ENVIRONMENTAL IMPACT ANALYSIS
OF
POTENTIAL GEOTHERMAL RESOURCE AREAS

Circular C-106

State of Hawaii
DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development

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Honolulu, Hawaii
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GEORGE R. ARIYOSHI
Governor

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PREFACE

Act 296, Session Laws of Hawaii 1983, as amended by Act 151, SLH 1984, requires that the Board of Land and Natural Resources examine various factors when designating subzone areas for the exploration, development, and production of geothermal resources. These factors include potential for production, prospects for utilization, geologic hazards, social and environmental impacts, land use compatibility, and economic benefits. The Department of Land and Natural Resources has prepared a series of reports which address each of the subzone designation factors. This report analyzes the major environmental impacts that may result from geothermal development. Impacts include risks to people and property as well as wildlife and plant life. The effect of various natural factors such as wind and rain are included. Land use compatibility and impact mitigation measures are also described.

Preparation of this report was coordinated by Sherrie Samuels, Planner, with the assistance and under the general direction of Manabu Tagomori, Chief Water Resources and Flood Control Engineer, Division of Water and Land Development (DOWALD), Department of Land and Natural Resources.

DOWALD staff members, engineers George Matsumoto, Thomas Nakama, and Neal Imada, and geologists Daniel Lum and Ed Sakoda, have made significant contributions throughout this report. Paul Haraguchi of Pacific Weather, Inc. prepared the section on meterology and Lee Hannah of the University of Hawaii Environmental Center prepared the section on flora and fauna.

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SUMMARY

This report addresses potential environmental impacts to flora and fauna, surface and ground water resources, ambient air quality, and ambient noise levels, historical and archaeological resources, and scenic and aesthetic values. The characteristics and effects of local and regional meteorology are also considered.

The compatibility of geothermal development with existing land uses and zoning is examined. Evaluation of each resource area provides the conclusion of the study.

Meteorology. Meteorology, in general, and winds, in particular, are very important in geothermal operations because of their effect on emissions and noise. While tradewinds are prevalent, both tradewind temperature inversions and ground temperature inversions affect the movement of air in and over geothermal resource areas.

Flora and Fauna. One of the more serious environmental impacts is the potential disruption of native forest ecosystems. Two indicators were used to assess impact--native habitat importance and forest quality. Native habitat importance was defined by the presence of endangered species since this factor correlates well with the value of an area to native fauna in general. The relative value of a native forest was assessed using a three-part categorization system based on the percent of canopy provided and the quality of native forest present, the assumption being that undisturbed closed canopy, native forest would be the most susceptible to disruption by geothermal development.

Of Hawaii's seven plant species which are formally listed as endangered, only one, Hawaiian vetch, was found in a geothermal resource area. The presence of an endangered species was used as an indicator of environmental sensitivity. Protection of other rare native plants, not listed as endangered, is to be undertaken on a case by case basis in siting geothermal facilities in the future.

Surface Waters. Environmental impacts to surface waters resulting from geothermal development are expected to be minimal. None of the geothermal resource areas contain perennial streams and geothermal fluids will be disposed of by reinjection.

Groundwater. Groundwater occurs as perched, dike and basal water in geothermal resource areas. Groundwater resources will not be effected since geothermal wells are drilled past groundwater aquifers and well casings are set and cemented through a competent subsurface formation below the basal water lens. All drilling, casing installation, maintenance and abandonment of geothermal wells and reinjection wells will be regulated and monitored to protect the groundwater aquifer.

Air Quality. The assessment of air quality impacts resulting from geothermal development required examination of ambient air quality along active rift zones, emissions from geothermal wells and power plants and the current level of geothermal emission abatement technology.

Geothermal developments in Hawaii will be required to have abatement systems that meet the proposed State Department of Health air quality standards. At present, the recommended H_2S abatement system, the Stretford System, is capable of removing over 99% of the H_2S contained in the non-condensable gases. Use of this system would enable facilities to comply with the proposed air quality standards that require 98% of the H_2S present to be removed.

It should be noted that due to the sulfur content of fuel oil, oil-fired power plants may emit at least ten times more sulfur dioxide per megawatt-hour than would a geothermal power plant. Therefore, replacement of oil-fired power plants with geothermal power plants may reduce the overall impact to the environment and air quality.

Historic and Archaeological Values. Geothermal development may potentially degrade remaining cultural and archaeological values by site clearing and facility construction. Literature searches, plotting of known sites and on-site archaeological reconnaissance surveys should be utilized to assess potential impacts; adjustment of facility siting to avoid archaeologically sensitive areas will mitigate potential impacts.

Noise. During the initial phases of geothermal development persons in the vicinity of a geothermal facility construction site will be exposed to noise levels varying from 40 to 120 decibels depending upon the distance from the site. High noise levels are produced by well drilling, production testing and well bleeding before connection to the generator. Use of accoustical baffling and rock mufflers will effectively muffle noise. Construction of rock muffler at the existing HGP-A well has reduced noise level to 44 decibels at the facility fence line.

Compliance with County of Hawaii noise guidelines will limit noise levels for geothermal activities to 45 decibels at night and 55 decibels during the day.

Scenic and Aesthetic Values. Most geothermal resource areas are located in remote, often heavily forested areas, however in some areas, development of geothermal facilities may result in visual intrusions depending on an observer's view point. Site clearing, temporary presence of drilling rigs, permanent power plant structures with 50-60 foot high cooling towers, fluid transmission lines, electrical transmission lines, and periodic steam plumes above the development site are possible sources of visual intrusions. Appropriate mitigation measures may help to minimize visual impacts, however, some impacts such as steam plumes will remain.

Land Use Zoning, Existing Land Uses and Land Use Compatibility. Act 296, in addressing the designation of geothermal resource subzones, requires assessment of each geothermal resource area by an examination of various factors including the compatibility of geothermal development and potential related industries with present uses of surrounding land and those uses permitted under Section 205-2 Hawaii Revised Statues, relating to State Land Use Districts, Section 183-41, HRS, relating specifically to Conservation Districts, and all uses permitted under County general plans or land use policies.

Act 296 also allows geothermal resource subzones to be designated within any of the four state land use districts established under Section 205-2 of the Hawaii Revised Statutes. As such, geothermal facilities could be located adjacent to any of the land uses existing or permitted in the four state land use districts.

The State Land Use Districts found in each of the potential geothermal resource rift zones are:

Kilauea East Rift Zone - Conservation, agricultural, and urban districts.

Kilauea Southwest Rift Zone - Conservation, agricultural, and urban districts.

Mauna Loa Southwest Rift Zone - Conservation and agricultural districts.

Mauna Loa Northeast Rift Zone - Conservation and agricultural districts.

Hualalai Northwest Rift Zone - Conservation and agricultural districts.

Haleakala Southwest Rift Zone - Conservation and agricultural districts.

Haleakala East Rift Zone - Conservation, agricultural, urban, and rural districts.

Actual land uses in geothermal resource areas although characteristic of their respective zoning, may vary considerably. As noted above, most geothermal resource areas contain conservation zoned land that includes forest reserve, national and state parks, other forested areas, brush and grass lands, and barren lava flows. Often conservation zoned lands provide habitat for native and rare or endangered species as well as hunting area, and watershed lands.

Potential subzone areas zoned agricultural are used mostly for livestock grazing.

Rural areas are characterized by low density residential uses on one-half acre lots and are often intermixed with small farms.

Urban areas include residential and commercial uses.

Some negative aspects, such as visual intrusions, are expected in developing geothermal resources; however, proper mitigation of undesirable characteristics can achieve greater compatibility.

In each resource area, both positive and negative aspects and possible mitigation were considered in assessing land use compatibility.

Evaluation of Impacts in Potential Geothermal Resource Areas

Evaluation of impacts was accomplished by reviewing available information for each geothermal resource area. Information on local meteorology, surface and ground water, underground injection control areas, existing land use and zoning, flora and fauna, historic and archaeological sites was systematically mapped and each area evaluated in terms of anticipated environmental impact.

Lower Kilauea East Rift Zone:

Development of geothermal resources in the Lower East Rift Zone has been underway since 1973-74 with the issuing of geothermal resource mining leases for four areas, designated GRML R-1, R-2, R-3, and R-4. Development of additional sites in the Lower East Rift zone will not impact any essential endangered species habitat, but may impact existing communities in terms of noise and aesthetics. The provision of a buffer zone will help to mitigate such impacts. Air Quality will not be impacted, since it is expected that given current level of abatement technology, geothermal facilities will comply with State Air Quality standards for geothermal development.

Upper Kilauea East Rift Zone:

Development of geothermal resources in the Kilauea Upper East Rift zone will be limited to areas outside the Hawaii Volcanoes National

Park. Air quality within surrounding areas will not be impacted given the current level of abatement technology.

Site development may impact endangered o'u habitat; however, as stated in the Kahauale'a Environment Impact Statement (June 1082), "the minimal removal of vegetation and trees within the Kahauale'a project area should not significantly threaten the O'u."

Kilauea Southwest Rift Zone:

Development of geothermal resources in portions of the Kilauea Southwest Rift Zone, outside the National Park, would probably result in minimal environmental impact.

Development proximity to the Pahala and Punaluu communities may result in aesthetic impacts, however, air quality will not be impacted.

Mauna Loa Northeast Rift Zone (Kulani):

Development of a geothermal resource in areas other than the cleared grazed agricultural area in this rift zone may impact the four endangered forest bird species and the Nene by disturbing essential habitat areas.

Mauna Loa Southwest Rift Zone (Kahuku Ranch):

Development of geothermal resources in the lower, agricultural-zoned portion of the proposed subzone may result in minimal environmental impact provided a buffer area is maintained between the geothermal development site and the Hawaiian Ocean View Estates.

Hualalai Northwest Rift Zone:

Development of geothermal resource in areas other than the grazed agricultural zoned portion of the subzone may impact the endangered species known to exist within the rift zone area. Alala, the Hawaiian Crow, is reported to number fewer than 20 individuals.

Disturbance of their Hualalai habitat may cause further decline of this species, or its extinction.

Haleakala Southwest Rift Zone:

Development of geothermal resources within the grazed agricultural zoned portions of the rift zone will result in minimal impact to fauna since no endangered species habitat is present.

Proximity to the Makena residential and resort development, Ulupalakua Ranch and upslope, the Haleakala "Science City" may be affected aesthetically. Air quality in urbanized areas will not be impacted since it is expected, given the current level of technology, that all air quality impacts will be abated so as to comply with State Air Quality standards for geothermal resource development.

Haleakala East Rift Zone:

Development of a geothermal resource in the Haleakala East Rift Zone in areas other than the grazed agricultural lands below the 1000-foot level may impact native forest bird habitat and above 4200 feet, endangered forest bird habitat. However, development of a geothermal resource below the 1000-foot level in grazed agricultural land could place a geothermal well and power plant as close as 7000 feet from the center of Hana Town. Quite clearly, the rural lifestyle of the Hana Community would be affected.

INTRODUCTION

Act 296, Session Laws of Hawaii 1983, requires that environmental impacts be considered when the Board of Land and Natural Resources designates subzone areas for the development of geothermal resources. This report addresses the major environmental impacts that are likely to result from geothermal development.

Environmental impacts are described generally; the effects of various natural factors such as wind and rain are included. Impacts include risks to people and property as well as to wildlife and plant life. Impact mitigation is also described and each resource area is evaluated.

METEOROLOGY: DESCRIPTION AND EFFECT

Climatological elements deemed important in assessing environmental impact in geothermal rift zones include rainfall, temperature, winds, trade wind inversions, and ground temperature inversions. Cloudiness, solar radiation, and relative radiation are not considered important elements in geothermal development and in Hawaii data for these factors are not available for areas within rift zones.

AIR TEMPERATURE

Air temperature decreases by approximately 3°F for each 1,000 feet rise in elevation in the Hawaiian Islands. This relationship is seen in Figure 1 where the heavy slanted line (towards the left or colder temperature) has a decrease in temperature of 3°F per 1,000 feet elevation rise. The horizontal lines represent the range of the average maximum and minimum temperatures at the different locations. For example, Haleakala Rangers Station at 7,030 feet elevation has a minimum temperature of 44°F and a maximum temperature of 63°F.

WINDS

The winds in the Hawaiian Islands are very important in geothermal operation because of their effect on emissions and noise. The most common winds over the Hawaiian Islands are the trade winds from the east which account for about 70% of the winds in the Islands. Figures 2a and 2b show the mean pressure and wind flow of the Pacific Anticyclone in the Eastern and Central North Pacific for January and July, the months representing the opposite seasons for winter and summer. The mean charts show the dominance of the high and outflowing trades in the Eastern and Central North Pacific especially in the summer. The mean trade wind pattern is a smooth version of the actual happenings. At any given time, the wind flow is not as static as it appears in the mean charts because the high, the source of the trades, is not as static, especially in the winter.

Over the Hawaiian Islands, the trades prevail over 90% of the time from June through August and only 40 to 60% of the time from January through March. During summer, the trade winds can persist through an entire month while during winter trade winds are sometimes absent almost an entire month. The reason for the high frequency of the trade winds during the summer is that the Islands are in the belt of the almost persistent trade winds from the Pacific Anticyclone. During winter, the mean position of the high is further south of the summertime position and the high is not as strong or as persistent. Interruptions in the trades over the Islands are much more frequent in winter than summer with the intrusions of low pressure systems displacing the high pressure area from the Islands or the high pressure area moves far away from the Islands. These are the times that non-trade winds mainly in the form of light and variable winds or light southerly winds occur in the Islands.

Winds over the rift zones are explained with limited data. There are a few wind summaries in or near the rift zones which were used but the main source of the material for the wind discussion was the knowledge of the behavior of the trade winds and the theory of the sea breeze and mountain breeze (local upslope and downslope winds).

Earlier written articles by others were also utilized in the formulation of the wind patterns over the rift zones.

TRADE WIND TEMPERATURE INVERSION

A temperature inversion is a layer in the atmosphere in which the air warms with increase in altitude which is the inverse of the normal temperature decrease through the atmosphere. Figure 3a shows an example of the vertical air temperature profile with a temperature inversion at 6,000 feet altitude.

The trade wind temperature inversion occurs about 70% of the time over the Hawaiian Islands caused by the sinking of the air at the level of the inversion from the high pressure area north of the Islands. The trade wind temperature inversion is generally persistent in space and time when it occurs. Its mean height above sea level is between 6,000 and 8,000 feet. Normally, it ranges in height between 5,000 and 9,000 feet. It occurs more often during the summer months than during the winter months. Its strength as measured by the temperature increase in the layer of the inversion from its base to its top, varies from no temperature increase through the layer to an increase of several degrees (°F) through the layer. The trade wind temperature inversion can be measured twice a day (2:00 am and 2:00 pm) in the radiosonde data at Hilo and Lihue Airports by the National Weather Service.

GROUND TEMPERATURE INVERSION

The cooler drainage air from the mountain tops flowing down the slopes and the radiational cooling of the ground at night can produce temperature inversion over some of the rift zones (Fig. 3b). The strength of this inversion in temperature is probably only a few degrees (°F) increase in temperature through a shallow layer of a few hundred feet. The inversion will break down by the heating of the land by the sun in the morning. The important conditions for the formation of the ground temperature inversion are:

1. clear night and few or no low cloud cover

2. low or no winds
3. stable atmosphere
4. cool air draining down from the higher slopes

The conditions that are against the formation of the ground temperature inversion are:

1. overcast low clouds
2. windy conditions
3. unstable atmospheric conditions, rain
4. no drainage wind flow

FLORA AND FAUNA

One of the most serious potential impacts of geothermal energy development in Hawaii is the disruption of native forest. Air pollution and groundwater impacts of geothermal development may be substantially avoided by requiring full control technologies; impact on native forest ecosystems can be mitigated through careful siting (EPA, 1978). Siting to avoid damage to biologically valuable forest can prevent both degradation of the forest due to invasion of weed species and disturbance of native bird species due to human activity and noise.

Native forests are particularly vulnerable to invasion by exotic species along roadways or other cleared areas (Carlquist, 1970). Once such as invasion begins, native forest is gradually altered, and non-native species, which initially invaded along relatively narrow corridors, spread and multiply (Corn, 1984). Major geothermal development, with an attendant network of roads and construction corridors, may be expected to dissect and eventually degrade undisturbed native forest by opening it to invasions by weedy species.

Geothermal development may also be expected to have negative impact on native forest birds, including many which are endangered. Construction noise and human activity are factors which favor urban nuisance species over native forest species (Berger, 1972). It is therefore important to consider the habitat of native bird species, particularly those which are endangered, in assessing the impact of geothermal energy development. Any development within the habitat of native birds will have potential environmental impact and should be fully investigated and mitigation measures implemented.

In selecting areas in which geothermal development will have the least environmental impact, it is therefore useful to assess both forest quality and native bird habitat. Those areas with mature native forest and significant native bird habitat will tend to be the most environmentally important, while those without native bird habitat and with less intact forest will be substantially less impacted. For this study, two indicators were used to distinguish, on a broad scale, areas of high and low potential environmental impact. The indicators chosen were native habitat importance and forest quality.

The indicator chosen to depict the value of an area to native fauna is the presence of endangered species. While under some circumstances a simple survey for endangered species is an unacceptably superficial form of environmental assessment, in the present situation the presence of endangered species correlates quite well with the value of the area to native fauna in general. Relative value of native forest has been assessed using a categorization system developed by the University of Hawaii Environmental Center based on forest type mapping done by the United States Fish and Wildlife Services (Jacobi, 1983). This system indicates areas in which geothermal development would have the greatest environmental impact, areas in which geothermal development would have little or no impact on valuable native forest, and areas in which the impact of geothermal development on native forest is uncertain. Map overlays were prepared to illustrate the distribution and intersection of essential habitat and forest quality factors.

Endangered species habitat was considered present wherever essential habitat outlined in an approved Endangered Species Recovery Plan existed. Endangered Species Recovery Plans are plans of action for restoring the population of a species pursuant to its listing as endangered by the Secretary of the Interior. Recovery plans are drafted by teams of wildlife experts from both state and federal agencies, and represent estimates of the range and life requirements of endangered species by the foremost experts in the field. Essential habitat outlined in an Endangered Species Recovery Plan is therefore almost without exception the most authoritative estimate of the actual habitat for a particular endangered species. Where no essential habitat has been designated, distribution was determined from population surveys conducted by the U.S. Fish and Wildlife Service or other available information (Scott, 1984). Essential habitats have been defined for all endangered forest birds and the Hawaiian Crow (Alala) on the island of Hawaii and for the Nene on both Maui and the Big Island. Essential habitat has not been determined for the endangered Maui forest birds, and therefore U.S. Fish and Wildlife Service population counts were used to determine habitat boundaries for these species.

The potential for environmental impact on the flora of the resource areas was assessed using a forest categorization system based on U.S. Fish and Wildlife Service vegetation type mapping. The U.S. Fish and Wildlife Service system incorporates information on extent of canopy cover, height of canopy, understory composition, and vegetation association type (Jacobi, 1983). Vegetation information has been assembled and mapped by the Service using this system for large portions of four of the five main Hawaiian islands, including Maui and Hawaii. Information in this form was available for all or portions of each of the resource areas. Areas not covered were lower Hana, lower Makena, Kilauea S.W. Rift, and Lower Puna. In these areas aerial photo interpretation was used to estimate vegetation type, and in high resource potential areas this aerial interpretation was verified on the ground from readily accessible roadways wherever possible. Lack of access routes made ground verification for the Kilauea S.W. Rift site impractical. The boundaries delineated on the aerial photographs were transferred to orthophoto quadrangles and assigned a vegetation type code following the USFWS system (Jacobi, 1983). Vegetation type data was then ranked according to potential for impact from geothermal development into one of three categories described below.

FLORA

Vegetation type data from U.S. Fish and Wildlife Service mapping or the present study were abstracted into a simplified, three category impact sensitivity classification system (see appendix A). The three categories of this system, which was developed by the University of Hawaii Environmental Center, and based on the assumption that undisturbed, closed canopy forest would be most susceptible to disruption due to geothermal development, are as follows:

CATEGORY 1 - Exceptional native forest;
closed canopy, over 90% native cover

CATEGORY 2 - Mature native forest;
over 75% native canopy

CATEGORY 2A - Native scrub or low forest

CATEGORY 3 - Cleared land; non-native forest;
bare ground or lava

In this system, Category 1 forests are presumed to be areas in which geothermal development would unquestionably result in environmental impact, and Category 3 lands presumed to be areas in which geothermal development would have little or no impact. Category 1 forest is vulnerable because of its high native composition, which indicates that it is virtually undisturbed, and because of its closed canopy, which indicates that any development activity would result in changes in forest structure. Category 3 lands are assumed to be of little biological value owing to high degrees of disturbance or low percentage of ground cover. Category 2 is comprised of areas which did not meet the rigorous standards of Category 1, but are not so heavily disturbed or sparsely vegetated that it can be assumed that development would not result in environmental impact. Category 2A represents areas in which the vegetation is predominantly native, but the tree layer is low and scattered and does not warrant the designation of forest. In wet forests, Category 2A vegetation is a sign of disturbance, but in dry regimes, particularly at altitude or along the coast, it is a healthy native ecotype. Both Category 2 and 2A are then classifications which convey that additional information is needed before it can be assumed that geothermal development would have little environmental impact.

The additional information needed to assess the biologic value of Category 2 forest pertains to forest diversity and the presence of rare plants. These factors were not included in the present assessment because this information is not available in any comprehensive form on such a broad scale. Information on species diversity is similarly unavailable in any readily accessible form. Because of these limitations of information availability, it is difficult to arrive at an objective classification for potential for impact by geothermal development for many forest types. There are unquestionably many excellent forest areas that have been placed in Category 2 because they fell just short of 90% native composition. There are equally certainly areas assigned Category 2 which are of little biological interest. Within these extremes, the majority of Category 2 forests are areas for which the USFWS vegetation type code tells only a part of the story, and diversity and rare plant information is required to discern the exact value and vulnerability to disturbance of the area. In the absence of a compelling reason to develop these areas, a reasonable assumption is that they are valuable and should not be disturbed. Where there is compelling reason to consider development, field reconnaissance of individual areas will be required to determine what, if any, level of environmental impact would result from development. Similar considerations apply to Category 2A areas. Vegetation types are assigned to Category 2A based on growth form, not biological value or environmental impact considerations. However, it may be worthwhile to emphasize that in wet areas at intermediate elevations, Category 2A usually represents a disturbed area or recent lava flow.

In summary, Category 1 areas are those in which substantial environmental impact can be expected to result from geothermal development, Category 2 and 2A areas are those in which geothermal development should be assumed to result in environmental impact in the absence of additional information, and Category 3 areas are those in which geothermal development may be expected to have little or no environmental impact.

Clearly the environmental advantage lies in developing within Category 3 areas. It is also worthwhile to note that environmental impact, especially on native forest birds, may result from development immediately adjacent to Category 2 areas or endangered species habitat, even if the site is Category 3, if it is in close enough proximity for noise or pollution to carry to the forest. In these instances, buffer zones can be utilized to mitigate any impact which may occur.

Rare Plants

Of Hawaii's seven plant species which are formally listed as endangered, only one, the Hawaiian vetch (Vicia menziesii) is found within the resource areas (see Figure 4). However, Hawaii has numerous rare plants, over 800 of which have been proposed for listing as endangered. Undoubtedly many of these candidate species may be found within the resource areas. For example, the endemic Hawaiian fern, Adenophorus periens, is known to be present in the Kahauale'a section of the Kilauea East Rift Zone.

Currently available information on rare species does not permit a comprehensive inventory of these species and their location, and therefore has not been addressed in this study. Protection of rare plant species will have to be undertaken on a project-by-project basis, where botanical surveys of specific areas being considered for development are possible. The forest categories presented in this study do not relate to endangered plant species presence. It should not be assumed that Category 3 areas will contain no rare plant individuals. Isolated rare native species are not uncommonly found in disturbed, non-native surroundings. Such individuals should be identified and protected, but the scope of the present study precluded such detailed analysis. Areas with high concentrations of rare plants are biologically valuable, and the presence of rare plants is one criteria which should be used in determining the potential impact of geothermal development in Category 2 areas. For example, the

Category 2 forests in the southwest quarter of the Mauna Loa East Rift area are the home range of Vicia menziesii and should therefore be considered very sensitive to environmental impacts, despite the fact that the forest type alone does not warrant ranking them in Category 1. Other areas such as this definitely exist within Category 2, and this is one reason why it is important to more completely characterize these areas before their sensitivity to impact is assigned.

FAUNA

Forest birds found in the resource areas include the I'iwi, Apapane, Elepaio, and others. The specific native forest birds present at a site are not as important as the relative value of the area as native bird habitat in general. Most native birds share habitat to some degree, and it is this characteristic which permits use of the existence of endangered bird habitat as an index of overall native bird habitat value. Because the list of native birds in the resource areas is long, discussion here will focus only on the endangered fauna found in the resource areas.

Federally designated threatened or endangered fauna within the resource areas include seven forest bird species, two seabird species, the Nene, the Hawaiian Hawk (Io) and Crow (Alala), and Hawaii's only resident mammal, the Hawaiian Hoary Bat. These species and their treatment in the resource area overlays are outlined below.

'Alala (Corvus tropicus) - One of the most critically endangered species in the United States. Population estimate 10-50 birds in the wild. Last field census reported 7 birds. Essential habitat identified, intersects majority of Hualalai resource area and flanks Kahuku Ranch resource areas (DLNR, 1984).

Hawaii Forest Birds - Includes the Hawaii Creeper (Loxops maculatus mana), Hawaii 'Akepa (Loxops coccineus coccineus), Akiapola'au (Hemignathus wilsoni), and 'O'u (Psittirostra psittacea). All are moderately endangered, with populations in the high 100's or above, except the 'O'u, which is relatively rare and has a much smaller population. Essential habitat common to all four species has been identified, and intersects all of the East Mauna Loa Rift area, most of Hualalai and Upper Puna, and flanks Kahuku Ranch (USFWS, 1982).

Maui Forest Birds - Includes Crested Honeycreeper (Palmeria dolei), Maui 'Akepa (Loxops coccineus), Maui Parrotbill (Pseudonestor xanthophrys). Essential habitat not yet identified. Distribution determined by USFWS, intersects upper Hana (Scott, 1984).

Nene (Branta sandwicensis) - Moderately endangered, maintained by captive breeding. Essential habitat identified, intersects all of East Mauna Loa Rift, most of Hualalai, and the upper elevations of Kahuku Ranch (USFWS, 1983). An upland bird adapted to sparse vegetation the Nene may be less sensitive to the presence of geothermal development than other native birds.

