POHOIKI GEOTHERMAL TRANSMISSION LINE ROUTING STUDY

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SUMMARY

Two 69 kv transmission lines will be required by 1991 to carry 25 megawatts of power from the proposed geothermal-electric power plant in Pohoiki to the Puna Substation near Keaau. This report describes the process of identifying the transmission line routes based on an analysis of environmental, social, economic and technical factors.

The methodology used for selection of the route is a sequence of steps organized into two phases. The first phase narrows down the number of routing possibilities by identifying optimum corridors for further study. Numerous data factors were evaluated in light of opportunities and constraints for the location of a transmission line, and then displayed in map form. These factors included exclusion areas such as protective subzone lands; geophysical factors such as slopes, soils and geologic hazards; biological considerations including special vegetation zones and wildlife habitats; socio-economic conditions such as land use, land regulation and land ownership patterns, recreation and archaeologic resources, and transportation and utility networks; and cost considerations based on land value, accessibility and maintenance requirements. An overlay mapping technique aided identification of less constraint areas for a transmission line, within which, potential corridors were delineated.

Phase 2 of the routing study leads to the selection of two specific route alignments based upon a more detailed analysis of conditions *within the corridors*. First-hand field observations by technical specialists such as archaeologists, botanists, entomologists, geologists, landscape architects and environmental planners, as well as secondary source material were used to identify and map data directly influencing the location of the transmission lines. The data factors for Phase 2 include land use, land ownership, land regulation, visual resources, vegetation zones, wildlife habitats and archaeological and historic sites.

The route identification process was accompanied by public involvement including meetings with State and County government agencies and community workshops in the study area.

Two alignments were identified between the proposed Pohoiki geothermal plant site and Puna Substation. One alignment heads mauka, skirting Leilani Estates and crossing Kalapana Road. It then proceeds northerly, passing mauka of Pahoa and Highway 130 until just before Keaau where it crosses Highway 130 to reach the Puna Substation. The other route heads north from Pohoiki, passing makai of Nanawale Estates crossing Hawaiian Paradise Park and tying in with the former railroad alignment which it generally continues to follow to the substation.

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GLOSSARY

GLOSSARY

TERM	DEFINITION
A'a (lava flow)	A rough-surfaced lava flow consisting of layers of glass-like fragments of lava. Pahoehoe lava flows often change to a'a as they advance downhill.
Alignment	The route of a proposed transmission line.
Archaeological site	Locations of prehistoric or historic use or habitation by humans.
Areas of least constraint	During the alignment identification process, the objective is to locate potential routes where the least environmental impacts are thought to occur. See Chapter V for the application of this concept.
Broadscale analysis	The process of mapping and analyzing available information to identify potential corridors warranting further study. See Chapter IV for the factors and criteria involved.
Composite map	This map is a composite of several environmental data factors. The purpose of the composite map is to present an overall view of the constraints and opportunities for the transmission line route. See Chapter V for a description of the final composite maps.
Conductor	The wire or cable suitable for carrying electric current.
Constraint	A condition which discourages, but not necessarily precludes, a transmission line route.
Corridor	A broad, linear area which provides ample space for delineating and studying several alternative alignments for a proposed transmission line.
Detailed analysis	During phase 2 of the routing study, following the broadscale analysis, a detailed analysis of the areas of least constraint is conducted. This activity requires the collection of detailed field data based on site surveys by environmental specialists. See Chapter VI for a description of this phase.
Distribution Line	A set of conductors which deliver electrical energy from the transmission system to the consumer.
Easement	An interest in land that entitles its holder to a specific land use, such as a transmission line.

TERM	DEFINITION
Endemic species	Plants and animals whose natural range is restricted to the Hawaiian Islands and are found nowhere else.
Firm power	Power which can be supplied on a 24-hour, 365 day-per-year basis.
Geothermal energy	The internal energy of the earth, available as heat from heated rocks or water.
Generation capacity	The nominal power output of a production facility, often measured in watts or megawatts.
Indigenous species	Species of plants and animals which are native to the Hawaiian Islands, but also with natural occurrences elsewhere.
Kilovolt (kV)	One thousand volts; a volt is a unit of electrical potential difference and electromotive force.
Load	The amount of electric power delivered or required at any specific point or points on a system. Load originates primarily at the power consuming equipment of the consumers.
Main power grid	Hawaii Electric Light Company's main transmission line system connecting generators to loads which provides power throughout the Island of Hawaii.
Makai	Hawaiian word for oceanward.
Mauka	Hawaiian word for mountainward.
Megawatt (MW)	One million watts; a watt is the absolute unit of electrical power equal to the rate of work represented by a current of one ampere under a pressure of one volt.
Native species	Plants and animals which are present in an environment and were not introduced to that type of environment by humans.
Opportunity	A favorable juncture of conditions for a transmission line route.
Pahoehoe (lava flow)	A smooth-surfaced lava flow, often with wrinkles formed by the movement of liquid lava beneath a cooler but still-plastic crust. The liquid lava sometimes leaves subsurface hollow tubes with diameters of up to 50 feet.
Peak load	The highest portion of demand, usually that occurring less than 10% of that time.

TERM	DEFINITION
Potential alignment	A potential alignment denotes a possible transmission line route. See Chapter V for discussion.
Potential corridors	Potential corridors are derived from the least constraint areas identified in the broad scale analysis. See Chapter IV and V for the identification of the corridors and a discussion of the analytical process.
Preferred alignment	A preferred alignment appears to have the least environmental impact, and to be the most desirable based on the study criteria. See Chapter V for discussion.
Pu'u	Hawaiian term for a hill, peak, or mound.
Rare and endangered species	Rare species or subspecies are animals or plants which are in such limited numbers throughout their range that they may become endangered if their environment worsens. Endangered species are threatened with extinction. Both terms have a legal definition and are used here in that sense.
Registered historic site	The legal recognition of an historic property. The *National* and Hawaii Registers of Historic Places are planning tools used to assess, but not necessarily prevent, the potential impact of a publicly funded, licensed or permitted activity on the cultural resources or heritage of the State.
Right-of-Way (ROW)	A legal right of passage over another person's land; the land used by a public utility.
Rift zone	A system of fractures and faults in the earth's crust.
Seismic	Pertaining to an earthquake or earth vibration, including those that are artificially induced.
Study corridors	Corridors selected for study in the detailed analysis phase. See Chapter VI.
Substation	A subsidiary station in which electric energy is transformed. It is often combined with a switching station.
Switching station	A subsidiary station in which electrical energy is switched from one circuit to another. It is often combined with a station.
Transmission line	A set of conductors which transport electrical energy between generators and loads.

CHAPTER I

CHAPTER I: SYSTEM REQUIREMENTS AND STUDY AREA

A. PROPOSED GEOTHERMAL DEVELOPMENT AND REQUIRED TRANSMISSION SYSTEM

Puna Geothermal Venture, a joint venture between Thermal Power Company and AMFAC Energy, Inc. proposes to develop a 25 MW (megawatt) geothermal-electric power plant at the Pohoiki Geothermal site (also referred to as "Pohoiki") in the Puna District, Island of Hawaii. (Exhibit I-1.) The plant would consist of two 12.5 MW generators. The first generator is scheduled to be completed in 1989 and the second in 1993. Thermal Power Company is preparing an environmental impact statement for the geothermal power plant.

Hawaii Electric Light Company (HELCO) is required to purchase[1] the electric power generated by the geothermal power plant and will distribute it to customers on the Island of Hawaii. To do this, HELCO must construct transmission lines to connect the proposed geothermal-electric generators at Pohoiki to the main power grid near HELCO's Puna substation[2] at Keaau, a straight-line distance of approximately 14 miles. It was determined that the most feasible point for connection of the HELCO grid is near the Puna Substation since this is the closest point on HELCO's 69 kV grid that could accept the 25 MW generation. The new transmission lines will be a part of the main power grid which is the total network of transmission lines connecting generating sources on the Island of Hawaii to the system loads at the various substations. HELCO proposes to construct two separate transmission lines capable of carrying 25 MW at 69 kV *(kilovolts)*.

If only a single line were to connect the 25 MW plant to the system, its failure would cause the power plant to be disconnected from the HELCO system. This occurrence would cause a major disruption to HELCO's customers. By installing two lines, HELCO would be able to provide continuous service to its customers and fulfill its obligation to provide and maintain reliable service.[3]

In addition, HELCO engineers have specified that the two 69 kV transmission lines should typically be separated by one-half mile to reduce the probability of losing both transmission lines at one time because of potential hazards such as hurricanes, earthquakes, lava flows and particularly brush fires in Puna District. Less separation may be acceptable where a suitable firebreak exists. For example, Highway 130 is of sufficient paved and cleared width to function as a fire break so that the two transmission lines could be placed on opposite sides of the highway, closer than one-half mile apart.

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1. The federal Public Utilities Regulatory Power Act (PURPA) requires a public utility to purchase electric power from independent producers or developers. Under PURPA, HELCO must buy power if offered for sale by a private producer.

2. HELCO's Puna Substation is located at the site of the former Puna Sugar Mill.

3. Reliable electric service is required by the State of Hawaii Public Utilities Commission standards for electric utility services. Under these standards, HELCO must prevent low voltages from occurring in transmission lines, a condition which may occur when a power source is lost to the main grid. It is desirable to prevent low voltage conditions because they can cause damage and abnormal operation of customer equipment.

