40-60%.	302°F	San Luis Valley, Colorado	8 p.73	Although there are no sugar beets grown in Hawaii, the cane sugar industry is well established with fully amortized sugar processing mills.
34 Cane Sugar Refining	study	Study project to determine the feasibility of utilizing geothermal energy at the Puna Sugar Mill.	Puna Reservoir	Keeau, HI	9	Although there are no sugar beets grown in Hawaii, the cane sugar industry is well established with fully amortized sugar processing mills.
Crop drying	economic analysis	Determine the feasibility of retrofitting current crop-dehydration plants or constructing new ones.	90-150°C	not specified	8 p.5	There are no existing crop dehydrating plants available for retrofitting. A similar retrofit for the Puna Sugar Mill is discussed in Ref. 9.
Desalination	engineering study	Engineering analysis for geothermal plants at various possible locations in New Mexico.	New Mexico KGRA's	New Mexico	7 p.91.	Although water is no problem at Paho, the process should be applicable to the hydrothermal fluid produced.

Table 3.1 Page 2

APPLICATIONS	NATURE OR STATUS	DESCRIPTION	RESOURCE CHARACTERISTICS	LOCATION	REF	FEASIBILITY EVALUATION
Ethanol Production	conceptual	Conceptual design of a facility to produce ethanol using 3 local crops: wheat, sugar beets and potatoes as feedstock.	Raft River KGRA	Idaho	11 p.139	Although feedstocks of wheat, sugar beets & potatoes are not available, a centralized molasses plant may be feasible if timing of geothermal development fits.
Ethanol Production	study	Outlines some geothermal systems with resource characteristic potentially suitable for ethanol production.	in excess of 100°C	not site specific	11 p.103	Study results will be useful.
Evaporation & crystallization	analysis	Processing: tomato paste, preserved fruits & vegetables, beet sugar refining & sodium chloride production.	300°F	--	8 p.91	Although the process appears attractive for future consideration, application in a newly established park at Pahoehoe should not be considered.
Fish Breeding	existing	Carp & eels are bred at this farm. The eels are bred in earthenware pipes: 24 cm dia. 6 m long. Water temp. is maintained at 23°C by mixing hot spring water with river water.		Skikabe, Hokkaido	12 p.308	Fish breeding of appropriate species will be required in an aquaculture application. However, the raising of eels in Hawaii is prohibited.
Fish Farming	existing		195 lb/sec 47°C	Paso Roldes, Calif.	Geo-thermal Hotline 12/74	Experience should apply.
Grain Drying	existing DOE funded demonstration project	Utilizes existing Madison Limestone well for grain drying.	one well @ 4100' 180 gpm 152°F	Mid Central S. Dakota	3 p.15	Concept applies although there are no grain crops produced in the Puna District.

Table 3.1 Page 3

3-6

APPLICATIONS	NATURE OR STATUS	DESCRIPTION	RESOURCE CHARACTERISTICS	LOCATION	REF	FEASIBILITY EVALUATION
Greenhouse	demonstration	Utilize geothermal water to heat a 250,000 sq.ft. greenhouse producing cut roses.	4000' well is to be drilled 9/79	Sandy, Utah	3 p.63	Greenhouse applications for vegetables & flowers appears attractive for the industrial park.
Greenhouse	feasibility study	An engineering, economic analysis and Fed. tax impact on a proposed geothermal greenhouse.	assumed 150°F @ 2000 ft.	San Luis Valley, CO	2 p.253	Similar use of Federal tax credits & tax deductions for geothermal direct heat applications in the Pahoa industrial will be included for processes selected.
Greenhouse	existing	Three wells are used to space heat greenhouses & Balneology.	34 lb/sec 52.6°C	Manley Hot Springs, Alaska	Ferkes Leonard Dinkel 1975	Although the Manley Hot Springs climate is considerably different from Pahoa the overall concept will apply.
Greenhouse	existing	Growing tomatoes in a 1390m <sup>2</sup> greenhouse at Hobo Wells hydroponic.	----	Susanville, Calif.	The Geyser 5-20-75	Application will relate to a similar process for Pahoa.



APPLICATIONS	NATURE OR STATUS	DESCRIPTION	RESOURCE CHARACTERISTICS	LOCATION	REF	FEASIBILITY EVALUATION
Industrial Park	conceptual plan	The plan proposes to develop an integrated geothermal energy park with various processes including sugar refining, refrigeration, salt prod., milk & fruit dehydration, etc.	140-150°C	Island of San Miguel Portugal	2 Meidav p.441	The concept of a similar integrated geothermal park applies to the objectives of this study.
Industrial Processes	market analysis	This analysis shows the national market trends for 4 industrial products identified as major candidates for direct applications in Calif. & HI. They are: 1. Food & Kindred Products 2. Lumber & Wood Products 3. Paper & Allied Products 4. Chemicals & Allied Products	undefined	CA & HI	2 p.357	The market analysis will provide source material for the Pahoa study.
Integrated Swine Raising	DOE contract, negotiating stage	A 1,200 sow swine raising complex utilizing geothermal energy will be designed, developed & constructed.	240°F 1600-3400' well	Kelley Hot Springs	3 p.31	A similar integrated swine industry appears attractive for the Hawaiian market.
Livestock	engineering & economic analysis	Study to determine the feasibility of direct applications of geothermal resource to a vertically integrated livestock complex.	1000 gpm 350°F	Mountain Home, Idaho	2 p.373	A similar integrated swine industry appears attractive for the Hawaiian market.
Lumber Kiln Drying	pilot project	The kiln has a 40m <sup>3</sup> capacity with monthly output of 240m <sup>3</sup> of dried lumber. Required temp. of 50-60°C with steam flow at 0.5 tons/hr.	Exploration well E-208 3.5 tons/hr @ 266°F	Taiwan	10	The koa lumber industry centered in Hilo could benefit from a similar operation in the Pahoa park.

Table 3.1 Page 5

APPLICATIONS	NATURE OR STATUS	DESCRIPTION	RESOURCE CHARACTERISTICS	LOCATION	REF	FEASIBILITY EVALUATION
Milk Pasteri- zation	existing	Geothermal fluid has been used to pasteurize milk for 30 yrs at Medo Bel Creamery. Milk is processed at 600 gal/hr or 500,000 lbs/mo. Corrosion has been minimum & doesn't affect stainless steel heat exchangers.	177-208°F 30 gallons/min.	Klamath Falls, Oreg.	10	There is no large dairy operation in the Puna District that would benefit from this process.
Mushroom farming	feasibility study	Determine the feasibility of constructing the first geothermal mushroom farm.	170-210°F	W. US	2 p.629	Mushroom growing in greenhouses may have an application.
Potato Processing	economic & feasibility study	Demonstrate the viability of using low grade geothermal resource for food processing.	250°F	Rexburg	3 p.39	Potatoes are not grown in the Puna District.
Poultry Production	existing	Floor-heating is utilized in sheds to raise chickens. 4 sheds at 132 m <sup>3</sup> and 2000 chickens/shed. Water circulates at 100°C in pipes under shed floor. annual production-40,000	100 lb/min	Izu Peninsula	10	Although attractive, the high cost of feed combined with the low cost of poultry products supplied from the mainland precludes consideration.
Pulp & Paper Mill	evaluation	A computer program has been developed to evaluate process heat applications utilizing geothermal energy.	165°C 200,000 kg/hr	Not site specific	2 p.527	Because eucalyptus chips are now being shipped from the Big Island of Hawaii to Japan for paper production, a pulp & paper mill for the Pahoia park should be considered.
Pulp & Paper Mill	existing	Tasman Pulp & Paper Mill using 148 K lb/hr steam at 1000 Btu/lb for log handling equipment, etc.	----	Kaweran NZ		Because eucalyptus chips are now being shipped from the Big Island of Hawaii to Japan for paper production, a pulp & paper mill for the Pahoia park should be considered.

Table 3.1 Page 6

APPLICATIONS	NATURE OR STATUS	DESCRIPTION	RESOURCE CHARACTERISTICS	LOCATION	REF	FEASIBILITY EVALUATION
Salt Production	attempted & abandoned	Evaporation of salt water in open tanks to produce salt crystals. Enterprise was abandoned because imported salt was cheaper.		Skikabe, Hokkaido Japan	10	Salt water is not available at Pahoa.
Soil Sterilization	existing	Utilizing geothermal resource for heating the soil to eliminate insects, fungus & other damaging growth.	-----	Rotorua-Tampo NZ	10	A similar process for the Puna District may have future applications.
3-9 Sulfur extraction & processing	existing	Geothermal steam is used to extract sulfur for use in fertilizer production.	150°C	Lake Rotokaua NZ	10	A similar process for the Puna District may have future applications.
Vegetable dehydr-	existing	Gilroy Foods Inc (CA) ships carrots, celery, peppers, onions & garlic to a geothermal food processor at Brady H.S. for drying.	143-165°C 76,600- 366,000 kg/hr	Brady H.S. Nevada	2 Rodzianko p.591 Silverman 8 p.105	The quantity of vegetables required for such an operation will not be produced on the Big Island in the foreseeable future.

Table 3.1 Page 7

APPLICATIONS	NATURE OR STATUS	DESCRIPTION	RESOURCE CHARACTERISTICS	LOCATION	REF	FEASIBILITY EVALUATION
Vegetable Processing	Study completed, construction underway	ORE-IDA plant retrofit: DOE funded. Geo. heat to be used for processing onions, corn & potatoes. Process steam @ 250 psig.	800 gpm 320°F	Ontario Oregon	8	Similar crops are not produced in quantity in the Puna District.

3-10

## Reference List

### DIRECT USES OF GEOTHERMAL ENERGY

1. "Business Profiles" Geothermal Energy 6 ; November 1978.
2. Geothermal Resources Council. Expanding the Geothermal Frontier, Transactions, Volume 3. (Geothermal Resources Council Annual Meeting, 24-27 September 1979; Reno, Nevada.), 1979.
3. U.S. Department of Energy. Direct Heat Application Program Summary, 1979.
4. "Geothermal Energy Used to Distill Alcohol." DOE News. (For immediate release; September 19, 1979.)
5. "INEL Geothermally Assisted Biomass-to-Liquid Fuel Research." (Unpublished fact sheet.)
6. Inventory and Case Studies of Louisiana, Non-Electric Industrial Applications of Geopressured Geothermal Resources. (Prepared for U.S. Department of Energy, Division of Geothermal Energy, by de Laureal Engineers, Inc., Division of Kidde Consultants, Inc.) February 1978.
7. Geothermal Resources Council. Geothermal Energy: A Novelty Becomes Resource. Transactions, Volume 2, Section 1. (Geothermal Resources Council Annual Meeting; 25-27 July 1978; Hilo, Hawaii.) 1978.
8. Direct Utilization of Geothermal Energy: A Symposium. January 31 - February 2, 1978; San Diego, California. CONF-780133. (Prepared by the Geothermal Resources Council for the U.S. Department of Energy.) April 1978.
9. Humme, John T. et al. Engineering and Economic Analysis for the Utilization of Geothermal Fluids in a Cane Sugar Processing Plant. Final Report. (Prepared for U.S. Department of Energy, Division of Geothermal Energy.) Honolulu; July 1979.
10. Geo-Heat Utilization Center, Quarterly Bulletin, Oregon Institute of Technology.
11. Geothermal Resource Council. DOE, Special Report No. 9, "Commercial Users of Geothermal Heat".
12. Geothermal World Directory. 1979/1980 Edition.

<u>Industry-SIC Group</u>	<u>°F</u>	<u>Application Temperature Requirement (°C)</u>	<u>Process Heat Used for Application 10<sup>12</sup> BTU/Yr (10<sup>12</sup> KJ/Yr)</u>		<u>Feasibility Evaluation</u>
<b><u>Group 20 - Food &amp; Kindred Products</u></b>					
Meat Packing - 2011					These processes may be applicable in the future if either (1) a large scale swine production is considered for the industrial park and/or (2) the beef feed lots & slaughterhouses are relocated from Barbers Point on Oahu to the Big Island.
Sausages and Prepared Meats - 2013					
Scalding, Carcass Wash and Cleanup	140	(60)	43.7	(46.1)	
Edible Rendering	200	(93)	0.52	(0.55)	
Smoking/Cooking	155	(68)	1.16	(1.22)	
Poultry Dressing - 2016					Poultry production is not economically competitive at this time.
Scalding	140	(60)	3.16	(3.33)	
Natural Cheese - 2022					The dairy operations in the Puna District are too small scale for geothermal direct heat applications.
Pasteurization	170	(77)	1.28	(1.35)	
Starter Vat	135	(57)	0.02	(0.02)	
Make Vat	105	(41)	0.47	(0.50)	
Finish Vat	100	(38)	0.02	(0.02)	
Whey Condensing	160-200	(71-93)	10.2	(10.8)	
Process Cheese Blending	165	(74)	0.07	(0.07)	

1/ DIRECT UTILIZATION OF GEOTHERMAL ENERGY: A TECHNICAL HANDBOOK, APPENDIX 1 OF GRC SPECIAL REPORT #7

Table 3.2  
Possible Industrial Processes Adaptable To  
Geothermal By SIC Group 1/

Industry-SIC Group	Application Temperature Requirement		Process Heat Used for Application		Feasibility Evaluation
	°F	(°C)	10 <sup>12</sup> BTU/Yr	(10 <sup>12</sup> KJ/Yr)	
Condensed and Evaporated Milk - 2023					The dairy operations in the Puna District are too small scale for geothermal direct heat applications.
Stabilization	200-212	(93-100)	2.93	(3.09)	
Evaporation	160	(71)	5.20	(5.48)	
Sterilization	250	(121)	0.54	(0.57)	
Fluid Milk - 2026					The dairy operations in the Puna District are too small scale for geothermal direct heat applications.
Pasteurization	162-170	(72-77)	1.44	(1.52)	
Canned Fruits & Vegetables - 2033					This process may be attractive in the future; not at this time.
Blanching/Peeling	180-212	(82-100)	1.88	(1.98)	
Pasteurization	200	(93)	0.15	(0.16)	
Brine Syrup Heating	200	(93)	1.02	(1.08)	
Commercial Sterilization	212-250	(100-121)	1.67	(1.76)	
Sauce Concentration	212	(100)	0.44	(0.46)	
Dehydrated Fruits and Vegetables - 2034					Dehydration of papaya is especially attractive. Freeze drying process appears attractive.
Fruit & Vegetable Drying	165-185	(74-85)	5.84	(6.16)	
Potatoes					
Peeling	212	(100)	0.33	(0.35)	
Precook	160	(71)	0.47	(0.50)	
Cook	212	(100)	0.47	(0.50)	
Frozen Fruits and Vegetables - 2037					Shipping costs preclude consideration of a frozen food industry.
Citrus Juice Concentration	190	(88)	1.33	(1.40)	
Juice Pasteurization	200	(93)	0.27	(0.28)	
Blanching	180-212	(82-100)	2.26	(2.38)	
Cooking	170-212	(77-100)	1.41	(1.49)	

3-13

3-14

Industry-SIC Group	Application Temperature Requirement		Process Heat Used for Application		Feasibility Evaluation
	°F	(°C)	$10^{12}$ BTU/Yr	( $10^{12}$ KJ/Yr)	
Prepared Feeds - 2048 Pellet Conditioning	180-190	(82-88)	2.28	(2.40)	There may be a future application.
Cane Sugar - 2062					Cane sugar processing can benefit from large quantities of low cost heat
Mingler	125-165	(52-74)	0.59	(0.62)	
Melter	185-195	(85-91)	3.30	(3.48)	
Defecation	160-185	(71-85)	0.44	(0.46)	
Granulator	110-130	(43-54)	0.44	(0.46)	
Evaporator	265	(129)	26.39	(27.84)	
Distilled Liquor - 2085					Applications in the future may apply to alcohol production as ethanol for gasohol.
Cooking (Whiskey)	212	(100)	3.16	(3.33)	
Cooking (Spirits)	320	(160)	6.27	(6.61)	
Evaporation	250-290	(121-143)	2.32	(2.45)	
Dryer	300	(149)	1.94	(2.05)	
Distillation	230-250	(110-121)	7.69	(8.11)	
Soft Drinks - 2086					Insufficient volume of soft drink consumption in the area surrounding Pahoā.
Bulk Container Washing	170	(77)	0.21	(0.22)	
Returnable Bottle Washing	170	(77)	1.27	(1.34)	
Nonreturnable Bottle Warming	75-85	(24-29)	0.43	(0.45)	
Can Warming	75-85	(24-29)	0.52	(0.55)	



<u>Industry-SIC Group</u>	<u>Application Temperature Requirement</u>		<u>Process Heat Used for Application</u>		<u>Feasibility Evaluation</u>
	<u>°F</u>	<u>(°C)</u>	<u>10<sup>12</sup> BTU/Yr</u>	<u>(10<sup>12</sup> KJ/Yr)</u>	
<b>Finishing Plants, Synthetic-2262</b>					
Washing	200	(93)	35.9	(37.9)	Inappropriate at this time; no basic raw materials and no markets identifiable.
Dyeing	212	(100)	15.2		
Drying & Heat Setting	275	(135)	23.2	(24.5)	
<b>Group 24 - Lumber</b>					
<b>Sawmills &amp; Planning Mills - 2421</b>					
Kiln Drying of Lumber	200	(100)	63.4	(66.9)	Koa lumber processing in and near Hilo, Hawaii, may benefit from these applications.
<b>Plywood - 2435</b>					
Plywood Drying	250	(121)	50.6	(53.4)	There is no local plywood production.
<b>Veneer - 2436</b>					
Veneer Drying	212	(100)	57.8	(61.0)	Veneer is not processed in Hawaii.
<b>Group 25 - Furniture</b>					
<b>Wooden Furniture - 2511</b>					
Makeup Air & Ventilation	70	(21)	5.7	(6.0)	Koa furniture manufacture may have considerable potential; upholstered furniture would be a "follow on" expansion.
Kiln Dryer & Drying Oven	150	(66)	3.8	(4.0)	
<b>Upholstered Furniture - 2512</b>					
Makeup Air & Ventilation	70	(21)	1.4	(1.5)	
Kiln Dryer & Drying Oven	150	(66)	0.9	(0.9)	

Table 3.2

Industry-SIC Group	Application Temperature Requirement		Process Heat Used for Application		Feasibility Evaluation
	°F	(°C)	$10^{12}$ BTU/Yr	( $10^{12}$ KJ/Yr)	
<b>Group 26 - Paper</b>					
Pulp Mills - 2611					Eucalyptus wood chips are now being shipped to Japan from the Big Island of Hawaii for processing into high quality paper. Long term contracts exist with Japanese firms for most of the available eucalyptus chip production.
Paper Mills - 2621					
Paperboard Mills - 2631					
Building Paper - 2661					
Pulp Refining	150	(66)	175	(185)	
Black Liquor Treatment	280	(138)	164	(173)	
Pulp & Paper Drying	290	(143)	383	(404)	
<b>Group 28 - Chemical</b>					
<b>Cyclic Intermediates - 2865</b>					
Styrene	250-300	(121-149)	35.0	(37.0)	Chemical production using geothermal brine & waste or by products of other industries located in the park may be feasible.
Phenol	250	(121)	0.45	(0.47)	
<b>Alumina - 28195</b>					
Digesting, Drying, Heating	280	(138)	113.2	(119.4)	"
<b>Plastic Materials &amp; Resins - 2821</b>					
<b>Polystyrene, suspension process</b>					
Polymerizer Preheat	200-215	(93-102)	0.102	(0.107)	"
Heating Wash Water	190-200	(88-93)	0.067	(0.068)	
<b>Synthetic Rubber - 2822</b>					
<b>Cold SBP Latex Crumb</b>					
Bulk Storage	80-100	(27-38)	0.179	(0.189)	"
Emulsification	80-100	(27-38)	0.086	(0.091)	
Blowdown Vessels	130-145	(54-63)	0.865	(0.912)	
Monomer Recovery by Flashing & Stripping	120-140	(49-60)	4.095	(4.319)	

Table 3.2

3-16

<u>Industry-SIC Group</u>	<u>Application Temperature Requirement</u>		<u>Process Heat Used for Application</u>		<u>Feasibility Evaluation</u>
	<u>°F</u>	<u>(°C)</u>	<u>10<sup>12</sup> BTU/Yr</u>	<u>(10<sup>12</sup> KJ/Yr)</u>	
Dryer Air Temperature	150-200	(66-93)	3.663	(3.864)	Chemical production using geothermal brine & waste or by products of other industries located in the park may be feasible.
Cold SBR, Oil-Carbon Black Masterbatch					
Dryer Air Temperature	150-200	(66-93)	0.506	(0.534)	
Oil Emulsion Holding Tank	80-100	(27-38)	0.090	(0.095)	
Cold SBR, Oil Masterbatch					
Dryer Air Temperature	150-200	(66-93)	1.09	(1.15)	
Oil Emulsion Holding Tank	80-100	(27-38)	0.090	(0.095)	
<u>Group 31 - Leather</u>					
<u>Leather Tanning &amp; Finishing</u>					
- 3111					An existing tannery operation in the Hilo area has experienced difficulty penetrating the Hawaiian market.
Bating	90	(32)	0.094	(0.099)	
Chrome Tanning	85-130	(29-54)	0.060	(0.063)	
Retan, Dyeing, Fat Liquor	120-140	(49-60)	0.15	(0.16)	
Wash	120	(49)	0.034	(0.036)	
Drying	110	(43)	2.05	(2.16)	
Finish Drying	110	(43)	0.13	(0.14)	
<u>Group 32 - Stone, Clay, Glass &amp; Concrete Products</u>					
Hydraulic Cement - 3241					Insufficient market volume. Hot water mix not considered necessary because of mild climate.
Drying	275-300	(135-149)	8.0	(8.0)	
Concrete Block - 3271					"
Low-Pressure Curing	165	(74)	12.29	(12.96)	
Ready-Mix Concrete - 3273					
Hot Water for Mixing Concrete	120-190	(49-88)	0.34	(0.36)	
Gypsum - 3275					Cement wallboard process has potential.
Wallboard Drying	300	(149)	11.18	(11.79)	

## INITIAL SCREENING

The following processes from the lists were identified as having no obvious shortcomings and so passed the initial screening:

- Aluminum Processing
- Aquaculture
- Cattle Feed Mill
- Cement Wallboard
- Chemical Production
- Confined Swine
- Desalting Water
- Ethanol Production
- Freeze drying
- Greenhouses
- Lumber Seasoning
- Manganese Nodule Processing
- Papaya Processing
- Protein Recovery Plant
- Pulp and Paper Production
- Research Laboratory
- Sugar Refining

These 17 processes were further researched and presented to the team. Team members were requested to examine and rank order these potential applications using the following selection criteria:

1. Has the process been adequately proven?
2. Does a market exist?
3. Is the process heat intensive?
4. Are transportation costs a serious concern?
5. Are there known serious barriers?
6. Are raw materials available locally or can they be provided competitively?
7. Is there a local or an off-island firm that would invest in the process?
8. Are there other local suppliers of a finished product?
9. Does the product make sense for Hawaii in the Puna district?

Highlights of the background information that were considered in the final recommendation are presented in the following pages.

## ALUMINUM PROCESSING

### Background and Considerations

- First stage of aluminum production is the Bayer operation in which bauxite ore is processed to alumina. Bayer economics generally dictate a modular plant rated capacity of 800,000 to 1,000,000 annual short tons (AST) depending on the grade and type of bauxite feed.
- The second stage of aluminum production is the smelting operation where alumina is reduced to molten aluminum metal in "potrooms", and processed to primary aluminum shapes including pigs, ingots and billets. This smelting process does not require process steam.
- Largest existing Bayer plant, in Australia, has about 2.5 million AST capacity. Such a plant would demand primary process steam of 750 psia at 750°F at a flow of about 6 million Btu per short ton alumina produced.
- Additional energy requirements:
  - 3 million Btu per short ton alumina for the calcining kilns;
  - 250 kw per short ton alumina for electric drives and support facilities.
- 1.9 short tons alumina produces 1.0 short tons molten aluminum metal.
- It is feasible to assume that approximately half of the Bayer plant output of an estimated 400 - 500 thousand AST aluminum metal production would be processed nearby into aluminum products, and the other 50% shipped overseas from Hawaii for processing.

- Bayer plants are operated continuously with an average annual load factor of about 95%.
- Although Australian government policy restricts the export of bauxite ore, it is considered possible to obtain an adequate supply for production in Hawaii.
- Additional sources of bauxite ore in the Pacific area are the Solomon Islands and Indonesia. There is also a small amount of low grade bauxite ore on the Hawaiian Island of Kauai.

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REFERENCE LIST  
Aluminum Processing

Private correspondence with Mr. E. F. Boobyer, Manager, Energy Technology, Kaiser Aluminum & Chemical Corporation.

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## AQUACULTURE DEVELOPMENT

### Background and Considerations

- Production could include prawns and/or tilapia.
- A growth rate increase of 5 - 7% per degree centigrade of temperature increase can be expected with the use of low grade geothermal heat.
- Dr. Linden Burzell of Lowe, Inc., an aquaculture development firm, suggested the following criteria for development cost:
  - Cost for the development should not exceed \$17,000 per acre of a 100 acre scale.
  - Earth work costs should not exceed \$5,000 - \$8,000 per acre.
- Soil conditions at the industrial park site are not well-suited to aquaculture as soil is too shallow to allow complete excavation of ponds and soil and bedrock are highly permeable.
- Local market potential is favorable with Hawaii's high seafood consumption (approached 30 million pounds in 1979).
- Export market potential appears favorable with Hawaii's strategic location between U.S. mainland and the Far East.
- Industry growth to date has been slow due to lack of experimental facilities to approximate commercial conditions and aquaculturist's inability to qualify for financial assistance.

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### REFERENCE LIST

#### Aquaculture Development

Department of Planning & Economic Development. Aquaculture Development in Hawaii. 1978.

Astral, Terry. Private Correspondence. Tilapia Research on Kauai, Hawaii. August, 1980.

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## CATTLE FEED MILL

### Background and Considerations

- The two existing feed mills in the State are Carnation Company and Waldron Limited; both are located on Oahu. Almost all ingredients are imported.
- Little heat is used by either of the feedmills, as most ingredients are in final use form when imported.
- Approximately 15 to 18% of the feed sales in the State are to the island of Hawaii.
- Sugar cane trash from the Puna Sugar Mill could be the main ingredient for this cattle feed roughage component.
- Large amounts of heat would be required to dry the cane trash which has moisture content of about 70%.
- There is a market for a roughage component of cattle feed in the Barbers Point feedlots on Oahu and in Japan.
- For the Japan market, roughage feed is selling at approximately \$160.00 per ton FOB Yokohama.

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### REFERENCE LIST

#### Cattle Feed Mill

"Use of Geothermal Heat for Crop Drying and Related Agricultural Applications." Final Report. Futures Group. March 1978.

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## CEMENT WALLBOARD PRODUCTION

### Background and Considerations

- There are no existing manufacturers of cement wallboard in the United States, though the product is widely manufactured in Europe. Canec, an insulating structural fiber board was manufactured in a plant in Hilo from 1932 - 1963. The canec plant closed because of the high costs of labor and shipping.
- Marketing potential of cement wallboard depends on the Big Island's construction demands. Construction growth on the Big Island appears marginal at this time.
- The cement component would have to be shipped from Honolulu to Pahoā.
- Heating requirements are 3.6 million BTUs per hour for a 50 cubic meter plant operating at temperatures between 130 - 150°F.
- A 3/4" cement wallboard panel can be produced for approximately \$.67/sq. ft.
- A 3/4" exterior grade plywood sheet retails for \$37.50 per 4' x 8' sheet in Honolulu (\$1.17/sq. ft.).

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### REFERENCE LIST

#### Cement Wellboard Production

Hubner, Jochen E. Project Feasibility Report for Century Board, Hawaii. June, 1979.

Smales, Fred. President of Cypress Cement Company - Bisonboard Process. January, 1980.

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## CHEMICAL PRODUCTION PROCESS

### Background and Considerations

- Major restraints relate to the availability of resources and the process dangers involved.
- Because of proximity to the geothermal rift zone, a chemical production plant should be limited to producing chemicals which both are nontoxic and non-explosive.
- Resources considered include direct use of geothermal brine, pumping sea water to the industrial park site, and using by-products from manganese nodule processing.
- In Iceland, salts are recovered from the geothermal brine which has heavy concentrations of dissolved salts apparently produced from intrusion of sea water in the brine. At Pahoa, the geothermal brine, based on the contents of brine from the HGP-A well, contains only approximately 5% sea water. Therefore, extraction of salts from this brine does not appear to be feasible.
- Pumping sea water to the industrial park 4 miles from the ocean would be very expensive. A manganese nodule plant has not yet been developed in Hawaii, the possibility of using waste materials from a plant is questionable.

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#### REFERENCE LIST

##### Chemical Production Process

Meadows, Katherine F. Geothermal World Directory - Geothermal World Corporation. 1979/1980.

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## CONFINED SWINE PRODUCTION

### Background and Considerations

- 70% of the pork consumed in Hawaii is imported.
- The major deterrent to locally producing pork is the high cost of feed, which consists of 70% of the production costs.
- Pork can be landed in Hawaii at an estimated cost of 57¢ a lb. of live weight, compared to a currently estimated production cost of 68¢ a lb. in Hawaii.
- Locally produced feed has not been competitive to date.
- The completion of a geothermally heated confined swine facility at Kelley Hot Springs in California may provide additional planning information of benefit to a Hawaiian facility.
- Penetrating the pork market in Hawaii would be difficult due to higher feed costs and lower price for pork from the mainland.
- Because of the warm Hawaiian climate there is limited need for additional heat which may not significantly increase the production levels.

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### REFERENCE LIST

#### Confined Swine Production

Hawaiian Agriculture Reporting Service, Statistics of Hawaiian Agriculture, June 1979.

Hawaiian Hog Producers, Feed Cost Figures, November 1979.

Pond, W. G. and Maner, J. H.; Swine Production in Temperate and Tropical Environments, Ltd., 1974, W. H. Freeman and Company.

Energetics Marketing and Management Associates, Ltd., Mountain Home Geothermal Project, San Francisco, California, February 1979.

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## DESALTING WATER

### Background and Considerations

- Research has been conducted in California's Imperial Valley demonstrating the use of geothermal fluids for desalting. Experiments running from 1972 through 1976 involved the installation, operation and modification of different desalting test units.
- There is currently no water shortage near Pahoa.
- The only water shortage that exists on the Island of Hawaii is on the West Coast. However, pumping the water to the West Coast of the Island may not be economically feasible.

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### REFERENCE LIST

#### Desalting Water

Co, A., D. B. Gey, and S. V. Cabibbo, "A Geothermal Desalination and Power Co-Generation Plant", Geothermal Council Transactions Vol. 3, 1979.

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## ETHANOL PLANT

- Process requires 54,000 - 140,000 BTU per gallon of ethanol produced.
- Previous laboratory experiment demonstrated the use of geothermally heated water at 240°F for fermentation and distillation to produce 95% ethanol from sugar beet syrup.
- Could serve possible mainstay (major income producing) industry for industrial park.
- No competing commercial-scaled fuel or alcohol plant exists yet in the state.
- The production of ethanol is consistent with national and state goals of achieving energy independence.
- Ethanol process based on Pilot Plant which would use cellulose feedstock such as wood residue and bagasse, was recommended.

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### REFERENCE LIST

#### Ethanol Plant

- Sladek, Thomas A. "Ethanol Motor Fuel and 'Gasohol'." Mineral Industries Bulletin 21:3. May, 1978.
- Kujala, Pauli. "Distillery Fuel Savings by Efficient Molasses Processing and Stillage Utilization." Sugar y Azucar 74:10. October, 1979.
- "Geothermal Energy Used to Distill Alcohol." DOE News. (For immediate release; September 19, 1979.)
- Garing, Kenneth L. and Glenn E. Coury. "Adaption of Geothermal Energy to Produce Alcohol from Agriculture Commodities." Expanding the Geothermal Frontier. Transactions, Volume 3.

## FREEZE DRYING PROCESS

### Background and Considerations

- Freeze drying is widely applied in the food processing industry for coffee, meats and vegetables. It is a technically and economically proven process, which can use geothermal energy for both heating and cooling.
- A variety of raw materials are available in Hawaii which may be freeze dried, including Kona coffee, papaya, guava, and meats.
- Although the source is limited, the market for freeze dried Kona coffee appears to be strong.

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### REFERENCE LIST

#### Freeze Drying Process

- "Air-Drying, Freeze-Drying, and Osmovac Dehydration of Foods with Solar Energy," J.H. Moy, U.H. Research, 1/77-6/81.
- Moy, James H. and Heinz Speilmann, "Economic Feasibility Studies: 1. Vacuum-Puff Freeze Drying of Fruit Juice Products; 2. Osmovac-Dehydration of Piece Form Fruit Products," University of Hawaii - College of Tropical Agriculture, Hawaii Agriculture Experiment Station, February 1977.
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## GREENHOUSES

### Background and Considerations

- Greenhouses for production of tomatoes and cucumbers, using geothermal heat have been successfully demonstrated at Susanville, California.
- Hawaii Koi Corporation, the major grower on the Island of Hawaii is located at a 3,000-ft. elevation. It is commonly believed that the optimum temperatures at the higher elevations enhance the quality of the product.
- The Koi Corporation is currently not interested in relocating to the Pahoa industrial park site, which is at a lower elevation. Presently no requirement for heating exists.
- Soil warming was investigated for anthurium production. However, the warmer soil does not improve production.
- A future potential for mushrooms and roses grown in greenhouses exists, but to date, imported products are less expensive and of higher quality.

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### REFERENCE LIST

#### Greenhouses

Personal Communication with Alvin Oyadomari, Cooperative Extension Service Agent; Hilo, Hawaii; October 15 and November 7, 1979.

Climatological Data, Hawaii & Pacific. Asheville, N.C. - National Oceanic & Atmospheric Admin., Environmental Data Service, various dates.

Personal Communication with Richard Nakano, Cooperative Extension Service Agent; Waimea, Hawaii - November 19, 1979.

Direct Heat Application Program Summary. Presented at the Geothermal Resources Council Annual Meeting, September, 1979. U.S. Department of Energy, Division of Geothermal Energy.

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## LUMBER SEASONING AND DRYING

### Background and Considerations

- Two saw mills are currently operating on the Island of Hawaii; both mills air dry the lumber.
- Kiln drying would reduce the moisture content to roughly 7%.
- Temperature between 110° and 120 °F would be required for the kiln.
- Although the main wood product is koa, other species including ohia and eucalyptus could be dried in the kiln.
- Critical unknown factors are the supply of lumber available on the Island of Hawaii and whether the value added by drying is warranted.

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### REFERENCE LIST

#### Lumber Kiln

- Mueller, Glenn. Personal Communication. Campbell-Burns Company  
Hilo, Hawaii. November, 1979.
- Shirota, Akiva. Personal Communication. Blair, Ltd. Hilo, Hawaii  
November, 1979.
- Reis, Harvey. Personal Communication. Ahualoa Sawmill. Ahualoa,  
Hawaii - November, 1979.
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## MANGANESE NODULE PROCESSING

### Background and Considerations

- Hawaii is located approximately 700 miles from a belt of hydrate manganese nodule deposits in the ocean.
- Currently four American led consortia are at various phases of planning for exploration and recovery of the nodules.
- Manganese nodules are chiefly mined for extraction of the copper, nickel and cobalt content.
- The reduction/ammonia leach process is energy intensive requiring temperatures as high as 1157°F.
- Geothermal energy alone would not completely meet process heat requirements.
- There would be substantial objection to the placement of the manganese processing plant in the Pahoia geothermal industrial park.
- For manganese processing plants to be economically feasible, a large scale facility is necessary, which may be too large for the park concept.
- Uncertainties surround the time-table of manganese nodule development and the optimal process.

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### REFERENCE LIST

#### Manganese Nodule Processing

"Preliminary Research on Geothermal Energy Industrial Complexes."  
Final Report. DSS Engineers. March 1978.

Stephen-Hassard, Dick Q. et al. The Feasibility and Potential Impact  
of Manganese Nodule Processing in Hawaii - Department of Planning  
& Economic Development, February, 1978.

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## PAPAYA PROCESSING

### Background and Considerations

- Five local companies pack and process an estimated 45 million pounds of papaya per year.
- In the Puna District 3,000 acres are dedicated to papaya production; however, only 1,800 acres are harvested at any one time. The remaining papaya land lies fallow as crops are rotated and the soil sterilized. The estimated annual production is 25,000 pounds per acre per year.
- 60% of the papaya is processed as fresh fruit. The balance is converted to puree.
- At the present time, there are three local companies making puree: Puna Papaya, Suisan Fruit Processing and Hawaiian Fruit Flavors.
- Very little heat is required to process puree. However, the present process requires refrigeration because the product is frozen for shipment and marketing. In the near future, it is planned to convert the process to an aseptic process which will eliminate the necessity for refrigeration in storage and shipment of the puree and require high temperatures.
- A dehydration process is being developed which will require a temperature of 250°F. The equipment is capable of producing 500 pounds of dried papaya per hour.
- A small business firm, La Malo'o, at Pahoia is currently developing an integrated system for the use of solar energy and biomass energy for the reclamation of papayas not considered suitable for marketing. This firm has developed contacts for marketing dried

papaya in Europe, Japan, Hawaii and the U.S. mainland.

- In preparation of fresh fruit for shipment, the fruit is soaked in a hot water, chemical solution for 20 minutes at a temperature of 120°F.

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REFERENCE LIST

Papaya Processing

Brebbe, J.E. et al. Operating Manual for Papaya Puree Processing.

DeBevec, John. Personal Consultation. Lodi, California - 1979/80.

Livingstone, David. Personal Consultation. La Malo'o, Hawaiian Dried Fruits & Herbs - 1979/80.

Souza, Robert A. Papaya Production Marketing and Income. Papaya Administrative Committee - September, 1979.

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## PROTEIN RECOVERY PLANT

### Background and Considerations

- Technology for a protein separation process has been developed by the U.S. Department of Agriculture, Western Regional Research Center (WRRC) in Albany, California.
- New protein separation process, known as Pro-Xan, concentrates the protein and xanthophyll components of green leaf crops, leaving a fiber that can be used as forage presscake while retaining a substantial amount of protein.
- The Pro-Xan process is being commercially produced in the United States and at several locations in Europe. The process was first introduced in the United States in 1978, when Valley Dehydrating Company (VDC) of Sterling, Colorado, modified one of its existing alfalfa dehydrating plants to the Pro-Xan process. This plant is presently in its second season of commercial operation.
- Leaf protein can be a valuable source of protein for human consumption as well as for cattle and poultry feed.
- Leaf protein will have to compete on an economic basis with soybean meal and other presently used protein sources.
- The Pro-Xan process is energy intensive requiring in excess of 8,000 pounds/hour of steam for a Pro-Xan plant designed to operate on 40 tons/hour of chopped alfalfa. The alfalfa dehydration plant at Sterling, Colorado, consumes 278 million cubic feet of gas annually for a 130 day operating season.
- Leucaena is believed to be adaptable as a green leaf crop supply capable of providing the protein rich material for the process.

- Annual yields of edible dry matter (from the leucaena) are 6 to 10 tons/acre. This is equivalent to the annual production of 800 to 4,300 pounds/acre of protein.

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REFERENCE LIST

Protein Recovery Plant

Kohler, George O. and Knuckles, Benny E., Edible Protein from Leaves, May 1977, Food Technology.

Milner, Max & Scrimshaw, Nevan S., Wang, Daniel I.C., Protein Resources & Technology: Status and Research Needs. Massachusetts Institute of Technology, 1978.

Kohler, George et al. Leaf Protein in Relation to Forage Crop Production & Utilization.

Edwards, R.H. et al., "Commercial Scale Production of Alfalfa Leaf Protein Concentrate (Pro-Xan): A Progress Report," Paper presented at the 1979 Winter Meeting, American Society of Agriculture Engineers, New Orleans, Louisiana, December 1979.

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## PULP AND PAPER MILL

### Background and Considerations

- The concept of using sugar cane bagasse as a fiber source for pulp or paper mill located in Hawaii has been extensively studied since the 1900's.
- A pulp and paper mill process, to date, has not been determined to be economically viable.
- Canec plant producing insulating structure fiberboard closed due to high labor and shipping costs.
- A pulp mill is a large energy consumer.

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### REFERENCE LIST

#### Pulp and Paper Mill

"First Draft of Feasibility Study Concerning the Possibility of Establishing a Pulp and/or Paper Mill on the Island of Hawaii," Prepared for C. Brewer and Company, Ltd, Mitsui and Company, Ltd, and Jujo Paper Manufacturing Company, Ltd, by Joseph E. Atchison Consultants, Inc., New York, January 20, 1969.

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## SUGAR PROCESSING

### Background and Considerations

- Sugar processing is an energy intensive industry and the use of geothermal energy in sugar processing and refining has been studied at several locations including applications at the Puna Sugar Mill. The Puna Sugar study concluded that the project would be only marginally economic primarily because of the capital needed for the geothermal steam transmission system from the wellhead.
- The high cost of relocating a sugar factory at the Pahoia industrial park may preclude further consideration by any sugar company.
- A proposal has been submitted to establish a major sugar refinery in Pahoia. Advantages include power, water, communications, labor, space and an assumption of geothermal energy in useable form. The finished product would be shipped by conventional freight as opposed to the special bulk ships now used.
- The fact that Hawaii and the Pacific Basin already have a refinery at Aiea on Oahu operated by C&H may serve as a major deterrent. A tremendous amount of new capital would be required to build a refinery with the capacity for 800,000 plus tons of refined product. The risks of geothermal reservoir depletion and volcanic disruptions and other such factors must also be considered.

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#### REFERENCE LIST

##### Sugar Processing

"Use of Geothermal Heat for Sugar Refining," Final Report, TFW Systems and Energy, May 1977.

Puna Sugar Co. Engineering & Economic Analysis for the Utilization of Geothermal Fluid in a Cane Sugar Processing Plant. Final Report - 1979.

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### RESEARCH LABORATORY

- A research laboratory could continue to evaluate and test direct applications of geothermal energy.
- Funding to come from a variety of sources including government and private, through grants and/or users fees.
- The laboratory is considered to be a support test facility for potential businesses.



## PROCESSES SELECTED FOR INITIAL ECONOMIC ANALYSIS

From the seventeen processes, nine were selected for further study in the initial economic analysis. The rationale in choosing these processes are presented below.

### Aquaculture

- In harmony and consistent with the Hawaii State Plan passed by the 1978 legislature.
- Initial studies show significant increase in growth rate of certain aquatic species due to an increase in water temperature.
- The local demand for seafood and cultured aquatic species is very high.
- The industry is energy intensive with low temperature requirements making it an ideal end user.

### Cattle Feed Mill

- The market potential for feed components in both Hawaii and Japan appears strong.
- The adaption of the existing technology to geothermal applications will require only minor modifications.
- Converting bagasse and cane leaf trash into feed components is more cost efficient than using it as a boiler fuel.
- Equipment and plant layout plans are available from existing facilities.
- The process is heat intensive and may require additional heat input for raising the temperature of the dryer.

### Cement Wallboard

- The demand for construction materials in Hawaii is extremely high with the market being very competitive.
- Initial estimates by Bison Werkes indicate a favorable return on investment with the cement wallboard directly competing with exterior plywood as a building material.
- The manufacturing process is heat-intensive.
- The product has been used extensively in both Switzerland and Germany as a construction material.
- The process is proven and the manufacturing equipment is readily available.

### Ethanol Production

It was generally agreed that a successful industrial park should have an industry which serves as the mainstay, that is, a major income producer. The mainstay industry should require large amounts of heat, involve a proven technical process and be relatively low risk. Other industries in the park may then be more risky without endangering the viability of the industrial complex.

The proposed ethanol plant was the first choice as a mainstay industry. However, because molasses may be too expensive as a feedstock, a process that can use various raw materials including wood residue and bagasse as well as molasses was recommended. Although the process selected was not a process currently in commercial production, significant portions of the process had been demonstrated in a laboratory pilot plant to indicate a high probability of success.

There is presently no competing commercial scaled fuel or alcohol plant in the State and there is a market being established for gasohol at this time.

One side benefit from selecting an ethanol plant would be the possibility of using an alcohol-powered truck fleet for the transportation requirements for the industrial park.

In summary, although a more detailed analysis of the applicability of geothermal resources to an ethanol plant was considered necessary, the combination of the availability of molasses and biomass and geothermal energy on the Big Island coupled with the local need for liquid fuel made an ethanol plant a good prospect for the proposed geothermal industrial park.

#### Freeze Drying

- The process is technically and economically proven.

- The raw materials are indigenous to Hawaii.

The process can utilize heat in both the heating and cooling stages.

- Availability of Kona coffee on the Island of Hawaii.

#### Lumber Seasoning & Drying

It was recognized that to perform an economic analysis of lumber drying/seasoning/wood chips, additional information would be needed on the supply of wood available on the Big Island and the nature of the market demand. In addition, a measure of the value added by drying lumber must be more carefully determined. Some concern was expressed that the time required for re-forestation would preclude any long-term high-level production calling for an expansion of the industry beyond the current levels.

However, in spite of the foregoing concerns, it was concluded that a lumber kiln could greatly benefit the local lumber industry and that such a kiln would utilize established technologies and could use quantities of medium grade heat. The process was recommended for further evaluation.

#### Papaya

- The industrial park site is located at the center of Hawaii's papaya production farmlands.
- Papaya production ranks fourth in Hawaiian agriculture.
- Approximately 40% of the papayas in Hawaii are culled with only a small percentage being processed. Thus a large supply of fruit for processing is available (presenting a favorable area for development).

#### Protein Recovery

- The process is a transfer of technology from existing protein recovery plants.
- An ample supply of feedstock is available on the Big Island of Hawaii.
- The market potential for protein appears high for use as a feed component in Hawaii and Japan and possibly for consumption in undeveloped countries.

#### Research Laboratory

A direct heat geothermal research laboratory will provide a facility that can test and develop promising processes for both the industrial park and for small scale low temperature applications. This facility would be in accord with the stated County policy regarding geothermal developments.

## PROCESSES NOT SELECTED

The following processes were not selected for the following primary reasons:

### Aluminum Processing

The large quantity of electrical power required for the smelting of aluminum may be available in the future using geothermal energy. However, for purposes of this study, application of direct heat would not be involved.

The first stage process in which the alumina is produced from bauxite ore requires direct heat applications. However, this process will normally be accomplished in Australia near the bauxite mines.

### Chemical Production

Chemical production was not selected because of the lack of readily available resources and the dangers and environmental hazards involved.

### Confined Swine

This process was not selected for three reasons, i.e. (a) the high cost of feed, (b) the difficulty in penetrating the local pork market in Hawaii's warm climate and (c) the process was not energy intensive.

### Desalting Water

This process was not selected because there is no apparent water shortage near Pahoa.

### Greenhouses

- Very little heating requirements because of climate.
- Heating requirements more economically met by solar applications.

### Manganese Nodules

Manganese nodules was not selected because the process was not environmentally and socially acceptable to the Pahoia community. Further, the manganese nodule processing development is too uncertain for selection at this time.

### Pulp and Paper Mill

This process was not selected because there was no economic market available and because of major environmental barriers.

### Sugar Processing

Sugar processing was not selected because of the high cost of relocating a sugar mill to the Pahoia industrial park.

### SUMMARY

Selection of the candidate industries for initial economic viability analysis are summarized in a process selection matrix (Table 3.3). with rank ordering of the 8 industrial processes and the research laboratory. Several processes not selected could be further evaluated by a research laboratory and subsequently be determined to be feasible.

**SELECTION MATRIX**

	Aluminum Processing	Aqua-culture	Cattle Feed Mill	Cement wallboard	Chemical Production	Confined Swine	Desalting water	Ethanol Production	Freeze Drying	Green-houses	Lumber Seasoning	Manganese Module Processing	Papaya Processing	Protein Recovery Plant	Pulp & Paper	Research Laboratory	Sugar Refining
Has the process been adequately proven?	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes	yes	yes	--	yes
Does a market exist?	yes	no	yes	yes	yes	yes	no	yes	yes	no	yes	yes	yes	yes	no	yes	yes
Is the process heat intensive?	yes	yes	yes	yes	yes	--	yes	yes	yes	no	yes	yes	--	yes	yes	yes	yes
Are transportation costs a serious concern?	yes	no	yes	yes	no	yes	yes	no	no	no	yes	yes	yes	no	no	no	yes
Are there known serious barriers?	yes	yes	no	no	yes	yes	no	no	no	no	no	yes	no	no	yes	no	yes
Are raw materials available locally or can they be provided competitively?	no	yes	yes	yes	no	no	no	yes	yes	no	yes	yes	yes	maybe	yes	yes	yes
Is there a local firm that would invest in the process?	no	no	yes	yes	no	yes	no	yes	yes	no	yes	yes	yes	yes	no	yes	no
Is there an off Island firm interested in investing in the process?	no	no	yes	yes	no	yes	no	yes	no	no	no	yes	yes	yes	no	no	no
Are there other local suppliers of a finished product?	yes	yes	yes	no	yes	yes	yes	no	yes	yes	no	yes	yes	no	yes	--	yes
Does the product make sense for Hawaii in the Puna district?	no	no	yes	yes	no	no	no	yes	yes	yes	yes	no	yes	yes	no	yes	no
Recommended and Selected Study Team's Rank Order	no	yes	yes	yes	no	no	no	yes	yes	no	yes	no	yes	yes	no	yes	no
		9	2	8				1	6		.7		3	4		5	

3-45

PROCESS SELECTION MATRIX  
Table 3.3

## CHAPTER 4

### INITIAL ECONOMIC VIABILITY ANALYSIS

#### Introduction

This chapter covers the initial quantitative review of those industries identified as possible candidate tenants of the industrial park. The eight potential industries, exclusive of the Geothermal Research Laboratory, selected for initial economic viability evaluation are as follows:

- Ethanol Plant
- Cattle Feed Mill
- Papaya Processing
- Protein Recovery Plant
- Freeze drying of Kona Coffee
- Lumber Kiln
- Cement Bonded Wallboard
- Aquaculture

#### Methodology Employed

The initial economic viability analysis assessed the availability of raw materials, market potential and the overall economic competitiveness. Significant barriers and risks in these areas were weighed against the cost advantages/disadvantages of locating at the geothermal park. When the problems clearly outweighed cost advantages, the industry was rejected from further analysis.

A differential cost analysis compared the cost of operation at the industry's current location to the proposed Pahoehoe industrial park. Cost differences arose due to:



1. Energy requirements - geothermal versus fossil fuel or other fuel source.
2. Freight and logistic requirements.
3. Relocation requirements.

A breakeven analysis was conducted assuming the industries were located at the Pahoehoe geothermal park. The required breakeven selling price was then compared with the current cost of the product in Hawaii to determine if locating at the geothermal park would provide a competitive edge.

## ETHANOL PLANT ANALYSIS

### Introduction

A commercial plant designed to produce 20,000 gpd of fuel grade ethanol and other energy products was selected for study. The specific process chosen was believed capable of utilizing a wide range of lignocellulosic feedstocks including bagasse, woodwastes and agricultural wastes. No waste products were anticipated from the ethanol process so it would be an effective net energy producer requiring no input of fossil fuel. This production could satisfy 24% of the projected 1985 State of Hawaii ethanol demand for use in a 10% gasohol mix.

### Availability of Feedstock

The proposed 20,000 gpd ethanol plant requires approximately 206,000 tons (50% moisture) of feedstock annually. This biomass feedstock consisting of sugar cane bagasse and wood chips/slash are the resultant product from sugar mill and lumbering operations respectively.

Initial surveys were conducted to determine the magnitude of existing feedstock from local industries. These surveys consisted of interviews with plant managers as well as correspondence by letter. The survey overall resulted in two conditional commitments made by each, AMFAC and C. Brewer & Co., Ltd. to sell upon reaching a mutually agreeable price and a satisfactory supply agreement, 250 tpd (50% moisture) of bagasse for a combined total of 500 tpd.

Surveys were also conducted to determine the availability of wood chips/slash. This survey found a total of 26,000 tons of wood chips/slash available annually.

It must be emphasized that the objective and intent of the survey was to determine that adequate feedstock is available and no attempt was made to quantify the total amount available.

The following table summarizes the results from the survey which, however, does not accurately indicate the total potential which can be developed.

Feedstock Source

Bagasse:

	<u>Tons/Day</u>	<u>Annual Total (Tons)</u>
Puna Sugar Mill/Amfac	250	91,250
Ka'u Sugar Mill/C. Brewer	125	45,625
Pepeekeo Sugar Mill/C. Brewer	125	45,625
	<hr/>	<hr/>
Total	500	182,500

Wood (Slash):

Campbell - Burns	20	8,000
Campbell Estates	50	18,000
	<hr/>	<hr/>
Total	70	26,000

Hence, this survey found as much as 208,500 tons/yr. compared to the estimated 206,000 tons/yr. required for the ethanol plant.

Market Potential

Hawaii urgently needs additional domestic energy sources to reduce its dependence on imported oil. Oil consumption in 1979 was approximately as follows:

Electric Generation	27,000 barrels/day
Motor Fuel	25,000 barrels/day
Jet Fuel	25,000 barrels/day
Other	<u>23,000 barrels/day</u>
	100,000 barrels/day

Virtually 100% of Hawaii's energy is supplied by imported oil and gas. In the last 12 months, the cost of energy to Hawaiian consumers has increased over 70%. Hawaii's 1980 oil bill exceeded \$1 billion.

Saleable products from the proposed plant would include ethanol, methanol, methane, steam, yeast and electricity. Ethanol production would total almost 7 million gallons/year. It would be produced at approximately 200 proof for use in the gasohol market in which 10 parts of ethanol is blended with 90 parts of unleaded gasoline to make gasohol. Pacific Resources, Inc. (PRI) has indicated an interest in marketing the ethanol. This firm is already a major energy supplier in the State and has established an initial ethanol/gasohol marketing program using ethanol imported from Bellingham, Washington.

Methanol output would be approximately 800,000 gallons/year. It could be used as boiler fuel or as feedstock in PRI's Hawaiian refinery to supplant imported crude oil.

Methane and steam are calculated to be substantial contributors to the energy output of the proposed plant and would be used in a co-generation plant to produce an estimated 10 MW of electric power.

#### Economic Competitiveness of the Ethanol Plant

The economic competitiveness of the plant would be affected to a large degree by the price to be charged for ethanol. The ethanol being shipped

by Pacific Resources, Inc., to Hawaii from the Bellingham plant in March 1980 cost \$2.05/gallon landed in Honolulu. Since ethanol is mixed on a 1:9 ratio with unleaded gasoline to form gasohol, the ethanol must ultimately compete with the price of unleaded gasoline unless the gasohol is to be sold at a premium. It is assumed the ethanol will be sold to the distributor at the same price effectively as unleaded gasoline.

The average rack price of unleaded gasoline in August 1980 was approximately \$1.36/gallon. This is an increase from 52¢/gallon a year ago. With the Federal Government subsidy on gasohol of 4¢/gallon in the form of a waiver on the 4¢/gallon excise tax and a similar provision by the State of Hawaii in waiving the 4% sales tax, an 8¢/gallon reduction in ethanol selling price can be realized by the consumer in the purchase of 10% mix gasohol. This means that the effective price of ethanol in today's market would be \$1.25 instead of \$2.05. However, as this subsidy is not received directly by the ethanol producer, the competitive selling price against which ethanol from the geothermal commercial park must compete is \$2.05/gallon.

#### Economic Viability Tests

The first economic viability test focused on the cost savings to be realized by locating an ethanol plant at the industrial park and utilizing geothermal energy versus locating at the Puna Sugar Mill and utilizing fossil fuel. At both locations, the major feedstock for the process would be a mixture of bagasse and wood wastes.

The Puna Sugar Mill was chosen as an alternate site for comparison with the industrial park. Differential cost include energy, transportation and construction. The results of this analysis presented in Table 4.1 indicate that savings of \$1,175,324 can be realized with a geothermal ethanol plant.

TABLE 4.1

DIFFERENTIAL COST ANALYSIS - ETHANOL PLANT

Energy

Assume: Substitute for geothermal steam would be fossil fuel.

	<u>Geothermal</u>	<u>Fossil Fuel</u>	<u>Difference - Geothermal Savings</u>
Cost per MBTU	\$2.67	\$7.46	\$ 4.79
Energy Requirement:			
3.431 x 10 <sup>9</sup> MBTU/yr	\$916,077	\$2,559,526	\$1,643,449

Transportation

Assume: The most likely location for the ethanol plant other than at the park would be at the Puna Sugar Mill. The cost of transporting the bagasse from the sugar mill to the park is \$3.64/ton.

	<u>Commercial Park</u>	<u>Sugar Mill</u>	<u>Difference Additional Commercial Park Expense</u>
Transportation cost based on feedstock requirement:			
280TPD x 365 days x \$3.64	\$372,008	—	(\$372,008)

Construction

Assume: A construction premium of \$30,000 for the park is added to the plant construction cost at the Puna Sugar Mill. The premium reflects additional transportation costs for the 16 miles from the sugar mill to the park site.

	<u>Commercial Park</u>	<u>Sugar Mill</u>	<u>Difference Additional Commercial Park Expense</u>
Construction cost for a 20,000 gallon per day ethanol plant	\$30,000	—	(\$30,000)

TABLE 4.1 (continued)

SUMMARY

	Savings/(Expense) by locating at commercial park versus Puna Sugar Mill
Energy	\$1,643,449
Transportation	( 372,008)
Construction	<u>( 30,000)</u>
Operations	<u>( 66,117)</u>
Net Savings/(Expense)	\$1,175,324

### Breakeven Selling Price

The breakeven selling price for the geothermal ethanol plant was determined. This price would have to be competitive with the current ethanol sales price in Hawaii of \$2.05/gallon. The breakeven analysis in Table 4.2 derived a \$1.06/gallon selling price for ethanol utilizing an estimated geothermal energy cost of \$2.67/MBTU.

### BREAKEVEN ANALYSIS

Assume: 20,000 gpd ethanol plant.

*Total Investment	\$21,000,000
Interest during Construction (12%)	<u>2,520,000</u>
Total Capital Cost	\$23,520,000
Amortization of capital cost 15%, 25 years	3,638,530
Annual Variable Cost	
*Operating and Maintenance	<u>4,100,000</u>
Breakeven revenue required	\$ 7,738,530/yr.
Breakeven selling price of ethanol (based on a 365 days/year operation)	<u>\$1.06/gallon</u>
Hawaii selling price of ethanol	
March, 1980:	\$2.05/gallon
August, 1980:	\$2.05/gallon

\* preliminary estimate

### Conclusion

Availability of resource: Assured  
Economic viability: Competitive  
Market Potential: High



## Molasses Ethanol

Although the basic ethanol process selected in the study converts cellulose to ethanol, an economic viability test of a proposed molasses plant was also undertaken. This proposed molasses plant was evaluated in the Hawaii Ethanol from Molasses Project (Hawaii Natural Energy Institute, U.S. Department of Energy, Contract No. DE-AC03-79ET23141, April 1980). The base process developed in that study utilized bunker C fuel or its equivalent and a molasses feedstock. The cost per gallon of ethanol was \$1.76 (August 1979 dollars), which equates to \$1.96 in March 1980 dollars. The same process was costed utilizing geothermal energy at \$2.67/MBTU as opposed to fossil fuel to determine the competitiveness of geothermal. Table 4.2 presents the results of the analysis. The HNEI molasses plant utilizing geothermal energy, could produce ethanol for \$1.87/gallon, a \$.09 savings over the use of fossil fuel.