Hawaiian Hawk (Buteo solitarius) - Relatively common over a wide range. No essential habitat established. Known nesting sites established by USFWS lie mainly in Lower Puna and East Mauna Loa Rift, but nesting observations are far from exhaustive and lie mainly along roadways and other accessible areas (Griffin, 1984).

Hawaiian Dark-Rumped Petrel (Pterodroma phaeopygia sandwichensis) - Primary nesting colonies on Maui, outside of resource areas. Also observed within Napau Crater in Volcanoes National Park (USFWS, 1983).

Hawaiian Hoary Bat (Lasiurus cinereus semotus) - A poorly characterized species (Kepler and Scott, 1980). No know roosting sites within resource areas. Most frequently observed in non-native vegetation. Impact of development on foraging habitat uncertain, possibly minimal.

Newell's Manx Shearwater (Puffinu puffinus newelli) - Classified as threatened. No known nesting colonies within resource areas. May occasion Upper Puna and East Mauna Loa Rift (Jacobi, 1984). Impact of development uncertain, may be minimal.

Figure 5 provides sketches for reference for the species named above.

Invertebrates

Rare invertebrates known to exist in the resource areas include scientifically important fruit flies (giant Drosophila spp), tree snails (Partulina spp), and special care-adapted fauna residing in lava tubes. The giant Drosophila species, focal point of important genetic research, are found in the Mauna Loa East Rift and Hualalai areas, and at upper elevations at Hana and Kahuku Ranch (Carson, 1984). Tree and land snails, many of which, like other Hawaiian invertebrates, are found nowhere else in the world, are associated primarily with native forest and probably exist in all resource areas.

Cave-adapted fauna might be found in lava tubes underlying any resource area, but are known to exist in Mauna Loa East Rift and Kilauea East Rift. These lava tube ecosystems are dependent on intact penetrating ohia root systems for their moisture supply, and are vulnerable to any development which results in forest clearing. While invertebrate species often receive less attention than vertebrate fauna, they comprise an important part of native ecosystems. Impacts on these species may be largely avoided by avoiding siting in native forest areas.

SURFACE WATER IMPACT

Geothermal development activities should not directly affect existing land uses since there are no surface streams located in the recommended areas. While drilling and construction phases of geothermal development may be a cause of concern, little or no environmental impacts are expected. However, if surface water becomes available, accidental pollution of streams should be prevented by use of adequate and safe disposal methods of geothermal brine.

Following initial development of the geothermal resources, the production of potentially valuable associated geothermal products--demineralized water and mineral salts--could have beneficial environmental consequences. From a resource point of view, their development is desirable and should be considered. However, then recovery and production of byproduct mineral salts from geothermal brines is not economically feasible, adequate and safe disposal by reinjection will be utilized.

Almost all geothermal fluids have a total dissolved solids content greater than 1000 ppm, and their indiscriminate discharge into streams, ponds, and watersheds should not be allowed. The normal disposal practice is expected to be by reinjection. In some cases it is possible that byproduct fluids may be of satisfactory quality to be disposed of without treatment. Surface disposal, in these case, could be allowed under controlled conditions.

Environmental impacts on surface waters resulting from the development of geothermal resources in the prospective geothermal subzones are expected to be minimal. None of the subzones under consideration contains perennial streams. One, the Haleakala East Rift Zone in Maui, contains a small intermittent stream and the headwaters of several other intermittent streams that exit the subzone at their upper reaches.

GROUNDWATER HYDROLOGY

Ground water in the various geothermal areas may occur as (1) perched water, (2) dike water, and (3) basal water.

Perched water, the least common, is water that is ponded on ash beds, soil formed on weathered lava, and on dense lava flows. Most perched water bodies are thin and show little lateral extent. The presence of perched water may be indicated by perched springs, usually found at higher elevations (Figure 6).

Dike water is water impounded in compartments between dikes in the rift zones of the volcanoes. The numerous dikes form nearly vertical walls that are less permeable than the masses of ordinary lava flows between them. In some of the dike complexes water is held between the dikes to a height of more than 2,000 feet above sea level.

Basal water occurs most commonly in the islands. The basal ground water body is the fresh water resting on salt water within the permeable rocks that make up most of the base of the islands. In the areas considered, ground water will not be adversely affected because geothermal wells are drilled past the ground water aquifer. In addition, surface casing will be set and cemented through a competent subsurface formation below the basal lens. The drilling, casing installation, maintenance and abandonment of all geothermal wells, including re-injection wells will be regulated and monitored to protect the groundwater aquifer. Subsurface disposal of geothermal fluids by re-injection would be allowed only under controlled conditions, and alternate safe disposal methods should be developed.

KILAUEA EAST RIFT ZONE

Ground water occurs as dike water and basal water in the Kilauea East Rift Zone. The only known perched water exists north of Mountain View.

Basal water underlies all of the Kilauea East Rift Zone except where dikes occur. Hydraulic gradients along the northeast coast of Puna range between 2 and 4 feet per mile, with water-table elevations of 12 to 18 feet above sea level 5 to 6 miles inland. Along the southeastern coast, gradients range between 1 and 2 feet per mile, with water-table elevations of 3 to 4 feet above sea level a mile and a half inland. The main reason for the difference in hydraulic gradients between the northeast and southeast coasts is the amount of rainfall per unit of surface area and the barrier effect of the east rift zone on ground water movement. The effectiveness of the east rift zone as a barrier to ground water movement is demonstrated by the difference in basal water-table levels (Figure 7).

The only significant source of saline water that contaminates the basal aquifer is sea water, with a chloride content of approximately 19,000 mg/l. Because of the effects of mixing, most ground water at the coast is brackish. Salinity and temperature vary greatly north and south of the rift zone. Wells and shafts north of the rift zone are characterized by lower temperatures and lower salinities. Wells in and near Keaau have water temperatures of 66° to 68°F. The water temperature of wells near Pahoa ranges between 72° and 74°F. Wells located more than 3 miles inland generally have a chloride concentration of less than 20 mg/l. South of the rift zone, high well-water temperatures and salinities are encountered. The water temperature of the Malama-Ki well, 2783-01, in 1962 was 127°-130°F with salinity between 5500 and 7000 mg/l at pumping rates of 100 to 480 gpm. The water temperature of thermal test well No. 3 in 1974 was 199°F, with salinity of 2000 mg/l. The average chloride content of ground water south of the rift zone is probably greater than 300 mg/l, probably due in part to heating of sea water by volcanic activity below the basal lens. The warmer, less dense sea water rises, contaminating the fresh water in the basal aquifer.

OTHER POTENTIAL SUBZONES

Ground water occurrences in the other potential subzones are similar to that found in the Kilauea East Rift Zone. Basal water underlies the areas except where the dikes of the rift zones occur. Isolated occurrences of perched water may be found but it would be of little significance. Water levels would vary according to the amount of rainfall in the area and the barrier effect of the rift zones. Water temperature and salinity in the rift zones would vary with the amount of residual heat from past volcanic activity. The greater the amount of heat present, the greater the temperature and salinity of the ground water.

AIR QUALITY

Assessment of air quality impacts resulting from geothermal development requires examination of ambient air quality in geothermal rift zones, emissions from geothermal wells and power plants, and the current level of geothermal emission abatement technology. Ambient air quality and potential environmental impacts from emissions are discussed in this report, geothermal development emissions and abatement techonology are discussed in a seperate report entitled Geothermal Technology, Circular C-108.

Environmental risks are due primarily to atmospheric emissions of noncondensing gases from the development and operation of geothermal wells and power plants. Hydrogen sulfide, and particulate sulfate from the atmospheric oxidation of hydrogen sulfide, benzene, mercury and radon are considered to be the more significant noncondensing gases from a health standpoint (Layton, 1981).

In addition, disposal of geothermal fluids can also pose a health risk if the disposal contaminates surface waters or, if injected, ground waters. The presence of arsenic in geothermal fluids is also a consideration.

The chemical composition of gases varies with the location of the geothermal reservior; however, the major constituent is typically carbon dioxide, and significant amounts of methane and hydrogen sulfide with trace amounts of benzene, radon and mercury. It should be noted that gases from igneous-related geothermal resources such as Kilauea East Rift Zone typically have much lower quantities of benzene or none at all.

Exposure to atmospheric concentrations of hydrogen sulfide, benzene, radon, and mercury poses potential hazards to public and occupational health. In addition, exposure to hydrogen sulfide and toxic chemicals contained in abatement systems also poses an occupational health hazard. (Layton, 1981).

HYDROGEN SULFIDE

Hydrogen sulfide is found in nearly all high temperature geothermal fluids. It also occurs naturally in coal, natural gas, sulfide springs and lakes and is a product of anaerobic decomposition of sulfur containing organic matter.

Production of hydrogen sulfide from volcanic gases is the result of the action of steam on inorganic sulfides at high temperatures. The same reaction is responsible for the production of the gas in steam from geothermal wells.

Hydrogen sulfide is a colorless gas which has a characteristic obnoxious odor of rotten eggs even at low concentrations (the odor threshold is in the micrograms per cubic meter). At higher concentrations the gas is toxic to human and animals and is corrosive to many metals (National Research Council, 1979). In humans at low concentrations it causes headache, conjuctivitis, sleeplessness, pain in the eyes, and similar symptoms. At high concentrations the gas can paralyze the olfactory nerve and at higher concentrations, result in rapid death. The following table identifies the range of effects at various concentrations.

Because hydrogen sulfide is rapidly oxidized in the blood to harmless and easily elimanted sulfates, it is considered a noncumulative poison. There is no evidence to indicate hydrogen sulfide is carcinogenic, mutagenic or teratogenic (Layton, 1981).

Plant species differ widely in their response to hydrogen sulfide, and in their response to different concentrations of the gas. Long-term exposure to hydrogen sulfide results in damage to plants at concentrations between 0.042 mg/liter (0.03 ppm) and 0.42 mg/liter (0.03 ppm). However at 0.03 ppm some species exhibit growth stimulation, but at 0.3 ppm these species show damage (National Research Council, 1979).

Table 1 summarizes hydrogen sulfide concentrations in the ambient air in the Kilauea East Rift Zone. Various standards, worldwide means and biological impact values are indicated.

The authors of the Environmental Baseline Survey at the Kilauea East Rift concluded in their first year report that current hydrogen sulfide levels in the Kilauea East Rift Zone are very low, and well below biological impact values. Occasional short-term H_2S episodes were observed during the baseline survey at two sites (Site 4, and Volcano Village, see Figure 8) but were of short, less-than-a-day duration and only at modest concentration levels.

SULFUR DIOXIDE AND ACID RAIN

Hydrogen sulfide, released from geothermal facilities will oxidize in the atmosphere to sulfur dioxide, which is then oxidized to sulfate aerosols (Layton, 1981). Sulfur dioxide is injurious to human health and the environment and is the princpal precursor of acid rain.

Studies dealing with acute inhalation of sulfur oxides generally indicate that health effects are unlikely at the ambient levels expected to occur as a result of atmospheric oxidation of hydrogen sulfide.

Table 1. Comparison of Hydrogen Sulfide Concentrations with Standards, Worldwide Means, and Biological Impact Values

Parameter	Concentration ($\mu g/m^3$)
Site 2, multi-day[1] integrated samples	< 0.07 - 0.7
Site 4, multi-day[1] integrated samples	< 0.06 - 1.8
Remote Site A, multi-day[1] integrated samples	< 0.06 - 0.8
Remote Site B, multi-day[1] integrated samples	< 0.1 - 1.2
Remote Site D, multi-day[1] integrated samples	< 0.06 - 0.5
Site 2, 15 min. avg.[2]	< 0.8 - 2.0
Site 4, 15 min. avg.[3]	< 0.8 - 11
Volcano Village, real time values[4]	< 1.5 - 10.1
Colortec Card Network[5] multi-day integrated values	< = 10
Ambient Air Quality Stds.	
1 hr., California	152
New York	152
1 time, U.S.S.R.	9.1
24 hrs., U.S.S.R.	9.1
TLV[6]	15,000
Typical Atmospheric Background	0.3
Miami, Florida, Polluted Air[7]	0.17 - 1.15
North Carolina, Polluted Marsh[7]	80
United States[7]	0.15 - 0.45
Panama[7]	0 - 1.0
Colorado[7]	0.04
Illinois & Missouri[7]	0.12 - 0.3
Miami, Florida[7]	0.008 - 0.08
West Germany[7]	0.035 - 1.65
Island of Sylt (North Sea)[7]	0.1
Ivory Coast[7]	0.1 - 8.7
France[7]	0.017 - 0.17
Above Polluted Air, New Zealand[7]	1,000
Polluted Air, U.S.A.[7]	1,000

Source: Houck, Vol. 1, 1984.

Table 1. (Continued)

Parameter	Concentration (μg/m³)
No injury to 29 plant species, fumigated for 5 hrs.	60,000
No damage to Boston Fern, apple, cherry, peach and Coleus, fumigated for 5 hrs.	600,000
Moderate damage to gladiolus, rose, castor bean, sunflower and buckwheat, fumigated for 5 hrs.	60,000 to 600,000
Odor threshold. No reported injury to health	1 - 45
Threshold of reflex effect on eye sensitivity to light	10
Smell slightly perceptible	150
Smell definitely perceptible	500
Minimum concentration causing eye irritation	15,000
Maximum allowable occupational exposure for 8 hours (ACGIH Tolerance Limit)	30,000
Strongly perceptible but not intolerable smell. Minimum concentration causing lung irritation	30,000 - 60,000
Olfactory fatigue in 2-15 minutes; irritation of eyes and respiratory tract after 1 hour; death in 8 to 48 hrs.	150,000
No serious damage for 1 hour but intense local irritation; eye irritation in 6 to 8 minutes	270,000 - 480,000
Dangerous concentration after 30 minutes or less	640,000 - 1,120,000
Fatal in 30 minutes	900,000
Rapid unconsciousness, respiration arrest, and death, possibly without odor sensation	1,160,000 - 1,370,000
Immediate unconsciousness and rapid death	1,500,000+

[1] 1/25/83 - 12/10/83

[2] 5/28/83 - 9/1/83

[3] 12/18/82 - 5/26/83

[4] 9/12/83 - 11/8/83

[5] 12/14/82 - 12/12/83

[6] American Industrial Hygiene Assoc., Maximum Recommendations for Exposure, 8 hrs/day, 5 days/week

[7] Source: Aneja, V.P., et al., Biogenic Sulfur Compounds and the Global Sulfur Cycle, J. Air Poll. Control Assoc., 1982, v. 32, pp. 803-807.

Source of other comparison values: Chemical Rubber Co., Handbook of Environmental Control, Volume 1, Air Pollution, 1972, and U.S. Dept. of Health, Education and Welfare, Preliminary Air Pollution Survey of Hydrogen Sulfide, 1969.

Source: Houck, Vol. 1, 1984

Other epidemiological studies suggest that the inhalation of particulate sulfates rather than sulfur dioxide is a primary source of risk associated with long-term, low-level exposure to polluted air. Sulfate aerosols are respiratory irritants, and are used to measure the health hazard of exposure to polluted atmospheres containing sulfur oxides and particles.

Acid rain usually originates with emissions of sulfur dioxide-SO_2, which can oxidize to SO_3, and eventually forms H_2SO_4-sulfuric acid, which falls as acid rain. Three potential sources of acid rain are: (1) natural volcanic emissions, (2) geothermal emissions, and (3) emissions from oil-fired power plants.

In the absence of a volcanic activity, sulfur dioxide values are low. However, during an eruption concentrations, due to volcanic activity, can exceed human health and plant impact values for days at a time.

Rainwater in the Puna and Ka'u districts in the vicinity of the Kilauea Rift Zone, is slightly acidic due to not only acidification from local volcanic sources of sulfur dioxide but also from long-range transport of pollutants across the Pacific.

At present, it is notable that no detectable amount of sulfur dioxide is emitted from the Puna HGP-A facility noncondensed gas stream. Hawaiian geothermal developments are expected to have abatement systems which can abate hydrogen sulfide emissions by about 99%, which should meet proposed state Department of Health air quality standards for geothermal development of 98% H_2S abatement during goethermal power plant operation in addition to an incremental standard.

It is expected that the remaining unabated 1% H_2S would take several days to become acidic and by that time, prevailing winds should take any pollutant remaining out to sea.

It should be noted that due to the sulfur content of fuel oil, oil-fired power plants may emit about 100 times more sulfur dioxide per megawatt-hour than would a geothermal power plant (Thomas, 1984). As such, replacement of oil-fired power plants capacity with geothermal plants may actually reduce the potential for acid rain. Thus, acid rain resulting from geothermal sources should not significantly effect nearby land areas.

Table 2 summarizes sulfur dioxide concentrations in the ambient air in the Kilauea East Rift Zone. Various standards, worldwide means, and biological impact levels are also indicated for comparison.

BENZENE

Benzene is associated with the gas phase of fluids derived from geothermal reservoirs of sedimentary origin. Igneous-related geothermal systems, such as Kilauea exhibit smaller levels of benzene or none at all because such systems contain less organic matter. (Layton, 1981).

Benzene is a hematotoxin that can cause various blood disorders. Epidemiological studies of workers exposed to benzene provide strong evidence that the chronic inhalation of benzene can lead to leukemia.

MERCURY

The health effects of long-term exposure to airborne elemental mercury have been studied less than the effects from ingestion of foods contaminated with the methylated form of mercury. However, epidemiological studies indicate that persons exposed to mercury vapor in the work environment have shown mercury intoxication resulting in muscle tremors, psychosomatic disturbances, deterioration of intelligence, inflammation of the oral cavity and lens discoloration (eye). Mercury emissions from geothermal facilities are not likely to cause acute health effects; however, prolonged exposure to atmospheric mercury may cause subtle effects such as psychosomatic disturbances and finger tremors. (Layton, 1981).

Elemental mercury vapor was measured in the Baseline Survey for the Kilauea East Rift Zone, and an increase in the particulate mercury content of samples during the January 1983 Kilauea eruption was noted. Table 3 from the Baseline Survey, Volume 1, provides a comparison of elemental mercury vapor and particulate mercury concentration in the Kilauea East Rift zone. Comparison with

Table 2. Comparison of Sulfur Dioxide Concentrations with Standards, Nationwide Means, and Biological Impact Values

Parameter	Concentration ($\mu g/m^3$)
Site 2, multi-day[1] integrated samples	< 0.06 - 8.7
Site 4, multi-day[1] integrated samples	< 0.06 - 43
Remote Site A, multi-day[1] integrated samples	< 0.06 - 28
Remote Site B, multi-day[1] integrated samples	0.14 - 39
Remote Site D, multi-day[1] integrated samples	< 0.05 - 31
Site 2, 15 min, avg.[2]	< 1.4 - 3.4
Site 4, 15 min, avg.[3]	< 1.4 - > 286, > 983[4]
Volcano Village, real time values[5]	< 4.0 - > 1964
Ambient Air Quality Stds.	
24 hr., Primary U.S.	365
Annual mean, Primary U.S.	80
24 hr., Hawaii	80
Annual mean, Hawaii	20
1 hr., California	2,857
8 hr., California	857
1 hr., New York	714
24 hr., New York	286
1 time, U.S.S.R.	1,543
24 hr., U.S.S.R.	171
TLV[6]	13,000
Typical Atmospheric Background	0.6
Yearly Avg. SO_2 (1968)	
Chicago	343
Cincinnati	57
Philadelphia	229
Denver	29
St. Louis	86
Washington, D.C.	114
Maximum 24 hr. avg. (1968)	
Chicago	1,457
Cincinnati	229
Philadelphia	1,029
Denver	143
St. Louis	457
Washington, D.C.	514
Plant Leaf Symptoms, 24 hr. exposure	800
Plant Chlorosis, single exposure	> 714
Plant Chlorosis, annual avg.	86
Plant Growth Altered	143 - 571
Odor	1,428 - 2,000
Taste	286 - 857
Epidemological Significance (24 hr., annual avg.)	43
Pulmonary Function, 10 min. exposure	4,571
Discomfort	14,285
Severe Distress, 10 min. exposure	14,285 - 28,570

Source: Houk 1984

1 1/25/83 - 12/10/83

2 5/28/83 - 9/1/83

3 12/18/82 - 5/26/83

4 The maximum dynamic range of the continuous H_2S/SO_2 monitor is 100 ppb (286 $\mu g/m^3$) due to its design for sensitive low-level background work. During the first phases of the Kilauea eruptions, this value was exceeded frequently. The State of Hawaii Dept. of Health reported on 1/8/83 a 24 hr. mean of 983 $\mu g/m^3$. This monitor was less than one kilometer from Site 4, hence 15 min. values greatly in excess of 983 $\mu g/m^3$ unquestionably occurred at Site 4.

5 11/8/83 - 12/31/83

6 American Industrial Hygiene Assoc., Maximum Recommendation for Exposure, 8 hrs/day, 5 days/week

Source of Comparison Data: Chemical Rubber Co., Handbook of Environmental Control, Volume 1, Air Pollution, 1972.

Table 3. Ambient Mercury Concentration - Comparison Values[1]

Sample Description	Concentration ng/m^3
Kilauea East Rift (This Study)	
Hg^0 Vapor	4-45
Total Particulate Mercury	below detection limit - 4
Atmospheric Concentrations	
Palo Alto, CA (vapor)	1-10
Los Altos, CA (vapor)	1-50
East Chicago, IN (particulate)	2-5
Niles, MI (particulate)	2 (typical)
Columbia, MO (particulate)	.2-.5
Chicago, IL (particulate)	3-38
Philadelphia, PA (particulate)	2 (typical)
Denver, CO (particulate)	2 (typical)
New York, NY (particulate, indoor)	1-41
New York, NY (particulate, outdoor)	1-14
Houston, TX (particulate)	<3
Beaumont, TX (particulate)	50
Toronto, Canada (particulate)	<1-4
Cincinnati, OH (total)	100
Charleston, WV (total)	170
"unpolluted air" (vapor)	8 (average)
Pacific Ocean (20 miles offshore)(vapor)	.6-.7
Pacific Ocean winds measured in California (vapor)	0.2 (average)
California (vapor)	1-50
Background, Arizona and California (vapor)	1.6-7.2
Kamchatka (vapor)	190
Moscow and Tula regions (vapor)	80-300
Non-minearalized, non-urban areas (total)	3-9
Ambient Air Quality Standards (24 hour Average)	
Bulgaria	300
Germany (Democratic Republic)	300
Israel	10,000
Romania	10,000
Soviet Union	300
Occupational Exposure Standards	
Czechoslovakia (inorganic)	50,000
Germany (Democratic Republic)(inorganic)	100,000
Germany (Federal Republic)(inorganic)	100,000
Great Britian (inorganic)	100,000
Hungary (inorganic)	20,000
Japan (inorganic)	50,000
Poland (inorganic)	10,000
USA[2] (total)	10,000
USA[3] (total)	100,000
USSR (inorganic - ceiling values)	10,000
USSR (Alkyl - counting values)	5,000
Volcanic Sources	
Mt. St. Helens Plume	
September, 1980 eruption	750-1800
Air of vent Breccias of mud volcanoes	300-700
Gases of mud volcanoes	700-2000
Gases, Mendeleev and Sheveluch volcanoes	300-4000
Gases from Hot Springs, Kamchatka and Kuriles	10,000-18,000

[1] Sources: Liptak, B.G., Air Pollution, Environmental Engineers' Handbook, Volume 2, 1974; Chemical Rubber Company, Handbook of Environmental Control, Volume 1, Air Pollution; U.S. Department of Labor, OSHA 2234, Mercury, Job Health Series, 1975; Noyes Data Corporation, 1974, Pollution Detection and Monitoring Handbook; U.S. Geological Survey Professional Paper 713, Mercury in the Environment, 1970; Lenihan, J. and Fletcher, W.W., 1977, Environment and Man, Volume 6, The Chemical Environment, Academic Press; and Varekamp, J.C. and Buseck, P.R., 1981, Mercury Emissions from Mount St. Helens during September 1980, Nature, Volume 293, pp. 555-556.

[2] American Industrial Hygiene Assoc. maximum recommendation for exposure - 8 hrs. per day, 5 days per week

[3] Occupational Safety and Health Administration, work place maximum level

atmospheric concentrations at other sites and communities outside of Hawaii can be made. Occupational Exposure Standards are also given.

It should be noted that elemental mercury vapor levels and particulate mercury levels in the rift zone are well below ambient air quality and industrial standard levels, but fall within the typical range of atmospheric concentrations.

Mercury concentrations in the East Rift Zone are also regulated by the inflow of trade winds from the ocean where mercury levels are extremely low.

RADON-222

Radon-222 is a radioactive gas naturally formed from the decay of radium contained in geologic materials. Due to the radioactivity of Radon-222 and its daughter products, and the fact that Radon-222 is a gas which can be inhaled, high Radon-222 concentrations are injurious to human health (Houck, 1984). Exposure to high levels of radon and its daughters is known to induce lung cancer. This has been documented by the excess cases of lung cancer among underground miners exposed to high levels of radon (Layton, 1981).

High radon emission rates are associated with volcanic and geothermal areas. Ambient concentrations of radon, measured in the Kilauea East Rift Zone Environmental Baseline Survey (Houck, 1984, page 106) range from 130 to 1000 pCi/m^3 (picoCurie of radiation per cubic meter) and up to 1960 pCi/m^3 in the remote Site B (see Figure 8)--an area of active volcanism. 130-1000 pCi/m^3 is considered to be more representative of the values to which rift zone residents are exposed. Table 4 shows that this range is not unusual for outdoor exposure levels and is well below indoor exposure levels of North American and European homes. Even the maximum level measured at the remote site is well below standards.

Table 4. Comparison of Radon-222 Activities with Indoor and Outdoor Values and Standards*

Location		Range of Reported Values (pCi/m^3)
KILAUEA E. RIFT (THIS STUDY)		130 - 1960
Kilauea E. Rift (excluding Remote Site B)		130 - 1000
Illinois	(outdoor)	50 - 1000
New York	(outdoor, city & State)	15 - 500
Ohio	(outdoor)	70 - 1040
Florida	(outdoor)	20 - 300
California	(outdoor)	2.5 - 10
Massachusetts	(indoor)	< 5 - 940
Tennessee	(indoor)	130 - 4800
Florida	(indoor)	30 - 3600
New York	(indoor)	60 - 390
Above Oceans		10
OSHA Uranium Mine Standard		66,000
U.S. EPA Indoor Standard for houses around inactive uranium mill tailings		4,000
California Ambient Air Standard		3,000
Houses built on Florida Phosphate Mining Regions:		
Level requiring remedial action		4,000
Level requiring reduction to a reasonably feasible level		2,000
Houses built on Canadian Uranium Mining Regions:		
Prompt remedial action required		30,000
Remedial action required		4,000
Investigation recommended		2,000
Sweden (maximum levels):		
Existing buildings		11,000
Houses undergoing remodeling		5,000
New houses		2,000
Union of Concerned Scientists:		
Remedial action indicated		» 5,000
Remedial action suggested		2,000 - 5,000
1% risk increase of dying of lung cancer increment (lifetime exposure)		4,000

*Data is from a collection of numerous studies compiled in: National Background Radiation, Report of Scientific Committee 43, National Council on Radiation Protection and Measurement, March, 1974, and, Indoor Air Pollution, 1983, Hileman, B., Environ. Sci. Technol., v. 17, n. 10, p. 469A.