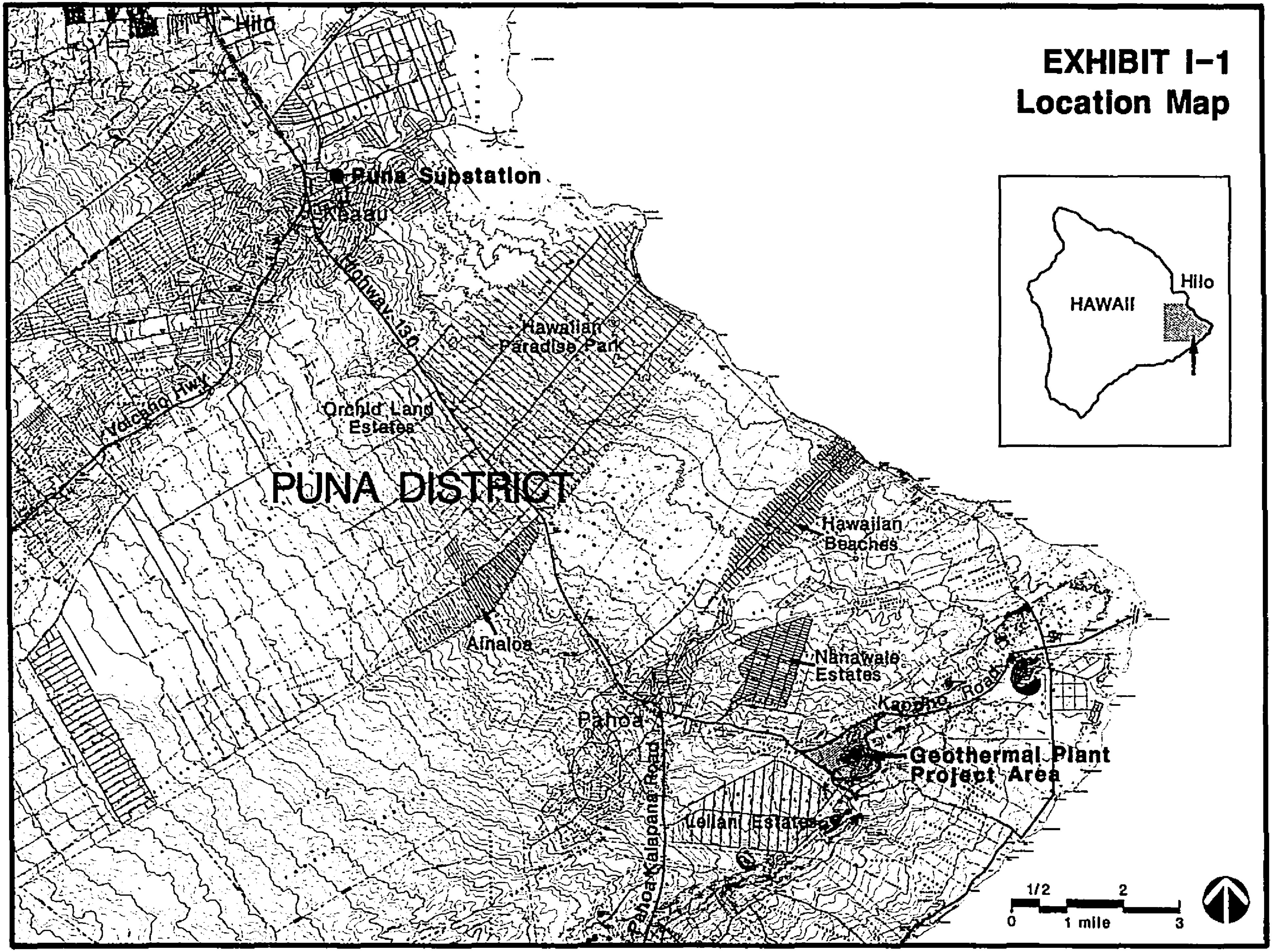

EXHIBIT I-1
Location Map
Hilo
Puna Substation
Keaau
Highway 130
Hawaiian Paradise Park
Volcano Hwy
Orchid Land Estates
PUNA DISTRICT
Hawaiian Beaches
Ainaloa
Nanawale Estates
Kapoho Road
Pahoa
Geothermal Plant Project Area
Leilani Estates
Pahoa Kalapana Road
HAWAII
Hilo
1/2
2
0
1 mile
3

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B. TRANSMISSION LINE FEATURES

Each proposed 69 kV transmission line will consist of three aluminum conductors (0.856 inches in diameter) which will be supported by horizontal post insulators or strings of suspension insulators attached to single wooden poles. The poles will be spaced approximately 300 to 600 feet apart and will carry a steel shield wire (0.375 inch in diameter) at the pole top for protection against lightning. (See Exhibit I-2.) The actual distance between poles will depend upon physical conditions in the vicinity of pole sites and various structural factors, such as tension or weight on the conductors caused by changes in the direction of the alignment or high wind velocities.

The wooden poles will range between 57.5 and 67 feet above ground with 7.5 to 8 feet embedded in the ground. The poles will have diameters of about 1.5 feet at their base, tapering to about 0.75 feet at the top. The wood will be fully treated against termite damage and rot. To provide stability against high winds and changes in direction of the alignment, guy wires and anchors may be installed on some poles.

HELCO requires a typical right-of-way (ROW) between 40 and 50 feet wide for each 69 kV transmission line. This will allow for conductor swing, use of multi-pole structures where necessary and adjustments of pole sites in the field during construction should the pole hole diggers encounter adverse geological conditions (such as lava tubes), archaeological and historic sites, or areas of ecological sensitivity. Additional land segments may be required in some cases to accommodate guy wires and anchors falling outside the typical right-of-way.

C. DEFINITION OF STUDY AREA

Although the required transmission lines will originate at the switching station near the geothermal plant, the origin of the lines for this study is considered to be the edge of the power plant project area (as shown on Exhibits I-1 and I-3). The reason for this is to avoid duplication between this routing report and Thermal Power Company's EIS which will cover the entire power plant area. The terminal point for the proposed lines is the existing 69 kV line that leaves Puna Substation heading west to Kaumana.

Theoretically, the shortest, most direct route between the proposed geothermal resource at Pohoiki and the Puna Substation is a straight line. However, there are numerous intervening factors which may make the idealized straight-line route for a transmission line impractical or undesirable.

The definition of a study region for the routing analysis balances these competing considerations. On one hand, the study region should be large enough to insure that no feasible alternatives are arbitrarily excluded at the outset. On the other hand, route length is obviously a limiting factor. Longer routes require more time, energy, manpower and materials to construct the transmission line. A longer easement is required. Furthermore, the energy loss would be greater over a longer distance.

To define the study region, a broad oval-shaped area was plotted which permits a variety of routing alternatives, including those which are up to 50 percent longer than the straight-line distance between the two terminal points of the proposed transmission lines. (See Exhibit I-3.) To determine this area, the ends of a string

50% longer than the straight-line distance was fixed at each terminal point. The string was then pulled taut at various points along its length, on either side of the straight-lined route to define an elliptical area around the straight-line.

Note that the ellipse includes areas behind the two terminal points, represented in Exhibit I-3 as the lighter-toned shaded areas. Portions of this lighter shaded area are included in the study region, because it is conceivable that a feasible alternative might double-back somewhat behind the terminal point to avoid major constraining factors or take advantage of certain routing opportunities. The study region window also includes areas which extend well beyond the ellipse.