An investigation was made to see if this cost saving was sufficient to cause any of the proposed molasses ethanol plants to locate in Pahoia. Hilo Coast Processing Company is studying a molasses ethanol plant at their sugar factory at Pepeekeo, approximately 25 miles away from Pahoia. It was evident that by locating this plant in the park, additional costs would be incurred in transportation and duplication of infrastructure and supervision. These additional costs would be greater than the energy saving.

The cost of additional processing capacity at the Hilo Coast Processing facility to handle molasses from other sugar factories on the Island of Hawaii would be significantly less than the cost of an independent plant in Pahoia.

TABLE 4.2

FOSSIL FUEL MOLASSES PLANT

COST COMPARISON-BASED ON HAWAII ETHANOL FROM MOLASSES PROJECT<sup>1</sup>

AND GEOTHERMAL MOLASSES PLANT

Cost Analysis for Base Processes for the Production  
of Ethanol with Deep Ocean Discharge of Stillage

	<u>Fossil Fuel Molasses Plant</u>		<u>Geothermal Molasses Plant</u>	
	<u>Annual</u> <u>(\$1000)</u>	<u>Cents</u> <u>per Gallon</u> <u>of Ethanol</u>	<u>Annual</u> <u>(\$1000)</u>	<u>Cents</u> <u>Per Gallon</u> <u>of Ethanol</u>
<u>Operating Costs<sup>2</sup></u>				
Labor and supervision (including employee benefits)	\$ 490	6.64	\$ 490	6.64
Supplies (chemicals, nutrients and water)	275	3.73	275	3.73
Fuel, bunker C or equivalent (1681.9 input minus 47.0 excess electricity, MJ/100 liters ethanol = 1634.9 MJ = 432,240 MBTU)	1,756	23.81	1,154	15.65
Repair and maintenance (3% of total investment of \$9,970,000)	332	4.50	332	4.50
Molasses feedstock (\$71.76/ton)	7,903	107.17	7,903	107.17
Contingencies (15% of above)	<u>1,614</u>	<u>21.89</u>	<u>1,523</u>	<u>20.65</u>
Total Operating Costs	12,370	167.74	11,677	158.34
<u>Depreciation and Interest</u>	<u>2,767</u>	<u>37.52</u>	<u>2,767</u>	<u>37.52</u>
<u>Total Cost</u>	<u>\$15,137</u>	<u>205.26</u>	<u>\$14,444</u>	<u>195.86</u>
<u>Less: Excess yeast (20 kg/tonne molasses @33.7¢/kg)</u>	<u>674</u>	<u>9.14</u>	<u>674</u>	<u>9.14</u>
<u>Net Cost</u>	<u>\$14,463</u>	<u>196.12</u>	<u>\$13,770</u>	<u>186.72</u>
<u>Difference from Molasses Plant</u>	<u>\$692</u>	<u>8.07</u>		

1 Table U.S. Department of Energy Contract No. DE-AC03-79ET23141, April 1980

2. Original unit costs and income stated in August 1979 dollars.

## CATTLE FEED MILL ANALYSIS

### Introduction:

This analysis focuses on the feasibility of locating a commercial plant designed to produce 240 tons per day of a cattle feed roughage component in the Pahoia Industrial Park. The specific process selected dries and forms sugar cane leaf trash into 1-1/4 inch cubes to be marketed as a roughage component of cattle feed in both Japan and Hawaii.

### Availability of Feedstock

The feedstock under consideration is sugar cane leaf trash, also known as "cane strippings". The sugar cane leaf trash @ 600 tons per 24 hours at approximately 70% moisture is available for study purposes from the Puna Sugar Mill which only recently installed a mechanism to separate the leafy cane trash. For this process evaluation an estimated cost of \$24.50/ton for cane trash will be used. In addition, transportation costs are \$3.64 per ton from the Puna Sugar Mill.

### Energy Requirements

- Total heat needed to dry 600 tons per 24 hrs. of sugar cane leaf trash with 70% moisture is approximately 72 MBTU/hr. assuming 50% efficiency.
- Geothermal heat using 375°F input to the furnace air preheater can provide 32 MBTU/hr.
- Process "fines" can be recovered and burned in the dryer furnace providing 15 MBTU/hr.
- Wood chips provide the balance of heat required i.e., 25 MBTU/hr. at a cost of \$75.00/hr.

Market Potential

Hawaii imports approximately 30,000 tons of cattle feed roughage each year. In Japan there is a shortage of 300,000 tons of roughage per year.

TABLE 4.3

Actual 1980 Selling Price/ton of Roughage Cattle Feed

	<u>Japan</u>	<u>Oahu</u>
Cubed sugar leaf trash	\$160.00	\$120.00
Alfalfa pellets from Mainland U.S.A.	280.00	175.00
Molokai guinea grass	180.00	58.00
Pineapple bran	—	120.00

TABLE 4.4

DIFFERENTIAL COST ANALYSIS - CATTLE FEED MILLEnergy

Assume: A substitute for geothermal steam would be fossil fuel where a comparable plant would be located at the Puna Sugar Mill.

	<u>Geothermal</u>	<u>Fossil Fuel</u>	<u>Difference Geothermal Savings</u>
Cost per MBTU	\$2.67 at Pahoa Ind. Park	\$7.46 at Puna Sugar	\$4.79
Cattle feed mill requirement 32 MBTU/hr.; 2.304 x 10 <sup>5</sup> MBTU/yr.	\$ 615,168	\$1,718,784	\$1,103,616
 <u>Transportation</u>			
	<u>Industrial Park</u>	<u>Puna Sugar Mill</u>	<u>Difference- Additional Ind.Pk.Expense</u>
Transportation/ton	\$3.64		(\$3.64)
Cattle feed mill requirement 600 TPD x 300 days x \$6.00	\$ 655,200	—	(\$ 655,200)

Construction

Assume: A construction premium of \$30,000 is added to plant construction at the park. This premium reflects additional transportation and infrastructure costs for the plant being 16 miles from the Puna Sugar Mill.

	<u>Industrial Park</u>	<u>Puna Sugar Mill</u>	<u>Difference</u>
Differential Construction Cost for 240 tons per day cattle feed mill	\$4,830,000	\$4,800,000	(\$ 30,000)

TABLE 4.4 (Continued)

SUMMARY

Savings/(Expense) by Locating  
at Industrial Park vs.  
Puna Sugar Mill

Energy	\$ 1,103,616
Transportation	( 655,200)
Construction	<u>( 30,000)</u>
Net Savings/(Expense)	\$ 418,416

BREAKEVEN ANALYSIS

Assume: 240 tons per day of feed cubes

*Total investment	\$ 4,830,000
Interest during construction (12%)	<u>579,600</u>
Total Capital Cost	\$ 5,409,600
Amortization (30yrs. @ 15%)	823,882
*Annual variable costs	\$ <u>8,000,000</u>
Breakeven revenue required	\$ 8,823,882

Breakeven selling price of feed cubes  
(based on 240 tons per day,  
300 days/year = 72,000 tons/year)                      \$122.55/ton

Conclusion

Raw product availability:	Assume available
Market availability:	Potential in Japan
Economic viability:	Marginal

\* preliminary estimate

## PAPAYA PROCESSING PLANT ANALYSIS

### Introduction

The center of the papaya industry resides in the Puna District of the Island of Hawaii, site of the proposed Pahoia Industrial Park. The district maintains between 75-80% of the State's productive capacity.

This analysis was made to determine the economic viability of locating a papaya industry at the industrial park which will process fresh papayas and utilize the geothermal resources for processing the culled papaya (those left in the field). It is estimated that approximately 40% of the papayas are currently being left in the field.

### Availability of Resources

Approximately 2900 acres of land on the island of Hawaii are under papaya cultivation. This represents a production capability of over 80 million pounds. The State of Hawaii has approximately 1,080 acres of additional land in the Puna District available for lease that are suitable for papaya cultivation. This alone represents another potential 30 million pounds of papaya. Additional land could be obtained through negotiations with various landowners with large holdings in Puna. The following table shows the total number of acreage held by the five major companies available for production on the Island of Hawaii.

TABLE 4.5\*

<u>Company</u>	<u>Total Acres Available</u>	<u>% of Total</u>	<u>Total Acres in Harvest</u>	<u>% of Total</u>
Puna Papaya	1,255	43%	666	36%
Mr. Papaya	750	26	500	31
Ono Pac	400	14	300	16
Diamond Head	300	10	160	9
Del Monte	200	7	150	8
Total	2,905	100%	1,776	100%

\*From Papaya Administrative Committee, projections are based on an 8-10% annual growth.



## Marketing Potential

The market potential of three papaya products, fresh papaya, papaya puree and dried papaya were analyzed. The major growth potential was seen in the Mainland U.S. market.

The primary demand trends for fresh, processed and dried fruit, as well as their existing and potential markets are illustrated in Table 4.6.

Note the per capita consumption of noncitrus fresh fruit and processed fruits in the U.S. has been increasing since 1975:

TABLE 4.6

<u>Year</u>	<u>Per Capita Pounds of Fresh Noncitrus</u>	<u>Per Capita Pounds of Canned &amp; Frozen Fruit Juices</u>	<u>Per Capita Pounds of Dried Fruit</u>
1960	57.5	24.2	3.1
1970	51.2	29.1	2.7
1973	47.3	32.4	2.6
1975	52.6	34.5	3.0
1976	55.2	34.6	2.6
1977	54.4	33.2	2.5
1978	55.3	34.9	2.0
1979	56.2	35.7	2.3

One significant marketing consideration is the new consciousness of nutrition. Papaya is considered an exceptionally healthful food. Seven ounces of papaya contain 3,500 units of Vitamin A, 112 mg. of Vitamin C, 468 mg. of potassium and a significant amount of calcium. All this nutrition is obtained with less than 80 calories.

The papaya industry in 1978 had its peak year with production over 83 million pounds. The breakdown is as follows:

approximately 5% unusable

54 million sold as fresh

9 million used in processing

15 million were left in the fields

The Papaya Administrative Committee projects the production and marketing prices of fresh papaya (that sold at the fresh produce section of a supermarket) as follows:

<u>Year</u>	<u>Total Fresh Production (in millions of pounds)</u>	<u>Farm Price (cents/pound)</u>
1978	54.6	14.4
1979	35.0*	27.0
1980	57.0	17.5
1981	65.0	19.0
1982	70.0	21.0
1983	75.0	23.0
1984	80.0	25.0

\*Setback in 1979 due to extreme temperature variations which enhanced disease.

Assumptions: Develop an integrated plant for fresh packing, puree processing and dry processing.

Fresh papaya sold to  
wholesaler or large  
retailer.

\$0.40 lb. FOB Hilo

Puree sold to food  
processors

\$0.28 lb. FOB Destination  
(This study assumes West Coast)

Dehydrated Snacks

\$4.00/lb. in bulk

BREAKEVEN ANALYSIS

Fresh Production: 13,000,000 lbs./yr.

Fixed assets

Building	\$ 800,000	
Equipment	1,900,000	
Other	<u>100,000</u>	
Total fixed assets	\$2,800,000	
Interest during construction (12%)	<u>336,000</u>	
		\$3,136,000
Amortization (30 yrs. @ 15%)		477,600
Variable Cost		<u>4,157,000</u>
Breakeven revenue required		\$4,634,600
Breakeven selling price required for a 15% ROI		\$0.36/lb.

Puree Production: 5,000,000 lbs./yr.

Fixed assets

Building	\$ 400,000	
Equipment	1,100,000	
Other	<u>75,000</u>	
Total fixed assets	\$1,575,000	
Interest during construction (12%)	<u>189,000</u>	
		\$1,764,000
Amortization (30 yrs. @ 15%)		268,657
Variable Cost		<u>1,106,000</u>
Breakeven revenue required		\$1,374,657
Breakeven selling price required		\$0.27/lb.

Dried Production: 880,000 lbs.

Fixed assets

Building	\$ 400,000
Equipment	1,500,000
Other	<u>110,000</u>

Total \$2,800,000

Interest during construction (12%) 241,200

\$2,968,000

Amortization (30 yrs. @ 15%) 342,858

Variable Cost 1,013,000

Breakeven revenue required \$1,355,858

Breakeven selling price required \$1.54/lb.

Energy Cost Analysis:

Puree plant requirements: 1,250 MBTU/yr.

Fresh plant requirements: 2,000 MBTU/yr.

Dehydration plant requirements: 3,520 MBTU/yr.

	<u>Geothermal</u>	<u>Fossil</u>	<u>Geothermal Savings</u>
Cost/MBTU	\$2.67	\$ 7.46	\$ 4.79
Puree: 1,250 MBTU	\$3,337	\$ 9,325	\$ 5,988
Fresh: 2,000 MBTU	\$5,340	\$14,920	\$ 9,580
Dehydrated: 3,520 MBTU	\$ 9,398	\$26,259	\$16,861

Summary

The papaya industry has ample room for growth, however, additional research is required to identify the various market demands on the Mainland U.S. for both the fresh and puree.

Conclusion

Availability of resources: Assured

Market potential: Good

Economic viability: Competitive

## LEUCAENA PROTEIN RECOVERY ANALYSIS

This industry would focus on recovering the leaf-protein concentrate (LPC) from leaves of the Hawaiian type leucaena using geothermal heat as a primary energy source. The process to be used, known as Pro-Xan, has been successfully used for two years in an alfalfa plant in Colorado.

### Description of the Pro-Xan Process

The Pro-Xan process starts with fresh green leaf (green-chop) being fed into a machine which grinds or macerates it. Next, the ground green leaf material is pressed to separate a protein-rich green juice from partially dewatered presscake. The Pro-Xan is extracted from this green juice by subsequent processing steps. To reduce the fiber content of Pro-Xan a defibering screen removes fibers suspended in the green juice. The green juice is then heated by direct steam injection from 80° to 95°C to precipitate most of the protein.

The heat-precipitated protein forms distinct curds which are separated from the green leaf solubles by centrifugation, then granulated or extruded and dried in a hot-air drying system. The resulting product is called Pro-Xan or leaf protein concentrate. Other products from the process are the presscake fraction, containing most of the fiber, and the green leaf solubles.

### Model 40-ton Per Hour Pro-Xan Plant

The U.S. Department of Agriculture Western Regional Research Center (WRRC) at Albany, California, has recently (January 1980) published estimates for a Pro-Xan plant designed to operate on a 40 tons per hour of

chopped alfalfa. A plant designed to use chopped leucaena would be similar in all respects. The following data are from the WRRRC publication, and are based on a Pro-Xan yield of 15%.

Material Balance

<u>Item</u>	<u>Pounds Per Hour</u>
green-chop input	80,000
green juice	121,600
wet presscake	35,200
heating steam used	8,433
wet Pro-Xan cake	6,600
dilute alfalfa solubles to evaporator	46,633
concentrated alfalfa solubles	5,812
alfalfa solubles (dry basis)	2,992
water evaporated from dilute solubles	40,821
presscake dryer input	41,012
water evaporated from presscake in dryer	24,012
water evaporated from presscake in grinder	739
water evaporated from Pro-Xan	3,667
Pro-Xan (10% water)	2,933
Dehy presscake (8% water)	16,261

Energy Requirements

Utilities required by the processing plant include electricity, natural gas, and water. An operating electrical load of 80% of total connected horsepower was assumed except for power required to run the green-chop grinder and the screw presses. The energy requirement for the grinder was

assumed to be 7.46 kilowatt hours per ton of green-chop and 5.97 kilowatt hours per ton of the double pressing operation. Electric motor efficiency was assumed to be 88%. Total electricity consumption for the model plant while operating for a 130 day season was estimated to be 5,857,280 kwh whether recovering 12, 15, or 18% Pro-Xan.

Natural gas was regarded as the fuel source for the boiler, presscake dryer and the Pro-Xan dryer. High temperature rotary dryers with an exhaust recycling system were used to dry the presscake in the Pro-Xan products. The exhaust gas recycle system in the presscake dryer is capable of recycling 50 to 75% of the normal exhaust gases. Such recycling raises the wet bulb temperature of the final dryer exhaust gases to approximately 180°F. These exhaust gases provide the primary heat source for the waste heat vacuum evaporator. For each pound of water evaporated from the presscake by the presscake dryer, 1.7 pounds of water are evaporated from the dilute alfalfa solubles in the evaporator. The energy requirement for dehydrating presscake with concentrated solubles added was assumed to be 1,500 BTU's per pound of water evaporated. Energy consumption by the Pro-Xan dryer was set at 1,600 BTU's per pound of water evaporated.

Steam is required for juice heating, pelleting and for the vacuum steam ejector system on the waste heat evaporator. The boiler, equipped with an economizer, was assumed to have an efficiency of 86%.

Total annual gas consumption for the model plant when yielding 15% Pro-Xan was 156,776,380 cubic feet. An alfalfa dehydration plant of the same capacity operating from the same number of hours per year would consume about 277,820,100 cubic feet of gas annually. Thus, for a Pro-Xan plant yielding 15% Pro-Xan gas reduction would be 44% over that for dehydration of chopped alfalfa.



Although the WRRC model plant was based on a 130-day season, which is typical of the mid-western United States, the Hawaiian plant would operate year round, providing considerably improved economics. As an example of this, WRRC computed that the annual rate of return on investment could be more than doubled if the season could be increased from 130 days to 230 days.

#### Leucaena Feedstock Description

Leucaena plants can be broadly classified into three types.

**Hawaiian Type:** Short, bushy varieties growing up to 15 feet in height that flower when very young. This type flowers year round rather than seasonally. Compared with the two types mentioned below, its yield of wood and foliage is low.

**The Salvador Type:** Tall, tree-like plants growing up to 65 feet in height with large leaves, pods, seeds and thick, branchless trunks. Originating from the inland forests of Central America, varieties of this type have been studied only in the last decade. This variety often produces more than twice the biomass of the Hawaiian type. Some extremely high-yielding Salvador type protovars are now being planted as sources of timber, wood products, and industrial fuel. They are known as "Hawaiian giants" or by the designations K-8, K-28, or K-67.

**The Peru Type:** Tall plants growing up to 45 feet, similar to Salvador type, but with extensive branching even low down on the trunk. They have a small trunk but extremely high quantities of foliage on their branches. Although these are highly productive forage varieties, they have only

recently been discovered, as their use outside Australia, Hawaii and Mexico still awaits testing.

The annual yield of dry matter is between 1 and 10 tons per acre. A small proportion of this is usually inedible woody stems. From the best foliage varieties on good sites, annual yields of edible dry matter (leaves and fine stems) are 6 to 10 tons per acre. Irrigation can increase this to higher levels. This is equivalent to the annual production of 800 to 4,300 pounds per acre of protein.

The leaf contains both nutrients and roughage essential for a complete ruminant feed comparable to alfalfa forage. Leucaena leaflets can readily be separated from the leaf stems providing a high-protein feed containing 27 to 34% protein. Because of the high protein content, leaflets are being sundried in Malawi, Thailand, and the Philippines for local use and exported to Japan and Singapore.

Leucaena's protein is of high nutritional quality. Amino acids are present in well-balanced proportions, similar to alfalfa. Leucaena can also be a rich source of carotene and vitamins.

#### Feedstock Availability\*

Leucaena is not grown in the Puna district at this time. However, there is approximately 2,000 acres of marginal sugar cane land that could be used. An additional 3,000 acres would be available elsewhere on the Big Island of Hawaii.

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\* In subsequent tests of samples of Hawaiian leucaena at the WRCC Laboratory, a serious gum problem was covered which eliminated further consideration of this process.

Lack of phosphate in the Puna district may be a limiting factor for plant growth. Correction of this deficiency may involve a major capital investment. For this reason as well as the possible need for drip irrigation, land development has been estimated to cost \$600.00/acre.

#### Market Potential

Protein from green leaves is marketable for animal feed and human consumption. The green liquid protein concentrate is sold primarily for animal feed at a cost of \$600.00/ton. Further processing produces a white product that is currently priced at \$1,500.00/ton. The presscake by-product selling price is \$188.00/ton.

PROTEIN RECOVERY

BREAKEVEN ANALYSIS

Assume: 35 tpd of protein concentrate operating 365 days per year and 20 hours per day.

Capital Costs

Land development for drip irrigation @ 600.00/acre for 5,000 acres	\$ 3,000,000
Extraction plant 5.0 million	<u>5,000,000</u>
Total investment	\$ 8,000,000
Interest during construction @ 12%	960,000
<u>Total Capital Cost</u>	<u>\$ 9,000,000</u>

Amortization of Capital Cost

15% @ 25 years	\$ 1,500,000
Total	<u>10,500,000</u>

Annual Variable Costs

Variable cost of production	3,100,000
Feedstock costs @ 12.50/ton	<u>3,600,000</u>
Subtotal	6,700,000
15% Contingency	1,005,000
Total Annual variable costs	<u>7,705,000</u>
Breakeven revenue required	\$ 18,205,000/year
Total Annual Production @ 8.8 tons/hr. = 64,240 tons	

Composite Breakeven price per ton = \$291.18

<u>8.8 tons/hr. Product</u>	<u>Breakeven Selling Price/ton</u>	<u>Current Market Price/ton</u>
.8 tons/hr. green LPC	—	\$ 600.00
.4 tons/hr. whets LPC	—	1,500.00
7.6 tons/hr. presscake	—	188.00
Composite	285.67	285.11

Current Market Value/8.8 tons product

Green LPC (0.8 tons) @ 600.00	= \$ 480.00
White LPC (0.4 tons) @ 1,500.00	= 600.00
Presscake - 7.6 tons @ 188.00	<u>1,429.00</u>
Total	\$2,509.00

Value/ton =  $2,509 \div 8.8 = 285.11$

CONCLUSION:

Availability of Resource: Unsuitable  
Market Potential: Good  
Economic Viability: Unsatisfactory

KONA COFFEE PROCESSING

Availability of Raw Material

The Kona Coffee Industry produced about 1.8 million pounds of parchment coffee in the 79-80 growing season. This is up 7% over the previous year despite a 5% decrease in harvested acreage. Several of the past years' production and price statistics are as follows:

Number of coffee farms, acres in coffee, acres harvested, yield, production, price, and value, 1973-80

Year	Farms	Acreage		Yield per harvested acre	Marketings (parchment)	Price per pound (parchment)	Value of sales
		In crop	Harvested				
	Number	Acres		1,000 pounds	Cents	1,000 dollars	
1973-74..	770	2,900	2,500	1.2	3,040	56.3	1,711
1974-75..	760	2,900	2,500	0.6	1,540	46.4	714
1975-76..	780	2,400	2,000	0.9	1,860	75.2	1,399
1976-77..	780	2,400	2,000	1.1	2,120	185.0	3,922
1977-78..	780	2,400	2,000	1.1	2,270	138.0	3,133
1978-79..	750	2,300	1,900	0.9	1,680	126.0	2,117
1979-80..	700	2,100	1,800	1.0	1,800	145.0	2,610

Source: Hawaii Department of Agriculture and U.S. Department of Agriculture; "Hawaii Coffee Annual Summary," January 24, 1980

Because coffee is a labor intensive crop and does not lend itself to mechanization, the Kona farms tend to be family oriented. Additionally, there seems to be a general lack of new farmers starting coffee production. Note that the number of farms has generally decreased since the early 1970's.

Energy Requirements

In general, soluble coffee is processed into regular powdered form or freeze dried forms. Regardless of the process, it takes approximately 2.5 lbs. of roasted green coffee to make 1 lb. of soluble coffee with 3% moisture. A typical process includes roasting, grinding, percolating,

drying and packaging. The spent coffee must be either dewatered and pressed for disposal or dewatered, pressed and subsequently burned in the boiler for heat recovery.

As mentioned above, for every pound of coffee solubles, there are 1.5 lbs. of dry spent coffee grounds. The spent coffee grounds, after accounting for associated moisture have about 7500 BTU of heat value per pound. If fuel oil costs \$30 per bbl (equate to 71¢/gal. or 8.9¢/lb.,) and provides 18,000 BTU heat per pound of oil, then the fuel cost associated with every pound of soluble coffee is about 5.6¢. Thus for a typical 3,000,000 lbs. per year plant, a saving of \$168,000 per year in fuel oil cost can be realized using spent coffee grounds as fuel.

The 3600 lbs./hr. of steam can be used as follows: 1150 lbs./hr. for heating percolation feed water, 400 lbs./hr. to dry spent coffee grounds, 50 lbs./hr. for the vacuum ejector, 1800 lbs./hr. for heating spray dryer air and 200 lbs./hr. for pre-heating boiler-feed water. However, there is still a need for roasting of the green coffee. Typically, the roasting temperature is approximately 540°F which is out of the reach of geothermal heat supply. Conventional gas or oil must be used to generate the heat.

Theoretically, it requires 900 BTU to reduce the moisture content in green coffee from 52% to 12% ready for shipping. Assuming 50% efficiency, it will take 1800 BTU per lb. of green coffee to dry. The drying temperature is typically 140°F which is ideally suited for geothermal application.

Assuming that coffee production on the Island of Hawaii is 1.8 M lbs. per year, the heat requirement for drying coffee is 3,240 MBTU/yr.

### Market Potential

Almost all of the coffee farmers belong to either the Kona Coffee Co-op (66%) or the Pacific Coffee Coop (33%). The Superior Coffee Company has contracts with both coops and buys the coffee for 20 cents/lb. over the Columbia Index on the world market. This year's crop was selling at \$2.30 - \$2.40 per pound for the top grade green bean. Eighty percent of the total Hawaii harvest is within this grade. The mild grade of bean receives \$1.80/lb.

The Kona Coffee Co-op believes that with certain changes a price of \$3.50/lb. could be obtained due to the high quality and limited supply of the Kona bean. It is interesting to note that some of the more exotic coffees, produced in countries where labor and production costs are much lower, receive over \$4.00/lb. in the green bean stage.

A local expert feels that the nature of the coffee crop and the costs of production here in the U.S. are such that little can be done to significantly alter the decline of the number of operating farms and harvested acreage.

### Feasibility Summary

In summary, the following conditions and trends exist:

1. The trend of Kona coffee production along with the number of farms and acreage under production is generally downward.
2. Superior Coffee seems to have a strong hold on the supply and market channels and already maintains a coffee processing plant in Hawaii.
3. Except perhaps in drying the green coffee, no particular advantage exists when using geothermal direct heat in the production process.



4. The quantity of green coffee produced each year in Hawaii is not quite sufficient to feed a plant of efficient size, (one able to process approximately 3,000,000 pounds of green coffee per year).

Although the Kona Coffee Co-op manager has valid marketing strategies for his Kona coffee producers, it will take a significant attitude change by farmers to want to expand production and look for more efficient production methods. Perhaps in future years, after the coffee producers gain greater control of their channels and can realize greater profits, existing and new farmers will be stimulated to expand production and market in a business-like manner. At this time, however, conditions are not appropriate to consider a coffee processing plant in the Pahoa Industrial Park.

BREAKEVEN ANALYSIS

Plant Capacity: 720,000 lbs./yr.  
Annual Input: 1,800,000 lbs./yr.

Total Assets: \$4,000,000  
Interest during construction (12%) \$ 480,000  
Total Initial Investment: \$4,480,000  
Capital Recovery (30 yrs. @ 15%): \$ 682,304  
Variable cost of production: \$4,600,000  
Breakeven revenue required: \$5,282,304  
Breakeven selling price: \$ 7.33

DIFFERENTIAL ANALYSIS

Heating Requirements: 3,240 MBTU/yr.

<u>Cost</u>	<u>Geothermal</u>	<u>Fossil Fuel</u>	<u>Geo-Saving</u>
Cost/MBTU	\$2.67	\$7.46	\$4.79
3,240 MBTU/yr.	\$8,650	\$24,170	\$15,520

Conclusion

Availability of Resources: downward trend  
Marketing Potential: assured  
Economic Viability: unproven

## LUMBER KIILN ANALYSIS

### Raw Material Availability

The volume of standing timber in Hawaii can sustain a somewhat larger cut than is being made. At present, the Island of Hawaii has 761 million board feet of timber, eleven inches or larger, suitable for commercial use. This volume is distributed fairly evenly on State lands and private lands. The availability of additional native ohia and koa is less certain. There is very little koa in accessible stands, either public or private. The existing stands are estimated to last ten years at present rates of logging.

The limited supply of koa can be attributed to three factors:

1. The location of recoverable koa timber on agriculturally zoned land.
2. The low yield of koa due to its slow rate of growth ( $1/2$ " dia. per year).
3. Former koa forest land is converted to grazing land after harvest with no reforestation program. At present, forestation programs are not being sustained at levels necessary to significantly improve the timber resource base.

### Market Potential

Market development is critically dependent on product quality and the product characteristics in terms of usefulness for the purpose at hand. The small local sawmills have experienced considerable difficulty in maintaining product quality. Negative market responses have occurred as a result of inadequate seasoning, improper or lack of grading, uneven cutting of boards and milled stock, lack of culling of defective materials and other processing faults.

Koa is well known and used for a variety of purposes, such as furniture production and decorative paneling. Locally, the wood is well known for its good quality and is considered quite exotic.

Sales distribution of Hawaii koa lumber is as follows:

U.S. Mainland	65%
State of Hawaii	20%
Japan	15%

It usually takes about 5 years for koa to become acceptable to mainland standards for furniture making where it is presently sold as black walnut. This is because many of the wood or furniture manufacturers have limited knowledge of koa which generates apprehension in working with new woods. Manufacturers tend to only introduce new products during times of surplus.

There has been no major commitment by the dealers in support of processing and marketing local koa woods. Apparently, local forest products have offered minor incentives for exploitation in competition with or relative to imports. Imported softwood and hardwood products have long held established positions in the local markets for which local products might compete. Until recently, no major commitment had been made to develop and hold an export market.

#### Systems and Operation

Moore International, Inc. and Lumber Systems, Inc. were contacted for a detailed analysis of kiln capacity, energy requirements and capital cost assuming the kiln will receive koa with 30-35% moisture and reduce the moisture down to 8%.

The following summarizes information on a typical kiln:

1. Four to five days are required to dry 4 x 4 koa from 35% to 8%, and 9 to 12 days to dry 4 x 8 koa from 35% to 8%. It is possible to achieve the lower limits if the kiln has good air flow.
2. A single compartment holding 30,000 board feet of lumber should be adequate, assuming half of the lumber dried is 4 x 8.
3. Moore International recommends a track kiln. This is to load the kiln charge on rails and roll it into the compartment. The main advantage of this design is that it provides excellent air flow patterns. The 30,000 board-foot kiln building would be approximately 34' X 32' wide and roughly 20' high with 3 tracks. Each track supports a line of 4-foot packages of lumber.
4. Maximum dry bulb temperature is 200°F. Maximum steam use is about 1800 pounds per hour. This is equivalent to about 2 MBTU/hr.
5. The estimated capital cost can be summarized as follows:

Complete Kiln F.O.B. Portland	\$ 80,000
Freight to Hilo	10,000
Site Prep and Foundation	<u>110,000</u>
Total	\$200,000

#### Transportation Costs

The estimated transportation cost to the industrial park at Pahoia from Hilo is as follows:

A typical 40-foot trailer can transport 10,000 board feet

3 hours for delivering the green lumber to Pahoia

3 hours for delivering the dried lumber to Hilo

6 hours total @ \$40/hr.: \$24/1,000 board-feet.

BREAKEVEN ANALYSIS

Assume: 1.5 Million board feet output annually.

Total Assets: \$500,000

Interest (1 yr. @ 12% for half of total assets) 30,000

Total Initial Investment \$530,000

Amortization (15%, 10 years) \$100,000

Variable Costs: 75,000

Transportation Costs: 36,000

Breakeven Revenue required to attain a 15% ROI \$211,000

Breakeven selling Price Required \$ .141 per sq. ft.

Average price per board foot (based upon Honolulu prices) 8.5¢

Variable Costs (per board foot):

Energy for heat (based upon Moore Int'l Kiln specifications and direct energy costs of \$3 mbtu/hr.) 2.2¢

Other production costs (based upon operators at 1.8¢ and other expenses at 1.0¢ per board foot) 2.8¢

Transportation (Hilo-Pahoa-Hilo) 2.4¢

Total Variable Cost 7.4¢

Initial Investment:

Kiln and Set-Up \$200,000

Building and other fixed and current assets 300,000

Total Investment \$500,000

Amortization of the initial investment at  
15% (including a 15% return on equity):

Years	
20	\$ 80,000
15	86,000
10	100,000

Since there is some doubt whether enough koa timber exists to supply Campbell-Burns for more than ten years, annual fixed cost is assumed to be \$100,000. The kiln will have little value after that 10-year period.

Approximate number of board feet needed to attain a 15% ROE =  $\frac{\$100,000}{.085 - .074} = 9,090,910$

Over 9 million board-feet of processing would be required if an independent business expected to attain a 15% ROI on the kiln operation. This is more than Campbell-Burns can ever expect to mill in one year. It is, therefore, considered an unprofitable venture as a single enterprise.

Stimulation of sustained commercial timber production in Hawaii will require two conditions: (1) Demonstration of willingness by the industry to pay prices for timber that will make it a profitable enterprise for the landowners and (2) Demonstration by landowners that an adequate supply of good quality timber can and will be grown on a sustained basis.

Although transportation costs and other difficulties would eliminate the possibility of locating a kiln in Pahoa, Campbell-Burns may consider locating such an operation at the present mill site. Further evaluation may determine whether such an investment will increase the market value of the product above the cost of drying. This strategy could also present potential transportation cost savings for the state-wide market.

Conclusion

Availability of resources:

Deficient

Marketing potential:

Unproven

Economic viability:

Uncompetitive



## CEMENT WALLBOARD PLANT ANALYSIS

### Introduction

The cement wallboard industry selected for analysis is known as Bison Board which consist of two basic building materials: wood and cement. The resultant product is a board that is both lightweight and sturdy. The product was first introduced in Germany and Switzerland where it was successfully used in construction. Due to its success in the European market, consideration was given to building a Hawaii based plant to meet current and future demands for construction materials.

Bison-Werkes Systems, a German-based firm, has manufactured cement wallboards for a number of years. Negotiations are underway to locate a manufacturing plant in the U.S., however, such a venture requires extensive analysis of marketing and construction trends as well as transportation cost. Transportation was one of the major reasons for shutting down the only manufacturing plant located in Atlanta, Georgia. The plant presently markets the machinery and equipment required for manufacturing the product but does not actually produce the wallboard.

Information was obtained from Bison-Werkes System to determine the economic viability of locating a geothermal cement wallboard manufacturing plant at the industrial park.

A 50 m<sup>2</sup> (1000 sheets 4' x 8', 5/8"/day) plant was conceived for the park. The requirements are as follows:

### Raw Materials

Cement (Portland-type cement): 730 kg per cu. meter (11,500 mt/yr)

Current price: \$88/ton

\*Wood: 270 kg bone dry/m<sup>3</sup> (4,200 mt/yr)

current price: \$30/ton

Chemicals: 1,500 kg/day

current price: 10% of cement

### Space and Building Requirements

Site: 25,000 square meters

Buildings: production area - 2000 m<sup>2</sup> per 8 m high

storage area - 1500 m<sup>2</sup> per 5 m high

chipper room - 100 m<sup>2</sup>

boiler house - 150 m<sup>2</sup>

### Energy Requirements

Electric consumption: 250 kwh/m<sup>3</sup> (3,500 mwh/yr.)

Heat consumption: 400,000 kcal/m<sup>3</sup> (6.5 billion Kcal/yr.)

Water consumption: 2,000 l/m<sup>3</sup> (27,000,000 liters/yr.)

### Annual Transportation Costs

Cement: (Honolulu - Pahoia) \$237,884

Wood (various local sugar mills) 25,494

Chemicals (Honolulu - Pahoia) 12,454

Cement boards (Pahoia - Honolulu) \$138,888

\$414,720

\* Wood chips or bagasse

### Availability of Resources

A cement wallboard plant requires several raw materials: wood chips, limestone, gypsum and silicon sand. The island of Hawaii being younger than both Molokai and Oahu, lacks limestone deposits which is the main ingredient (80%) found in cement. Therefore, all the cement would have to be imported from Honolulu due to the lack of a cement plant on the Island of Hawaii. However, the Island has an abundance of wood chips and bagasse with over 569,000 acres of commercial forest land and over 583,000 acres of non-commercial forest land. The various sugar mills combined have an annual output of bagasse in excess of hundreds of thousands of tons.

### Marketing Potential

At the present time, there is no direct marketing information on cement wallboards because it is relatively unknown to the local construction industry. However, if introduced, it is expected to directly compete with plywood which has an approximate current demand of approximately 560,000 sheets (4 ft. x 8 ft.).

BREAKEVEN ANALYSIS

Output: 1,000 sheets (4'x 8', 5/8") 50 m<sup>3</sup>/day

Total Assets	\$10,500,000
Interest during construction (12%)	<u>1,260,000</u>
Total capital cost	\$11,760,000

Amortization (25 yrs. @ 15%)	\$1,819,272
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Annual Variable Cost:

Operating & Maintenance	3,600,000
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Transportation	<u>415,175</u>
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Breakeven Revenue Required	\$5,834,447
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Breakeven selling price (based on a 300 days/years operation)	\$19.44/sheet or \$0.61/ft. <sup>2</sup>
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Hawaii selling price of plywood	\$18/sheet or \$0.58/ft. <sup>2</sup>
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Differential Cost Analysis

Heat Requirement: 6.5 billion Kcal/yr.

	<u>Geothermal</u>	<u>Fossil Fuel</u>	<u>Geo-Savings</u>
Cost/MBTU	\$2.67	\$7.46	\$4.79
6.5 billion Kcal/yr.	\$68,860	\$192,393	\$123,533

Summary of savings/loss for locating at Pahoa vs. Honolulu:

Energy:	\$123,533
Transportation:	(\$415,175)
Net Savings (Expense)	(\$291,642)

### Summary

The economic analysis indicates that the cost of transporting both the raw materials and the finished product between Pahoa and the market in Honolulu makes this process impractical for the industrial park at Pahoa.

Currently, the following trends and conditions exist:

1. All the cement and chemicals are shipped from Oahu.
2. Most of the finished product will have to be shipped back to Oahu.
3. There is no large market on the Island of Hawaii.
4. The product is virtually unknown in Hawaii.

### Conclusion

Availability of Resource:	Good
Marketing Potential:	Unknown
Economic Viability:	Non-competitive

Conditions are inappropriate for locating a cement wallboard plant in the industrial park.

## AQUACULTURE PRODUCTION ANALYSIS

### Introduction

Local leading experts in the field of aquaculture on Oahu were contacted, including Lowe, Inc., Nui Nui Farm, and Astro Farms.

Both tilapia and prawn (*M. Rosenbergii*) production were chosen as leading candidates for analysis because of current experiences of local firms. Vital information such as:

- yield per acre
- harvest per year
- optimum and critical temperatures
- environmental hazards
- growth patterns
- production cost
- marketing information and
- others

were obtained to determine the viability of locating an aquacultural farm at the industrial park. The analysis included an evaluation of:

- soil conditions at the site
- construction cost
- economic analysis
- marketing potential

### Soil Condition

The soil at the park site consists of clay loams which are widely used in sugar cultivation. Bedrock ranging from the surface to depths of approximately a foot are also found in the area.

Since the soil is too shallow to allow complete excavation of the ponds and excavation of the bedrock is extremely expensive, the berms would have to be built up from the surface of the soil to provide the required depth. It was assumed that some a'a lava material would be available elsewhere on the park grounds for the berm construction.

Construction Cost

A complex consisting of twenty half-acre ponds in a rectangular array, separated by 18 foot wide shoulders and capable of bearing vehicular traffic is examined. Each pond would measure five feet in depth with the water level at 4 feet. Information obtained from the local Marine Advisory Program suggests using a water flow between 15-25 gpm per acre.

The following costs were estimated for the 10-acre aqua-farm:

	<u>Geothermal (Hawaii)</u>	<u>Existing (Oahu)</u>
Clearing and grubbing	\$ 48,200	\$ 10,000
Pond excavation	250,000	50,000
Shoulder construction	165,000	20,000
Importation of shoulder material	158,750	-0-
*Pond lining materials	433,000	-0-
Fencing	<u>30,600</u>	<u>30,600</u>
Total	\$1,085,550	\$110,600

The construction cost per acre is \$108,585, much lower than the estimated cost of constructing comparable tanks as shown below:

\* Due to the high permeability of the soil, it is assumed that lining is required.

SUMMARY OF COSTS - ONE ACRE OF AQUACULTURE TANKS

Concrete Tanks (8 tanks, 55' x 100', water depth 3 feet)

Clearing and grubbing		\$ 5,650
Roadfill/foundation material		41,850
Tanks		121,080
Concrete	\$61,890	
Reinforcing rods	47,560	
Hollow tile	3,730	
Labor	<u>7,900</u>	
Fence		<u>10,420</u>
		\$179,000

Doughboy Tanks (130 tanks, 24' diameter, water depth 3 feet)

Clearing and grubbing		\$ 11,030
Roadfill/foundation material		81,680
Tanks		94,760
Materials	\$ 85,860	
Labor and transport	<u>8,900</u>	
Fence		<u>14,560</u>
		\$202,030

Corrugated Galvanized Metal Tanks (48 tanks, 40' diameter, water depth 3 feet)

Clearing and grubbing		\$ 9,560
Roadfill/foundation material		70,800
Tanks		166,750
Materials	\$159,750	
Labor and transport	<u>7,000</u>	
Fence		<u>13,620</u>
		\$260,730

Fiberglass Tanks (384 tanks, 12' diameter, water depth 4 feet)

Clearing and grubbing		\$ 9,870
Roadfill/foundation material		73,100
Tanks		629,760
Fence		<u>13,860</u>
		\$726,590



### BREAKEVEN ANALYSIS

Species:	Freshwater prawns (Macrobrachium Rosenbergii)
Yield:	0-4000 lbs./acre/yr.
Optimum Temperature:	77°F
Facility	20 half-acre ponds
Annual yield @ optimum condition	40,000 lbs.
Construction	\$1,186,000
Land purchase	120,000
Total capital cost	1,306,000
Interest (1 yr. @ 12% - 1/2 TA)	<u>78,360</u>
Total Investment	\$1,384,360
Amortization (30 yrs. 15%)	210,838
Variable Cost:	
Energy	200,000
Production	21,300
O/M	<u>45,000</u>
	\$ 244,300
Annual Revenue required to attain 15% ROI	477,138
Breakeven selling price	\$ 11.92/lb.
Current selling price	\$ 4.50/lb.
Breakeven selling price assuming no charge for energy	\$ 6.92/lb.

### BREAKEVEN ANALYSIS

Species: Tilapia (Sarotherodon)

Yield: 0-20,000 lbs./acre/yr.

Optimum temperature: 81°F

Facility 20 half-acre ponds

Annual yield @ optimum conditions 200,000 lbs.

Construction \$1,186,000

Land purchase (12,000/acre) 120,000

Total capital cost 1,306,000

Interest during construction (12%) 156,720

Total Investment \$1,462,720

Amortization (30 yrs. 15%) 210,838

#### Variable Cost:

Energy 200,000

Production 20,000

O/M 45,000

Total 265,000

Breakeven revenue required 475,838

Breakeven selling price \$ 2.37/lb.

Current price \$ 1.80/lb.

Breakeven selling price required with no charge for energy \$ 1.38/lb.

#### Summary:

Results from the economic analysis indicate a high differential price which is above and beyond what the market will bear. The extremely high breakeven price obtained is primarily due to the following reasons:

- High construction cost for earth work required in that area.
- Transportation cost incurred
- Cost of energy exceeds by far the potential yield or benefits derived from utilizing geothermal energy.
- High cost of land lease.

Unless the energy required can be obtained at an extremely low cost (negotiable, if the park cascades the energy, in which case, aquaculture would be the end user) and the construction costs are lower, aquaculture is not recommended as a viable industry for the park.

The aquaculture industry in Hawaii is comprised of both large and many small scale operations, the so called "back yard operations".

Although the demand is proven, aquaculture can be a very unprofitable and risky business. This holds especially true for the large farmers with a sizable investment where a disease or the unexpected could inflict heavy losses. This problem coupled with a high operation and maintenance cost makes aquaculture a very delicate business. However, a small backyard type operation will generally fare better due to low overhead and the amount of time dedicated to the business.

#### Conclusion

Availability of Resources: Assured

Market Potential: Sound for Prawns; doubtful for Tilapia

Economic Viability: Uncompetitive

### Summary of Potential Industry's Economic Analysis

The analysis of all potential industries indicate that although many of the industries appear attractive, only the ethanol plant, and the papaya processing plant were sufficiently competitive to warrant further analysis. In addition, although the cattle feed mill was judged to be only marginal in economic viability, further analysis was recommended because of the large amount of locally available raw material considered to be a waste or by product in the sugar industry. A summary of the conclusions is shown in Table 4.7.

<u>Potential Market</u>	<u>Annual Net Savings by Locating in Commercial Park</u>	<u>Availability of Resources</u>	<u>Market Potential</u>	<u>Economic Viability</u>	<u>Breakeven Selling Price</u>	<u>Comments</u>
Ethanol	1,142,043	assured	high	competitive	\$1.06/gallon	Appears attractive with good market potential for commercial park primary/anchor industry.
Cattle Feed Mill	714,638	assume available	good in Japan	marginal	\$122.50/ton	Although marginal, believe to have sufficient potential to evaluate and analyze further.
Papaya	27,958	assured	relative	competitive	36¢/lb. fresh 27¢/lb. puree \$1.75/lb. dried	Because there is room for growth in the industry and market indicators are positive, process is selected.
Leucaena Protein Recovery	N/A	very doubtful	very good	marginal	\$285.67/ton	Although economically marginal, the process is marginally attractive, the feedstock availability in the Puna District is very doubtful, therefore not recommended.
Kona Coffee Processing	8,846	downward trend	assured	unproven	\$7.33/lb.	Because of downward trend of resource availability and high selling price required, process not selected.
Lumber Kiln	15,520	deficient	unproven	uncompetitive	\$.14/sq. ft.	Over 9 million board feet of processed lumber needed to attain 15% ROI on kiln operation. This exceeds koa lumber supply.
Cement Wallboard	123,533	assured	unproven	marginal	\$.78/sq. ft.	This process is proven, however, cement wallboards are relatively unknown in the U.S., specifically the construction industry.
Aquaculture	N/A	assured	good for prawns doubtful for tilapia	uncompetitive	\$11.91/lb. prawns \$1.95/lb. tilapia	Process not competitive because of high production costs; not selected.
Research Laboratory						Not intended to be an economically productive entity.

Summary of Initial Economic Viability

Table 4.7

## CHAPTER 5

### CONCEPT OF THE COMMERCIAL PARK

#### Introduction

After identifying those industries that are economically viable in an industrial park near Pahoa, it is possible to deduce how the park might appear. This chapter is a description of that concept of the industrial park. The concept as described here was the basis for discussion between public officials, concerned citizens, potential investors, environmental and sociological experts and other interested parties.

The site just outside of the Kilauea Volcano east rift zone was selected to demonstrate the feasibility of such an industrial park site using direct geothermal heat in industrial processes. Amfac, Inc., the landowner, authorized the use of this site "for study and analysis purposes only"; no other authorization was implied. From the analysis, extensive information was developed that could be used by developers to plan, build and operate such an industrial park or parks at several locations near Pahoa.

#### Park Concept

The conceptualized industrial park would initially consist of:

- An ethanol plant capable of producing 20,000 gpd of fuel grade ethanol and other energy products including 10 MW of electric power. The principal feedstock requirements are 280 tpd of bagasse and 340 tpd of wood at 50% moisture content.
- A feed mill capable of producing 240 tpd of a roughage component for cattle feed using 600 tpd sugar cane leafy trash at 70% moisture.

- A papaya processing facility capable of processing:
  - 13,000,000 lbs./year fresh fruit
  - 5,000,000 lbs./year puree
  - 880,000 lbs./year dehydrated snacks.
- A research laboratory that would assist with the development of other industries including some of the other processes evaluated in the study.

The park would contain several contiguous industrial plots at approximately 6 acres each. If feasible, the process steam could be cascaded or reused. However, this concept will have to evolve; at this time, it does not appear feasible to attempt to market a site for a process that would be dependent upon steam cascaded or made available from another process that might not survive.

An artist's conception of the park is shown in Figure 5.1.

As illustrated, the proposed park would be eventually surrounded by a silvi-culture energy tree farm development that would provide feedstock for the proposed ethanol plant. In addition, the energy tree farm would provide separation between the industrial sites and residential areas.

Two geothermal resource scenarios were evaluated in Chapter 2; one with a 25 MW electric power generating plant and one with only the direct heat applications. However, the final concept of the park does not include a separate 25 MWe power plant because the purpose of the study focuses on direct heat applications.

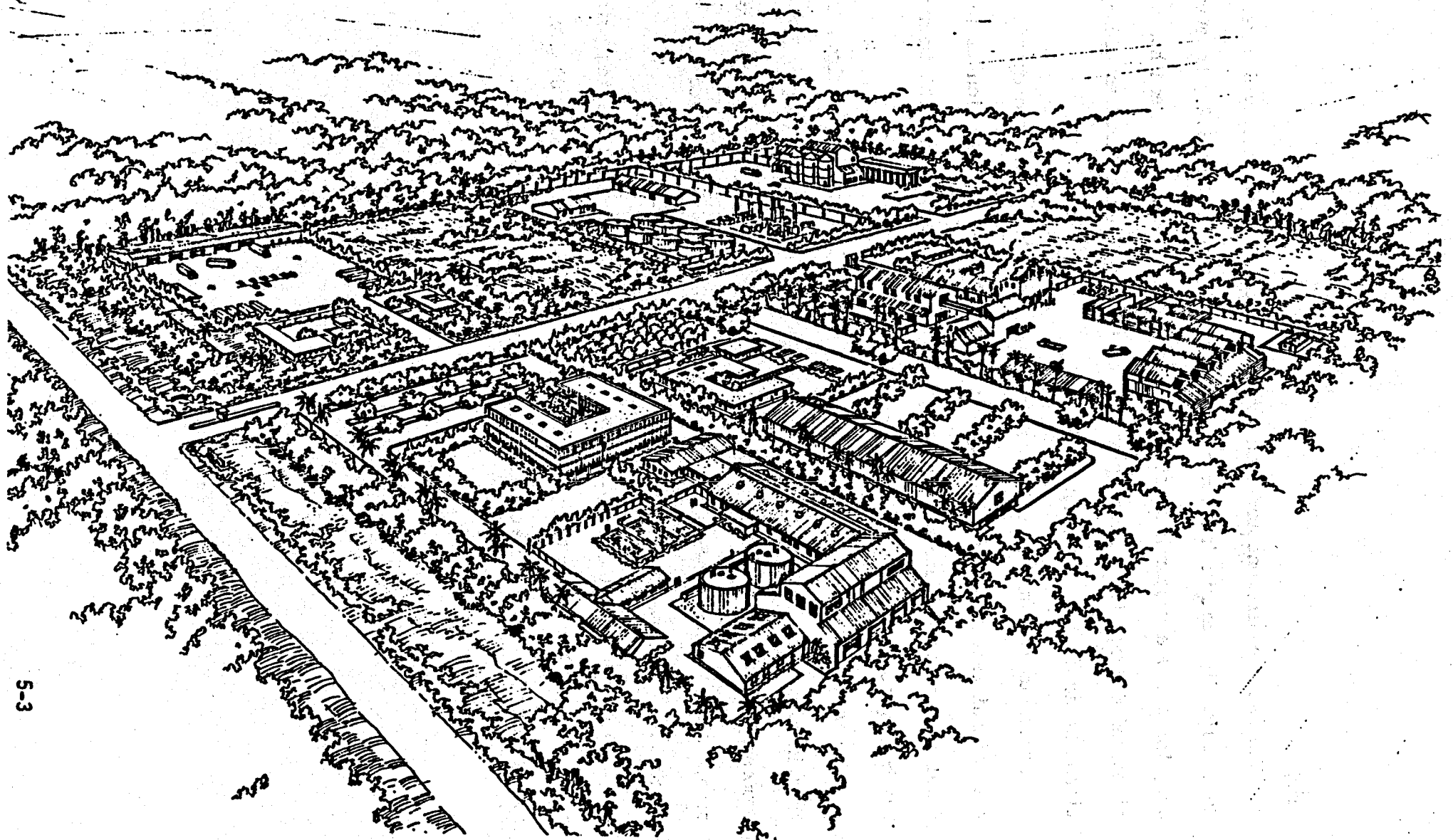


Figure 5.1 Artists's conception of the industrial park



## Land

The land requirement for each industry totals approximately 6 acres. Initially, five to six industries were planned (see Figure 5.2), however, only three and a research laboratory were finally selected. Each has been allocated 6 acres for a total planned acreage of 24 acres with an additional 24 acres for expansion.

Access to the initial site was from the Pahoa-Kalapana road opposite the Leilani Estates residential subdivision. A bypass road which is in the final design stages pending community acceptance and governmental funding has been proposed to divert heavy traffic around Pahoa Town.

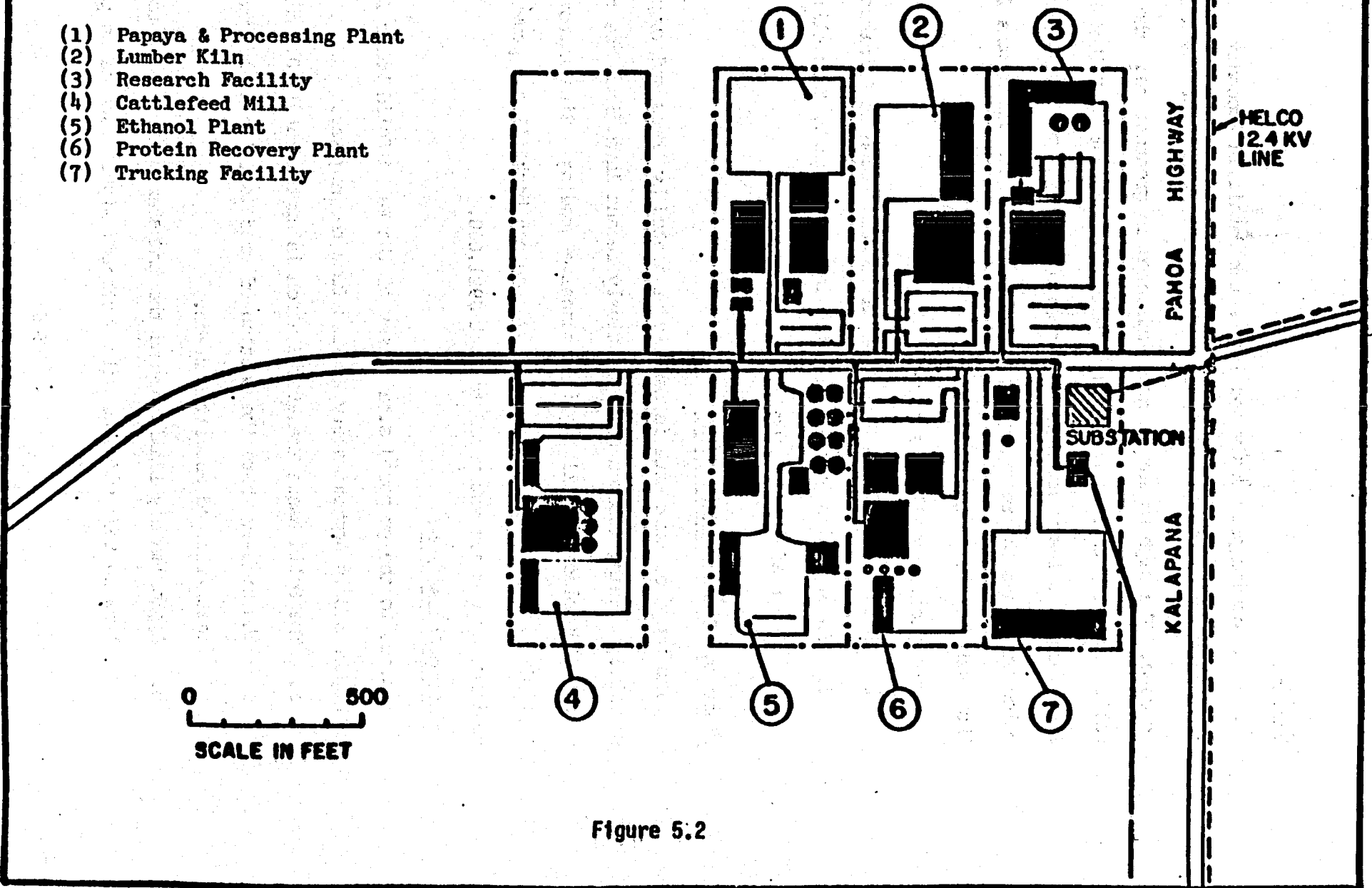
Due to the strong opposition at early public information meetings to this initial site and the corresponding heavy truck traffic implied, the proposed site was shifted approximately 3 miles due north of the original site. Access to this new site would be via the Pahoa Solid Waste Road which would minimize the impact of traffic and noise.

Land costs for study purposes were based on the current selling price of unimproved land near the proposed park site. A cost of \$12,000 per acre for fee simple agricultural land was estimated.

# PAHOA GEOTHERMAL INDUSTRIAL PARK

## INTERIM CONCEPT

- (1) Papaya & Processing Plant
- (2) Lumber Kiln
- (3) Research Facility
- (4) Cattlefeed Mill
- (5) Ethanol Plant
- (6) Protein Recovery Plant
- (7) Trucking Facility



S-5

Figure 5.2

## Geology

As discussed previously and in greater detail in Appendix A, a substantial geothermal potential exists in the east rift zone of the Kilauea Volcano. The high potential zone indicated is greatest near the HGP-A well. However, this is believed to exist as far west as Heiheiahulu which lies about 2 miles west of the proposed well site. This zone is about 2 miles wide, and the resources are likely to be found at depths 2 to 3 thousand feet below sea level.

The specific drilling site was selected at:

1. A location within a geothermal anomaly known as Opihikao.
2. An elevation greater than the industrial park, thus eliminating the need for pumping.