Source: Houck, 1984

ARSENIC CONTAMINATION

The presence of arsenic in geothermal fluids can cause negative health effects including skin cancer if fluids are allowed to contaminate surface waters or ground waters.

Common practice is to inject residual geothermal fluids back into a geothermal reservoir for disposal, thus isolating spent fluids from drinking water supplies. Injection wells like geothermal wells are drilled past the ground water aquifer and cased so that no leakage to an aquifer can occur.

OTHER GASES

The Environmental Baseline Study for Kilauea East Rift included data on chlorine gas and carbon monoxide. Table 5, presenting survey measurements, standards, and biological impact values for chlorine gas, is provided for reference.

AMBIENT AIR QUALITY IN THE KILAUEA EAST RIFT ZONE

Quantification of pre-development concentrations of naturally occurring emissions in geothermal rift zones is essential in order to assess any future changes in emission concentrations resulting from development of the geothermal resources.

Quantification has been undertaken by the State Department of Planning and Economic Development in a two-year environmental baseline survey of the Kilauea East Rift Zone (Houck, 1983). Volume 1 of the survey report covers the period between December 1982 and December 1983. A second-year progress report for the period between January 1, 1984 and May 31, 1984 is also available.

The principal parameters measured in this study include atmospheric concentrations of particulate material, sulfur dioxide gas, hydrogen sulfide gas, chlorine gas, carbon monoxide gas, elemental mercury vapor, radon, elemental and organic content of particulate material, rainwater pH, elemental and anionic content of rainwater, and wind speed and directions.

Table 5. Comparison of Chlorine Gas Concentrations With Standard and Biological Impact Values

Parameter	Concentration ($\mu g/m^3$)
Site 2, multi-day[1] integrated samples	< 0.02 - 0.7
Site 4, multi-day[1] integrated samples	< 0.007 - 0.15
Remote Site A, multi-day[1] integrated samples	< 0.02 - 0.14
Remote Site B, multi-day[1] integrated samples	< 0.02 - 0.37
Remote Site D, multi-day[1] integrated samples	< 0.02 - 0.07
TLV[2]	1,500
Damage to some plants (2 hr. exposure), bleaching between veins, leaf abscission	316
Coleus (2 hr. exposure), incipient injury	1,770
Azalea (4 hr. exposure), incipient injury	2,500
Corn (1 hr. exposure) plants die	196,000
Odor threshold	450
Generally still tolerable for animals	≈ 4,741
No damage when repeatedly exposed (animals)	65,433
Exposure causes sickness	≈ 190,000
Respiratory rate increases during exposure	632,000 - 3,161,000
Death occurs	≈ 1,900,000
Brief exposure kills even large animals	3,161,000

[1] 1/25/83 - 12/10/83
[2] American Industrial Hygiene Assoc., Maximum recommendations for exposure, 8 hrs./day, 5 days/week
Source of Comparison Values: Chemical Rubber Co., Handbook of Environmental Control, Volume 1, Air Pollution, 1972.

Source: Houck, 1984

In January 1984, two addtional monitors were added to measure inhalable and respirable particles. Also, data from other research sources were collected to establish baseline conditions.

First-year results of the Environmental Baseline Survey have been summarized as follows (see Figure 8 for sites referenced):

(1) Total suspended particulate levels on the Rift Zone are extremely low. The combined effect of the drought, the brush fires, and the eruptions of Kilauea, which occurred during the study period, makes even these low TSP values higher than what would probably normally be characteristic of the Rift Zone.

(2) Sea salt aerosol, road and soil dust, volcanic emissions, diesel exhaust, and organic material (pollen, spores, vegetative fragments, and smoke particles) are the principal current sources of TSP.

(3) Sea salt aerosol is relatively more important at Sites 1, 2 and 3 than it is at Site 4 as a source of particles due to their closer distance to the coastline. Conversely, volcanic fume is more dominant at Site 4 due to its proximity to volcanic emission sources.

(4) Sulfate particulate material and, under certain conditions, heavy metals contained in particulate material can be related to volcanic emissions.

(5) Current hydrogen sulfide and chlorine gas levels are very low and well below biological impact levels. Occasional short term H_2S episodes have been observed at Site 4 and at Volcano Village. These episodes are at only modest concentration levels and are less than a day in duration.

(6) Sulfur dioxide concentrations due to volcanic activity can exceed standard values, values typical of urban areas, and human health and plant impact values for days at a time. Higher SO_2 values have been measured in the upper part of the Rift Zone than in the lower portion. In the absence of volcanic impact, SO_2 values are low.

(7) Rain water is slightly acidic in the Puna and Ka'u districts due to the long range transport of pollutants across the Pacific. Locally, additional acidification occurs due to volcanic emissions of SO_2, and rainfall collected within approximately ten kilometers downwind of sources of volcanic fume have a consistently lower pH. Conversely, sea salt aerosol reduces the acidity of rain, and areas closer to the coastline have a tendency to have a higher pH.

(8) The chemical composition of rain shows the impact of sea salt and, to a lesser extent, geological materials. The impact of sea salt on its chemical composition decreases with distance from the ocean (increase in elevation). Sulfate in the rain water samples is higher at Site 4 than at Site 2, again due to SO_2 emitted by the volcano. Nitrate is very low in the Hawaiian rain water samples. All trace elements which were capable of being measured to the level specified by drinking water criteria standards (except selenium) were found to be below the drinking water threshold values. The data for selenium is limited, but it appears that the drinking water threshold values may be exceeded for selenium in some rain water samples. Most conclusive is the fact that the pH of rainfall in the Puna and Ka'u districts is uniformly more acidic than the drinking water criteria range.

(9) Ambient mercury and radon values were more or less typical of atmospheric values nationwide. The impact of volcanic emissions on the atmospheric radon content could be seen by noting the higher values measured at the site closest to the current eruption area in Kahauale'a.

(10) The complexity of the land/sea breeze and trade wind interaction is apparent in the diurnal fluctuation of wind direction seen at Site 2 and the drainage wind phenomenon seen carrying volcanic fume from Kahauale'a over the Pali along the Chain of Craters/Kalapana Road.

(11) Both temporal and spatial variability in rainfall is dramatic in the Kilauea East Rift Zone area. This variability can effect the

magnitude of TSP material originating from such sources as road and soil dust and spores and pollen from vegetation.

The first-year report also summarizes data for each type of emission and provides for comparison, emission standards of other states and countries, as well as biological impact values for each type of emission and includes table from the Baseline Survey. Figure 8 shows the approximate location of survey monitoring stations in the Kilauea East Rift Zone.

EMISSIONS FROM GEOTHERMAL DEVELOPMENT AND CURRENT ABATEMENT TECHNOLOGY

The Geothermal Technology report, Circular C-108 of this series, provides a discussion of the current level of abatement technology available for use in developing and operating geothermal wells in Hawaii.

The recommended H_2S abatement system, the Stretford System, is capable of removing over 99% of the H_2S contained in the noncondensable gases.

Use of this system would enable facilities to comply with the proposed State Department of Health air quality standard for geothermal developments since this standard requires 98% of the H_2S present to be removed.

As noted in the Geothermal Technology report, given the characteristics of the HGP-A reservoir fluids and the available emission abatement technology which would be required to comply with proposed State air quality standards, geothermal facility cooling tower emissions should not be toxic and the plume should consist entirely of water vapor. Brine from the plant will be injected back into the geothermal reservoir.

Abatement of Radon-222 is unnecessary since the level emitted from the power plant is lower than most indooor levels where cement emits radon in most buildings.

STATE OF HAWAII, DEPARTMENT OF HEALTH PROPOSED AIR QUALITY STANDARDS FOR GEOTHERMAL DEVELOPMENT

The State Department of Health has drafted revisions to its Adminstrative Rules Chapter 11-59, Ambient Air Quality Standards, and Chapter 11-60, Air Pollution Control, covering geothermal activities (see appendix B).

Proposed revisions to Chapter 11-59-4 specify ambient air concentrations of carbon monoxide, nitrogen dioxide, suspended particulate matter, ozone, sulfur dioxide, lead and hydrogen sulfide. Under the proposed rule revisions, concentrations of hydrogen sulfide shall not exceed 139 ug/m^3 or 100 ppb.

Chapter 11-60 is to be amended by adding a new section 11-60-23.1 covering allowable emissions of particulates and hydrogen sulfide for geothermal wells and emissions of hydrogen sulfide only from geothermal power plants.

Chapter 11-60 is to be further amended to provide provisions for prevention of air pollution emergency episodes. Table 6 summarizes in outline form the proposed additions and revisions to the Department of Health Administrative Rules.

Chapter 11-60 is to be amended by adding sections dealing with geothermal wells and power plants and a section on air pollution emergency episodes.

Secton 11-60-23.1 defines geothermal wells, and sets standards for particulates and hydrogen sulfide. Prior to a well being connected to a power plant, well emissions shall not be in excess of five pounds of particulates, and five pounds of hydrogen sulfide, per one hundred pounds of each respective pollutant in the resource. After a well is connected to the power plant, emissions shall not exceed two pounds per 100 pounds of hydrogen sulfide in the geothermal resource. Permits to construct and operate a geothermal well are required of the well owner or operator.

Table 6. SUMMARY OF DRAFT REVISIONS/ADDITIONS TO DEPARTMENT OF HEALTH ADMINISTRATIVE RULES, CHAPTER 11-59

Chapter 11-59-4, Ambient Air Quality Standards:

- o rule limits the time averaged concentration of specified polluants dispersed or suspended in the ambient air.
- o limiting concentrations for a twelve-month period or a calendar year shall not be exceeded.
- o limiting concentrations for one-hour, eight-hour, and twenty-hour periods shall not be exceeded more than once in any twelve month period.
- o CARBON MONOXIDE
  1. Concentration shall not exceed an average value of ten milligrams per cubic meter of air during any one-hour period.
  2. Concentration shall not exceed an average value of five milligrams per cubic meter of air during any eight-hour period.
- o NITROGEN DIOXIDE concentrations shall not exceed seventy micrograms per cubic meter of air during any twelve-month period.
- o SUSPENDED PARTICULATE MATTER
  1. Concentration shall not exceed a geometric mean of sixty microgram per cubic meter during any twelve-month period.
  2. Concentration shall not exceed an average value of one hundred and fifty micrograms per cubic meter of air during any twenty-four-hour period.
- o OZONE concentrations shall not exceed one hundred micrograms per cubic meter of air during any one-hour period.
- o SULFUR DIOXIDE
  1. Average concentration shall not exceed the average value of eighty micrograms per cubic meter of air in any twelve-month period.
  2. Average concentration shall not exceed an average value of three hundred sixty-five micrograms per cubic meter of air in any twenty-four hour period.
  3. Average concentration shall not exceed one thousand three hundred micrograms per cubic meter of air during any three-hour period.
- o LEAD--elemental lead concentrations shall not exceed 1.5 micrograms per cubic meter of air during any calendar quarter.
- o HYDROGEN SULFIDE concentrations shall not exceed one hundred thirty-nine micrograms per cubic meter of air in any one-hour period.

Section 11-60-23.2 defines geothermal power plants and sets standards for hydrogen sulfide. Hydrogen sulfide emissions from a power plant shall not exceed two pounds per one hundred pounds of hydrogen sulfide in the incoming geothermal resource. The maximum allowable increase in hydrogen sulfide concentration in the ambient air above natural background level shall be thirty-five micrograms per cubic meter as a one-hour average. The maximum allowable increase may be exceeded once per twelve-month period at any one location. Permits to construct and operate a power plant are required.

Section 11-60-19, Prevention of Air Pollution Emergency Episodes, is designed to prevent excessive buildup of air contaminants during air pollution episodes. Episodes are classified as an air pollution alert, air pollution warning, or an air pollution emergency. Maximum concentrations for each level, alert, warning and emergency are set for sulfur dioxide, particulate matter, combined sulfur dioxide and particulate matter, carbon monoxide, ozone, nitrogen dioxide and hydrogen sulfide. Appendix B specifies these concentrations.

NOISE IMPACT

During the initial phases of geothermal development, persons in the vicinity of a geothermal site may be exposed to noise levels varying from 40 to 120 decibels, depending upon the distance from the well site. High noise levels are produced by well drilling, production testing, and well bleeding before connection to the generator. While most operations can be effectively muffled by acoustical baffling and rock mufflers, some emit unavoidable noise.

The design standard for the HGP-A Wellhead Generator Project specifies that the noise level one-half mile from the well site must be no greater than 65 decibels. Construction of a rock muffler at the facility has reduced noise levels to about 44 decibels at the fence line of the project (See Figure 9, Noise Characteristics at HGP-A).

Proposed county noise guidelines are 45 decibels at night and 55 decibels by day. It is expected that geothermal facilities will comply with this guideline.

HISTORIC AND ARCHAEOLOGICAL VALUES

Historical values, in this context, refer to the range of historical activities carried out by early Hawaiian residents. Archaeological values refer to all structures and artifacts that provide evidence of early habitation.

The Hawaiian land use concept of the ahupuaa is most useful in understanding the range of activities likely to have occurred within a rift zone area, as well as the potential for discovery of archaeological sites. For example, early coastal fishing villages often had inland agricultural fields. In addition to fishing and farming, various forest products were harvested from mauka or upland areas (i.e., koa for canoes, pulu for stuffing, ohia logs, birds for feathers) and early trail systems connected remote villages.

Evidence of these activities found in remaining archaeological sites is critical to reconstructing Hawaiian history and pre-history.

Geothermal development runs the risk of destroying such remaining evidence by site clearing and facility construction.

Estimates of likely impacts can be accomplished by (1) plotting the location of known archaeological sites within and nearby proposed subzones, (2) completing an archaeological literature search for each geothermal resource subzone for evidence of early human activity, and (3) by archaeological reconnaissance surveys on site.

The Department of Land and Natural Resources, Division of State Parks, Outdoor Recreation and Historic Sites, under its Historic and Archaeological Program, maintains records of all known historical and archaeological sites in the State of Hawaii. A survey of available information was made to determine the type, extent and significance of sites within or nearby the proposed geothermal resource subzones.

Subzone boundaries were drawn on copies of Historic Sites maps showing known sites and their identification numbers. The most recent updated mapping, done under the Coastal Zone Management (CZM) program, was used, and where updated mapping was not available, other available maps prepared by DLNR, Historic Sites section were utilized.

Each site located within a proposed geothermal resource subzone or nearby its boundaries was identified and a review of Historic Sites section records made. This information has been summarized in Appendix D including State and National Register status.

A literature search was prepared for the Kahauale'a EIS (Appendix C). Similar searches accompanied by maps showing known sites would be prepared and on-site reconnaissance surveys performed, once geothermal development sites have been selected.

SCENIC AND AESTHETIC VALUES

Scenic and aesthetic values, in general, refer to landscape qualities likely to be impacted by geothermal development. Since most geothermal resource rift zones are located in remote wilderness areas, some of which are heavily forested, development of geothermal facilities can represent a visual intrusion.

Potential sources of visual intrusion include:

- o Clearing forested areas for construction of facilities
- o Temporary 2-3 month presence of drilling rigs
- o Night lighting of drilling rigs
- o Continued drilling for new wells, replacement wells, and injection wells (continued presence of drilling rig)
- o Permanent presence of power plant structures with cooling towers (50 to 65 feet in height)
- o Geothermal fluid transmission lines
- o Electric transmission lines (70 + feet in height)
- o Periodic presence of steam plumes above well heads and power plant cooling towers (under certain climatic conditions, steam plume may rise to 150 to 200 feet above the site)

Estimates of visual impact are accomplished by preparing an area wide terrain analysis to determine locations outside the project area from which drilling rigs, powerlines, power plant facilities, etc., can be seen. A terrain analysis of visual impacts was completed for the preparation of the Kahauale'a Environmental Impact Statement (Kahauale'a Revised EIS, June 1982) and is provided here as Appendix D, for reference.

In preparing a terrain analysis of visual impacts, various observer location points are selected and view lines calculated at each site. The observer is assumed to have an eye level 10 feet above ground surface and power plant height is assumed to be 80 feet above ground level (alternate height considered is 65 feet). Profiles or visual perspectives are constructed to show the view lines from each observer location to a proposed power plant location. From such a profile, it is possible to determine the extent to which a site is visible from each observer location.

A similar terrain analysis should be included in environmental impact assessments for the development of specific sites within a geothermal resource subzones.

RECREATIONAL VALUES

Recreational values in remote areas, include hiking, hunting, fishing, and camping. These activities are usually not limited to specific areas and can therefore occur anywhere in a rift zone.

However, there are existing, well used hiking trails in many areas; some have names and are segments of longer trail systems. In some areas, pre-historic and historic Hawaiian trail systems remain. Often, local hikers and hunters develop trails by usage.

Public hunting areas referred to as game management areas are defined in Department of Land and Natural Resources rules and mapped for public convenience on handout sheets. Conditions for use of public hunting areas is specified in the rules; however, game may also be hunted on private land at any time with a valid hunting license and permission from the landowner.

The impact of geothermal development to remote area recreation uses such as hiking and hunting may result in the loss of segments of some trails and could affect the number of game animals present in the vicinity of the geothermal development.

STATE LAND USE DISTRICTS, COUNTY GENERAL PLANS AND EXISTING LAND USES

STATE LAND USE DISTRICTS

The State Land Use Commission has placed all lands within the State of Hawaii in four major land use districts: urban, rural, agricultural and conservation.

The standards for determining the boundaries of each land use district are set forth in Chapter 205, HRS, and are as follows:

Urban Districts include those lands that are now in urban use and activities or uses as provided by ordinances or regulations of the county within which the urban district is situated.

Rural Districts include activities or uses as characterized by low density residential lots of not more than one dwelling house per one-half acre and where small farms are intermixed with the low density residential lots.

Agricultural Districts include activities or uses as characterized by the cultivation of crops, orchards, forage, and forestry; farming activities or uses related to animal husbandry, and game and fish propagation; services and uses accessory to the above activities including but not limited to living quarters, mills, storage facilities, processing facilities; and roadside stands for the sale of products grown on the premises; agricultural parts and open area recreational facilities.

Conservation Districts include areas necessary for protecting watershed and water sources; preserving scenic and historic areas; providing park lands, wilderness, and beach; conserving endemic plants, fish, and wildlife; preventing floods and soil erosion; forestry; open space areas whose existing openness, natural condition, or present state of use, if retained, would enhance the present or potential value of abutting or surrounding communities, or would maintain or enhance the conservation of natural or scenic resources; areas of value for recreational purposes; and other related activities; and other permitted uses not detrimental to a multiple use conservation concept.

The State Land Use Districts found in each of the potential geothermal resource rift zones are:

Kilauea East Rift Zone - Conservation, agricultural, and urban districts.

Kilauea Southwest Rift Zone - Conservation, agricultural, and urban districts.

Mauna Loa Southwest Rift Zone - Conservation and agricultural districts.

Mauna Loa Northeast Rift Zone - Conservation and agricultural districts.

Hualalai Northwest Rift Zone - Conservation and agricultural districts.

Haleakala Southwest Rift Zone - Conservation and agricultural districts.

Haleakala East Rift Zone - Conservation, agricultural, urban, and rural districts.

CONSERVATION DISTRICT AND SUBZONES

Of the four land use districts, the Conservation District is the only one administered by the State of Hawaii. Individual counties administer urban, rural and agricultural lands.

Chapter 183-41, HRS, established Conservation Districts and enabled the State Department of Land and Natural Resources to promulgate regulations to implement the statute. Implementation was accomplished under the Department's Administrative Rule, Title 13, Chapter 2. Under this rule, the Conservation District is further subdivided into five subzones: Protective (P), Limited (L), Resource (R), General (G) and Special Subzones (SS).

The Protective Subzone has as its objective the protection of valuable resources in such designated areas as restricted watersheds; marine, plant, and wildlife sanctuaries, significant historic, archaeological, geological, and volcanological features and sites; and other designated unique areas. The Limited Subzones are designated areas where natural conditions suggest constraints on human activities. The objective of the Resource Subzone is to develop, with proper management, areas to ensure sustained use of the natural resources of those areas. General Subzones are open space areas where specific conservation uses may not be defined, but where urban use would be premature. Special Subzones are specifically designated areas which possess unique developmental qualities which complement the natural resources of the area. At the present time there are four Special Subzones all located on the island of Oahu.

In accordance with the Administrative Rules of the Department of Land and Natural Resources, State of Hawaii §13-2-11, 12, 13, and 14 certain uses are permitted within each of the Conservation District subzones. The following uses are permitted in the Protective Subzones:

(1) Research, recreational, and educational use which require no physical facilites;

(2) Establishment and operation of marine, plant, and wildlife, sanctuaries and refuges, wilderness and scenic areas, including habitat improvements;

(3) Restoration or operation of significant historic and archaeological sites listed on the national or state register;

(4) Maintenance and protection of desired vegetation, including removal of dead, deteriorated and noxious plants;

(5) Programs for control or animal, plant, and marine population, to include fishing and hunting;

(6) Monitoring, observing, and measuring natural resources;

(7) Occasional use; and

(8) Governmental use not enumerated herein where public benefit outweighs any impact on the conservation district.

The following uses are permited in the Limited Subzone:

(1) All permitted uses stated in the (P) subzone;

(2) Emergency warning systems or emergency telephone systems;

(3) Flood, erosion, or siltation control projects; and

(4) Growing and harvesting of forest products.

The following uses are permitted in the Resources Subzone:

(1) All permitted uses stated in the (P) and (L) subzone;

(2) Aquaculture;

(3) Artificial reefs; and

(4) Commercial fishing operations.

The following uses are permitted in the General Subzone:

(1) All permitted uses as stated in the (P), (R), and (L) subzones; and

(2) Development of water collection, pumping, storage, control, and transmission.

COUNTY GENERAL PLANS AND LAND USE POLICIES

The Agricultural, Urban and Rural Land Use Districts are administered by the individual counties. Counties administer land uses through their General Plan and/or Community Plans.

The County General Plan sets forth the broad objectives and policies for the long-range development of the County. Community Plans provide more detailed schemes for implementing the General Plan.

Hawaii County

The County of Hawaii General Plan, adopted December 15, 1971, sets forth the following goals and policies for Land Use.

Goals:

1. Designate and allocate land uses in appropriate proportions and in keeping with the social, cultural, and physical environments of the County.
2. Protect and encourage the intensive utilization of the County's limited prime agricultural lands.
3. Protect and preserve forest, water, natural and scientific reserves and open areas.

Policies:

1. Zone urban-type uses in areas with ease of access to community services and employment centers and with adequate public utilities and facilities.
2. Promote and encourage the rehabilitation and utilization of urban areas which are serviced by basic community facilities and utilities.
3. Allocate appropriate requested zoning in accordance with the existing or projected needs of neighborhood, community, region and County.
4. Establish a "land zoning bank" from which land use zoning may be allocated to specified urban centers and districts.
5. Conduct a review and re-evaluation of the tax structure to assure compatibility with land use goals and policies.
6. Incorporate innovations such as the "zone of mix" into the Zoning Ordinance in order to achieve a housing mix and to permit the more efficient development of lands which have topographic and/or drainage problems.

7. Incorporate the concept of a "floating zone" for future industrial and retreat resort areas. This concept would allow flexibility in locating future needed developments in districts which cannot be pinpointed at this time, especially in the more rural and/or remote areas.

Land uses are categorized as follows in the plan:

Urban Centers:

High Density: Commercial, multiple residential and related services (general and office commercial; multiple residential--87 to 43.6 units per acre).

Medium Density: Village and neighborhood commercial and residential and related functions (3-story commercial; multiple residential--35 to 11.6 units per acre; single-family residential--5.8 units per acre).

Low Density: Residential and ancillary community and public uses (single-family residential--no more than 4 units per acre).

Industrial Area: Manufacturing and processing; wholesaling; large storage and transportation facilities; power plants; and government baseyards.

Resort Area: Hotels and supporting services.

Agriculture Area:

Intensive: Sugar; orchard; diversified agriculture; and floriculture.

High: Fertile soil.

Low: Less fertile soil.

Extensive: Pasturage and range lands.

Orchard: Those agricultural lands which though rocky in character and content support productive macadamia nuts, papaya, citrus and other similar agricultural products.

Public Lands: Federal, State, University and County-owned lands.

Open:

Parks and historic sites.

Conservation Area: Forest and water reserves; natural and scientific preserves; open; etc.

The five potential geothermal resource areas on Hawaii contain the following county designated land use categories:

Kilauea East Rift Zone - This area is comprised of conservation, low density, medium density, resort, open area, orchards, alternate urban expansion, and extensive agriculture zones.

Kilauea Southwest Rift Zone - This area is comprised of conservation, extensive agriculture, intensive agriculture, low density, medium density, open area, and orchard zones.

Mauna Loa Southwest Rift Zone - This area is comprised of conservation, orchards, intensive agriculture, and extensive agriculture zones.

Mauna Loa Northeast Rift Zone - This area is comprised of conservation and extensive agriculture zones.

Hualalai Northwest Rift Zone - This area is comprised of conservation, extensive agriculture, and orchard zones.

Maui County

The land use objectives and policies of the Maui County General Plan December 28, 1977 are as follows for Land Use.

Objectives:

1. Uses of land meeting the social and economic needs of the people.
2. Availability of agriculture lands that are well-suited and feasible for agricultural products.
3. A lifestyle pattern based on consistent and harmonious use of land.

Policies:

1. Discourage the unwarranted conversion of agriculture lands to non-agricultural uses.
2. Minimize the encroachment of urban uses on agriculture lands.