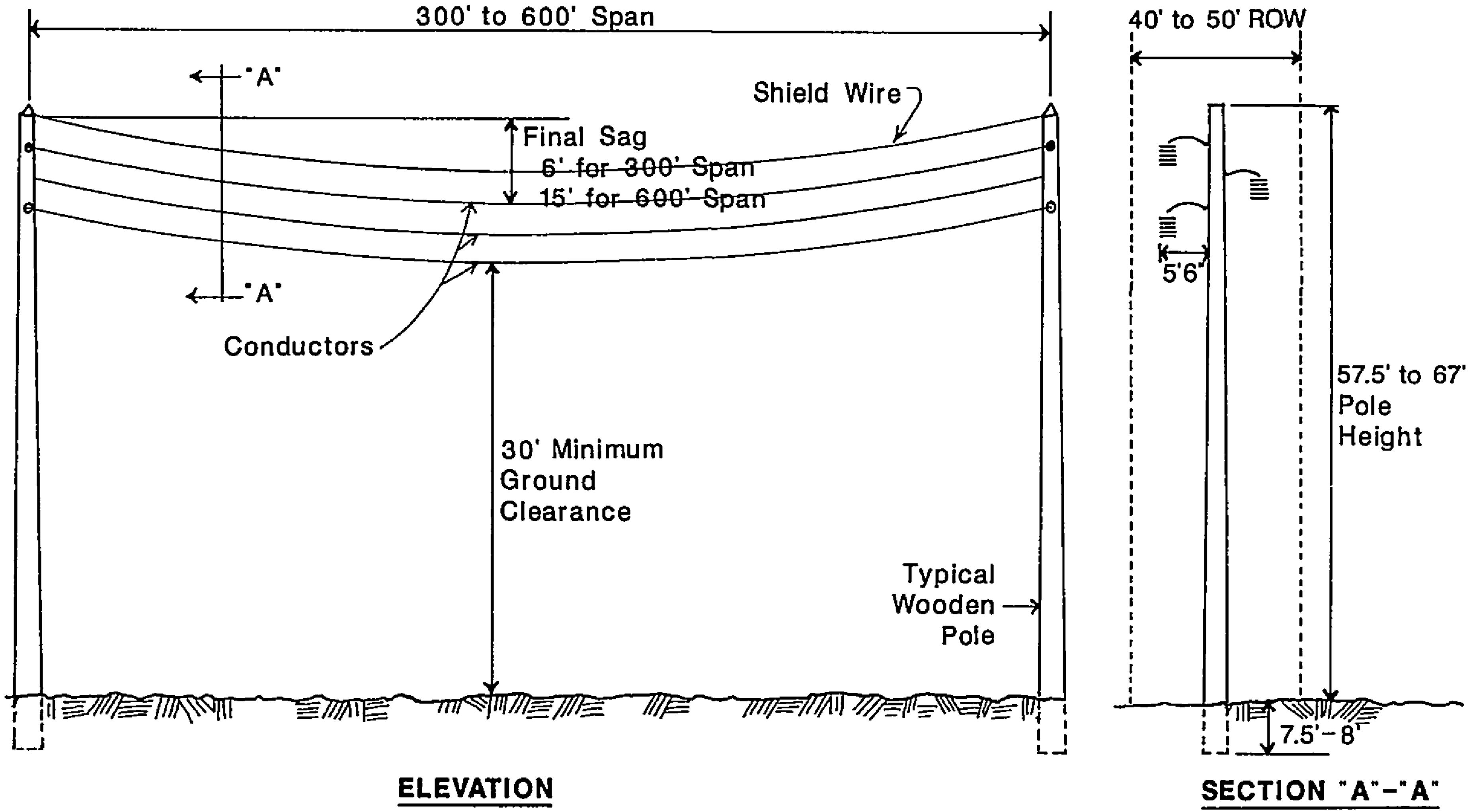

EXHIBIT I-2 Typical 69kV Line Spacing and Line Sag

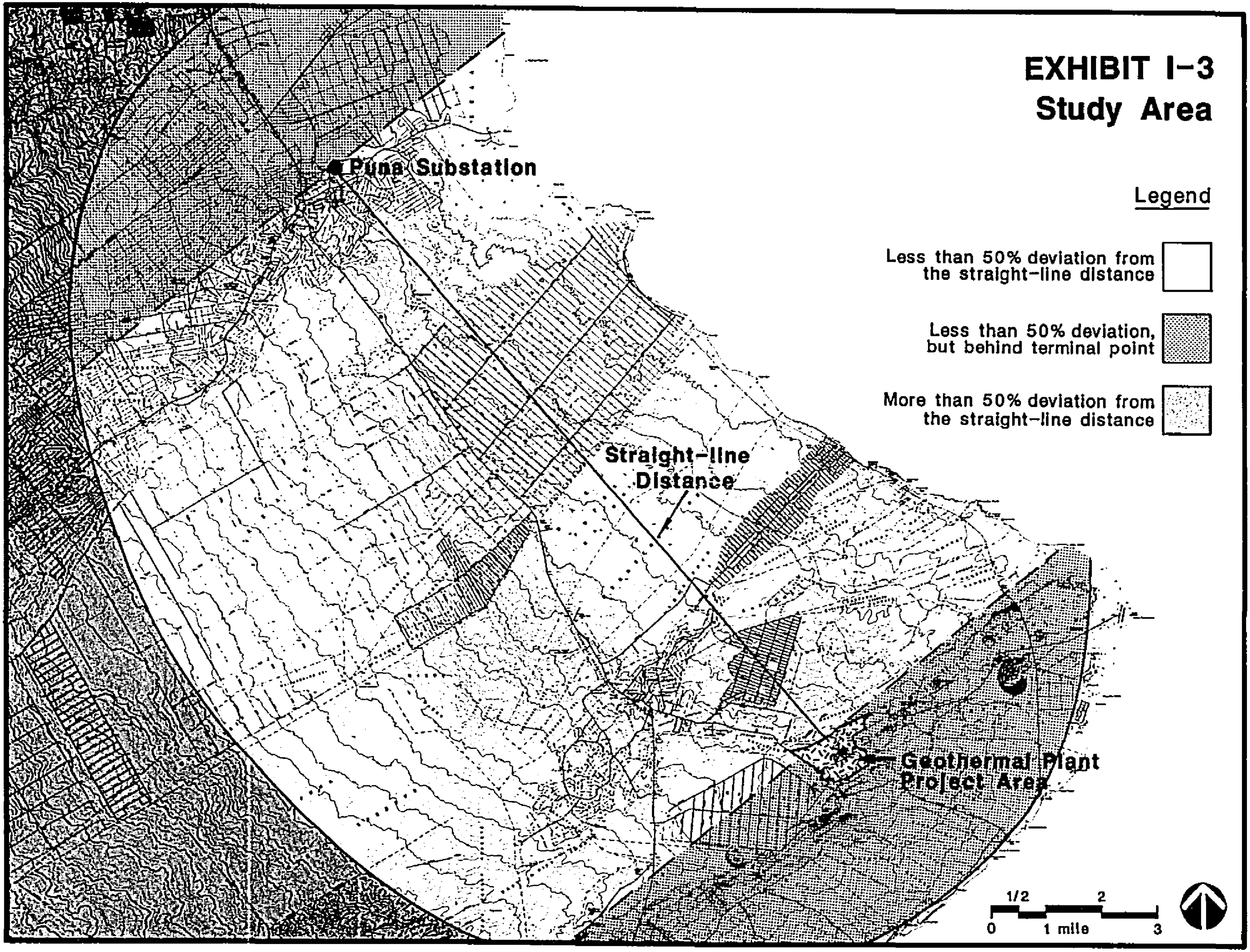
EXHIBIT I-3
Study Area
Legend
Less than 50% deviation from the straight-line distance
Less than 50% deviation, but behind terminal point
More than 50% deviation from the straight-line distance
Puna Substation
Straight-line Distance
Geothermal Plant Project Area
1/2
2
0
1 mile
3

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CHAPTER II

CHAPTER II: TRANSMISSION LINE ROUTING METHODOLOGY

A. OVERVIEW

There is a wide range of geographic alternatives for routing a transmission line between Pohoiki and the Puna Substation, a straight-line distance of approximately 14 miles. HELCO's objective is to select the route which has the least environmental and capital cost, and minimal impact on land use along the route.

The methodology used for the selection of the route is a sequence of steps organized in two phases. Phase 1 narrows down the large number of possibilities by identifying an optimum corridor for further study based upon a broadscale analysis of opportunities and constraints for a transmission line route. The width of the study corridor may vary, depending upon the type and number of constraining factors in any particular vicinity, but will be ample enough to permit several alternative alignments. Phase 2 leads to the selection of a specific route alignment, based upon a detailed analysis of conditions within the study corridor and the development of measures to mitigate the potential adverse effects of the line.

During each phase a comprehensive set of data factors is used to structure the analysis. For Phase 1, Broadscale Analysis, the factors are grouped under five general categories: Exclusion Areas, Geophysical Factors, Biological Factors, Socio-Economic Factors and Cost Factors. The data categories span a wide range of considerations that relate to construction of overhead transmission lines.

Exhibit II-1 outlines the data categories and data factors used in Phase 1. They are defined briefly as follows:

EXHIBIT II-1
PHASE 1
BROADSCALE ANALYSIS
DATA CATEGORIES AND FACTORS

CATEGORY		FACTOR	
A.	Exclusion Areas	1.	Protective Subzones
B.	Geophysical Factors	1.	Slope and Soils
		2.	Geologic Hazards
C.	Biological Factors	1.	Vegetation
		2.	Wildlife
D.	Socio-Economic Factors	1.	Recreation
		2.	Land Use
		3.	Transportation and Utilities
		4.	Land Ownership
		5.	History and Archaeology
		6.	Land Regulation
E.	Cost Factors	1.	Land Value
		2.	Maintenance
		3.	Access

Exclusion areas are those where regulatory controls are so restrictive that they essentially preclude a transmission line route.

Geophysical factors relate to the physical properties and processes of the earth. The specific factors which affect the location of transmission lines are:

- Topographic features, particularly slopes and soils.

- Geologic characteristics, including seismic, volcanic and other types of foundation hazard.

Biological factors include both plant life and animal life. The specific factors are:

- Vegetation zones and their susceptibility to construction activity.

- Wildlife habitats, particularly for species which are susceptible to potential hazards from transmission lines.

Socio-economic factors relate to the human use of land and the effect which a transmission line might have upon the use or value of land. Specific factors are:

- Recreational resources, such as parks, boat launching ramps, hiking and hunting areas.

- Urban and non-urban land uses of various categories.

- The transportation and utilities network.

- Land ownership patterns.

- Historic and archaeological resources.

- Regulatory controls over land use, other than Exclusion Areas, such as special management area, or subzones in State Conservation Land Use District.

Cost factors are those which the utility company, and eventually the utility customers, pay for the acquisition of an easement and the construction and maintenance of a transmission line. These factors are:

- Land value based on assessed valuations.

- Physical conditions which affect the maintenance and operation of the line.

- The relationship between site accessibility and construction and maintenance costs.

The data factors are further defined by criteria which have for the most part been developed in previous scientific and planning studies sponsored by government agencies. The criteria deal with conditions on a general level. They are evaluated in terms of constraints or opportunities for the location of a transmission line and then displayed in map form shown in Chapter IV.

Phase 2, Detailed Analysis, involves a similar analytical framework. However, the analysis is much more detailed, relying on first-hand field observations as well as secondary sources, and covers the corridor areas identified in the Broadscale Analysis which appeared to pose less constraint or provide greater opportunity for transmission lines. Along with a more detailed scale of study, comes a revised description of data categories and factors (Exhibit II-2). These are derived from factors which directly influence the location of a transmission line such as land use, land ownership, land regulation, and visual resources, and from the field survey reports which provided detailed information on insects, birds, vegetation, archaeological sites, geology and soils.

EXHIBIT II-2

PHASE 2
DETAILED ANALYSIS
DATA CATEGORIES AND FACTORS

CATEGORY	FACTOR
A. Physical Conditions	1. Land Use Existing electric distribution and transmission lines Existing telephone lines Productive agriculture lands Archaeological and Historic sites Pahoa Bypass Highway Urban District
	2. Biological Vegetation Insects Birds
	3. Land Ownership Privately owned Publicly owned Hawaiian Home Lands
B. Visual Resources	1. Visual Screens
	2. Views

B. STEP-BY-STEP PROCEDURE

The following is a description of the sequence of steps leading to route selection. The procedure is illustrated in Exhibit II-3. Detailed descriptions of the data sources and methods used can be found in the texts of Chapters IV through VI.

PHASE 1: BROADSCALE ANALYSIS

Step 1: Review System Requirements and Define Study Area

The system requirements and terminal points for the geothermal transmission line were established by HELCO and are described in Chapter I. Definition of the study area is also discussed in Chapter I.

Step 2: Describe and Analyze Transmission Line Alternatives

There are three transmission line alternatives for the project: overhead lines, underground cables and submarine cables. The design features of the latter two and their limitations and advantages relative to an overhead line are discussed in Chapter III.

Step 3: Define Data Categories and Factors

This step provides a structure for analyzing and evaluating physical, social and economic conditions which create constraints or opportunities for routing an overhead transmission line. The data categories and factors are defined in the preceding pages and a more detailed discussion of them is made in Chapter IV.

Step 4: Develop Evaluation Criteria for Broadscale Analysis

Criteria for evaluating the relative constraints and opportunities for the transmission line route within each data category are described in Chapter IV. These evaluations rely almost entirely on secondary source material, particularly data and planning maps prepared by government agencies.

Step 5: Identify Areas of Less Constraint and Potential Corridors

Broadscale evaluation criteria are displayed through an overlay mapping process which highlights the areas of less constraint or opportunity for a transmission line route. Potential corridors are identified by linking the areas of less constraint to provide a continuous connection between the Pohoiki geothermal site and the vicinity of the Puna Substation. The areas of less constraint are more extensive in some areas than in others, so the corridor width varies accordingly.

Step 6: Evaluate and Select Study Corridors

The potential corridors are rated quantitatively by measuring the type and extent of constraint area crossed by a "test route" through each of the corridor segments. This rating, combined with a narrative description, leads to the selection of the study corridor. Steps 5 and 6 are included in Chapter V.

PHASE 2: DETAILED ANALYSIS

Step 7: Map Conditions in Study Corridors

Conditions in the study corridors which will influence the routing of the transmission line are defined and mapped. The types of conditions correspond to the data factors for the broadscale analysis but more detailed criteria and information sources are used for this phase. Secondary sources are used, when available. These are supplemented with visual analyses, aerial photo interpretation, field surveys, and consultation with technical specialists, resource managers and land agents. In addition, the technical and engineering requirements of HELCO are considered at this time. These considerations include maintaining a minimum vertical separation distance on the same pole from a lower voltage line; a minimum horizontal separation distance of one transmission line pole length (approximately 80 feet) from existing telephone lines; a minimum separation distance of three fourths the pole height of a transmission line (approximately 60 feet) from an existing power line unless the power line would be placed on the same poles beneath the transmission line.

Step 8: Identify Potential Alignments

Based on an analysis of constraints in the mapped data, preliminary potential alignments are delineated. Along some sections of the corridor, particularly where there are trade-offs between the types of constraints which are encountered, more than one potential alignment may be shown. The potential alignments are used as a basis for consulting with various government regulatory agency representatives and landowners who would be affected by the proposed easement.