## Clearing, Grading and Fencing

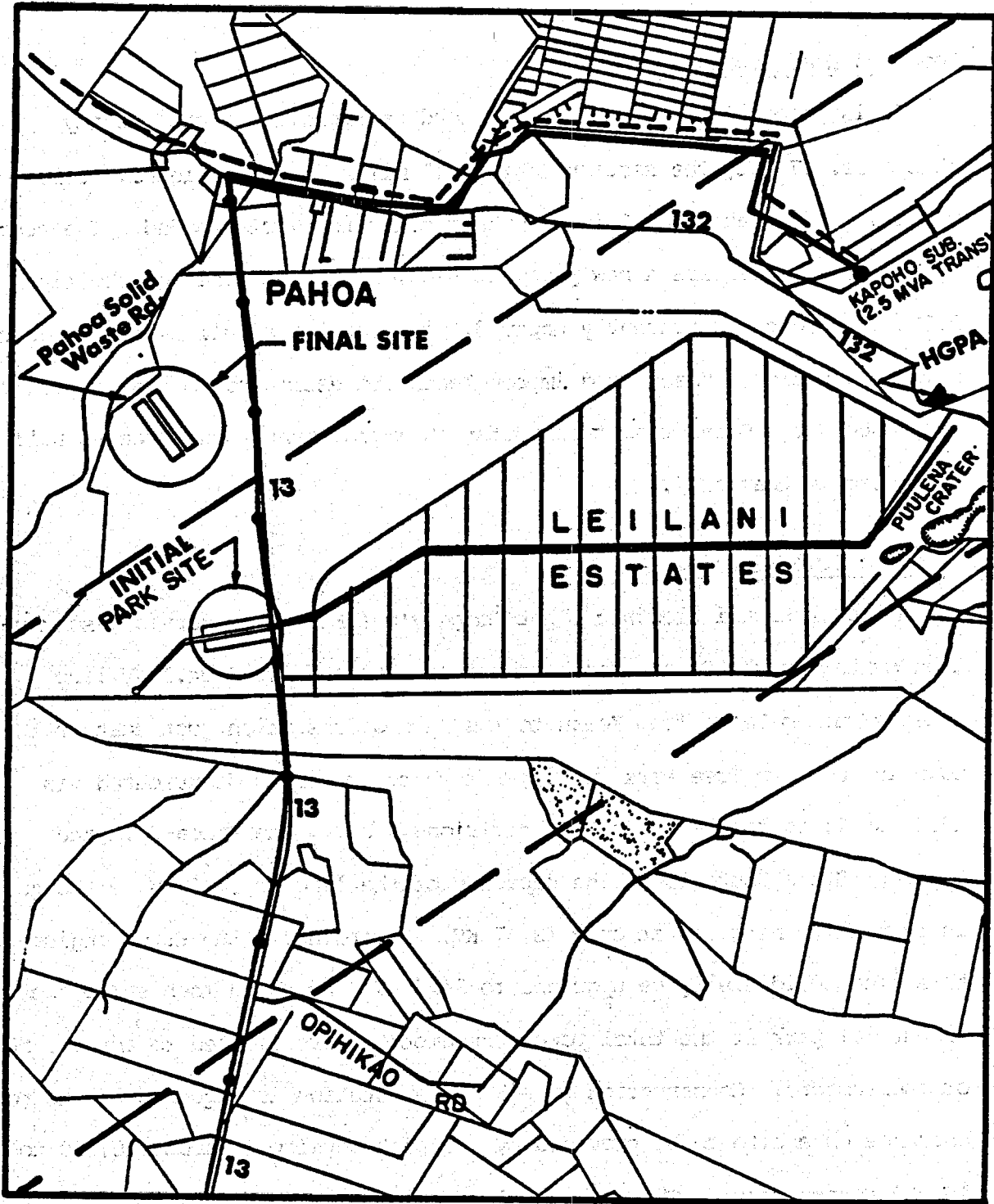
The proposed park site is densely vegetated by trees and tropical shrubbery. Being located on a relatively recent lava flow, the terrain is somewhat jumbled and will require extensive grading. Site improvements including clearing and grading, excavation and backfill and providing for a drainage system are estimated to cost \$921,000.

## Existing Access Road

Access to the proposed site by way of the Pahoa Solid Waste Road shown on Figure 5.3 is approximately 2 miles from the highway.

- a. The Solid Waste Transfer Station is approximately 0.7 miles from the highway where the section of road is 2 lanes, approximately 20 feet wide and asphalt surface.
- b. Approximately 1 mile beyond the transfer station, the road is one lane 10 feet wide, asphalt surfaced; sight distance is poor.

# HELCO ELECTRIC DISTRIBUTION IN THE PAHOA AREA



- 34.5 KV
- 12.47 KV
- 34.5 KV (ENERGIZED AT 12 KV)
- ==== EAST RIFT ZONE

Figure 5.3

- c. The remaining distance to the site is a gravel cane haul road approximately 10 feet wide.

#### Required Road Improvements

It is proposed that the existing road be improved to meet County standards. First, the section of road .7 miles from the highway would be widened to 24 feet and a 2 inch asphalt-concrete overlay added. The next 1.0 miles will require a new pavement section 14 feet wide and the final 2,500 feet which is presently unpaved, will require a full 24 feet wide new pavement section. These road improvements are estimated to cost approximately \$900,000. Other road transportation improvements and concerns will be addressed in Chapter 7.

#### Electric Power Service

A map of Hawaii Electric Light Company's (HELCO's) electric distribution system in the Pahoa area is shown in Figure 5.3. A 34.5 KV line extends out to Pahoa from Keaau to the Kapoho Substation just east of the town in the Lava Tree Park area. From there, power is distributed via 12.47 KV lines to the various subdivisions. Along the Pahoa-Kalapana Highway (State Route 130), the capacity of the line is 34.5 KV, although it is currently energized at only 12.47 KV. According to the HELCO engineers, this line could easily be upgraded to 34.5 KV, and could then serve the industrial park if the total power consumption were limited to about 5 MW or thereabouts. Construction of a 5 MVA substation is required at the park entrance on a site to be provided by the park developer (about 10,000 to 15,000 square feet). The park developer would presumably pay for the substation but probably not for the upgrading work along the Pahoa-Kalapana Highway.

The situation is different when it is anticipated that the ethanol plant would be sized such that it would be capable of generating 10 MW of power in excess of the power that would be consumed by the other industries in the park. However, the substation would have to be sized for the worst case, which is when the full output of the ethanol steam plant is exported to the grid. In this case, the power requirements of the entire Puna District would be exceeded (if Puna Sugar Company is excluded), and there would be a net export of power to Keaau and Hilo. One additional factor to be considered is the proposed arrangement to be negotiated by the ethanol plant developer with the Puna Sugar Company to provide power in return for the bagasse provided as feedstock for the ethanol plant. HELCO is presently unable to determine how this would affect the Pahoia area system until a more detailed load study could be made. The possibility of upgrading the 34.5 KV transmission line running between Keaau and Pahoia to 69 KV was suggested. In this case, the question of who would pay for the 69 KV is a complicated one which will depend on whether the action would primarily benefit the park or improvements in the overall quality of service would be realized for all users in the area. A recent case was cited concerning the Honokaa Sugar Mill, in which a power-supply contract was negotiated; in that case, Honokaa assumed the costs of transmission line upgrading.

Another important issue is the price which HELCO would pay for any power exported to the grid by the industrial park. This would depend primarily on whether the power is to be supplied on a firm capacity, firm energy, standby, or dump basis. Past experience with power-supply contracts negotiated between HELCO and the sugar companies indicates that

the firm supply prices are significantly higher than standby or dump. The price would have to be less than the utility's oil-fired electricity (from HELCO's viewpoint). The Public Utilities Commission, under the recent PURPA and State rulings, would ultimately determine the fair rate to be charged. At this time, it is estimated for study purposes that power would be priced at 60 mills.

Power distribution within the industrial park would be via a 12.47 KV transmission line extending from the substation at the park entrance to the water well (a distance of about 4,000 feet).

Estimated costs are as follows:

10 MVA substation - \$750,000

Park transmission line - \$40,000.

Cost of upgrading portions of HELCO's network, if required, and whether the costs are to be borne by the park developer, is not known at this time.

#### Water Supply

The water requirements for the park were estimated at 250,000 gpd.

The primary water supply in the Pahoa area is the Pahoa Deep Wells, located south of Pahoa along the Pahoa-Kalapana Highway. There are currently two wells pumping water at 600 gpm into a 300,000-gallon reservoir located about a mile south of the town at an elevation of 827 feet. A third well is currently being developed on the northwest side of the town, which will ultimately feed an additional 700 gpm to the reservoir. The safe capacity of the system would be based on the oldest pump (350 gpm) being out of commission. County water rates for the area are currently 65 cents per 1000 gallons. The new 700 gpm well is being developed to serve the anticipated future needs of the State agricultural park expansion

(Phase II and subsequent expansions), as well as the subdivisions in the area which are now on catchment systems. The Department of Water Supply has future plans to connect the Pahoa and Ola'a water systems, however, authorization is pending. Pahoa uses an average of 200,000 gallons per day (140 gpm) with maximum demand at approximately 300 to 400 thousand gallons per day (200-300 gpm). The industrial park at 250,000 gallons per day (175 gpm) would more than double the present water demand of the town.

Three alternative plans for an industrial park water supply were prepared. These plans and their respective estimated costs are summarized in Table 5.1. Alternative III, a private system was selected; the location is shown on Figure 2.1. The cost/1000 gallons for the water provided by this system is developed below:

Cost of water facilities: \$943,000

Amortized cost: assume 20-year life, 12% cost of money, capital recovery factor CRF (20;12%) = \$0.134

$$0.134 \times \$943,000 = \$126,362$$

O & M costs, at 2% of project cost:

$$0.02 \times \$943,000 = \underline{\$18,860}$$

Total annual costs \$145,222

System design average water supply: 250,000 gpd

Annual water supply = 250,000 x 365 days = 91,250,000 gallons

$$\text{Cost per gallon} = \frac{\$145,222}{91,250,000}$$

$$= \$0.00159 \text{ per gallon}$$

Cost per 1000 gallons = 1000 x \$0.00159 = \$1.59/1000 gallons



Table 5.1 - Industrial Park Water Supply Alternatives

Alternative I: Utilize Department of Water Supply System (DWS)

- a. Increase pumping capacity of DWS wells by replacing the older 350 gpm pump with a 650+ gpm pump.
- b. Add a booster pump at the existing 300,000 gallon tank to pump water to the industrial park site.
- c. Construct a 500,000 gallon reservoir.
- d. Install a 6" diameter pipeline to the new reservoir.
- e. Install a 12" and 8" diameter transmission line for park water distribution.
- f. Install 6 fire hydrants along the park access road @ 300' separation.

Estimated Cost: \$1,162,000

Alternative II: Private System

- a. Construct new well south of the DWS wells at the 740' elevation.
- b. Construct a 500,000 gallon reservoir.
- c. Install a 6" diameter pipeline to the new reservoir.
- d. Install a 12" and 8" diameter transmission line for park water distribution.
- e. Install 6 fire hydrants along the park access road @ 300' separation.

Estimated Cost: \$1,199,000

Alternative III: Private System

- a. Construct a new well at 1,100' elevation.
- b. Construct 500,000 gallon reservoir adjacent to the well.
- c. Install a 12" and 8" diameter transmission line for park water distribution.
- d. Install 6 fire hydrants along the park access road @ 300' separation.

Estimated Cost: \$943,000

Recommended Plant: Alternative III

### Wastewater Disposal

At this time, the exact nature of the waste streams from each of the proposed industries is unknown. Therefore, the developer will be required to provide for specialized chemical waste treatments of all toxic wastes. For sewage, and innocuous industrial water waste, simple cesspools, or shallow (20 feet or so) injection wells for each industry is recommended. The anticipated 125,000 gallons per day of waste water from the ethanol plant, for instance, amounts to less than 90 gpm. Cesspools are a common practice in the area and on the Island in general because of the high permeability of the soil.

The estimated cost to each industry for a cesspool or shallow injection well is about \$10,000.

### Cascading of Geothermal Heat

The idealized concept for an industrial park is to have several processes arranged to use the heat in sequence. Those processes or portions of processes requiring a higher temperature would use the heat first and the steam or hot water from the process output would be used again in another process having a lower temperature requirement. As mentioned previously, this concept will have to evolve because it is unlikely an investor would depend on a heat supply provided by another industry at a favorable rate only to find someday the other industry is no longer viable or unable to provide the heat.

A conceptual cascading flow diagram is shown on Figure 5.4. Papaya is the burdened process because its heating requirements are less than the other two industries. A varying amount would be required by the research laboratory.

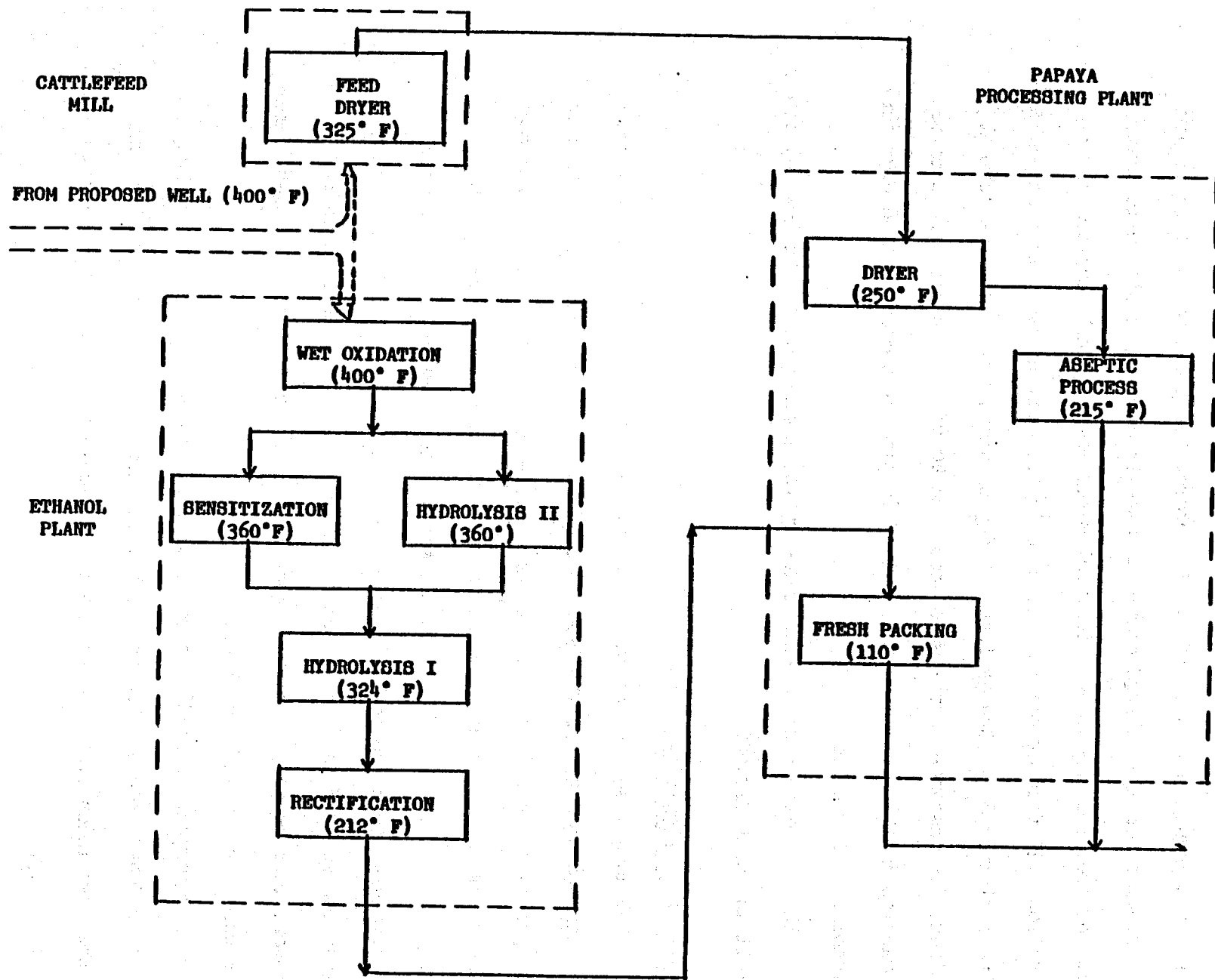


Figure 5.4 Conceptual Cascading Flow Diagram

### Summary

The concept of the industrial park has been described for study purposes. It has been sited on a 50 acre plot within an 800 acre area of land authorized by Amfac, Inc. Utilities, access and improvements have been evaluated. A nearby potential geothermal resource is considered available and hazards from earthquakes and lava flow have been addressed. The proposed park site was relocated in response to objections from residents of the nearby Leilani Estates and to minimize objections to traffic congestion and trucking noises. The new site is also outside the rift zone.

## CHAPTER 6

### ENGINEERING EVALUATION & ECONOMIC ANALYSIS

#### Introduction

Only three processes survived the initial test of economic viability.

They are:

- an ethanol plant
- a cattle feed mill.
- a papaya processing facility.

All other processes were discarded from further analysis as a result of one or more of the following reasons; the availability of raw materials, the prospective market potential and the overall economic viability of the industry. In this chapter, a detailed engineering evaluation and a thorough economic analysis for each of the three processes are described in separate sections.

## PART A: ETHANOL PLANT

### Introduction

The ethanol production plant analyzed in this study is based on the University of California Forest Products Laboratory (UCFPL) proprietary process which uses lignocellulosic feedstocks. The proponents of this process claims the following advantages:

- Utilizes the world's most abundant biomass material, lignocellulose, the vegetative part of plants, as feedstock.
- Includes a highly exothermic process that obviates the need for fossil fuel.
- Feedstock is taken to extinction with no waste materials produced.
- All products of the process are useful energy sources.
- The process is environmentally benign.
- Approximately 80 percent of the energy contained in the feedstock is recovered as energy products.

The UCFPL process concept includes a highly exothermic wet oxidation stage, an endothermic fermentation stage and several distillation stages. Although this process to date has not been fully demonstrated in a commercial plant, the process components are in commercial use and believed to be compatible.

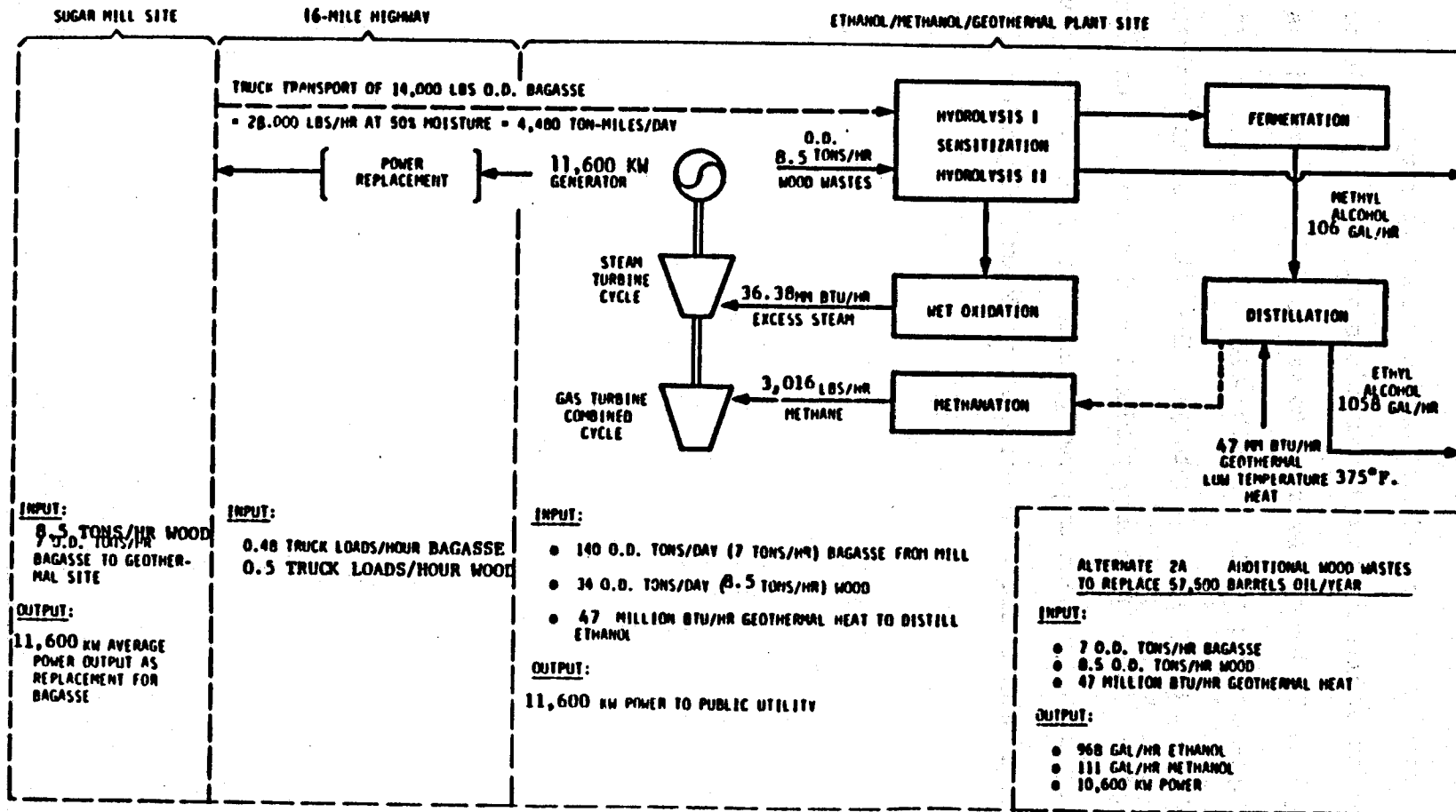
### GENERAL PROCESS DESCRIPTION

The UCFPL process is designed to accept lignocellulosic feedstock along with other feedstock comprising of starches, sugars or combinations of these biomass materials. The feedstock is subjected to dilute acid hydrolysis to convert the cellulose and the hemicellulose material to sugars.

The sugar solution, after certain purification steps, is then fermented with yeast, using conventional equipment and techniques. The resultant beer is distilled to produce ethanol of the desired purity.

Lignin residue from the acid hydrolysis stage, comprising 20 to 30% of the dry weight of feedstock, is taken to wet oxidation, where it is oxidized to produce organic acids and methanol. The organic acids can then be methanated to convert them to methane. The wet oxidation process is highly exothermic. Thermal energy produced at this stage is used to generate steam to supply heat to other process stages and the surplus is used to generate electricity. The process is described graphically in Figure 6.1.

**OBJECTIVE** : TRANSPORT BAGASSE FEEDSTOCK TO ETHANOL/GEOTHERMAL SITE; ADD WOOD FEEDSTOCK; GENERATE MAXIMUM ELECTRIC POWER TO REPLACE FUEL LOST AS BAGASSE FROM MILL; MARKET ETHANOL AND METHANOL.



6-4

Figure 6.1 Ethanol Process Flow Chart



## Converting Lignocellulose to Sugar

Bagasse is similar to other lignocellulosic materials and composed mostly of polysaccharides comprised of linear chains of certain monosaccharides. The monosaccharides include both hexose and pentose that can be fermented to alcohol.

The bonds that link monosaccharides into linear chains found in lignocellulosic material are called beta-glycosidic linkages. In starches found in such products as corn or wheat, the monosaccharides are bonded by alpha-glycosidic linkages. Both types of linkages are formed in the plant during biosynthesis by the elimination of a molecule of water for each bond that is formed. In order to convert the polysaccharides to monosaccharides, which are soluble in water, a molecule of water must be added back to each glycosidic bond that has been formed. To accomplish this with either the polysaccharides in bagasse, or starches in products such as corn, a catalytic reaction known as hydrolysis is used.

Hydrolysis requires a catalyst that can be either an enzyme or a hydrogen ion. Certain enzymes, for instance those found in certain grains, are specific for the hydrolysis of alpha-glycosidic linkages of starches that are typical of grains. Similarly, other enzymes, e.g. those found in certain fungi, are specific for the hydrolysis of the beta-glycosidic linkages of polysaccharides found in lignocelluloses. On the other hand, the hydrogen ion is not specific and will catalyze the hydrolysis of both types of glycosidic linkages. For this reason, a hydrolytic system utilizing the hydrogen ion as catalyst is capable of hydrolyzing the polysaccharides of all feedstock materials; whereas, a system relying on enzymes can utilize only polysaccharides of feedstocks that are specifically cleared for the particular enzymatic system used.

Hydrolysis requires that the aqueous borne catalyst comes into intimate contact with the solid surface at the point of each linkage connecting monosaccharides in the linear chain. In the case of lignocellulosic material, this requires penetration of a highly complex laminated structure. The hydrogen ion is able to penetrate this structure due to its minute size. Enzymes, being large-protein molecules, cannot penetrate and reach all linkages without a pretreatment of the feedstock material. Enzymatic hydrolysis systems, typically require pre-treatment that usually removes a portion of the lignin and reduces particle size so that all linkages in the remaining polysaccharides are rendered available to the catalyst involved. Such pre-treatment stages can be expensive and heavily energy dependent. Enzymatic hydrolysis of unaltered lignocellulosic material, therefore, generally results in poor rates of hydrolysis and low sugar yields due to the inaccessibility to the enzyme of a majority of the bonds linking the monosaccharide units.

Various acids may be used to provide the hydrogen ions required to hydrolyze the monosaccharide bonds and provide sugar solutions for a fermentation industry. Acid hydrolysis to convert wood to sugars for ethanol fermentation was used extensively by Germany in both World Wars. During peace time, the low price of oil discouraged extensive research to improve these old processes. With the world-wide energy search focusing on alternate sources, reinvestigation of these proven processes has resulted in improvements and updated technology that is efficient and economical. In general, two types of processes have been used; i.e., dilute acid hydrolysis and concentrated acid hydrolysis. Concentrated acid hydrolysis can be carried out at ambient temperatures, however, it requires elaborate acid

recovery steps with attendant dangers, complications and costs. Dilute acid hydrolysis requires higher pressures and temperatures (150°C and higher), but the low acid requirement eliminates the need for a difficult acid recovery step. The UCFPL process uses dilute acid hydrolysis to convert the polysaccharides in the wood (or bagasse) feedstock to their constituent sugars.

### Process Steps

Raw material (bagasse, supplemented with other available lignocellulosic material) is sized by hammermilling and then subjected to air elutriation or magnetic collectors to remove extraneous inorganic material such as tramp metal and sand. Other such extraneous matter can be removed by centrifugation or sedimentation procedures at later points in the process.

Stage I Hydrolysis is carried out in a pressure vessel. The raw material, sized and cleaned, is introduced with its attendant moisture content and dilute acid is added to it. The easily accessible polysaccharides, mostly hemicelluloses, are hydrolyzed in this stage and separated from the other material for introduction into the Liquid Extraction No. 2. The remaining material leaving the separator is in friable particles in a slurry. This considerable reduction in particle size is accomplished with very little mechanical energy compared to the requirements to reduce the original feedstock to this size.

Sensitization and Stage II Hydrolysis are carried out to hydrolyze the more inaccessible polysaccharides, those not hydrolyzed in Stage I. The Sensitization step includes the addition of oxygen and acid to provide an acceptable pH and increase the rate at which cellulose hydrolyzes. The

Stage II Hydrolysis is carried out at elevated temperatures in a pressure vessel. Hydrolyzate from Stage II Hydrolysis may be introduced into Stage I Hydrolysis to carry out reactions in that reactor, thereby increasing sugar concentration and minimizing the amount of acid required.

Liquid Extraction No. 2 may be required to remove from the hydrolyzate any organic product that might act as an inhibitor in the fermentation vessel. The organic product extracted in this stage may be treated as a feed stock to produce various products, or added to the feed stream entering either the wet oxidation or methanation stages.

Fermentation of the sugar solution from the liquid extractor stage is accomplished by yeast in conventional equipment and with proven technology.

Rectification of the dilute ethanol stream from fermentation is accomplished by distillation in conventional equipment and with proven technology. Ethanol of the required purity is obtained in this stage.

Wet Oxidation is used in a technique developed to oxidize the ligneous residue from the hydrolysis stages. The process is highly exothermic, producing steam in controllable amounts. The process can be designed to maximize either the thermal energy produced in the form of steam, or the organic products. The organic products are converted to methane in the methanation stage. The wet oxidation stage is one of the key elements in the UCFPL process. Ligneous residue, an insoluble product of all hydrolysis processes using lignocellulose, has almost never been utilized to produce significant products. Although ligneous residues are produced in great quantities by the pulping industry, nearly all of it is burned as part of the fuel required in the pulping process. To produce significant amounts of ethanol from a process designed to use lignocellulosic

feedstock, it is an environmental and economic necessity that the lignin be converted to a valuable product. The UCFPL process is the first one capable of accomplishing this on a large scale and does not involve the inefficient process of drying and combusting the lignin in a conventional solid-fuel boiler. Methanation is used to convert the soluble organic products from the wet oxidation stage, and the unfermented products from the fermentation stage, into methane. This is accomplished in conventional equipment and with proven technology. Other products, in addition to methane, are carbon dioxide and an aqueous stream containing soluble inorganics. The soluble inorganics originate from inorganic components contained in the feedstock and the residual acid reagent (e.g., nitrogen) that provide soluble salts subsequent to the above sequence of processing steps.

#### Feedstock

The proposed plant will be specifically designed to use lignocellulosic feedstock comprised of bagasse and wood. Feedstock requirements will be a minimum of 140 tpd on an oven-dry (O.D.) basis, or approximately 280 tpd on an as-delivered basis, assuming material as delivered will contain 50% water. Specific feedstock material indigenous to Hawaii were not analyzed for this study; however, examination of the literature provided data essential in approximating its chemical composition. For purposes of this study, the analyses of white fir and bagasse presented in a recent paper by D. L. Brink and M. M. Merriman, "Potential for Producing Alcohol from Organic Residues", is used. The analyses as presented in the Brink-Merriman paper are as follows:

Approximate Chemical Composition  
(Oven Dry Material)

<u>Component</u>	<u>Percentage</u>	
	<u>White Fir</u>	<u>Bagasse</u>
Cellulose	38.9	31.3
Hemicellulose: Glucomannans	17.6	
Xylans (Pentosans)	7.3	(27.1)
Acetyl	1.7	6.0
Uronic Anhydrides	3.3	3.0
Lignin	27.3	17.9
Extractives: Alcohol: Benzene	1.6	5.2
Hot Water	2.0	6.6
Ash	<u>0.3</u>	<u>2.9</u>
Total	100.0	100.0

Ethanol Marketing

Alcohol fuels are suitable for use in many applications where liquid fuels from petroleum are now used. In Hawaii, ethanol is currently being blended with gasoline to produce gasohol. An ethanol plant production of over 7 million gallons per year of power ethanol would be blended into 70 million gallons of gasohol.

The State of Hawaii consumed 325 million gallons of gasoline (all grades) in 1979, of which about 130 million gallons (40%) were unleaded. It is projected that in 1985, gasoline consumption will again be approximately 325 million gallons assuming the declines in gasoline consumption per capita are offset by an increased number of cars. An estimated 195 million

gallons (60%) will be unleaded grades, The increasing number of new cars requiring unleaded gasoline accounts for the increase.

Projected sales of over 70 million gallons of gasohol would represent approximately 36% of the 1985 unleaded gas market of 195 million gallons. This is considered a feasible objective in the 1980-1985 time frame. Public acceptance of gasohol will continue to grow and the price differential with gasoline should continue to narrow with increasing world prices for crude oil and the decontrol of U.S. crude oil prices.

As of April 1980, gasoline prices at Hawaii's pumps range as follows:

<u>Cents Per Gallon</u>	
Gasoline: Regular	128.3
Premium	138.7
Unleaded	135.0
*Gasohol: Premium	135.0

In August, 1978, the U.S. Department of Energy's Alcohol Fuels Task Force concluded that "...the high cost of alcohol fuels relative to conventional sources of petroleum appears to be the major obstacle to widespread commercialization." (Statement of Alvin L. Aln of the U.S. Department of Energy before the Senate Committee on Energy and Natural Resources, Subcommittee on Energy Research and Development, August 8, 1978.) At today's prices, the State Tax Incentive would make the price of regular gasohol competitive with that of unleaded gasoline and lower than the price for premium. The State Tax Incentive will virtually eliminate the pump price differential between gasoline and gasohol during the next few years, which is the critical consumer acceptance period.

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\*Reflects 4¢/gal. Federal tax exemption and 4¢ Hawaii excise tax exemption.

Gasohol has been marketed in Hawaii during the last ten months. Ethanol from Bellingham, Washington has been blended in a 90/10 mixture by Pacific Resources, Inc. (PRI) and distributed by tank truck to seven service stations. Gasohol sales are expected to increase to over 2,000,000 gallons per year with the incentive of the State 4% Excise Tax benefit which equates to a 5 cent per gallon saving to the consumer. The market expansion potential appears limited only by the ability to supply and distribute ethanol.

A major marketing effort will be required to increase Hawaii's gasohol sales. It is likely that the present level of less than 1.0% of the unleaded market share in Hawaii will increase gradually to 25% by 1983 and then to a 36% share by 1985. Commercial acceptance by competing marketers as well as their gasoline suppliers is the major risk in attaining this high market. It is estimated that gasohol would have to be supplied through about 100 of Hawaii's 523 gasoline stations in order to achieve a 36% market share or sales of 70 million gallons of gasohol annually.

Other ready markets for gasohol include the Federal, State and Local governments whose combined consumption represents a significant portion of Hawaii's gasoline market. It is also expected that U.S. military forces in the State will give strong support to the Administration's gasohol program. State and local governments have indicated strong support for the use of gasohol in their vehicles since the production of ethanol locally ties in well to the sugar and agricultural industries and brings the State closer to its goal of being more self-sufficient in energy. The County of Hawaii will be supportive of a major effort to penetrate the Island of Hawaii market. The five major oil companies, who control most of the retail



outlets in Hawaii, will need to be assured of supply, pricing, and consumer preference. The oil companies in turn need to convince their dealers to commit financial resources to convert certain pumps and tanks to handle gasohol. This could entail the phasing out of one gasoline grade such as leaded premium where the physical layout and number of tanks/pumps, limit the grades that can be marketed. Some minimal gasohol conversion costs would be required at all outlets.

The proposed procedure for sales and distribution of ethanol once the Pahoia plant is operable is as follows:

- a. Island of Hawaii Sales: Ethanol trucked to Hilo for blending in pipeline from distillery to a gasoline terminal for storage before distribution to stations by tank truck.
- b. Distribution to other islands: Shipped by barge from Hilo to a Honolulu gasoline terminal for storage and distribution.

This marketing analysis indicates that the lower price of the locally produced ethanol combined with unleaded gasoline could boost the demand for gasohol above 100 million gallons by 1985.

It is estimated that the Pahoia Industrial Park can be in full production by 1985. In that time period, the possibility exists that one or two Hawaiian ethanol plants using molasses as a feedstock may also be in commercial production. However, for purposes of this analysis, that production was not considered. The lower production cost of the ethanol produced at the Pahoia facility should allow consideration of entering both the Japanese and Alaskan markets.

## Plant Site Area Requirements and Elements

The basic ethanol production plant conceptual site layout is shown on Figure 6.2. The detail of the raw material unloading and storage is shown in Figure 6.3. The overall dimensions of the initial plant site are 620 feet by 400 feet or 248,000 square feet (5.7 acres). As shown on Figure 6.2, an additional 40 feet by 620 feet and 60 feet by 400 feet or 51,200 square feet (1.2 acres) has been reserved for expansion purposes.

The site area includes the following major elements:

**Administration Building** - Containing offices, toilet rooms, shower room, locker room, lunch room and control room. Total building area required is 3,600 square feet.

**Power Plant** - including a 5,000 KW steam turbine and generator, a 5,000 KW gas turbine and generator, a 1,000 HP air compressor and associated switchgear, controls and other required equipment for 10,000 KW system. Total area required for the power plant building is 7,500 square feet.

**Maintenance** - Service shops and dry storage. Total area required is 4,500 square feet plus a 5,200 square-foot concrete slab fronting the building.

**Feedstock storage building** - total area required is 14,400 square feet.

This would be a metal A-frame type building.

**Evaporator, separator, hydrolysis, steamer, oxidation and distillation units.**

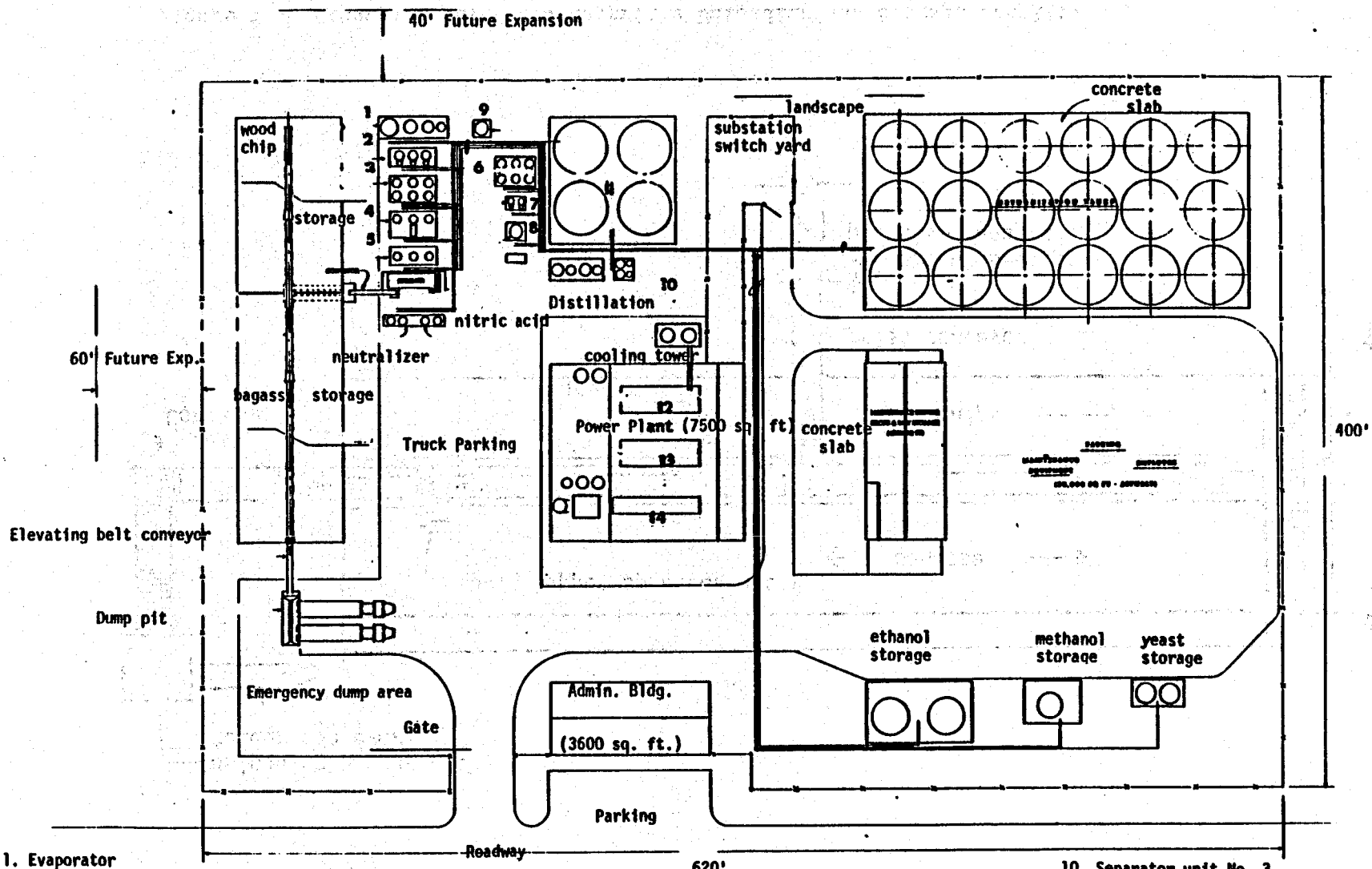
**Four fermentation tanks** - 30 feet in diameter by 21 feet high.

**Eighteen methanization tanks** - 30 feet in diameter by 27 feet high.

**Ethanol, methanol and yeast storage tanks.**

**Truck, employee and maintenance equipment parking areas.**

6-15



- 1. Evaporator
- 2. Separator unit No. 1
- 3. Hydrolysis unit No. 2
- 4. Sensitization
- 5. Hydrolysis unit No. 1
- 6. Wet oxidation
- 7. Separator unit No. 2
- 8. Liquid extractor unit No. 2
- 9. Liquid extractor unit No. 1

Figure 6.2

**ETHANOL PLANT PLAN**

SCALE: 1" = 50'

- 10. Separator unit No. 3
- 11. Fermentation tanks
- 12. Turbine & air compressor
- 13. Gas turbine 2 generator
- 14. Gas turbine 2 generator

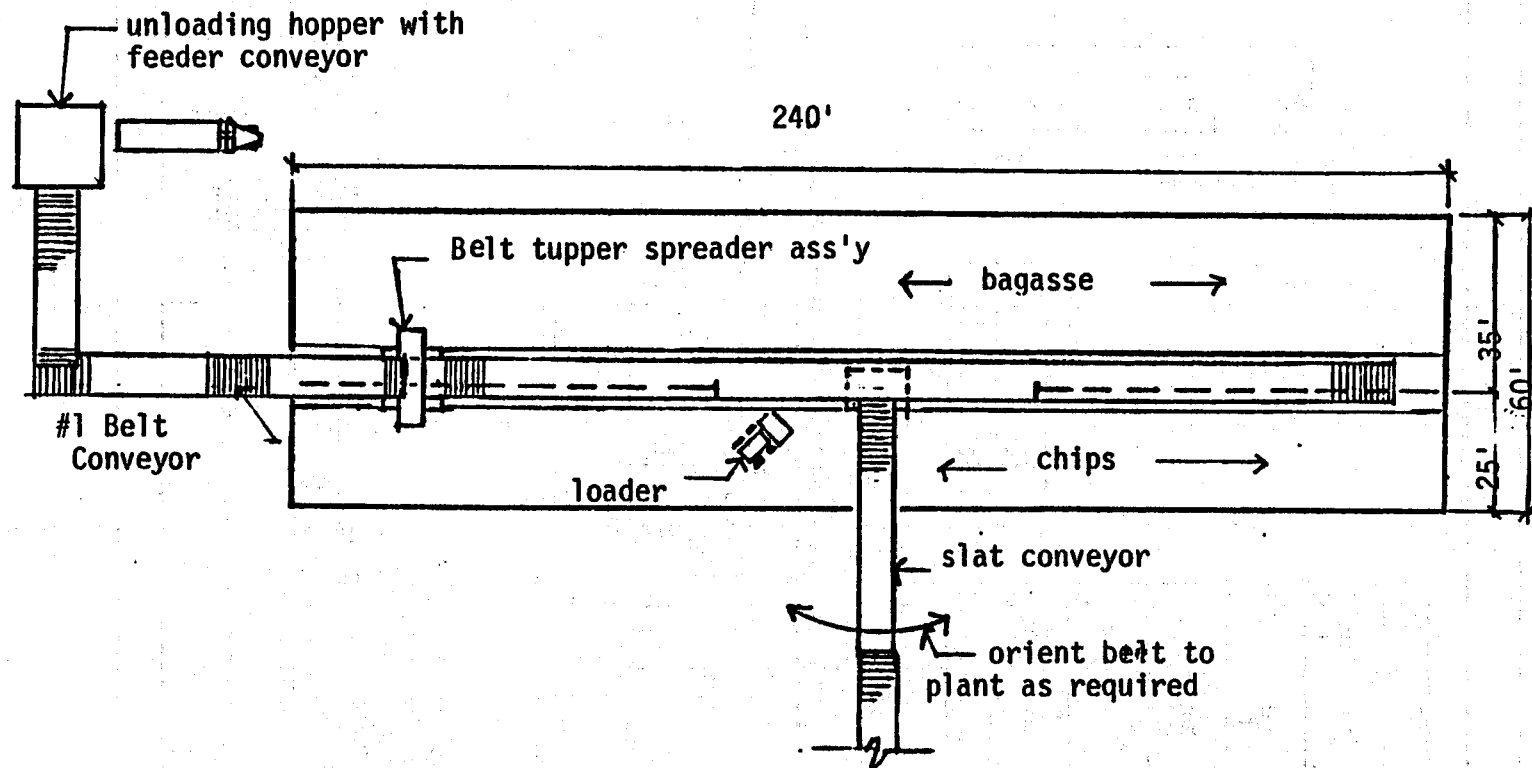


Figure 6.3 Ethanol Plant - Raw Materials Unloading and Storage Facility

All facilities within the conceptual plant area have been sited to provide an efficient flow from receipt of the raw feedstocks through the production of the final products and to provide adequate margins of safety.

Construction Costs and Annual Operations and Maintenance Cost Estimates

The cost estimates below are based on the facilities shown in Figures 6.1 and 6.2 and are in terms of July 1980 dollars. These costs are only for those items within the fenceline of the plant and should be considered as order of magnitude costs.

Construction Cost Estimate

Site preparation, drainage facilities, perimeter fencing and gate, A-C paving, 5,200 square-foot concrete slab in front of service shops building, site fire protection, yard lighting and water and sewer lines (to fenceline).	\$ 717,100
Tank and machinery foundations	420,000
Building and Shops:	
Administration building (3,600 square feet) including offices, toilet rooms, shower room, locker room, lunch room and control room.	288,000
Maintenance and service shop building (4,500 square feet)	202,500
Feedstock Equipment:	
Feedstock receiving facilities, including receiving hopper, bottom screw conveyor, covered elevating belt conveyor and one rubber-tired, on cubic-yard front-end loader.	116,000
Feedstock storage and distribution facilities, including 14,400 square foot A-frame storage building, distributing belt conveyor, traveling tripper, recovery screw conveyors and tunnel for recovery conveyors, receiving hopper, and covered elevating belt conveyor.	620,000
Plant Equipment:	
Process area concrete slabs (38,000 square feet)	152,000

Rotating Steamer (8 feet in diameter x 30 feet long) with 5 HP motor	61,250
Hydrolysis Unit No. 1 consisting of three stainless steel 3.5-foot diameter by 32.1-foot tall tanks and one 200 GPM pump with 40 HP motor	151,580
Neutralizer tanks consisting of two stainless steel 4-foot diameter by 5-foot tall tanks and a feed pump with 0.5 FH motor.	13,300
Nitric acid tanks - two stainless steel 4-foot diameter by 6-foot tall tanks with feed pump and 0.5 FH motor.	26,110
Sentization unit consisting of three stainless steel 2.5-foot diameter by 29.9-foot tall tanks, 2-foot diameter by 10-foot long heat exchanger and one 200 GPM pump with 5 FH motor.	108,200
Hydrolysis Unit No. 2 consisting of six stainless steel 3.5-foot diameter by 30.6 foot tall tanks.	567,380
Centrifugal separator Unit No. 1 consisting of three 50 HP separators with pumps and 5 HP motors	184,000
Evaporator unit with one stainless steel 10-foot diameter by 20 tall tank, one stainless steel 8-foot diameter by 12-foot tall tank, and one stainless steel 40-foot diameter by 12-foot tall tank, all with 5 HP pumps.	184,500
Liquid Extractor Unit No. 1 with one stainless steel 10-foot diameter by 12-foot tall tank with one 5 HP and one 1 HP pumps.	52,300
Wet oxidation unit consisting of six stainless steel 4-foot diameter by 34.2 foot tall tanks with 2 HP pumps.	983,100
Centrifugal Separator Unit No. 2 with two 40 HP separators and a 3 HP pump.	103,500
Liquid Extractor Unit No. 2 with one stainless steel 10-foot diameter 12-foot tall tank with 0.25-inch thick walls and one 5 HP and one 1 HP pumps.	52,800
Solvent recovery unit with one 3-foot diameter by 10-foot tall tank.	4,800
Distillation unit with two stainless steel 6-foot diameter by 30-foot tall tanks with 38 bubble trays, 2-foot diameter by 10-foot long heat exchanger, two 4-foot by 12-foot vapor condensers, and two 3 HP pumps.	180,400

Centrifugal Separator Unit No. 3 with two 25 HP separators	60,000
Fermentation unit consisting of four stainless steel 30-foot diameter by 21.3-foot tall tanks.	1,593,600
Methanization unit consisting of 18 mild steel, 30-foot diameter by 27.3-foot tall tanks, 1 HP pumps on each tank, one gas compressor and one receiver tank.	3,516,550
Ethanol storage unit consisting of two 20-foot diameter by 20-foot tall mild steel tanks, 5 HP pump and truck loading station.	98,500
Methanol storage unit with one 12-foot diameter by 16-foot tall mild steel tank, 5 HP pump, and truck loading station.	29,140
Yeast storage unit with two 5,000 gallon mild steel tanks and 1 HP pump.	17,100
<b>Piping Fitting Valves:</b> Miscellaneous stainless and mild steel piping, fittings and valves.	745,000
Power Plant Building (7,500 square feet) with steam and gas turbines for 5,000 KW generators, 1,000 HP air compressor, heat recovery system, stack, two 3-foot diameter by 12-foot tall air receiver tanks, three fan cooling tower 8' x 24' x 12', cooling water pumps and switchgear, controls, etc. for 10,000 KW.	3,450,000
Power lines and electrical hook-up.	109,600
<b>Instrumentation, Etc.:</b> Instrumentation and controls	320,000
Geothermal steam piping (within fenceline).	90,000
Start-up and emergency power.	50,000
Retaining walls around ethanol and methanol tank areas.	33,500
Contingencies and miscellaneous items.	<u>1,530,670</u>
<b>Subtotal</b>	<b>\$16,833,000</b>

Design, engineering and construction management (assume 12 percent of construction costs)	<u>2,019,900</u>
Total Estimated Costs	<u>\$18,852,900</u>

Annual Operations and Maintenance Costs

Administration:

1 Superintendent	\$ 40,000
1 Office Manager/Clerk/Typist	<u>20,000</u>
	\$ 60,000

Plant Operation:

6 Operators (\$10.00/hr + 35%)	\$168,480
3 Clean-up (3.00/hr + 35%)	25,272
3 Laborers (6.00/hr + 35%)	50,544
1 Warehouse (5.00/hr + 35%)	<u>14,040</u>
	\$258,336

Maintenance:

3 Mechanics (\$10.00/hr + 35%)	\$ 84,240
2 Tradesmen (12.00/hr + 35%)	67,392
5 Helpers (6.00/hr + 35%)	84,240
2 Yardmen (4.00/hr + 35%)	<u>22,464</u>
	\$258,336

Sub-Total	\$576,672
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Maintenance Material Cost:

(1/2 of 1% of construction costs w/o management charge)	<u>\$ 84,165</u>
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Total Operating and Maintenance Costs	\$660,837
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O & M costs do not include the annual costs of the geothermal fluid or the royalties associated therewith, electricity purchased from the utility, potable water, feedstocks, trucking O & M costs, or applicable taxes and insurance. It is assumed that the trucking O & M costs will be borne by a trucking contractor.



## Nature and Composition of Waste Streams and Atmospheric Emissions

One of the claimed advantages of the UCFPL ethanol process is that there are no feedstock waste materials produced. However, there will be five waste water streams.

### Waste Water Streams

Sanitary Wastes. Based on the numbers and categories of personnel required, a 20-hour operating period, 365 days per year, sanitary wastes have been calculated to be approximately 2,000 gpd or 600,000 gpy. It is assumed that in the development of the industrial park, a sewage treatment plant would be constructed to serve the entire park. Sanitary wastes from the ethanol plant would be directed to this treatment plant.

Plant Process Waste Water. The plant process waste water has been calculated to be approximately 150,000 gpd at a temperature of 130°F. This waste water would essentially contain the inorganic matter of the biomass raw materials with small quantities of inorganic agents. No organic matter is expected in this water stream.

Clean-up Water. This quantity is estimated to be approximately 5,400 gpd at a temperature of 75°F. The waste stream would contain small amounts of plant materials from the various processing stages. It is recommended that this water be filtered prior to disposal.

Truck and Equipment Wash Water. Estimates of this waste stream are approximately 1,500 gpd at 75°F. This waste stream would contain small amounts of raw feedstock materials, oils grease, sand and dirt.

Solid and grease traps and oil separators should be provided for this waste stream and all equipment washing should be confined to one area.

Site Drainage Water. Based on rainfall and net evaporation rate studies conducted for the Island of Hawaii, the quantity of rainfall from the entire 5.7 acre plant site for the average ten-year storm is estimated at 45 cubic feet per second (CFS). This runoff would be directed to storm drains strategically located within the plant area which would discharge into the main storm water disposal system.

#### Atmospheric Emissions

Atmospheric emissions from the ethanol plant would be expected to be minimal. There essentially would be two direct atmospheric emission sources. The first is steam blow-off from several points, all of which have not been identified. It is expected that the steam turbine would be one source of steam blow-off, as would other equipment units such as the evaporator and steamer. These emissions are expected to be intermittent only. The causes of these emissions are the excess pressure resulting from the wet oxidation process equipment and leaking glands.

The second potential source of atmospheric emissions would be the gas turbine exhaust flue gases. Based on the assumption that approximately 3,000 pounds of methane ( $\text{CH}_4$ ) would be burned per hour, the following atmospheric emissions are expected:

- $\text{CO}_2$  - 8,202 pounds per hour
- $\text{H}_2\text{O}$  - 6,730 pounds per hour
- $\text{N}_2$  - 39,800 pounds per hour

These quantities are based on the following:

- 2.744 pounds of  $\text{CO}_2$  per pound of methane
- 2.246 pounds of  $\text{H}_2\text{O}$  per pound of methane
- 13.275 pounds of  $\text{N}_2$  per pound of methane

These atmospheric emission constituents are not generally considered to be pollutants as described by either the Federal or State Air Quality Standards. However, it is possible that, through chemical reactions with each other, gases considered to be pollutants, such as  $\text{CO}_2$ ,  $\text{N}_2$  or  $\text{O}_3$  (ozone) could be produced. The latter might be produced by sunlight oxidation. It is noted that prior to construction and operation, State permits to Construct and Operate would be required. A portion of the data required for the permit applications would be the complete identification of all potential air pollutants and the quantities to be emitted by the plant. The methods to be employed to control the potential emissions of pollutants must be identified in the permit applications.

Additional potential atmospheric emissions may be dust from the ethanol plant grounds and odors from processing operations. Adequate landscaping and paving of the majority of the plant grounds would severely limit the quantities of dust generated. Therefore, dust is not considered to be a significant source of atmospheric emissions. Similarly, process odors would not be present except in the case of a malfunction of equipment or process pressure vessels. Should a malfunction occur, immediate remedial action would be taken to alleviate the problem.

Indirect sources of atmospheric emissions in and around the ethanol plant would be vehicle emissions, the natural emissions from the steam vents and other volcanic factors characteristic of the Puna District of the

Island of Hawaii. An attempt to quantify these emissions has not been made because of the many unknown site specifications regarding the industrial park and surrounding environs.

#### Industrial Support Requirements

The proposed Pahoia industrial park would be the first such facility to be located in an area that currently has a low population level and is primarily used for residential and agricultural purposes. Therefore, the generally required support businesses have not yet been established. Nor are they likely to become established (at least) until after the industrial park would be under construction. For an undetermined period of time, the industrial park and the tenants thereof, would have to depend on support businesses located in the Hilo area. These support businesses would range from operation and maintenance material suppliers to office supplies and vending machine products.

The park would also have to rely on present or concurrently developed infrastructural components such as roads, water, sewer and to a limited extent, electrical power.

Additional requirements for the ethanol plant operations would be reliable supplies of nitric acid, neutralizers and other process supplies.

#### Feedstock Hauling and Trucking

The feedstock requirements for the proposed ethanol plant is assumed to be approximately 283 bdt/day of lignocellulosic material, principally bagasse and wood chips. Anthurium growers have obtained small amounts of bagasse from the Ka'u Sugar Company in Pahala at a price of \$20 per ton on wet basis. Hauling costs depend on the equipment which is used and the hauling

distance. Both tandem trailers and compacting trailers were considered. Compacting trailers were chosen because bagasse is easily compressed to densities up to 20 lbs./cu. ft. A limitation on the allowable length of truck/trailer combinations limits the load that can be carried in the case of tandem trailers, called a "train." Compacting trailers are currently used by the County at solid waste transfer stations, and have been used to compress bagasse. A problem has been encountered when the bagasse is compacted too much as it tends to jam up at the exit. Testing will be required to determine the optimal bagasse compaction. Assuming 90 cubic yard compacting trailers, the cost of hauling bagasse from Puna Sugar Company to the park site in Pahoia would be about \$3.64/ton, while from Ka'u Sugar Company the cost would be about \$7.81/ton.

In the supply of wood, harvesting costs must also be considered. Hilo Coast Processing Company has been buying waste wood chips from Capitol Chip Company for \$6.25/ton, however in this case the product is considered waste because it is unsuitable for Capitol Chip's prime market, which is Japanese paper manufacturers. The pulp grade chips command up to \$110/ton. In order for the price to be economical for the ethanol plant, waste wood such as cull trees and timber slash should primarily be considered. A forestry consultant estimated that timber could be harvested from chia stands in upper Puna, chipped, and delivered at a cost of from \$26 to \$30 per green ton to the park site at Pahoia. Of this, about \$12 per ton is attributable to the actual logging operations, including roads, based on a production level of 15,000 to 20,000 tons per year.

The wood could either be chipped on-site, or hauled down to the ethanol plant as logs to be chipped there. The operations would probably be a com-

ination of both techniques, with whole logs trucked to the park site, but the tree tops, being bulkier and less dense, would be chipped on-site and trucked as chips.

For purposes of this investigation, the hauling costs were estimated for the hauling of wood as chips. These calculations are similar to those for bagasse, although it is assumed that wood chips will not compact as easily, and the density will be about 16 lb./cu.ft. or about 18 tons per truckload. Hauling costs are then estimated at \$5.56/ton for wood chips hauled from upper Puna area, and \$10.42/ton if the wood comes from Capitol Chip's operations near Paauilo on the Hamakua Coast.

#### Availability of Feedstock

An initial survey (Chapter 4) found approximately 208,500 tons/year of available feedstock, of which 85% was bagasse. The minimum feedstocks requirements for the ethanol plant are 206,000 tons/year. The intent of the survey was to determine the magnitude of existing feedstock.

Surveys were performed to determine the availability of wood on public and private lands.

The State holds a large portion of the commercially forested land in the Puna District which could be obtained through public auctions. Of the large private land owners surveyed, the majority were cautiously agreeable to further discussions.

A local firm has begun demonstration tree farming operations which should cover approximately 900 acres by the end of the five year contract period with the Department of Energy.

## Raw Materials Unloading and Storage

A schematic layout of a bagasse and wood chip storage facility for the conceptual ethanol plant has been developed (Figures 6.2 and 6.3).

1. Basis: Bagasse 140 bdt/day, 280 tons/day as milled.  
Wood 171 bdt/day, 285 tons/day as received @ 40% moisture.

Plant operates at an 83% capacity factor (20 hours per day), but the storage facility design must be based on 24 hours/day.