3. Provide for compatible alternative uses on non-productive agriculture lands.
4. Enhance agricultural land use activities by providing public incentives and encouraging private initiative.
5. Develop land use guidelines reflecting the individual character of the communities and regions of the County of Maui.
6. Guide land use development patterns in sympathy with an area's natural topographic features, environmental hazard constraints, scenic amenities and other natural resource potentials.
7. Maintain the opportunity to pursue a rural lifestyle.
8. Encourage land use methods that provide a choice of housing types and locations.
9. Continue programs to identify and preserve unique and significant historic sites and natural areas.
10. Provide a wide-range of compatible land uses based on individual, community, regional and county needs.
11. Ensure the effective protection and prudent use of Maui County's coastal areas.
12. Encourage the "most reasonable and beneficial use" of land by discouraging practices that promote "the highest and best use" concept of land use.
13. Establish guidelines and programs to further reduce land speculation.,
14. Guide and integrate the development of public facilities and infrastructures with established County land use policies.
15. Encourage the Hawaiian Homes Commission to establish additional homestead lands throughout the County of Maui.

The land use categories were obtained from various community plans covering the two potential resource areas of Maui. These community plans are mandated by the Charter of Maui County (1977) and the Maui County General Plan which was adopted on June 24, 1980 as Ordinance No. 1052.

Conservation:

This use is to protect and preserve wilderness areas, open spaces, beach reserves, scenic areas, historic sites, open ranges, watersheds, and water supplies; to conserve fish and wildlife; and to promote forestry and grazing. It is intended that all lands designated as Conservation be governed by the requirements and procedures of Chapter 205, HRS, as amended, and administered by the State Department of Land and Natural Resources.

Rural:

This use is to protect and preserve areas consisting of small farms intermixed with low-density, single-family residential lots. It is intended that, at minimum, the requirements of Chapter 205, HRS, as amended shall govern this area.

Agriculture:

This use is to provide areas for agricultural development which would be in keeping with the economic base of the County and the requirements and procedures of Chapter 205, HRS, as amended. It is also expected that the County will impose more stringent requirements on these areas to ensure their use for agriculture.

Reserve:

This is primarily for areas within the State Urban District which have low priority for urban development because of environmental concerns, such as natural hazard and resource areas, archaeological sites, and other considerations, or the costs entailed with development because of the lack of nearby or adequate public facilities and services.

Single-Family Residential:

This includes single-family detached and duplex dwellings.

Multi-Family Residential:

This includes apartment and condominium buildings that have more than two dwellings.

Business/Commercial:

This includes retail stores, offices, entertainment enterprises and their accessory uses.

Light-Industrial Use:

This is for warehousing and service and craft-type industrial operations.

Heavy-Industrial Use:

This is for major industrial operations whose effects are potentially noxious due to noise, airborne emissions or liquid discharges.

Hotel/Resort:

This applies to transient accommodations which do not contain kitchens within individual living units but may include a restaurant or small shops serving hotel guests.

Public/Quasi Public:

This includes schools, libraries, fire/police stations, government office buildings, public utilities, hospitals, churches, cemeteries, and community centers.

Airport:

This includes all commercial and general aviation airports.

Park:

This includes all public active and passive parks.

The two potential resource areas on Maui contain the following land uses:

Haleakala Southwest Rift Zone - This area is comprised of conservation, agriculture and park zones. The park area is located southwest of Kihei Road at Cape Kinau.

Haleakala East Rift Zone - This area is comprised of conservation, agriculture, rural, reserve, single-family residential, multi-family residential, business/commercial, light-industrial use, hotel/resort, public/quasi public, and park zones.

EXISTING LAND USES

Existing land uses in potential geothermal resource areas are characteristic of their respective zoning. Most potential areas are zoned conservation and may include forest reserve, national and state parks, other forested areas, brush and grass lands, and barren lava flows. Often conservation zoned lands provide habitat for native and rare or endangered species as well as hunting area, and watershed lands.

Potential resource areas zoned agricultural are used mostly for livestock grazing.

The only urban zoned areas are those located at Pahoa and Kapoho in the Kilauea East Rift Zone, Hawaii; and Hana, in the Haleakala East Rift Zone, Maui. The only Rural zoned area is located at Pahoa, Hawaii.

Table 7 summarizes existing land uses in each resource area.

COMPATIBILITY OF GEOTHERMAL RESOURCE DEVELOPMENT WITH SURROUNDING LAND USES, AND ZONING

Act 296 in addressing the designation of geothermal resource subzones requires assessement of each geothermal resource area by an examination of various factors including the compatibility of geothermal development and potential related industries with existing land uses and those uses permitted under Section 205-2, Hawaii Revised

Table 7. Land Use in Geothermal Areas

Description	Kilauea			Mauna Loa		Hualalai	Haleakala	
	NE Rift Lower	NE Rift Upper	SW Rift Kau	E Rift	SW Rift	NE Rift	NE Rift Hana	SW Rift
URBAN:								
Residential	●						●	
Commercial	●						●	
RURAL:								
Residential	●							
AGRICULTURE:								
Cropland	●	●						
Grazing	●	●	●	●	●	●	●	●
Residential	●	●			●			●
CONSERVATION:								
Forest Reserve	●	●					●	●
National Park		●	●					
State Park	●							
Other Forests	●	●	●	●		●	●	●
Brush & Grassland	●	●	●	●	●	●	●	●
Lava Flows (barren)	●	●	●	●	●			●
Endangered Mammal				●	●			
Endangered Bird				●	●	●		●
Wildlife Sanctuary				●	●			
Hunting Area	●	●		●	●			
Watershed							●	●

Statutes, relating to State Land Use Districts, Section 183-41, HRS, relating to Conservation Districts and all uses permitted under County general plans or land use policies.

Act 296 allows geothermal resource subzones to be designated within any of the four state land use districts--urban, rural, agricultural and conservation. As such, once subzones are established, geothermal facilities could be located adjacent to any land use existing or permitted in any of the four districts.

Compatibility simply means being capable of living or performing in harmonious combination with each other. Some land uses are obviously more compatible than others depending on their characteristics.

As noted in the Flora and Fauna Section of this report, forested areas may be categorized by the amount of canopy and quantity of native forest present, the assumption being that undisturbed closed canopy native forest would be the most susceptible to disruption by geothermal development. Thus, geothermal development would be least compatible with a Category 1 forest consisting of exceptional native forest with a closed canopy and over 90% native cover. Category 2 forest consists of mature native forest with over 75% native canopy. Category 2A consists of native scrub and low forest and Category 3 consists of cleared land, non-native forest, or bare ground or lava. Category 3 forest is considered more compatible with geothermal development than Category 1 forest. However, construction of a geothermal power plant in Category 2A native scrub and low forest or in Category 3 open, cleared land or barren-lava flows result in visual intrusions which might be otherwise hidden in a Category 1 or 2 forest.

Conservation districts constitute a large percentage of the potential resource areas. Each area within the conservation district has permitted uses. In each of the subzones mentioned, Protective, Limited, Resource and General; the use of the area for "monitoring, observing, and measuring natural resources" is permitted. In this respect exploration of geothermal resources can be allowed in a conservation district. The development of these resources can then eventually lead to widespread public benefit. The use of lands within a conservation district in which "governmental use not enumerated herein where public benefit outweights any impact on the conservation district" is permitted. In managing the uses of conservation lands, careful analysis of the proposed use is required. Thus, only when the benefits of the proposed use are determined to be greater than any impact on the land, will the use be permitted.

In addressing land use compatibility, several assumptions must be made.

- o Ambient air quality will not be effected since it is expected that current abatement technology will be fully utilized in compliance with proposed State Department of Health air quality standards for geothermal development.
- o Proposed County of Hawaii Noise Guidelines of 45 decibels at night and 55 decibels by day will be complied with. It is also assumed that the County of Maui will adopt similar noise guidelines in reference to geothermal activities.
- o Geothermal facility siting will be adjusted to avoid endangered plants and significant archaeological or historical sites.
- o Visual impacts will be minimized by adjusting the location of the site, the alignment of structures so as to present the smallest possible aspect and by blending structures with surroundings by painting appropriately and by use of non-reflective, light absorbent materials and textures and by shielding facilities from view by locating behind a puu, or hill, or by placement in a forested area.
- o Impacts will be further minimized by use of buffer zones surrounding geothermal facilities.

EVALUATION OF IMPACTS ON POTENTIAL GEOTHERMAL RESOURCE AREAS

Evaluation of impacts on potential geothermal resource areas was accomplished by reviewing available information for each geothermal resource area. Information on meteorology, surface water, ground water, underground injection control areas, existing land uses, flora and fauna and historic and archaeological sites was developed by mapping on a series of overlays for each geothermal resource area. The following evaluation is the product of the overlay mapping and data review process.

KILAUEA EAST RIFT ZONE

Under trade wind conditions, during the day, northeast trade winds pass through the entire rift zone. Wind speeds vary from light to fast depending on the topography. The southern half of the rift zone will have moderate to fast trade winds, while the northern half will have light to moderate wind speeds. At night, the moderate northeast trades pass through the eastern end of the zone while gentle to moderate northerly drainage downslope winds pass through the remainder of the rift zone.

Under non-trade wind conditions, during the day, gentle to moderate sea breeze-upslope winds from the southeast through southwest pass through the rift zone. At night, gentle to moderate downslope winds from the higher slopes drain down through the rift zone from the north through west.

Rainfall is heavy over most of the central northeast half of the rift zone--over 100 inches a year. Rainfall falls off sharply at the western end of the rift zone from 100 inches a year to 35 inches a year in a short distance of less than 2 miles. The western end of the rift zone has the lowest rainfall.

Hawaii Volcano National Park Headquarters at 3,970 feet elevation, Pahoa at an elevation of 650 feet, and Pohoiki at an elevation 10 feet can be used as representative temperature stations in the rift zone. Pahoa and Pohoiki have average annual maximum and minimum temperatures of 78.2°F and 63.4°F, and 81.2°F and 67.2°F, respectively. The average annual temperature at National Park Headquarters is 68.1°F and 52.9°F.

There are no known surface streams or natural water storage features in the Kilauea East Rift Zone, with the exception of Green Lake in Kapoho Crater.

Ground water occurs as dike water and basal water in the Kilauea East Rift Zone. The only known perched water exists north of Mountain View.

Basal water underlies all of the Kilauea East Rift Zone except where dikes occur. Hydraulic gradients along the northeast coast of Puna range between 2 and 4 feet per mile, with water-table elevations of 12 to 18 feet above sea level 5 to 6 miles inland. Along the southeastern coast, gradients range between 1 and 2 feet per mile, with water-table elevations of 3 to 4 feet above sea level a mile and a half inland. The main reason for the difference in hydraulic gradients between the northeast and southeast coasts is the amount of rainfall per unit of surface area and the barrier effect of the east rift zone on ground water movement. The effectiveness of the east rift zone as a barrier to ground water movement is demonstrated by the difference in basal water-table levels.

The only significant source of saline water that contaminates the basal aquifer is sea water, with a chloride content of approximately 19,000 mg/l. Because of the effects of mixing, most ground water at the coast is brackish. Salinity and temperature vary greatly north and south of the rift zone. Wells and shafts north of the rift zone are characterized by lower temperatures and lower salinities. Wells in and near Keaau have water temperatures of 66° to 68°F. The water temperature of wells near Pahoa ranges between 72° and 74°F. Wells located more than 3 miles inland generally have a chloride concentration of less than 20 mg/l. South of the rift zone, high well-water temperatures and salinities are encountered. The water temperature of the Malama-Ki well, No. 2783-01, in 1962 was 127-130°F with salinity between 5500 and 7000 mg/l at pumping rates of 100 to 480 gpm. The water temperature of thermal test well No. 3 in 1974 was 199°F, with salinity of 2000 mg/l. The average chloride content of ground water south of the rift zone is probably greater than 3000 mg/l, probably due in part to heating of sea water by volcanic activity below the basal lens. The warmer, less dense sea water rises, contaminating the fresh water in the basal aquifer.

LOWER KILAUEA EAST RIFT ZONE

Property in the lower portion of the Kilauea East Rift Zone is owned by six large area landowners and numerous small area landowners. Large area landowners include the State of Hawaii, Bishop Estate, Campbell Estate, Puna Sugar Company, Kapoho Land Development Corporation, and Tokyu Land Development Corporation.

Property within the Lower East Rift Zone is zoned Agricultural, Conservation, Urban and Rural. It should be noted that existing land uses in Agricultural zoned areas include both cultivated and uncultivated land, and agricultural subdivisions. Agricultural subdivisions are designated by the County of Hawaii as A-1a, meaning an agricultural subdivision of one acre lots. Five one-acre subdivisions are located within the rift zone boundaries, and include Leilani Estates, and Nanawale Subdivision. Conservation zoned areas include Forest Reserve lands, the Wao Kele O Puna Natural Area Reserve and the Kapoho Lava flow of 1960. Urban areas within the rift zone boundaries include Pahoa, Kaniahiku Village and a small portion of the Kapoho Beach Lots.

Lava flows in the Lower East Rift Zone include flows dated 1750, 1790, 1840, 1845, 1955, 1960, 1961, and 1983.

Forested areas in the Lower East Rift Zone consist primarily of Category 2 and 2A forest, mature native forest with over 75% native cover and native scrub and low forest. Isolated areas of Category 1 exceptional native forest with over 90% mature cover and closed canopies do exist in the Keauohana Forest Reserve, consisting of ohi'a-lama forest, in the vacinity of Puu Kaliu and at higher elevations in the Wao Kele O Puna National Area Reserve. Category 3, bare lava, cleared land is more evident in coastal area, especially in the Kapoho area, at Cape Kamukahi.

There is no endangered species essential habitat in the Puna area, since large portions of the area are either cleared agricultural land or bare lava.

Five historic sites are located in the Lower East Rift Zone:

Site No. 7388 - Pahoa District, town.

Site No. 4295 - Pualaa Complex, including an ancient holua slide.

Site No. 2501 - Kapoho Petroglyphs, considered unique, and placed on the State Register of Historic Sites.

Site No. 7492 - Lyman Historic Marker

Site No. 2500 - Kukii Heiau, reamins of heiau built by Umi on his tour of Hawaii after coming to power.

Development of geothermal resources in the Lower East Rift-Zone has been underway since 1973-74 with the issuing of geothermal resource mining leases for four areas, designated GRML R-1, R-2, R-3, and R-4. Development of additional sites in the Lower East Rift zone will not impact any endangered species essential habitat, but may impact existing communities in terms of noise and aesthetics. The provision of a buffer zone will help to mitigate such impacts. Air Quality will not be impacted, since it is expected that given current level of abatement technology, geothermal facilities will comply with State Air Quality standards for geothermal development.

UPPER KILAUEA EAST RIFT ZONE

Property in the Upper East Rift Zone is owned by four large area landowners, the United States of America (Hawaii Volcanoes National

Park), the State of Hawaii, Bishop Estate, and Campbell Estate. Smaller holdings owned by various individuals are found in the Royal Gardens Subdivision along the coast and in urban and agricultural zoned areas in the Kilauea-Olaa area at the mauka boundary of the rift zone.

The Upper East Rift Zone is primarily zoned Conservation, Protective, Resource and Limited Subzones. Exceptions are the Ainahou Ranch land, Royal Gardens Subdivision, zoned for agricultural use, and the urban and agricultural zoned areas in the Kilauea-Olaa area.

Existing land uses include the Hawaii Volcanoes National Park (the largest area), forested areas in Kahauale'a, a grazed area in the vicinity of Ainahou Ranch, a portion of the Wao Kele O Puna Natural Area Reserve, and the Volcano and Royal Gardens Subdivisions. Also included are portions of the Kilauea Forest Reserve, Kilauea Military Camp, and Kilauea Golf Course.

Included on the list of existing land uses is the Campbell Estate/True Mid-Pacific Geothermal Development area as approved for exploration by the Board of Land and Natural Resources in 1983.

Forested areas in the upper portion of the East Rift Zone consist primarily of Category 1, exceptional native forest with over 90% native cover and closed canopy, and Category 2 mature native forest with over 75% native cover interspersed with bare lava flows, dated 1968-1973, 1977 and 1983-84.

Essential endangered species habitat for 'o'u encompasses a major portion of the Kahauale'a area, and extends into the Hawaii Volcanoes National Park land to the south. The Dark-rumped Petrel is known to nest in Napau Crater and I'o have established territory at Makapuhi Crater and at lower elevations in the vacinity of the Royal Gardens Subdivision.

There are no known archaeological sites within the Upper East Rift zone.

Development of geothermal resources in the Kilauea Upper East Rift zone will be limited to areas outside the Hawaii Volcanoes National Park. Air quality within surrounding areas will not be impacted since it is expected that, given the current level of abatement technology, geothermal facilities will comply with State Air Quality standards for geothermal development.

Site development may impact endangered o'u habitat; however, as stated in the Kahau'alea Environment Impact Statement (June 1982), "the minimal removal of vegetation and trees within the Kahau'alea project area should not significantly threaten the O'u." (pg. 5-11).

It should also be noted that a portion of the O'u habitat has been lost due to recent lava flows.

KILAUEA SOUTHWEST RIFT ZONE

Under trade wind conditions, during the day, moderate to moderately strong northeast trade winds are expected to sweep through the rift zone. At night moderate drainage winds from the upper slopes of Mauna Loa should sweep through the rift zone from the north.

Under non-trade wind condition, during the day, light to moderate southerly sea breeze-upslope winds are expected to pass through the rift zone. At night, the light to moderate drainage winds from the north are expected to pass through the rift zone.

There is great variation in the amount of rainfall over this rift zone--from about 100 inches a year at the northern end of the rift zone near Hawaii Volcano National Park Headquarters to about 20 inches a year at the southern end of the rift zone near Hilina Pali in the Kau Dessert. The greatest variation in rainfall is at the upper end of the zone where in the short distance of about a mile from the National Park Headquarters to Halemaumau, the rainfall drops from 100 inches a year to 50 inches a year. There are no rainfall stations in the Kau Dessert.

Hawaii Volcano National Park Headquarters, at 3,970 feet elevation, with an average maximum and minimum temperature of 68.1°F and 52.°F, respectively, is the only temperature station in the rift zone.

There are few streams in the Kilauea Southwest Rift Zone because the water quickly percolates into the young and highly permeable lava flows. A few well-defined stream channels are found between Waiahaka Gulch, near Kapapala Ranch, and Hilea Gulch. No stream has continous flow into the sea, and flood flows reach the sea infrequently and only for short periods.

Ground water in the coastal areas of the rift zone is brackish; at higher elevations dike confined water is present. The Underground Injection Control line is set at an elevation of 200 feet in most of the coastal area but drops to an elevation of 100 feet within the rift zone near Waiapele Bay. Lava flows within the rift zone are dated 1823, 1868, 1920, 1971 and 1974.

Property within the Kilauea Southwest Rift Zone is owned by the State of Hawaii, United States of Amercia (Hawaii Volcano National Park), Bishop Estate, Ka'u Sugar, International Air Service, Seamountain Hawaii, C. Brewer, and a number of small parcel landowners.

Rift zone areas are zoned either Conservation, Resource and Limited Subzones, or Agricultural. All rift zone areas, except for National Park lands, are presently used for grazing.

The nearest urban or residential areas are Pahala, north of the rift zone, and Punaluu, west of the rift zone. Both communities essentially border the rift zone area.

This area is poorly characterized biologically. It was not included in USFWS vegetation mapping. The area is generally disturbed, with some pockets of native scrub along the coast and near the boundary of the national park, and is of little biological significance since it contains no endangered species habitat.

There are no known archaeological sites within this subzone.

Development of geothermal resources in portions of this rift zone, outside the National Park, would probably result in minimal environmental impact.

Development proximity to the Pahala and Punaluu communities may result in aesthestic impact. Air Quality will not be impacted since it is expected, given the current technology level that all air quality impacts will be abated so as to comply with State Air Quality standards for geothermal development.

MAUNA LOA NORTHEAST RIFT ZONE (KULANI)

Tradewinds during the day diverge around Mauna Loa and pass through the rift zone from the east to southeast. At night, reverse flow results from drainage of mountain breeze-downslope winds. Under non-trade conditions, light to moderate sea breeze-upslope winds flow through the rift zone from southeast to east. At night, mountain breeze downslope winds flow from the west.

Rainfall is heavy--150 inches a year at the 3,500-foot elevation to 60 inches a year at the 7000 foot elevation. Kulani Camp receives 102 inches a year (elevation 5,170 feet). Temperature at Kulani Camp ranges from an average annual maximum of 63.5°F up an average annual minimum of 46.5°F.

There are no known surface streams in this subzone area. Dikes occur above the 5400-foot elevation. The subzone area ranges in elevation from 3600 feet to 7000 feet.

Property within the proposed subzone is owned by Bishop Estate and the State of Hawaii, and is zoned Agricultural and Conservation. The nearest residential area is Kaumana on the north, approximately 6 miles from the subzone boundary. Volcano House in the National Park is approximately 8 miles from the southern subzone boundary.

Existing land uses within the proposed subzone boundary include the Agricultural zoned grazing land belonging to Bishop Estate and the State's Kulani Honor Camp, located in the Conservation District, Resource Subzone. The remaining lands within the subzone are forested and includes portions of the Mauna Loa, Kilauea, and Upper Waiakea Forest Reserves and two game management areas on the northwest and southwest corners of the subzone. Puu Makaala Natural Area Reserve is included in the southeast corner of the subzone.

Forested areas consist of Category 1, exceptional native forest; closed canopy with over 90% native cover. The remaining forest areas, consist of Category 2, mature native forest with over 75% native canopy. Forested areas in the upper and northern portion of the proposed subzone are dissected by recent lava flows dated 1852, 1942, and 1984.

Category 1 forests include tall Metrosideros polymorpha (Ohia lehua), and Acacia koa (koa) with native shrubs and tree ferns (Cibotium spp. hapuu). Category 2 includes moderate to tall Ohia lehua and koa, with native shrubs and ferns. Category 2A includes scattered Ohia lehua and Mamane, in some areas.

Mauna Loa forests within the subzone area provide habitat for four endangered forest bird species; the Hawaii Creeper, Akepa, Akiapola'au and the 'O'u, and the Nene. The Mauna Loa East Rift forests have been designated as essential habitat for the four endangered forest birds. In addition, 'Io, the Hawaiian Hawk, is known to nest at two sites, one on the lower slopes of Kulani Cone and a second site directly due West at an elevation of 5500 feet.

It should be noted that the designated essential habitat area includes the grazed agricultural zoned areas belonging to Bishop Estate since these areas contain both Category 1 and 2 forests as well as open areas. There are no known archaeological sites within the subzone area.

Development of a geothermal resource in areas other than the cleared grazed agricultural land may impact the four endangered forest bird species and the Nene by disturbing essential habitat areas.

MAUNA LOA SOUTHWEST RIFT ZONE (KAHUKU RANCH)

There are no wind data in this rift zone. Under trade wind condition, during the day, the lower half of the rift zone is expected to have light to moderate easterly trades passing through the rift zone. The northern upper half of the rift zone will likely have light to moderate upslope winds from the south. During the night, light to moderate northerly mountain breeze-downslope winds are expected to flow through the rift zone.

Under non-trade wind conditions, during the day, light to moderate southerly upslope winds are expected to pass through the rift zone. During the night, gentle to moderate drainage winds from the higher slopes are expected to pass through the rift zone from the north. Precipitation ranges from 40 to 50 inches decreasing at the upper elevations to 40 inches.

No surface streams are found within the subzone area. Dikes are found in the upper elevations of the subzone area; basal ground water is fresh, and the UIC line lies to the south outside the subzone area. There are no existing wells within the subzone area.

The subzone area is almost wholly owned by the S.M. Damon Estate, except for a small portion on the eastern subzone boundary which is state-owned.

Existing land uses within the potential subzone area include grazing land, a portion of the sparsely settled Hawaiian Ocean View Estates, and forest lands. The subzone boundary extends makai of Highway 11, to the Kahuku Ranch area. The nearest population centers are to the east, Waiohinu and Naalehu towns, and Kiolakaa-Keaa Homestead area. The subzone area is zoned agricultural and conservation.

Forested areas consisting mostly of mature native forest, with over 75% native cover, are interspersed with areas of bare lava from flows dated 1886, 1887, 1907, 1916, and 1926.

Above the 5000-foot elevation, forested and bare lava areas provide habitat for the Nene and two species of endangered forest birds, Hawaiian Creeper and Akiapolaau. On the eastern boundary between the 3000-foot and 3600-foot elevations, three species of endangered forest birds (Akepa, Akiapolaau and Hawaiian Creeper) occupy an area designated as exceptional native forest, with a closed canopy and over 90% native forest cover. The subzone area lies to the east of the Manuka Natural Area Reserve; no portion of the reserve is included in the proposed subzone.

Historic sites are found only at the subzone perimeter at Kahuku Ranch. No significant archaeological or historic sites were recorded within the subzone boundaries.

Development of geothermal resources in the lower, agricultural-zoned portion of the proposed subzone may result in minimal environmental impact provided a buffer area is maintained between the geothermal development site and the Hawaiian Ocean View Estates.

HUALALAI NORTHWEST RIFT ZONE

Although no wind instrumentation exists on Hualalai, knowledge of other upland areas indicated that light to moderate upslope sea breezes converge on Hualalai during the day; at night, the reverse gentle to moderate downslope mountain breezes diverge in all directions from the Hualalai Summit. Rainfall varies from light to moderate, from 30 to 40 inches a year.

There are no known surface streams in this area; however south of the subzone area, man-made catchments and collecting ponds are used to provide water for ranch purposes. Dikes occur in this subzone and elevations range from 3400 feet to 7200 feet.

Property within the subzone is wholly owned by Bishop Estate and zoned Conservation except for a triangular section on the southeast slope, and two small segments along the northwest perimeter that are zoned agricultural. The nearest residential areas occur along the Mamalahoa Highway to the west; Kailua-Kona is located seven miles southwest of the subzone. Except for the triangular shaped agricultural land, which is grazed, all other land within the subzone is forested. Approximately one-half of the forested area lies within the Kaupulehu Forest Reserve.

Forested areas consist of mature native forest, with over 75% native canopy. Exceptional native forest with over 90% native canopy is found along the subzone boundary between elevations of 4000 to 6500 feet. Species composition consists primarily of Metrosideros polymorpha (ohia lehua), Acacia koa (koa), and Sophora chrysophylla (mamane). The subzone is crossed by a single lava flow, the Kaupulehu Flow.

Hualalai slopes within the subzone area provide habitat for four endangered species. The species composition varies with elevation. Between 3200 feet and 6000 feet Alala, Hawaiian Creeper and Akepa are found; between 6000 and 7000 feet Hawaiian creeper, Akepa and Nene are found; and above the 7000-foot elevation, only Nene.