Step 9: Determine Preferred Alignment

Adjustments to the potential alignments are made as the result of consultations in Step 8. A rationale for the selection of the preferred alignment is then elaborated based on the various selection criteria.

C. PUBLIC REVIEW

Workshops were held throughout the route selection process with government agencies and residents of the Big Island, particularly the Puna District, to inform them of the progress of this study and actively solicit their opinions and concerns. Three sets of public meetings were held. Each set of meetings consisted of a workshop for government agencies in Honolulu and in Hilo, and a public meeting in the evening at Pahoa. Government agencies were invited through written notices based on the OEQC mailing list. The public was invited through notices in newspapers, and letters sent to the community associations in Puna. These meetings were held in November and December of 1986 and in September of 1987.

In addition, a special meeting was held in April, 1987 at the request of the Hawaiian Paradise Park Community Association for their membership. The meeting addressed residents' concerns about the impacts of the proposed transmission lines if routed through their community. Representatives from HELCO also met with representatives of this group on two earlier occasions.

Summaries of the workshops, and copies of the notices and mailing lists are included in Appendix A.

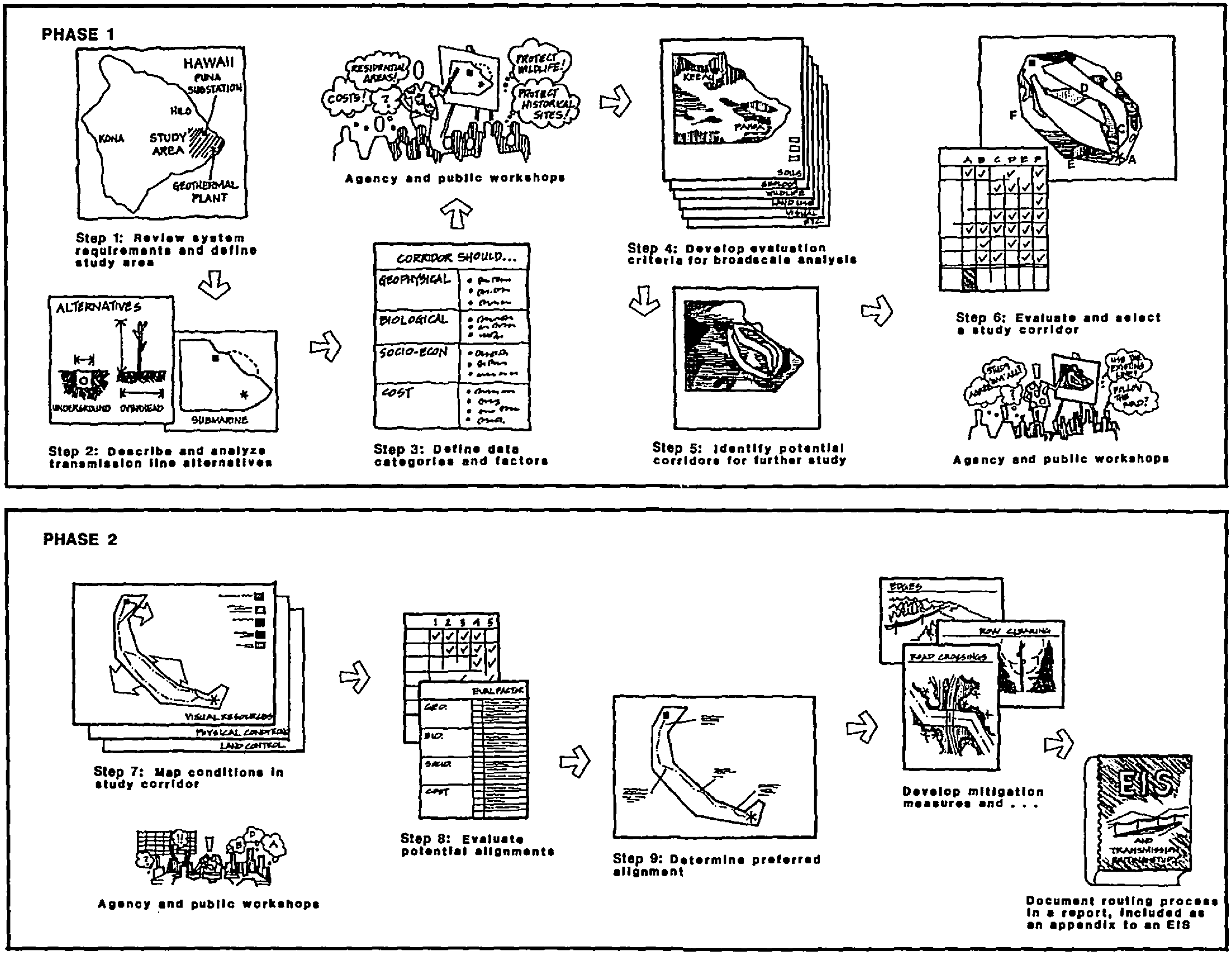

EXHIBIT II-3 Transmission Line Routing Study Process **DHM inc.**

CHAPTER III

CHAPTER III: TRANSMISSION LINE ALTERNATIVES

A. TYPES OF ALTERNATIVES

Electrical transmission lines can be designed and constructed in three basic configurations: overhead lines, underground cables, and submarine cables. A transmission line project may utilize any one of the three forms, or combinations of any two, or all three forms. The determining factors would be environmental considerations, economics and system reliability. Experience has shown that the most economical method of transmitting bulk electrical power over a long distance is via overhead transmission lines. Underground transmission cables are utilized primarily in densely populated areas and over short distances. Nationwide, there are 323,000 miles of transmission lines and only 3,000 miles of these are underground.[4] Submarine transmission cables are utilized primarily where there is no land connecting the two terminal points, such as between Oahu and the island of Hawaii, or if the submarine route is more viable than the overland route. For the transmission of geothermal power from Pohoiki to the Puna Substation, overhead lines are proposed and have been described in Chapter I. Underground cables and submarine cables are presented as alternatives in this chapter.

There are two basic electrical modes to transmit bulk power: alternating current (ac) and direct current (dc). Electric power is usually generated, transmitted, and distributed entirely using alternating current. However, when transmitting bulk power over long distances on an ac system, the energy losses become considerable and use of a dc system, which has significantly lower energy losses, becomes more attractive. As the ac and dc systems are incompatible and cannot be directly connected together, interfaces must be installed at some point (often at the generating plant) to convert the ac to dc, and at another point (often at the load or at a substation) to invert the dc to ac. These interfaces are expensive. The cost may be justified when the value of electric power transmitted over this type of system does not exceed the value of power generated locally and transmitted via ac circuits. This situation varies with the length of transmission lines and other factors. For example, the proposed Hawaii Deep Water Cable program justifies the use of dc for submarine cable routes when crossing channels between the major Hawaiian Islands because of the great distances involved.[5]

This is not the case for this transmission line routing study because the distance between Pohoiki and Puna via a submarine route is relatively short, about 23 miles, of which only 11 miles would be underwater. Therefore only an ac submarine cable was considered.

The following sections will discuss generic issues related to the underground and submarine cable alternatives as compared to an overhead transmission line, and will consider factors which would influence the routing of an underground or submarine cable.

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4. HELCO, Speech to the Hawaiian Paradise Park Community Association, April 7, 1987.

5. The Hawaii Deep Water Cable (HDWC) Program, which is studying the technical feasibility of electrically linking the islands of Hawaii and Oahu (and possibly Maui and Molokai, as well), is considering a submarine, high voltage, direct current (HVdc) cable system. See various reports on the HDWC Program prepared for the Department of Planning and Economic Development, State of Hawaii.

B. UNDERGROUND CABLE

Components

The basic components of an underground transmission system include cables, its encasement, and manholes.

1. Cables and Encasement

At the present time, the most commonly used underground system for 69 kV circuits in the United States consists of insulated cables installed in buried conduits. The cables have either copper or aluminum conductors and are insulated with a synthetic dielectric material. These are installed in conduits encased in concrete for mechanical protection.

2. Manholes

Most underground systems require manholes at intervals along the cable routes. These manholes are used for installing, joining, splicing and maintaining the cable system. The maximum spacing between manholes is limited by the amount of tension which can be used to pull the cable into the pipe. In some cases, the maximum length of cable that can be transported to the job site may also have a bearing on the manhole spacing.

There are certain inherent technical disadvantages associated with underground systems. A primary consideration in the design, manufacturing, installation and operation of these systems is the insulation and cooling of conductors. Overhead conductors are cooled and insulated naturally by the air which surrounds them. Underground cables must be insulated artificially to prevent electric charge from escaping into the surrounding environment. The artificial insulating material, however tends to trap heat, thereby reducing power capacity. The resulting heat build-up impairs the electrical insulating properties of the insulating material itself.

Impacts

The potential impacts relating to the construction, operation and maintenance of an underground cable between the Pohoiki and Puna terminal points have been placed in four categories and are discussed below.

1. Geophysical Impacts

In general, the construction of an underground transmission system would have more extensive impacts on topography and soils than an overhead system because greater alteration to surface and subsurface conditions is involved. The construction of the underground system requires excavation and backfill along the entire length of the cable, whereas the overhead line requires only the installation of poles spaced several hundred feet apart and the area between poles remains relatively undisturbed.

Changes in physical characteristics of the soils affected by an underground line include compaction of surface soils from movement of equipment and personnel, changes in grain size and chemical make-up from accelerated soil weathering caused by earthwork and excavation and soil warming from cable operations, and visible changes in soil color and texture at the ground surface, especially in off-road barren areas.

A related impact is the rate of soil erosion, which would be increased due to greater rainfall runoff over the compacted soils. Also, after vegetation clearing during construction, a different type of vegetation, often less effective at retaining soil, may take root within the easement boundaries. Surface water runoff could be altered in a number of ways as well, including

changes in runoff rates due to changes in soil characteristics and vegetative cover, and changes in surface runoff patterns due to surface grading and excavation.

Alterations to land forms from construction of the underground line may occur by grading within the easement, particularly on hillsides in steep terrain, grading for access roads, and excavating and filling trenches.

2. Biological Impacts

The construction of underground transmission lines tends to affect a variety of vegetation types over the entire length of the corridor. The degree of disturbance may vary. For example, in open grasslands, vegetation would recover rapidly. In mature forests, recovery would be much slower and the likelihood of exotic species reforestation would be high. In the case of overhead lines where routes through tall trees have been avoided, the impacts may not be significant because such an installation, which is greater in height than the surrounding vegetation, does not require cutbacks during construction.