Storage is sized for five days.

2. Maximum processing rate:

Bagasse 7 bdt/hour @ 50% moisture = 14 gross tons/hr.

Wood 8.5 bdt/hr. @ 40% moisture = 14.2 gross tons/hr.

Total 28.2 gross tons/hr. = 676 gross tons/day

3. Maximum storage required: 5 days @ 676 tons/day = 3380 tons.

4. Size of building required:

336 tons bagasse - 672,000 lbs. @ 15 lbs./cu.ft. = 45,000 cu.ft. for 1 days storage.

340 tons wood - 680,000 lbs. @ 22 lbs./cu.ft. = 31,000 cu.ft. for 1 days storage.

5. Trucking Requirements:

Based on operations at the Hilo Coast Processing Company

1 truckload bagasse = 13 tons

1 truckload wood chips = 21 tons

Daily truckloads bagasse =  $\frac{336 \text{ tons/day}}{13 \text{ tons/load}} = 25.8$

Daily truckloads wood =  $\frac{340 \text{ tons/day}}{21 \text{ tons/load}} = 16.2$

Total truckloads = 42 per day.

6. Unloading and Storage Operation:

Using end-dumping trailers with conveyor chain unloading, trucks will drive over an unloading hopper with conveyor that feeds an inclined belt conveyor into the storage house. A belt-tripper/spreader assembly on rails can be positioned at the appropriate place to direct bagasse or wood chips to the appropriate reclaim pile. A 15-foot wall which divides the storage house into separate bagasse and wood chip bins with an approximately 60/40 split in storage volume. It is assumed that the feedstock must be co-mingled, at a certain ratio for effective operation, hence the need for separate storage piles for bagasse and wood.

7. Feedstock and Reclaim Operation:

A reclaim pit 8 feet wide, by 12 feet long and 10 feet deep is centrally located in the storage house building, which is 50 feet long and 30 feet wide. There is room for the loader to maneuver in the building around the pit. Bucket loader reclaims bagasse or chips from the appropriate reclaim pile and dumps it into the pit, which feeds a slat conveyor which in turn feeds a belt conveyor that runs to the ethanol plant.

Feedstock reclaim requirement: 14 tons/hour bagasse @ 133 cu.ft./ton plus 14 tons/hour wood chips @ 92 cu.ft./ton gives about 0.5 tons per minute, or about 60 cu.ft./min. A 3 cu. yd. loader bucket (81 cu. ft.) will be more than adequate, assuming a one-minute per load cycle time (average).



ANNUAL PRODUCTION COST

Feedstock Costs

Bagasse:	280 tpd (50% moisture) @ \$30/ton	\$3,066,000
Wood chips:	285 tpd (40% moisture) @ \$30/ton	3,120,750
Nitric acid 100%:	200 gpd @ \$2.50/gal.	182,500
Basic neutralizer (caustic soda)	1,400 lbs. @ \$.18/lb.	91,980
Make-up water	150,000 gpd. @ \$.000682/gal.	<u>37,340</u>
	<b>Total Feedstock Costs</b>	<b><u>\$6,498,570</u></b>

Power Costs

500,000 KWH @ 8¢/kwh \$ 40,000

Water Costs

69,000,000 gal @ \$.000682/gal \$ 47,058

Steam Cost

47 MBTUH @ \$2.67/MBTU \$ 916,077

## FINANCIAL ANALYSIS

### Assumptions:

Operate: 20 hrs./day, 365 days/yr.

### Investment:

Site preparations	\$ 714,100
Tank and machinery foundations	420,000
Building & shops	490,500
Feedstock equipment	736,000
Plant equipment	8,140,110
Piping, fitting, valves, etc.	745,000
Power plant buildings & equipment	3,450,000
Power lines and hookup	109,600
Instrumentation	493,500
Miscellaneous items & contingencies	1,530,670
Subtotal	16,833,000
Design & engineering	<u>2,019,900</u>
TOTAL	\$ 18,852,900

### Annual Revenue:

Ethanol (20,000 GPD @ \$1.80/gal.)	\$ 13,140,000
Methanol (2,200 GPD @ \$0.50/gal.)	401,500
Yeast (6,700 lbs./day @ \$0.17/lb.)	415,735
Electricity (72.9 million Kwh/yr. @ 60 mills/kw)	<u>4,374,000</u>
TOTAL	\$ 18,331,235

### Annual Operating Expenses:

Geothermal Steam (47 MBTUH @ \$2.67/MBTU)	916,077
Operation and Maintenance	660,837
Feedcost (including trucking)	6,498,570
Utilities	<u>87,058</u>
TOTAL	\$ 8,162,542

**Escalation:**

8% year

**Investment Tax Credit:**

20%

**Tax Depreciation:**

17.5 years

Double declining balance

Zero salvage

**Tax Rate:**

50%

<u>End of Year</u>	<u>Investment and other Cash Flow</u>	<u>Profit before Depreciation &amp; Income Tax</u>	<u>Depreciation for Tax Purposes</u>	<u>Taxable Income</u>	<u>Tax</u>	<u>Income after Tax</u>	<u>Total Cash Flow</u>
0	(18853)						(18853)
1	3770	10168	2155	8013	(4007)	4007	9932
2		10981	1908	9073	(4537)	4537	6445
3		11860	1690	10170	(5085)	5085	6775
4		12809	1497	11312	(5656)	5656	7153
5		13834	1326	12508	(6254)	6254	7580
6		14940	1174	13766	(6883)	6883	8057
7		16136	1040	15096	(7548)	7548	8588
8		17462	921	16541	(8271)	8271	9192
9		18820	816	18004	(9002)	9002	9818
10		20326	744	19582	(9791)	9791	10535
11		21952	744	21208	(10604)	10604	11348
12		23708	744	22964	(11482)	11482	12226
13		25605	744	24861	(12431)	12431	13175
14		27653	744	26909	(13455)	13455	14199
15		29866	744	29122	(14561)	14561	15305
16		32255	744	31511	(15756)	15756	16500
17		34835	744	34091	(17046)	17046	17790
18		37622	372	37250	(18625)	18625	18997
19		40632		40632	(20316)	20316	20316
20		43882		43882	(21941)	21941	21941
21		47393		47393	(23697)	23697	23697
22		51184		51184	(25592)	25592	25592
23		55729		55729	(27865)	27865	27865
24		59701		59701	(29851)	29851	29851
25		64477		64477	(32239)	32239	32239

	<u>Discount Rate</u>		
	15%	20%	25%
Present Value	\$46,137	27,111	16,294
After tax discounted cash flow			
Rate of return:	43.6%		
Payback:	2.4 years		

Table 6.1  
 ETHANOL PLANT  
 FINANCIAL ANALYSIS I (STEAM AT \$2.67/MBTU) (\$000)

## Summary

The conclusion from this analysis is that the ethanol plant would make an after tax discount cash flow rate of return of 43.6% with a payback of 2.4 years. This is based on a steam selling price of \$2.67/MBTU. The conclusion from this is that the cellulose to ethanol plant could be a viable anchor industry for the industrial park.

## ALTERNATIVE FINANCING ANALYSIS - ETHANOL AS ONLY TENANT

Having found that the ethanol plant could be viable as a component in an ongoing industrial park, the question was raised whether the ethanol plant would be viable if it were the only industry. This is likely being the anchor industry, the ethanol plant would likely be established prior to any other industry. It was assumed that one developer would develop the resource and transmission and develop the industrial park based solely on the ethanol plant.

An implementation scenario was hypothesized in which a wellfield and pipeline would be developed just for the ethanol plant. This is shown in Table 6.2. Then an analysis was made to see if the ethanol plant is viable in that situation.

What follows is an analysis of that limited geothermal development to determine the required selling price of steam when serving only the ethanol plant. It proves to be \$5.934/MBTU to provide a required after tax rate of return of 27%.

Following that is an analysis of the ethanol plant using this higher price for steam.

PERMITTING

- Well #1
- Well #2
- Comm. Park
- Well #3

CONCEPT DESIGN STUDY

- Drill 1st Well
- Test 1st Well
- Drill 2nd Well
- Test 2nd Well
- Drill 3rd Well
- Test 3rd Well
- Wellsite construction
- Decision to Build Plant
- Finish Design
- Construct Park/Plant
- Construct Pipeline
- Test Operations
- Attain Full Production
- Complete 1 year full Production



Table 6. 2 Hypothetical Implementation Schedule

Geothermal Investment Costs - For Ethanol Plant Only

ETHANOL PLANT 47 MBTU/hr.

<u>Wells:</u>	1 production well	\$ 1,600,000	
	1 standby well	1,600,000	
	1 dry well	<u>1,600,000</u>	
	Total		\$ 4,800,000

Well Site Equipment:

Site preparation	\$ 255,000	
Two phase separator	70,000	
Evaporators	700,000	
H <sub>2</sub> S abatement system	600,000	
Site utility, roads, etc.	<u>530,000</u>	
Total		\$ 2,155,000

Resource Transmission:

Pipeline	409,990	
Installation	298,905	
Insulation	736,960	
Service road	<u>114,500</u>	
Subtotal		\$ 1,560,355
Engineering (15%)	234,053	
Contingency (20%)	<u>312,071</u>	
*Total		2,106,479
EIS, Legal, Administration, Social Environmental, etc.		<u>450,000</u>

Total Field Development \$12,392,212

\*The lower cost is due to the smaller diameter pipe required and the corresponding insulation material required. This in turn lowers the engineering design factor and contingency.

TABLE 6.3

Geothermal Resource Development  
Assumptions

Construction Costs:

The total construction cost of \$12.4 million is spread over three years following the same development timetable as presented in Table 6.4.

Escalation:

Construction costs are escalated at 8% a year.

Revenue:

A steam load factor of 90% was assumed. The amount of annual saleable steam was calculated as follows:

$$\begin{aligned} \text{Annual Saleable Steam} &= 49,200 \text{ lbs./hr.} \times 24 \text{ hrs.} \times 360 \text{ days} \\ &\times .90 = 382,579,200 \text{ lbs./year.} \end{aligned}$$

Revenues equal the annual steam production times the selling price.

The required selling price was derived through computer iteration.

Operating Expenses:

Field operation and maintenance

Estimated at \$158,900 in 1980 dollars

Other Expenses

Estimated at \$22,700 in 1980 dollars

Expenses escalated at 8% a year.

Intangible Drilling Costs (IDC):

Consistent with current practice, 80% of total well costs (including well equipment and associated permitting, lease, legal and administrative expenses) were designated as IDC and expensed in the year incurred.



TABLE 6.3 (Continued)

Geothermal Resource Development  
Assumptions

Depreciation:

All capitalized construction costs were depreciated using accelerated depreciation over the allowable tax life:

Wells	20 years
Pipeline	30 years
Other Equipment	22.5 years

Wells and other equipment were depreciated when they became operable.

Royalty:

In the analysis, the base case royalty assumption is 10% of gross revenues (Option 1). Sensitivity analyses were included in the model with royalty rates of 12% (Option 2) and 15% (Option 3) representing the basic state royalty plus an assumed 2% override and a 5% negotiated rate with a private owner respectively.

Depletion Allowances:

Depletion allowance totaling 15% of net revenue (gross revenue less royalties) were deducted from net revenue to arrive at taxable income.

Income Tax Rate:

The statutory combined State and Federal tax rate was assumed to be 50%.

PAHOA INDUSTRIAL PARK STUDY  
REVISED STEAM PRICE  
(\$000)

PAHOA INDUSTRIAL PARK STUDY  
REVISED STEAM PRICE  
(\$000)

PAHOA INDUSTRIAL PARK STUDY  
REVISED STEAM PRICE  
(\$000)

Table with 4 columns of periods (1980-1990, 1991-2001, 2002-2007) and 27 rows of financial categories including Description, Inflation Rate, Revenue, Expenses, Income, Earnings, Cashflow, and Capitalized Expenses.

Table 6.4  
Pahoa Industrial Park Study  
Revised Steam Price  
(\$000)

FINANCIAL SUMMARY

	<u>Option 1</u> <u>10% Royalty</u>	<u>Option 2</u> <u>12% Royalty</u>	<u>Option 3</u> <u>15% Royalty</u>
<b>Present Value at</b>			
<b>Following Discount Rates:</b>			
15%	\$ 7,004	\$ 6,722	\$ 6,301
20%	2,861	2,684	2,419
25%	738	617	436

**After-Tax Discounted Cash Flow:**

Rate of Return	27.8%	27.4%	26.7%
Payback	5.8 years	5.9 years	6.0 years

The conclusion from this analysis is that a steam selling price of \$5.93/MBTU is adequate and gives an after tax discounted cash flow rate of return of about 27% and a 5.9 year payback. This return is relatively insensitive to the royalty rate in the range of 10% to 15% royalty.

ANALYSIS OF ETHANOL PLANT AS ANCHOR INDUSTRY

Using the computed steam selling price of \$5.93/MBTU, the ethanol plant was re-analyzed. Other than the steam price, all inputs are the same as used in the initial analysis. Table 6.5 shows this financial model.

From this model was computed an after tax discounted cash flow rate of return of 40.1% with a payback of 2.6 years which indicates that the ethanol plant is still an attractive opportunity on its own, even with the higher steam cost.

<u>End of Year</u>	<u>Investment and other Cash Flow</u>	<u>Profit before Depreciation &amp; Income Tax</u>	<u>Depreciation for Tax Purposes</u>	<u>Taxable Income</u>	<u>Tax</u>	<u>Income after Tax</u>	<u>Total Cash Flow</u>
0	(18853)						(18853)
1	3770	9048	2155	6893	3447	3446	9371
2		9772	1908	7864	3932	3932	5840
3		10554	1690	8864	4432	4432	6122
4		11398	1497	9901	4951	4950	6447
5		12310	1326	10984	5492	5492	6818
6		13294	1174	12120	6060	6060	7234
7		14358	1040	13318	6659	6659	7699
8		15507	921	14586	7293	7293	8214
9		16747	816	15931	7966	7965	8781
10		18087	744	17343	8672	8671	9415
11		19534	744	18790	9395	9395	10139
12		21097	744	20353	10177	10176	10920
13		22784	744	22040	11020	11020	11764
14		24607	744	23863	11932	11931	12675
15		26576	744	25832	12916	12916	13660
16		28702	744	27958	13979	13979	14723
17		30998	744	30254	15127	15127	15871
18		33478	372	33106	16553	16553	16925
19		36156		36156	18078	18078	18078
20		39048		39048	19524	19524	19524
21		42172		42172	21086	21086	21086
22		45546		45546	22773	22773	22773
23		49190		49190	24595	24595	24595
24		53125		53125	26563	26562	26562
25		57375		57375	28688	28687	28687

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Financial Summary  
Discount Rate

	15%	20%	25%
Present Value	\$39,784	22,770	13,079
After tax discounted cash flow			
Rate of return:	40.1%		
Payback:	2.6 years		

Table 6.5  
ETHANOL PLANT FINANCIAL ANALYSIS II (STEAM AT \$5.93/MBTU) (\$000)

### Ethanol Plant Summary and Conclusion

It appears that an ethanol plant using bagasse and wood as feedstock would be the most likely industry to succeed in the geothermal industrial park setting either as a component in an ongoing park or as a pioneering industry on its own. The feedstock is considered reasonably available and the market potential for the ethanol product to produce gasohol is promising.

However, significant risk is associated with the process selected. Before an investor can be attracted, more definitive information is considered necessary concerning the complete process technology. Data is especially needed on the specific process performance using sugar cane bagasse and Hawaiian woods such as chia, eucalyptus and leucaena as feedstock.

From the technological development standpoint, a reasonable time frame of less than 5 years is estimated to plan, construct and place in operation a commercial-sized ethanol plant once the process is proven.

## PART B: CATTLE FEED MILL

### Introduction

The proposed cattle feed mill to be located in the Pahoia Industrial Park is designed to produce 240 tons per day of a cattle feed roughage component.

The process involves separating, washing, compacting and loading onto trucks 600 tons per day of sugar cane leaf trash for delivery to the cattle feed mill at the industrial park. Here the leafy trash is dried and formed into 1-1/4" x 1-1/4" particles to be marketed as a roughage component of cattle feed in both Japan and Hawaii.

### Availability of Feedstock

The two feedstocks under consideration are bagasse and cane strippings with emphasis on cane strippings because of its higher feed value. Cane strippings, otherwise known as sugar cane leaf trash consists of the upper leaves, whereas bagasse is mainly the fibrous and pithy portion of the stalk. The strippings are higher in moisture content (60 - 70% water) and lower in fuel value than bagasse, thereby not exclusively used as boiler fuel.

The volume of sugar cane leaf trash of 600 tons per 24 hours (approximately 70% moisture) is considered available from the Puna Sugar Mill, which recently installed a mechanism to separate the leafy cane trash. This trash is currently burned (as fuel) in a boiler. Therefore, it is assumed that satisfactory negotiations can be made with the Puna Sugar Mill to obtain the cane trash in exchange for electricity produced by the ethanol plant in the industrial park. For the process evaluation,

cane trash is estimated to cost \$30.00/ton. In addition, transportation costs are included for hauling the cane leaf 16 miles from Puna Sugar Mill to the industrial park.

#### Description of Drying and Cubing Process

The sugar cane leaf trash is separated from the stalk at the sugar mill, where it is washed and chopped into lengths approximately 4 inches long (Figure 6.4). The cane trash is then conveyed into a compactor where it is compressed into loaves or bales approximately 30 feet long, 8 feet wide and 6 feet high.

The compacted loaves are then transported on low bed conveyor type bottom trailers to the industrial park where it is fed into a twin drum bale breaker via an elevating conveyor. Once the leaf trash is separated, it is conveyed at constant uniform speed into a rotating drum type dryer. A control system is used to maintain constant steady operation which is a critical factor in the drying process.

The cane trash is dried by forced heat convection in the dryer furnace: Incoming air is preheated by geothermal steam to 350°F via heat exchangers. The air temperature is then further elevated by routing the air through the burner front of the furnace. A draft fan linked to the control system regulates the air flow in and out of the furnace.

The rotating drum dryer is under negative pressure and as the drum rotates, flights inside the drum move the material through heated air from the inlet to the discharge end. The heavier dried materials drop out of the bottom of the chambers into a chain type flight conveyor. The fines are collected through cyclone separators and also drop on the conveyor.



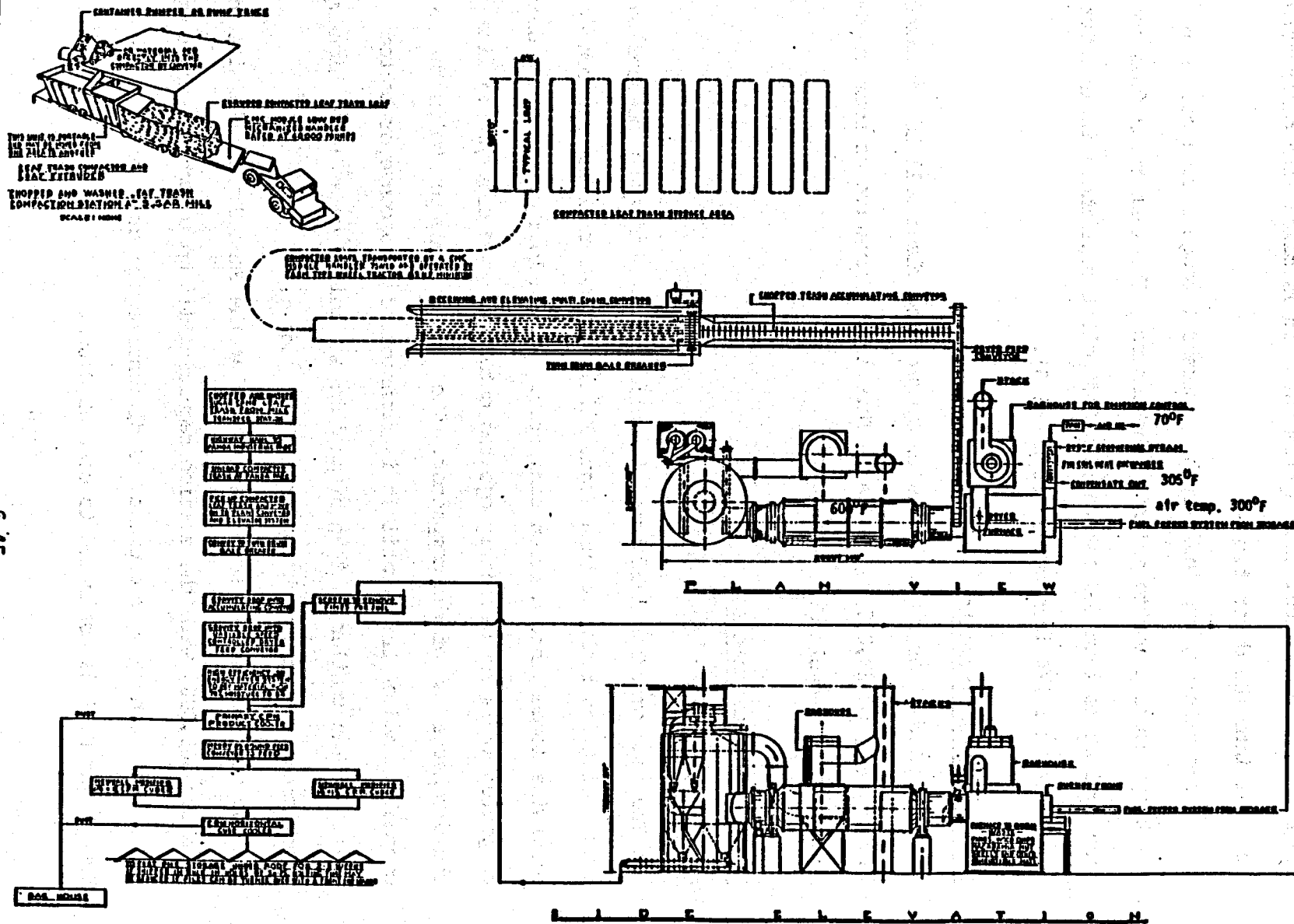


Figure 6.4 Schematic layout of the feedmill

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The dried material leaving the drier is conveyed through a vibrating screen to sift out the fines unsuitable for cubing. The fines collected are returned to the fuel feed system where it is mixed with other materials for fuel into the dryer furnace.

After sifting, the leaf trash is passed through a cube cooler to lower the temperature prior to entering the cubers. The leaf trash from the primary coolers is then fed into a modified pellet mill where it is compressed into 1-1/4 x 1-1/4 inch cubes (Figure 6.5).

### Electrical Requirements

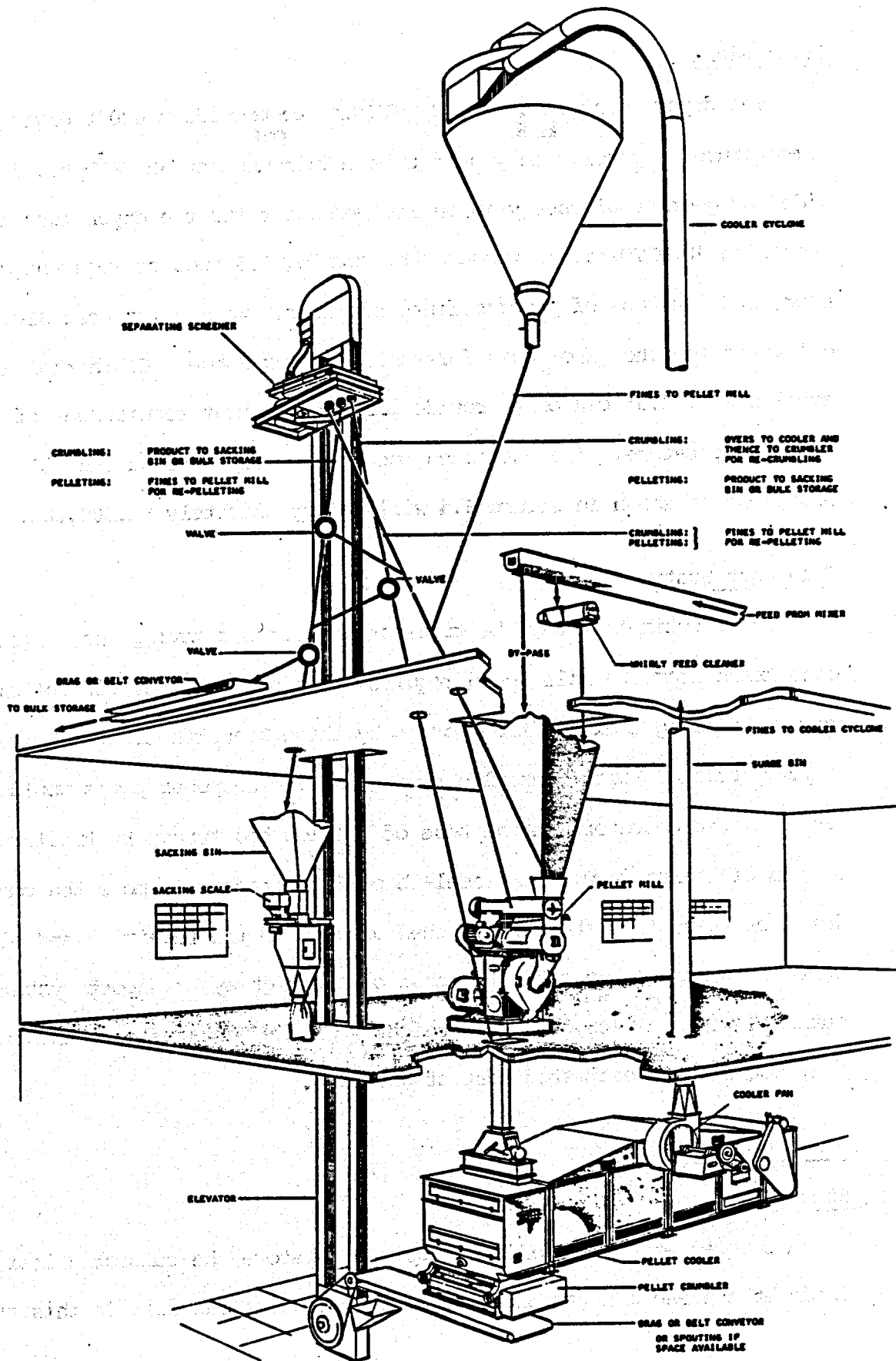
Estimated power requirements to operate the plant will be approximately 1240 hp or 23,800 kw/hr./day. This is conservative as some of the motors will be cycling.

### Equipment Requirements

#### Compactor

The cane or other leaf trash is collected, washed and processed to remove dirt and rocks at Puna Sugar Mill. The material is then conveyed or otherwise loaded into a trash compactor. When a load of trash has been compacted it is automatically ejected onto a storage conveyor in line with the discharge end of the compactor. The storage conveyor holds the 25 ton compacted load of trash until it is transferred to a conveyor bottom trailer. The trailer is then hitched to and pulled by a diesel highway truck tractor to the park for drying and cubing.

The cost of the compaction equipment at the Puna Sugar Mill site will be about \$68,000, with the station requiring 115 hp to operate the compactor and related conveying equipment. Additional equipment needed at the Puna Sugar Mill is estimated to cost \$500,000.



**FIGURE 6.5 PELLETING SYSTEM FLOW DIAGRAM**  
 (with horizontal cooler)



## Dryer Plant

The dryer plant requires 72 MBTU/hr. to provide a 600°F drying temperature. Approximately half this requirement or 32 MBTU/hr. is provided by geothermal energy in an air preheater for the dryer furnace. The remaining 40 MBTU/hr. is produced by burning 1.5 tons of wood chips per hour, and 1.4 tons of process fines per hour. Wood chips cost \$30.00/ton delivered to Pahoa from ohia forest lands near Pahoa. Geothermal heat available at 375° can only provide part of the heat requirement of a 600°F dryer temperature. The estimated cost of the dryer plant and all related equipment as shown in Figure 6.4 will be approximately \$2,500,000.

## Transport System

It is estimated that the transport system for moving the compacted cane trash from the mill would require at least four conveyor bottom, module handling trailers transported by three Kenworth or equal diesel highway tractors with hydraulic power packs. The power packs would operate the transfer conveyors on the beds of the low bed transport trailers. The system will also require a diesel-wheel-type tractor to move the compacted loads of trash from the storage shed area on to the receiving and elevating conveyor system. The estimated cost of the highway transport system as outlined will be \$446,000 plus freight from the West Coast, estimated at 20%, for a total estimated cost of \$535,200.

## Plant Facilities

### Storage

A covered structure will be required to store the compacted leaf trash loads at the Pahoa dryer site due to the frequent rainfall in this area.

An open front 3-sided building 50' x 150' (7500 sq.ft.) with a 12'-0" eave height is suggested.

The estimated cost of this building would be \$85,000.

#### Mill Building

A mill building to house screening equipment is necessary with a primary product cooler, distribution conveyors, machinery supporting platforms, stairs and walkways, cubers, cube coolers and a baghouse including a fire sprinkler system. This building should have an eave height of 20' with a total area of (7,500 sq. ft.).

Estimated cost of this building would be \$150,000.

#### Cube Cooling

A finished cube cooling and storage building is needed for flat pile storage during the two week cooling period. The building must be sized to accommodate 60 tons per day. This would require a structure 100' x 300' (30,000 sq. ft.) with a 15 ft. eave height and a fire sprinkler system.

Estimated cost of this building would be \$450,000.

## OPERATIONAL REQUIREMENTS

### Employees

If that the leaf trash drying and cubing plant is located in the same general area as the ethanol plant and is operated by the same company, the same administration and maintenance forces as outlined for the ethanol plant could also be used to administer and maintain the trash drying and cubing plant. It is estimated that the plant could be operated by 5 persons per shift, for a total of 15 operators. The annual estimated cost of operation for the cattle feed processing plant with 15 full time employees is \$486,000.

### Truckdrivers

Four truck drivers per shift would be needed to operate the transport system. The annual estimated cost for these drivers is \$861,537.

## MARKETING

### Cattle Needs

Cattle must have fiber in their diets. The minimum level of fiber in the ration is 18% for dairy and 10-12% for beef. If there is a fiber deficiency, other nutrients are not effectively utilized, resulting in poor animal performance. The abnormal and inefficient animal metabolism caused by fiber deficiencies can be offset by including a sufficient fiber level in the ration. Feedstock with high fiber is important and the requirements can be met by including a minimum in the ration. In other words, if the ration requirement were 18% fiber, this level can be attained using much less material if the material used is high in fiber. Sugar cane by-products such as cane strippings contain approximately 44% fiber as

compared to high quality feeds such as alfalfa which contains from 20-28% fiber. Areas needing fiber to meet minimum requirements normally can use between three to five pounds of high-fiber materials such as cane strip-pings in the ration.

#### Physical Considerations of Feed

Since the products under consideration are being used to satisfy fiber requirements, the integrity of the fiber is critical. In processing, the product should be shredded instead of being cut. Length of fiber from four to five inches would be best. The product must be clean to be acceptable; and on a dry matter content, ash should be below 10%. A preferred quality criteria would be that the final product contain some green color, which has traditionally been used to indicate a succulent, actively growing starting material and the presence of carotene, a precursor of vitamin A. The product must also be dry, for ease of use, convenience of blending into the total ration, and for storing and shipping.

#### Market Potential

Hawaii imports from 25,000 to 35,000 tons of roughage each year to satisfy the needs of the dairy and beef industries. Cubed alfalfa is one of the items imported in large quantities along with such materials as almond hull, cottonseed hull and other high-fiber by-product feeds which basically provide fiber for the cattle in Hawaii. The State imports approximately one ton of roughage for each of the 12,000 dairy and 15,000 beef cattle on feed throughout the year. The market remains relatively constant despite attempts to develop feed and forage for livestock production in the State. Sugar and pineapple occupy the prime agricultural lands with only limited lands available for feed and forage production.

The beef and dairy farming businesses in Japan are facing difficult situations at the present time due to: (1) limited farm space, (2) low breeding rates, (3) high rates of metabolic diseases causing low productivity, and (4) severe shortage of roughage.

Dairy farmers and ranchers in Japan fully realize the necessity of feeding more roughage to their livestock. The substitution for the lack of it by feeding imported concentrates bearing a high production cost, even more important, having an adverse effect on the health, reproduction, and overall productivity of the herds. Past records show that various farmers' associations, prefectural governmental institutions, and livestock raisers have put a great deal of effort into up-grading the rate of self sufficiency in roughage. Recent data makes it clear that domestic self sufficiency in roughage is only 20% or possibly less in all areas of Japan, other than Hokkaido, the northern most island. Recent automation in harvesting rice has adversely affected the availability of rice straw as a roughage.

While the shortage mentioned in the foregoing paragraphs is to some extent being relieved by imports from the United States and the Peoples Republic of China, there is still a shortage of approximately 300,000 tons of roughage.

In summary:

1. Japan requires approximately 3,500,000 metric tons of forage to be self sufficient.
2. The shortage of roughage in Japan is estimated at 700,000 tons per year.
3. Sixty percent of this shortage, 420,000 metric tons, is made up by imported alfalfa.



4. Forty percent of this shortage, 280,000 metric tons, is to be made up of straw and other available roughages such as cane strippings.
5. Because of the agricultural automation in Japan, rice straw is in reduced supply.
6. Sugar by-products are gaining interests; Taiwan and the Philippines are shipping a limited supply of cane tops to Japan. This supply is very limited.
7. The pricing of intermediate quality forages in Japan will be approximately the mid-price between cubed alfalfa and rice straw.

In consideration of a market, one must consider both Hawaii and Japan in order to be able to sell sufficient volume to warrant the capital investment. The physical handling of the product, including cleaning, drying, compressing, transportation, as well as possibly physical and chemical modifications of the product requires a sizeable market in order to offer a satisfactory return on the necessary capital investment. Hawaii's market alone is insufficient.

The major feed and forage import statistics, by customs records for Japan, are shown in Table 6.6. Table 6.7 shows the composition and value of feeds imported into Japan. Imports of alfalfa meal, alfalfa cubes and beet pulp have increased greatly from 1977 to 1979. While at the same time, the imports of forage, including cane tops have decreased. Japan needs some intermediate to good quality roughages.

TABLE 6.6 - JAPAN IMPORTS: MAJOR FEED AND FORAGE STATISTICS BY CUSTOMS RECORD

Commodity	Origin	Imp-1977	Imp-1978	Imp-1979
Oats (Free)	Canada	1,606 MT	651 MT	3,530 MT
	U.S.A.	19,321	26,671	2,957
Wheat Bran Pellets	Canada	113,343 MT	85,115 MT	85,689 MT
	U.S.A.	1,924	—	10
G.S.P.	Canada	125,120 MT	140,820 MT	145,143 MT
	U.S.A.	38	16	10
Beet Pulp	Canada	4,963 MT	3,000 MT	7,294 MT
	U.S.A.	172,738	292,642	458,554
Rape Seed Meal	Canada	1,573 MT	—	1,648 MT
Alfalfa Meal Pellets	Canada	138,409 MT	175,526 MT	203,363 MT
	U.S.A.	121,989	120,840	119,174
Alfalfa Cubes (Including Ipil-Ipil)	Canada	1,100 MT	808 MT	14,752 MT
	U.S.A.	137,183	193,465	276,604
	China	—	1,287	2,995
	Taiwan	—	—	2,071
	Philippines	1,344	232	20
Alfalfa Bales	Canada	—	—	465 MT
	U.S.A.	27,648 MT	44,843 MT	53,086
	China	23,681	11,590	25,373
	Taiwan	51	446	589
	Philippines	2,328	853	889
Forage (Including Cane Tops)	China	60,211 MT		
	Taiwan	14,447		
	Philippines	9,061		
	Thailand	1,946		

	Crude Protein	Crude Fiber	Crude Fat	Crude Ash	TDN	DCP	@/UG
Pineapple Cubes (Hawaii)	7.5	24.5	4.0	---	----	----	\$220 (55)
Guinea/Cane Strippings (Hawaii)	3.6	37.6	0.8	---	----	----	\$212 (53)
Cane Stripping (Hawaii)	2.2	40.6	0.4	---	----	----	\$204 (51)
Guinea Grass (Hawaii)	4.7	38.5	1.3	10.0	46.2	----	\$232 (58)
Cane Tops (Taiwan)	6.0	27.0	1.9	7.1	50.4	4.2	\$220 (55)
Cane Tops (Philippines)	9.7	28.7	3.5	7.3	52.0	4.5	\$220 (55)
Napier Grass (Philippines)	13.12	27.6	4.0	10.6	----	----	----
Ipil-Ipil Pellets (Philippines)	26.0	10.1	5.8	8.6	----	----	----
Alfalfa Hay	14.0	34.6	1.7	8.2	50.0	10.3	\$276 (69)
Alfalfa Dehydrated Pellets	17.0 Min.	25.0	3.3	9.5	53.9	12.7	\$208 (52)
Alfalfa Hay Cubes	17.0 Min.	28.0 Max.	1.7	7.9	53.4	10.3	\$252 (63)
Sudan Grass	12.0	29.2	0.7	12.3	51.8	5.5	\$260 (65)
Cutting Clover (China)	14.3	25.4	2.5	7.3	49.0	10.3	\$228 (57)
Pineapple Meal Pellets	5.6	18.3	1.1	5.0	68.1	----	\$200 (50)
Beet Pulp	9.1	19.0	0.6	3.6	67.2	4.3	\$240 (60)
Soybean Meal	45.8	4.8	1.4	5.8	75.3	42.1	\$332 (83)
Rice Straw	4.2	28.6	1.7	15.4	37.8	----	----
Copra Meal	21.8	7.6	8.5	5.3	70.4	17.5	\$260 (65)

TABLE 6.7 COMPOSITION AND VALUE OF FEEDS IMPORTED INTO JAPAN

FINANCIAL ANALYSIS - CATTLE FEED MILL

ASSUMPTIONS:

Operate:	24 hrs./day, 300 days/year	
Investment:	Compaction Equipment	\$ 68,000
	Puna Sugar Mill Alterations	1,000,000
	Transport System	535,200
	Dryer Plant	2,500,000
	Storage	85,000
	Mill Building	150,000
	Cube Cooling Building	450,000
	Design, Engineering, Construction Management Costs (12% of Construction Costs)	<u>574,584</u>
	Sub Total	\$5,362,784
	15% Contingency	804,418
	<b>TOTAL INVESTMENT</b>	<u>\$6,167,202</u>

Revenue:	Selling Price \$120/ton @ 72,000 tons/yr.	
	<b>TOTAL REVENUE</b>	\$8,640,000

Operating Expenses:	Geothermal (25 MBTU/hr. x 24 hrs. x 300 days x \$2.67 MBTU)	\$ 480,000
	Wood Chips (2.5 tons/hr. x 24 hrs. x 300 days x \$30/ton)	540,000
	Electricity (992 Kw/hr. x 24 hrs. x 300 days x \$.08/kwh)	571,392
	Sugar Cane Leaf Trash (25 tons/hr. x 24 hrs. x 300 days x \$30/ton)	5,400,000
	Land Purchase	36,000
	Operators (15 x \$13.50/hr. x 8 hr./shifts x 300 days)	486,000
	Truck Drivers (12 x \$29.91 x 8 hr./shifts x 300 days)	<u>861,538</u>
	<b>TOTAL OPERATING EXPENSES (YEAR 1)</b>	\$8,375,530

Escalation:	8% year
Investment Tax Credit:	10%
Tax Depreciation:	13.5 years - Double Declining Balance Zero Salvage
Tax Rate:	50%

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<u>End of Year</u>	<u>Investment and other Cash Flow</u>	<u>Profit before Depreciation &amp; Income Tax</u>	<u>Depreciation for Tax Purposes</u>	<u>Taxable Income</u>	<u>Tax</u>	<u>Income after Tax</u>	<u>Total Cash Flow</u>
0	(6167)						(6167)
1	617	294	914	(620)	(310)	(310)	1221
2		318	778	(460)	(230)	(230)	548
3		343	663	(320)	(160)	(160)	503
4		370	565	(195)	(98)	(97)	468
5		400	481	(81)	(41)	(40)	441
6		432	410	22	11	11	421
7		467	349	118	59	59	408
8		504	309	195	98	97	406
9		544	309	235	118	117	426
10		588	309	279	140	139	448
11		635	309	326	163	163	472
12		686	309	377	189	188	497
13		740	309	431	216	215	524
14		800	153	647	324	323	476
15		864		864	432	432	432
16		933		933	467	466	466
17		1007		1007	504	503	503
18		1088		1088	544	544	544
19		1175		1175	588	587	587
20		1269		1269	635	634	634
21		1370		1370	685	685	685
22		1480		1480	740	740	740
23		1598		1598	799	799	799
24		1726		1726	863	863	863
25		1864		1864	932	932	932

Financial Summary

IRR: 7.75%  
 PV(10%): (1003)  
 (12%): (1666)  
 (15%): (2392)

Table 6.8  
 CATTLE FEED MILL  
 FINANCIAL ANALYSIS (\$000)

## Cattle Feed Mill Summary and Conclusion

The after tax discounted cash flow rate of return of 7.75% is too low. Further evaluation is necessary to refine the costs. One particular uncertain item is the cost of transportation to Japan. A conservative figure of \$40.00/ton is assumed.

There are also uncertainties about the ability to penetrate the Hawaii feedlot and dairy industries. Recent information indicates that guinea grass produced on Molokai can be delivered to the feedlot for \$58.00/ton. Feedlot operators advise that quality and price must compete with that \$58.00 price. This is impossible using the proposed feedstock and process selected for the cattle feed mill.

Therefore, the Japanese export market appears to be more attractive for the product from the proposed mill. However, the transportation cost for delivery in Yokohama and a long term sales agreement would be required.

Most significantly for this study, the economies that result from the use of geothermal steam are not large enough to be the determinant in the success of a cattle feed mill.

At this time, it does not appear feasible to further consider a cattle feed mill for the Pahoehoe commercial park.

## PART C: PAPAYA PROCESSING

### Introduction

This analysis concerns the feasibility of locating a papaya processing and/or fresh packing facility in a geothermal industrial park at Pahoā. Because over 75% of the State's production of papaya is located in the Pahoā area of the Big Island and because the papaya industry expansion can benefit the residents of lower Puna considerably more than other potential industries, the study effort concerning papaya was extensive.

The analysis reviewed the following:

- Market potential for papaya
- Product characteristic, channels of distribution, promotion strategy and pricing strategy
- Current papaya industry trends and problems
- Supply projections for fresh and processed papaya
- Processing and packing technology

Financial plans for the following proposed alternatives were developed:

1. Fresh packing only.
2. Puree processing only.
3. Dry processing only.
4. Fresh packing and puree processing integrated.
5. Fresh packing and dry processing integrated.
6. Fresh packing, puree processing and dry processing integrated.

### I - THE HAWAIIAN PAPAYA INDUSTRY

#### Overview

In 1978, the State of Hawaii produced approximately 14,849,000 pounds of fresh papaya. This represented a value of \$9,510,000 or 2.7%<sup>1</sup> of the

value of all Hawaii crops. As a crop, papaya ranked 4th in production, behind sugar, pineapple and macadamia nuts.

In 1979, extreme temperature variations, severe rainstorms, and flash flooding damaged many acres of papaya trees and enhanced disease in many more. As a result only 10,189,000 pounds of fresh papaya was produced in 1979.<sup>2</sup> The industry is still recovering from this set-back and is not expected to attain the 1979 levels of production until 1981. The Papaya Administrative Committee (PAC)\* projects the production, marketing and prices of fresh papaya. Their projection of papaya to be sold at the fresh produce section of supermarkets is shown below.

<u>Year</u>	<u>Total Fresh Production (in millions of pounds)</u>	<u>Farm Price (¢ per lb.)</u>
1978	54.6	14.4
1979	**35.0	27.0
1980	57.0	17.5
1981	65.0	19.0
1982	70.0	21.0
1983	75.0	23.0
1984	80.0	25.0

In May, 1980 the state's total acreage in papaya crop was 2975 acres as compared to the 1979 high of 3,245.<sup>3</sup> The center of the papaya industry resides in the Puna district of the Island of Hawaii and maintains 75% of the state's productive capacity. This relationship is expected to continue

\* Local private agency responsible for papaya market development

\*\* Setback due to severe weather conditions and temperature variations.



since Maui's Princess Orchards operation is phasing out and Oahu's orchards are used mainly for supplying the Oahu market. Kauai is rapidly developing a papaya industry, however the Island of Hawaii is expected to continue producing 75% of the State's papaya crop.

## II - PAPAYA PRODUCTS AND THEIR MARKETS

### The Market

This analysis concerns itself with three types of products: Fresh papaya, papaya puree and dried papaya. At present, only fresh and puree papaya have a significant market. In 1975 approximately 41 million pounds of fresh papaya were packed and marketed, while over 2 million pounds of puree were processed from sub-standard papaya and marketed.

Due to the lack of market information on fresh and dried fruits from abroad and the established market in Hawaii, this study will only concentrate on the potential mainland U.S. market.

As shown below, the per capita consumption of noncitrus, fresh fruit in the U.S., has generally been increasing since 1975:<sup>4</sup>

TABLE 6.9 - FRESH FRUIT CONSUMPTION IN THE U.S.

<u>YEAR</u>	<u>PER CAPITA POUNDS OF DRIED FRUIT</u>	<u>PER CAPITA POUNDS OF FRESH NONCITRUS</u>	<u>PER CAPITA POUNDS OF FRESH CITRUS</u>	<u>PER CAPITA POUNDS OF CANNED &amp; FROZEN FRUIT JUICES</u>
1960	3.1	57.5	32.5	24.2
1970	2.7	51.2	28.1	29.1
1973	2.6	47.3	26.9	32.4
1975	3.0	52.6	28.7	34.5
1976	2.6	55.2	28.5	34.6
1977	2.5	54.4	25.2	33.2
1978	2.0	55.3	26.3	34.0
1979	2.3	56.2	24.3	35.7

Dried fruit consumption has generally decreased since 1960, but has recently demonstrated a positive trend.

The reasons for the increase in fruit product consumption per capita, and in total dollars of production, is due to changes in the values and attitudes of consumers. Essentially, these trends are as follows:<sup>5</sup>

1. There is a trend toward increased total family income and smaller households which increases family disposable and discretionary income.
2. Households are generally younger and willing to try new things, such as eating ethnic type foods.
3. People are eating out more. Eating away from home is up 50% per capita, and restaurant sales account for about 35% of this increase.
4. People are losing their "sweet tooth" and becoming more nutrition conscious. A recent survey by Women's Day Magazine indicated that 71% of their women respondents said that nutrition was their primary concern when planning meals. 77% of those surveyed indicated that this interest in nutrition had mushroomed within the last few years.

These favorable demands and attitude trends indicate an opportunity for the papaya industry to expand to new markets. Papaya is considered an exceptionally nutritious food with seven ounces of papaya containing approximately 3,500 units of Vitamin A and 80 calories.<sup>6</sup>

#### Papaya Product Characteristics

The primary product of the papaya industry is the fruit sold fresh to the retail consumer through grocers and restaurants. These papayas provide the grower with most of his income, an average of \$0.2 - \$0.3 per pound. The puree and dried papaya must be considered by-products of the industry since it only provides the farmer with an average of \$.03/lb.

#### Fresh Papaya

The Papaya Administrative Committee establishes quality standards for the marketing of fresh papaya. These standards, to some degree, determine

the proportion of total production available for the fresh and process markets. Some lowering of standards occur during times of short supply with elevating of standards occurring during times of surplus production. In the fresh fruit market, quality standards are essential and some control is needed. The control currently provided by USDA inspectors is expected to continue.

#### Papaya Puree

The market for canned fruit nectar is expanding rapidly as people turn from sweet sodas to more natural and healthy fruit juices. Companies such as Kerns and Meadow Gold\* have demonstrated the ability to market the nectars of exotic fruits as well as common juices.

Although canned fruit juices have had more success in comparison to frozen puree, some prospects of concentrated products appear encouraging. The "aseptic" process of producing nectars allows a company to package individual cans that can be stored at room temperature. Since much of the world does not use frozen foods regularly, this new process provides a significant advantage over frozen juices.

#### Dried Papaya

A very limited quantity of dried papaya is presently sold in health food stores included in "trail mixes".

A new process called the "deBevec process", is said to be able to produce large quantities of dried fruit that is essentially the same size and shape as its input and tastes very similar to fresh.

\* Meadow Gold is the local producer/distributor of dairy/dairy products and processed juices. Kerns is a nationally reputable firm involved in canned fruit juices.

If these product characteristics are accurate, dried papaya can become an alternative use for sub-standard papaya. This product could be sold as a health food or snack which is distributed in bulk to another processor or packaged for final consumption.

Dried fruits and nuts are among the most common and best selling areas of many supermarket chains.<sup>7</sup> Some authorities estimate this segment is growing at 6% a year - twice that of other grocery products.<sup>8</sup>

This study will assume the characteristic of the dried papaya as indicated and further assume it will be packaged in bulk and sold to others for further packaging and mixing. Continuous product development effort must be provided in the business plans of any organization incorporating this new process.

#### Product Positioning

Orange juice, grapefruit and other breakfast fruit and juices are papaya's most direct competition. Consumers tend to consider papaya a breakfast fruit. Therefore an effective marketing plan should emphasize the versatility of the fruit.

Fresh papaya may be positioned as a low calorie dessert. Similarly, the fresh and dried papaya may be considered a nutritious and healthful snack. The puree may be developed as the base for all-day, refreshing and healthful drink as well as a base for use in cakes, yogurts and ice cream.

In summary, the industry should promote papaya products as a nutritious, healthful and natural food that can be used with any meal or as a between meal refreshment and snack.

## Channels of Distribution

### Channel Members

At present, papaya packers sell 75% of their production directly to retailers or through a major marketing arm. These marketing arms may be organizations closely associated with the packers such as Mr. Papaya's Puna Processors or totally independent such as Puna Papaya's Californian Avocado Cooperative (Calavo).

Restaurants also provide a potential market for fresh papaya and papaya puree. While this channel of distribution may not provide the volume of other channels, it can serve to introduce new customers to the products. This trend, coupled with a promotion effort that cooperates with restaurant chains can develop a whole new market (restaurants) as well as stimulate demand in the grocery channels.

### Physical Distribution

At present, the U.S. Mainland is the largest volume market for papaya. The major U.S. destination points for fresh papaya are listed below in the order of the quantities received:

1. Los Angeles
2. San Francisco
3. Seattle
4. Portland
5. New York
6. Chicago
7. Detroit
8. Minneapolis
9. Boston
10. Washington, D.C.

Other major markets include Japan and Canada (Toronto and Vancouver).

Markets outside the United States appear "timely" for development. Many countries around the world are following trends similar to those in

the U.S., and thus creative marketing and product development strategy could open these new opportunities. This analysis concentrates on marketing papaya to the U.S. as marketing to foreign countries involves factors beyond the scope of this study.

The uncertain availability of overseas transportation coupled with high transportation costs are definite concerns of the papaya industry in Hawaii County. The basic transportation alternatives for the Island of Hawaii to points within the United States are shown in Table 6.10.

TABLE 6.10  
Transportation Alternatives for Fresh Papaya

Transportation Alternatives	No. of Days in Transit	Cost Per Pound	Damage Rate	Trans. Cost Per Usable Pound	Damage Cost Per Usable Pound	Total Cost Per Usable Pound
<u>Air</u>						
United Hilo-L.A.	1	15.4¢	2.5%	16.2¢	0.9¢	17.1¢
DHL-Continental						
Weekday	2	13.5¢	5%	14.2¢	1.8¢	
Weekend	2	11.4¢	5%	12.0¢	1.8¢	13.8¢
<u>Surface</u>						
Matson						
Hilo-L.A.	7-10	2.4¢	20%	3¢	8.7¢	11.7¢

The surface route is the lowest cost alternative when 1/4 ripe fruit is shipped. Papayas are usually transhipped via L.A. to eastern destinations. When speed is important or when 1/2 - 3/4 ripe fruit is shipped, air transport must be used. Products such as papaya are normally shipped FOB - Destination. The processor will have to absorb the cost of transportation and the cost of inventory while in shipment.

Most of the fresh papaya reaches restaurants and grocers close to major air transportation centers.

The alternative transportation forms, along with their approximate cost per pound for puree or dried papaya, are as follows:

Air:

United (Hilo-Los Angeles)	13.9
Continental DHL (Hilo-Honolulu-Los Angeles)	12.5¢

Surface:

Matson (Hilo-Los Angeles)	2.2¢
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Prices

Prices of fresh papaya vary considerably from year to year and seasonally. Much of this variation is due to the total supply of fresh fruit in the market. Farm prices of fresh papaya shipped to the Mainland varied from 13.2¢ per pound in November 1979 to 35¢ per pound in May 1979. In 1980, the price received by the packers has varied similarly to the farm price and averages about 40¢ per pound.

Much of the price variation can be reduced through effectively matching supply with demand. In times of excess supply relative to established market demand, firms in the industry can:

1. Channel fresh fruit to market development areas for special promotions with retailers.
2. Channel some fresh fruit to the production of puree and dried papaya. In this way, excess papaya can be stored in another form. When demand is high, channel less into the by-product and sell off the stored inventory.

The prices of all papaya products may also be stabilized through proper product positioning. By developing a papaya products image of a nutritious, healthful and exotic fruit, it becomes more compatible with the attitudes and desires of the current market.

Dried and pureed papaya have less price fluctuations due to their long storage capability. Pureed papaya is now selling at \$0.28 per pound, FOB-Destination. Negotiations for better terms should be possible as the market for all papaya products increase. The current retail price of dried fruit ranges between \$1.59 to \$4.00 per pound bulk. The price to a wholesaler is estimated to be \$1.75 per pound in bulk FOB-Destination.

### III - CURRENT AND POTENTIAL SUPPLY OF PAPAYA PRODUCTS

In 1978, the industry's peak year of production, over 83 million pounds of papaya were produced with approximately 5% being unusable. Approximately 54 million pounds were sold as fresh papaya, 9 million pounds were used in puree production and over 15 million pounds were not sold by the farmer. The 1978 yield per acre was 29,200 pounds.

The papaya industry controls approximately 2900 acres on the Island of Hawaii. This represents a potential yield of over 80 million pounds of papaya. Another 10-20 million pounds could be produced on neighboring islands. This represents the short-run potential.

Additional land is available in the Puna District for papaya production. The State of Hawaii has approximately 1080 acres of land



available for lease that could be used. Additionally, the Hawaiian Homes Commission\* and private individuals have acreage not otherwise being used. The State's acreage alone represents a potential 30 million pounds of papaya.

The market requires further development before the farmers will expand and increase production. Growers are cautious because it costs \$1200 to \$2000 an acre to prepare new land for planting.

To compete in the market for puree and dried papaya, low cost sources of papaya are necessary. Because of the low price paid to farmers for their "culled" papaya, the pureed and dried papaya should be considered a by-product of fresh papaya production. Current research is being performed to develop a low cost, large "melon-type" papaya for processing purposes.

#### Fresh Papaya Packing

There are five major papaya packing and processing companies in Hawaii. These firms, along with the number of acres papaya production and the total number of acres available for production are as follows:

Company	Total Acres Available	% of Total	Total Acres in Production	% of Total
Puna Papaya	1255	43%	666	36%
Mr. Papaya	750	26	500	31
Ono Pac	400	14	300	16
Diamond Head	300	10	160	9
Del Monte	200	7	150	8
Total	2905	100%	1776	100%

These figures provide an indication of the potential supply of papaya available to each packer at the present time.

\* A local organization with large land holdings.

Based upon current acreage and a five year projection, it is possible to distribute the Papaya Administrative Committee's supply projections among the local packers (Table 6.11). These supply projections are shown in Table 6.12.

The supply projections are based on a 8-10% annual growth rate. Until it is demonstrated that aggressive marketing effort can effectively stimulate demand for papaya at a profitable price, these projections should be used as a guide for farmers.

TABLE 6.11  
FRESH PAPAYA PRODUCTION, MARKETING, PRICES AND INCOME

1974 - 1984

(PRODUCTION IN MILLIONS OF POUNDS)

	Local	Exports			Total Fresh	Percent Exported	Fresh Farm Price (¢ per LB.)	Fresh Sales (Millions 0=\$)
		Foreign <sup>1</sup>	Mainland <sup>2</sup>	Total				
1974	13.1	3.0	18.5	21.5	34.5	62.3	13.9	\$ 4.0
1975	12.2	3.3	19.5	22.8	35.0	65.1	15.8	5.5
1976	12.7	3.9	27.0	30.9	43.6	70.9	13.5	5.9
1977	13.2	4.6	36.2	40.8	54.0	75.6	13.2	7.1
1978	14.8	7.1	33.7	39.8	54.6	72.9	14.4	7.9
1979*	10.5	5.5	19.0	24.5	35.0	70.0	27.0	9.4
1980*	14.5	9.5	33.0	42.5	57.0	74.6	17.5	10.0
1981*	15.0	12.0	38.0	50.0	65.0	76.9	19.0	12.5
1982*	15.5	14.0	40.5	54.5	70.0	77.9	21.0	15.0
1983*	16.0	16.0	43.0	59.0	75.0	78.9	23.0	17.0
1984*	16.5	18.0	45.5	63.5	80.0	79.4	25.0	20.0

\* 1979 - 1984 Estimated

1/ Includes direct sales to Japan, Canada and other foreign destinations.

2/ Includes direct sales to Canada.

Source: Papaya Administrative Committee

TABLE 6.12

PAPAYA INDUSTRY SUPPLY PROJECTIONS 1980-1985

	Hawaii County Distribution				
	State Total	Hawaii County	AMFAC Puna	Mr. Papaya coop	All Other
% acres under harvest in 1980		100% (1836)	36%	31%	33%
<b>1980 Projection</b>					
Fresh	57.00	42.75	15.39	13.25	14.11
Process	26.31	19.73	7.10	6.12	6.51
Total Usable	<u>83.31</u>	<u>62.48</u>	<u>22.49</u>	<u>19.37</u>	<u>20.62</u>
<b>1981 Projection</b>					
Fresh	65.00	48.75	18.23	14.63	15.90
Process	30.00	22.50	8.42	6.75	7.33
Total Usable	<u>95.00</u>	<u>71.25</u>	<u>26.65</u>	<u>21.38</u>	<u>23.23</u>
<b>1982 Projection</b>					
Fresh	70.00	52.50	20.37	15.23	16.90
Process	32.31	24.23	9.40	7.02	7.81
Total Usable	<u>102.31</u>	<u>76.73</u>	<u>29.77</u>	<u>22.25</u>	<u>24.71</u>
<b>1983 Projection</b>					
Fresh	75.00	56.25	22.61	15.75	17.89
Process	34.62	25.97	10.44	7.27	8.26
Total Usable	<u>109.62</u>	<u>82.22</u>	<u>33.05</u>	<u>23.02</u>	<u>26.15</u>
<b>1984 Projection</b>					
Fresh	80.00	60.00	24.96	16.20	18.84
Process	36.92	27.69	11.52	7.48	8.69
Total Usable	<u>116.92</u>	<u>87.69</u>	<u>36.48</u>	<u>23.68</u>	<u>27.53</u>
<b>1985 Projection</b>					
Fresh	87.00	65.25	28.06	16.97	20.23
Process	40.15	30.11	12.95	7.83	9.33
Total Usable	<u>127.15</u>	<u>95.36</u>	<u>41.01</u>	<u>24.80</u>	<u>29.56</u>
% Acres available for production in 1985		100% (2905)	43%	26%	31%

#### IV - PAPAYA PROCESSING

Presently, there are three major companies in Hilo, Hawaii making puree, Puna Papaya, Suisan Fruit Processing and Hawaiian Fruit Flavors. Puna Papaya deals solely with papaya while the others process guava and passion fruit as well. The island of Hawaii's total papaya puree production is estimated at 5000 to 6000 pounds per day.