No archaeological or historical sites have been recorded within the subzone area.

Development of geothermal resource in areas other than the grazed agricultural zoned portion of the subzone may impact the endangered species known to exist within the proposed subzone area. Alala, the Hawaiian Crow, is reported to number fewer than 20 individuals. Disturbance of their Hualalai habitat may cause further decline of this species and, possibly, its extinction.

HALEAKALA SOUTHWEST RIFT ZONE

Wind data for coastal sites indicate that under tradewind conditions, during the day light to moderate sea breeze-upslope winds from the southeast and the west flow from the coast to upper elevations. At night the reverse, mountain breeze-downslope winds occur. Similar sea breeze, mountain breeze winds, occur during non-tradewind conditions.

Rainfall in the rift zone ranges from 16 inches a year in coastal areas to 54 inches a year near Polipoli Spring.

Average annual maximum and minimum temperatures at the coast in the rift zone are expected to be about 84°F and 64°F, respectively; at 3000 feet 72°F and 55°F could be expected, and at 7000 feet a maximum of 63°F and a minimum of 44°F.

There are no know surface streams in this geothermal resource area. Several springs along the mauka northern fringes of the area provided water for minor uses, including camp water for the Polipoli Mountain Park.

Ground water in the rift zone is brackish below 1600 feet level and fresh basal water above. However, the rift zone also contains dike-confined ground water.

Property within the rift zone is owned by the State of Hawaii, Ulupalakua Ranch and other individual holders of smaller parcels. The coastal portions of the rift zone and mountain areas above 5000 feet are zoned Conservation, Protective, and General Subzones, and Resource Subzone, respectively. All mid-level areas not zoned Conservation are zoned for agricultural use.

The Ahihi-Kinau Natural Area Reserve from Kanahena to Keoneoio, including near-shore submerged lands, is located in the coastal portion of the rift zone. This Natural Area Reserve contains anchialine pools, marine ecosystems and the last lava flow (dated 1790) on the Island of Maui. Upslope, Ulupalakua Ranch land is used for grazing. The upper most portion of the rift zone above 5000 feet is designated as the Kula and the Kahikinui Forest Reserves. Polipoli State Park is located along the northern rift zone boundary. The nearest urban or residential areas are Makena, one mile north of the rift zone boundary; Ulupalakua Ranch, immediately northwest of the rift-zone along the Kula/Piilani Highway; and Keokea, approximately 2 miles northwest of the upper portion of the rift zone. "Science City" and the perimeter of the Haleakala National Park are located five miles upslope of the upper boundary of the rift zone.

Vegetation in the Haleakala Southwest Rift Zone consists of native scrub vegetation and some exotic tree plantings as well as substantial areas of pastureland with occasional forested areas. The lower portions of the rift zone are barren lava with isolated pockets of Category 1, exceptional native forest with closed canopy of over 90% native cover.

There is no endangered species habitat in this rift zone, although the middle elevations contain some very valuable, although disturbed, dry native forest.

There are five known archaeological sites in or on the perimeter of the rift zone:

1. Poo Kanaka Stone (site #1021) located near the Kula Highway and has been placed on the State Register of Historic Sites;
2. Puu Naio Cave (site #1009) located on the southwest rift zone boundary at an elevation of 1100 feet; also on the State Register;
3. Kalua O Lapa Burial Cave (site #1017) located at the eastern boundary of the Ahihi-Kianu Natural Area Reserve;
4. Maonakala Village Complex (site #1018) a coastal village site, also within the Natural Area Reserve;
5. La Perouse Archaeological District located at the southern boundary of the rift zone and on the State Register.

Development of geothermal resources within the grazed agricultural zoned portions of the rift zone will result in minimal environmental impact since no endangered species habitat is present.

Makena residential and resort developments, Ulupalakua Ranch and upslope, the Haleakala "Science City" may be affected aesthetically. Air quality in urbanized areas will not be impacted since it is expected, given the current level of technology, that all air quality impacts will be abated so as to comply with State Air Quality standards for geothermal resource development.

HALEAKALA EAST RIFT ZONE

In coastal areas, during tradewind conditions, northeast tradewinds prevail during the entire day and night. Wind speeds are moderate during the day and light at night. During a non-tradewind conditions, the winds are almost calm during the night and light during the day. The direction of the wind is from the south during the night and from the west during the day, which is opposite of what would be expected under the sea breeze-upslope winds during the day and mountain breeze-downslope winds during the night.

In upper areas, northeast tradewinds continue across the rift zone during the day and the night, however mountain breeze downslope winds meet the trades somewhere mid-level in the subzone.

Under a non-tradewind condition, gentle to moderate daytime sea breezes flow upslope and night time mountain breezes move downslope.

The average annual rainfall in the upper half of the rift zone is 200 inches with a possible maximum of over 300 inches on the northern side of the zone. Rainfall decreases toward the east to 65 inches a year at the coast.

At Hana Ranch the average annual maximum temperature is 80°F, and the average anuual minimum is 67.4°F.

Extrapolated average annual maximum and minimum temperatures at upper elevations are 72.4°F/56.8°F at 2500 feet; and 58.9°F/45.4°F at 7000 feet.

Streams in the Haleakala East Rift Zone are ephermal in spite of the high rainfall. The rocks are highly permeable, allowing all but the heaviest rains to sink rapidly into the ground. Rising from sea level at Hana Bay to the 7000-foot level near the eastern rim of Haleakala Crater, the area's rugged topography contains the headwaters of the several tributaries of Kawaipapa Gulch along the resource area's northern boundary and Moomoonui Gulch along the southern boundary. The makai area contains the intermittent Holoinawawae Stream that empties into Hana Bay.

Dikes occur throughout the middle and lower portions of the rift zone. The Underground Injection Control (UIC) line is set at an elevation of 200 feet.

Property within the rift zone is owned by the Hana Ranch, (lower elevations), the State of Hawaii (mid and upper elevations) and the United States of America (upper-most elevations). Smaller parcels in coastal areas belong to other landowners.

Lower elevation Hana Ranch land is zoned for agricultural use and is grazed. State land above the Hana Forest Reserve Boundary is zoned Conservation, Protective and Resource Subzones and is also designated as a Public Hunting area where wild pig and goat can be hunted year-round.

Hana Town and its rural community are located within the proposed subzone area along the coast.

Forested areas above 3000 feet uniformly consist of Category 1 exceptional native forest, closed canopy with over 90% native cover. Below the 3000-foot level the forest is more disturbed and gradually blends into Category 2, mature native forest with over 75% native canopy. Below the 1000-foot level the forest gives way to pastureland with occasional forested areas.

Forested areas above the 5000-foot level provide habitat for three endangered forest birds, the Maui Parrot bill, the Crested Honeycreeper, and the Akepa. Akepa habitat extends to lower elevations to the 4200-foot level.

All known archaeological sites are at or below the 200- foot level. Site No. 1078, at 200 feet is a fishing shrine which is on the State Register of Historic Places. Six other sites are located at lower elevations in coastal areas in rural and urban zoned areas.

Development of a geothermal resource in the Haleakala East Rift Zone in areas other than the grazed agricultural lands below the 1000-foot level may impact native forest bird habitat and above 4200 feet, endangered forest bird habitat. However, development of a geothermal resource below the 1000-foot level in grazed agricultural land could place a well and power plant as close as 7000 feet from the center of Hana Town. Quite clearly, the rural lifestyle of the Hana Community could be affected.

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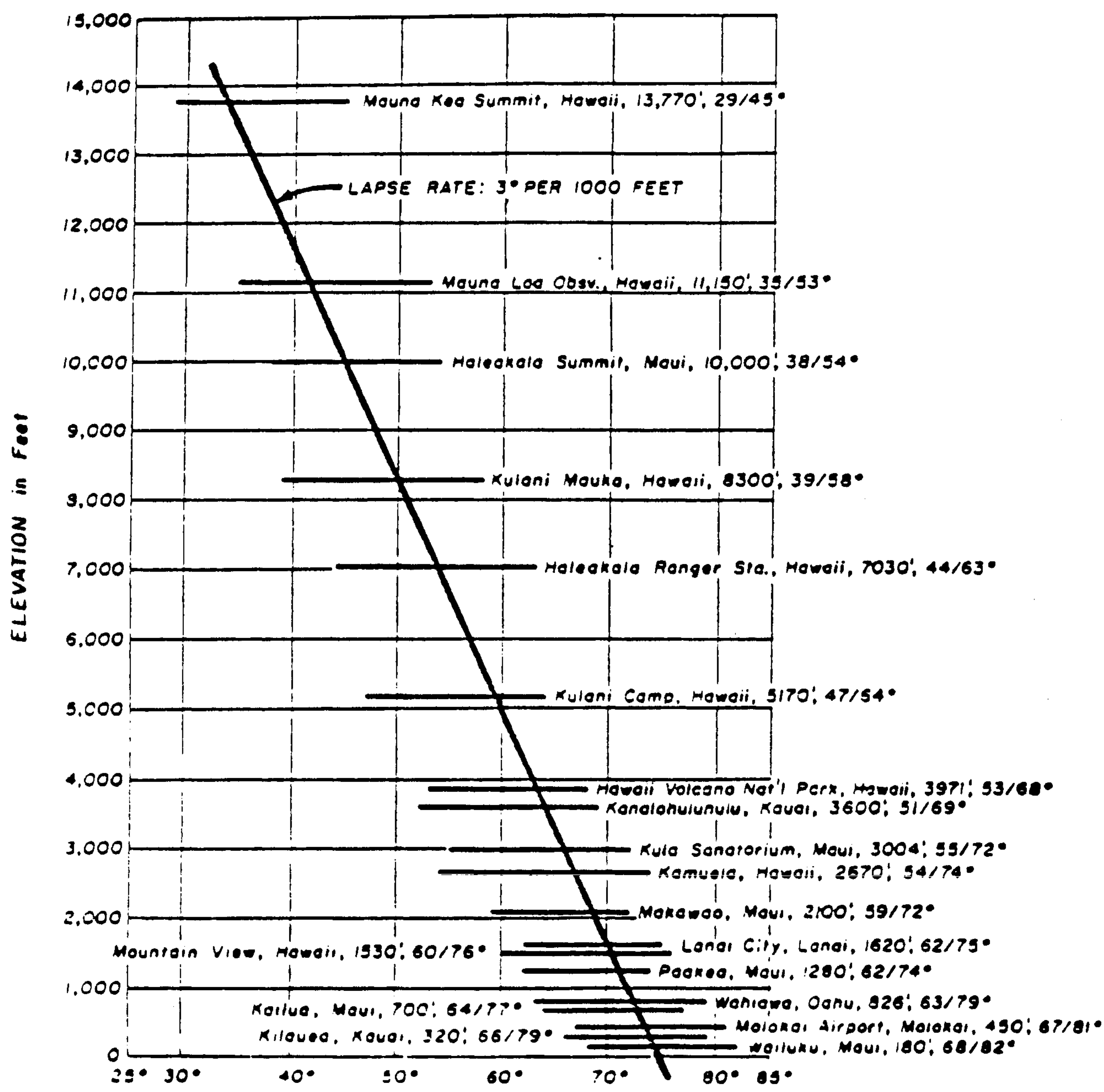

Figure 1. Decrease in Temperature at Various Elevations, Various Locations in the State of Hawaii.

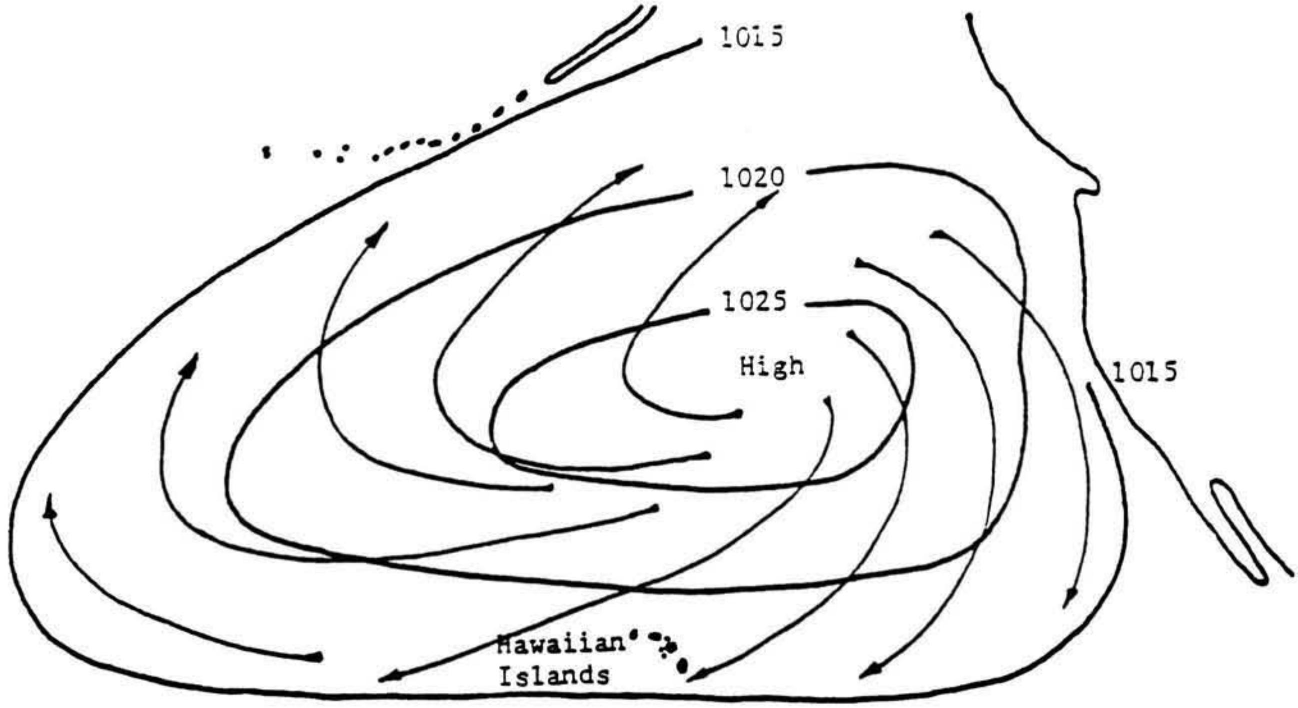

Figure 2a. Mean Pressure (millibars) and Wind Flow in the Eastern and Central North Pacific for July (summer).

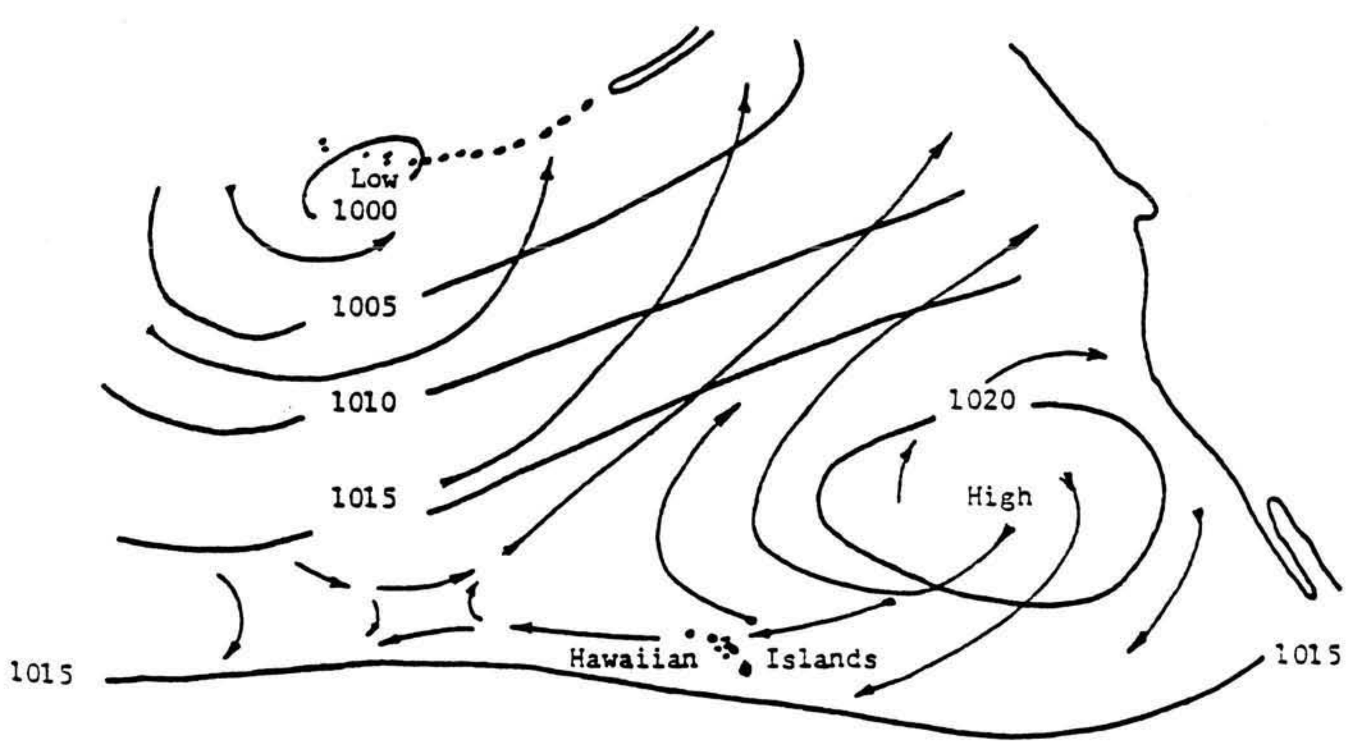

Figure 2b. Mean Pressure (millibars) and Wind Flow in the Eastern and Central North Pacific for January (winter).

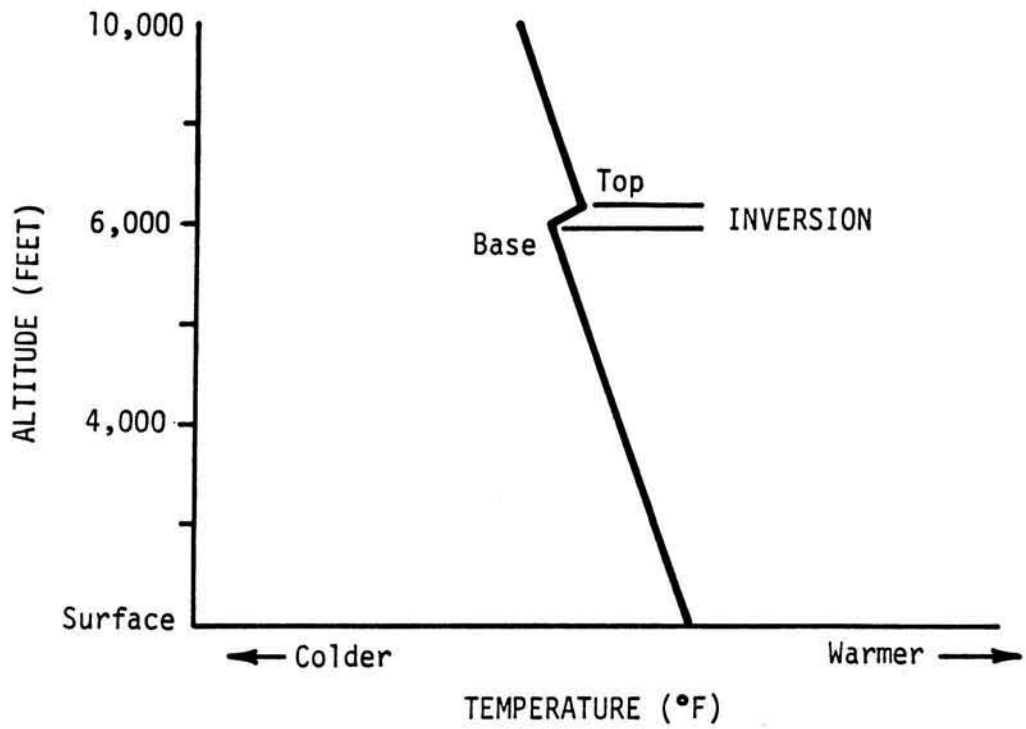

Figure 3a. Trade wind Temperature Inversion

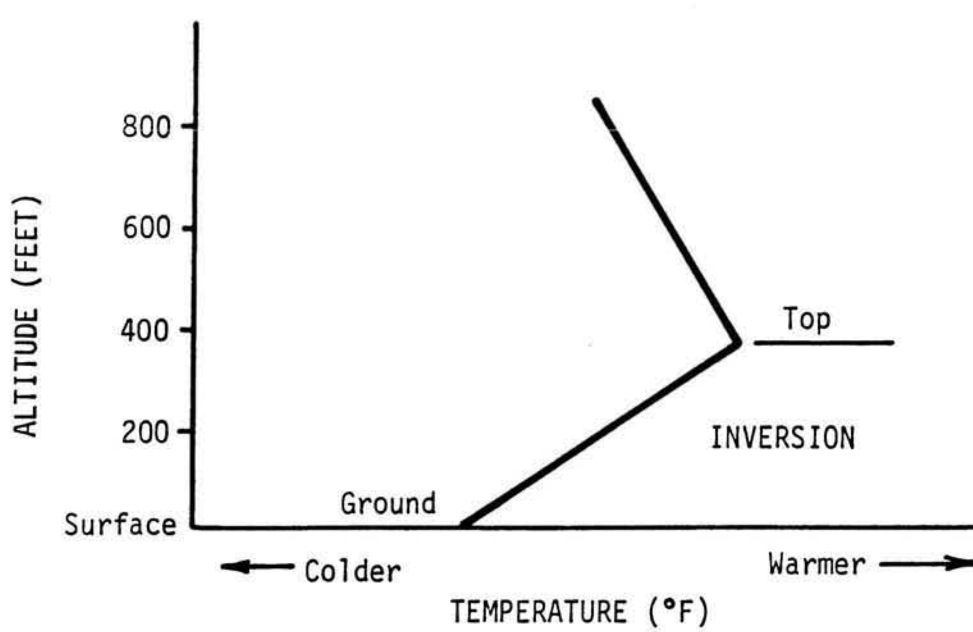

Figure 3b. Ground Temperature Inversion.

Figure 4. Endangered Native Flora

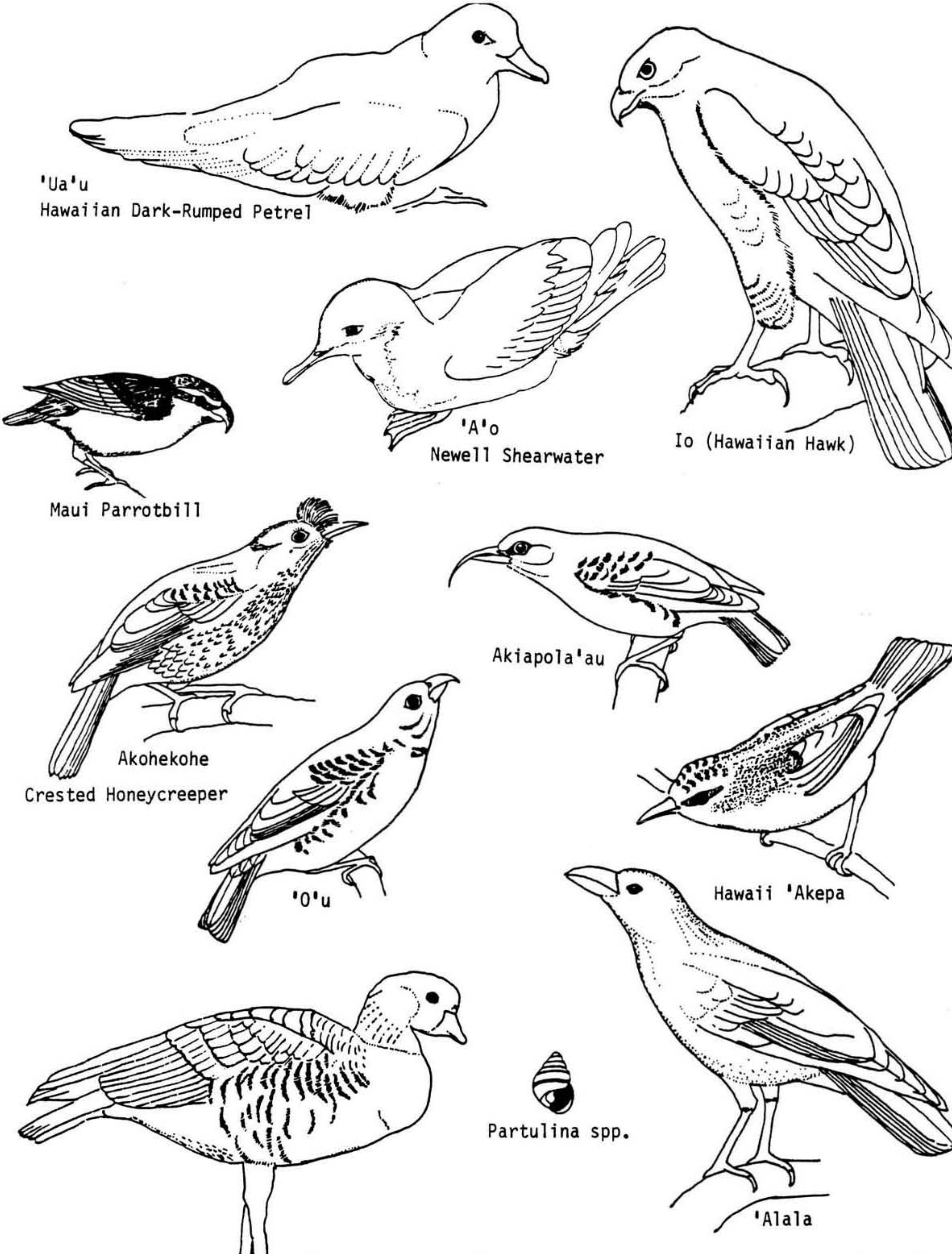

Figure 5. Endangered Native Fauna

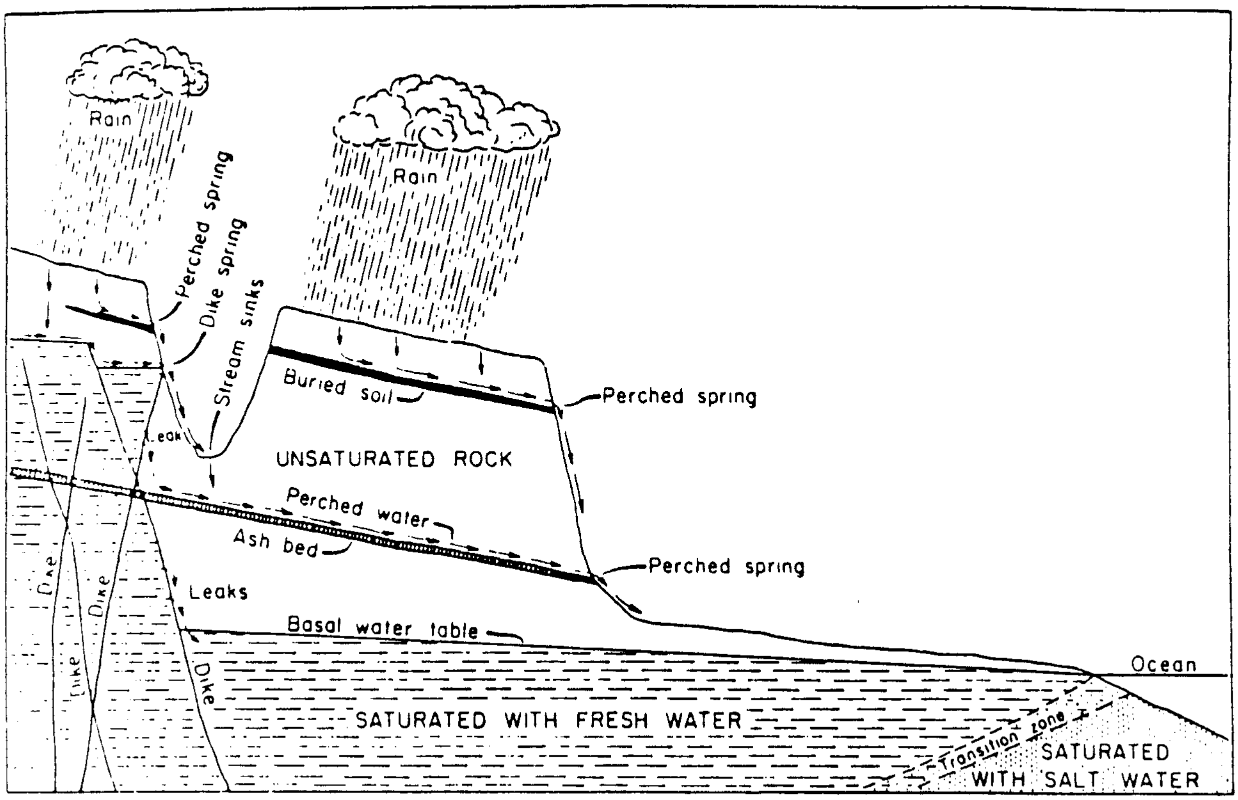

Figure 6. Diagram showing perched water, water confined between dikes, basal water, and pweched and basal springs (Modified after Stearns and Macdonald, 1946).