During operation, maintenance of the underground line would tend to take place at manholes. The majority of the surface above an underground line, after the initial recovering by vegetation, would tend to remain undisturbed by maintenance activities. These effects may not be significantly different from those of an overhead line constructed through low forest or ground cover where maintenance pruning would not be required because the line would be above the vegetation.

Wildlife is affected by underground transmission lines primarily because of the changes caused to vegetative habitats. For example, removing vegetation affects wildlife by changing the cover and food supply. These impacts would be felt particularly among Hawaii's native birds. Direct impacts could occur to microorganisms or insect communities which are found at or near the surface.

3. Socio-Economic Impacts

In many respects, the generic socio-economic impacts of an underground cable and an overhead transmission line are similar. Considerations such as land use and land regulation, transportation and utility easements, land ownership and recreation areas are dependent upon the route rather than the type of system which is selected.

In areas where the transmission corridor is exposed to public view, the underground cable would be perceived as having less adverse impact on visual quality than an overhead line would. However, the extent of the overhead line's impact varies according to the closeness of view range, the character of the visual background, the configuration of the overhead line and its supporting structures and the subjective preferences of the viewer.

Overhead transmission line routes through densely developed urban settings have a great deal of potential view exposure. This consideration, in combination with other socio-economic factors, such as high land values, fragmented ownership patterns, restrictive land regulation and potential interference with a wide variety of human activities, sometimes makes undergrounding the transmission cable beneath public streets, along with other utility lines, an attractive option.

However, if an underground line is not placed within an existing right-of-way, the limited use of the land above the line is a disadvantage. For instance, a wall cannot be built over an underground line; crops, trees, bushes cannot be planted over an underground line. Also, construction and maintenance is more time consuming, thus more inconvenient to the public.

The potential impacts of an underground system on historic and archaeological sites are relatively greater than those of an overhead line due to the greater degree of disturbance to surface and subsurface areas. More extensive surveys of an underground route would be necessary to determine the location of archaeological remains.

4. Cost Impacts

Costs specific to the underground system, including the cable material, conduits, installation (trenching, backfill, manholes, joint bays) and operation (energy losses), are very high compared to the capital costs of an overhead line. An underground system between Pohoiki and Puna Substation is estimated to cost $18.6 million or nearly 5 times the estimated $3.8 million cost of the proposed overhead line[6].

Normal operation and maintenance costs are higher for an underground line. Annually, HELCO estimates that an underground line for this project would cost more than the maintenance and repair costs of an overhead line. Also, when something does go wrong with the underground cable, it is more expensive and time-consuming to repair than an overhead line because of the difficulty in locating the cause of cable failure and getting access for repair crews and equipment. The cost of service restorations are three times greater than an overhead line.[7]

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6. HELCO, Speech to the Hawaiian Paradise Park Community Association, April 7, 1987.

7. Ibid.

C. SUBMARINE CABLE

Components

The components of a submarine cable system[8] are as follows:

1. Cable

Submarine cables consist basically of a central conductor surrounded by insulating material, enclosed in hard armoring. There are four types of submarine cables depending upon the type of insulation: self contained oil-filled, pipe, solid paper and solid dielectric. The self contained oil-filled cable has a history of good performance in the transmission of both 138 kV and 69 kV power, and would most likely be the type of cable used for this kind of project. The pressurized oil, or dielectric fluid, is very light, similar to mineral oil.

2. Terminal Stations

In addition to the cable itself, a submarine cable system requires terminal stations where the cable is brought above ground and connected to overhead equipment or lines. These would be located close to the shoreline. For public safety, system security, and reliability, the cable is usually buried in a trench for approximately 100 feet from the terminal station.

There are 26 submarine high-voltage electric transmission cables in operation throughout the world. The first submarine cable was installed in 1942. Submarine cables share with underground systems the technical disadvantages of insulation and cooling. In addition, there are other difficulties posed by the marine environment. These include extremely high pressures on the exterior surface of the cable when submerged at depths, the corrosive nature of seawater, and problems with currents and rough ocean bottoms which constitute an abrasive climate to the exterior skin of the cable.

The potential marine route for this project runs parallel to the shoreline between Cape Kumukahi and Kaloli Point. (See Exhibit III-1.) The distance of the route from the shoreline would depend largely upon benthic characteristics. Since the ocean bottom drops sharply from this coastline and the laying of submarine cable in deep waters presents added complications, it is likely that the route would be within a few hundred feet of the shore.

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8. Discussion of cable components and history of usage is based on H. H. Hwang and Bryan Young, A Study of the Feasibility of Linking the Islands of Maui, Molokai, and Lanai with Submarine Electrical Power Cables (Honolulu: University of Hawaii, Hawaii Natural Energy Institute, January 1979); and G. Krasnick and G. A. Chapman, for Hawaiian Electric Company, Inc., and the State of Hawaii Department of Planning and Economic Development, Hawaii Deep Water Cable Program, Phase II-A, Task I: Environmental Analyses) (Honolulu: Parsons Hawaii) March 1984.

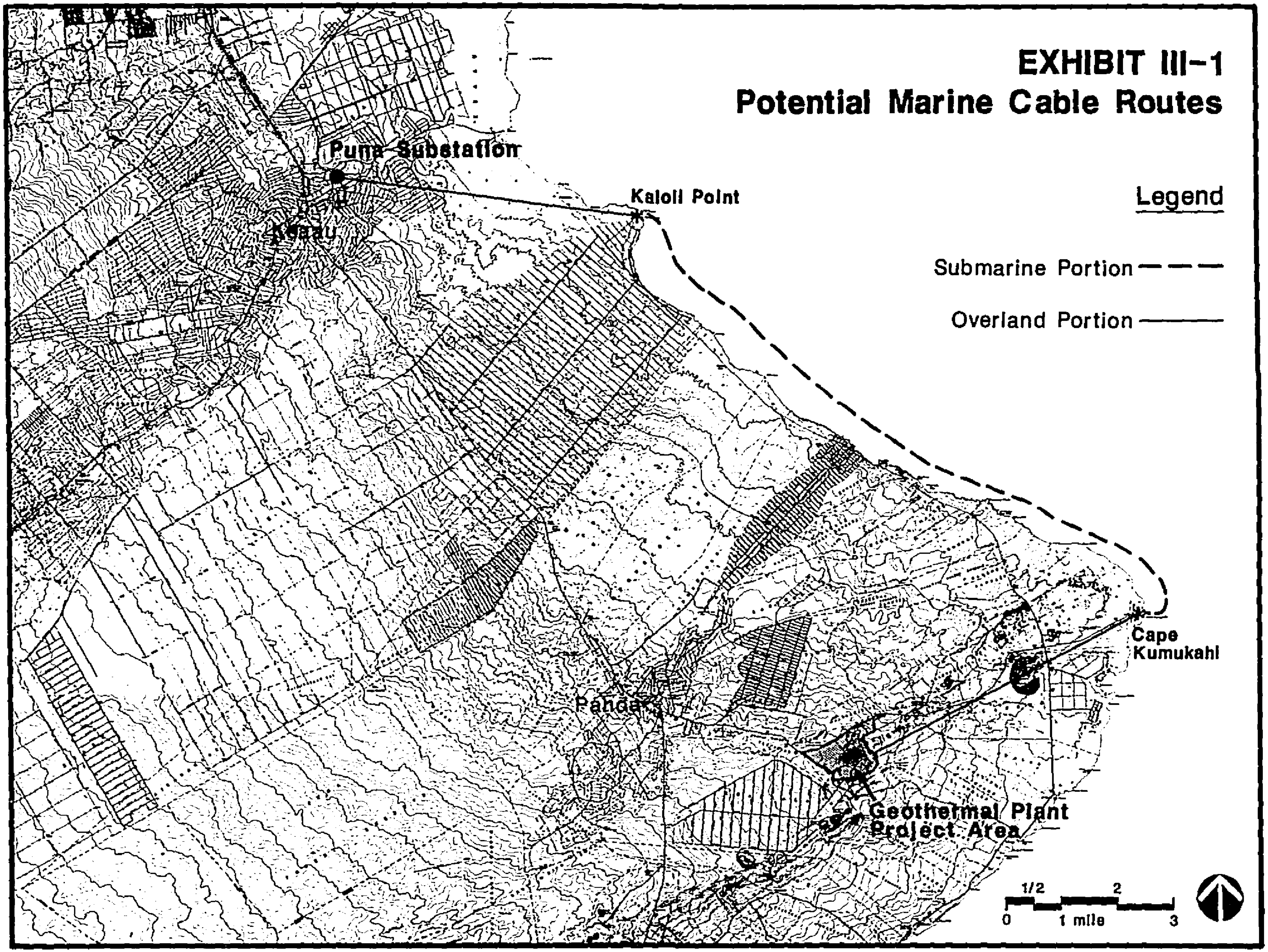
EXHIBIT III-1
Potential Marine Cable Routes
Puna Substation
Kaloli Point
Keaau
Legend
Submarine Portion
Overland Portion
Pahoa
Cape Kumukahi
Geothermal Plant Project Area
1/2
2
0
1 mile
3

DHM inc.

The main impacts related to submarine cables are described below:

1. Geophysical Impacts

This stretch of coast is a series of low bluffs meeting the ocean with abrupt descents of 10 to 40 feet[9]. Much of the shoreline and sea bed consists of irregular, rocky surfaces due to prehistoric and historic lava flows[10]

The typical ocean current flows northwest and generally parallels the coast from Cape Kumukahi to Kaloli Point. Because of the exposure to North Pacific storm swells, surge action is also possible. This action could potentially cause chafing of the cable along the ocean bottom. Since the surface of the ocean flow is rough in this vicinity, additional armoring of the cable may be necessary to prevent wear. The shoreline terminals for the cable would have to be suitably protected against potential inundation and damage from a tsunami triggered elsewhere in the Pacific ring.

Damage from earthquake and volcanic activity is another potential hazard in this area. The study region, including off-shore areas, has one of the highest incidences of historic seismic and volcanic activity in Hawaii. Seismic events could produce underwater landslides which could bury or undermine the cable. The shoreside terminal or portions of the cable could also be damaged or buried by a lava flow. Several lava flows have extended seaward along this coast in historic times.

2. Biological Impacts

According to Chapman and Krasnick, the cable route would not cross any particularly viable coral communities. Therefore, the marine biological impacts would be localized, temporal and generally not significant[11].

Energy loss through the cable will be dissipated as heat and conducted to surrounding marine waters. This discharged heat poses a potential impact to benthic organisms in the immediate area of the cable. The temperature elevation would be confined primarily to the substrate because of the diluting effect and current flow of the surrounding waters.

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9. U. S. Department of Commerce, National Ocean and Atmospheric Admin., United States Coast Pilot, Pacific Coast: California, Oregon, Washington and Hawaii, Sixteenth Edition (Washington D.C.: U.S. Government Printing Office) June 1980.