In 1980, the Island of Hawaii should have almost 20 million pounds of papaya available for processing. This represents approximately 9 million pounds of potential puree. By 1985, over 30 million pounds of papaya or 13.5 million pounds of puree could be available.

La Malo'o, a new papaya drying operation, produces approximately 500 lbs. of dried papaya a month using an experimental solar heat process. The product is good, a bit sticky and tastes like apricots. Assuming 10 million pounds of papaya were available for processing using the deBevec technique, it is estimated that approximately 800,000 pounds of dried papaya would result.

Because the supplies of processed papaya products are closely tied to the fresh papaya market, coordination of demand and supply is required to make an integrated packing processing operation profitable.

#### PROCESSING TECHNOLOGY

The proposed papaya processing plant at the geothermal industrial park would utilize the papaya industry's current engineering and technology for both fresh and puree processing. The deBevec dehydration process for dried papaya is a relatively new process developed in Nevada.

### Fresh Papaya Packing

The papaya reaches the packing plant in field boxes. These boxes are dipped in 120°F water for 10 minutes to kill any larvae on the skin. The boxes are then sprayed with cold water to prevent overheating the fruit. After heat treatment, the papaya is fumigated with methol bromide and is ready for packing.

In the packing plant, papaya is sorted according to ripeness and size and packed into different size boxes for shipment. Packed boxes are refrigerated until shipment.

### Puree Processing

A typical puree processing plant washes the papaya before putting it through a slicer. The sliced papaya are then mashed and seeds and skin are separated from the pulp through a rotating sieving system. The juice is then chilled and the ph of the juice is adjusted accordingly. The chilled juice is packed in plastic bags or drums for shipment. A disadvantage of this method of processing is that refrigeration of the juice is required throughout the distribution process.

The new aseptic process is proposed for the geothermal industrial park. (See Figure 6.6). In this process the juice is heated to 205°F for a set time and quickly chilled to 80°F and packed under sterile conditions in containers. The advantage of this process is that refrigeration of the finished product is not required. Puna Papaya, Inc. has tried a batch of this process and their experience has been that the juice kept extremely well and no difference in taste was detected after 3 months. They are currently testing for longer shelf life. No results have been reported to date.

The recovery rate of the puree is approximately 45% of the input culled papaya by weight.

#### Papaya Drying Process

The papaya drying process (deBevec process) utilizes a special drying technique which has not been proven on a commercial size scale. In such a plant, the fruit would be halved and deseeded with chunks of the fruit being removed. The drying process requires heat of approximately 140 to 150°F. Part of the process is accomplished in a vacuum with a vegetable oil media.

It is assumed that such a plant would produce 500 lbs. per hour of dried output utilizing processing machinery costing approximately \$500,000. Over 40% of the culled papaya is usable and the finished product is 20% of the usable papaya.

#### Integrated Plant

Figure 6.6 shows a schematic for a 3-process integrated plant. The main advantage of the plant is the shared functions of receiving, shipping and sorting.

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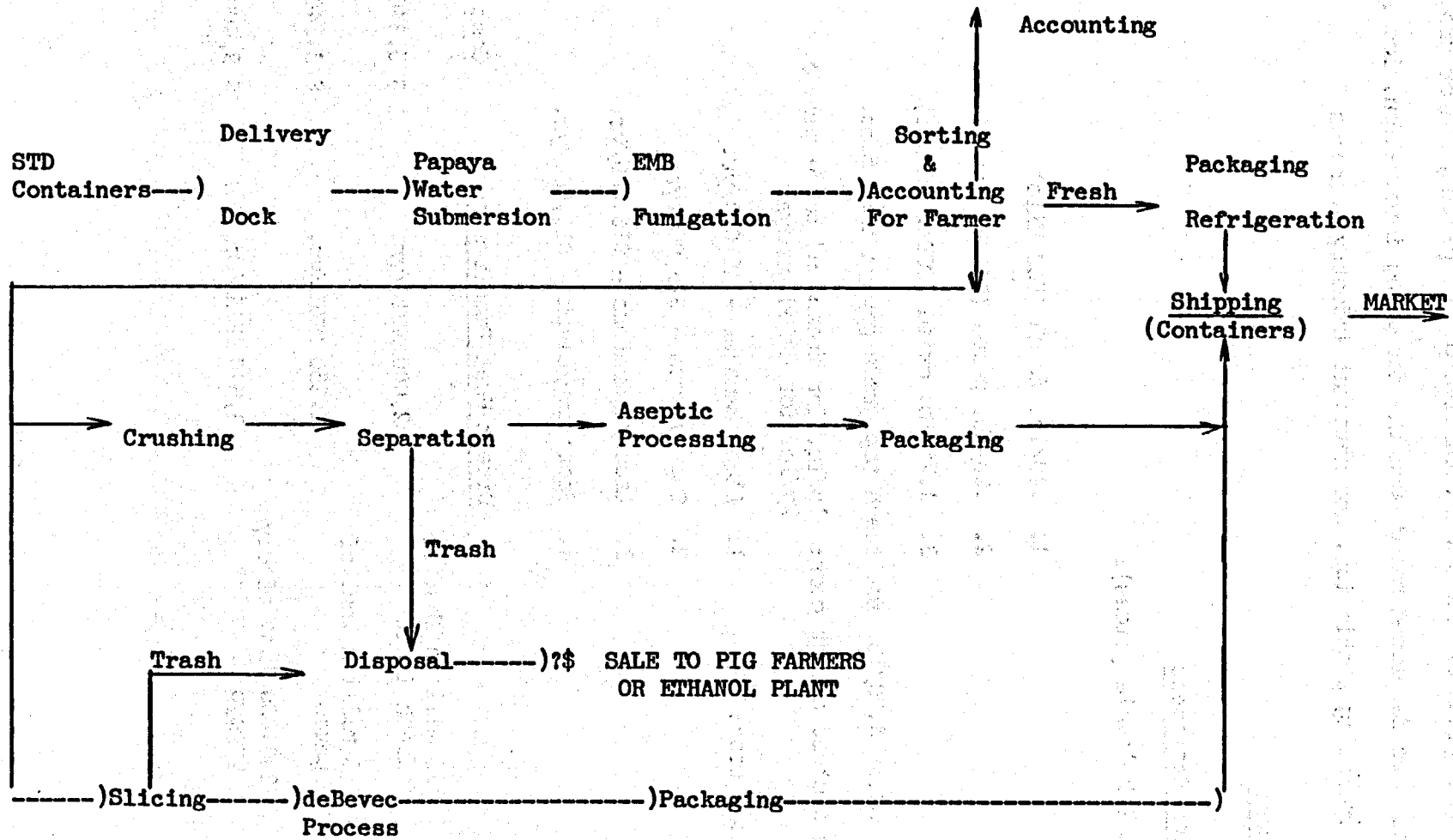


Figure 6.6 INTEGRATED PLANT PROCESS SCHEMATIC

## V - FINANCIAL PLANS

Financial plans of the six alternative papaya packing and/or processing facilities were developed based upon the foregoing information, local industry operating statistics, and national industry averages.

### Assumptions:

#### Income Statement

Net sales (wholesale prices):

1. .40/lb. fresh (FOB Hilo)
2. .28/lb. puree (FOB W. Coast)
3. 1.75/lb. dried (FOB W. Coast)

Cost of Goods: \$.20/lb. for fresh top grade papaya from farm.

Packaging & other direct cost: 1¢/lb. for fresh and puree papaya.  
2¢/lb. for dried papaya.

Direct labor cost:

1. Plant Manager - 40,000/yr.
2. Supervisors - \$25,000/yr.
3. Labor/operators - \$16,000/yr.
4. Secretary/clerk - \$16,000/yr.

Energy:

	<u>Direct Heat Requirement</u>	<u>Cost</u>
13 million lbs. of fresh fruit	2,000 MBTU/yr.	\$ 5,340
5 million lbs. of puree	1,250 MBTU/yr.	\$ 3,340
880,000 lbs. of dry papaya	3,520 MBTU/yr.	\$ 9,400



Insurance, fees, taxes, and inspection: 2.5% of sales.

Royalties: 5¢/lb. of dried (deBevec process only).

Land purchase: \$12,000/acre

Cost of production: 1 - 1.5% of sales.

Depreciation: 20 yr. straight line.

Shipping & receiving cost: \$68,000/yr. including personal supplies & equipment.

Sales & advertising: 5% of sales

Transportation: 1¢/lb. - local      2.2¢/lb. - overseas

Market & product development cost: 2.5% of sales

Interest rate: 12% - long term

Miscellaneous sales and administrative expense: 2% of sales

Other income: Unusable portions of papaya sold to ethanol plant as feedstock for \$25/ton.

#### Papaya Processing Plant Site Area Requirements and Elements

The basic papaya processing plant conceptual site layout is shown on Figure 6.7. The overall dimensions of the plant site are 520' x 280' or 145,600 square feet, which equals 3.3 acres. This initial plant area size contains sufficient area for expansion.

The site area includes the following major elements.

- Administration Building - containing offices, laboratory, lunch room, locker area, toilets and shower room. Total building area required is 3,600 square feet.
- Maintenance/Storage Building - consisting of equipment, carpentry and electrical shops, spare parts storage, and operations and maintenance supplies and equipment. Total building area required

is 3,000 square feet. This is assumed to be a pre-engineered metal type building.

- Warehouse and Process Building - housing the three process lines and equipment; 2,800 square-foot freezer with 48,000-pound capacity and 15-ton refrigeration unit; storage/labeling/shipping area of 3,500 square feet; incoming fruit storage and sorting area of 3,500 square feet; a covered dock of 4,500 square feet for loading/unloading purposes; and a storage warehouse area of 8,000 square feet. This latter area would be available for process line expansion, if required. Total area covered by the warehouse building is 32,000 square feet.
- Truck, Employee and Maintenance Equipment Parking Areas.

All facilities within the plant area have been sited to provide an efficient flow from receipt and storage of the raw products through shipping of the finished products.

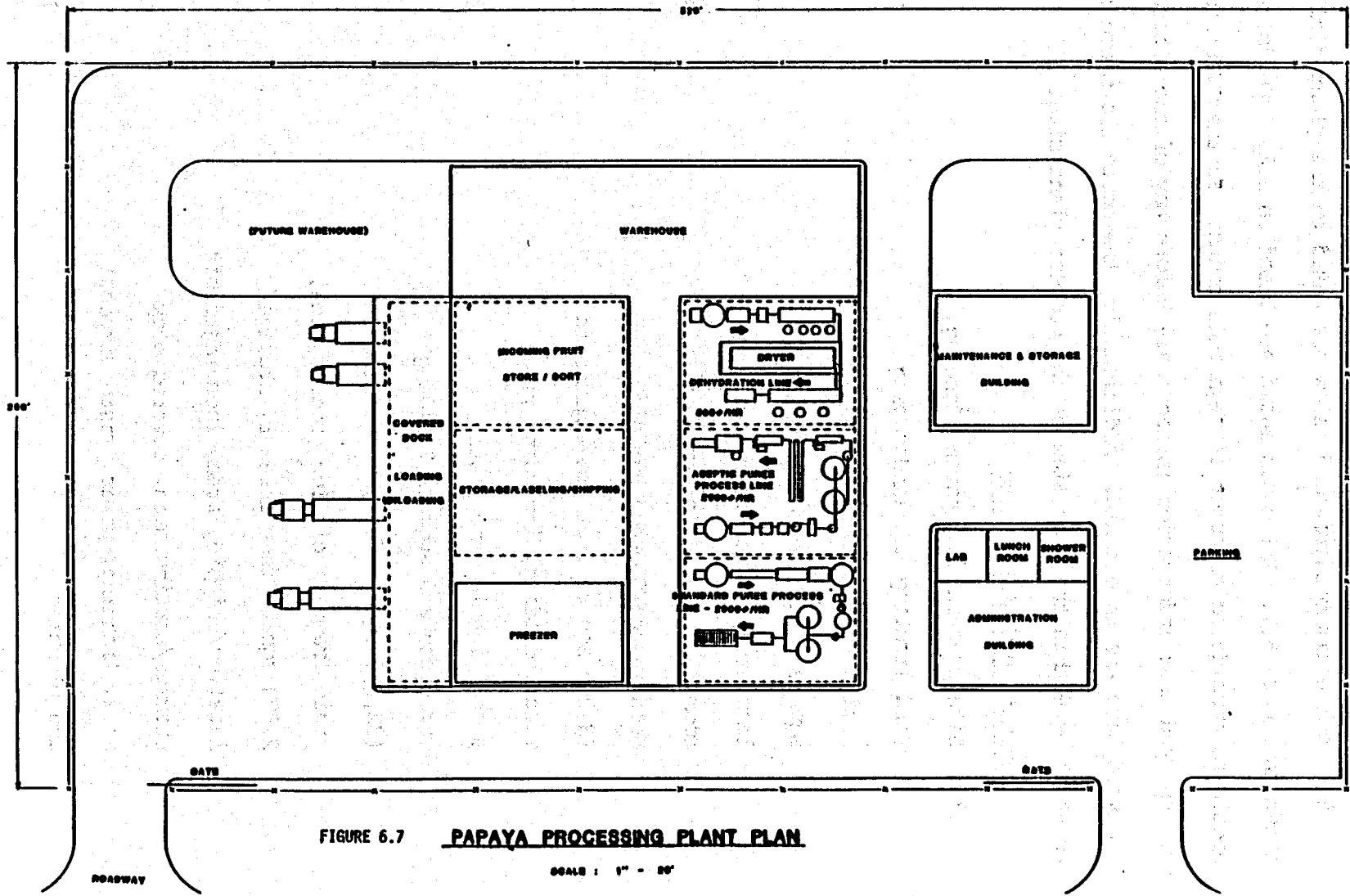


FIGURE 6.7 PAPAYA PROCESSING PLANT PLAN

SCALE: 1" = 20'

### Construction Costs and Annual Operations and Maintenance Cost Estimates

The cost estimates provided below are based on the plant facilities shown on Figure 6.7. All costs shown are based on July 1980 dollars and should be considered as order of magnitude costs. Further verification of revenue and cost information is necessary before any of the alternatives analyzed here are undertaken. Additionally, the costs shown are only for those items within the fenceline of the process plant site.

#### Construction Cost Estimate

- Site preparation, paving fencing,  
yard lighting and landscaping \$ 350,805
- Administration Building (3,600  
square feet) including offices,  
laboratory, lunch room, toilet  
room, shower and locker room \$ 337,920
- Maintenance/Storage Building  
(3,000 square feet pre-engineered  
metal building) including floor  
slab, lighting and power \$ 69,150
- Warehouse and Process Building  
(32,000 square feet, pre-engineered  
rigid frame) including process area,  
2,800 square feet freezer, storage/  
labeling/shipping area, incoming fruit  
storage/sorting area, covered dock  
area, lighting, power, waste disposal  
and plumbing \$1,030,825

• Water Supply Line, Drainage Structures, Electrical Supply Lines, Boiler and Air Compressor House	\$ 141,380
• Miscellaneous Items and Contingencies	\$ <u>193,020</u>
Subtotal Construction Costs	\$2,123,100
Design, Engineering and Construction Management (assume 12 percent of Construction Costs)	\$ <u>245,770</u>
Total Estimated Construction Costs	<u>\$2,368,870</u>

Annual Operations and Maintenance Costs

• Annual Personnel Costs	\$ 420,000
• Annual Maintenance Costs (one-half of one percent of total construction costs)	\$ 11,845
• Annual Operation Costs (5 percent of total equipment costs, estimated to be \$800,000)	\$ 40,000
• Annual Operations and Maintenance Costs	\$ <u>51,845</u>
Total Annual Personnel and O & M Costs	\$ 523,690

The personnel and O & M costs do not include the annual costs of geothermal fluids, electricity purchased, potable water, raw products, trucking O & M or personnel costs, taxes, insurance, royalties or process licensing fees.

## Plant Site Utility Requirements

The quantities listed below are based on the plant layout and facilities shown on Figure 6.7. Certain assumptions, based on available literature, have been made regarding process equipment utility requirements. Additionally, for the purposes of this study, it is assumed that the freezer unit would be a conventional freezer. Should geothermal fluids be used for freezer purposes, the quantity of steam required will be greater than that shown.

- Process steam - maximum flow required will be 1,100 pounds per hour at 5 psig, for a total annual requirement of  $35 \times 10^6$  pounds.
- Electrical power - maximum required for process equipment will be 100 KW per hour. Lighting and other miscellaneous items, such as office air conditioning, will require 40 KW per hour. Total annual requirements will be 650,000 KW.
- Water - maximum quantity required for process purposes will be 70 gallons per minute (GPM). Building requirements for showers, drinking purposes and sanitary sewage will be 15 GPM. Fire protection requirements will be 600 GPM, for a total annual requirement of  $13 \times 10^6$  gallons.
- Waste Water Streams - process waste water is estimated to be 70 GPM at a temperature of 70°F to 80°F and sanitary wastes are estimated to be 15 GPM. The only other waste water stream will be storm water runoff, which is estimated to be 30 cubic feet per second, based on the average ten-year storm.

## Atmospheric Emissions

Atmospheric emissions from the papaya processing plant are expected to be minimal since there are few potential sources. The nature and quantity of emissions from the process equipment cannot be stated with any degree of reliability at this time, since the various components are unknown. However, assuming there are either steamers for sterilization or other pressure vessels, atmospheric emissions from this equipment would indicate a malfunction of the equipment and remedial action would be taken immediately.

Indirect sources of atmospheric emissions will be vehicle emissions generated by delivery trucks and employee vehicles. The quantities of emissions are expected to be minimal and not adversely impact the industrial park area. However, total park vehicle emissions should be estimated once the total numbers of processes and vehicles are known.

Fugitive dust is not expected to present serious impacts since adequate plant area landscaping will help control dust. It has been estimated that the majority of the papaya processing plant site will be paved for parking or vehicle maneuvering, further decreasing the potential dust sources.

## VI - RISKS

Potential problems of the Hawaii Papaya Industry were summarized in a presentation to the Agriculture Coordination Committees for the State of Hawaii on March 21, 1979.

1. Lack of an economically acceptable alternative to EDB (ethylene dibromide) for fumigating papaya for export.
2. Inadequate air-lift for exporting papayas and for shipping papayas from Hawaii and Kauai to Oahu for transshipment to export markets.

3. Lack of adequate control measures for post-harvest diseases and the lack of full understanding and control measures for preventing the rapid deterioration of papayas after they arrive on the mainland.
4. Inadequate market development for fresh papaya and papaya products.
5. Papaya mosaic virus continuing to be a threat to the papaya industry.
6. Lack of adequate weed control.
7. Lack of continuity and reliability of supply.
8. Lack of freezing technology for papayas and inadequate information on aseptic packaging of papaya puree for overseas shipping.
9. Farmers unable to obtain the quantity and quality of people they need.
10. Methods to overcome the yield decline problem and the magnitude of the problem are not known.
11. Cultivators with resistance to papaya mosaic virus and fruit and root diseases are not available.
12. Lack of adequate control methods for powdery mildew.
13. Insufficient research on market potential and market development.
14. Insufficient information on what effect irrigation has on yield in Puna, Hawaii, and yield, fruit quality, fruit set, and sterility in Moloaa, Kauai.
15. Lack of adequate containers for surface shipments.
16. Lack of information on current costs, returns and profitability of papaya production.
17. Critical nutrient levels for trees up to 12 months of age and for trees over 30 months of age are not known. Minor and micro-element needs for trees older than 30 months are not known.
18. Overcoming apparent lack of understanding and specific information exchange between lenders and borrowers (farmers) on financing papaya farms.
19. Lack of adequate packaging and packaging systems for shipping papayas by air and surface.



20. Costs of ownership and operation of alternative mechanical harvesting methods for various-sized farms are not known.
21. Lack of effective, registered chemical to control mites in dry production areas.
22. Many public rules and regulations put unnecessary burden on farmers.

Even though the papaya industry in Hawaii has existed since the 1940's, it is still unsophisticated in production and marketing technology.

Other risk factors must also be evaluated. Some of these factors are included in Table 6.13. The integration of 3 processes reduces the risk attendant to any one process standing along. The fresh packing and puree processes have fewer associated uncertainties because such facilities already exist with proven technology and marketing channels.

Level of Risk or Uncertainty

Factors Affecting Risk	Fresh Only	Puree Only	Dry Only	Fresh & Puree	Fresh & Dry	Fresh, Dry & Puree
Dependence upon raw material supply	Medium	High	High	Low to Medium	Low to Medium	High
Production Technology	Low	Low to Medium	High	Low	Medium	Medium to High
Market Trends	Low	Low to Medium	Medium	Low	Low to Medium	Medium to High
Financial	Medium	High	Medium	Low to Medium	Low to Medium	High
Revenue Deviations	Medium	Low	Medium to High	Low to Medium	Medium to High	Medium to High
Cost Deviations	Low to Medium	Low to Medium	Medium to High	Low to Medium	Medium	Medium to High
Probability of Direct Competition	High	Medium	Low	Medium	Low to Medium	Low
Overall Risk	Low to Medium	Medium	Medium to High	Low to Medium	Low to Medium	High

Table 6.13  
RISK ASSESSMENT

Considerable uncertainties exist with the deBevec drying process. As more information becomes available, these uncertainties may be reduced. The study still recommends incorporating an integrated fresh packing and dry processing facility, provided additional information verifies the information utilized in this analysis.

## VII - CONCLUSIONS AND RECOMMENDATIONS

### Financial Evaluation

The objective of this report is to provide financial plans for the various alternative facilities. Table 6.14 evaluates the important financial statistics of each alternative relative to one another and relative to the industry averages. Fresh processing alone provides the best return. It is also obvious that additional returns can accrue to a firm that invests in processing papaya by-products such as dried or pureed fruit.

Those alternatives with lowest return on equity and cash-flow are the single puree and drying plants and the 3-process integrated plant. The return on assets of these facilities is quite low, indicating inadequate utilization of assets. While profit margins seem adequate or above industry averages, there will not be significant papaya (culls) available in the near future to provide a better operating volume. This is especially true in the case of the 3-process integrated plant that could efficiently process as much as 35 to 70 million pounds of papaya culls a year. This would require a fresh papaya market of 75 to 150 million pounds per year.

TABLE 6.14

## Alternative Facility

Financial Factors	Fresh Only	Puree Only	Dry Only	Fresh & Puree	Fresh & Dry	Fresh & Puree & Dry
Plant Utilization	Low to Medium	Very Low	Very Low	Low to Medium	Low	Very Low
Profit Margin	High	Medium	High	High	High	Medium
Leverage Flexibility	Medium	Low	Low	Medium to High	Medium to High	Low
Return on Equity	Very High	Low	Medium	High	Very High	Low
Cash Flow	Low to Medium	Very Low	Low	Low to Medium	Low Medium	Very Low
Resistance to Cycle & Seasonal Fluctuation	Low	Medium to High	Medium to High	Medium	Medium	Medium to High

To increase the ROA, these facilities must go outside the papaya industry and process other types of locally available fruit. Although there is considerable competition in the puree area, the guava and passion fruit industries are growing. The drying facility could also dry banana, coconut, pineapple and vegetables if sufficient supplies of these raw materials were available. As long as a profit margin exists, all additional production will assist in increasing the returns on equity and cash flows of all facilities processing papaya by-products.

The 3-process integrated facility, however, appears too large for the papaya industry at the present time. To arrive at a 13.5% return, the large facility would have to process over 34 million pounds of papaya to break even on the by-product processing. This low level of plant utilization would require that growers produce an additional 14 million pounds of papaya by its first year of operation. This would require approximately 1,000 acres of production, or an addition of 3-400 acres not presently

devoted to papaya. By 1985, more normal returns from this facility would exist assuming a 10% growth per year, or another 150 acres of production. At the present time, it is unreasonable to expect farmers to invest over \$1 million in land preparation without some guarantee of sales.

Of the two single by-product facilities, the drying operation offers the best potential. While the market channels for papaya puree have been developed, the profit margin is lower compared to the dried product. Since the drying facility produces a product that is unique within the industry, a more inelastic price will result allowing potentially larger margins. Also the potential for processing other fruits and vegetables is large. Alternative products, such as trail mixes, are also possible.

Additionally, this process provides for a different market for papaya products. While papaya puree has established markets, it also has the potential for greater competition among processors. The drying process is thus recommended over the puree process due to its future profit potential.

An integrated plant provides for cost savings from more efficient use of resources. Savings could be realized in the areas of transportation and sorting consolidation as well as administrative overhead. Additionally, an integrated facility provides the flexibility of directing papaya supplies to the most profitable output. In times of excess supply, more by-products may be produced and stored, for example. As noted in the 1985 projections, the returns on the drying and fresh facility are greater than the fresh alone. This return does not include some of the cost savings discussed or indicated in below.

POSSIBLE COST SAVINGS DUE TO SITE  
LOCATION AND INTEGRATION OF ACTIVITIES

Cost Items	Fresh Only	Puree Only	Dry Only	Fresh & Puree	Fresh & Dry	Fresh, Puree & Dry
Direct Heat	Medium	Low	High	Medium	High	High
Refrigeration/ Absorption	High	Medium	None	High	High	High
Electricity	Low	Low	Low	Low	Low	Low
Transportation Consolidation	High	Low	Low	High	High	High
Land/Building Lease Cost	Low	Low	Low	Low	Low	Low
Sorting Consolidation	High	Low	Low	High	High	High
Administrative Overhead	None	None	None	Medium	Medium	Low

Except for the cost savings identified, there is no particular reason for having a fresh facility in the Pahoa Industrial Park as opposed to anywhere else in the Hilo or Puna areas. Because of the scale of the operation, 10-20 million pounds a year, an existing packer moving to the site is the only viable alternative. The two packers of sufficient size and investment capabilities at present are Amfac's Puna Papaya and the growers' cooperative, Mr. Papaya. Although further study is needed, the cost savings of moving to a new facility would probably not be as large as the cost of moving. In the case of an integrated plant, however, the cost savings coupled with additional returns might be a significant inducement to move.

Provisional Ranking

Based upon the information presented and assumptions utilized, this analysis provisionally concludes that all alternative facilities except the 3-process integrated plant are viable options for inclusion in the conceptual

Pahoa Industrial Park. The dry processing with a fresh packing facility is ranked number one. The ranking of the alternatives is:

1. dry processing with fresh packing
2. dry processing only
3. puree processing with fresh packing
4. puree processing only
5. fresh packing only.

It will take an existing organization with sufficient capital and assurances of large supplies of papaya to implement the recommended plan. Some assistance may be found in the minority business program of the Small Business Administration.

Table 6.15  
COMPARISON OF PROCESSING ALTERNATIVES

PROFORMA INCOME STATEMENT 1980 Estimates (000)	FRESH ONLY	PUREE ONLY	DRY ONLY	FRESH AND PUREE	FRESH AND DRY	FRESH, DRY AND PUREE (Dry & Puree at breakeven Fresh at 17 mll lbs)
Net Sales	5200	1400	1540	6600	6740	8470
Cost of Goods Sold						
Direct Cost						
Raw Materials	2600	440	440	3040	3040	3908
Packaging & other	390	150	53	540	443	629
Labor:						
Supervision & Maintenance	50	50	50	50	50	100
Operations	160	38	63	192	224	320
Total Direct	3200	678	606	3822	3757	4957
Production Overhead						
Secretary/clerk/records	16	8	8	16	16	32
Energy and Utilities	80	10	50	90	130	160
Insurance, taxes, inspection fees (excludes Fed. taxes)	125	45	45	170	170	250
Royalties	-	-	44	-	44	24
Depreciation	140	80	100	213	235	395
Lease Cost	22	22	22	44	44	44
Other	40	20	20	50	60	100
Total Production Overhead	423	185	289	583	699	1005
Total Cost of Goods Sold	3623	863	895	4405	4456	5962
GROSS MARGIN	1577	537	645	2195	2284	2508
Sales and Administration						
Receiving and Shipping	50	30	42	68	68	90
Sales and Advertising	260	70	77	330	337	524
Market & Product Development	130	35	39	165	169	262
Transportation:						
Local	130	50	9	180	139	205
Overseas	-	110	20	110	20	77
Plant Manager	-	-	-	50	50	50
Misc.	104	28	31	132	135	200
Total Sales & Administration	674	323	218	1035	918	1408
OPERATING PROFIT	903	214	427	1160	1366	1100
INTEREST EXPENSE	218	123	154	331	364	603
PROFIT BEFORE TAXES	685	91	273	829	1002	497
Other Income Possibilities	70	67	125	67	125	100



PROFORMA BALANCE SHEET 1980 Estimates	FRESH ONLY	PUREE ONLY	DRY ONLY	FRESH AND PUREE	FRESH AND DRY	FRESH, DRY AND PUREE
<b>ASSETS</b>						
<b>Current Assets</b>						
Cash and Equivalent	60	45	35	105	95	140
Accounts Receivable	295	80	85	375	380	460
Inventory	85	185	215	270	300	485
Other	<u>160</u>	<u>55</u>	<u>15</u>	<u>215</u>	<u>175</u>	<u>230</u>
<b>Total Current Assets</b>	600	395	350	965	950	1315
<b>Fixed Assets:</b>						
Buildings	800	400	400	1150	1150	1600
Equipment	1900	1100	1500	2950	3350	6000
Other	<u>100</u>	<u>75</u>	<u>110</u>	<u>150</u>	<u>200</u>	<u>300</u>
<b>Total Fixed Assets</b>	2800	1575	2010	4250	4700	7900
<b>TOTAL ASSETS</b>	<u>\$3400</u>	<u>\$1940</u>	<u>\$2360</u>	<u>\$5215</u>	<u>\$5650</u>	<u>\$9215</u>
<b>LIABILITIES &amp; NET WORTH</b>						
<b>Current Liabilities</b>						
Trade Credit	115	70	68	185	182	250
Notes payable @ 12% (includes other AP, accrued expenses, etc.)	230	140	135	370	366	500
	<u>115</u>	<u>70</u>	<u>67</u>	<u>185</u>	<u>182</u>	<u>250</u>
<b>Total Current Liabilities</b>	460	280	270	740	730	1000
<b>Long Term Debt @ 12%</b>	1580	880	1145	2385	2660	4525
<b>NET WORTH</b>	<u>1360</u>	<u>780</u>	<u>945</u>	<u>2090</u>	<u>2260</u>	<u>3690</u>
<b>Total NW &amp; Liabilities</b>	<u>\$3400</u>	<u>\$1940</u>	<u>\$2360</u>	<u>\$5215</u>	<u>\$5650</u>	<u>\$9215</u>

Table 6.15 Page 2

FINANCIAL STATISTICS	INDUSTRY WHOLESALE FRESH	AVERAGE MFG. PROCESS	FRESH ONLY	PUREE ONLY	DRY ONLY	FRESH AND PUREE	FRESH AND DRY	FRESH, DRY AND PUREE
Number of Units Produced - Fresh lbs Puree lbs Dry lbs			13 mil	5 mil		13 mil 5 mil	13 mil	17 mil 3 mil
					880,000 lbs		880,000 lbs	475,000 lbs
Return on Net Worth	24.4%	23.7%	50.4%	11.7%	28.9%	39.7%	44.3%	13.5%
Return on Total Assets	8.4%	8.3%	20.1%	4.7%	11.6%	15.9%	17.7%	5.4%
Asset Turnover	4.9	2.0	1.53	.72	.65	1.27	1.19	.92
Profit Margin	2.5%	5.6%	13.2%	6.5%	17.7%	12.6%	14.9%	5.9%
Leverage	2.8	2.3	2.5	2.5	2.5	2.5	2.5	2.5
Interest Coverage	5.5	6.3	4.1	1.74	2.77	3.50	3.75	1.82
Cash Flow/Current Maturities: ( $\frac{\text{net pft} + 2}{\text{amount long-term debt retired}}$ )	4.2	5.5	3.05	1.43	2.06	2.63	2.77	1.42
Variable cost per unit			\$ .3012	\$ .1956	\$1.002			
Variable cost per \$ revenue			\$ .7548	\$ .6986	\$ .5727	\$ .7402	\$ .7098	\$ .6809
Profit per unit of fresh			\$ .0527	\$ .007	\$ .021	\$ .0638	\$ .0771	\$ .0292
Fixed cost contribution per unit			\$ .0981	\$ .0844	\$ .748			
Fixed cost contribution per \$ revenue			\$ .2452	\$ .3014	\$ .4753	\$ .2598	\$ .2902	\$ .3191
Breakeven in units			6,014,000	3,922,000	515,000			
Breakeven in revenue			\$2,406,000	\$1,098,000	\$811,000	\$3,410,000	\$3,287,000	\$4,776,000
Retirement of long-term debt, if desired over a 10-year period			\$158,000	\$88,000	\$115,000	\$239,000	\$266,000	\$453,000

Table 6.15 Page 3

FINANCIAL PROJECTIONS (\$000)	FRESH ONLY	PUREE ONLY	DRY ONLY	FRESH AND PUREE	FRESH AND DRY	FRESH, DRY AND PUREE
<b>1985</b>						
Additional Revenue times	1,600	465	532	2065	2132	5171 <sup>2</sup>
Contribution margin per \$	x.2452	x.3014	x.4753	x.2598	x.2902	x.3191
Additional Contribution	392	140	253	536	619	1,650
Less additional Fixed Cost Depreciation <sup>1</sup>	-75	-	-	-75	-75	-100
Additional Profit over 1980	317	140	253	461	544	1,550
Total 1985 Profit	1,002	231	526	1290	1546	2,047
+ Depreciation	215	80	100	288	310	495
- Income taxes @ 50%	501	115	263	645	773	1,023
Cash Flow in 1985	716	196	363	933	1083	1,519
Return on Net Worth	51.1%	29.6%	55.7%	48.0%	54.1%	33.8%
Profit per lb of Fresh (17 mil)	\$.0589	\$.0136	\$.0309	\$.0759	\$.0909	\$.0552
Price Paid Grower	\$.2000			\$.2000	\$.2000	\$.2000
Total Available to Coop Grower	\$.2589			\$.2759	\$.2909	\$.2552
<b>1980</b>						
Total Profit Before Taxes	685	91	273	829	1002	497 <sup>2</sup>
+ Depreciation	140	80	100	213	235	395
- Income Taxes (.5)	-342	-45	-136	-414	-501	-248
Cash Flow from Operations	483	126	237	628	736	644
Return on Net Worth	50.4%	11.7%	28.9%	39.7%	44.3%	13.5%
Profit per lb of Fresh (13 mil)	\$.0527	\$.007	\$.0182	\$.0638	\$.0771	\$.0292
Price paid Grower	\$.2000			\$.2000	\$.2000	\$.2000
Total Available to Coop Grower	\$.2527			\$.2638	\$.2771	\$.2382

<sup>1</sup> Assumes an additional investment of 1.5 million in Fresh Only, Fresh & Puree and Fresh & Dry processes and an additional investment of 2 million in the Fresh, Dry & Puree process.

<sup>2</sup> The fully integrated facility is based on 17 million lbs of fresh papaya in 1980 and 27.5 million lbs of fresh papaya in 1985.

FINANCIAL ANALYSIS

PAPAYA FRESH/PROCESSING PLANT

Assumption

Operation: 16 hours/day for 365 days

Investment:

Equipment

- Production	\$ 2,800,000
- Installation	2,800,000
- Transportation	400,000
- Other Miscellaneous	<u>300,000</u>

Subtotal \$ 6,300,000

Building Construction 1,600,000

Land (2 acres @ \$12,000/acre) 24,000

Total Capital Cost 7,924,000

Revenue

Fresh (17 million lbs./yr.) \$ 6,800,000

Puree (3 million lbs./yr.) 840,000

Dried (475,000 lbs./yr.) 831,250

Operating Cost

Raw materials \$ 3,908,000

Packaging and other 629,000

Labor 420,000

Production overhead 32,000

Energy and Utilities 160,000

\$ 5,149,310

<u>End of Year</u>	<u>Investment and other Cash Flow</u>	<u>Profit before Depreciation &amp; Income Tax</u>	<u>Depreciation for Tax Purposes</u>	<u>Taxable Income</u>	<u>Income after Tax</u>	<u>Total Cash Flow</u>
0	(7924)					(7924)
1	792	3322	633.90	2,688	1,344	2,770
2		3588	583.20	3,005	1,502	2,085
3		3875	536.50	3,338	1,669	2,206
4		4185	493.60	3,691	1,846	2,339
5		4520	454.10	4,065	2,033	2,487
6		4881	417.80	4,463	2,232	2,649
7		5272	384.40	4,887	2,444	2,828
8		5693	353.60	5,340	2,670	3,023
9		6149	325.30	5,823	2,912	3,237
10		6641	299.30	6,341	3,171	3,470
11		7172	275.40	6,897	3,448	3,724
12		7746	253.30	7,492	3,746	4,000
13		8365	233.10	8,132	4,066	4,299
14		9035	223.40	8,811	4,406	4,629
15		9757	223.40	9,534	4,767	4,990
16		10538	223.40	10,315	5,157	5,381
17		11381	223.40	11,158	5,579	5,802
18		12291	223.40	12,068	6,034	6,257
19		13275	223.40	13,051	6,526	6,749
20		14337	223.40	14,113	7,057	7,280
21		15484	223.40	15,260	7,630	7,854
22		16722	223.40	16,499	8,250	8,473
23		18060	223.40	17,837	8,918	9,142
24		19505	223.40	19,282	9,641	9,864
25		21065	223.40	20,842	10,421	10,644

Table 6.16  
 PAPAYA PROCESSING  
 FINANCIAL ANALYSIS  
 (\$000)

IRR 33.3%  
 Payback 4.4 years

## Papaya Processing Facility Summary and Conclusion

Based on revenues from three products, fresh, dried and puree, the after tax discounted rate of return is 33% with a 4.4 year payback.

However, the potential for a papaya processing facility in the proposed industrial park near Pahoa is considered only fair. Such an industry is clearly considered secondary and not of sufficient potential to be proposed as a principal industry for initiating park development.

The heat requirements are too small to warrant the drilling of a dedicated well. Further, the nature of the analysis has precluded the development of a shallow well. In like manner, it has not been considered cost-effective to transport the geothermal brine to the industrial park.

It is not considered feasible to move the existing plants because of the relatively small savings that may be realized from the use of geothermal steam. The present plants appear to be adequate for the existing and on expanded production. Only a breakthrough in a large scale dehydration capability coupled with a dried product marketing plan would alter this conclusion.

#### REFERENCES

1. Statistics of Hawaiian Agriculture 1979 (Hawaiian Agriculture Reporting Service, June, 1980), p 16.
2. IBID.
3. Hawaiian Papaya (Agriculture Reporting Service), June 16, 1980
4. "Statistical Highlights", National Food Review (USDA, Spring 1980), p. 35.
5. For a complete discussion see C. Stowell III, "Where, What and How We Eat," (Advertising Age, April 30, 1979), p. 2+ and "Eating Habits Force Changes in Marketing," (Advertising Age, October 30, 1978) p.65+.
6. Weiss, S. "Papayas are a Natural for Mainland Menus," (Food Institutions, September, 1978), p. 101.
7. Azzarone, S., "Natural Snacks Up Produce \$\$," (Super Marketing, September, 1978), p. 1+.
8. "Food: A move to Higher Margin Products," (Business Week, January 1979), p. 34+.

ENGINEERING EVALUATION AND ECONOMIC ANALYSIS, SUMMARY

After a detailed engineering and economic analysis of the three candidate industries:

- Ethanol from cellulose is a candidate anchor industry. It appears to be economically viable either on its own or as a component in the industrial park. The major hurdle to be overcome is risk associated with the proposed acid hydrolysis process.
- A cattle feed mill is not a candidate for the industrial park.
- Papaya processing would be economical in an ongoing park but it is questionable whether the cost of moving an existing operation to the park would be justified.



## CHAPTER 7

### CONCERNS - IMPEDIMENTS - BARRIERS

#### Introduction

This chapter describes the principal issues that could impede the development of an industrial park near Pahoa. These issues relate to community acceptance, transportation and environmental concerns as well as legal aspects relating to resource ownership, pipeline easements and permitting requirements. The planning for infrastructure improvements and the permitting procedures used by the County of Hawaii are discussed.

#### COMMUNITY ACCEPTANCE

Representatives of the community provided feedback information to the study team at three meetings in Pahoa. Conceptual plans for the hypothetical park development were presented to the residents and related concerns were discussed. These concerns of the community can be summarized as follows:

- Introduction of outsiders to operate the industries.
- Objection to certain industries by some residents.
- Mistrust of developers by some residents.
- Objection to the specific study site location of the industrial park by some local residents.
- Overloading of the local two-lane highway and the associated traffic noise.
- Objection to any type of development by some residents.
- Change of rural life-style.
- Lack of control over development by the local community.
- Threatened interests of marijuana growers.

- Noise from an industrial park and geothermal development.
- Degradation of ambient air and water quality.
- Ownership of the geothermal resource.

Some of the concerns listed can only be accommodated by stopping geothermal and industrial development. Others can be addressed satisfactorily with changes in the proposed development plans. The concerns are discussed below:

#### Job Opportunities

It is possible to provide local residents with both jobs and training programs in preparation for the proposed geothermal developments. The Puna Hui Ohana advocates an analysis of skills available in the resident community and the skill levels required in any future geothermal and industrial development. A Staff Researcher for the Puna Hui Ohana has proposed a curriculum development program and specialized training courses. Of particular promise is the possibility of a training program at Pahoehoe to match the developer's needs. Training through the College of Continuing Education could begin during the developers' planning or construction stages. A prospective developer could define specific requirements for individual positions. Appendix D discusses labor and economic development in more detail.

The following job opportunities are estimated for the industrial park and industries recommended in this study.

#### Construction and Development Phase

- o Resource Development including drilling of wells and construction of geothermal steam pipeline - 35
- o Industrial park site preparation - 40

- ° Construction of Ethanol Plant - 40
- ° Construction of Cattle Feed Mill - 35
- ° Construction of Papaya Processing Facility - 30

Operation and Maintenance Phase - Permanent Positions

- Ethanol - 35
- Cattle Feed Mill - 25
- Papaya Processing - 20

Support Infrastructure - Permanent Positions

- Trucking - 30
- Forestry - 25
- Papaya farming - 20

It is estimated that there would be a 2.3 multiplier associated with these job opportunities. The number of jobs that local residents of the Puna district, aboriginal Hawaiians and other ethnic groups, would receive depends on several factors including:

- Local government encouragement through innovative incentives or other arrangements.
- Goodwill of developers and investors.
- Abilities/skills and attitudes of local labor force and the opportunity to receive timely training.

Objection to Certain Industries by Some Residents

Some industries such as the processing of pulp for the manufacture of paper would be objectionable to many local residents. During community meetings some residents expressed a desire for "clean" industries. There is concern about large industrial developments that

would turn Pahoia into a "Pittsburg of the Pacific". In contrast, there are others who would support carefully planned industrial growth that would provide jobs as well as investment opportunities. These pro industry supporters accept and endorse appropriate environmental controls and procedures.

#### Mistrust of Developers

The Puna district is generally a rural area of Hawaii populated by a mixture of people who have arrived over the years for various reasons. The background and attitude of these residents are described more fully in Appendix F which points out that some newly arrived residents dislike or distrust geothermal development as a matter of personal preference. This attitude which has been expressed in permit hearings by these residents can have a serious impact on developments if the developers are not adequately responsive.

#### Objection to the Specific Study Site

During the course of the study the industrial park site was relocated from the original location opposite the Leilani Estates residential subdivision. The final site which was considered more acceptable by residents attending community meetings is in a more remote area with an access road that would take truck traffic and associated noise away from Pahoia and most residential areas.

#### Overloading of the Local Highway/Traffic Noise

Increased traffic, density and noise associated with the trucking requirements for the ethanol plant and the cattle feed mill is a major concern of residents. This topic is described more fully in a later section titled "Transportation Concerns".

### Objection to Any Kind of Development

In the community meetings and in geothermal permit hearings, there was a small number of individuals who strongly voiced their objection to industrial development of any kind for various reasons. However, no representative organization took this position.

### Change of Rural Life Style

Several people from newly established residential subdivisions objected to industrial development because they had recently chosen to move from urban areas such as Los Angeles to the Pahoa area. They perceived that they had moved from an industrial area to a non-industrial area with an implied promise that industrial development would not occur in Pahoa.

### Lack of Control by the Local Community

Community representatives indicated the willingness to share in the decision making process related to the geothermal and other industrial development. These representatives expressed frustration alleging that government and developers were making decisions with no input from them. However, this feeling of frustration was ameliorated somewhat by the community meetings and the special use permit hearings for geothermal development which occurred during the study period. At these meetings and hearings, the residents were provided an opportunity to voice their concerns about the various planning aspects of the hypothetical industrial park as well as the ongoing and planned geothermal exploratory well drilling.

### Threatened Interests of Marijuana Growers

The nature and extent of the illegal practice of growing and marketing marijuana was not studied. However at the various meetings and hearings there appeared to be a "hidden agenda" item related to that subject. Certain industrial growth and development in the Puna district would have a substantial impact on this lucrative although illegal activity. The people involved were perceived to voice objections to industrial development based on other issues for obvious reasons.

### Noise from Industrial and Geothermal Development

The Puna district has been a quiet rural community where people sleep with windows wide open . Thus, an increase in night time noise level is a major concern; especially truck traffic noise and geothermal well drilling noise. Current well drilling which is being conducted 24 hours a day, 5 days a week is accepted, but to date, round the clock drilling seven days a week has not been permitted.

### Degradation of Ambient Air and Water Quality

Pure water and blue skies with clean air are environmental corner stones of major importance in Hawaii.

At permitting hearings, H<sub>2</sub>S abatement procedures during well drilling as well as production operations were described. In addition, baseline environmental surveys are planned to monitor significant air and water quality indicators. These plans are discussed more fully in a later section of this chapter and in Appendix E.

### Ownership of the Geothermal Resource

The complex issue which is discussed in a later section of this chapter and more fully in Appendix B is a major concern for the developers and the large landowner. Except for the benefit that will derive to those of Hawaiian ancestry other residents have not indicated this to be a major immediate concern.

### TRANSPORTATION CONCERNS

Transportation to and from an industrial park located near Pahoa is of major importance for several reasons. Pahoa is 22 miles from the deep water port of Hilo which is 170 miles by water to Honolulu and 2500 miles by air to Los Angeles. The associated freight charges are significant. Also, the two lane roadway serving the proposed industrial park is considered inadequate or marginal for handling any substantial increase in truck traffic required by an industrial park.

The Keaau-Pahoa Road is the main roadway serving the Pahoa, Kapoho, and Kalapana areas in Hilo. A proposed Keaau-Pahoa By-Pass Project is in the advanced planning stage; construction could begin as early as 1983.

The 1980 peak hour traffic load is estimated to be over 400 vehicles. The major industry utilizing the Route 130 between Keaau and Pahoa is Puna Sugar Company (cane haul trucks), while other major users include those who market the following products: papaya, vanda orchid, anthuriums, lava rock slabs, pumice or cinder, macadamia nuts, citrus fruits, and other diversified farming. Tour buses are another major user, as there are a number of tourist attractions in the area: the Kapoho eruptions, Lava Tree Park, black sand beaches along the Kalapana Coast, and Chain of Craters Road into the National Park. Rental cars, presumably tourists, pass through Pahoa about 240 times daily.

### Impact of Industrial Park

The impact that the industrial park would have on the traffic situation may be significant. It would be reasonable to assume that the park would generate on the order of 75 to 100 primary jobs. Assuming a minimum of car-pooling, this would add 10-20% to the current peak traffic hour load. It is estimated that truck traffic may increase by 150 truck passes per day with additional trucking for miscellaneous plant supplies requiring about 75 truck passes per day. From the information in the traffic projections, this would increase truck traffic in the Pahoa area by about 25% over the 1980 traffic load. Partially for this reason, the industrial park was relocated so access would be via the Pahoa Solid Waste Plant Road avoiding Pahoa Town. However, some wood feedstock may be supplied from forest lands south of Pahoa. Thus the need for a by-pass road is strongly supported.

### Air Transportation

Due to the combination of airline deregulation, the cost and availability of jet fuel and the economic downturn on the mainland, Hilo-mainland direct air cargo shipments have recently been curtailed to a significant degree. During the fall of 1979, an average of 22 jumbo jet passenger aircraft per week were hauling some 2.1 million pounds of lift each month out of Hilo for the mainland. By the end of September 1980, that number was down to seven flights per week with lift capacity of about half a million pounds per month.

The above cargo consists mainly of papayas, cut flowers and foliage, potted plants, and some fresh fish. As flights have been cut



back, inter-island air freight haulers have been able to tranship some of the cargo through the Honolulu International Airport and some cargo has been diverted to surface shipment.

### Water Transportation

The future of surface shipping remains sound. Young Brothers provides regular barge transportation between Honolulu and Hilo, 3 times a week and Matson freighters provide a limited service 4 to 6 times per month between Hilo and Honolulu and one time a month direct to mainland ports.

For ethanol distribution, it is planned to negotiate with Pacific Resources, Inc. (PRI) for barges to haul the product to the PRI refinery at Barbers Point. PRI barges presently haul motor fuel products to Hilo and back haul empty.

For cattle feed transportation to Japanese markets either barge or tramp line bulk cargo shipments would be contracted for direct service between Hilo and Yokohama.

## ENVIRONMENTAL CONCERNS

### Introduction

The ethanol plant, the cattle feedmill and the papaya processing facility selected in this study for consideration in an industrial/agricultural park near Pahoehoe are essentially clean industries. Even so their operations and the associated geothermal development operations could possibly affect the physical environment in the surrounding area. Appendix E which discusses in detail an environmental impact assessment program for the proposed ethanol plant is condensed in the following pages.

## Description of the Environment

The Puna District, site of Pahoa and the proposed Pahoa commercial park is the easternmost region of the Island of Hawaii. It is somewhat more than 50 square miles in extent, and consists largely of undissected volcanic uplands with Kilauea to the north and Kalapana to the south. Between these uplands, extending eastward from the Kilauea Caldera complex to Cape Kumukahi and the sea is the Puna Cone and crater area marked by eruptions.

The young lavas of Puna which cover most of the district are covered with sparse organic soils. Across the west central portions of the district are low-lying fertile fields with abundant vegetation, and upper slopes covered with open forests of ohia. Rainfall is abundant. In east Puna is found one of the state's major papaya areas and in the west, highly productive sugar lands.

It is generally thought that the Puna area is underlain by a basal lens of freshwater floating on denser salt water, but the southern part of the district contains a narrow band of dike-confined freshwater. Salinities in excess of several hundred ppm are found in some of the district's wells at relatively shallow depths. Except for moderate coliform counts in one or two instances, ground waters show no chemical or microbiological features of concern.

With its proximity to the fumaroles and other active features of Kilauea, it is not surprising that air and soil are influenced by distinctive volcanic chemistry. Included is an air mercury level that ranges around  $1 \text{ g/m}^3$  under virtually all conditions except heavy rains and strong tradewinds. In general,  $\text{SO}_2$  and  $\text{H}_2\text{S}$  fall below 10 ppb. As in other volcanic regions, soils tend to run high in mercury and occa-

sionally yield unusual levels of arsenic and thallium. Vegetation tends to reflect elevated environmental levels of these elements.

### Environmental Concerns

The environmental concerns relevant to the proposed industrial operations include:

- ° Water quality deterioration
  - a. holding ponds
  - b. springs, wells and other sources of ground waters
- ° Noise pollution
- ° Soil disturbances
  - a. habitat impairment
  - b. exposure of erodible soils
  - c. vegetation removal
- ° Air quality deterioration

### Geothermal Wellsite Baseline Monitor Program

A baseline monitoring program similar to the one carried out for the HGP-A well and the Barnwell Opihikao drilling operation is recommended. It should include water and air quality, noise pollution, soil deterioration, and biologic and ecological effects at the geothermal well drilling site.

### Air Quality Monitoring of Site and Environs

Monitor hydrogen sulfide continuously at selected locations within the development area. These include samples from the various plant components within the park site.

Check general ambient levels by means of air spot samples within the industrial park compound. Deploy indicator tags

(Metronics type) daily over 2-3 downwind arcs in a concentric array to a maximum distance of about 1 mile. Monitor plant personnel with H<sub>2</sub>S indicator tags issued and reclaimed daily.

In addition, air samples are taken within property lines to monitor other potentially airborne major toxicants including SO<sub>2</sub>, SO<sub>3</sub> (H<sub>2</sub> SO<sub>4</sub> aerosols), Hg, AsH<sub>3</sub> and Boron.

Carbon dioxide monitoring is required only within poorly ventilated spaces or stagnant enclosures where personnel may experience even casual exposure. Build-up of the other relatively dense gaseous emissions (eg. SO<sub>2</sub> or H<sub>2</sub>S) would be revealed by their own odors at pre-toxic levels, a distinction not shared by CO<sub>2</sub>.

#### Water Quality Monitoring of Well Drilling Site and Environs

During the initial phases of drilling operations, take samples of water for the following analysis:

1. In-line measurements for arsenic, mercury and boron.
2. At discharge point:
  - a. Metals: Arsenic, antimony, beryllium cadmium, copper lead mercury, nickel, thallium zinc.
  - b. Non-metals, metalloids: Selenium, fluoride, boron.

Any elements consistently below analytical detection levels can then be transferred to the "infrequent" list, subject to semi-annual or annual review.

Holding pond: Analyze all above listed elements not transferred to the "infrequent" category. For pond sampling, include top, middle and bottom depths at the center and edge.

For the Puna Aquifer: Locate springs, wells or other sources of ground waters downstream from the commercial park sample monthly for all elements monitored in the holding period.

#### Bioassays

Establish two bioassay elements - one for atmospheric pollution, and the other for water contamination. New factors or substances, or combination of known factors or substances which are individually harmless (e.g. synergists) can bring about subtle, long-term environmental deterioration.

This possibility should not be overlooked in the monitoring program for the commercial park development. The ethanol plant processes combined with geothermal direct heat applications provide complex air and water sources of possible toxicants or toxicant combinations.

#### Air Pollution Indicators

Plant woody perennials, either ornamental or fruit bearing as indicators of general environmental quality. Initiate in-depth analysis of the ambient and air effluents when any sign of pathology not ascribable to parasitic infection occurs.

#### Discussion

Little is known about unique pollution symptomatology among native Hawaiian plants, however, it is quite clear that tip and marginal discoloration and chlorosis are common signs of physiological stress induced by air toxicants. Further, some geothermal emissions like mercury induce defoliation and premature fruit drop.

### Water Pollution Indicator

Maintain specific cultivated plants for water quality growth tests using hydroponic procedures. The water sources are to be compared among:

- a. Standard complete nutrient (Hoagland types).
- b. Geothermal discharge waters.
- c. Geothermal discharge waters supplemented with complete nutrient.

Use test plants to determine lay growth experiments.

Include chinese cabbage, tomato, cucumber and eggplant. Examine for pathology and record growth fresh and dry weights. Whenever growth is consistently inferior in wellwater and nutrients, identify the toxicants that are indicated.

### Noise

Carry out routine monitoring monthly at well site and commercial park boundaries and at one-half mile distance from source. Use noise limitations specified in U.S.G.S. Regulations. Give special consideration to traffic noise associated with potential feedstock trucking operations. When any change in plant operation or procedure is required, conduct an immediate noise check.

### Ethanol Plant Assessment Program for Commercial Park

The organization of an assessment program for the Pahoia commercial park must include general tasks as well as those related to specifics of site and use:

- Direct Environmental Baseline Requirements:
  - a. Site-use Independent
  - b. Site-use Related
- Direct Environmental Impact Follow-Up:
  - a. Site-use Independent
  - b. Site-use Related
- General Site Support Environmental Concerns.

#### Surrounding Area Assessment Program

The fundamental use-independent baseline tasks for surrounding area must include:

- A general description of the vegetation and physiographic ecology sufficient to provide for recognition of degradative changes.
- A tally of area (e.g. site plus 1 km ambient) endangered biota especially plant, bird and mammalian species.
- A survey of similar extent and scope for historic or archaeologically valuable structures and sites.

Monitor noise standard conforming to the USGS figure of 65dbA at the park property line.

For the proposed ethanol plant:

- Monitor the fermenter-distillery unit area for alcohol and aldehyde vapors and evaluation of the sensitivity of local nearby biota to such volatiles.
- Monitor disposition of stillage from the fermentation process for concentrations of heavy metals and other toxicants, namely Hg, cadmium, arsenic and lead.

### Direct Environmental Impact Follow-Up

The tasks required for follow-up are dictated by both the assessment program for the commercial park and the geothermal wellsite monitor program. The targets of assessment - plants, soils, air, etc. - need not be repeated here, but, the timing of follow-up programs is important.

General site support means those operations contributing to geothermal heat-based alcohol production at the Pahoia Industrial Park but located elsewhere. These are the facility for conversion of cellulosic materials to glucose and any sites committed to cultivation of plants for biofuel-related uses. These additional support sites must also be reviewed for environmental impact.

### Cattle Feed Mill Assessment Program

The feed mill has only 2 basic components, thereby reducing the areas of environmental concern.

Dust particles generated in the dryer as well as in the furnace are trapped, collected and vented to the furnace for incineration. However, this is not 100% effective, therefore the remainder are removed from stack gases by a "baghouse installation" effectively reducing emissions within the standard EPA limit of 40 lbs./hr. of any type of particle.



## Standards and Agency - Recommended Values

### Threshold Limit Values:

(Hawaii Occupational Safety & Health Standards Act 57, 1972 -  
Revision - August, 1977)

H<sub>2</sub>S 10 ppm for 8 hours

SO<sub>2</sub> 5 ppm for 8 hours

H<sub>2</sub> SO<sub>4</sub> 3 mgm for 5 minutes

NO<sub>2</sub> 5 ppm for 8 hours

CO 50 ppm for 8 hours

AsH<sub>3</sub> 0.05 ppm for 8 hours

Hg(albyl) 10 ugm<sup>-3</sup> for 8 hours

Hg(all) 50 ugm for 8 hours

### EPA Regulations

Ambient Air Quality:	1 gm <sup>-3</sup>
Arsenic	50 ppb
Mercury	2 ppb
Emission	1600gm per day
Discharge	(incinerations)
Into fresh water	20 ppb
Into saline water	100 ppb

## LEGAL ASPECTS

### Introduction

The development of an agricultural park instead of an industrial park in Pahoa, was evaluated from a legal viewpoint. Subsequently it was determined that the park would continue to be referred to as an industrial park. However, in this section and in Appendix B, the terms "agricultural" and "industrial" are used interchangeably when referring to the park.