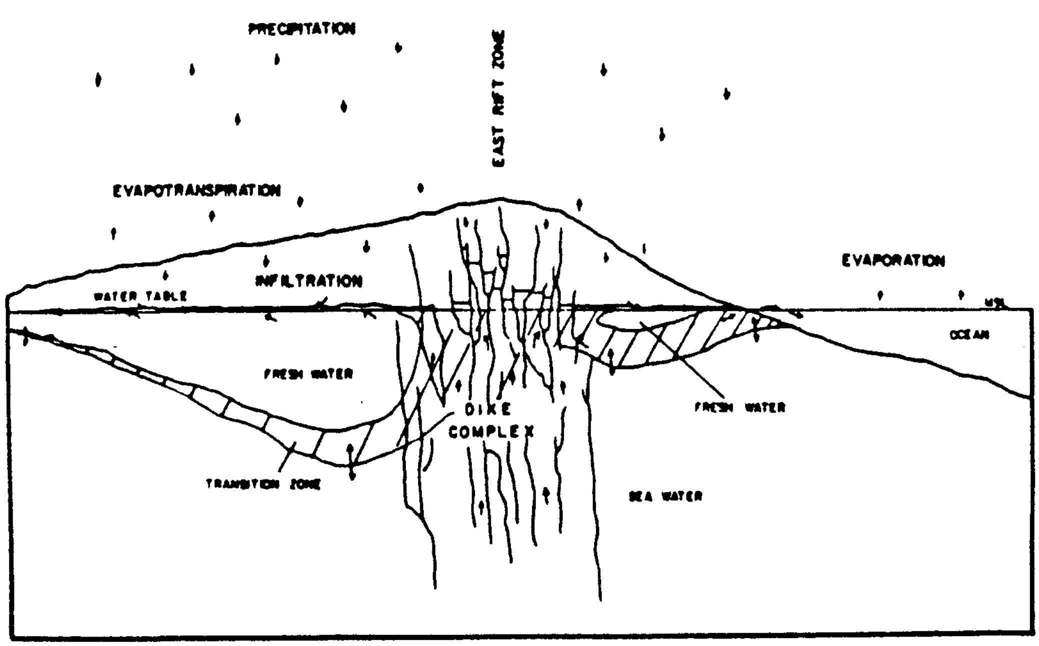

Figure 7. Diagrammatic north-south section through Puna District showing recharge, movement, discharge, storage and subsurface geology of ground water.

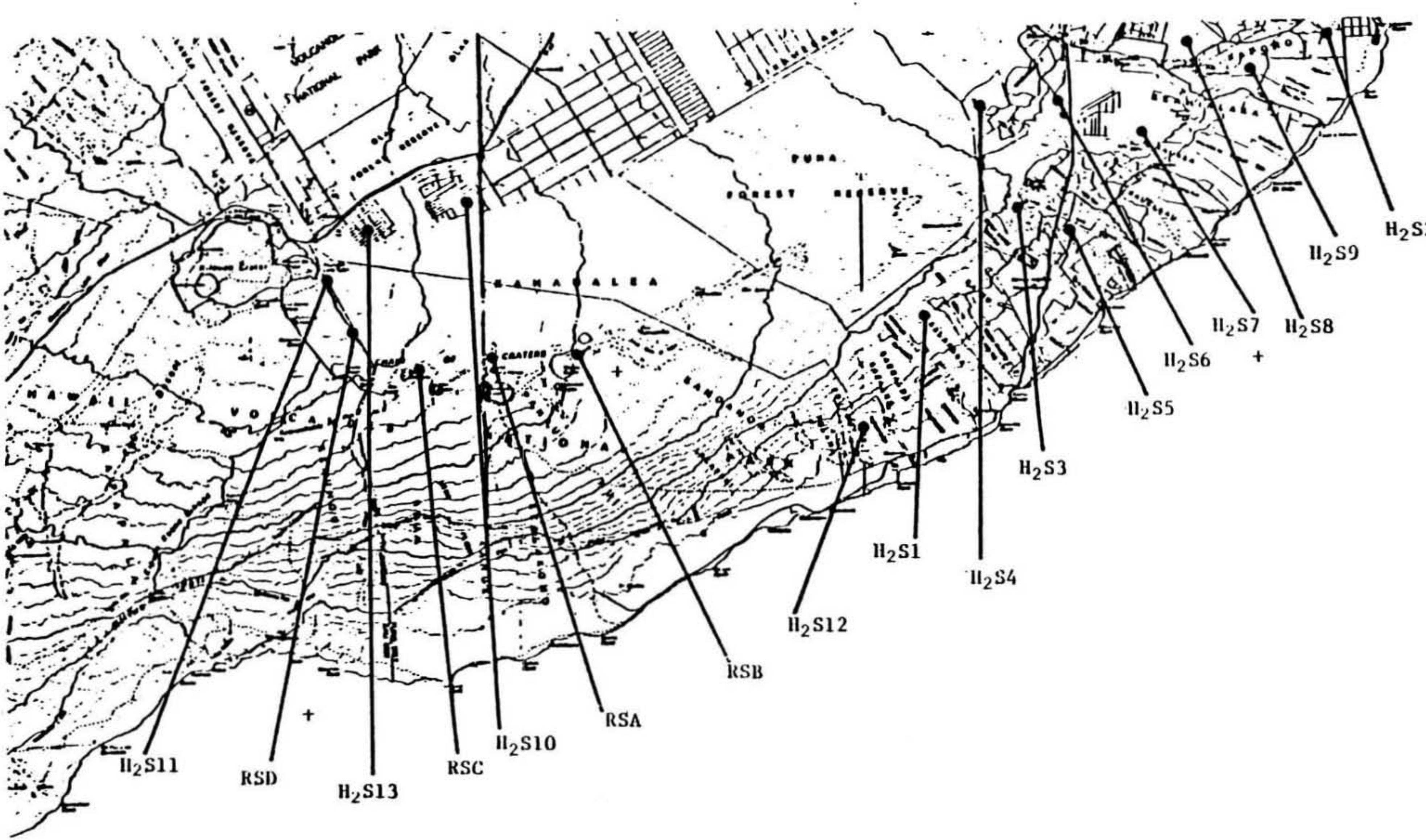

Figure 8. Approximate Loaction of Passive H_2S, Radon, and SFU Monitoring Stations (H_2S1-H_2S13 and RSA-RSD).
(SFU-stacked filter unit)
Source: Houck, 1984

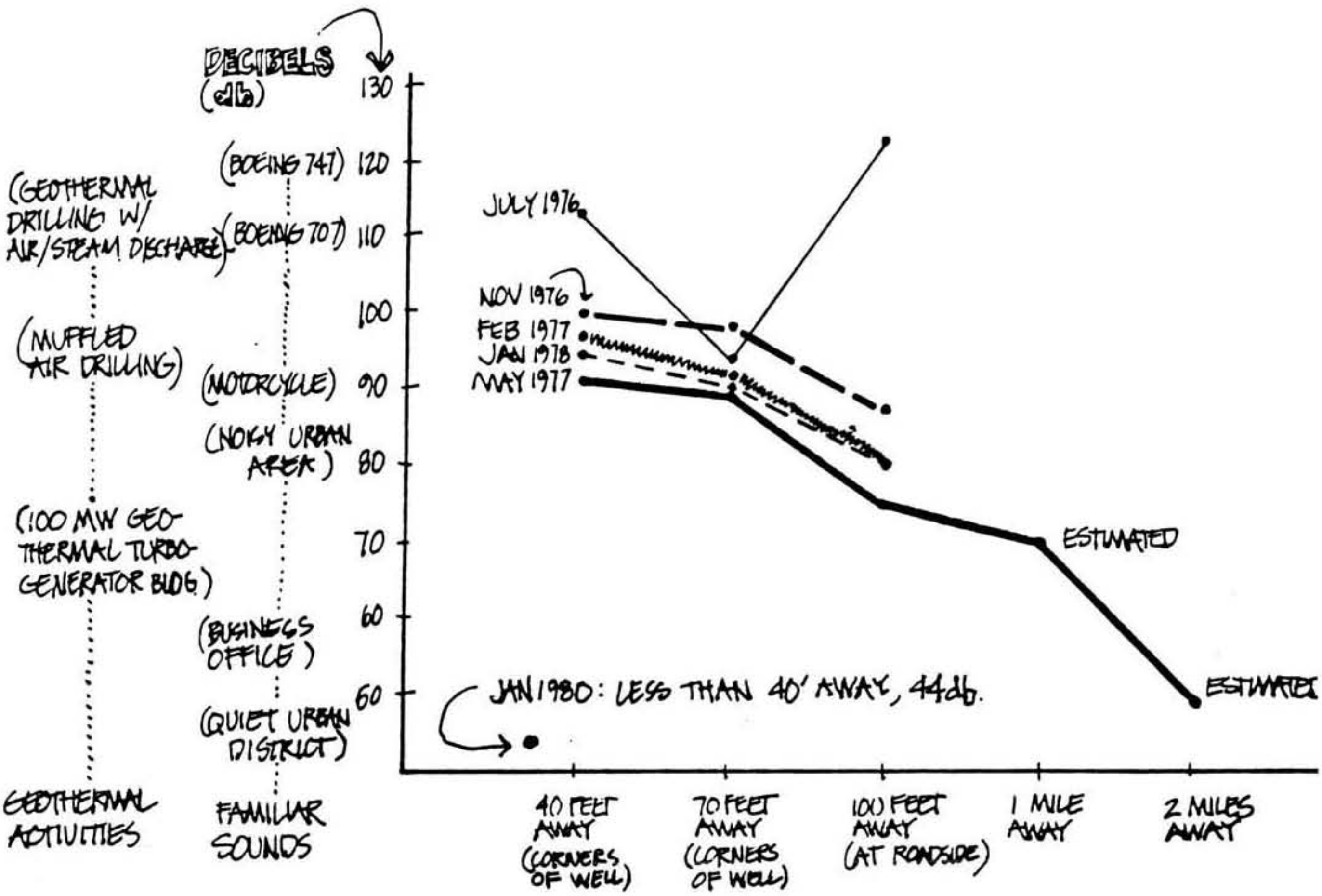

Figure 9. HGP-A Noise Characteristics
(Source: Yen and Iacofano, Geothermal Energy for Hawaii, A Prospectus, 1981).

APPENDIX A

Criteria for Vegetation Categorization from
USFWS Mapping Code

and

Dominant Species Composition in
Selected Rift Zones

Typical Mapping Code:

```
1 2    3  4    5    6
\ |  __/  |  __/    /
 o3Me,2nt(W:tf,ns)sng
```

1. TREE CANOPY CROWN COVER

c = closed canopy, most crowns interlocking	>60% cover
o = open canopy, some or no interlocking crowns	25-60% cover
s = scattered trees	5-25% cover
vs = very scattered trees	<5% cover

2. TREE CANOPY HEIGHT

1 = low scrub trees, monopodial	2-5m tall
2 = scrub trees, moderate stature	5-10m tall
3 = tall stature trees	>10m tall

3. TREE SPECIES COMPOSITION

a) Species name or association abbreviations

Ac = *Acacia koa* (koa)
Al = *Aleurites moluccana* (kukui)
Ep = *Euphorbia* sp. ('akoko)
Me = *Metrosideros polymorpha*
Mr = *Myrica faya* (Firetree)
My = *Myoporum sandwicensis* (naio)
nt = native tree association
Psc = *Psidium cattleianum* (strawberry guava, waiawi)
Sa = *Sapindus saponaria* (Manele; soapberry)
So = *Sophora chrysophylla* (mamane)
xt = introduced tree association

b) Species dominance

Species composition:*	Relative Dominance:
A	only A present
A-B	A and B codominant
A,B	A dominant, B subdominant
A,B-C	A dominant, B and C subdominant
A-B,C	A and B codominant, C subdominant
A-B-C	A,B,C codominant

*Substitute the appropriate species name or association abbreviation for the letters A, B, or C.

4. SPECIES ASSOCIATION TYPE

D = Dry habitat species
M = Mesic habitat species
W = Wet habitat species

5. UNDERSTORY SPECIES COMPOSITION

a) Species name or association abbreviation (Note: Species name abbreviations for trees may also be used if the understory is dominated by individuals of that species, less than 2m tall).

bg = structured bog
mf= matted ferns, Dicranopteris spp., Hicriopteris sp., Sticherous sp.
mg = mixed native-introduced grasses, sedges, or rushes
ng = native grasses
ns = native shrubs
Pm = Passiflora mollisima (banana poka)
tf = treeferns, Cibotium spp. (hapu´u)
xg = introduced grasses, sedges or rushes
xs = introduced shrubs
xx = bare ground (at least 25% of the area)

b) Species dominance (use same format as for tree species)

6. OTHER INFORMATION

bur = recently burned
clr = recently cleared or logged
fum = volcanic fume defoliation
msc = miscellaneous unit - mix of native and introduced species in low elevation areas
pio = pioneer vegetation, seral stage on recent lava flow
sng = many standing dead or defoliated trees

CATEGORY

1	c3, c2, or 3 w/tf, o2 w/tf (o3 if dry or mesic) and 90% or more native species by cover
2	co3, co2 and 75% native canopy (or simply 75% native canopy in non-ohia dominated dry and mesic communities)
2A	s vs 3 or 2, c o s vs 1, o2 w/mf and 50% or more native species by cover
3	Less than 50% native species or [3] Less than 50% ground cover [xx)

Hualalai

Category 1 contains three vegetation compositions. The first type consists of an open canopy of tall Metrosideros polymorpha (Ohia lehua) dominant to moderate size native trees with mesic habitat native shrubs forming the understory. Closed canopies of tall Acacia koa codominant with Metrosideros polymorpha comprise the second composition type. Moderate size native trees and an understory of mesic native shrubs and introduced grasses also occupy these areas. Codominant medium size Sophora chrysophylla (Mamane) and small native trees are scattered throughout the third composition type with dry habitat native shrubs and mixed grasses forming the underbrush.

Category 2A covers a large eastern portion of Hualalai. Dry habitat native shrubs scattered over bare ground comprises the largest section. An area stretching west to northeast of this section also contains very scattered Metrosideros polymorpha of moderate stature codominant with low standing native trees in addition to the underbrush described previously.

Category 2 generally consists of open and closed canopies of moderate to tall Metrosideros polymopha dominant with small to medium size native trees although some large areas also contain Acacia koa. Either dry habitat native shrubs, mesic native shrubs and introduced shrubs and grasses, or wet species of introduced and native shrubs and treeferns form the understory. Pioneer vegetation also grows in some areas.

Category 3 encompasses three compositions of vegetation. The largest section, lying in the western portion of Hualalai, contains scattered tall Metrosideros polymorpha codominant with medium size native trees and tall introduced trees. Mesic introduced grasses comprise the understory. East of this large section lies a plot of scattered, codominant tall Acacia koa, Metrosideros polymorpha, and medium size native trees. The understory consists of mesic introduced grasses. A smallplot of cleared land also exists.

Mauna Loa Southwest Rift

Category 1 contains open and closed canopies of tall Metrosideros polymorpha dominant to native scrub trees and shrubs. The species association type is generally mesic although wet and dry habitat species also exist.

Category 2A contains scattered Metrosideros polymorpha of low to moderate stature codominantly associated in some areas with low lying native trees. Dry habitat native shrubs scattered throughout bare areas are also present.

Category 2 is dominated by open and closed canopies of moderate to tall Metrosideros polymorpha interspersed with low to moderate size native trees and an understory of mesic to dry species of natural shrubs and introduced shrubs and grasses. Large plots of sub-dominant Acacia koa are located on the eastern areas while matted ferns occupy small areas of the Southern portion of the south west rift.

Category 3 contains large plots of bare land scattered with native shrubs. Scattered to very scattered Metrosideros polymorpha of moderate to tall stature occupy smaller areas dispersed throughout the southwest rift. Low to moderate size native trees codominate these areas, and introduced shrubs and grasses as well as native shrubs make up the underbrush. Tall Acacia koa can be found scattered in some areas, codominant with Ohia and native trees.

Mauna Loa East Rift (Upper Piihonua)

Category 1 consists predominantly of closed canopies of tall Metrosideros polymorpha with subdominant association of moderate size native trees. Small plots also contain tall Acacia koa trees. Mesic to wet habitat species of native shrubs and treeferns (Cibotium; hapu'u) comprise the underbrush.

Category 2A contains scattered Metrosideros polymorpha of various sizes codominantly associated in some area with native trees. Wet and mesic species of natural shrubs occupy most of the understory although one small plot contains dry habitat native shrubs and mixed grasses. Large segments of land also have defoliated trees and pioneer vegetation.

Category 2 generally contains open canopies of moderate to tall Metrosideros polymorpha standing alone with mesic species of native shrubs and pioneer vegetation occupying the understory. Some scattered areas also contain moderate size native trees. Beside the native shrubs, matted ferns and defoliated trees occupy small plots of wet areas while mixed grasses exist in some of the mesic and dry habitats.

Category 3 compositions are not found in this section.

Mauna Loa East Rift (Puu Ulaula)

Category 1 contains two types of vegetation compositions. The northern areas consist of closed and open canopies of Acacia koa codominant with Metrosideros polymorhpa. Native trees of moderate height and mesic habitat native shrubs and mixed grasses also occupy these areas. The southern plots contain open canopies of moderate size Metrosideros polymorhpa with an understory of dry habitat native shrubs.

Category 2A generally contains scattered to very scattered Metrosideros polymorpha of low to moderate height. In small areas, very scattered Sophora chrysophylla codominates with Metrosideros polymorpha. Scattered Acacia koa of moderate stature also occupy small plots codominating with native trees. Dry habitat, native shrubs occupy all areas while bare land covers at least 25% of these areas especially in the southern part of the rift zone. Mixed grasses also inhabit small, scattered plots.

Category 2 compositions are scattered throughout this zone. These areas contain open canopies of moderate size Metrosideros polymorpha. Dry habitat native shrubs and mixed grasses make up the understory.

Category 3 which covers over 50% of this section consists of bare ground with scattered native shrubs.

Mauna Loa East Rift (Kulani)

Category 1 contains two major compositions of vegetation. Large areas, especially in the eastern parts, are dominated by open and closed canopies of tall Metrosideros polymorpha accompanied by moderate size native trees and a wet understory habitat of native shrubs and treeferns. Open and closed canopies of tall Acacia koa codominant with Metrosideros polymorha occupy other large areas. The understory contains either mesic native shrubs and treeferns. Moderate stature native trees also exist in these areas.

Category 2A consists of several different compositions. Most common are the open canopied and scattered Metrosideros polymorpha of low stature with an understory of dry habitat native shrubs scattered along bare ground. Western areas contain this combination. Pioneer vegetation also inhabits some of these areas. Small plots of codominant, scattered Acacia koa of moderate stature and native trees occupy the extreme northwest and southwest parts accompanied by an understory of dry habitat native shrubs and mixed grasses. A long, narrow band running north to northeast consists of bare ground with scattered mesic native shrubs and pioneer vegetation. To the extreme northeast lie several small plots consisting of scattered Metrosideros polymorpha condominant with moderate size native trees. Wet habitat native shrubs and defoliated trees form the understory. The eastern portion of this section features three areas containing introduced trees either dominant or codominant with Metrosideros polymorpha and native trees. Wet species of natural and introduced shrubs and matted ferns inhabit the understory of these areas.

Category 2 contains scattered and closed canopy coverings of moderate to tall Metrosideros polymorpha dominant or codomiant with smaller native trees. Dry to mesic habitats form the Western area underbrush consisting of native shrubs and mixed grasses. Wet species of native shrubs and treeferns inhabit the understory of the eastern plots. Several eastern areas also contain defoliated trees. Acacia koa exist in small plots in the southwest, and pioneer vegetation occupies southern and central plots in this region.

Category 3 consists of large areas of bare ground with scattered native shrubs in the extreme west. Scattered to very scattered Acacia koa of moderate to tall stature codominate smaller plots with native trees and Metrosideros polymorpha. Mesic to dry native shrubs and mixed grasses occupy the understory of these plots. Very scattered, tall Metrosideros dominate a recently cleared plot accompanied by mesic native shrub and introduced shrubs and grasses. A cleared plot and two other unmapped areas are also present.

APPENDIX B

Proposed Revisions to State of Hawaii, Department of Health Administrative Rules, Chapter 11-59, Ambient Air Quality Standards and Chapter 11-60, Air Pollution Control, covering Geothermal Activities.

Chapter 11-59 includes one-hour standard for H_2S of 100 ppb. Chapter 11-60 includes emission standards for geothermal wells and geothermal power plants and H_2S episode levels.

DRAFT—3/22/84

Amendments to Chapter 11-59, Administrative Rules.

1. §11-59-4, Administrative Rules, is amended to read as follows:

"§11-59-4 Ambient air quality standards. (a) [Interpretation.] The numercial ambient air quality standards below limit the time-averaged concentration of specified pollutants dispersed or suspended in the ambient air of the [state] State, but these standards do not in any manner authorize the significant deterioration of existing air quality in any portion of the [state] State.

(b) [Application.] Limiting concentrations specified for a twelve-month period or a calendar quarter shall not be exceeded. Limiting concentrations specified for one-hour, three-hour, eight-hour , and twenty-four-hour periods [less than twelve months] shall not be exceeded more than once in any twelve-month period.

(c) [Carbon monoxide.] In the ambient air the concentration of carbon monoxide measured by a reference method shall not exceed:

(1) An average value of ten milligrams per cubic meter of air during any one-hour period.

(2) An average value of five milligrams per cubic meter of air during any eight-hour period.

(d) [Nitrogen dioxide.] In the ambient air the average concentration of nitrogen dioxide measured by a reference method during any twelve-month period shall not exceed seventy micrograms per cubic meter of air.

(e) [Suspended particulate matter.] In the ambient air the concentration of suspended particulate matter measured by a reference method shall not exceed:

(1) [An average value] A geometric mean of [fifty-five] sixty micrograms per cubic meter of air during any twelve-month period.

(2) An average value of [100] one hundred fifty micrograms per cubic meter of air during any twenty-four-hour period.

(f) [Ozone.] In the ambient air the average concentration of ozone measured by a reference method during any one-hour period shall not exceed [100] one hundred micrograms per cubic meter of air.

(g) [Sulfur dioxide.] In the ambient air the average concentration of sulfur dioxide measured by a reference method shall not exceed:

(1) An average value of [twenty] eighty micrograms per cubic meter of air in any twelve-month period.

(2) An average value of [eighty] three hundred sixty-five micrograms per cubic meter of air in any twenty-four-hour period.

(3) An average value of [400] one thousand three hundred micrograms per cubic meter of air in any three-hour period.

(h) [Lead.] In the ambient air the average concentration of lead measured as elemental lead by a reference method during any calendar quarter shall not exceed 1.5 micrograms per cubic meter of air.

(i) In the ambient air, the concentration of hydrogen sulfide measured by a reference method shall not exceed one hundred thirty-nine micrograms per cubic meter of air in any one-hour period." [Eff. November 29, 1982; am] (Auth: 42 U.S.C. §7410, 7416; 40 C.F.R. Parts 50, 51; HRS §342-3, 342-22) (Imp: 42 U.S.C. §7407, 7409, 7410, 7416; 40 C.F.R. Parts 50, 51; HRS §342-22)

2. Material, except source notes, to be repealed is bracketed. New material is underscored.

3. Additions to update source notes to reflect these amendments are not underscored.

4. These rules shall take effect ten days after filing with the Office of the Lieutenant Governor.

I certify that the foregoing are copies of the rules, drafted in the Ramseyer format pursuant to the requirements of section 91-4.1, Hawaii Revised Statutes, which were adopted on ________________________, and filed with the Office of the Lieutenant Governor.

CHARLES G. CLARK
Director of Health

APPROVED AS TO FORM:

Deputy Attorney General

Amendments to Chapter 11-60, Administrative Rules.

1. Chapter 11-60, Administrative Rules, is amended by adding a new section, 11-60-23.1, to read as follows:

"§11-60-23.1 Geothermal wells. (a) A well as used in this section and section 11-60-23.2 means any well which obtains, or is designed to obtain, a geothermal resource.