10. Discussion of geophysical conditions is drawn largely from Ralph Moberly Jr., et. al., Hawaii's Shoreline, Appendix I: Coastal Geology of Hawaii, (Honolulu: University of Hawaii, Hawaii Institute of Geophysics) November 1963..

11. Discussion of biological factors is based primarily on G. Krasnick and G. A. Chapman, op. cit. The substantial shield and armoring (see description in Chapter I) of the cable will prevent potential electromagnetic field effects on marine animals).

Trenching of the nearshore areas will probably require blasting because of the hard substrate, resulting in a temporary shock wave impact to biota in the vicinity. However, endangered marine species such as the humpback whale and green sea turtle are not known to frequent the area of the route[12]. In any event, it is possible to conduct blasting at a safe range and avoid potential harm to these species.

A break of the cable could result in the discharge of insulating dielectric oil into marine waters. It may be necessary, depending upon the repair strategy, to continue to pump oil through the cable to prevent the inflow of sea water. By the time the cable break is located and repaired, a considerable volume of oil could have been discharged into the ocean. However, the dielectric oil is of very low viscosity, solubility and toxicity. The oil would rise to the ocean surface and evaporate rapidly. There are no heavy hydrocarbons or polychlorinated biphenols (PCB) in the oil to cause ecological damage. Biodegradation would occur within thirty days[13].

3. Socio-Economic Impacts

Depending on the depth of the cable and its placement along the ocean bottom, commercial and sport fishing activities may constrain a submarine cable alternative. Eighty-one percent of reported damage to existing submarine cables during a six year period (1975 to 1981) was attributed to external damage[14]. Of this percentage, 45 percent of the damage was caused by fishing and trawling gear, and 22 percent was caused by anchors. Trawling is not a factor along this route, however, because of the rough ocean bottom. The potential for damage from other fishing activities also appears to be remote, based on experience with other undersea cables in the Hawaiian islands[15].

4. Cost Impacts

A major cost consideration is related to route length. A submarine corridor would be an indirect and lengthy route between the geothermal well site and the Puna substation. Installation proceeds much more quickly than with an overhead line because the cable is laid directly on the ocean bottom by a cable-laying barge. However, this savings in labor costs is more than off-set by the expense of the cable material and use of a cable-laying barge. The cost of installing a submarine cable for about 11 miles, including the

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12. S. F. Payne and E. O. Hartwig. "The Ecology of Hawaiian Marine Animals Emphasizing the Impact of Ocean Thermal Energy Converstion (OTEC) on Endangered Species" Lawrence Berkeley Laboratory, Marine Sciences Group MSG-82-017, LBL-13192. 1982.

13. G. Krasnick and G. A. Chapman, op. cit.

14. Sumitomo Electric Technical Review, Number 21, January 1982, "Studies on Submarine Cables with High Resistance to External Damage", Mitsuru Takada, Kusuo Sanjo and Minoru Kameda.

15. Letter from Mr. Henry M. Sakuda, Division of Aquatic Resources, State of Hawaii Department of Land and Natural Resources, to Mr. George Krasnick, Parsons Hawaii, dated November 1, 1983.

terminal stations, is approximately $80.5 million.[16] In addition, there still remains the cost of the overland portion of the marine route which is approximately 12 miles or three-fourths of the proposed overland route. The total cost of the submarine route would exceed $83.5 million. The cost of regular maintenance of a submarine cable is minimal. Emergency repair to the cable, however, represents a significant cost. Adverse weather and sea conditions can seriously impede access to the cable. In 1977, for example, a crew from the Long Island Lighting Company had to abandon its repair barges due to a storm.

5. <u>Other Considerations</u>

Installation of a submarine cable would come under the review of both Federal and State agencies. The U. S. Army Corps of Engineers would base its review of an application to do work in navigable waters on an evaluation of the probable impact of a submarine cable on the public interest, which the Corps defines with a wide range of physical, environmental and socio-economic criteria.

The State government's review of a submarine cable proposal would be coordinated by the Department of Land and Natural Resources (DLNR), which administers the State Conservation District. The entire submarine route is in the Resource (R) subzone of this District, so the cable would require a permit from DLNR's Board. The R subzone is less restrictive than two of the three other Conservation District subzones[17]. Nevertheless it would be necessary to demonstrate that the cable would not adversely affect the "sustained use of the natural resources" of the subzone. Given the uncertainties about the long-term impacts of these cables, this would not be easy to show conclusively.

The submarine route would still require a significant length overland between the geothermal well site to the seashore and from the shore to the Puna Substation. The constraints for these land portions are analyzed in Chapter IV.

D. SUMMARY AND CONCLUSIONS

Environmentally, the impacts of the submarine cable or underground line are, in many respects, as great or greater than those of an overhead line. Although all three alternatives have their own unique set of impacts, none is significantly more adverse than the others.

An overhead line is unique because of its exposure to the public and its potential for contact with plants and animals. In Puna, it may be possible (because of the nature of the relatively flat topography, the significant roadside vegetation and the general lack of extensive view planes) to screen the proposed transmission lines from frequent public view. Careful routing and various design, construction and operations measures, can avoid or minimize adverse impacts on physical and visual resources.

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16. HECO, Letter of May 18, 1987 to DHM inc.

17. The Protective (P) and Limited (L) subzones are more restrictive than the R subzone as to use. The fourth subzone, the least restrictive, is the General (G) subzone.

The cost per mile and the total cost for construction of a submarine cable or an underground transmission line would be substantially higher than for an overhead line. The submarine route, including the overland portions, would be over 23 miles long or about 6-9 miles longer than a reasonably direct overland route. The high cost of these two alternatives makes them relatively infeasible when compared to an overland line.

Chapter IV, which follows, describes criteria for routing an overhead transmission line in a way which responds to sensitive environmental factors.

CHAPTER IV

CHAPTER IV: BROADSCALE ANALYSIS

A. INTRODUCTION

As described earlier, an initial step in the overhead line route selection process is the identification and definition of criteria for broadscale analysis. These criteria consist of data factors that have a bearing on the location of a transmission line. The evaluation of criteria relies essentially upon information which is already available in mapped form without having to do field surveys. This forms a sufficient data base for the broadscale analytical objectives of Phase 1.

The data factors for the routing evaluation are organized under five broad data categories - "Exclusion Area", "Geophysical", "Biological", "Socio-economic" and "Cost". A narrative for each data category describes the issues considered in the routing of an overhead transmission line in the study region. Data factors are described and quantified to provide a basis for comparison.

Under each data factor, with the exception of "Exclusion Areas", the conditions are evaluated in terms of degrees of constraint for the location of transmission lines. These constraints ranged in three degrees from "high" to "low" for each factor, with a description of the criteria used to rate the conditions. A constraint map accompanies the analysis of each data factor. The lower the constraints in a given area, the greater the opportunity for placing a transmission line corridor there.

Each data factor is evaluated separately and equally with no weighting given to any factor. No single factor is a determinant of the route. The routing opportunities are identified through a composite view of the data factors provided by an overlay mapping process.

B. EXCLUSION AREAS

Regulatory restrictions on land use are generally considered potential constraints in the evaluation of physical and socio-economic data factors. In their most restrictive form, regulatory measures may preclude rather than constrain the location of transmission lines. Consequently, such areas are excluded at the outset from the analysis of potential routes. The exclusion areas are as follows:

1. Protective Subzone - The Board of Land and Natural Resources has established boundaries and regulations for four major subzones of the State Conservation District. The most restrictive of these subzones is the Protective Subzone, which includes "restricted watersheds, fish, plant and wildlife sanctuaries, significant historic, archaeological, geological and volcanological features and sites, and other designated unique areas[18].

C. GEOPHYSICAL FACTORS

The geophysical factors considered in the study region are slope and soils, and geologic hazards, particularly seismic and volcanic activity. These factors influence the stability of the transmission poles which support the line, and therefore the reliability of power.

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18. State of Hawaii, Board of Land and Natural Resources, Regulation No. 4, pursuant to Chapter 183-41, Hawaii Revised Statutes, Honolulu, Hawaii, May, 1978.

POHOIKI GEOTHERMAL TRANSMISSION LINE ROUTI

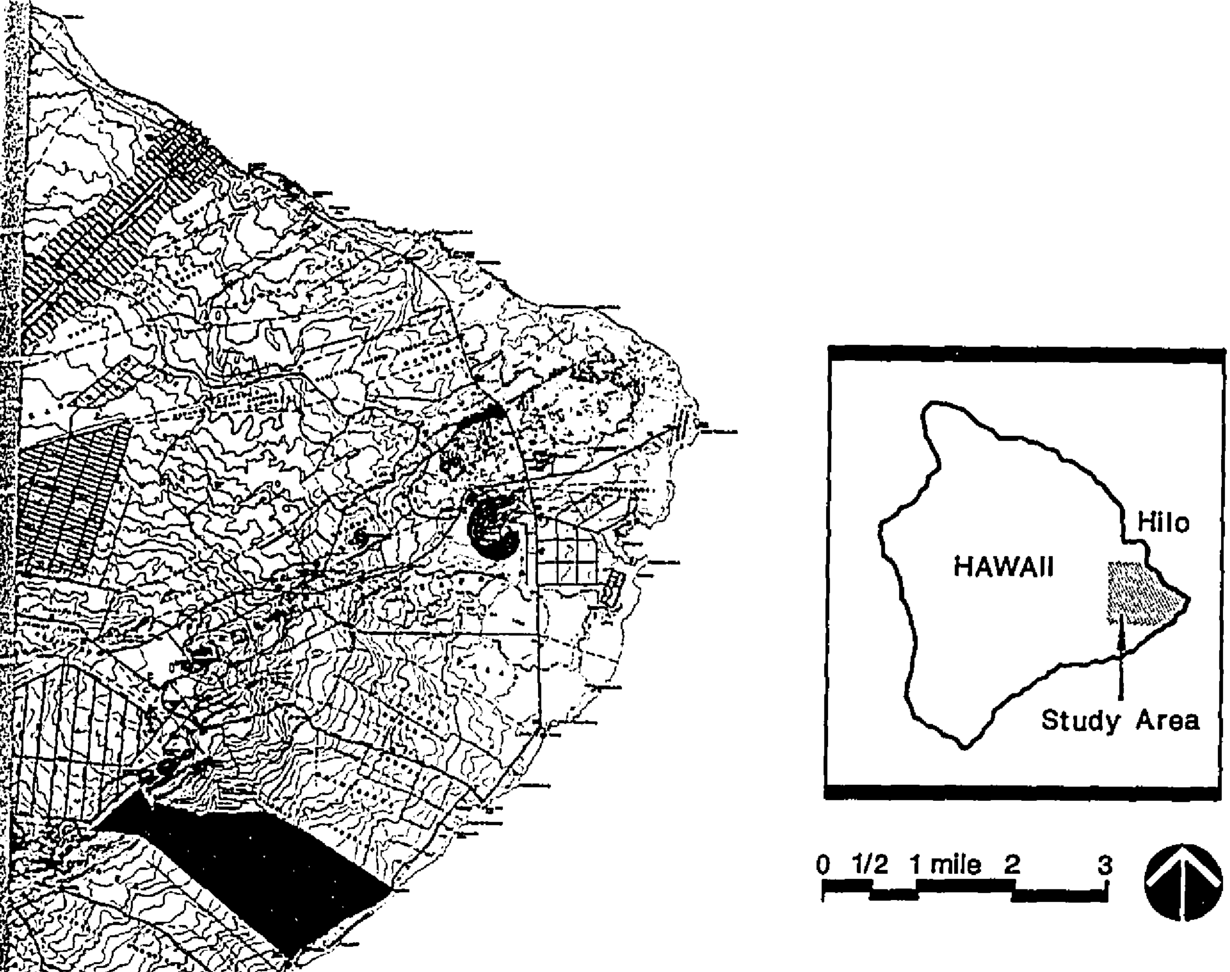
EXHIBIT IV-1

EXCLUSION AREAS

Exclusion Areas

Source

State of Hawaii, Department of Land and Natural Resources, Conservation District Subzones.