Such a park will involve drilling for geothermal resources, transporting the geothermal resources from the well sites to the park,

obtaining governmental approval of the construction of the park, and conducting business in the park. Some areas of concern which require legal analysis have been identified as follows:

1. Ownership of geothermal resources.
2. Easements for pipelines for transmission of the resource.
3. County and State permitting requirements for development of the agricultural park instead of an industrial park. The following discussion is a condensation of Appendix B.

#### Ownership of Geothermal Resources

A developer of geothermal resources in Hawaii should be aware that there exists a serious question as to who owns the geothermal resources located in Hawaii in parcels where the State of Hawaii did not explicitly reserve mineral rights.

In states other than Hawaii, the question of ownership of geothermal rights has arisen, and there have been debates as to whether geothermal resources should be considered a mineral, water, or sui generis. The tendency has been to classify geothermal resources as a mineral. However, the problem is more complicated in the State of Hawaii.

Even if it is determined that geothermal resources are a mineral, in Hawaii there will remain a second difficult question: Who owns the mineral rights? Since Hawaii has never experienced any substantial amount of commercial mining, landowners in Hawaii have generally not been concerned about the ownership of mineral rights. Now that geothermal energy promises to be a valuable resource in Hawaii, the ownership of mineral rights has become an important issue. Serious

questions have arisen as to whether or not the State of Hawaii reserved mineral rights in a large number of land grants given without explicit mineral reservations.

The matter will probably be ultimately decided by the Supreme Court of Hawaii that geothermal resources are a mineral. This is the definition established by the Hawaii State Legislature and favored by courts in other jurisdictions.

There exists a possibility that the State of Hawaii will attempt to claim all geothermal resources for itself. Should it decide to do so, there are available certain legal theories which would be invoked to attempt to accomplish the task. In the absence of a claim to all geothermal resources by the State, mineral rights owners should prevail over other claimants in the contest over ownership of the resource.

#### Effect of Ownership Uncertainty on Geothermal Developer

Because of the uncertainty concerning the ownership of geothermal rights in Hawaii, the prudent developer should be careful to negotiate with the private landowner a geothermal lease which will anticipate the possibility of a claim by the State of Hawaii to the geothermal resources. If the well site involves land with no explicit mineral reservation to the State of Hawaii, the lease between the developer and private landowner should specifically deal with the question of payment of royalty in the event that the State of Hawaii claims the geothermal resources. One possible alternative is to provide that royalty payments will be withheld by the developer until such time that a court of competent jurisdiction finally determines who owns the geothermal resource, at which time the developer will make royalty payments to the rightful owner. Such a provision, which is

very favorable to the developer, has been negotiated and agreed upon in certain geothermal lease options now in effect on the Island of Hawaii. Another possibility is to provide that royalty payments will be made to the landowner, presuming that the landowner is the owner of the geothermal resource, until a court of competent jurisdiction decides otherwise. A lease containing such a provision has been negotiated and is now in effect on the Island of Hawaii. Still another alternative would be to provide for the payment of royalty into escrow in an interest bearing account until ownership of the resource is determined.

A lessee under a geothermal lease, or any person acquiring the rights of a lessee in a geothermal lease, by carefully structuring the provision recognizing the uncertainty of ownership of the geothermal resources, can avoid the devastating possibility of double payment of royalty, minimize the exposure to expensive litigation, and even enhance cash flow.

#### Easements for Steam Transmission Pipelines

At the present time, there is no statutory authority giving a producer or developer of geothermal resources a power of eminent domain to acquire pipeline easements leading from the geothermal well to the industrial park. Public utilities are given by statute the right of eminent domain. HRS Section 101-4. However, Section 269-27.1(b) of the Hawaii Revised Statutes, which was enacted in 1978, specifically excludes "the producer of geothermal steam or electricity generated from geothermal steam" from coverage of the term "public utility". As regulation by the Public Utilities Commission was one of the chief barriers pre-

venting the development of geothermal resources, it would seem that the exclusion, although literally referring only to the "producer of geothermal steam or electricity generated from geothermal steam" would be construed to include geothermal hot steam, hot water, or electricity producers will not be deemed public utilities, and consequently will not have the power of eminent domain provided for in HRS Section 101-4.

There is some question as to how the eminent domain power of the State or County may be used to acquire energy corridors for the purposes of transmitting the geothermal resource from the wells to the agricultural park site. Section 101-2 of the Hawaii Revised Statutes provides that "private property may be taken for public use." HRS Section 101-13 provides that the County may commence an eminent domain proceeding whenever it "deems it advisable or necessary to exercise the right of eminent domain in the furtherance of any governmental power . . ." HRS Section 46-61 provides that the County shall have the power to "take private property for . . . rights-of-way for drains, sewers, pipelines, aqueducts, and other conduits for distributing water to the public . . ." The creation of energy corridors for a geothermal project cannot be said to fall clearly within the language of the above quoted statutes. It is likely that appropriate legislation will have to be enacted in order to specifically allow the acquisition of easements by eminent domain for the purpose of transporting geothermal steam and water.

In the event an attempt is made to transport geothermal resources prior to the enactment of such legislation, it will be necessary to negotiate with the owners of parcels of land between the well site and

the agricultural park for easements for pipelines. The difficulty of such a task will depend upon the number of parcels involved, and the particular predisposition of the landowners.

## State Permitting Requirements for Development of an Agricultural Park

### Introduction

Because the existing land use classifications for the selected study site for the industrial park is zoned for agriculture and because most direct use applications involve the processing of agricultural products, the feasibility of developing an agricultural park in lieu of an industrial park was considered. Before an agricultural park can be developed, it must be shown that the proposed use falls within the permissible uses under the State Land Use Commission District Regulations, as well as under the County Zoning Code. An Environment Impact Statement may also be required, and, an amendment to the General Plan of the County of Hawaii may also be necessary.

### State Land Use Designation

The State Land Use Commission District Regulations, Part III, 3-3(11) provides that "agricultural parks" fall within the permissible uses within an agricultural district. However, the term "agricultural parks" as used in the Regulations is generally understood to refer merely to a subdivision located in agriculturally zoned land, or to a situation where the crops to be processed are grown on the land where the processing plant is located. The "agricultural park" contemplated by this study would probably be considered an industrial park, and would pro-

bably not be found to fall within the meaning of 3-3(11).

However, 3-3(10) provides that permissible uses include "buildings and uses, including but not limited to mills, storage and processing facilities, maintenance facilities that are normally considered direct (sic) accessory to the above permitted uses." The "above permitted uses" include cultivation of crops (including flowers, vegetables, foliage, fruits, forage and timber). Thus, the proposed anchor industries for the agricultural park would be permissible uses within the agricultural district if they are "normally considered direct accessory" to the cultivation of crops. There may be some question as to whether an ethanol plant is "normally considered direct accessory" to the cultivation of timber or other crops.

If it is determined by the State Land Use Commission that any of the proposed uses contemplated by the agricultural park does not fall within the meaning of 3-3(10), then there would be two possible courses of action.

#### Special Use Permit

The first possible course of action would be to petition for a special use permit. In order to qualify for a special use permit, one would have to show "unusual and reasonable use." The State Land Use Commission District Regulations, Part V, 5-2 provides the following guidelines to be applied in determining an "unusual and reasonable use."

1. Such use shall not be contrary to the objectives sought to be accomplished by the Land Use Law and Regulations.

2. That the desired use would not adversely affect surrounding property.
3. Such use would not unreasonably burden public agencies to provide roads and streets, sewers, water, drainage and school improvements, and police and fire protection.
4. Unusual conditions, trends and needs have arisen since the district boundaries and regulations were established.
5. That the land upon which the proposed use is sought is unsuited for the uses permitted within the District."

The procedure for applying for a special use permit is described in Appendix B.

The advantage of a special use permit is that it can be obtained simply and quickly. The disadvantage would be that the permit would be applicable only for the specific use petitioned for, i.e., an ethanol plant, a cattle feed mill, or a papaya processing plant. If at any time in the future a new industry were to replace one of the original industries, or if a new industry were to be added to the original industries, the new industry would have to qualify independently for a special use permit.

#### District Boundary Amendment

The other possible course of action would be to petition for a State Land Use District Boundary Amendment from agricultural to urban. The procedure for petitioning for a district boundary amendment is set forth in the State Land Use Commission's Rules of Practice and Procedure, Part VI. The next step would be to amend the County of Hawaii General Plan so as to provide for



industrial uses at the proposed site for the agricultural park. A general plan amendment would not be necessary if the proposed site is located in a zone designated in the general plan as "alternate urban expansion." The next step would be to petition the County for rezoning of the parcel involved. Finally, if the land is to be subdivided into separate parcels for the various industries, it would be necessary to petition for subdivision approval.

#### County Zoning Code

The study site selected for the proposed agricultural/ industrial park falls within an agricultural district for County zoning purposes. The Hawaii County Zoning Code, Article 7, Section 3, Paragraph B provides that among the permitted uses in an agricultural district are:

"All forms of agriculture; the growing and gathering of crops, fruits, vegetables, flowers, trees, and other plants; the raising and keeping of animals and fowls except as listed in Item 9; the physical processing, storage and sale of the products produced on the premises."

Paragraph N provides that among the permitted uses in the agricultural district are:

"Processing, storage, packing, and sale of products produced on the premises provided the site or building used for such activity shall be at least one hundred (100) feet from any property line."

It appears that under both of the relevant paragraphs quoted above, processing is limited to products produced on the premises.

Since the products to be processed in the agricultural park presumably will not be produced on the premises, it appears that the agricultural park will not be permitted under the agricultural zoning. Rezoning to industrial designation will thus be necessary.

#### Hawaii County Planning & Permitting Procedures

The permitting procedures as outlined by the County of Hawaii was designed to assure and provide both the public and policy-makers with an opportunity to review any project development plans to determine the impact of such a project on the overall community and environment.

The procedure is merely a review process through which all concerns can be addressed and the safety and well-being of the community and environment protected. The welfare of the people and the environment and the application of equitably reasonable requirements to achieve that end are accepted functions of government.

Many factors influence the length of time necessary for completion of the permitting process. Some of these factors are a) the completeness and clarity of the information provided by the applicant, b) the existing workload of the review staff, c) the minimum length of time which must pass before certain actions can be taken (prescribed by law), d) the ability and willingness of the applicant to comply with conditions required for approval of various permits (e.g., assurance that all possible mitigating measures will be taken with regard to noise) and e) the public's willingness to allow the approval of the applicant's project.

In order to prevent unreasonable delays from occurring there are specific provisions in the law which limit the maximum time allowable for review of any one application.

Provision for Infrastructure by the County of Hawaii For An Industrial Park

Upon review of a request to develop or improve any land within the County's jurisdiction, the Planning Department would assess, in addition to other aspects, the County's existing plans for that area and the requirements for roads, sewers, etc. If the development/improvement does require additional infrastructure and they are within the County's plans and fiscal means, it is possible that the County would make those provisions depending on the project's timetable.

On the other hand, if there are neither plans or funds available to make improvements, the developer may be required to provide the additional infrastructure or be denied project approval. It is not inconceivable, however, for government to amend its plans if a development is seen to have major benefit to the community.

While the above discussion assumes the roadway, for example, is County owned, it is possible that it be Federal, State, or privately owned. In these instances, the developer must work with the appropriate owners on the question of additional infrastructure. The Pahoia landfill road, in specific, is a County maintained, State owned road. As such, it is appropriate for the developer to work with the State regarding improvement.

Hawaii County Permit Procedures for this Geothermal Industrial Park

In some instances, uses which are not allowed on agricultural lands can be made permissible through a number of ways. A special permit or floating zone concept are applicable provided the project is

small. In this case, however, due to the nature and extent of the development, a General Plan amendment is called for.

The procedure for a General Plan amendment and related zoning changes are as follows:

1. The applicant files a General Plan amendment request with the County Planning Department. The Chapter 343 HRS requirements (EIA) would apply and the applicant should conform to them.
2. Upon receipt of the application, the Planning Department staff would review it with the EIA, and the Director would make a determination as to an EIS requirement. Should the EIS be required, the applicant must prepare and submit same. In this case, it is reasonable to assume that an EIS would be required and the applicant should consider submitting it with the initial application to save time. This step may take 4 to 6 months.
3. When the application and EIS review is completed the matter goes before the Planning Commission for approval. The Planning Director then forwards the matter to the County Council for approval. Upon arrival by the Planning Commission, the applicant may want to begin preparing the next application (boundary amendment), again to save time. This step may take from 6 to 8 months, and would complete the General Plan amendment process.
4. A boundary amendment application must subsequently be filed with the State Land Use Commission. This step, including review and amendment action, may take from 8 to 12 months.
5. The applicant must now file another application with the Planning Department for a rezoning of the land from agricultural to

industrial. This step, including rezoning action, may take from 4 to 5 months.

6. Final plans for plan approval, building plans for a building permit, and, possibly, construction plans for a grading permit are then submitted to the Planning and the Public Works departments for issuance at their respective permits. This step may take one month.

Total permitting time including preparation of an EIS may take roughly four years to complete. Assuming the applicant submits an EIS with the original General Plan amendment request and that the scheduling of all hearings, reviews, etc. are completed within the minimum time, as required by law, the processing may take about two years.

In terms of the actual construction, the customary practice of the County and State is to allow development to proceed on an incremental basis. That is, unless the applicant can show sufficient reason for the entire 50 acres to be developed concurrently, only portions of that 50 acres would be allowed to be developed at any given time, and in a sequential manner.

#### Summary

The issues related to impediments and concerns are complex. No easy or early solution is readily apparent to assure a developer or an investor that development of a geothermal industrial park will be an easy task. More so perhaps than at other locations, it does appear that any development should be undertaken with local partners who should be able to more easily undertake the necessary work avoiding as much waste motion and as many pitfalls as possible.

A mechanism does exist to obtain appropriate State and County zoning. However, obtaining that zoning will be time consuming and may take up to four years. Preparing and presenting the requests for zoning changes will be expensive for any developer. It is evident that the application must be prepared in concert with the local community, addressing their concerns and issues.

## CHAPTER 8

### DISCUSSION AND CONCLUSION

#### Discussion

This study examined the viability of a geothermal industrial park near Pahoā. It entailed an analysis of both the economic viability of the various tenant industries and the geothermal resource and the park development. Also, recognizing that even though a venture may be economically practical in today's climate, unless the other issues are manageable, then a successful project cannot result. Accordingly, the non-financial barriers to a successful geothermal industrial park were evaluated. In the following appendices are discussions addressing a number of the issues that could thwart the development of the park.

#### Resource

Appendix A contains a more complete discussion of the availability of the geothermal resource than was contained in Chapter 2. As indicated in Chapter 2, it is concluded that the geothermal resource is probably available within a reasonable distance of the selected park site.

Consideration of the use of low temperature heat available at the wellhead was considered beyond the scope of this study.

#### Legal

Appendix B is a more complete discussion of a number of legal aspects related to the direct application of geothermal energy in an industrial park oriented to agricultural processes. Abbreviated discussions of these issues were contained in Chapter 7.

One of these legal aspects is the ownership of the geothermal resource. It is clear that this is an unresolved issue particularly on a number of parcels where the land ownership has had a confusing history. However, the interests of the landowners, State of Hawaii, and other interested parties, are generally served by geothermal development proceeding. Consequently it is believed that a mutually agreeable arrangement will be worked out so that development will not be blocked while the legal issues are being resolved.

The acquisition of necessary easements for construction of a pipeline leading from the geothermal well to the park can be a real barrier to a developer. Legislation may be necessary to provide power of eminent domain so that energy corridors for geothermal pipeline transmissions can be provided.

Appendix B also discusses State and County permitting requirements oriented to the development of an agricultural park as compared to an industrial park using the premise that only agricultural products would be processed. The issue of rezoning of land use, and procedures for acquiring necessary permits is discussed in considerable detail.

From a review of Chapter 7 and Appendix B, it is concluded that although the legal aspects of the industrial park development require substantial attention, there is no special legal barrier that in itself will preclude the park development.

#### Social Impact

In Appendix C, Dr. Penelope Canan, Professor - Department of Sociology, University of Hawaii at Manoa, presents a background and rationale for social impact assessment. Dr. Canan stresses the importance of developing



a working model of the entire community in process to determine the social impacts of developing geothermal energy in Hawaii. She argues that this should be a continuous enterprise throughout the development of geothermal energy.

In Chapter 7, community acceptance and job opportunities were discussed. The community acceptance issues discussed at the various meetings with representatives of the community do not appear to be of the nature that will preclude development. The job opportunities described in Chapter 7 can be a very favorable force working to support park development.

In summary, it is concluded that the social impact of a park development is very sensitive requiring an ongoing partnership between the developer and the community representatives that will involve them to a substantial degree in the critical decisions affecting the community.

#### Labor and Economic Impact

In Appendix D, Mr. Everett Kinney, Staff Researcher of the Puna Hui Ohana has presented a discussion relating labor procurement to economic development. He points to the need for a training program whereby currently under-employed local labor can be provided the necessary skills for the developing geothermal technology. As indicated, there is flexibility in programs at the Hawaii Community College and the College of Continuing Education and Community Services that could help with broad based training programs aimed at meeting both the community and the developers needs. There is no assurance such a program will be developed without careful attention by the many vested interests involved.

#### Environmental

In Chapter 7, the various aspects of an environmental impact assessment program were presented. In Appendix E, Dr. Sanford Siegel has

presented a more detailed discussion for those readers requiring same. From an environmental standpoint, there does not appear to be any unsurmountable problems that cannot be suitably resolved.

### Financial

In Appendix F, Mr. Kenneth McNerney and Mr. John Woods have presented general terms and conditions which an investor and/or developer may expect from a lending institution. Providing the marketing, the technical process, and the geothermal resource are properly addressed and presented, financing an industrial park development should not in itself be a barrier.

### Financial Viability

This study was initiated because there is a widely-held belief that the relatively cheap energy available in a geothermal resource will attract industry. Although this is true in theory, when it comes to a specific site, particularly a remote site such as Pahoia, it is difficult to find industries which would make the move to such a location. An extensive literature search identified 31 candidate industries, but this list quickly narrowed to the following 8 industries that justified initial economic analysis:

- Ethanol Plant
- Cattle Feed Mill
- Papaya Processing
- Protein Recovery Plant
- Freeze drying of Kona Coffee
- Lumber Kiln
- Cement Bonded Wallboard
- Aquaculture

That economic analysis described in Chapter 4 reduced the list of potential industries to only three that justified detailed engineering and economic analysis. These were the ethanol plant, the cattle feed mill, and the papaya processing plant. From the detailed analysis only the ethanol plant is clearly an economically attractive industry, papaya processing is marginal, and the cattle feed mill is not endorsed.

#### Summary Discussion

Having examined all of the above issues, there is no apparent "showstopper" to the successful development of a geothermal industrial park. There are obviously some difficult and complex issues which will have to be managed for a park to be successful, but there is nothing that precludes successful development. However, a developer should approach planning for a direct heat application in an industrial park near Pahoia with great care. The experience being acquired by those involved in the current geothermal resource development should be heeded. There is a considerable body of knowledge and expertise that has been acquired and developed. Much has been learned through the numerous hearings conducted during the past year. An emerging geothermal technology infrastructure capable of providing engineering, financial, analytical, environmental and technical services can be of great assistance. County of Hawaii and State of Hawaii personnel have also acquired some of the necessary knowledge and capability to be of beneficial assistance. In the same manner, community leaders and representatives in the Puna District and in Pahoia Town are informed and can present their needs to a developer effectively assuring the developer he will know their concerns and their needs.

In all the economic studies, it became clear that there are few industries in which the cost of energy determines its viability. It is

difficult to find an industry that has more than 10% of its production costs represented by energy. In analyzing the ethanol plant, the exercise was conducted to raise the price of steam from \$2.67/MBTU to \$5.93/MBTU. This increase in steam price only reduced the internal rate of return from 43.6% to 40.1%. This insensitivity to energy cost is true of other industries.

### Conclusion

A detailed look demonstrated that it is practical to build an industrial park that would use geothermal steam near Pahoa in Puna. The environmental, legal, geologic, and financial impacts are manageable. The social impact can be managed provided the park is not of such a massive scale to change the character of Pahoa and provided the residents are involved in the decision making process.

Cellulose to ethanol plant could be an anchor industry in the industrial park if a proven process can be provided. No other businesses were identified which would justify starting the park. A papaya processing facility would make sense in the park if there is need for an additional processing plant in Puna, but probably does not justify relocation of existing plants. No other industry was discovered which would be clearly profitable in the geothermal industrial park. No existing process was identified which could operate successfully in Pahoa, and which had a large enough energy content to justify the move to Pahoa. No other potential process was identified that was sufficiently energy intensive to be further considered.

There may be some industries which were rejected which could be developed to be practical in Pahoa by a research laboratory. Until such laboratory generates new businesses or until an anchor industry such as ethanol production is commenced, an independent industrial park intended to utilize direct heat geothermal energy in Pahoa will be a very questionable investment.

APPENDIX A

GEOHERMAL RESOURCES OF PUNA

by Charles E. Helsley

HAWAII INSTITUTE OF GEOPHYSICS

INTRODUCTION

The volcano Kilauea on the island of Hawaii has long excited scientists and laymen with its spectacular displays of volcanic activity. Most of this activity is confined to the summit region of the volcano and, therefore, this portion of the volcano has received most of the attention of volcanologists during this century. From the geothermal point of view, however, this focus on the summit region is somewhat misleading for only a small portion of the magma supplied from deep within the earth remains in the summit region, either as intrusives or as surficial lava flows. The majority of the magma supplied by the volcano estimated to be about 0.1 cubic km per year (Swanson, 1972) leaves the summit region after a brief storage period via cracks and fissures associated with the southwest rift zone and southeast rift zone of the volcano. Much of this magma eventually finds its way to the surface where it forms extensive lava flows on the flanks of the volcano, however, a small portion of the magma, variously estimated at 1 to 25 percent of the total volume, remains in the subsurface as small intrusive bodies distributed along the rift zone. These intrusive bodies are the source of the heat for the geothermal resources along the rift system.

The amount of heat migrating into the rift zones via this process is quite large for a cubic meter of magma contains about 50,000 BTU. Most of this heat, however, is lost to the environment surrounding the rift zone due to the fact that the lava is brought to the surface where it is cooled by exchange with the atmosphere and groundwater. Only those portions of the magma that remains deep within the subsurface retain much of their initial thermal energy. Assuming that 1 percent of the magma supply remains in the subsurface (probably a low estimate), one can calculate a steady-state heat input into the subsurface portion of the lower east rift of Kilauea volcano of 50,000,000,000 BTU per year. Since this heat flux has been essentially continuous throughout the life of the volcano, estimated to be about 100,000 years plus or minus 50%, one can easily calculate that very large heat resources are likely to exist in the subsurface beneath the rift zone of Kilauea.

#### HISTORICAL BACKGROUND

The geologic study of the Hawaiian Islands began many centuries ago, for the Hawaiian legends have vivid accounts of volcanic activity. These legends include not only a wealth of information about volcanic activity in the near past, but also include an historical summary that properly identifies the progressive development in time of the Hawaiian volcanic chain. Written descriptions of the volcanic activity commence shortly

after the discovery of the islands by Capt. James Cooke in 1778. Ellis (1825) provides the first written account of activity at the Kilauea summit and records native accounts of the past activity of Kilauea as well as other Hawaiian volcanos. Some of the more significant flows that occurred in historic time on the island of Hawaii are shown in Figure 1.

Historical activity in the Puna district, that is the southeast rift system of Kilauea, is succinctly summarized by Macdonald and Eaton (1964). Eruptions in the lower half of the rift zone have occurred about 1750, about 1790, in 1840 and in 1955, 1960 and 1961. In 1924, a swarm of small earthquakes occurred near Kapoho very similar to those that preceded the 1955 eruption. Shortly after the peak of this activity, a great subsidence occurred at Halemauau crater within the Kilauea caldera. It is not known where the lava went, but Jaggar (1947) suggests that the lowering of the magma level in the caldera resulted from the intrusion of the magma into the lower east rift in the vicinity of Kapoho. If we include this 1924 event, there have been seven periods of intrusive or extrusive volcanic activity in the lower east rift since 1750.

The 1955 eruptions were exceptionally well observed and documented by Macdonald and Eaton (1964). In general, the land to the southeast of the eruptive centers subsided between 1 and 2 feet and was displaced horizontally to the southeast between 2.3 and 5.4 feet during the eruption. This data suggests that a

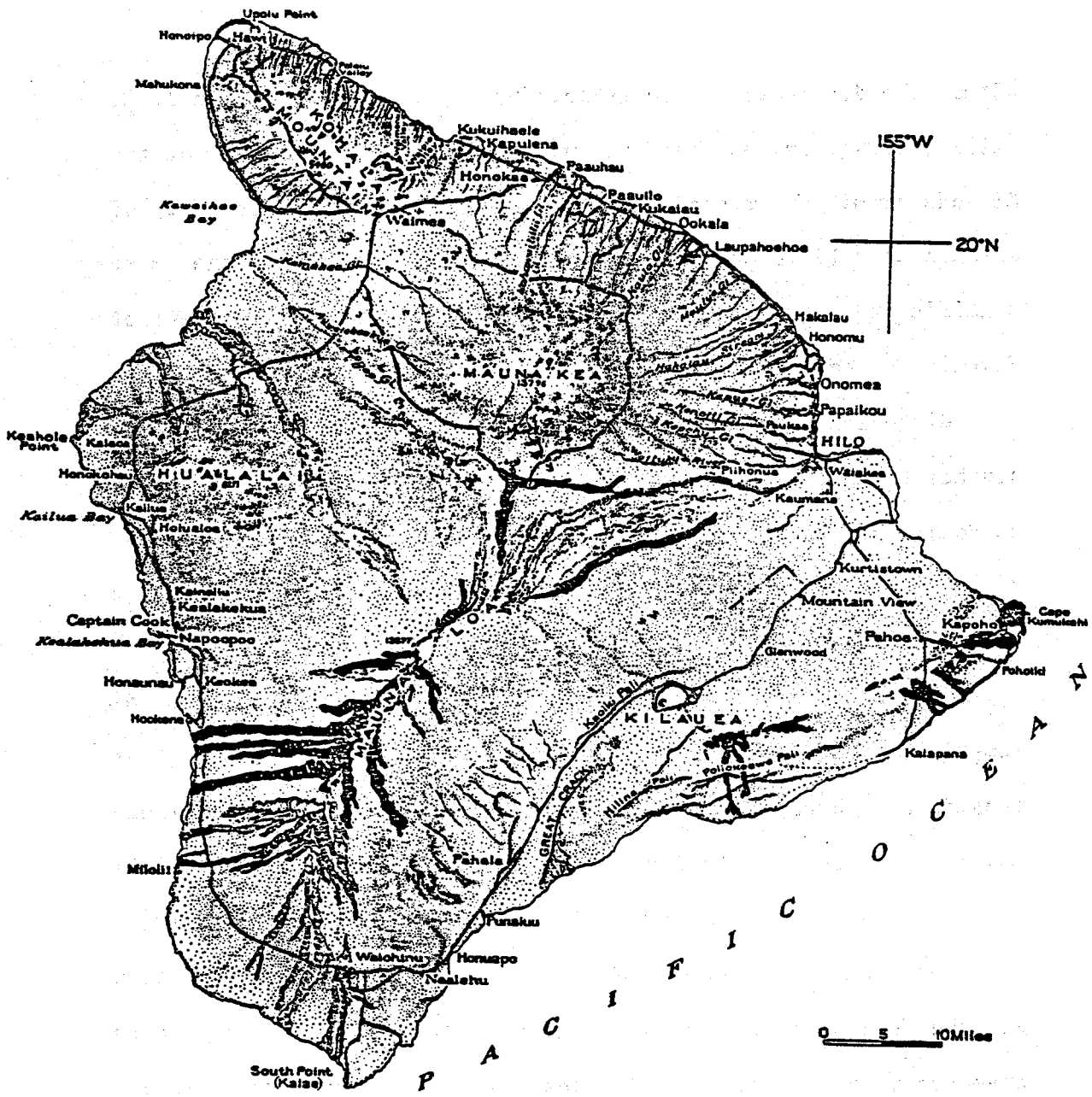


Fig. 1. Topographic map of the island of Hawaii showing historic flows along the east rift zone of the Kilauea volcano.



near-vertical, tabular intrusive body was emplaced in the subsurface during the eruption and that the thickness of this body was some 2 to 5 feet. This would make it comparable in thickness to other dikes observed in exposed, but older, rift zones elsewhere in the Hawaiian Islands.

#### GEOLOGY OF THE EAST PUNA DISTRICT

The only known geothermal resource in the State of Hawaii is in the eastern portion of the Puna District, about 25 miles from the summit of the Kilauea volcano. The geology of the region is given in considerable detail by Macdonald and Eaton (1964) as part of their description of the events surrounding the 1955 lava flow. From geophysical studies conducted in the summit region we now know that the magma (molten rock) entering the Kilauea volcano comes from deep within the earth and collects in a shallow storage reservoir beneath the summit caldera. Most of this stored magma leaves the summit region via subsurface conduits and shows up again as lava flows emerging to the surface along the rift zones. This process is illustrated diagrammatically in Figure 2.

The southeast rift zone of Kilauea commences at the Kilauea crater and extends in a southeasterly direction for about 4 1/2 miles where it makes an abrupt bend and continues on a trend of about N65E to Cape Kumukahi. This zone is marked by numerous pit craters and cinder cones as well as a number of fissures from which historic lavas have come and a number of other cracks that

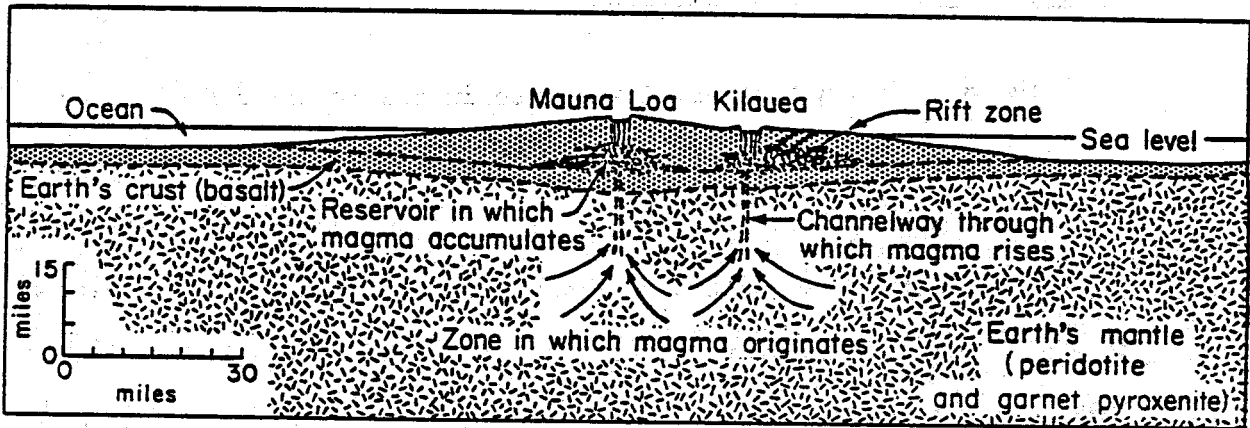
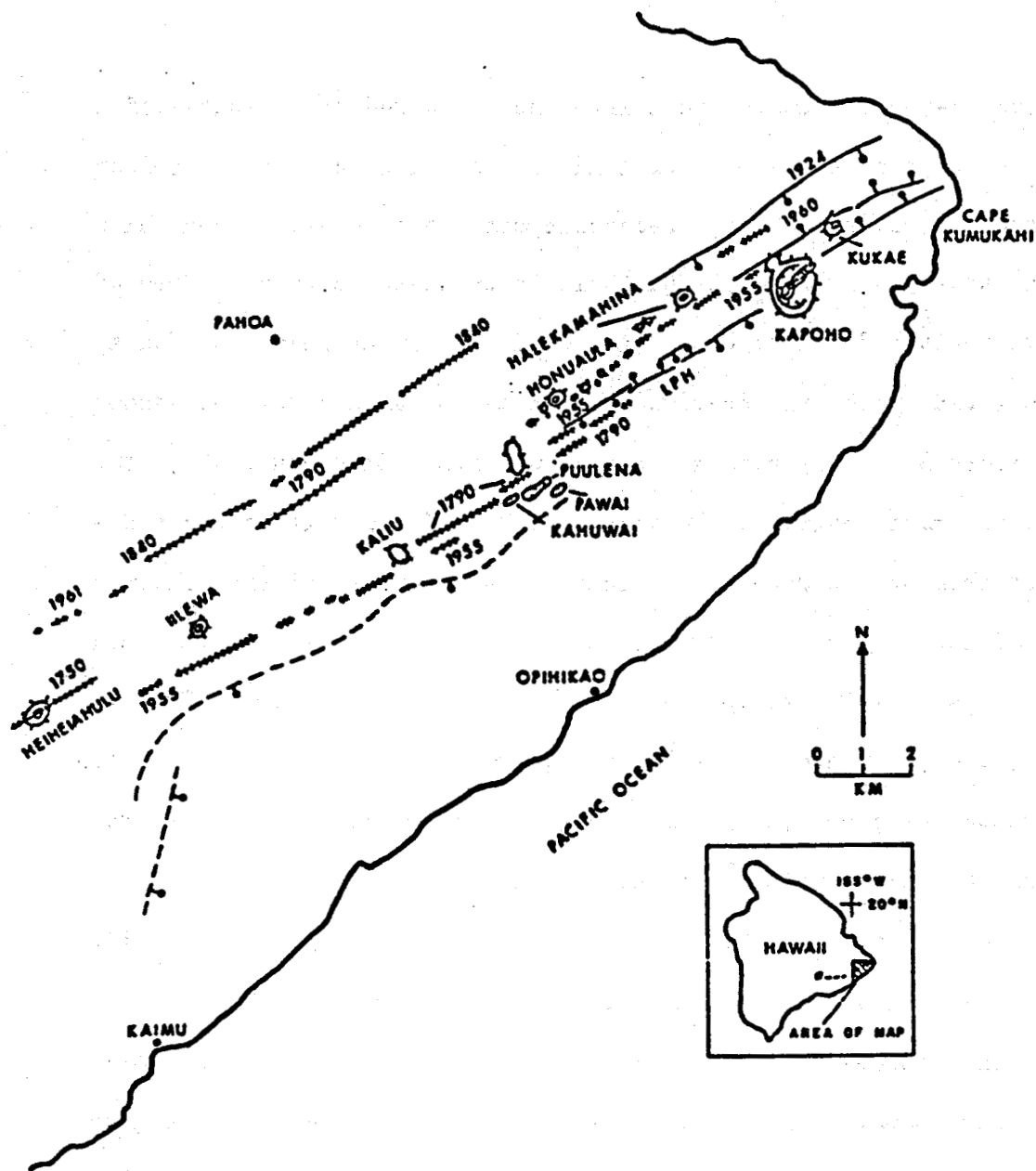


Fig. 2. Vertical cross-section through the island of Hawaii showing the source of magma for Kilauea and Mauna Loa volcanoes and the shallow magma reservoirs that are the source of the lava observed in the eruptions along the rift systems.

extend several tens of feet into the earth and have lengths of a few of tens of feet to several miles. Along this zone of recent volcanic activity, one can recognize more than 70 vents from which lava has issued either in historic or prehistoric times. Some of these vents and cinder cones as well as fractures and faults associated with the eastern part of the southeast rift are shown in Figure 3. This figure, extending from Cape Kumukahi, the eastern most point of the island of Hawaii, to Heiheiashuhu a few miles west of the Pahoa-Kaimu road, shows a number of the features associated with historic volcanic activity in this region as well as a few fault scarps and craters of prehistoric age. In this area, the rift zone appears to be up to 4 km wide and consists of a number of parallel to subparallel eruptive fissures and faults. Figure 4 extends these features further west along the rift zone to the vicinity of Kalalua crater. Figure 4 also shows the site of the 1961 eruption, which, along with the 1977 Kalapana flow, are expressions of the most recent volcanic activity in the lower east rift zone. Figure 5 from the Macdonald and Abbott's book on the geology of the Hawaiian Islands (Macdonald and Abbott, 1970), shows the extent of the surficial lava flows associated with the eruptive fissures shown in Figure 3. It should be noted that the 1960 flow, in the vicinity of Kapoho, is not shown in this figure but is included in Figure 6. The 1960 Kapoho eruptions covered two features of considerable geothermal interest: (1) The warm spring just north of Puu Kukae and (2) The boundary of the graben



Tectonic map of the east Puna region (lower east rift zone of Kilauea volcano) (from Zablocki, 1977). Eruptive fissures are shown cross-hatched and faults are shown as solid lines with the down-thrown side indicated by dots. Inferred faults are shown by dashed lines. Prominent cinder cones and pit craters are also shown.

Figure 3

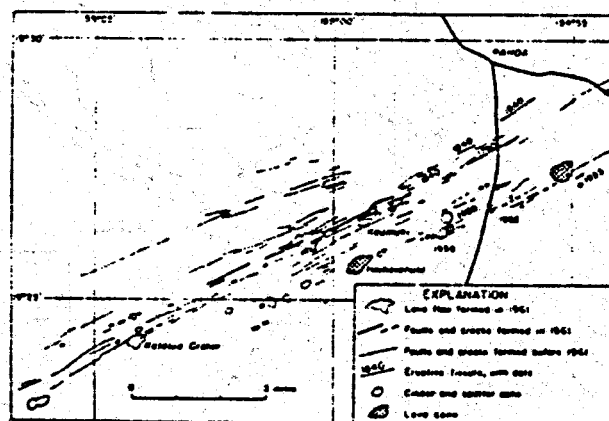


Fig. 4. Map of part of the east rift zone of Kilauea west of Fig. 3 showing faults, cracks and lava flows formed in 1961 (from Macdonald and Abbott after Richter and others, 1964).

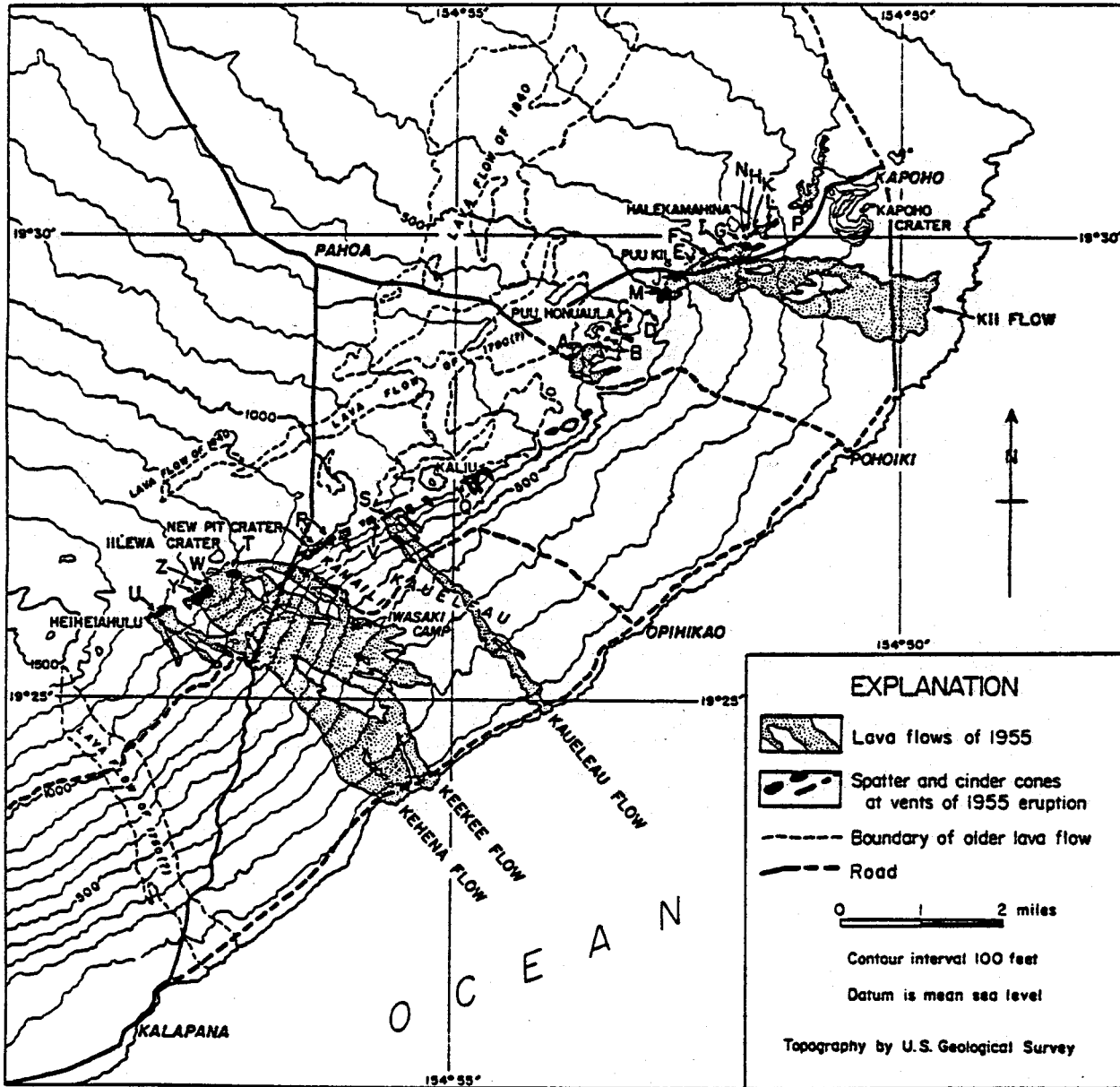


Fig. 5. Map of the eastern portion of the Puna district showing the lava flows of 1955 and their relationship with older historic flows (from Macdonald and Abbott, 1970).

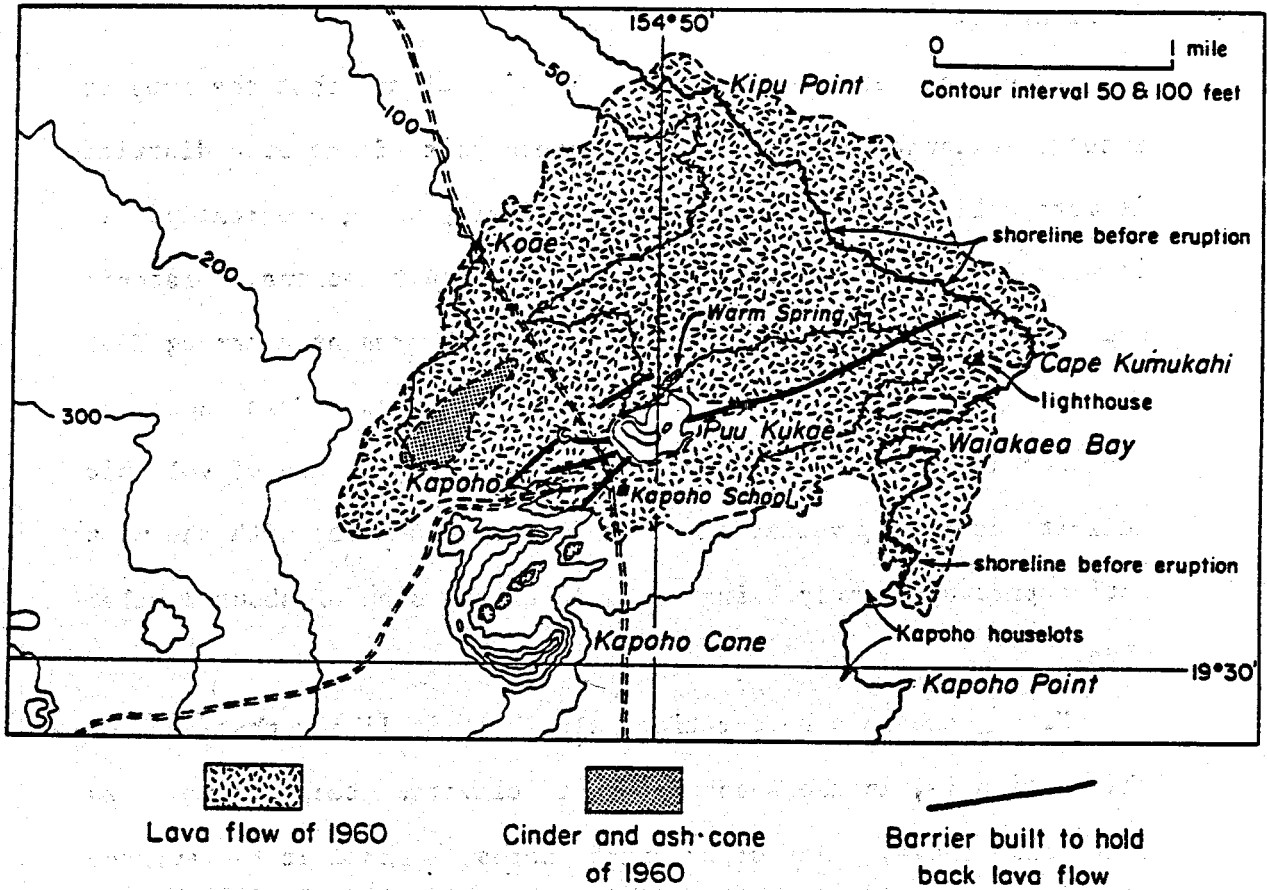


Fig. 6. Map of the easternmost portion of the island of Hawaii showing distribution of the lava flows erupted in 1960. Note location of the areas of the warm spring covered by the 1960 lava (from Macdonald and Abbott, 1970).

formed in 1924 and showed in Figure 3. Other older maps also show a warm spring to the northeast of the warm spring locality shown in Figure 6.

From the above discussion it is clear that the zone of intense volcanic activity in the eastern part of the Puna district is very well expressed, both topographically and geologically. It is marked by a series of eruptive vents, fault scarps, historic and prehistoric cinder cones, all of which present a strong N65E trend on geologic maps and aerial photographs. This zone of pronounced surficial features indicating the presence of volcanic activity at depth, varies in width from 2 to 4 miles with the most active part apparently being confined to the zone of about 2 miles wide.

From geologic considerations alone, it is likely that much of this region is, in the subsurface, at elevated temperature. As mentioned above, the older rift zones, exposed at the surface elsewhere in the Hawaiian island chain, consist of dike complexes in which the dikes vary in thickness from 1 to 5 feet averaging between 2 and 3 feet. In the older rift zones these dikes trend in various directions but generally have an average trend within about 20 degrees of the trend of the rift zone as a whole. Where these dikes are exposed in rift zones, such as that of the Koolau Volcano on Oahu, they comprise some 25 percent or more of the total volume of the rift zone. Thus, one can estimate that the east Puna rift zone may contain 1000 to 2000 dikes in a generally



fractured zone into which new lava moves from time to time.

Each of these numerous dikes is intruded at a temperature in the vicinity of 1100 degrees centigrade. Since the dikes comprise about 25% of the rift zone at depth, we can calculate that the temperature within the rift zone, at a depth significantly below sea level where water circulation has not been great, should be about 300 degrees centigrade; assuming that the ambient earth condition is about 20 degrees centigrade and that no heat is lost to the outside world. This assumption, of course, is unrealistic. However, in view of the extensive heating that takes place during the passage of magma through the dike during eruptions and during the emplacement of the dike, it may not be as unrealistic as it at first seems. Eruptions, as should be obvious from the above discussions, occur frequently in the east Puna district, and since 1750, have averaged about one every 30 years.

This inferred subsurface geology discussed in the paragraphs above was confirmed by the drilling of the HGP-A well in 1976. Figure 7 shows the temperature observed in HGP-A under three conditions: (1) Natural earth temperature measured while the hole was still filled with mud, and therefore not convecting or producing internally; (2) Temperature profile taken during the shut-in period after production had been achieved and the mud had been removed from the hole. This curve shows a much more elevated temperature than the natural earth temperature; apparently resulting from fluids entering the hole at depth and leaking from

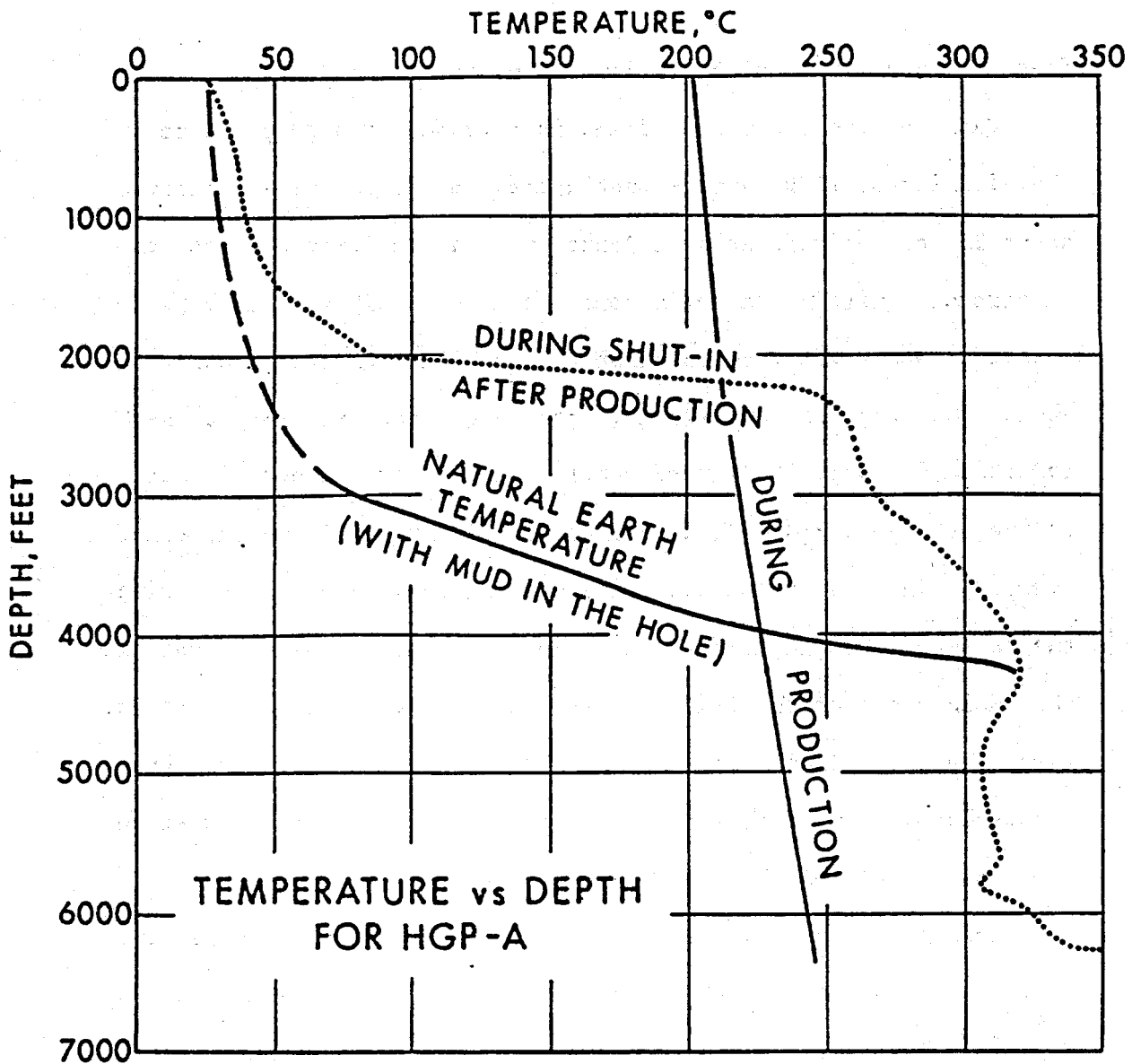


Fig. 7. Temperature versus depth at the HGP-A well under three separate conditions (from Helsley, 1977).

it at the base of the casing, which in this case was at a depth of about 2250 feet. This shut in temperature curve is important, however, for it gives us some idea of what the ambient temperature is at depths greater than 4000 feet; depths that were not observed under static conditions with mud in the hole due to mudcaking in the hotter portions of the reservoir. (3) Curve shows the temperature versus depth plot during production. During production the well flashes to steam within the well bore (and probably also within the formation outside the well bore) and thus, the temperature is considerably lower in the producing zone.

The rocks encountered during the drilling of HGP-A gives further evidence of the subsurface conditions within the rift zone. Examination of the cuttings and cores collected during the drilling of HGP-A indicate that lavas of subaerial origin continue to well below sea level. These materials continue to a depth of at least 450 feet below sea level and perhaps continue to nearly 800 feet below sea level. These rocks of subaerial origin are characterized by high porosity with vesicularity ranging up to 25%. Below 1400 feet, the vesicularity appears to decrease markedly and the rocks begin to be progressively and pervasively hydrothermally altered. All samples below 3000 feet depth show evidences of alteration with the formation of secondary minerals such as pyrite, chlorite, actinolite and quartz, as well as numerous zeolites (see Figure 8). These minerals, characteristic of hydrothermal alteration of basaltic rocks, continue for

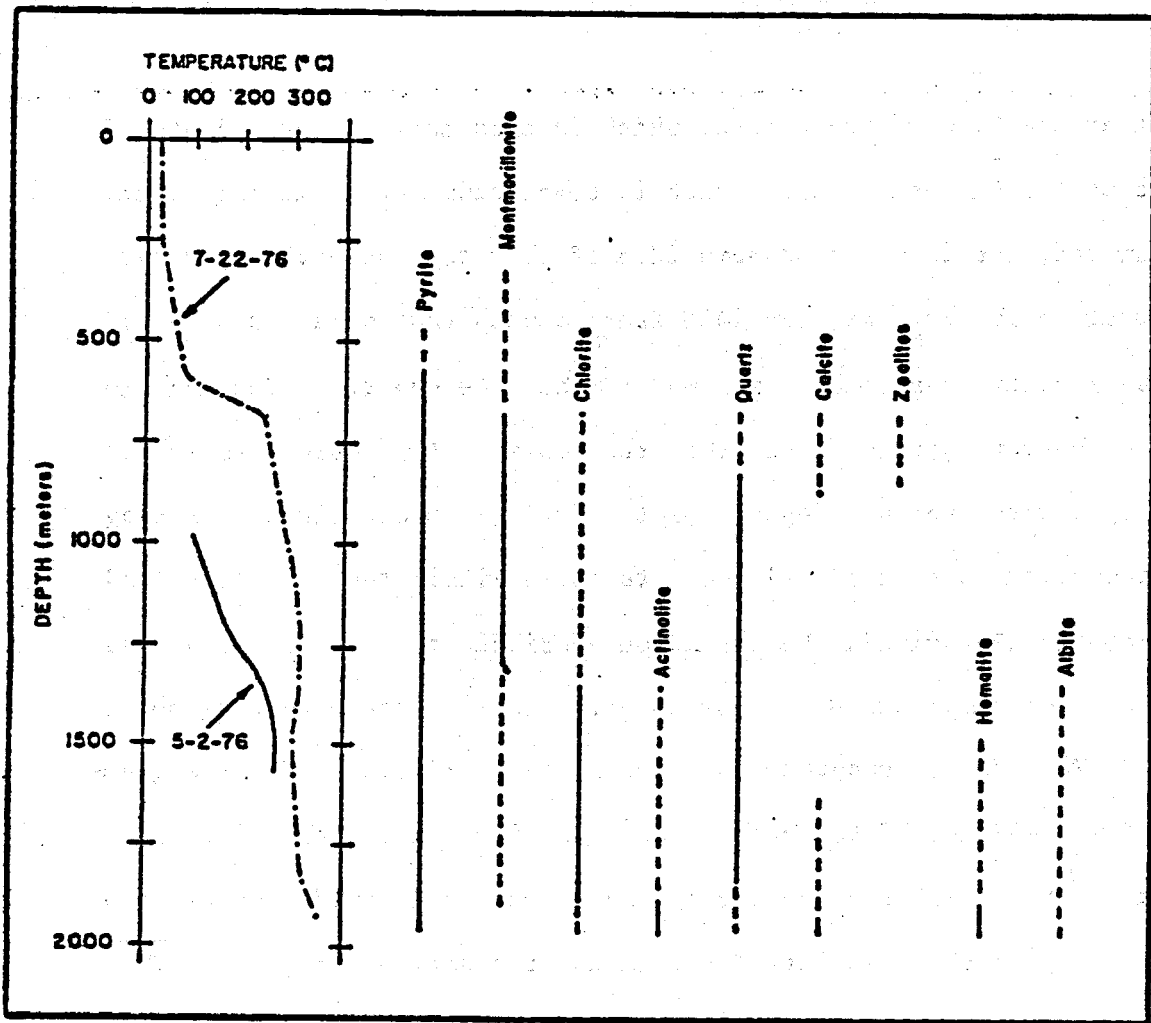


Fig. 8. Alteration mineralogy observed in samples from HGP-A (from Stone, 1977).

approximately 3000 feet to the bottom of the hole. The rocks are not vesicular below 3000 feet and even the fractures tend to be heavily filled with secondary minerals. This secondary mineralization of the fractures apparently provides a permeability barrier and permits the formation of the reservoir.

The fluid within the HGP-A well has an abnormally low salinity being approximately 15 percent of that of normal sea water. The water table was not observed during the drilling of the well, however, nearby wells indicate that the water table is but a few feet above sea level throughout the region. Moreover, the chemistry of the fluid in the HGP-A well indicate that at least a portion of the recharge is coming from relatively high elevations, say 3000-4000 feet, implying that much of the fresh water now at HGP-A has an origin as rainfall on the higher slopes of the volcano. Most likely this high elevation rainfall becomes channeled within fractures and lava tubes, eventually reaching the rift zone where it flows down the rift zone to the vicinity of the HGP-A well.

Near surface rocks in Hawaii are extremely porous and have very high permeability. This permeability is dependent on the presence of fractures, inter-flow spaces, and lava tubes rather than on the vesicularity itself for the vesicles are not well connected. At greater depth, where the vesicles are absent and the inter-flow spaces are minimized, most of the permeability is probably due to fractures; fractures that may have been due to

thermal stressing of the rock during previous eruptions. The presence of secondary minerals within the well indicates that these fractures are filled, thereby restricting the movement of water and providing a "self-sealing" mechanism for the geothermal reservoir.