(b) Prior to a well being part of a distribution system which supplies a geothermal resource to a power plant which has commenced using the geothermal resource, emissions from the well shall not be in excess of five pounds of particulates, and five pounds of hydrogen sulfide, per one hundred pounds of each respective pollutant in the geothermal resource.

(c) After a well is part of a distribution system which supplies a geothermal resource to a power plant which has commenced using the geothermal resource, emissions from the well of hydrogen sulfide shall not be in excess of two pounds per one hundred pounds of hydrogen sulfide in the geothermal resource.

(d) The owner or operator of a well shall obtain an authority to construct and a permit to operate as follows:

(1) Prior to commencement of well construction, an authority to construct shall be obtained in conformance with subchapter 3, and if applicable, subchapter 4.

(2) Prior to a well being part of a distribution system which supplies geothermal resource to a power plant which has commenced using the geothermal resource, a permit to operate shall be obtained in conformance with subchapter 3.

(e) This section shall be in effect immediately for any well which has not begun actual construction before the effective date of this section. An existing well or one which has begun actual construction before the effective date of this section shall be in compliance with this section by December 31, 1986." [Eff.] (Auth: HRS §§342-3, 342-22, 342-23) (Imp: §§342-3, 342-22, 342-23)

2. Chapter 11-60, Administrative Rules, is amended by adding a new section 11-60-23.2 to read as follows:

"§11-60-23.2 Geothermal power plants. (a) A power plant as used in this section and section 11-60-23.1 means any power plant which uses or is designed to use, a geothermal resource. A power plant as defined shall not include the well(s) supplying the geothermal resource to the power plant.

(b) Hydrogen sulfide emissions from a power plant shall not exceed two pounds per one hundred pounds of hydrogen sulfide in the incoming geothermal resource.

(c) The maximum allowable increase in hydrogen sulfide concentration in the ambient air above natural background level shall be thirty-five ug/m^3 as a one-hour average, considering all stationary sources except geothermal wells in the area affected by the power plant applying for an authority to construct. The maximum allowable increase may be exceeded once per twelve-month period at any one location.

(d) No power plant shall consume any part of the thirty-five ug/m^3 maximum allowable increase until an authority to construct application is certified complete by the director.

(e) The owner or operator of a power plant shall obtain an authority to construct and a permit to operate in conformance with subchapter 3, and if applicable, subchapter 4.

(f) This section shall be in effect immediately for any power plant which has not begun actual construction before the effective date of this section. An existing power plant or one which has begun actual construction before the effective date of this section shall be in compliance with this section by December 31, 1986." [Eff.] (Auth: HRS §§342-3, 342-22, 342-23) (Imp: HRS §§342-3, 342-22, 342-23)

3. §11-60-35, Administrative Rules, is amended and renumbered to read as follows:

"[§11-60-35] §11-60-19 Prevention of air pollution emergency episodes. (a) Notwithstanding any other provision of [the air pollution control regulations, this episode regulation] this chapter, this section is designed to prevent the excessive buildup of air contaminants during air pollution episodes, thereby preventing the occurrence of any emergency due to the effects of these contaminants on the public health.

(b) [Episode criteria.] Conditions justifying the proclamation of an air pollution alert, air pollution warning, or air pollution emergency shall be deemed to exist whenever the director determines that the accumulation of air contaminants in any place is attaining or has attained levels which could, if such levels are sustained or exceeded, lead to a threat to the health of the public. In making this determination, the director [will] shall be guided by the [following] criteria [:] set forth in subsections (c) to (g).

[(1)] (c) "Air pollution forecast": An internal watch by the department shall be actuated by a national weather service advisory that atmospheric stagnation advisory is in effect or the equivalent local forecast of stagnant atmospheric conditions.

[(2)] (d) "Alert": The alert level is that concentration of pollutants at which first stage control action is to begin. An alert [will] shall be declared when any one of the following levels is reached:

[(A)] (1) SO_2 - [800] eight hundred ug/m^3 (0.3 ppm), [24-] twenty-four hour average;

[(B)] (2) Particulate matter - [3.0 COHs or 375] three hundred seventy-five ug/m^3, [24-] twenty-four hour average;

[(C)] (3) SO_2 and particulate matter combined - [product of SO_2, ppm, 24-hour average and COHs equal to 0.2 or] product of SO_2, ug/m^3, [24-] twenty-four hour average and particulate matter, ug/m^3, [24-] twenty-four hour average equal to 65x10^3;

[(D)] (4) CO - [17] seventeen mg/m^3 ([15] fifteen ppm), [8-] eight hour average;

[(E)] (5) [Oxidant] Ozone - [200] four hundred ug/m^3 ([0.1] 0.2 ppm), [1-] one hour average;

[(F)] (6) NO_2 - [1,130] one thousand one hundred thirty ug/m^3 (0.6 ppm), [1-] one hour average; [282] two hundred eight-two ug/m^3 (0.15 ppm), [24-] twenty-four hour average; or

(7) H_2S - one hundred thirty-nine ug/m^3 (0.10 ppm), one hour average;

and meteorological conditions are such that this condition can be expected to continue for twelve or more hours.

[(3)] (e) "Warning": The warning level indicates that air quality is continuing to degrade and that additional abatement actions are necessary. A warning [will] shall be declared when any one of the following levels is reached:

[(A)] (1) SO_2 - [1,600] one thousand six hundred ug/m^3 (0.6 ppm), [24-] twenty-four hour average;

[(B)] (2) Particulate matter - [5.0 COHs or 625] six hundred twenty-five ug/m^3, [24-] twenty-four hour average;

[(C)] (3) SO_2 and particulate matter combined - [product of SO_2, ppm, 24-hour average and COHs equal to 0.8 or] product of SO_2, ug/m^3, [24-] twenty-four hour average and particulate matter, ug/m^3, [24-] twenty-four hour average equal to 261×10^3;

[(D)] (4) CO - [34] thirty-four mg/m^3 (30 ppm), [8-] eight hour average;

[(E)] (5) [Oxidant] Ozone - [800] eight hundred ug/m^3 (0.4 ppm), [1-] one hour average;

[(F)] (6) NO_2 - [2,260] two thousand two hundred sixty ug/m^3 (1.2 ppm), [1-] one hour average; [565] five hundred sixty-five ug/m^3 (0.3 ppm), [24-] twenty-four hour average; or

(7) H_2S - one thousand three hundred ninety ug/m^3 (1.00 ppm), one hour average;

and meteorological conditions are such that this condition can be expected to continue for twelve or more hours.

[(4)] (f) "Emergency": The emergency level is reached when the warning level for a pollutant has been exceeded and:

[(A)] (1) The concentrations of the pollutant are continuing to increase[,]; or

[(B)] (2) The director determines that, because of meteorological or other facts, the concentrations will continue to increase[,]; or

[(C)] (3) When any one of the following levels is reached:

[(i)] (A) SO_2 - [2,100] two thousand one hundred ug/m^3 (0.8 ppm), [24-] twenty-four hour average;

[(ii)] (B) Particulate matter - [7.0 COHs or 875] eight hundred seventy-five ug/m^3, [24-] twenty-four hour average;

[(iii)] (C) SO_2 and particulate matter combined—[product of SO_2, ppm, 24-hour average and COHs equal to 1.2 or] product of SO_2, ug/m^3, [24-] twenty-four hour average and particulate matter, ug/m^3, [24-] twenty-four hour average equal to 393x10^3;

[(iv)] (D) CO - [46] forty-six mg/m^3 ([40] forty ppm), [8-] eight hour average;

[(v)] (E) [Oxidant] Ozone - [1,200] one thousand ug/m^3 (0.6 ppm), [1-] one hour average;

[(vi)] (F) NO_2 - [3,000] three thousand ug/m^3 (1.6 ppm), one [1-] hour average; [750] seven hundred fifty ug/m^3 (0.4 ppm), [24-] twenty-four hour average; or

(G) H_2S - thirteen thousand nine hundred ug/m^3 (10.0 ppm), one hour average.

[(5)] (g) "Termination": Once declared, any [status] episode level reached by application of these criteria [Will[shall remain in effect until the criteria for that level are no longer met. At [such] that time, the next lower [status] episode level [will] shall be assumed." [Eff. November 29, 1982; am and ren S11-60-19] (Auth: HRS SS342-3, 342-22; 42 U.S.C. S7407, 7410, 7416; 40 C.F.R. Parts 50, 51, 52) (Imp: HRS SS342-3, 342-9, 342-22; 42 U.S.C. SS7407, 7410, 7416; 40 C.F.R. Parts 50, 51, 52)

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____

CHARLES G. CLARK

Director of Health

APPROVED AS TO FORM:

____

Deputy Attorney General

APPENDIX C

ARCHAEOLOGICAL LITERATURE SEARCH

Kilauea East Rift Zone, (True/Mid Pacific Geothermal Venture, Revised Environmental Impact Statement for the Kahaualea Geothermal Project, June, 1082, prepared by Tommy Holmes, April 1982).

Archaeological Literature Research
Tommy Holmes
April 1982

The following is a brief summary of the findings of a documentary literature search on the ahupuaa of Kahauale'a in the Puna District of the island of Hawaii. Attention is given to the entirety of the ahupuaa, though the emphasis is on the mauka portions from about 1,500' to 3,800' elevation, or roughtly three miles inland to the northern terminus of the ahupuaa, just below Kilauea Iki. The present document consists of excerpts from a longer report entitled "A Preliminary Report on the Early History and Archaeology of Kahauale'a, Puna, Hawaii" prepared by Tommy Holmes for the Estate of James Campbell.

TRAILS

In Puna, where canoe landing and launching sites were very few and extremely dangerous, trails held special significance. Given terrain that was alternately rugged lava and thick jungle, Puna residents had no choice but to develop a good trail system over which a great part of trade, communications and transportation occurred.

Several old trails were known to have either passed through Kahauale'a ahupuaa or started at some point outside the area or at the coast and penetrated into Kahauale'a for a certain distance. At least four of these trails traversed Kahauale'a in a rough east-west direction. The trail most makai followed the contour of the coastline just a few feet from the ocean.

A second ancient trail called on maps today the Kalapana or Volcano-Kalapana Trail crossed Kahauale'a a little more than half a mile inland. This was apparently the preferred route in traveling from Puna to the Volcano area (although there were other routes, e.g. Ellis' path).

Coming up on this same trail from Puna, one could continue on to the Volcano or branch off to the right just below Makaopuhi crater to re-enter and recross Kahauale'a at about the 2,700-ft. level. About ten miles inland, this ancient trail, called the Glenwood-Makaopuhi Trail on today's maps, took one through to Keeau and Ola'a and eventually back to Hilo.

The fourth ancient trail, used by Capt. Wilkes' party in 1840, apparently began just to the east of Makaopuhi and traversed Kahauale'a at about the 2,200-ft elevation, passed just north of Kalalua crater and continued down the rift zone.

Hudson also mentions an "old trail across the lava flow south of Makaoiki [a heiau in Kahauale'a about a mile inland].

Makai-mauka trails are shown on U.S. Geological Survey maps compiled in 1912 and 1922. A single trail begins at the coast on the border of Kahauale'a and Kapaahu ahupuaa and runs inland for about three miles in a roughly northerly direction before it branches. The major branch, called the Kapaahu trail, continues into Kahauale'a till about the 1,500-ft. elevation where on the map it terminates. The branch trail fairly closely parallels the Kapaahu trail before it too seems to end at about the same elevation. Most likely one or both trails might have at one time gone considerably further inland serving bird-catchers, canoe-makers, upland farmers, forest product gatherers, travelers, etc. Chester Lyman reported in 1846, taking a trail that appears to have started at the coastal village of Kahauale'a and continued almost due north into the interior of Kahauale'a and back to Hilo.

Indeed there were probably a number of coast-inland trails that accessed the archaeological sites, reported as far as three miles or more inland on neighboring ahupuaa of Kahauale'a. That some would have gone inland up the Kahauale'a corridor is very likely.

The manufacture and export of pulu, the soft, wooly substance found at the base of hapuu ferns, was, according to Thrum, an important industry from 1851 to 1884. Most pulu came from an extensive tract of fern and ohia forest in the Kilauea vicinity. Brigham noted that, "In the early sixties [1860's] the business of picking and packing pulu had become so important that trails cut by the many natives thus employed opened the crater country far more than ever before."

SITES

As mentioned previously, most known sites in Kahauale'a are found quite close to the shore. The most seaward is a canoe ladder site, one of several along the cliff-bound coast of Puna.

Considering the numerous ahupuaa that make up the Puna District, the reported presence of three heiaus in Kahauale'a alone, where many other Puna ahupuaa, often more populous, had none is of some interest.

Located within a couple of hundred yards from the sea adjoining Waikupanaha pond is what Hudson calls Waiaka heiau.

A second heiau, called Punaluu, unquestionably in Kahauale'a, was quite large and complex.

The other reported heiau in Kahauale'a, called by Thrum and Hudson, Makaoiki, was located "about a mile inland from Kupaahu village...in the middle of an aa flow. The adjacent graves are pits sunk in the surface of the flow. Hudson also notes a "former burial cave, a short distance south of site 179 [Makaoiki]. The cave is known as "Kalua Makini".

In the land of Pulama (on old maps the ahupuaa bordering Kahauale'a to the west) Hudson reports a heiau, Makaiwa, three miles from the sea. Thrum calls it an "ipuolono" or agricultural-type heiau. Early Hawaiian scholar S. M. Kamakau says such "ipuolono heiaus... temples, or more properly household shrines, were to foster food.

Mention of this heiau, though it is not in Kahauale'a, is made here for two reasons.

First: The location of Makaiwa heiau three miles inland, coupled with the location of several other heiau in the southwest Puna area that Hudson places nearly as far inland, strongly suggest that there was significant activity in Kahauale'a and nearby ahupuaa well inland of what was expected when the present study was initiated.

Second: At three miles from shore, Makaiwa heiau and attendant sites are almost to the furthest inland reaches of Pulama which is bounded by a dog-leg of Kahauale'a to the north. In fact, Makaiwa heiau and the other sites are located just a few hundred yards outside Kahauale'a. Hudson notes that in support of the classification of Makaiwa as an "ipuolono" heiau are "the many old agricultural workings found nearby [that] indicate that the purpose of the heiau was to protect and fructify the crops". He goes on to say "In the neighborhood of Makaiwa heiau are a number of platforms, house sites, terraces, pens, and walls.

To extrapolate that there might be sites or site complexes a few hundred yards away in Kahauale'a, at the same distance or more inland, is not unreasonable.

UPLAND SITES

It is, in fact, at the elevation of Makaiwa heiau and accompanying sites that Jim Jacobi [personal communication 1982] reported during a bird survey done in the late 1970's, seeing a number of sites. His recall is that these sites were about 1½ to 2 miles below Kalalua Crater situating them in Kahauale'a at about 1200'-1500' elevation, 3½ to 4 miles inland, and by crude calculation relatively near the Makaiwa heiau complex.

Moving up in elevation Mr. Jacobi also recalled seeing a scattering of apparent sites immediately mauka of Kalalua Crater. He also reported part of the ancient trail that Wilkes' party used as still being in evidence in this Kalalua vicinity. Lastly, he recalls seeing certain cultigens, particularly the ti plant, growing in the Kalalua area, further suggesting one time agricultural activity.

Handy recorded information regarding the extent of inland agricultural activity in western Puna in 1935, when there were still individuals living who were familiar with Puna's early history. According to his informants, there is very strong evidence for agricultural activities well inland in Kahauale'a. "Land northeast of Kapa'ahu [that, according to Handy's informants]...used to be covered with plantations" is adjacent and virtually identical in terms of terrain and vegetative cover to the lower mauka portions of Kahauale'a. The description of Kaho'onoho at least 2.5 miles into Kahauale'a's forested interior, and Wala'ohia, also considerably inland, as "the two great forest planting areas in Kahauale'a" rather pointedly suggests upland agricultural activity in Kahauale'a. Similarly, the Kupahua homesteading area, upper Kalapana and upper Kaimu are all three to four miles inland, quite close to Kahauale'a, and similar in nature of terrain and vegetation. Supporting Handy's observations on agricultural activity in western Puna are other references, some already noted and more below.

Two other references, if calculations and assumptions are correct, would place agricultural activities well into Kahauale'a's interior. An "extensive upland taro patch" referred to in 1841 by Capt. Charles Wilkes, head of the U.S. Exploring Expedition, was apparently in Kahauale'a, probably at about 2,000' to 2,200' elevation.

Chester Lyman, who traveled through Puna in 1846 with Rev. Coan, also reports a plantation about five miles inland in Kahauale'a.

At 10 miles he makes note of "a small grass shanty" that could have been a temporary abode for travelers, farmers, or forest product gatherers.

At Panau, a small village near Kahauale'a at about 2,500' elevation and just below Napau crater, there was also agricultural activity. Rev. William Ellis, traveling in 1823 through what appears to be the Panau area, says "The natives ran to a spot in the neighborhood, that had formerly been a plantation, and brought a number of pieces of sugar-cane..."

That there was a permanent village this far inland (about 5 miles) and within minutes of walking time from Kahauale'a, would lead one to suspect that permanent and temporary inhabitants of Panau made regular trips into Kahauale'a for various forest products.

Wilkes, in 1841, says of Panau that "Here many canoes are built and transported to the sea, the trees in the vicinity being large and well adapted to this purpose. What this and other canoe related references suggest is that logging koa trees for canoe hulls and procuring wood for other canoe parts might well have been another inland forest activity within Kahauale'a.

The pre- and early post-contact native forest regime of mauka Kahauale'a, with its extensive ohia canopy provided a near ideal habitat for many of the birds sought after by bird-catchers, kia manu. Feathers from certain birds were made into the highly-prized feather work artifacts of the ali'i - capes, cloaks, helmets, kahili, etc.

Early Hawaiian scholar, N. B. Emerson writing in 1895 about bird-catching considered Kilauea, Puna, and upper Hilo amongst the most desirable bird-catching areas in the islands, implying that Kahauale'a by its location (in Puna and contiguous with Kilauea) and type of vegetative, cover was ideal bird country.

Hudson, while not mentioning Panau by name, says that "a few sites were also found in the upland forest region around Makaopuhi and Napau craters at an elevation of about 2,700 feet 6 miles from the sea". Unfortunately, he does not elaborate further on just where the sites were located or what type they were. He does, though, go on to describe other suspected and known sites, including a pulu factory, and possible religious and habitation sites in the Panau village vicinity.

These sites would all be very close to the border of Kahauale'a. Ellis mentions in 1823 a heiau to Pele near Kilauea-iki which is all but contiguous with the northern-most terminus of Kahauale'a.

Whatever the exact location of these other inland sites the point is firmly made. There was a variety of activities, such as canoe building, agriculture, and birdcatching, in the greater volcano area and regular travel through it along several trails. Kahauale'a mauka was an integral part of the physical and resource bounds of these early inhabitants, temporary workers, and transients. In summary, it would not be unreasonable to expect that there are archaeological sites in the mauka portions of Kahauale'a.

APPENDIX D

ARCHAEOLOGICAL SITES IN GEOTHERMAL RIFT ZONES

Source: Department of Land and Natural Resources, Division of State Parks, Historic Site Section maps and site records as of July, 1984.

Site Number	Description
KILAUEA EAST RIFT ZONE	
10-52-5508	Old Volcano House #42 (National Register)
10-60-7371	Kapapala Ranch Manager's House
10-60-7372	Kapapala Ranch Complex
10-68-7361	Punaluu Landing and Railroad Terminal
10-69-7362	Pahala District
10-68-7370	Site of former Opukahaia House
19-53-7414	Volcano Residential District
10-68-4310	Wailau Complex 1
10-68-4368	Koloa Complex
10-68-4370	Luu Complex
50-10-46-4295	Pualaa Complex II
10-45-7387	Puulaa Congregational Church
50-10-46-4250	Kings Cairns
50-10-46-4251	Kumakahi Grave Sites (State Register)
50-10-46-7492	Lyman Marker
50-10-46-2501	Kapoho Petroglyphs (State Register)
50-10-46-4278	Kahuwai Village Complex
50-10-55-7388	Pahoa District
50-10-46-2500	Kukii Helau
50-10-46-4294	Pualaa Complex I
50-10-46-4254	Kapoho Pt. Platform
50-10-46-4255	S. Kapoho Pt. Complex
50-10-46-2529	MacKenzie Petrogyph Filed (State Register)

MAUNA LOA SOUTHWEST RIFT

10-73-7353	Kahuku Ranch House
10-73-7357	Captain Robert Brown Marker
10-66-7313	Tobacco Barn
10-66-7314	Kona House #10
10-66-7315	Kona House #11
10-66-7316	Hoopuloa Church Site
10-66-7317	I.M. Littorin House
10-66-7318	Kona House #12
10-66-7311	Tobacco Barn & Slaughter House
10-66-7312	McWayne House
10-66-7365	C.Q. Yee Hop Lumber Mills
10-71-2162	Lava Tube Complex (State Register)
10-72-3700	Kalanamauna Upland Complex (State Register)
10-73-7364	Kamoa Homestead House
10-72-2161	Keawaiki Complex (State Register)

MAUNA LOA EAST RIFT ZONE-no sites indicated

HUALALAI-no sites indicated

HALEAKALA EAST

50-50-13-1078	Kalapuni Ko'a (State Register)
50-50-13-1482	Ka'uiki Hill
50-50-13-1485	Kawaipapa Complex (State Register)
50-50-13-107	Waikaloa Platform (State Register)
50-50-13-109	Kauleiula Heiau (State Register)

50-50-13-110	Kauleilepo Heiau (State Register)
50-50-13-1487	Noa Fishponds (State Register)
50-50-13-117	Koahaepali Heiau
50-50-13-522	Aleamai Enclosure (State Register)
50-50-13-573	Ka Iwi O Pele Complex
50-50-13-1491	Kainalimu Enclosure (State Register)

HALEAKALA SOUTHWEST RIFT ZONE

50-50-14-192	Papanuiokane Heiau
50-50-14-1017	Kalua O Lapa Burial Cave
50-50-14-1018	Maonakala Village Complex (State Register)
50-50-14-1021	Poo Kanaka Stone (State Register)
50-50-14-1009	Puu Naio Cave (State Register)
50-50-14-1385	La Perouse Archaeological District (State Register)
50-50-14-1006	Kanaio Mauka Complex (State Register)
50-50-14-1019	Paako Point Ko'a
50-50-15-572	Hoapili Trial (State Register, National Register nomination)
50-50-14-1234	Kaipolohua Cave (State Register)
50-50-14-1235	Cave of Seven Coffins (State Register)

APPENDIX E

VISUAL IMPACT ANALYSIS

(True/Mid Pacific Geothermal Venture, Revised Environmental Impact Statement for the Kahaualea Geothermal Project, June 1982).

VISUAL IMPACTS

Concern has been raised about the possible adverse impact that the power plants might have on the vistas within the Hawaii Volcanoes National Park (HVNP). The EIS addresses this issue in Sections 5 and 6. To further document the very minimal visual impacts of the project facilities, an area terrain analysis was made to determine locations outside of the property from which the facilities could be seen. Figure 1 shows the "observer locations" around the Park used in the terrain analysis. Figures 2 through 7 represent visual perspectives from selected observer stations.

Points were chosen at 100-foot elevation increments along the approach road to the Park (Volcano Highway) as well as the nearby public roads in the Park. For each of these points, a view line was calculated from an observer (whose eyes were considered to be 10 feet above the road) to the top of an 80-foot high power plant (A, B, C or D) or a 65-foot high power plant (E). In almost all cases, this view line went below the surface of the ground between the observer and the power plant. Two exceptions to these results occur (1) in the immediate vicinity of the entrance road to the dump site (transfer station) along the Volcano Highway about 2.5 miles east of the Volcano community (Station 7) and (2) a 1,500-foot section of the Chain of Craters Road just as it starts over the Kalanaokuaiki Pali near the turn-off to the Ainahou Ranch where a view corridor is present in which the upper 20 feet (more or less) of a power plant at Site E could be seen.

View lines were also calculated for points along the Napau Crater Trail as well as for other points north of this trail between the trail head and Puu Kamoamoa. The power plants would be visible from about half of the length of this trail as well as from many points in the barren lava fields of the area. Based upon this analysis as well as visual inspection of air photos and maps, it is estimated that one or more power plants may be visible from about 30 percent of the rift zone area north of the trail in this region. To the south of the Napau Trail, the power plants cannot be seen except from a few high points due to the abrupt change of regional slope. Even when the power plants are visible, they are at distances of one to six miles and thus they would not be significant intrusive features with proper design and construction considerations. In no case are they expected to be seen as a silhouette on the horizon, but instead, they would be a feature in the middle to far distant background.

Since the primary visual concern revolves about the possible view of the power plants from publicly accessible view points in the park where large numbers of tourists would likely visit, a series of profiles or visual perspective were constructed to show that the view lines from these points are blocked. Perspectives are shown in Figures 2 to 7. It should be noted that no correction for trees has been incorporated into these perspectives. If the trees are included, only Plant E could be viewed from any nearby road in the park or those immediately outside the park. (Observers on the Mauna Loa strip road at a distance greater than 10 miles may be able to see one or more of the plants once they go above 6,000 feet.) For Plant E, the only areas of visibility from publicly accessible roads are from the Napau Trail parking lot and access road and the portion of Chain of Craters Road immediately to the south of Pauahi Crater and north of the Aina Loa Ranch turnoff.

It is possible that the moist warm air from the cooling towers will condense as it rises under certain atmospheric conditions to form a small cloud mass similar to that often observed near cracks and puu's along the remote part of the East Rift Zone east of Mauna Ulu under the same conditions. During normal atmospheric conditions, no visible vapors are expected from the cooling towers.