ON LINE ROUTING STUDY • DHM inc.

Hydrologic characteristics are not a significant factor in the study region because there are no major streams or inland water bodies. While average annual rainfall ranges from 75 to 200 inches, almost all of the study region has a wet climate with the seasonal variations causing distinctive dry periods.

1. Slope and Soils

Slope and soil characteristics, particularly erosion hazard potentials, are two related factors which should be considered when locating a transmission corridor.

Slope affects the length of transmission lines, location of the line, positions of utility poles and substation, length of access roads, construction methods required for access roads, the amount of earth movement for road and utility pole construction, and vegetation removal. Gentler slopes are more suitable then steeper slopes for pole construction and access road location because road and line distances are shorter and necessary earth movement and vegetation removal are minimal. A common threshold used to distinguish "steep" from "gentle" slopes for land use suitability analysis is 20 percent[19]. This is a standard which is appropriate for identifying "high" constraint areas for transmission corridors. Slopes between 10 to 20 percent are a "medium" constraint.

Soils conditions combine with slopes to define topographic constraints. The clearing of vegetation and placement of structures is less desirable in an area whose soils are subject to considerable wind and water erosion than in areas where this hazard is not as significant. While the utility poles would not occupy a large area, the stability of these structures may be lessened by erosion. In addition, the presence of man-made structures, including access roads, tends to aggravate natural erosion hazards. Thus, soils with severe erosion hazard potential should be avoided, if possible. The U. S. Soil Conservation Service has rated the erosion hazard potential as "severe", "moderate" or "slight" for each of the soil classifications which they have identified and described for the study region[20]. These ratings correspond to "high", "medium" and "low" constraints respectively.

Many areas of the project region are covered by relatively recent lava flows that have not yet deteriorated sufficiently to produce true soil layer. Hawaii's volcanoes produced two types of lava: pahoehoe and a'a[21]. Pahoehoe flows pose a relatively greater constraint because the smooth, hard face of these flows is often underlain by cavities known as "lava tubes". On the other hand, a'a, which is basically the same composition as pahoehoe,

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19. EDAW inc., State of Hawaii Use Districts and Regulations Review, Honolulu, Hawaii, 1969. Plate 10, page 44, Potential Hazard Areas.

20. U. S. Department of Agriculture, Soil Conservation Service, Soil Survey of the Island of Hawaii, State of Hawaii, (Washington, D. C.: U. S. Government Printing Office) 1973.

21. Ibid.

flows to form a "...massive, relatively dense interior...[22]. Pahoehoe flows are therefore considered a "medium" constraint because it can be difficult to locate a suitable suite for transmission pole placement in this material.

SLOPE AND SOILS

DEGREE OF CONSTRAINT	CRITERIA
High	Soil erosion hazard potential rated "severe"; slope greater than 20 percent.
Medium	Soil erosion hazard potential rated "moderate"; pahoehoe lava flows; slope between 10 and 20 percent.
Low	Soil erosion hazard potential rated "slight".

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22. Macdonald, Gordon A. and Agatin T. Abbott, Volcanoes in the Sea: The Geology of Hawaii, University of Hawaii Press, Honolulu, p. 26, 1970.

CORRECTION

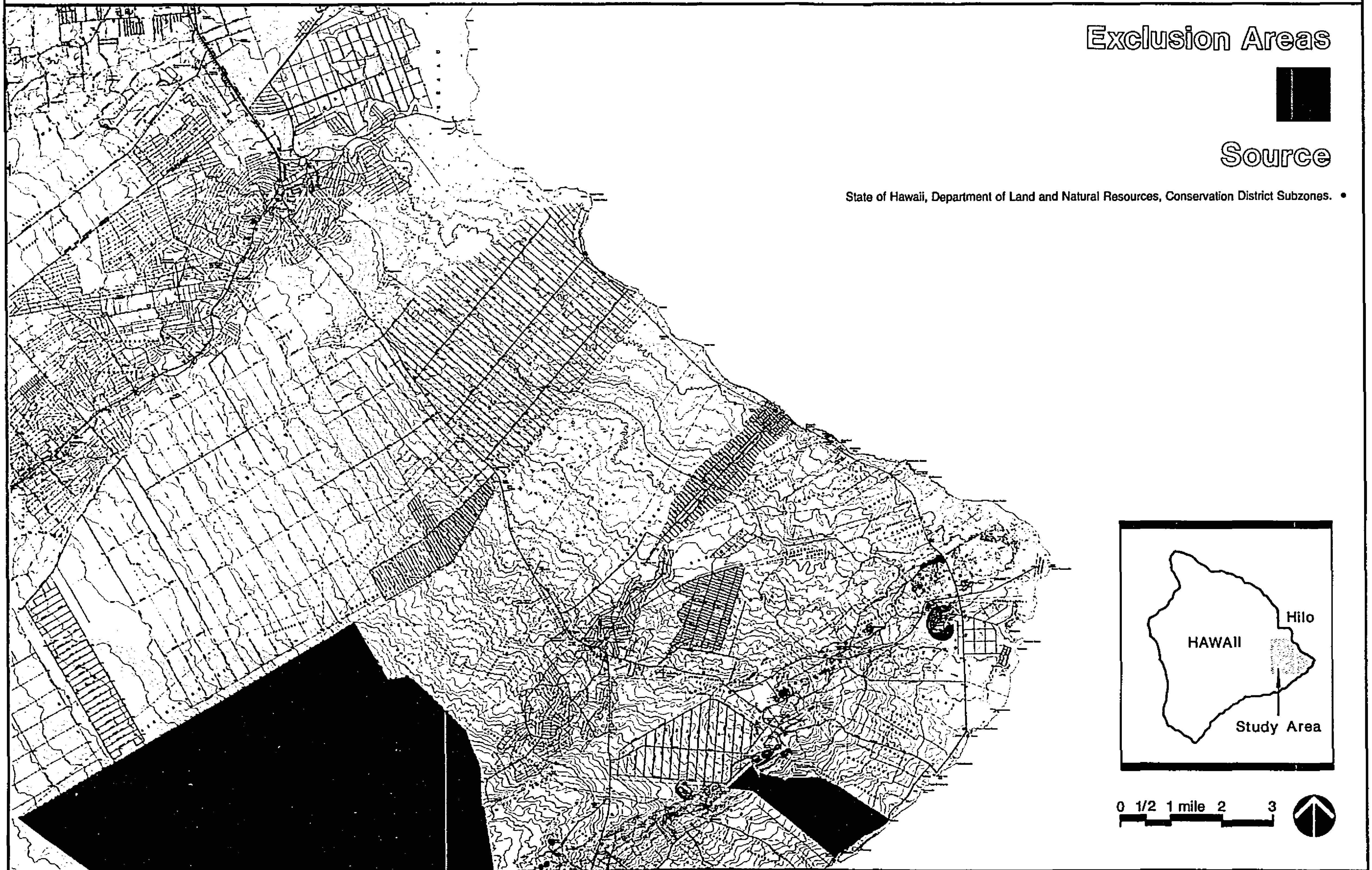
THE PRECEDING DOCUMENT(S) HAS BEEN REPHOTOGRAPHED TO ASSURE LEGIBILITY

SEE FRAME(S)

IMMEDIATELY FOLLOWING

EXHIBIT IV-1

EXCLUSION AREAS



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19. EDAW inc., State of Hawaii Use Districts and Regulations Review, Honolulu, Hawaii, 1969. Plate 10, page 44, Potential Hazard Areas.

20. U. S. Department of Agriculture, Soil Conservation Service, Soil Survey of the Island of Hawaii, State of Hawaii, (Washington, D. C.: U. S. Government Printing Office) 1973.

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SLOPE AND SOILS

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Low	Soil erosion hazard potential rated "slight".