### REGIONAL GEOPHYSICS

Regional geophysical studies of the lower east rift have been conducted by both the Hawaii Volcano Observatory (USGS) and the University of Hawaii through the studies of the Hawaii Institute of Geophysics. The most prominent geophysical expression of the rift system in the east Puna district is a concentration of small earthquakes along this zone. These are illustrated in Figure 9 which shows the earthquakes during a representative period observed by the Hawaii Volcanoes Observatory network of seismic stations. The marked decrease in number of earthquakes in the eastern portion of the rift is always observed and suggests that the earthquake hazard and risk of volcanic eruption decrease significantly east of Heiheiulu. The distribution of the earthquake activity with depth suggests that they are generally confined to a zone that parallels the rift system but is inclined slightly to the south, that is, they express a fault zone that dips at an angle of 60 to 70 degrees, with respect to horizontal, to the south. The near surface portions of this fault may be much more vertical.

The rift zone also dominates the electrical self-potential map shown in Figure 10. Positive self potentials are thought to be due to the leakage of warm water from geothermal reservoirs in the above sea level portion of the island. Three such areas are denoted in Figure 10 and are labeled as A, B-C, and D. A more detailed view of the B-C anomaly adjacent to the HGP-A well is shown in Figure 11. One must remember, however, that the high self-potentials shown on these figures must be created by the streaming of warm fluids in the above sea level portion of the island and that the self-potential map itself says little about the source of reservoirs at depth, only their zones of leaking.

Electrical conductivity surveys have been conducted on the lower east rift, notably by Keller et al., (1977) and Kauahikaua and Klein (1977) as well as more recently by Kauahikaua (pers. comm.). All of these surveys indicate that high conductivity zones are present at depth, but none of these surveys has succeeded in penetrating to depths that are sufficient to define reservoir boundaries. Thus, one can only say that the region is highly conductive and underlain by rocks saturated with warm or hot water, but one cannot define where the warmest areas are. The most prominent of the anomalies appears to be in the vicinity of the A and B anomalies of Figure 10 as well as the region between Cape Kumukahi and the Kapoho crater (see Figure 3).

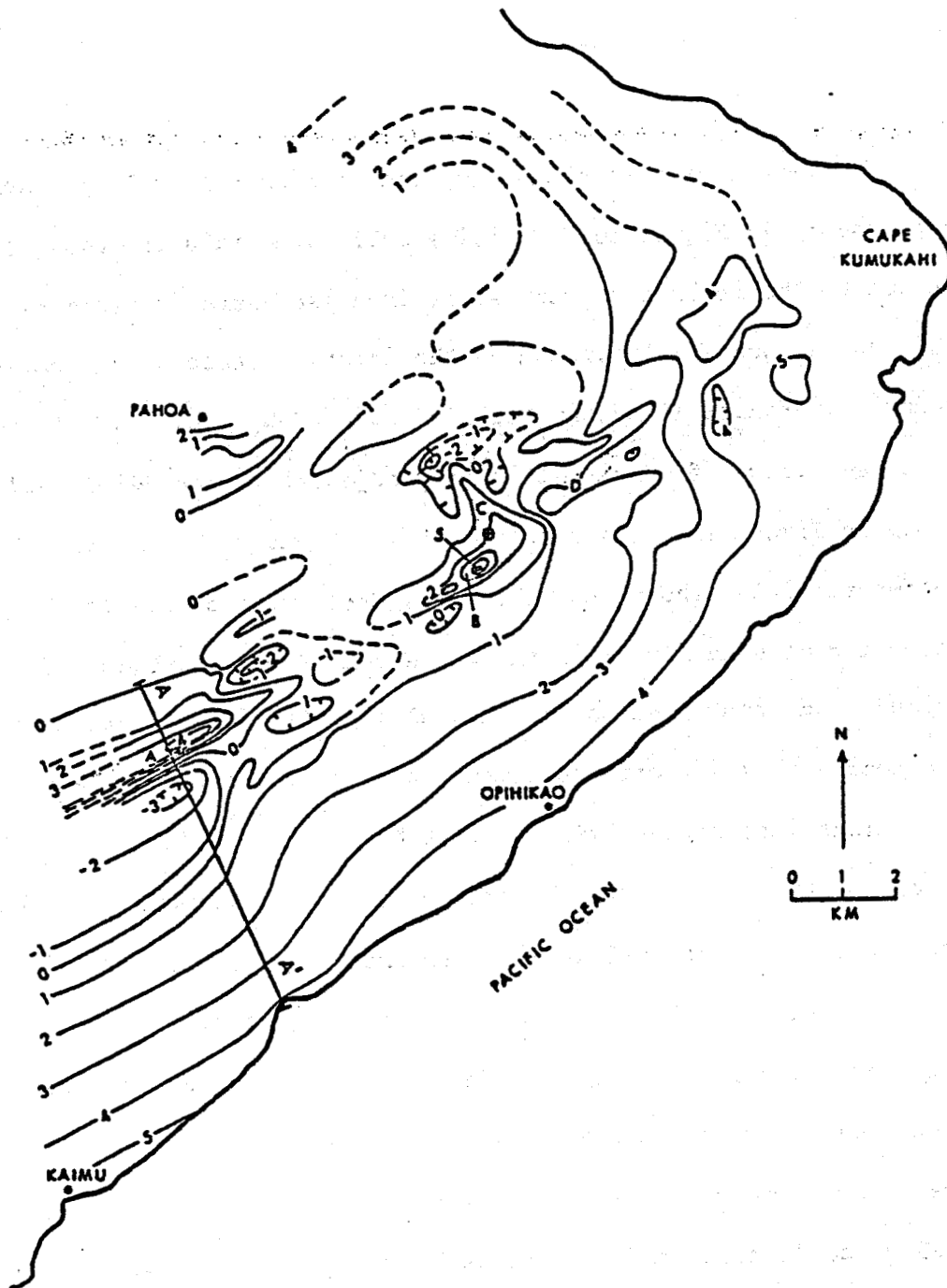
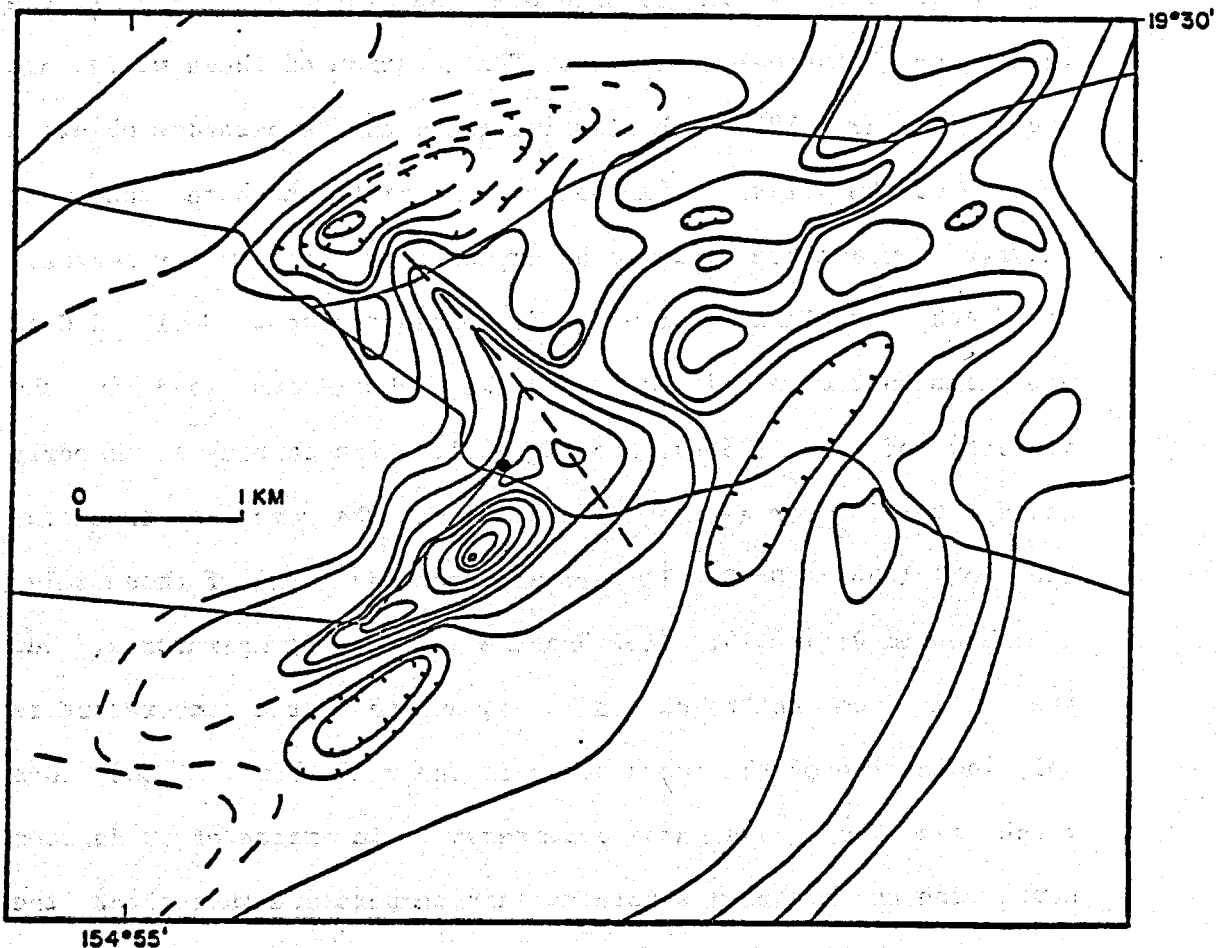


Fig. 10. Contour map of the electrical self-potential observed in the lower east rift zone (dashed where inferred). Crossed circle shows the location of HGP-A. Areas of maximum positive anomaly are noted A, B-C and D (from Zablocki, 1977).





**Fig. 11.** Detailed contour map of the electrical self-potential in the vicinity of HGP-A. Rapid changes in potential are indicative of a near-surface origin for the anomaly (from Zablocki, 1977).

### SHALLOW WELL DATA

A number of shallow wells have been drilled in the east Puna region in the search for probable groundwater as well as in the search for geothermal resources. The location of these wells are shown in Figure 12, which also indicates the temperature observed in each of the wells. Wells nearest the rift zone have the most elevated temperature as would be expected if geothermal reservoirs at depth were leaking warm fluids to the surface. Geo1 and Geo2 are wells that were drilled near the Pahoa-Kaimu road in the vicinity of the 1955 vent by an exploration company in an early attempt to discover geothermal resources. The same is true for the well labeled Geo3. Temperature profiles for 5 of these wells are shown in Figure 13. Geo2 has the highest temperatures, but the well does not reach sea level, and thus, the temperature is only indicative of the steam phase in the well bore. Geo3 does reach sea level and has a temperature in excess of 90 degrees centigrade and has been stable at this temperature throughout the past decade, indicative of reasonably large resource that is recharging this well. Since the water table is always near sea level in this region, and the above sea level rocks are very porous, it is very unlikely that temperatures much in excess of 100 degrees centigrade will ever be observed in shallow wells, although an abundant warm water resource is present at a depth of a few hundred to a thousand feet in the region.

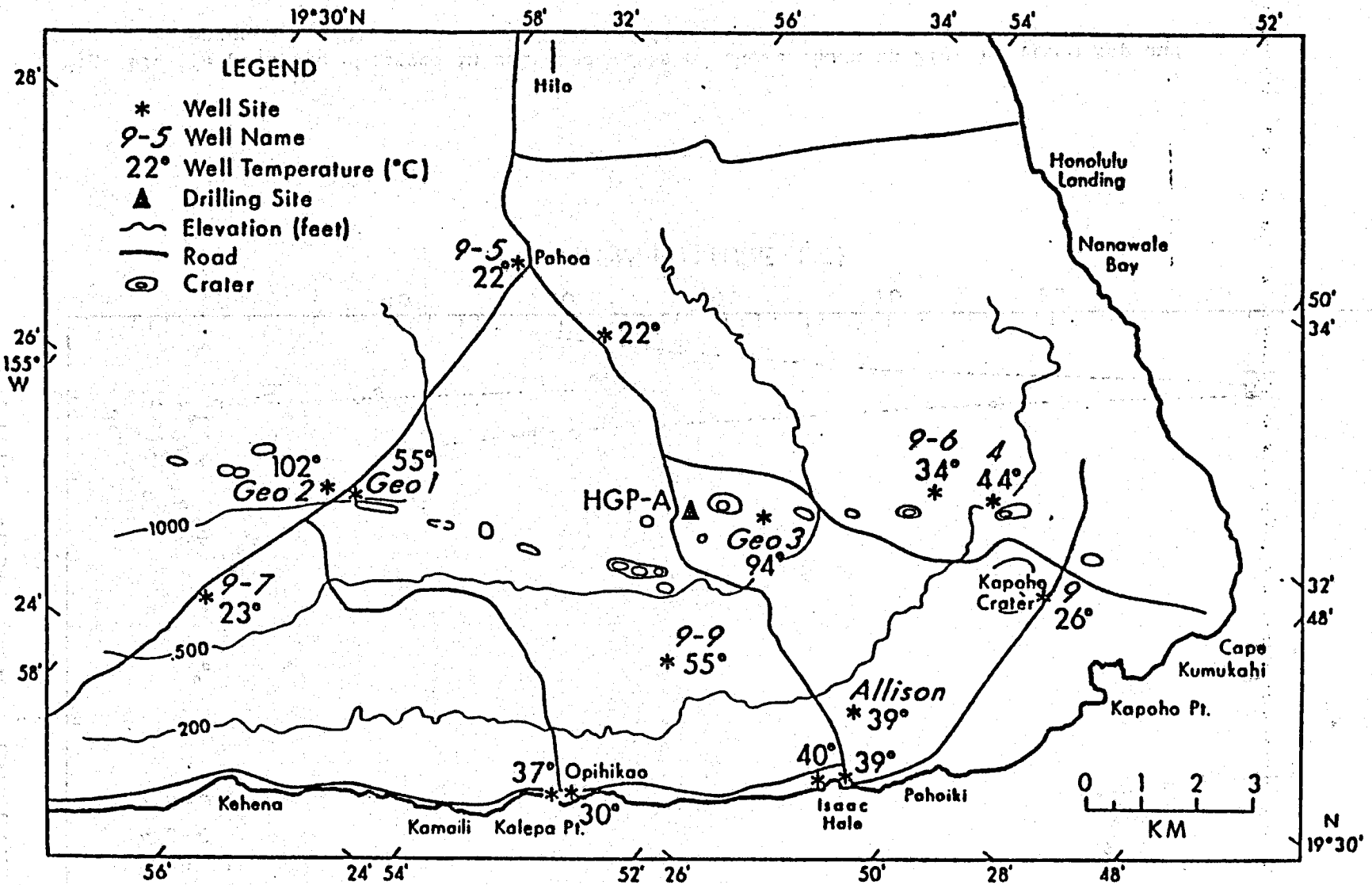


Fig. 12. Map of the Puna district showing the location and temperature of all groundwater sources (from Kroopnick et al., 1977).

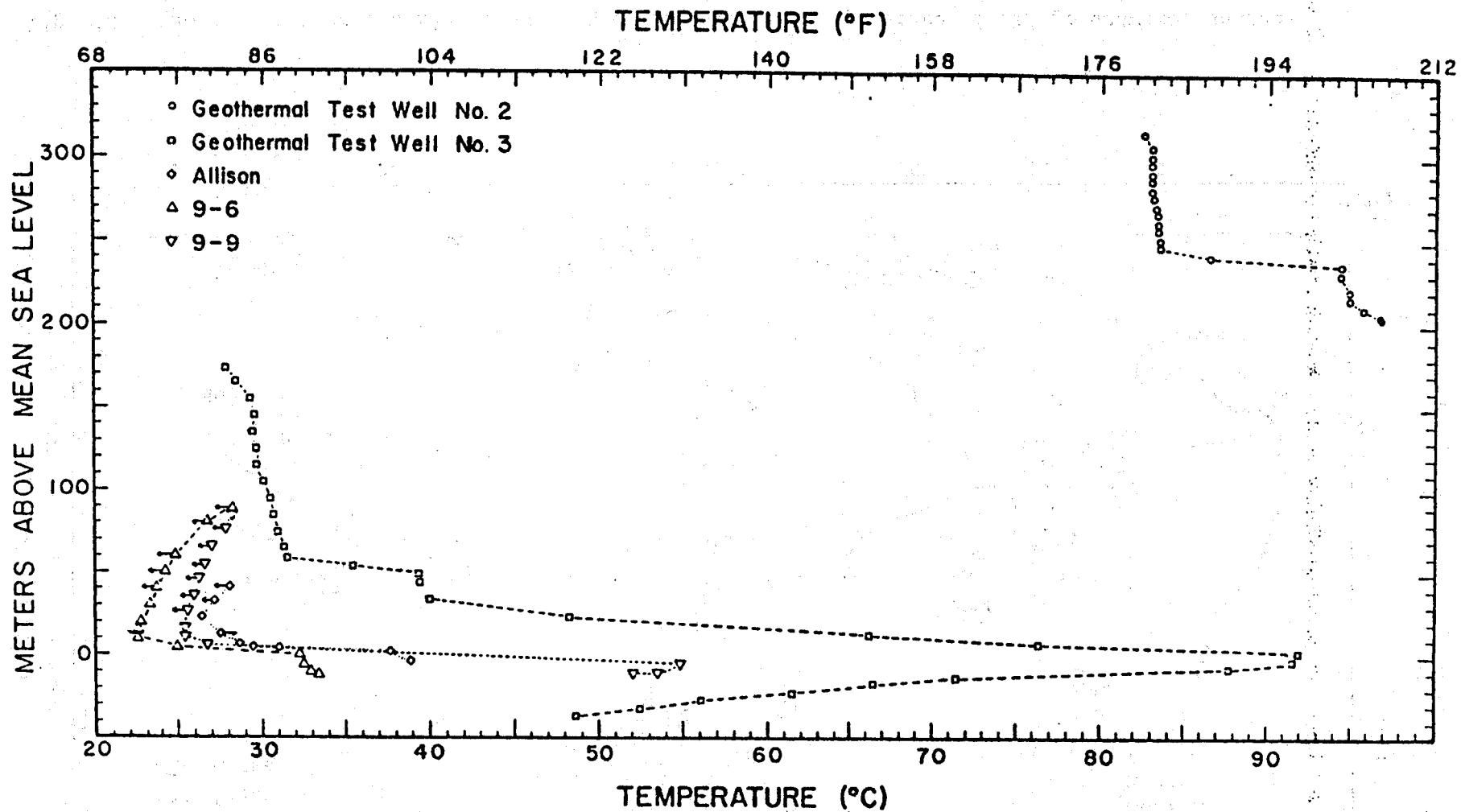


Fig. 13. Temperature observed in selected wells of those shown in Fig. 12 (from Epp and Halunen, 1979).

## GEOLOGIC HAZARDS

The island of Hawaii is very young, with the oldest rocks now exposed to the surface being less than 500,000 years old. The Kilauea volcano is even younger and few of the surface rocks on Kilauea are older than 2000 years. Any area with young geologic features has concomittant geologic hazards and Kilauea volcano is no exception. The primary hazard along the rift zone consists of earthquakes, lava flows, eruptions, and sudden ground movement associated with faulting. Although these hazards are present, the economic risk is probably small.

The largest earthquake in the recent past was the Kalapana earthquake of 1975 (M=7.2). Smaller earthquakes occurred in 1954 (M= 6.5), in 1951 (M= 6.5 and M= 6.9), in 1929 (M= 6.5), and in 1868 (large but magnitude unknown). Despite the size of these earthquakes, little structural damage occurred and accelerations rarely exceed 0.4g. These accelerations have a peak amplitude response primarily in vertical direction. In a risk analysis for the current well site (Rogers Engineering, 1978), it was recommended that the design criteria for primary components (components whose failure involves severe economic loss or possible loss of life or severe injury) be adequate to withstand a ground acceleration of 0.41g with a response spectrum peaking at approximately 4 hz. These characteristics were recommended on the basis of a 30-year design life and an assumption that it was acceptable for the ground acceleration to exceed 0.41g with a

probability of 10 percent in the 30-year period.

Volcanic hazards within the rift zone can be divided into 2 categories: Those due to events taking place in the immediate vicinity of an eruption and those that are associated with the downslope movement of lava issuing from a vent. The best, and perhaps only, way of mitigating the first hazard is to locate the physical facilities outside the zone of potential active eruptive activity. The industrial park site being considered is in such an area. Within the rift zone itself, past eruptions have been frequent in some areas and virtually absent in others. Thus, even within the rift zone there are areas where the hazard due to eruptive activity can be minimized, perhaps to the point of being insignificant. The area between the 1840 vents at the north edge of the rift zone, and the 1790 and 1955 vents at the south edge of the rift zone is such an area (see Figures 3 and 5). The bulk of the Leilani Estates may also be in such a relatively low hazard area. These areas, while having a low hazard relative to eruptive activity, have a high hazard relative to lava flow. The lava flows tend to pond and flow within the rift zone area as is evidenced by the 1790 eruption which underlies much of Leilani Estates. Outside of the rift zone, there is still a significant hazard due to flowing lava. The use of artificial barriers or construction on high ground tends to minimize this hazard. According to the Rogers Engineering report, 3 to 8 percent of the land area within the rift zone is likely to be buried by lava

flows in any given 20 year period, while only 0.5 to 3 percent of the area outside the rift zone would be covered during the same period. Thus, location of the major physical facilities outside the rift zone, particularly if the location is in an area of high ground, should provide an adequately low risk for a major investment.

Ground subsidence has historically been limited to the rift zone itself or to areas to the south of the rift zone in the vicinity of the Halini Pali fault zone. Subsidence occurred within the rift zone in 1924 and again in 1955 in association with eruptive activity and also occurred south of the rift zone in 1975 at the time of the 1975 earthquake. There is no historic record of subsidence taking place north of the rift zone. Thus, subsidence should not be a significant hazard to a plant site located north of the rift zone.

The above analysis has primarily dealt with the hazard at the proposed industrial park site. The producing wells and the pipeline are subjected to all the hazards of the rift zone by necessity, for that is where the resource is located. Earthquakes will probably not result in damage to either installation, with the possible exception that the well bore could be disrupted should a fracture intersect the well bore. This an unlikely possibility and can be best mitigated by having several producing wells separated from each other by some distance. The pipeline itself should not be injured by earthquakes, nor should eruptive

activity disturb it so long as steam continues to flow within the pipeline for it is then essentially self-cooling. Lava flows, on the other hand, could disrupt the pipeline if they become very viscous or blocky, while little disruption is likely to occur if the pipeline is on the surface and is overrun by the very fluid flow. Hazard to the pipeline can probably be minimized by shallow burial or by surface installation with downslope support structures. Since the pipeline must be designed with numerous expansion joints in order to accommodate thermal expansion and contraction, ground subsidence or extension should have little effect on its operation.

In summary, the geologic hazard inherent in the east Puna region can be greatly minimized by careful selection of industrial park site and by awareness of the natural hazard of the region during design and construction of all surface facilities. Although it is difficult to estimate the extent of economic loss that might result from the natural hazards of the area, the risk of significant economic loss should be considerably less than 5 percent during the useful life of the installation (estimated as 30 years) if care is used in the choice of site and proper engineering design and construction techniques are used.



## DISCUSSION AND SUMMARY

The major resources within the region are likely to be found in association with the 2-mile-wide rift zone that extends in a N65E direction from the vent 4 1/2 miles south of Kilauea to Cape Kumukai. Exactly where the resources will be along this trend is, at present, anyone's guess, for we have too little geophysical data to pinpoint detailed targets. However, the surface geological expressions suggest that resources are likely to be found more or less continuously throughout this zone, rather than in only a few isolated spots. Thus, for planning purposes, a model site seem appropriate. As development occurs it may be possible to identify a resource within a mile and a half of the site where the 1840 vent line appears to provide evidence of a potential resource near the northwestern boundary of the Leilani Estates.

It is expected that future development in the southwest rift of Kilauea will result in a series of sites separated by one to three miles, thus planning for industrial parks should be sufficiently flexible that they can be located near one of these development areas rather than requiring a development area of their own. The existence of the current HGP-A well would suggest that one such site might be due north of the HGP-A well. However, the site under study is ideally suited for the drilling that is currently going on at the Craddick-Barnwell location which is approximately 3 miles SSE of the proposed site adjacent to the

easternmost vent of the western zone of the 1955 eruptive activity.

#### CONCLUSION

The geology and historic volcanic activity of the lower east rift system of Kilauea volcano suggest that geothermal resources will be found at numerous sites between Cape Kumukahi and the National Park boundary. The zone of geothermal potential is on the order of 2 miles wide, and the resources are likely to be found 2 to 3 thousand feet below sea level throughout this zone. However, the western, higher elevation portions of the rift system have considerable higher risk of lava inundation, thus the ideal areas to be considered for initial development probably lie to the east of Heiheiahulu which lies about 2 miles west of the Pahoa-Kaimu road. The resources available even in this limited area probably sufficient to supply the need of at least ten industrial parks the size of the one envisioned.

## REFERENCES

- Ellis, W., 1825. A journal of a tour around Hawaii, the largest of the Sandwich Islands, 264 pp, Boston; reprinted in part of Am. Jour. Sci., 1st ser., v. 11, p. 7-36.
- Epp, D. and A.J. Halumen, Jr., 1979. Temperature profiles in wells on the island of Hawaii, Hawaii Inst. of Geophys. Rept. HIG-79-7, 31 pp.
- Hawaii Geothermal Project Well Completion Report HGP-A, 1976. Prepared for University of Hawaii Research Corp. and U.S. Energy Research & Dev. Admin., by Kingston Reynolds Thom & Allardice Ltd., Auckland, New Zealand.
- Helsley, C.E., 1977. Geothermal Potential for Hawaii in Light of HGP-A in Geothermal+ State of the Art, Geothermal Res. Council. Davis, CA, p. 137-138.
- Jaggard, T.A., 1947. Origin and development of craters, Geol. Soc. Am., Mem. 20.
- G.V. Keller, C.K. Skokan, J.J. Skokan, J. Daniels, J.P. Kauahikaua, D.P. Klein, and C.J. Zablocki, 1977. Geoelectric studies on the east rift, Kilauea volcano, Hawaii island, Hawaii Inst. of Geophys. Report HIG-77-15, 195 pp.
- Kroopnick, P.M., R.W. Buddemeier and D.M. Thomas, 1978. Hydrology and geochemistry of a Hawaiian Geothermal System: HGPA. Hawaii Inst. of Geophys. Report HIG-78-6.
- Macdonald, G.A. and J.P. Eaton, 1964. Hawaiian volcanoes during 1955, Geological Survey Bull. 1171, U.S. Govt. Print. Off. Washington, D.C.

Macdonald, G.A. and A.T. Abbott, 1970. Volcanoes in the Sea, The University Press of Hawaii, Honolulu, HI , 441 pp.

Roger's Engineering, Co. Inc., 1978. Seismic and Lava Flow Risk Analysis for Geothermal Well site, HGP-A Island of Hawaii. San Francisco, CA.

Stone, C. and P. Fan, 1978. Hydrothermal alteration of basalts from Hawaii Geothermal Project Well-A, Kilauea, HI. Geology, v. 6, p. 401-404.

Swanson, D.A., 1971. Magma supply rate at Kilauea volcanoes, 1952-1971, Science, v. 175.

**FIGURE CAPTIONS**

Figure 1. Topographic map of the island of Hawaii showing historic flows along the east rift zone of the Kilauea volcano.

Figure 2. Vertical cross-section through the island of Hawaii showing the source of magma for Kilauea and Mauna Loa volcanoes and the shallow magma reservoirs that are the source of the lava observed in the eruptions along the rift systems.

Figure 3. Tectonic map of the east Puna region (lower east rift zone of Kilauea volcano) (from Zablocki, 1977). Eruptive fissures are shown cross-hatched and faults are shown as solid lines with the down-thrown side indicated by dots. Inferred faults are shown by dashed lines. Prominent cinder cones and pit craters are also shown.

Figure 4. Map of part of the east rift zone of Kilauea west of Figure 3 showing faults, cracks and lava flows formed in 1961 (from Macdonald and Abbott after Richter and other, 1964).

Figure 5. Map of the eastern portion of the Puna district showing the lava flows of 1955 and their relationship with older historic flows (from Macdonald and Abbott, 1970).

Figure 6. Map of the easternmost portion of the island of Hawaii showing distribution of the lava flows erupted in 1960. Note

location of the area of the warm spring covered by the 1960 lava (from Macdonald and Abbott, 1970).

Figure 7. Temperature versus depth at the HGP-A well under three separate conditions (from Helsley, 1977).

Figure 8. Alteration mineralogy observed in samples from HGP-A (from Stone 1977).

Figure 9. Map showing the distribution of earthquakes associated with the east rift system of Kilauea. Note the marked decrease in number of earthquakes per unit time in the easternmost portion of the rift. This boundary lies just to the west of the Pahoa-Kaimu road.

Figure 10. Contour map of the electrical self-potential observed in the lower east rift zone (dashed where inferred). Crossed circle shows the location of HGP-A. Areas of maximum positive anomaly are noted A, B-C and D. (from Zablocki, 1977).

Figure 11. Detailed contour map of the electrical self-potential in the vicinity of HGP-A. Rapid changes in potential are indicative of a near surface origin for the anomaly. (from Zablocki, 1977)

Figure 12. Map of the Puna district showing the location and temperature of all groundwater sources (from Kroopnick et al., 1977).

Figure 13. Temperature observed in selected wells of those shown in  
Figure 12 (from Epp and Halunen, 1979).

## APPENDIX B

RE: LEGAL ASPECTS OF DIRECT APPLICATIONS OF GEOTHERMAL ENERGY IN AN AGRICULTURAL PARK IN PAHOA, HAWAII

by: Sanford K. Okura - Carlsmith, Carlsmith, Wichman and Case

### I. INTRODUCTION:

The development of an agricultural park in Pahoa, Hawaii, will involve drilling for geothermal resources, transporting the geothermal resources from the well sites to the agricultural park, the obtaining of governmental approval of the construction of the agricultural park, and the conducting of business in the agricultural park. Some areas of concern which require legal analysis have been identified as follows:

- (1) Ownership of geothermal resources.
- (2) Easements for pipelines for transmission of the resource.
- (3) County and State permitting requirements for development of the agricultural park.

### II. OWNERSHIP OF GEOTHERMAL RESOURCES IN HAWAII:

#### (A) Overview of the ownership problem.

A developer of geothermal resources in Hawaii should be aware that there exists a serious question as to who owns



the geothermal resources located in Hawaii in parcels where the State of Hawaii did not explicitly reserve mineral rights.

In states other than Hawaii, the question of ownership of geothermal rights has arisen, and there have been debates as to whether geothermal resources should be considered a mineral, water, or sui generis. The tendency has been to classify geothermal resources as a mineral. However, the problem is more complicated in the State of Hawaii.

Even if it is determined that geothermal resources are a mineral, in Hawaii there will remain a second difficult question: Who owns the mineral rights? Since Hawaii has never experienced any substantial amount of commercial mining, landowners in Hawaii have generally not been concerned about the ownership of mineral rights. Now that geothermal energy promises to be a valuable resource in Hawaii, the ownership of mineral rights has become an important issue. Serious questions have arisen as to whether or not the State of Hawaii reserved mineral rights in a large number of land grants given without explicit mineral reservations.

(B) Hawaii's statutory definition of geothermal resources as a mineral.

In 1963, the Hawaii State Legislature enacted Act 11 (now HRS Chapter 182) with the expectation that bauxite (or gibbsite) which had been discovered in certain

of the Hawaiian Islands, would be commercially mined.<sup>1</sup> HRS Chapter 182 provides for the reservation of mineral rights to the state, as well as for the disposition of government mineral rights, including details concerning mining leases, exploration, etc.

As originally enacted, HRS Chapter 182 included a definition of the word "minerals." In 1974, the Hawaii State Legislature enacted Act 241, which amended HRS Section 182-1(1) by including "all geothermal resources" in the definition of "minerals".<sup>2</sup> At the same time, HRS Section 182-1 was amended by adding a new subsection defining the term "geothermal resources."<sup>3</sup> The legislature thus attempted to resolve the problem of ownership of geothermal resources by clearly defining geothermal resources to be a mineral. As will be shown below, the problem has not been resolved.

(C) Reservation of mineral rights by the State of Hawaii.

(1) Frequency of Grants without Reservation of Mineral Rights.

It appears that the State legislature enacted Act 241 in 1974 on the assumption that it was thus providing for ownership of geothermal resources by the State of Hawaii except for unusual cases where the government had granted land without reserving mineral rights.<sup>4</sup> However, contrary

to the assumption of the legislature, a 1977 study of grants and land patents for parcels adjacent to the initial geothermal sites in Puna showed that 57% of the area is either owned by the State or held under an explicit mineral reservation to the State, 12% of the area is without mineral reservation to the State, and approximately 30% is held by private owners under documents lacking an explicit mineral reservation, but deriving from land grants originally patented subject to an explicit reservation.<sup>5</sup> It is expected that geographical areas other than the Puna District will similarly have a substantial percentage of grants in which the State did not explicitly reserve mineral rights.

(2) Statutory Requirement of Reservation of Mineral Rights.

The statutory requirement that the Hawaiian Government reserve mineral rights to itself was first found in "An Act to Organize The Executive Departments of the Hawaiian Islands," which was enacted on April 27, 1846, by the Nobles and Representatives of the Hawaiian Islands. One section of that Act provided the form which was to be used for all royal fee simple patents disposing of government lands. That form included the phrase "excepting and reserving to the Hawaiian

Government, all mineral or metallic mines, of every description."<sup>6</sup>

In 1859, the King, Nobles, and Representatives of the Hawaiian Islands enacted The Civil Code of The Hawaiian Islands, effective August 1, 1859. Since the Civil Code was a comprehensive statutory scheme, it necessitated the repeal of various statutes which had been enacted from 1845 to 1856, including most of "An Act to Organize The Executive Departments of the Hawaiian Islands." The form for royal fee simple patents which required a mineral reservation was one of the numerous provisions repealed.<sup>7</sup> Thus, after August 1, 1859, for more than a century, there was no statute requiring that government grants of land reserve mineral rights.

In 1962, the legislature enacted Act 32, which provided that rights to minerals and water were to be reserved to the State in the lease or sale of public lands.<sup>8</sup> HRS Chapter 182, described above, which was enacted in 1963, also provided for the reservation of mineral rights.<sup>9</sup> Thus, from 1846 to 1859, and from 1962 to the present, the reservation of mineral rights in grants by the State has been statutorily required. No such statutory requirement existed from August 1, 1859, to 1962.

With the exception of a few royal grants made before 1848, "Kamehameha" deeds issued up to 1865 and Quitclaim Deeds issued by the Minister of the Interior around 1882, all of the land grants or patents issued from 1846 until the Annexation of Hawaii included a reservation of mineral rights to the King, the Provisional Government or the Republic.<sup>10</sup> However, in 1900, the mineral reservation was removed from the patent form. In 1955 the Territory again began to include mineral reservations in patents, but not consistently. Since 1963 the mineral reservation has been standard. Thus, between 1900 and 1963, land was frequently, if not typically, conveyed by the Territory and later by the State of Hawaii without reserving mineral rights to the government.<sup>11</sup>

(3) Land Commission Awards and Royal Patents.

The question of ownership of mineral rights in Hawaii is further complicated by the method by which fee simple lands were originally granted in Hawaii. The enactment of the statute of December 10, 1845, created the Board of Commissioners to Quiet Land Titles, commonly known as the Land Commission. On April 27, 1946, this statute was re-enacted as Article IV of An Act to Organize the Executive Departments of the Hawaiian Islands.<sup>12</sup> In 1848, there occurred the Great Mahele, or division, wherein there was

a clear separation of the rights to land belonging to the King on the one hand, and to the chiefs and konohikis on the other.<sup>13</sup> The high chief and the lesser konohikis who participated in the Great Mahele were required to thereafter present their claims before the Land Commission to receive awards covering the land quitclaimed to them by Kamehameha, III.<sup>14</sup> The land commission handled over 12,000 such claims from 1848 until its dissolution in 1855.<sup>15</sup>

A Land Commission Award gave complete title to the land confirmed, except for the government's right of commutation, which was generally one-third of the value of the unimproved land as of the date of the award.<sup>16</sup> Upon payment of the commutation, the Minister of Interior issued to the chief or konohiki the royal patent upon the award.<sup>17</sup> The royal patent was ". . . merely a quitclaim of the interest of the government in lands."<sup>18</sup> It was of a ministerial character and neither conveyed nor confirmed title.<sup>19</sup>

(4) In Re Land Title Robinson.

The system of issuing a royal patent upon a Land Commission Award gave rise to a problem considered by the Supreme Court of Hawaii in In Re Land Title Robinson.<sup>20</sup> In that case, two Land Commission Awards had been made without reference to any mineral reservation, but the patents

issued upon said awards contained mineral reservations. In a proceeding before the Land Court to register title in the lands, the Land Court held that the statutory form of patent requiring a mineral reservation applied only to sales of government land, and not to patents issued on Land Commission Awards, and that since the awards in question contained no mineral reservation, the reservation in the patents was improper. The Supreme Court reversed, holding that the statutory form of patent, which included a mineral reservation, applied to both sales of government land and to patents issued on Land Commission Awards, and that an award issued without the required mineral reservation implicitly included such reservation. In short, In Re Land Title Robinson holds that where a Land Commission Award was issued without a mineral reservation, and was followed by a royal patent with a mineral reservation, mineral rights are reserved to the State. It should be noted that two of the five Supreme Court Justices dissented.

The court in In Re Land Title Robinson specifically left open the question as to who owns the mineral rights where neither the Land Commission Award nor the royal patent issued upon the award reserves such rights to the State.<sup>21</sup> That question, if and when raised in the courts,

will probably be phrased in terms of "waiver," i.e., did the State of Hawaii by issuing both a Land Commission Award and a royal patent on the award without mineral reservation rights waive its rights to such reservation which was authorized by the statute? A court which approves of the holding in Robinson would likely hold that the mineral reservation is implicit even if not mentioned in either the Land Commission Award or the royal patent. Such an outcome would seem to logically follow the Robinson holding viewed in the light of the doctrine that a royal patent was nothing more than a quitclaim of the government's right to commutation. Since the royal patent neither conveyed nor confirmed title, it would appear that any omission in the royal patent would not be adequate to waive the government's right to minerals implicitly reserved by the Land Commission Award.

A separate problem exists where a royal patent issued upon a Land Commission Award does contain a mineral reservation, but the land is later divided into smaller pieces (apanas) for which new land patents are issued by the Hawaii government without mineral reservations. This situation allegedly exists with several large tracts of land in the Puna area, and probably in other areas in the State as well.<sup>22</sup>



(5) Original Land Grants Other Than Land  
Commission Awards and Royal Patents; Attorney General  
Memorandum.

In addition to conveyances by Land Commission Awards and Royal Patents, original land titles in Hawaii were conveyed by the King or government by means of Kamehameha Deeds, Grants, Royal Patent Grants, and other government grants. One of the most significant questions remaining unanswered concerns the ownership of mineral rights in lands originally conveyed by such documents between 1859 and 1963 without a mineral reservation to the Hawaiian government. In a memorandum issued by the Department of the Attorney General of the State of Hawaii on August 25, 1976, the Attorney General's office stated its opinion that unless a reservation of mineral rights explicitly appears in a grant<sup>23</sup> made between 1859 and 1963, the mineral rights are not reserved to the State.<sup>24</sup>

The Attorney General memorandum is a short statement based on rather limited research. It apparently did not take into consideration political factors which may ultimately determine the resolution of the question of ownership of geothermal resources. As the State legislature apparently assumed that it was putting geothermal resources in the hands of the State by enacting the amendment to HRS

Section 182-1, it is possible that the State may now attempt to look for some other means of claiming to itself the valuable resource.

(D) The Hawaii Supreme Court's proclivity to state ownership of valuable resources.

(1) Beaches.

In the case of In Re Application of Ashford<sup>25</sup> the Hawaii Supreme Court was faced with the question of the location of the makai (seaward) boundary of two parcels of land which were described in the royal patents as running "ma ke kai" (along the sea). The court rejected the contention that the boundary should be at mean high water mark, as determined by a survey based on publications of the U.S. Coast and Geodetic Survey. Stating that "Hawaii's land laws are unique in that they are based on ancient tradition, custom, practice and usage," the court approved testimony that according to ancient tradition, custom and usage, the boundary dividing private land and public beaches was along the upper reaches of the waves as represented by the edge of vegetation or the line of debris. Justice Marumoto dissented, pointing out, inter alia, that for nearly 50 years the legislative, executive and judicial branches of government in Hawaii had recognized the mean high water

line as the location of the high water mark in situations involving private rights.<sup>26</sup>

In County of Hawaii v. Sotomura,<sup>27</sup> the court reaffirmed the Ashford doctrine and further held that where the wash of the waves is marked by both a debris line and a vegetation line lying further mauka (inland), the boundary line lies along the vegetation line. The court concluded that all of the land below that line belongs to the State of Hawaii. Justice Marumoto dissented to that part of the majority opinion which held that the boundary line lies along the vegetation line, on the ground that the majority was engaging in judicial law-making.

Sotomura was followed by In Re Application of Sanborn,<sup>28</sup> wherein the court held that even where a private landowner held a land court decree containing a description in azimuths and distances of the high water line, such description was in error and the true makai boundary was the vegetation line. It thus appears that the Hawaii Supreme Court has firmly claimed to the State all beach property below the vegetation line.

(2) Water in natural watercourses.

In the case of McBryde Sugar Co. v. Robinson,<sup>29</sup> the Supreme Court of Hawaii held that the right to water could not be, and was not transferred by Land Commission

Awards and Royal Patents. All water in natural watercourses belongs to the state, subject to certain appurtenant rights of landowners to the water. Justice Muramoto dissented to McBryde I, and both Justices Levinson and Marumoto dissented to McBryde II, in which Justice Levinson entered into an extensive analysis of Hawaiian water law, arguing for private ownership of water. One of the private land owners subsequently filed a complaint in U.S. District Court, alleging that the Hawaii Supreme Court decision was unconstitutional. Robinson v. Ariyoshi, 441 F. Supp. 559 (1977). The U.S. District Court held that the State Supreme Court's decision in McBryde would deprive the private landowners of due process under the Fourteenth Amendment, and that injunctive relief should be granted. The case has been appealed to the Court of Appeals for the Ninth Circuit and is awaiting oral arguments.

(3) New land created by lava flows.

The Hawaii Supreme Court's most recent act of claiming to the State a valuable resource is found in State of Hawaii v. Zimring.<sup>30</sup> In that case the Court was faced with the question whether new land formed by a lava flow which extended the shoreline belong to the owner of the adjacent property beyond which the lava flow extended, or to the State of Hawaii. The court held for the State, denying that customary Hawaiian usage had been established

by a governmental act in 1877 which recognized private ownership of land formed in the lava flow of 1868. Judge Vitousek, a circuit court judge sitting in for Justice Kobayashi, dissented vigorously.

The line of cases from Ashford to Zimring demonstrates the strength and consistency of the Hawaii Supreme Court's bias toward State ownership of valuable resources. If either the state legislature or Supreme Court decides that all geothermal resources should be owned by the State, there are a number of theories which may be used in an attempt to support such a claim.

(E) Possible theories for State ownership of geothermal resources.

1. No repeal of Mineral Reservation Requirement.

A close reading of In Re Land Title Robinson reveals that, contrary to a statement made in the Attorney General memorandum, the court in that case did not expressly "hold" that the change in the law was a repeal, but rather characterized the change as a "repeal" without discussing the issue as to whether or not the repeal was intended. The argument might be made by the State that the recent enactments of HRS Section 171-58 and HRS Section 182-2 merely continue the requirement that government grants of land reserve mineral rights, which requirement was inadvertently

omitted from the statutes after 1859. The continued practice of reserving mineral rights to the government after the statutory requirement was dropped in 1859 and until 1900 might be cited as evidence that the Hawaiian government never intended to permit grants without mineral reservations.

(2) McBryde Sugar Co. v. Robinson: Important usufruct of land.

In the case of McBryde Sugar Co. v. Robinson, supra, the Supreme Court of Hawaii held that "the ownership of water in natural water courses, streams and rivers remained in the people of Hawaii for their common good."<sup>31</sup> The court arrived at this conclusion by the following line of reasoning: The Land Commission was authorized to convey only those of the King's rights in land which had been bestowed on individuals by him. The King could not surrender certain prerogatives, including the prerogative "To encourage and even to enforce the usufruct of lands for the common good\*\*\*." The right to water is one of the most important usufruct of lands. Therefore, the right to water was specifically reserved for the people of Hawaii for their common good, and could not be conveyed by Land Commission Awards and subsequent royal patents.<sup>32</sup> Although this theory might have been used to

claim for the State the rights to all water, the language in the opinion specifically referred to water in "natural water courses, streams and rivers."

In the dissent of Judge Levinson in *McBryde II*,<sup>33</sup> it is aptly pointed out that "to say that the King retained the power to 'encourage' and 'enforce' the 'usufruct' of land is not to say that, ipso facto, he retained title to all surface water in his kingdom."<sup>34</sup> Nevertheless, the majority in the *McBryde* cases held that as one of the most important usufruct of land, the right to water is reserved to the State.

The question arises as to whether geothermal resources might be deemed to be an important usufruct of lands, which Land Commission Awards and Royal Patents could not grant, and which were therefore reserved to the State even in the absence of any language in the grants regarding mineral reservation. The term "usufruct" is defined as "The right of enjoying a thing, the property of which is vested in another, and to draw from the same all the profit, utility, and advantage which it may produce, provided it be without altering the substance of the thing."<sup>35</sup> It is arguable that if the right to water is to be considered a usufruct of land, then the right to geothermal resources should also be deemed a usufruct of land, for water is a

chief component of geothermal resources. If the court were to focus on heat as being the most important part of the geothermal system, arguably drawing heat from the earth does not alter the substance of the land. Although such an application of the term "usufruct" might be unique, it is not impossible that the Hawaii Supreme Court would resort to such a device were it to decide that geothermal resources should belong to the State.

(3) Public trust doctrine.

The Hawaii Supreme Court has also used the "public trust doctrine" to claim valuable resources for the State. It appears that the court first adopted this doctrine in King v. Oahu Railway and Land Co.<sup>36</sup> In that case, the court held that the people of Hawaii hold the absolute rights to all its navigable waters and the soils under them for their own common use. The lands under the navigable waters in and around the territory of Hawaii are held in trust for the public uses of navigation.<sup>37</sup> In County of Hawaii v. Sotomura,<sup>38</sup> the court extended the public trust doctrine to the beaches, and held that "land below the high water mark, like flowing water, is a natural resource owned by the State 'subject to, but in some sense in trust for, the enjoyment of certain public rights.'"<sup>39</sup> In State of



Hawaii v. Zimring, supra, the court further extended the public trust doctrine to lava extensions.<sup>40</sup>

The public trust doctrine appears to contemplate the actual enjoyment of the resource by the people. In Illinois Central R.R. v. Illinois,<sup>41</sup> a case that was heavily relied upon by the court in King v. Oahu Railway and Land Co., the U. S. Supreme Court held that title to land below the high water mark was different from that which the State holds in other lands:

"It is a title held in trust for the state, that they may enjoy the navigation of the waters, carry on commerce over them, and have liberty of fishing therein freed from the obstruction or interference of private parties . . . . The control of the state for the purposes of the trust can never be lost, except as to such parcels as are used in promoting the interests of the public therein, or can be disposed of without any substantial impairment of the public interest in the lands and waters remaining."<sup>42</sup>

In State of Hawaii v. Zimring, the court described the State's duty as trustee of property held in public trust for the benefit, use and enjoyment of all the people:

"Presumptively, this duty is to be implemented by devoting the land to actual public uses, e.g., recreation. Sale of the property would be permissible only where the sale promotes a valid public purpose."<sup>43</sup>

The public trust doctrine thus appears to contemplate boating, fishing, the carrying on of commerce, recreation, and other such physical enjoyment which the people of the State derive from the resource held by the State as trustee. Nevertheless, given the ingenuity of the Hawaii Supreme Court, it would appear that the extension of the public trust doctrine to include geothermal resources is feasible. Although geothermal resources could not ordinarily be enjoyed physically by the people, it is arguable that under the public trust doctrine, the State could develop the resource and use the profits therefrom for the general welfare of the public, and thus for the enjoyment of the people of the State. This approach would appear permissible under the language in Zimring providing for sale of the public trust property "where the sale promotes a valid public purpose."

(4) Ancient Hawaiian Tradition, Custom, Practice and Usage.

In Ashford, supra, the Hawaii Supreme Court claimed for the State beach property below the edge of vegetation or the line of debris, on the ground that the makai boundary to private property was thus established by ancient Hawaiian custom. The dissent in that case suggests that the majority's position is not supported by established Hawaiian law.

In McBryde, the court claimed the water in natural water courses to the State, despite the dissent's argument that the majority's position was not supported by ancient Hawaiian usage. In Zimring, supra, the majority acquired lava extensions for the State by discounting contrary evidence of one instance of relevant earlier Hawaiian usage.

It thus appears that evidence of ancient Hawaiian tradition, custom, practice and usage can be either used or ignored by the court to arrive at a decision based on its sentiments favoring public ownership of property. At first blush, it may appear that since the discovery of the usefulness of geothermal resources is recent, there could have been no ancient usage of the resource. However, the ancient Hawaiians may have bathed in geothermally heated pools, or used the steam escaping from vents in the earth. It is not

impossible that the Hawaii Supreme Court could cite such evidence in support of a decision to establish ownership of all geothermal resources in the "people of Hawaii," i.e., the State.

(5) Rights of Native Tenants.

Ancient custom among the Hawaiian people recognized certain rights which the common people had in the land. On November 7, 1946, the nature and extent of those rights were spelled out in Section No. 1 of the Joint Resolution on The Subject of Rights in Lands, etc.<sup>44</sup> The current provision in HRS Section 7-1 abrogated and superceded the rights of tenants under both ancient custom and prior statutory law.<sup>45</sup> HRS Section 7-1 provides as follows:

"Building materials, water, etc.; landlords' titles subject to tenants' use. Where the landlords have obtained, or may hereafter obtain, allodial titles to their lands, the people on each of their lands, shall not be deprived of the right to take firewood, house-timber, aho cord, thatch, or ki leaf, from the land on which they live, for their own private use, but they shall not have a right to take such articles to sell for profit. The people shall also have a right to drinking water, and running water, and the right of way. The springs of water, running water, and roads shall be free to all, on all lands granted in fee simple; provided, that this shall not be applicable to wells and water-courses, which individuals have made for their own use."

The right to geothermal resources would not appear to fall within the rights of native tenants, as the right to springs of water is not applicable to "wells . . . which individuals have made for their own use." Furthermore, the items to which the people have a right are enumerated in HRS Section 7-1. The language in this section would have to be strained considerably to construe it to include geothermal resources.

(6) Section 5(f) of the Admission Act.

In the appeal to the Court of Appeals for the Ninth Circuit from the District Court decision in Robinson v. Ariyoshi, supra, an amicus-curiae brief has been filed by Ho'ala Kanawai, Inc. (awakening the law), a nonprofit organization interested in the rights of native Hawaiians. The arguments made by Ho'ala Kanawai, Inc. for the reversal of the District Court decision, and for the affirmation of the Hawaii Supreme Court's decision that the water belongs to the state would apply just as well to the issue of ownership of geothermal resources.

The argument rests on the premise that the Civil Code of 1859 did not effectively repeal the requirement that a mineral reservation clause appear in Royal Patents. The argument is that Section 43 of the

Civil Code of 1859 provides that the Royal Patent shall continue to be the method of conveyancing, and that to take the position that the King, Prime Minister, and Minister of Interior continued to sign Royal Patents which included the mineral reservation clause without realizing that the Civil Code of 1859 had repealed the clause would be an embarrassment to His Majesty's Government. Section 1492 of the Civil Code of 1859 provided that ". . . there may be no . . . embarrassment to his Majesty's Government, from any change, . . ." as a result of repeal of the 1849 Legislation. The argument then continues that under the Organic Act, the requirement that Royal Patents include a mineral reservation clause, which requirement was not effectively repealed in 1859, became the law in the Territory, and was subject to repeal only by the Legislature of Hawaii or by Congress.

The final steps to the argument are as follows. Upon annexation, the Republic of Hawaii deeded its title to all public lands and property, including mineral rights, to the United States, and the Territory obtained only the possession, use and control of the public lands and properties within the limitations provided for by

the Organic Act. The Territory's subsequent conveyance of lands without reservation of minerals could not convey mineral rights, which belonged to the federal government. Upon the admission of the State of Hawaii into the Union, the United States granted to the State title to all the public lands and other public property, including mineral rights, within the boundaries of the State of Hawaii, aside from certain exceptions. These lands granted to the State of Hawaii are to be held by the State of Hawaii as a public trust for public education, for the betterment of the native Hawaiians, for the development of farm and home ownership, for the making of public improvements, and for the provision of lands for public use.<sup>46</sup>

The entire argument by Ho'ala Kanawai, Inc. depends on the assumption that the Civil Code of 1859 did not effectively repeal the requirement that Royal Patents contain a mineral reservation clause. This argument does not seem to be reasonable. Although the arguments advanced in the amicus-curiae brief do not seem to be particularly convincing, there is a possibility that the state Supreme Court would hold that the repeal of the mineral reservation requirement was not intended, and therefore is not effective.

(F) Federal ownership of mineral rights.

In Hawaii, there is generally no federal ownership of mineral rights, except in lands owned by the federal government outright. Under the joint resolution of annexation, approved July 7, 1898, numbered 55,<sup>47</sup> the Republic of Hawaii ceded and transferred all of its public property to the United States. Such public property remained in the possession, use, and control of the government of the Territory of Hawaii.<sup>48</sup> When Hawaii was admitted into the Union as the fiftieth state, the United States granted back to the State of Hawaii all of the lands and properties that had been ceded to the United States by the Republic of Hawaii under the joint resolution of annexation approved July 7, 1898, or that had been acquired and exchanged for lands or property so ceded.<sup>49</sup> Thus, even assuming that grants made after 1900 by the Territory of Hawaii reserving mineral rights reserved such rights to the United States of America, all title to such mineral rights would have been conveyed to the State of Hawaii in 1959.

(G) Constitutional considerations.

A contest over the ownership of geothermal resources, particularly if the State of Hawaii attempts to claim all of the resources to itself, will likely give rise to constitutional issues. Traditional arguments of depri-



vation of property violative of the due process clauses of the U.S. and State constitutions may be anticipated.<sup>50</sup> Given the Hawaii Supreme Court's bias towards State ownership of property, such arguments will probably be ignored by the court. The constitutional arguments would probably stand a much better chance of prevailing in the Federal Courts.

(H) Summary on ownership of geothermal resources.

If the issue of the identity of the resource is raised, it will probably be ultimately decided by the Supreme Court of Hawaii that geothermal resources are a mineral. This is the definition established by the Hawaii State Legislature and favored by courts in other jurisdictions.

There exists a possibility that the State of Hawaii will attempt to claim all geothermal resources to itself. Should it decide to do so, there are available certain legal theories which would be invoked to attempt to accomplish the task. In the absence of a claim to all geothermal resources by the State, mineral rights owners should prevail over other claimants in the contest over ownership of the resource.

(I) Effect of ownership uncertainty on geothermal developer.

Because of the uncertainty concerning the ownership

of geothermal rights in Hawaii, the prudent developer should be careful to negotiate with the private landowner a geothermal lease which will anticipate the possibility of a claim by the State of Hawaii to the geothermal resources. If the well site involves land with no explicit mineral reservation to the State of Hawaii, the lease between the developer and private landowner should specifically deal with the question of payment of royalty in the event that the State of Hawaii claims the geothermal resources. One possible alternative is to provide that royalty payments will be withheld by the developer until such time that a court of competent jurisdiction finally determines who owns the geothermal resource, at which time the developer will make royalty payments to the rightful owner. Such a provision, which is very favorable to the developer, has been negotiated and agreed upon in certain geothermal lease options now in effect on the Island of Hawaii. Another possibility is to provide that royalty payments will be made to the landowner, presuming that the landowner is the owner of the geothermal resource, until a court of competent jurisdiction decides otherwise. A lease containing such a provision has been negotiated and is now in effect on the Island of Hawaii. Still another alternative would be to provide for the pay-

ment of royalty into escrow in an interest bearing account until ownership of the resource is determined.

A lessee under a geothermal lease, or any person acquiring the rights of a lessee in a geothermal lease, by carefully structuring the provision recognizing the uncertainty of ownership of the geothermal resources, can avoid the devastating possibility of double payment of royalty, minimize the exposure to expensive litigation, and even enhance cash flow.

### III. ACQUISITION OF EASEMENTS

At the present time there is no statutory authority giving a producer or developer of geothermal resources a power of eminent domain to acquire pipeline easements leading from the geothermal well to the industrial park. Public utilities are given by statute the right of eminent domain. HRS Section 101-4. However, Section 269-27.1(b) of the Hawaii Revised Statutes, which was enacted in 1978, specifically excludes "the producer of geothermal steam or electricity generated from geothermal steam" from coverage of the term "public utility". As regulation by the Public Utilities Commission was one of the chief barriers preventing the development of geothermal resources, it would seem that the exclusion, although literally referring only to the

"producer of geothermal steam or electricity generated from geothermal steam" would be construed to include geothermal hot water producers as well. Thus, it is expected that geothermal steam, hot water, or electricity producers will not be deemed public utilities, and consequently will not have the power of eminent domain provided for in HRS Section 101-4.

There is some question as to how the eminent domain power of the State or County may be used to acquire energy corridors for the purposes of transmitting the geothermal resource from the wells to the agricultural park site. Section 101-2 of the Hawaii Revised Statutes provides that "private property may be taken for public use." HRS Section 101-13 provides that the County may commence an eminent domain proceeding whenever it "deems it advisable or necessary to exercise the right of eminent domain in the furtherance of any governmental power . . ." HRS Section 46-61 provides that the County shall have the power to "take private property for . . . rights-of-way for drains, sewers, pipelines, aqueducts, and other conduits for distributing water to the public . . ." The creation of energy corridors for a geothermal project cannot be said to fall clearly within the language of the above quoted statutes.

It is likely that appropriate legislation will have to be enacted in order to specifically allow the acquisition of easements by eminent domain for the purpose of transporting geothermal steam and water.

In the event an attempt is made to transport geothermal resources prior to the enactment of such legislation, it will be necessary to negotiate with the owners of parcels of land between the well site and the agricultural park for easements for pipelines. The difficulty of such a task will depend upon the number of parcels involved, and the particular predisposition of the landowners.

IV. COUNTY AND STATE PERMITTING REQUIREMENTS FOR DEVELOPMENT OF THE AGRICULTURAL PARK:

(A) Introduction.

Before the agricultural park can be developed, it must be shown that the proposed use falls within the permissible uses under the State Land Use Commission District Regulations, as well as under the County Zoning Code. An Environment Impact Statement may also be required, and, an amendment to the General Plan of the County of Hawaii may also be necessary.

(B) State Land Use Designation.