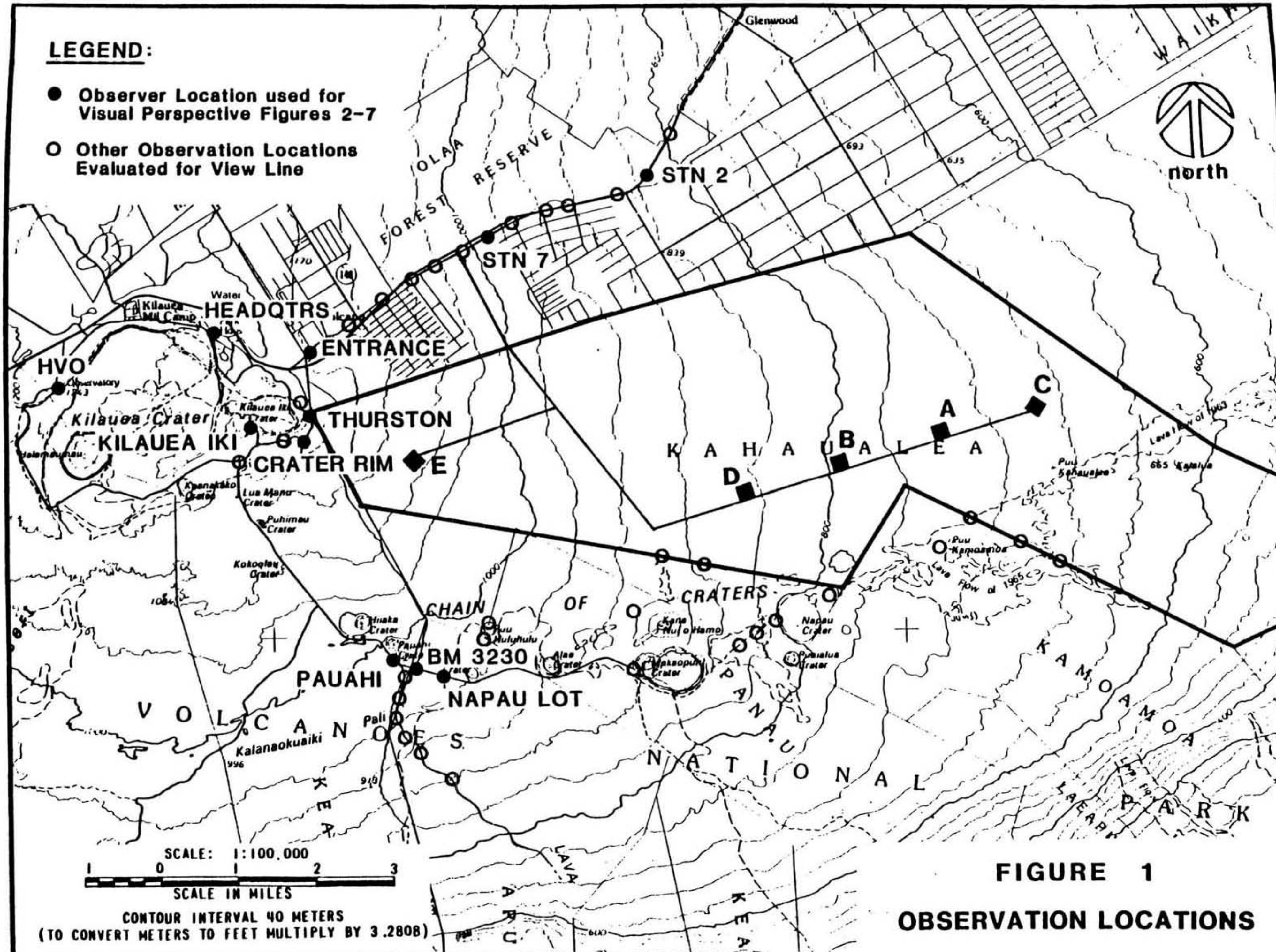

FIGURE 1

OBSERVATION LOCATIONS

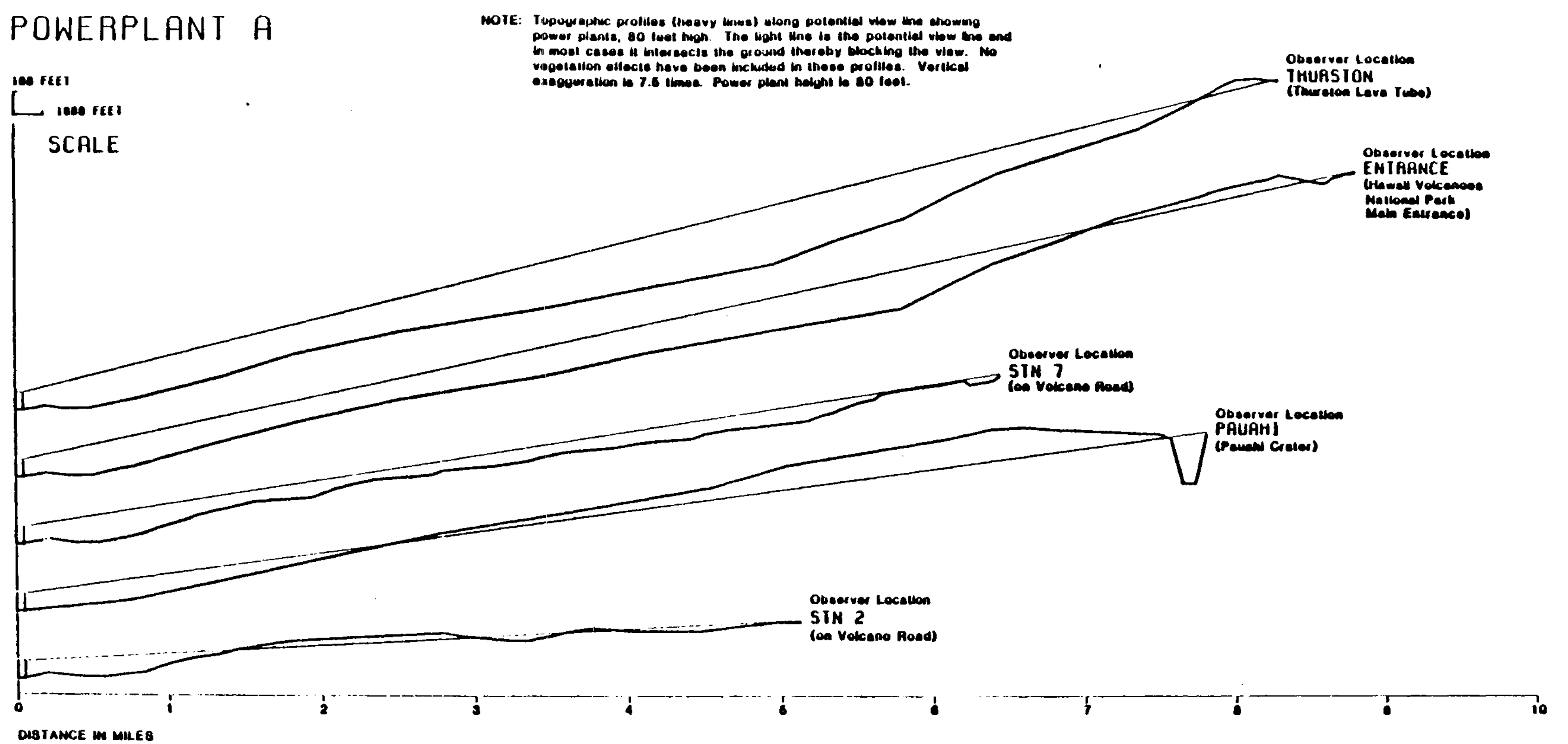

FIGURE 2

VISUAL PERSPECTIVE FROM SELECTED LOCATIONS TO POWER PLANT A

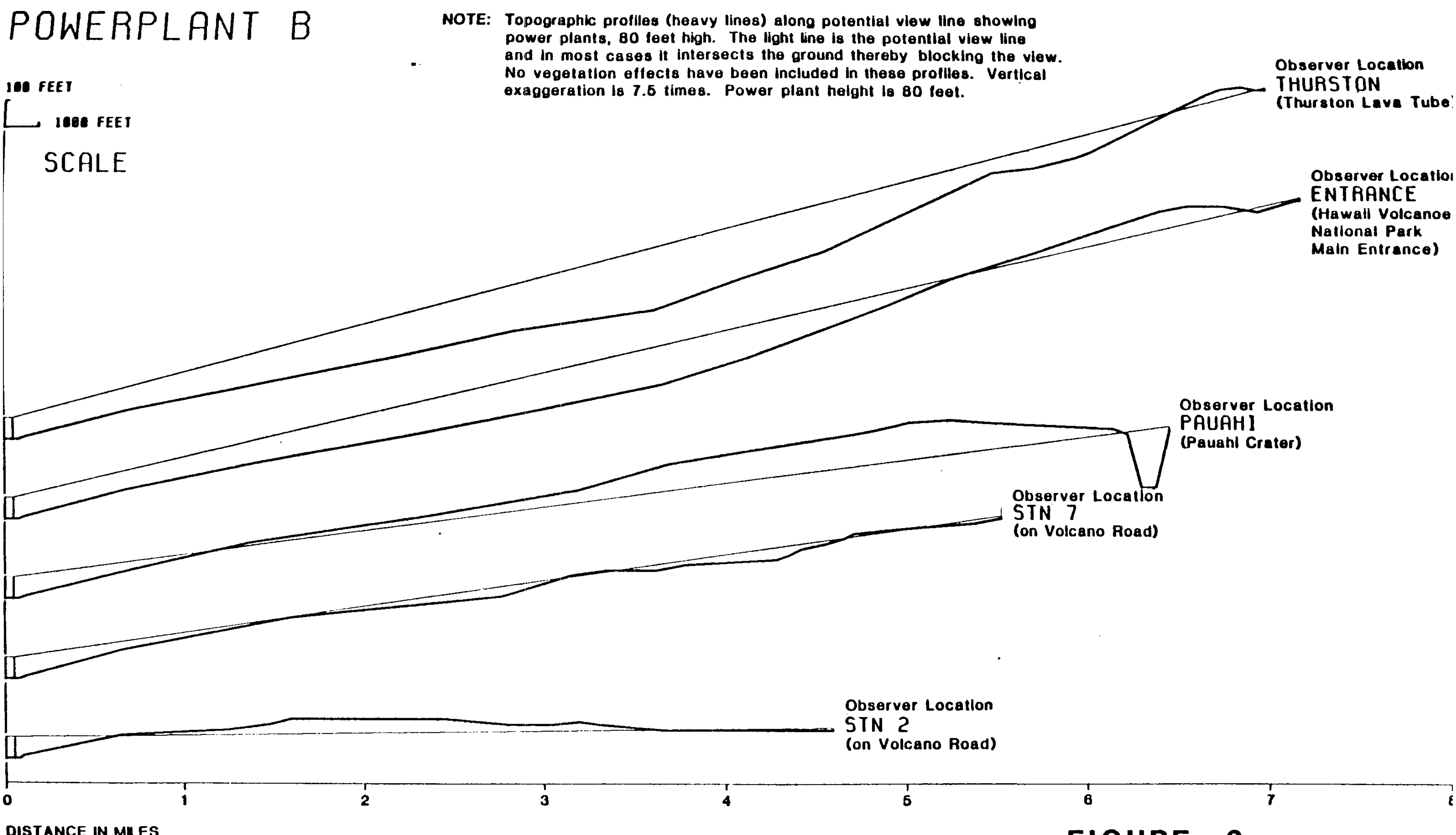

FIGURE 3

VISUAL PERSPECTIVE FROM SELECTED LOCATIONS TO POWER PLANT B

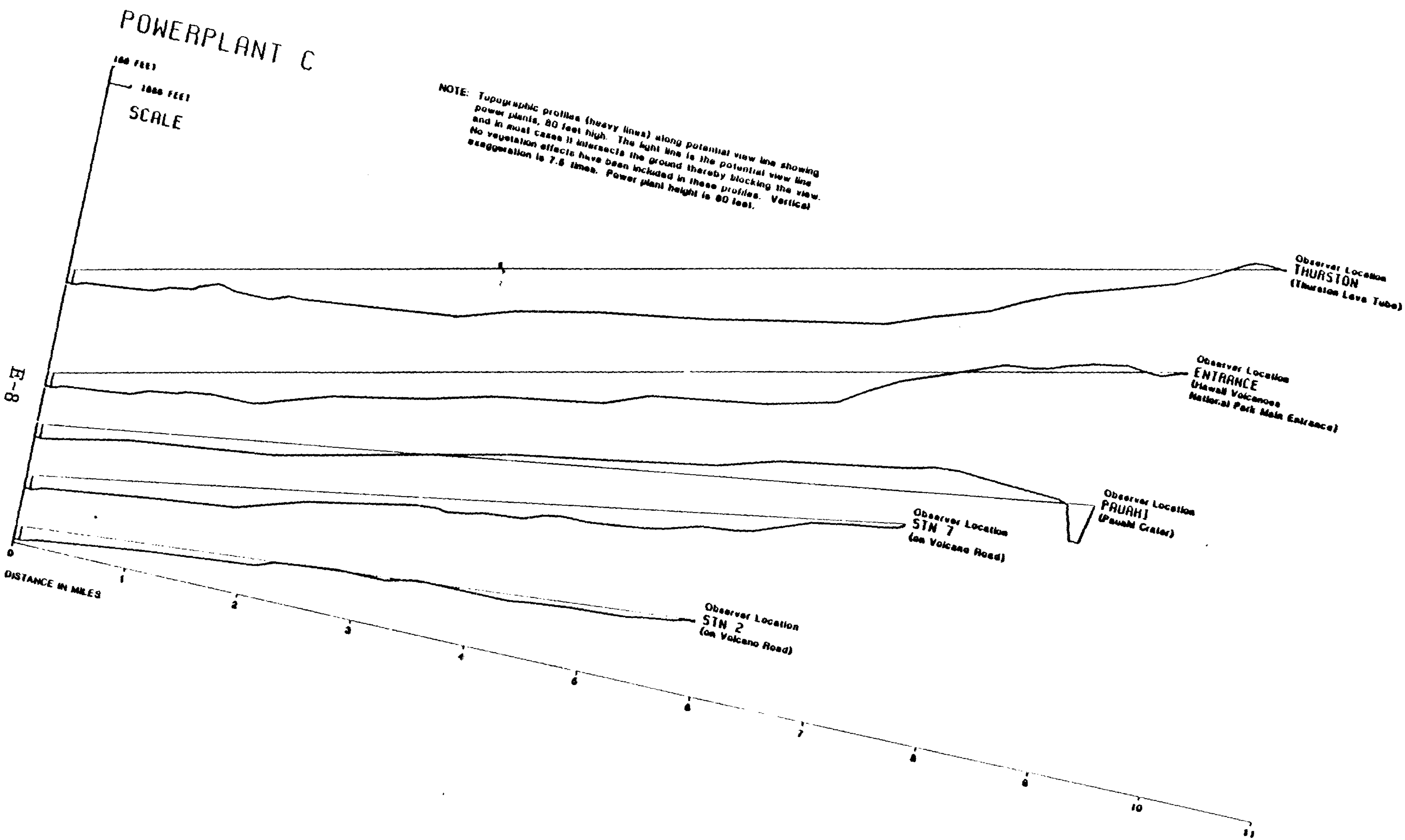

FIGURE 4

VISUAL PERSPECTIVE FROM SELECTED LO
TO P

POWERPLANT D

NOTE: Topographic profiles (heavy lines) along potential view line showing power plants, 80 feet high. The light line is the potential view line and in most cases it intersects the ground thereby blocking the view. No vegetation effects have been included in these profiles. Vertical exaggeration is 7.5 times. Power plant height is 80 feet.

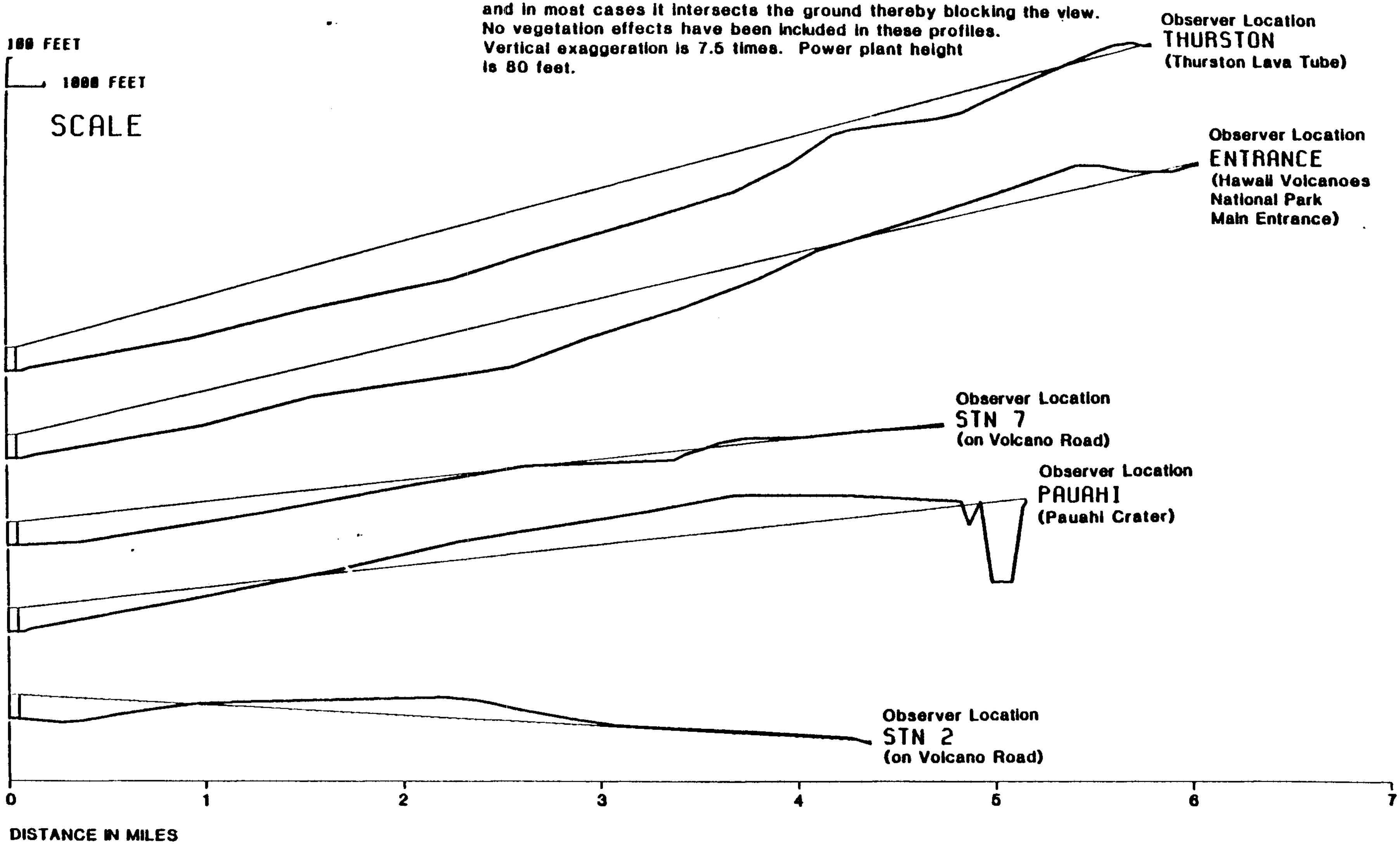

FIGURE 5

VISUAL PERSPECTIVE FROM SELECTED LOCATIONS TO POWER PLANT D

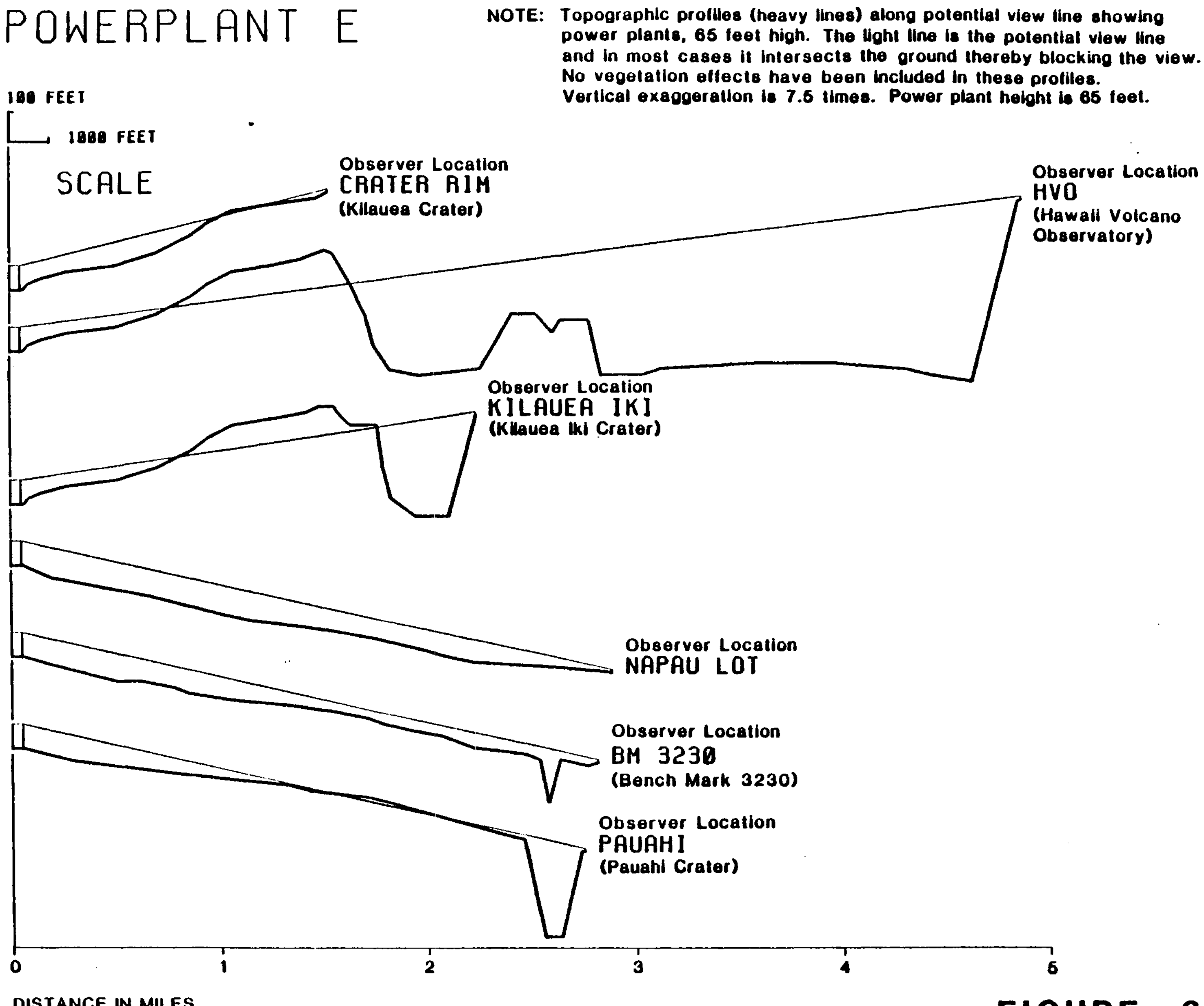

FIGURE 6

VISUAL PERSPECTIVE FROM SELECTED LOCATIONS TO POWER PLANT E

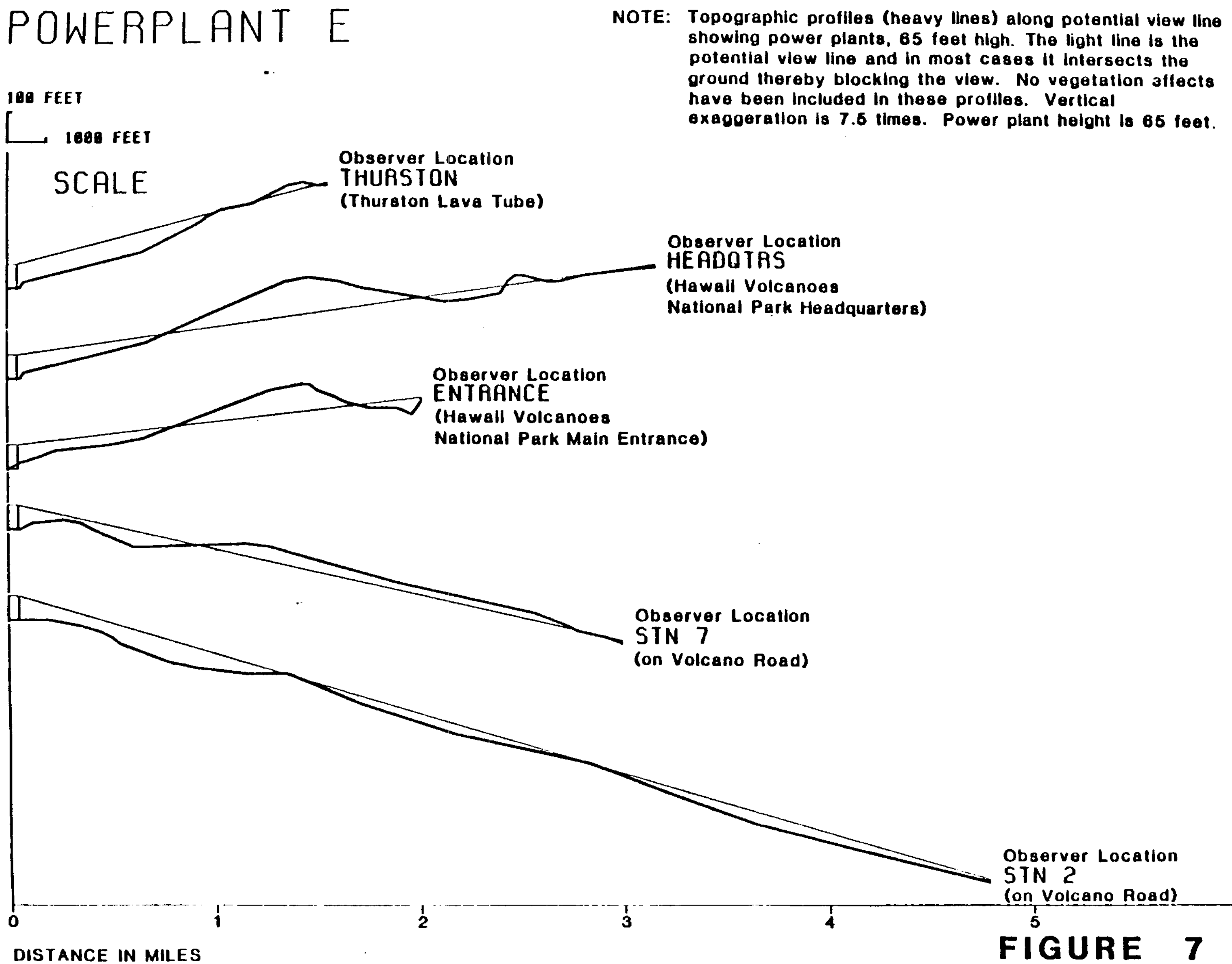

FIGURE 7

VISUAL PERSPECTIVE FROM SELECTED LOCATIONS TO POWER PLANT E