It is assumed that the proposed site of the agri-

cultural park falls within an agricultural district for State Land Use purposes. The State Land Use Commission District Regulations, Part III, 3-3(11) provides that "agricultural parks" fall within the permissible uses within the agricultural district. However, the term "agricultural parks" as used in the Regulations is generally understood to refer merely to a subdivision located in agriculturally zoned land, or to a situation where the crops to be processed are grown on the land where the processing plant is located. The "agricultural park" contemplated by this study would probably be considered an industrial park, and would probably not be found to fall within the meaning of 3-3(11). 3-3(10) provides that permissible uses include "buildings and uses, including but not limited to mills, storage and processing facilities, maintenance facilities that are normally considered direct (sic) accessory to the above permitted uses." The "above permitted uses" include cultivation of crops (including flowers, vegetables, foliage, fruits, forage and timber). Thus, the proposed anchor industries for the agricultural park would be permissible uses within the agricultural district if they are "normally considered direct accessory" to the cultivation of crops. There may be some question as to whether an ethanol plant

is "normally considered direct accessory" to the cultivation of timber or other crops.

If it is determined by the State Land Use Commission that any of the proposed uses contemplated by the agricultural park does not fall within the meaning of 3-3(10), then there would be two possible courses of action.

The first possible course of action would be to petition for a special use permit. In order to qualify for a special use permit, one would have to show "unusual and reasonable use." The State Land Use Commission District Regulations, Part V, 5-2 provides the following guidelines to be applied in determining an "unusual and reasonable use."

"(1) Such use shall not be contrary to the objectives sought to be accomplished by the Land Use Law and Regulations.

(2) That the desired use would not adversely affect surrounding property.

(3) Such use would not unreasonably burden public agencies to provide roads and streets, sewers, water, drainage and school improvements, and police and fire protection.

(4) Unusual conditions, trends and needs have arisen since the district boundaries and regulations were established.

(5) That the land upon which the proposed use is sought is unsuited for the uses permitted within the District."

The procedure for applying for a special use permit is as follows:

"a. File Application for Special Permit with the County Planning Department.

b. A public hearing is conducted within a period not less than 30 nor more than 120 days from the filing of the application.

c. The Planning Commission renders a decision no earlier than 15 days after the public hearing.

d. If the County Planning Commission denies the special permit applied for, such denial may be appealed to the Circuit Court. If the Commission approves the special permit applied for, the Planning Director transmits the decision together with the findings pertaining thereto to the State Land Use Commission within 60 days after the decision is rendered. The transmission to the State Land Use Commission is not necessary if the land involved is less than 15 acres. (Although the rules of the County Planning Commission specify 10 days, the Addendum to the State Land Use Commission Rules of Practice and Procedure, effective March 27, 1977, changes the permitted time to 60 days.)

e. The State Land Use Commission will act on the petition within 45 days after receipt of the County Planning Commission's favorable decision.

f. The applicable regulations are Rule 6 of the Planning Commission's Rules Relating to Administrative Procedure, and Part IX of the Rules of Practice and Procedure and District Regulations of the State Land Use Commission.



The advantage of a special use permit is that it can be obtained simply and quickly. The disadvantage would be that the permit would be applicable only for the specific use petitioned for, i.e., an ethanol plant, a cattle feed mill, or a papaya processing plant. If at any time in the future a new industry were to replace one of the original industries, or if a new industry were to be added to the original industries, the new industry would have to qualify independently for a special use permit.

The other possible course of action would be to petition for a State Land Use District Boundary Amendment from agricultural to urban. The procedure for petitioning for a district boundary amendment is set forth in the State Land Use Commission's Rules of Practice and Procedure, Part VI. The next step would be to amend the County of Hawaii General Plan so as to provide for industrial uses at the proposed site for the agricultural park. A general plan amendment would not be necessary if the proposed site is located in a zone designated in the general plan as "alternate urban expansion." The next step would be to petition the County for rezoning of the parcel involved. Finally, if the land is to be subdivided into separate parcels for the various industries, it would be necessary to petition for subdivision approval.

(C) County Zoning Code.

It is assumed that the site for the proposed agricultural park falls within an agricultural district for County zoning purposes. The Hawaii County Zoning Code, Article 7, Section 3, Paragraph B provides that among the permitted uses in an agricultural district are:

"All forms of agriculture; the growing and gathering of crops, fruits, vegetables, flowers, trees, and other plants; the raising and keeping of animals and fowls except as listed in Item 9; the physical processing, storage and sale of the products produced on the premises."

Paragraph N provides that among the permitted uses in the agricultural district are:

"Processing, storage, packing, and sale of products produced on the premises provided the site or building used for such activity shall be at least one hundred (100) feet from any property line."

It appears that under both of the relevant paragraphs quoted above, processing is limited to products produced on the premises. Since the products to be processed in the agricultural park presumably will not be produced on the premises, it appears that the agricultural park will not be permitted under the agricultural zoning. Rezoning to industrial designation will thus be necessary.

(D) Environmental Impact Statement.

Section 343 of the Hawaii Revised Statutes provides in pertinent part that an "environmental assessment" shall be required for any action which proposes any amendments to existing county general plans where such amendment would result in designations other than agriculture, conservation, or preservation. Thus, if it is necessary to amend the General Plan, an environmental assessment would be filed. The appropriate agency would then determine whether or not an Environmental Impact Statement is required.

(E) Building Permit.

Before commencing any construction, the developer would have to obtain an ordinary building permit. If the plans are in order, the permit is usually issued within two to four weeks after the filing of an application. Approval may take longer if problems exist. The applicable regulations would be the Building code of the County of Hawaii.

FOOTNOTES

<sup>1</sup> Act 11 passed in 1963 was an updated version of Act 255 passed by the Legislature of the Territory of Hawaii in 1957. As Act 255 was enacted prior to statehood and contained some provisions which were related to the Organic Act, it could not become effective until ratified by the Congress of the United States of America. As Congress never ratified Act 255, the Hawaii State Legislature passed Act 11 in 1963, after Hawaii had become a state.

<sup>2</sup> "Minerals" means any or all of the oil, gas, coal, phosphate, sodium, sulphur, iron, titanium, gold, silver, bauxite, bauxitic clay, diaspore, boehmite, laterite, gibbsite, alumina, all ores of aluminum and, without limitation thereon, all other mineral substances and ore deposits whether solid, gaseous, or liquid, including all geothermal resources, in, on, or under any land, fast or submerged; but does not include sand, rock, gravel, and other materials suitable for use and used in general construction." HRS section 182-1(1).

<sup>3</sup> HRS Section 182-1(9) provides as follows:  
"Geothermal resources" means the natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas or other hydrocarbon substance."

This definition of geothermal resources is patterned after the definition adopted by the California Legislature.

<sup>4</sup> Kamins, Ownership of Geothermal Resources in Hawaii, 1 Univ. of Haw. L.R. 69, 70 (1979).

<sup>5</sup> Ibid., at 70, 71, footnote 12.

<sup>6</sup> Laws of Hawaii 1849, Part I, Chapter VII, Article II, Section VI, Pages 100-101 provides:

"Section VI. The form of all royal fee simple patents shall be as follows:

"KAMEHAMEHA-- ,by the grace of God, King of the Hawaiian Islands, by this his royal patent, makes known unto all men, that he has for himself and his successors in office, this day granted and given, absolutely, in fee simple unto \_\_\_\_\_, his faithful and loyally disposed subject, for the consideration of \_\_\_\_\_ dollars, paid into the royal exchequer, all that certain piece of land, situated at \_\_\_\_\_, in the Island of \_\_\_\_\_, and described (by actual survey or by natural boundaries as the case may be) as follows:

containing \_\_\_\_\_ acres, more or less; excepting and reserving to the Hawaiian government, all mineral or metallic mines, of every description.

To have and to hold the above granted land in fee simple, unto the said \_\_\_\_\_, his heirs, and assigns forever, subject to the taxes to be from time to time imposed by the legislative council equally, upon all landed property held in fee simple.

In witness whereof I have hereunto set my hand, and caused the great seal of the Hawaiian Islands to be affixed, at Honolulu, this \_\_\_\_\_ day of \_\_\_\_\_, 18\_\_\_\_.

(L.S.)  
Attest, \_\_\_\_\_

Premier.

<sup>7</sup>"An Act to Organize The Executive Departments of The Hawaiian Islands" consisted of approximately 225 pages of statutes, include the form of the royal fee simple patent quoted in footnote 10 above, which required the reservation to the Hawaiian government of all mineral or metallic mines. Thus, it appears that although there was no specific intention to repeal the requirement that government grants of land reserve mineral rights, such requirement was repealed along with the repeal of numerous other statutes for which the Civil Code was substituted in 1859.

<sup>8</sup>The pertinent part of Act 32 is HRS Section 171-58, which provides in part:

"Minerals and water rights. Except as provided herein, the right to any mineral or surface or ground water shall not be included in any lease, agreement, or sale, such right being reserved to the State; provided, that the board of land and natural resources may make provisions in such lease, agreement, or sale, for the payment of just compensation to the surface owner for improvement taken as a condition precedent to the exercise by the State of any reserved rights to enter, sever, and remove minerals or to capture, divert, or impound water.

"Disposition of mineral rights shall be in accordance with the laws relating thereto enacted or hereafter enacted by the legislature."

<sup>9</sup>HRS Section 182-2 provides in full as follows:

"Mineral rights reserved to the State. (a) All minerals in, on or under state lands or lands which hereafter become state lands are reserved to the State; provided, that the board of land and natural resources may release, cancel, or waive the reservation whenever it deems the land use, other than mining, is of greater benefit to the State as provided for in Section 182-4. Such minerals are reserved from sale or lease except as provided in this chapter. A purchaser or lessee of any such lands shall acquire no right, title, or interest in or to the minerals. The right of the purchaser or lessee shall be subject to the reservation of all the minerals and to the conditions and limitations prescribed by law providing for the State and persons authorized by it to prospect for, mine, and remove the minerals, and to occupy and use so much of the surface of the land as may be required for all purposes reasonably extending to the mining and removal of the minerals therefrom by any means whatsoever.

"(b) Subject to subsection (a), all land patents, leases, grants, or other conveyance of state lands shall be subject to and contain a reservation to the State of all the minerals, and shall also contain a reservation to the State, and persons authorized by it, of the right to prospect for, mine, and remove the minerals by deep mining,

strip mining, drilling, and any other means whatsoever, and to occupy and use so much of the surface as may be required therefor. [L 1963, c 11, pt of §1; Supp, §99A-2]"

<sup>10</sup>Kamins, supra, at 71, footnote 17.

<sup>11</sup>Kamins, supra, at 71-72.

<sup>12</sup>J. Chinen, The Great Mahele, University of Hawaii Press, 1958, Page 8.

<sup>13</sup>A konohiki was the head of a unit of land known as an ahupuaa.

<sup>14</sup>Ibid, page 20.

<sup>15</sup>Ibid. page 12.

<sup>16</sup>Ibid. page 15.

<sup>17</sup>Ibid. page 21.

<sup>18</sup>Mist v. Kawelo, 11 Haw. 587 (1898).

<sup>19</sup>Brunz v. Minister of Interior. 3 Haw. 783 (1877),  
Hawaii v. Liliuokalani, 14 Haw. 88 (1902).

<sup>20</sup>In Re Land Title Robinson, 49 Haw. 429, 421 P.2d 570 (1966).

<sup>21</sup>Id. at 443, footnote 14, 421 P.2d 578, footnote 14.

<sup>22</sup>Kamins, supra, at 71-72.

<sup>23</sup>The Attorney General memorandum uses the terms "award" and "grant" interchangeably, and does not distinguish between a Land Commission Award followed by a Royal Patent on the one hand, and a direct grant of government land to an individual on the other.

<sup>24</sup>Memorandum from Eric Y. Marn, Deputy Attorney General, to Christopher Cobb, Chairman of the Board of Land and Natural Resources, dated August 25, 1976. The memorandum provides in pertinent part as follows:

"Research was conducted on the question of whether the State of Hawaii could assert a claim to the geothermal resources beneath lands granted to private persons without mineral reservations to the State. Our research indicates that up to the Civil Code of 1859, the King could not grant away mineral rights when lands were given to private persons. This restriction was explicitly stated in the law of 1856, entitled, "An Act to Organize the Executive Departments of the Hawaiian Lands, Section IV". However, from 1859 to 1963, the mineral rights reservations was dropped; there was no express repeal of the reservation but rather was the apparent result of oversight. However, in the case of In Re Land Title of Robinson, 49 Haw. 429 (1966), our court held that the change in the law was a repeal of the mineral rights clause.

"Thus, it would appear that unless a reservation was made in an award granted between 1859 and 1963, the mineral rights would not be explicitly reserved to the State.

"In conclusion, then, it would appear that any grant conveyed between 1859 and 1963, which did not contain a mineral reservation to the State, transferred the mineral rights to the Grantee."

<sup>25</sup> In Re Application of Ashford, 50 Haw. 314, 440 P.2d 76 (1968).

<sup>26</sup> Id. at 345, 440 P.2d at 94.

<sup>27</sup> County of Hawaii v. Sotomura, 55 Haw. 176 (1973), 517 P.2d 57 (1973), cert. denied 419 U.S. 872 (1974).

<sup>28</sup> In Re Sanborn, 57 Haw. 585, 562 P.2d 771 (1977).

<sup>29</sup> McBryde Sugar Co. v. Robinson, 54 Haw. 174, 504 P.2d 1330 (1973), hereinafter referred to as "McBryde I;" and McBryde Sugar Co. Ltd. v. Robinson, 55 Haw. 260, 517 P.2d 26 (1973), on rehearing, hereinafter referred to as "McBryde II," cert. denied 417 U.S. 976 (1974).

<sup>30</sup> State of Hawaii v. Zimring, 58 Haw. 106, 566 P.2d 725 (1977).

<sup>31</sup> 54 Haw. 174 at 187, 504 P.2d at 1339.

<sup>32</sup> Id. at 186, 504 P.2d at 1338.



<sup>33</sup> Only Judge Marumoto dissented in McBryde I. After rehearing, both Judge Marumoto and Judge Levinson dissented in McBryde II.

<sup>34</sup> 55 Haw. at 270, 517 P.2d at 32.

<sup>35</sup> Black's Law Dictionary, 3rd Ed. (1933), page 1790.

<sup>36</sup> 11 Haw. 717 (1899).

<sup>37</sup> Id. at 725.

<sup>38</sup> 55 Haw. 176, 517 P.2d 57 (1973).

<sup>39</sup> Id. at 183-184, 517 P.2d at 63.

<sup>40</sup> State of Hawaii v. Zimring, 58 Haw. 106 (1977).

<sup>41</sup> Illinois Central R. R. v. Illinois, 146 U.S. 387 (1892).

<sup>42</sup> Id., quoted in King v. Oahu Railway & Land Co., 11 Haw. 717 at 723-724.

<sup>43</sup> State of Hawaii v. Zimring, 58 Haw. 106, 121 (1977).

<sup>44</sup> Cannelora, Lewis, "The Origin of Hawaii Land Titles and of the Rights of Native Tenants" (1974), page 38.

<sup>45</sup> Dowsett v. Maukeala, 10 Haw. 166 (1895).

<sup>46</sup> Section 5(f) of the Admission Act provides as follows:

"(f) The lands granted to the State of Hawaii by subsection (b) of this section and public lands retained by the United States under subsections (c) and (d) and later conveyed to the State under subsection (e), together with the proceeds from the sale or other disposition of any such lands and the income therefrom, shall be held by said State as a public trust for the support of the public schools and other public educational institutions, for the betterment of the conditions of native Hawaiians, as defined in the Hawaiian Homes Commission Act, 1920, as amended, for the development of farm and home ownership on as widespread a basis as possible for the making of public improvements, and for the provision of lands for public use. Such lands,

proceeds, and income shall be managed and disposed of for one or more of the foregoing purposes in such manner as the constitution and laws of said State may provide, and their use for any other object shall constitute a breach of trust for which suit may be brought by the United States. The schools and other educational institutions supported, in whole or in part, out of such public trust shall forever remain under the exclusive control of said State; and no part of the proceeds or income from the lands granted under this Act shall be used for the support of any sectarian or denominational school, college, or university."

<sup>47</sup>USCA Section 511 (30 Stat. 750).

<sup>48</sup>USCA Section 511.

<sup>49</sup>Public Law 86-3, Section 5(b) provides as follows:

"Except as provided in subsection (c) and (d) of this section, the United States grants to the State of Hawaii, effective upon its admission into the Union, the United States' title to all the public lands and other public property within the boundaries of the State of Hawaii, title to which is held by the United States immediately prior to its admission into the Union. The grant hereby made shall be in lieu of any and all grants provided for new States by provisions of law other than this Act, and such grants shall not extend to the State of Hawaii" U. S. Code Congressional and Administrative News, 86th Congress, 1st Session 1959, page 6.

Public law 86-3 Section 5(g) provides as follows:

"As used in this Act, the term "lands and other properties" includes public lands and other public property, and the term "public lands and other public property" means, and is limited to, the land and properties that were ceded to the United States by the Republic of Hawaii under the joint resolution of annexation approved July 7, 1898 (30 Stat. 750), or that have been acquired in exchange for lands or properties so ceded." Id. at 7.

<sup>50</sup>See for example the argument in Levinson's dissent in *McBryde II* that the majority's decision constituted an unconstitutional deprivation of property without just compensation. 55 Haw. 260, 298-303. See also the same

argument in the dissent to Zimring in regard to the State's acquisition of lava extensions. Zimring, supra, at 56-57. See also Robinson v. Ariyoshi, supra.

## APPENDIX C

### GEOHERMAL ENERGY IN PAHOA, HAWAII SOCIAL IMPACT ASSESSMENT Penelope Canan, Ph.D.

#### Background and Rationale

1. The State of Hawaii stands to make a relatively swift transition from near-total dependence on imported petroleum for its electricity needs to local, renewable sources of power generation. One of the options is geothermal energy which has been found to exist in the Puna District of the Big Island. The nature of the reservoir is uncertain as is the proper mode to develop and utilize it.
2. Uncertainty is an uncomfortable state of affairs. Attempts to rationally plan reflect the desire to reduce the uncertain nature of the future.
3. The energy crisis presents a veritable crossroads that means tremendous social change. Change itself can be traumatic. As people alter what has become a "natural" technological mode, patterns of social life will definitely be dramatically changed.
4. Lifestyle changes may or may not be associated with enhancing the quality of living conditions.
5. Hawaii's current population and economic conditions are such that concentrations are not located close to known geothermal reservoirs. Supply and demand are physically distant.
6. Using existing corporate/government costing perspectives, acceptable profit margins for geothermal development exist at the 50 MW point.

This amount of power cannot be used at the location of the reservoir under present conditions, nor can the Big Island use this amount given present conditions.

7. Given current corporate/government costing perspectives as well as geographic conditions, population distributions and patterns of economic activity, there are presently four geothermal development scenarios under consideration:
  - a. Power export to other islands, especially Oahu, designed to enhance the State's ability to maintain present energy uses.
  - b. Importation of energy intensive industries to a predominantly rural community.
  - c. Ethanol production coupled with power exportation and several cascading direct applications.
  - d. Power exportation to other places on the Island of Hawaii where energy intensive industries could locate.
8. Geothermal development with or without an industrial park means the introduction of major technological change into the District, specifically in the Pahoa community.
9. Just as technological and economic factors have been studied very carefully to determine the feasibility of developing known geothermal reservoirs, environmental ramifications must be considered. To do otherwise is to "externalize" true costs thus rendering rational planning impossible.
10. Human concerns are vital elements of the environment and must not be minimized or externalized in the comparison of costs and benefits of geothermal development.

11. Geothermal development's negative impacts on the physical environment (noise, odor, irreversible conversion of agricultural land to industrial usage, pipes, transmission lines, traffic increases) and on the social environment (irreversible change of a relatively quiet rural/agricultural and retirement/tourist community) are experienced only locally.
12. Changes on local lifestyles may be predicted. These are predicted social consequences of development. Whether they are evaluated as welcome or undesirable depends on the subjective perceptions of the people of the local community. These subjective evaluations are what are known as social impacts.
13. The local community is not a single entity for all purposes. Rather, it is an amalgamation of diverse interests, some of which would be enhanced by prospects of geothermal development. Other interests, however, are threatened. In other words, local benefits and costs vary. Nevertheless, the local lifestyle will be changed.
14. For people to be able to render their subjective opinions of a proposed development, they must be given the opportunity to understand what it will mean to them. Broadly targeted community education is absolutely essential. At this time only the aboriginal Hawaiian community has been involved in self-education about geothermal energy due to a grant from the U.S. Department of Energy/Hawaii State Department of Planning and Economic Development. Others in the community are relatively unfamiliar with the options available. Some negativity stems from lack of information.

15. Many factions within the local community stand in the extremely uncomfortable position of feeling threatened and lacking any meaningful control over their own community. Their fears are hardly unwarranted: as far as they can tell externally sourced actions (Federal, State, and County policies as well as corporate decisions) are aimed at development regardless of their wishes.
16. Social considerations have been identified as "major barriers to development." The use of the word "barriers" reveals that government and private enterprise view local people's concerns as something to "get around."
17. Concern for the social impacts of technological innovations and development policies is fairly new. There is no tried-and-true methodology. The best available advice is to follow accepted techniques of social science as closely as possible.
18. A major challenge to normal scientific rigor stems from the reflexive nature of social impact assessment. That is to say that attempts to discover in advance what social impacts will occur partly contaminates the future impacts. This points to the opportunity for responding to adverse conditions as they are detected. In other words, social impact assessment is an appropriate planning tool that enhances smooth development. It is also a continuous enterprise entered into for responsible development aimed at enhancing the quality of life.
19. Despite statements by government and industry representatives that social impacts are most troublesome, neither has assumed responsibility

for adequately assessing them. Indeed, failure to do so thus far has already had negative impacts on some portions of the Pahoa community. If traditionally ineffective public education avenues have once again proven ineffective, innovative methods of community education and involvement are called for. A true commitment to assessing social impacts over time is absolutely essential.

20. The social impact assessment currently funded by USDOE/HDPED appears thoughtfully constructed. It is, however, designed for only one sector of the Pahoa community. It represents an opportunity to determine the ability of local people to become part of the planning process. However, other people must become similarly involved. A working model of the entire community in process must be developed to determine the social impacts of developing geothermal energy in the Puna District.
21. Social impact assessment is part of a comprehensive planning process. It should be a continuous enterprise throughout the development.



## APPENDIX D

### LABOR PROCUREMENT ISSUES AND GEOTHERMAL/ECONOMIC DEVELOPMENT

Mr. Everett Kinney, Staff Researcher  
Puna Hui Ohana

#### Introduction

Providing an adequately skilled labor population in Puna to meet the employment needs of potential commercial/industrial expansions appears to be a serious, on-going issue. A casual survey reveals most of the skilled labor is employed out of the district, in Hilo, or have moved to Honolulu. Remaining behind are unskilled workers at slightly over minimum wages on anthurium, sugar, orchid, macadamia or papaya farms. Many such workers, however, are underemployed either because they refuse to travel or are unable to find jobs out of the district. The inability or failure of the community to meet anticipated labor needs points to large-scale importation of "outsiders" labor--relegating lower level (non-skilled) positions to local workers.

To avoid this social crisis, improvement plans should be designed which alert the community and provide solutions for the problem. Of primary importance is an analysis of available baseline skills and current employment conditions of district workers. Several questions addressed to the resolution process include; 1) is there a definable geothermal technology, 2) to what extent will the needs of future industry be geothermally-oriented, 3) are current mechanical, research or clerical skills acquisition adequate and, 4) if training programs are needed, how will these programs be implemented to fit special needs of the community.

Fortunately, the problem is essentially medium-term (approximately three to five years at a minimum) allowing for examination of practical

alternatives as, 1) designing broad-based skills training or retraining programs based on the demographic analysis, 2) inviting prospective developers to submit their employment needs which, hopefully, could be met through the inventory or, 3) requiring all developers to allocate apprentice-training slots to attract local workers.

### Education and Training

Subsequent discussions with Mr. Goto, Curriculum Specialist, Hawaii Community College, revealed a lack of curriculum planning leading to an Associate Degree in geothermal technology and furthermore, that curriculum module development takes about two years or four full semesters to develop. Longer long-range planning is required at the University of Hawaii, Hilo. A high-intensity education in any of the vocational sciences is needed to meet a reduced time-framework. Concentration of a pre-engineering major leading to petroleum or geothermal geology, engineering or a geophysicist-chemist degree needs to be implemented at UHH. At this time, plumbing, welding, carpentry, metal-work, electric and equipment operator appear to fill construction and blue collar operational needs.

Conversations with Mary Matayoshi of the College of Continuing Education and Community Services indicated the CCECS system could adapt readily to the community's educational needs, including specialized training courses. Planning and implementation could be completed within a semester of actual employment demand. Flexibility of CCEC's range of instructional activity and staff mobility would also allow for instruction at the community site, an important consideration with regard to the rural culture.

Because of the CCECS reaction/adaption time, training courses may be designed within the developer's time framework, that is, training could

begin during the developer's planning or construction stages, following an inventory of skills announcement by the developer. Additionally, a prospective developer could also define specific requirements for individual positions.

### Planning Process

Discussions with the University are positive and very encouraging, possibly reaching the activation stage before the end of the year. I have suggested that the process for planning include the following steps:

1. Establish time framework (3-5 years)
2. Complete baseline skills inventory and analysis.
3. Design corrective/remedial programming through:
  - a. Developing basic skills
  - b. Expanding existing skills
4. Basic skills program:
  - a. Developing individual awareness skills, career counseling
    1. Personal awareness, attitudinal development
    2. Interactive ability, individual and group
5. Expanding current skills program:
  - a. Retraining - vocational improvement
  - b. Leadership, academic counseling
6. Learning new technical skills
  - a. Career redevelopment
    1. Psychological confirmation for change option (i.e. permanency of geothermal energy and growth over time)
7. Define over-all goals
  - a. Skills attainment
  - b. Certification of skill acquisition
8. Process objectives
  - a. Determine and design group learning styles to meet an accelerated, effective and productive learning program.

## Assumptions

Some simplistic theoretical assumptions, with reference to the local conditions and local employment needs as a foundation, for discussion and goals implementation include:

1. Labor supply ability = geographic/hierarchical base  
(Local - District - County - State - Mainland)  
This merely states that the ability to fill labor needs is dependent on baseload inventories of available supply within the hierarcy from local to state levels.
2. Projective Labor market = nature and scope of potential industry needs.
  - a. Research - (abstract/scientific)
  - b. Exploration/drilling - (geological/mechanical)
  - c. Energy conversion - (mechanical)
  - d. Administrative, office - (clerical)
  - e. Industrial applications - (vocational)

This statement of projective labor market needs reflect labor inventory needs of a potential industry with respect to type of employment and area of skills knowledge.

3. Satisfaction of specific skills demands = base technical skills + increase level of education.

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$T_1, T_2, T_3$

(A function of economic pressure/development over time)

This states that the satisfaction of unanticipated skills demands is dependent on base load technical skills plus increased retraining over periods of time.

4. Estimated demand matrix:\* (medium capacity industry)

	<u>Construction</u>	<u>Operational</u>	<u>Maintenance</u>
**Construction	500	---	---
Operational	---	50	---
Maintenance	---	---	4

Note: 1. Labor demand in energy-conversion are minimal due to high automative level.

2. A construction project may require a large employment force. The potential for serious socio/psychological distruption when project completion sets off massive lay-offs points to displacement of the community's social fabric.

### Conclusion

In conclusion, developing an underemployed or unfulfilled worker's psychological ability to undertake change option may prove to be a primary problem. An unwillingness to change, for whatever reasons, will not only deny the workers potentially greater satisfaction and earnings but may signal widespread labor in-migrations whose social characteristics may be largely contradictory to the contemporary social-cultural landscape. To avoid community stress conflicts, this phenomena invites early in-depth study and resolution.

## APPENDIX E

### ENVIRONMENTAL IMPACT ASSESSMENT PROGRAM FOR A GEOHERMAL BIOMASS ETHANOL FACILITY SITED AT THE PROPOSED PAHOA INDUSTRIAL PARK AND THE FEEDSTOCK

SUPPORT SYSTEM IN THE PUNA DISTRICT  
by: Dr. Sanford Siegel, Dept. of Botany, Univ. of Hawaii

The Puna District, site of Pahoia and the proposed Pahoia Industrial Park including the ethanol plant is the easternmost region of the Island of Hawaii. It is somewhat more than 50 square miles in extent, and consists largely of undissected volcanic uplands, Kilauea to the north and Kalapana to the south. Between these uplands, extending eastward from the Kilauea Caldera complex to Cape Kumukahi and the sea is the Puna Cone and crater area marked by recent eruptions, most notably that of 1955.

With 8300 inhabitants, the Puna District contains somewhat more than one-tenth of the Island of Hawaii's population. Most (about 75%) of these residents live near their main source of livelihood, the Puna Sugar Company, in widely spaced clusters of houses along the coast, or in slowly growing subdivisions. The remainder live in the only two "towns" in the district, Kea'au and Pahoia, each with little over 1000 population.

The young lavas of Puna which cover most of the district are blanketed with sparse organic soils - histosols - except for the west central entisols across the west central portions of the district. These latter include low-lying fertile fields with abundant vegetation, and more youthful upper slopes with open forests of Ohia, the Hawaiian endemic Metrosideris. Rainfall is abundant. In east Puna is found one of the State's major papaya areas and in the west, highly productive sugar lands.

It is generally thought that the Puna area is underlain by a basal lens of freshwater floating on denser salt water, but the southern part of the district contains a narrow band of dike-confined freshwater. Salinities in excess of several hundred ppm are found in some of district's wells at relatively shallow depths. Except for moderate coliform counts in one or two instances, ground waters show no chemical or microbiological features of concern.

With its proximity to the fumeroles and other active features of Kilauea (the main vent is only 40 km to the west), it is not surprising that air and soil are influenced by distinctive volcanic chemistry. Included is an air mercury level that ranges around  $1 \text{ g/m}^3$  under virtually all conditions except heavy rains and strong tradewinds. As in other volcanic regions, soils tend to run high in mercury and occasionally yield unusual levels of arsenic and thallium. Vegetation tends to reflect elevated environmental levels of these elements.

In general  $\text{SO}_2$  and  $\text{H}_2\text{S}$  fall below 10 ppb. Two geothermal electric facilities are now under development. One is the original University of Hawaii experimental well, HGP-A, first flashed in July, 1976. It is scheduled to go on-line as a 3 MW electric generator in 1981. Site-specific data concerning well site geophysics, downhole water chemistry, general hydrology and hydrogeochemistry have been developed since 1975. Environmental geotoxicology, including air, water, soils and vegetation and the impact of effluents have also been under study since 1975. The site has been assessed for endangered plants and birds and historic-archaeologic features.

The second site, about 3 km SW of HGP-A, is a private undertaking on an area also subjected to baseline environmental assessment for air, water, soil and vegetation chemistry, endangered plants and birds and sites of cultural interest. The impact of geothermal development at this site will be monitored if and when the drilling operation now underway is successful.

Both current geothermal operations provide important background information that will contribute significantly to the overall assessment at the Pahoehoe Industrial Park. These will replace site-specific and use-related assessments but will simplify and expedite identification of potential impacts and general environmental needs and issues.

A. Ethanol Plant Site and Environs for Air Monitoring

Hydrogen sulfide will be monitored continuously at selected



locations within the development area. These include samples from the ethanol plant components including the distillation and fermentation vessels and the hydrolysis and oxidation tanks, also at the well site, the transmission corridor and at the ethanol plant within the industrial plant site. General Ambient levels will be checked by means of air spot samples within the industrial park compound. In addition, indicator tags (Metronics type) will be deployed daily over 2-3 downwind arcs in a concentric array to a maximum distance of about 1 mile. Plant personnel will be monitored with H<sub>2</sub>S indicator tags issued and reclaimed daily. Our objective is to meet the following limits:

MAC for 8 hours (Hawaii OSHS, Act 57, 1972 rev. 1977)	10 ppm
Threshold limit value (American Conference of Government and Industrial Hygeinists, 1972)	10 ppm
Ambient Air (State of Calif. Ambient Air Quality Standard for 1 hour)	0.03 ppm for 1 hour
Emission standards (EPA)	0.2-0.4 kg/MWH (Geysers Electrical)

A small mobile weather station providing temperature gradients, barometric pressure for rain and wind data is being considered as a means for more regular, although not continuous monitoring of other potentially airborne major toxicants including SO<sub>2</sub>, SO<sub>3</sub> (H<sub>2</sub>SO<sub>4</sub> aerosols), Hg, AsH<sub>3</sub>, and boron. This will take the form of on-line sampling (which will also serve as a water assessment procedure,) and the analysis of effluents. It is assumed that the sulfur

oxides and acids, if present, are products of H<sub>2</sub>S oxidation after its release. Accordingly, the sulfur oxides will not be included in in-line measurements, but rather in effluent and ambient gas analyses. Within the ethanol facility property lines, air samples will also be taken for the above mentioned substances. This sampling program will initially be effected twice weekly, and more or less frequently as findings thereafter warrant. No personnel or area exposure precautions are projected unless the level of SO<sub>2</sub>, etc. should suggest an elevation into a hazardous range not currently reflected in existing data.

Carbon dioxide monitoring is contemplated only within poorly ventilated spaces or stagnant enclosures where personnel may experience even casual exposure. Build-up of the other relatively dense gaseous emissions (eg. SO<sub>2</sub> or H<sub>2</sub>S) would be revealed by their own odors at pre-toxic levels, a distinction not shared by CO<sub>2</sub>.

Special provisions for plant damage assessment, both with native and cultivated species will be discussed below.

The monitoring program will be based on the following limits:

SO<sub>2</sub> (Sulfur dioxide)

"Alert level" 24 hr. average

0.3 ppm

TLV

5 ppm

MAC

10 ppm  
for 8 hours

Hg (Mercury)

Regulatory levels:

National, Industrial and Occupational Safety & Health Standards (NIOSH) 50  $\mu\text{g m}^{-3}$   
for 8 hours

TLV (Hawaii OSHS):

MAC for 8 hrs. 50  $\mu\text{g m}^{-3}$   
for 8 hours

Incinerator facilities emissions allowed 1600  $\text{g}_{24} \text{hr}^{-1}$

Coal-fired plant emissions allowed 2300  $\text{g}_{24} \text{hr}^{-1}$

Recommended levels:

MAC for 8 hrs. 10  $\mu\text{g m}^{-3}$

General ambient air 1  $\mu\text{g m}^{-3}$

EPA ambient air quality for 30 day average 1  $\mu\text{g m}^{-3}$

CO<sub>2</sub> (Carbon dioxide)

MAC for 8 hrs. 5000 ppm

SO<sub>2</sub> (Sulfur dioxide and sulfuric acid aerosols)

TLV (Hawaii OSHS) 1  $\text{mg m}^{-3}$   
for 8 hours

Maximum average (Hawaii OSHS) 3  $\text{mg m}^{-3}$   
for 5 minutes

Arsenic and Arsine

TLV (Hawaii OSHS) 0.05 ppm  
for 8 hours

Boron

There are no standards for boron atmospheric toxicity as yet.

### B. Kilauea-East Rift Well Site

The ambient atmosphere in the lower Puna district is subject to the influence of natural geothermal processes associated with volcanic and fumarolic activities on the East Rift. This natural influence accounts not only for the high baseline air mercury levels of about  $1 \text{ ugm}^{-3}$  but also for the levels of 5-10  $\text{ugm}^{-3}$  observed during some periods of operation. The ability to correctly interpret high levels of pollutants at the HGP-A well site as a result of activity elsewhere was attributable to the operation of a long-standing program of volcanic gas measurements at various fumarolic sites, calderas, etc. on the Kilauea East Rift. Lacking this backup, information based on local measurements alone, would have led to an incorrect, essentially negative assessment of the well and of any other facilities located in the lower Puna district. Therefore, it is proposed to include a mobile or portable aerometric facility capable of periodic air sample collections (t minutes to 5 hours) and analysis of  $\text{H}_2\text{S}$ ,  $\text{SO}_2$ ,  $\text{CO}_2$ , and  $\text{H}_g$ . These gases are chosen not only for toxicological reasons, but also because these include sensitive indicators of changing magmatic activity. Such a unit could also respond to residents' reports of unusual conditions, i.e. odors, etc.

### C. Ethanol Plant Site and Environs for Water Monitoring

It is proposed that during the initial phases of operations, samples of waters should be taken for the following analyses:

1. In-line measurements for arsenic, mercury and boron.

2. At discharge point:

- a. Metals: Arsenic, antimony, beryllium cadmium, copper lead mercury, nickel, thallium zinc.
- b. Non-metals, metalloids: Selenium, fluoride, boron.

Any elements consistently below analytical detection levels can then be transferred to the "infrequent" list, subject to semi-annual or annual review.

Holding pond: Analyses will be carried out for all above listed elements not transferred to the "infrequent" category. Pond sampling will include top, middle and bottom depths at the center and edge.

The Puna Aquifer: Springs, wells or other sources of ground waters downstream from the Ethanol Facility will be located and sampled monthly for all elements monitored in the holding period.

D. Bioassays

It is recognized that new factors or substances, or combination of known factors or substances which are individually harmless (e.g. synergists) can bring about subtle, long-term environmental deterioration.

This possibility should not be overlooked in the monitoring program for the ethanol fuel industry development, because the ethanol plant processes combined with geothermal direct heat applications provide complex air and water sources of

possible toxicants or toxicant combinations. It is proposed, therefore, to establish two bioassay elements--one for atmospheric pollution, and the other for water contamination.

1. Air Pollution Indicators - Specific plants have been shown to be of utility as air pollution indicators. Examples are pinto bean and head lettuce (Los Angeles County), wrapper leaf tobacco varieties (Mid-Atlantic and New England states) and tomatoes (New York City), all for photochemical surveys. Three lichens have been known for some time to be sensitive to SO<sub>2</sub> levels in the English industrial midlands.

Little is known about unique pollution symptomatology among native Hawaiian plants, however, it is quite clear that tip and marginal discoloration and chlorosis are common signs of physiological stress induced by air toxicants here as elsewhere. Further, geothermal emissions such as mercury, induce defoliation and premature fruit drop. Therefore, woody perennials are proposed for use, either ornamental or fruit bearing as indicators of general environmental quality. Any sign of pathology not ascribable to parasitic infection will initiate in-depth analysis of the ambient and air effluents.

2. Water Pollution Indicator - Specific cultivated plants will be maintained for water quality growth tests using hydroponic procedures. The water sources will be compared among.

- a. Standard complete nutrient (Hoagland types).
- b. Geothermal discharge waters.
- c. Geothermal discharge waters supplemented with complete nutrient.

Test plants are to be determined by growth experiments but may include Chinese cabbage, tomato, cucumber and eggplant. These will be examined for pathology and growth recorded as fresh and dry weights. If growth is consistently inferior in wellwater + nutrients, one or more toxicants are indicated and efforts will be made to identify them.

3. Noise - Noise limitations to be used are specified in U.S.G.S. Regulations. Routine monitoring will be carried out monthly at well site and ethanol plant boundaries and at one-half mile distance from source. Special consideration will be given to traffic noise associated with potential feedstock trucking operations. In addition, any change in plant operation or procedure will require an immediate noise check.

#### 4. Bioenergy Tree Farms/Silviculture

- Biofuel tree farms require site preparations as do processing and production facilities such as sugar mills, fermentation plants etc. These are subject to the same requirements for use-independent baseline and follow-up assessment tasks set forth above.
- Use-related features of such sites include applications of fertilizers, pesticides and phytohormones not employed in that location previously. Rates of application of organic chemicals must be related to biodegradability and dispersal into the ambient soil environment via groundwater and, if applied in aerosol form, via the atmosphere as well.

Finally, if exotic species, cultivars or varieties of fuel plants are introduced, their containment must be assured until it is established that such forms cannot compete with or otherwise threaten local species in the eco-system at large. Such confinement may require chemical and/or mechanical cordoning of the cultivation area, if an inability to propagate in the wild or naturalized state is not or cannot be programmed genetically.

#### ETHANOL PLANT ASSESSMENT PROGRAM

The organization of an assessment program for the Pahoa Industrial Park must include general tasks as well as those related to specifics of site and use:

- Direct Environmental Baseline Requirements:
  - Site-use Independent.
  - Site-use Related.
  
- Direct Environmental Impact Follow-up:
  - Site-use Independent.
  - Site-use Related.
  
- General Site Support Environmental Concerns.

Independent of the projected specific uses intended for the Pahoa Industrial Park, or of any renewable energy site, there are Direct Environmental Baselines to be established.

The fundamental use-independent baseline tasks include:

- A general description of the vegetation and physiographic ecology sufficient to provide for



recognition of degredative changes. This should include transect and quadrat analyses as needed, and photo documentation.

- A tally of area (e.g. site plus 1 km ambient) endangered biota especially plant, bird and mamalian species.

- A survey of similar extent and scope for historic or archaeologically valuable structures and sites.

The general purpose for the Pahoia site is development of non-electric uses for a natural hydrogeothermal resource. Specifically, it seeks to apply geothermal direct heat in the fermentation of glucose derived from celluloses and lignocelluloses, and distillation of the ethanol produced. Accordingly, potential use-related impacts involve geothermal working fluids and fermentation effluents. For purposes of the present environmental assessment, W.A. Hirai & Associates, Inc. will assess the appropriate health and safety procedures relating to distillation vapors.

- Sampling and analysis of the site air, water, soil and vegetation for geotoxicants related to surfacing of hydrogeothermal working fluids. Examples of such toxicants are mercury, arsenic, sulfur dioxide and hydrogen sulfide in air; mercury arsenic, and possibly other hazardous metals or metalloids in waters, surrounding soils and tissues of selected indicator plant species. Plants to be included in the industrial park area are represented by Metro-

sideros (ohia), Psidium (guava), the ferns Nephrolepis and Dicranopteris and a lichen Stereocaulon. Sampling locations will include salient upwind and downwind directions relative to the locus or loci of emissions. EPA standards do not apply to soils or plants but where they exist for air and discharges or effluents, they will apply.

• A noise standard conforming to the USGS figure of 65dba at the facility property line or 0.5 mile, whichever is closer will be applied to well head or other venting facilities.

The alcohol production use-related tasks include:

- Monitoring the fermenter-distillery unit area for alcohol and aldehyde vapors and evaluation of the sensitivity of local nearby biota to such volatiles. This is deemed a low probability hazard, but dense relatively consensible substances could exert a localized impact on that part of the ecosystem adjacent to the production unit. More pressing is monitoring associated with disposition of stillage. Residues from the fermentation process have great nutritional and/or soil improvement potential. Because these are biological in nature (i.e. yeast-based), they also tend to concentrate heavy metals and other toxicants. Elements of particular concern are mercury, cadmium, arsenic, lead and similarly. It will be necessary to establish for these and other elements the levels pre-

sent in stillage from this operation. If animal feed standards are not met, the composition can be compared with local soils which are naturally high in many of the same elements. Its final disposition will depend upon these assessments of impact on soil chemistry.

The tasks required for the Direct Environmental Impact Follow-up are dictated by the baseline determinations discussed above. The targets of assessment - plants, soils, air etc. - need not be repeated here, however, the timing of follow-up programs is important.

- Site use independent follow-up tasks begin with earliest phases of site selection and preparation, namely survey, clearing, and grading and related activities. In the unlikely event that an endangered plant species is located at a proposed site, the uniqueness of that site for that species, its distribution outside the site and its relocatability would all have to be evaluated.

Monitoring at 4 month intervals within Year One, at 6 month intervals through Year Three, and annually through Year Five is recommended.

- Site-use related follow-up monitoring tasks for geothermal will begin when drilling is completed. The schedule proposed for the use-independent tasks can be applied here. Exceptions are Hydrogen

sulfide and mercury in the air. It is recommended that atmospheric sulfide be monitored continuously from the completion of well drilling through all tests and until an operating facility with needed abatement procedures is on-time and performance falls within existing ambient (30ppb) and PSD emission (250 tons p/a at any facility) standards. If continuous monitoring is not feasible, it should be scheduled immediately before, during and immediately after flow tests and other operating procedures and not less than 8 hrs/wk. Air mercury should also be sampled in conjunction with any well tests on a "just prior", "during" and "just after" basis, and otherwise no less than monthly. All discharge waters should be analyzed for sulfide and mercury during tests as noted above for air sampling and otherwise monthly, at least for the first year; quarterly thereafter through year five.

"General site support" are those operations located elsewhere contributing to the Pahoia Industrial Park, such as the facility for conversion of cellulosic materials to glucose and any sites committed to cultivation of plants for biofuel-related uses. These additional support sites must also be reviewed for environmental impact.

The hydrolysis of vegetable matter to glucose will involve

by-product methane, carbon dioxide and wastewater. The facility carrying out the conversions yielding these products and discharge is to be located at existing sugar cane processing sites. There is no need for general use-independent assessment, as the nature of added operations does not entail unusual processes or fabrications. With respect to use-related assessment tasks, the wastewater must be monitored for heavy metals such as mercury that tend to accumulate in plants growing on many volcanic soils in Hawaii. The soils and any waters, e.g. streams or wells that might be influenced by such discharge must be monitored before hydrolytic facility discharge operations begin to provide a baseline reference. If the discharge toxic metal content proves negligible using feedstock plants grown in mercuriferous volcanic soils, no follow-up program is needed.

#### STANDARDS AND AGENCY-RECOMMENDED VALUES

##### H<sub>2</sub>S Threshold Limit Value:

(American Conference of Government and Industrial Hygeinists, 1972)	10 ppm for 8 hrs.
(Hawaii Occupational Safety and Health Standards Act 57, 1972 Revised August 1977)	10 ppm for 8 hrs.
<b>Short-Term Limit Value:</b>	
(Pennsylvania Dept. of Health, 1965)	20 ppm for 20 min.
(Hawaii Occupational Safety and Health Standards Act 57, 1972, Revised August 1977)	20 ppm for 5 min.

##### SO<sub>2</sub> Threshold Limit Value:

(American Conference of Governmental and Industrial Hygeinists, 1972)	5 ppm for 8 hrs.
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(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

5 ppm for 8 hrs.

**Short-Term Limit Value:**

(Pennsylvania Dept. of Health, 1965)

20 ppm for 20 min.

(Hawaii Occupational Safety and Health  
Standards Act 57, 1973, Revised  
August 1977)

20 ppm for 5 min.

**Maximum allowable concentration for 8 hrs:**

(Federal Occupational Safety and Health  
Standards)

10 ppm

**Maximum allowable concentration for 5 minutes:**

(Federal Occupational Safety and Health  
Standards)

20 ppm

**Alert level**

0.3 ppm  
24 hr. average

**H<sub>2</sub>SO<sub>4</sub> Threshold Limit Value:**

(Registry of the Toxic Effects of  
Chemical Substances, 1976)

3 mgm<sup>-3</sup> for 8 hrs.

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

3 mgm<sup>-3</sup> for 5 min.

**Maximum average:**

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

3 mgm<sup>-3</sup> for 5 min.

**NO<sub>2</sub> Threshold Limit Value:**

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

5 ppm for 8 hrs.

Short-Term Limit Value:

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

5 ppm for 8 hrs.

Short-Term Limit Value:

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

25 ppm for 5 min.

Alert level

0.15 ppm  
24 hr. average

CO Threshold Limit Value:

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

50 ppm for 8 hrs.

Short-Term Limit Value:

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

400 ppm for 15 min.

AsH<sub>3</sub> Threshold Limit Value:

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

0.05 ppm for 8 hrs.

Hg (alkyl)  
Threshold Limit Value:

(Hawaii Occupational Safety and Health  
Standards Act 57, 1972, Revised  
August 1977)

10  $\mu\text{gm}^{-3}$  for 8 hrs.

(National Industrial, Occupational,  
Safety and Health)

10  $\mu\text{gm}^{-3}$  for 8 hrs.

Hg (all forms except alkyl)  
Threshold Limit Value:

(Hawaii Occupational Safety and Health Standards Act 57, 1972, Revised August 1977) 50  $\mu\text{gm}^{-3}$  for 8 hrs.

(National Industrial, Occupational, Safety and Health Standard) 50  $\mu\text{gm}^{-3}$  for 8 hrs.

Ambient Air Quality:

(Environmental Protection Agency's recommended 30 day average, Federal Regulations, 1975) 1  $\mu\text{gm}^{-3}$

Occupational: (Gertner and Huff, J. Toxicology and Environmental Health 2:491, 1977) 10  $\mu\text{gm}^{-3}$  maximum allowable concentration for 8 hrs.

Ambient Air Quality: (Gertner and Huff, J. Toxicology and Environmental Health 2: 491, 1977) 1  $\mu\text{gm}^{-3}$  maximum allowable concentration for 8 hrs.

Emission:

(Environmental Protection Agency Regulations National Emission Standards 121:0461, 1976)

Incinerations; wastewater; sludge 1600 gm. per day

Coal fueled power plants 2700 gm. per day

Water - No data pertinent to re-injection have been found.

Use is made of State of Hawaii Department of Health Class 2

Water Quality which includes agricultural uses.

pH:

(Hawaii Environmental Laws and Regulations Chapter 37A, 1972, revised 1974) not less than 6.5 nor more than 8.5 units



Total Phosphorus:

(Hawaii Environmental Laws and Regulations Chapter 37A, 1972 revised 1974)

not over 0.20 mg/l

Salinity:

(Hawaii Environmental Laws and Regulations Chapter 37A, 1972, revised 1974)

no stipulation for other than class AA water

Arsenic:

(Community Water Systems, EPA Primary Drinking Water Regulations, 40 CFR 141, June 1977)

50 ppb

Mercury:

(Community Water Systems, EPA Primary Drinking Water Regulations, 40 CFR 141, June, 1977)

2 ppb

Discharge:

(Federal Regulation 38,247, Dec. 1973)  
Into fresh water  
Into saline water

20 ppb\*  
100 ppb\*

\*Only if low flow in water body is 10 times flow of waste stream.

Noise - It is anticipated that the noise level will begin to approach the level of a "quiet suburban residence" of 48-52 dBA<sup>1</sup> or of a business office of 50-60 dBA after completion of the well-head installation. In general, noise levels decrease 3 to 6 dBA with every doubling of distance. The maximum sound recorded at Geysers, California Geothermal Site was a free

venting well without any mufflers at 8 meters and was approximately 120 dBA, which equals the sound of a jet airplane at 100 feet. For these extreme conditions occupational safety would be urged and the wearing of protective devices required. OSHA currently allows 90 dBA for an eight hour day and 115 dBA for 15 minutes without protection.

ldBA means "A-weighted" sound level measured in decibels above a reference sound pressure of different frequencies so that the response of the human ear is simulated.

Noise limitations should conform, as an initial minimum, to the regulations issued by the U.S. Geological Survey for geothermal operations on Federal lands; i.e. not to exceed 65 dBA at the lease boundary or one-half mile from the source, whichever is greater.

Item 6.3 is discussed under items 6.1.4/6.1.5.

#### E. Regulations

State of Hawaii:

Department of Planning and Economic Development, Revised Environmental Impact Statement for the Hawaii Geothermal Research Station, Utilizing the HGP-A Well at Puna, Island of Hawaii, 1978.

Hawaii Occupational Safety and Health Standards, Act 57, 1972 revised 1977.

Department of Health, Public Health Regulations, Chapter 42, Ambient Air Quality Standards, 1971.

Hawaii Environmental Laws and Regulations, Chapter 37A, 1972 revised 1974.

State of Pennsylvania:

Public Health Regulations. Air Quality Standards, 1965.

National Industrial, Occupational, Safety and Health Standards, 1972.

United States Environmental Protection Agency (EPA):

The Clean Air Act (as amended August 1977).

The 1977 Clean Air Act: Prevention of Significant Air Quality Deterioration. Part V. Federal Register 43 (118), pp. 26380-26410, 1978.

Community Water Systems, EPA Primary Drinking Water Regulations, 40 CFR 141, 1971.

Discharge. Federal Regulations, 38, 247, 1973.

Background Information on National Emission Standards for Hazardous:

Air Pollutants-Proposed Amendments to Standards for Asbestos and Mercury. 450/2-74-009A, October 1974.

National Emission Standards 121:0461, 1976.

National Primary and Secondary Ambient Air Quality Standards.

Federal Register 36(84) Part II, 1971, pp. 8186-8201.

Pollution Control Guidance for Geothermal Energy Development.

EPA-600/7-78-101. June 1978.

United States Department of Energy:

Geothermal Energy Research and Development, and Demonstration.

Program. 2nd Annual Report (1978). DOE/ET-0039/1, IGCC-3.

United States Government Registry of the Toxic Effects of Clinical Substances, 1976.

American Conference of Governmental and Industrial Hygienists (1972).

The only means for identification of additional health hazard potentials are chemical and clinical. Compliance with all mandated standards and regulations and continued surveillance as set forth above eliminates from this consideration materials hazards already identified. Any substantive change in or modification of existing materials or procedures must therefore, be accompanied by an assessment of said changes or modifications for hazard potential before they are installed or effectively with approval contingent on control and safety measures as appropriate.

Any innovations involving known or suspected teratogens, carcinogens etc., would be strictly prohibited without full containment provisions.

The "unknown and unrespected" hazard can only be dealt with by a medical program for workers and close cooperation with community medical and health specialists and agencies.

Occupational and community standards regulations and monitoring activities relevant to safety have been set forth.

Note:

(Plant and general safety matters e.g., steamliners, caustics, falling I-bearing etc., are not our area but should be developed as management/engineering matters.)

ENVIRONMENTAL TOXICANT OUTPUT IN RELATION  
TO SCALE-UP OF GEOTHERMAL ENERGY PRODUCTION

<u>Energy Output Megawatts</u>	<u>Scale Factor</u>	<u>Possible Sources</u>	<u>Hg. Emission* g. 24 hr<sup>-1</sup></u>	<u>H S Emission**metric</u>		
				<u>2 tons/yr</u>	<u>Abatement %</u>	<u>99+</u>
3	1 (Kapoho)	1	1.09	277	8.3	2.8***
25	8.33 (Kapoho)	1	9.13	-	69.1	23.3
200	66.6 (Kapoho)	1	72.6	-	562.8	186.5
500	166.6 (Kapoho)	1	181.6	-	7383	466.2
1000	333.3 (Hawaii)	4	363	-	2766	932
3000	1000 (State)	10	1089	-	8298	2796

- \* 0.001 ppm wellhead maximum at 100 kilo-lb. hr<sup>-1</sup>, steam Qual. 0.6.  
 \*\* 700 ppm wellhead maximum at 100 kilo-lb. hr<sup>-1</sup>, steam Qual. 0.6.  
 + Current, using caustic soda and ruckpile sparger system.  
 + Projected for completed generator facility at 16G9-A.  
 \*\*\* Applies to the one deep well considered necessary to support the ethanol development project.

APPENDIX F

Financing Plans for Geothermal  
Development

by Kenneth W. McNerney  
John H. Woods

Bank of Montreal (California)  
The First Canadian Bank of California

The following general terms and conditions are those which an investor and/or developer may expect from a lending institution.

- Borrower: To be announced
- Loan Amount: Equal to the amount guaranteed by the United States Department of Energy ("DOE") under Title II of the Geothermal Energy Research, Development and Demonstration Act of 1974 as amended, (the "Act"). At your option we will offer a 50% participation in any corresponding loan to an institutional investor that will be arranged by Merrill Lynch, Pierce, Fenner & Smith.
- Purpose: To develop a geothermal energy resource and to construct, own and operate an integrated, direct use ethanol, agricultural complex.
- Borrower's Equity: Project equity is to be obtained equal to a minimum of 25% of the estimated project costs. Borrower's equity may be injected on a 3:1 basis as the DOE guaranteed loan is funded.
- Term: The earlier of 1 year after completion of construction, or commencement of full operating revenues, with an additional 2 year option term to allow the borrower to arrange permanent financing.

Repayment: Interest only (capitalized) payable quarterly in arrears until the earlier of (a) one year after completion of construction, or (b) commencement of full operating revenues. Then, during the option term, up to 23 equal monthly payments of principal (calculated on a 25-year amortization basis) with accrued interests, with all remaining principal and accrued interest due in the 24th month.

Long Term Financing: Our Bank will use our best efforts to assist in arranging long-term financing with institutional investors (in connection with Merrill Lynch). The Long Term Financing can be arranged for a maximum of 30 years including the construction and option period. We will agree to service the long-term financing for the institutions.

Prepayment: Without penalty.

Interest Rate: Interest rate on disbursements will not be more than 3/4% over Bank U.S. prime rate, floating, calculated on the basis of a 360-day year. With reference to Long Term financing rates, it is estimated that the rate will be fixed at approximately 50 Basis Points over comparable long term Government Bonds.

Fees: Administrative fee of 1/4 of 1% of the Loan Amount of which 1/3 will be payable at the time we issue our firm loan commitments.

All administrative fees will be refunded except for \$15,000 if the loan does not close because DOE declines to issue its guaranty. The balance of the administrative fee will be due upon closing of the loan and is used to cover the Bank's legal and consultant costs.

Loan servicing fee of \$2,000 per month in arrears, starting when DOE issued its guaranty. This fee will be re-negotiated after construction is completed and on each third anniversary date thereafter, based on the amount of service work required.

Security: Generally, the following security is required:

1) Deed of Trust on Borrower's land, building, and improvements. Security agreements covering geothermal resources, equipment, sales contracts and accounts receivable, feed stock contracts, inventory, operating licenses, construction, and management contracts. UCC Financing Statements.

2) Security interest in maintenance reserve account (1% of full operating revenues, buildup to 5% of original capital equipment costs, to be used for maintenance and repair of capital equipment and to be replenished at the same 1% rate).

3) Security interest in debt service reserve account (10% of principal and interest payments, buildup to one year's maximum annual debt service, to be used to cover debt service during force majeure and plant shut down events and to be replenished at same 10% rate).

Bank Account: A special project loan account will be opened with the Bank, however, there is no minimum compensating balance required.

Conditions: Commitment expiration date: The commitment will require the loan to close by a specified date and in the event the loan is not closed by that date, the closing date may be extended at the Bank's option or the commitment may be cancelled at the option of the Borrower or the Bank.

The Commitment will be subject to a loan agreement and related documentation containing affirmative and negative covenants and other customary cross-default and similar provisions and requiring various security agreements, financing statements and other documents and conditions that may be determined to be required are to be furnished to the Bank prior to disbursement, all in form and substance satisfactory to Borrower, DOE and the Bank. Such documents will include but is not limited to:

- plant cost breakdowns, plans and specifications, construction contracts, building permits, regulatory approvals, surveys, ALTA title insurance, insurance certificates, and consultant reports and contracts.



- management plan, including consulting, resource, management, operations, maintenance and sales contracts.

- partnership and individual partners closing documents, including partnership agreement, articles of incorporation, bylaws, good standing certificates, certificates of incumbency, certified resolutions, financial statements, and opinions of counsel to Borrower, DOE and Lender.