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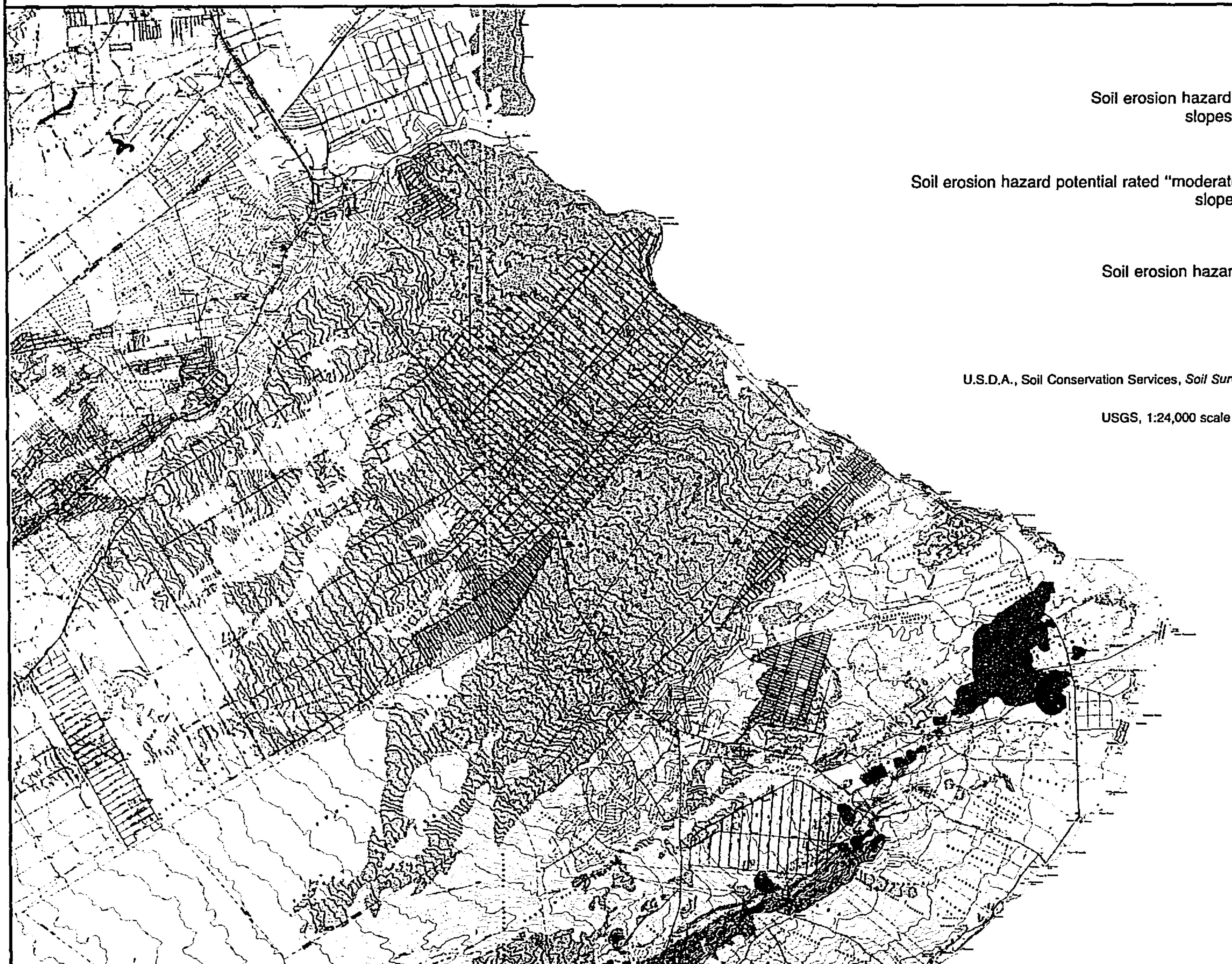
22. Macdonald, Gordon A. and Agatin T. Abbott, Volcanoes in the Sea: The Geology of Hawaii, University of Hawaii Press, Honolulu, p. 26, 1970.

EXHIBIT IV-2

SLOPE AND SOILS



Constraints

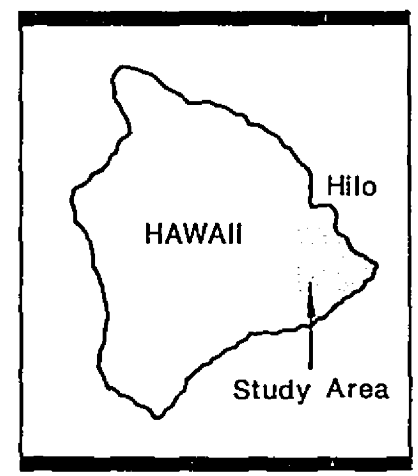
H — Soil erosion hazard potential rated "severe"; slopes greater than 20 percent.

M — Soil erosion hazard potential rated "moderate"; Pahoehoe lava flows; slope between 10% and 20%.

L — Soil erosion hazard potential rated "slight."

Source

- U.S.D.A., Soil Conservation Services, *Soil Survey of the Island of Hawaii, State of Hawaii,* Washington, D.C., 1973.
- USGS, 1:24,000 scale Topographic Quadrangle Maps, 1980-1983.
- DHM inc.



0 1/2 1 mile 2 3

2. Geologic Hazards

The Island of Hawaii is geologically the most active in the Hawaiian archipelago. Many volcanic eruptions and earthquakes on this island have been recorded in historic times. Several faults and rift zones are present, as well as potential lava flows, tubes and vents from volcanic activity. These hazards pose a physical constraint for the location of transmission lines. While the entire project region is a potential hazard area in this respect, there are various degrees of risk according to location. Historical records of lava flows and seismic events provide some indication of the relative risk in various geographic areas of the island[23]. The southern portion of the project area, in particular, is subject to the influence of the Kilauea volcano and rift zone. Part of the west central section of the project region, in the vicinity of Mountain View, is within the recently mapped Mauna Loa Rift Zone[24].

The risk of seismic and volcanic hazard has been rated as "high", "medium" and "low", based on data regarding lava flows and rift zones. The characteristics of these constraint areas are as follows:

GEOLOGIC HAZARDS

DEGREE OF CONSTRAINT	CRITERIA
High	Rift zones; areas covered by lava flows since 1778.
Medium	Other areas which have been covered by lava flows within the past 5000 years.
Low	All remaining areas.

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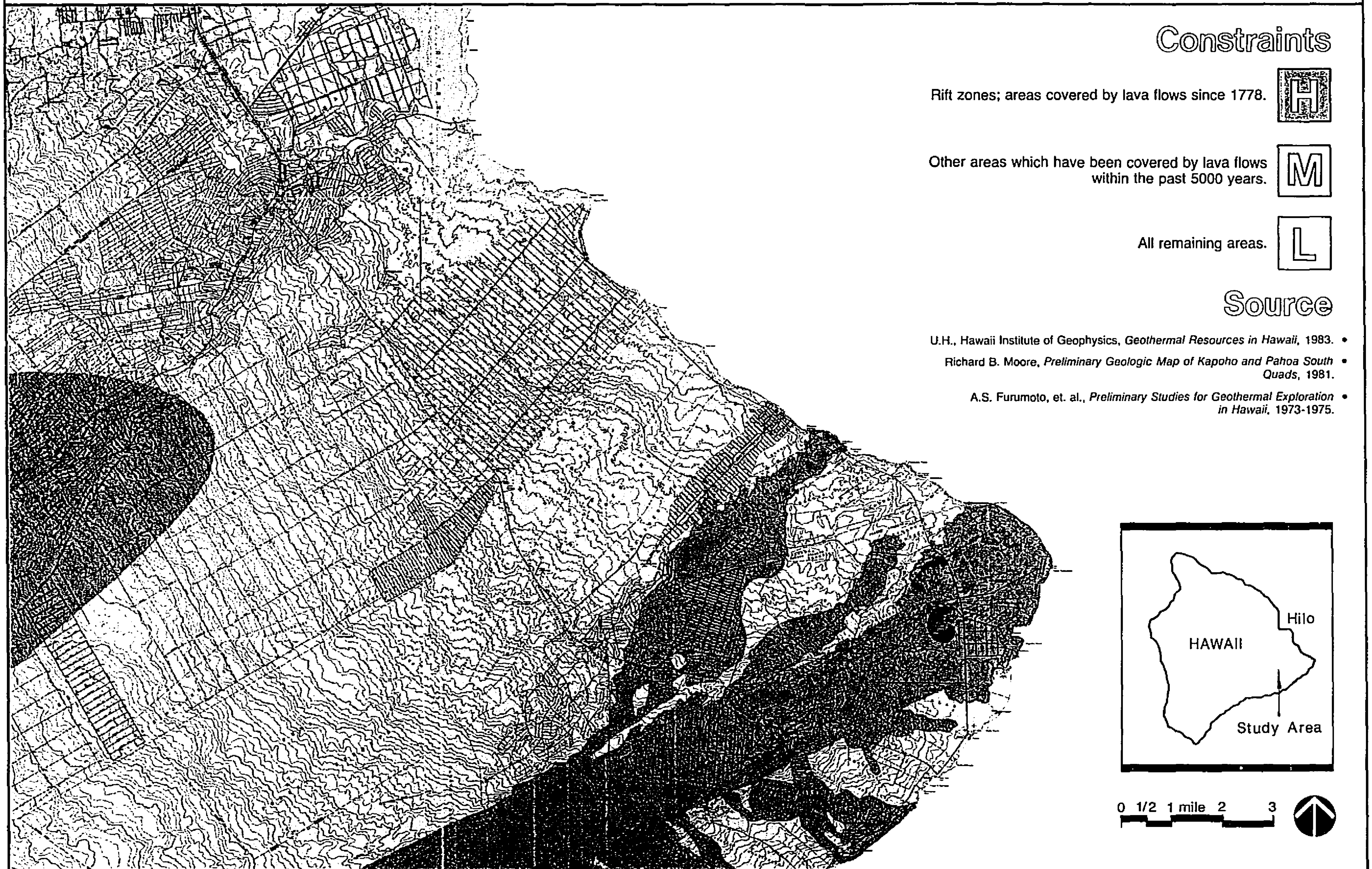
23. U. S. Department of the Interior/Geological Survey, Natural Hazards on the Island of Hawaii, Washington, D. C.: U. S. Government Printing Office, 1977. Figures 2 and 4, pp. 7 and 11; and Donald R. Mullineaux and Donald W. Peterson, Volcanic Hazards on the Island of Hawaii, U. S. Geological Survey Open File Report 74-239, 1974. Written historic records of volcanic and other events commenced shortly after the arrival of Captain James Cook in 1778.

24. University of Hawaii, Hawaii Institute of Geophysics, Geothermal Resources in Hawaii, 1983.

EXHIBIT IV-3
GEOLOGIC HAZARDS



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D. BIOLOGICAL FACTORS

The potential biological effects of 69 kV ac transmission lines include disturbance to vegetation and disruption of habitat for wildlife due to the construction and maintenance of the lines. These effects can be minimized by careful choice of a transmission line route and through construction and maintenance policies.

Based on available scientific data, potential health effects on humans or other species associated with electromagnetic fields are not a major consideration in the routing of these lines because of their relatively low voltages[25]. However, human exposure to transmission lines is a consideration in the following section, Socio-Economic Factors.

1. Vegetation

The construction and maintenance of a transmission line inevitably entails some disturbance to ground areas, including the removal of foliage. The degree of disturbance to plant communities can be reduced in various ways. For example, if no continuous access road is constructed along the transmission line alignment, the potential for cumulative disturbance to adjoining plant communities is reduced. This is particularly important in the case of native ecosystems, which are vulnerable to invasions by competing exotic species of plants and the disruptive activities of feral mammals and humans. Impacts on forest areas may be reduced by "feathering back" the taller trees within the transmission line easement rather than uprooting them to provide adequate clearance for the transmission conductors. Avoiding the use of herbicides or other chemical substances within the transmission line easement would also mitigate potential impacts on surrounding planting communities.

The kind and rigor of mitigating measures necessary to avoid adverse ecological effects depends upon the characteristics of the plant community and its degree of sensitivity to disturbance. In the study region, the plant communities most sensitive to disturbance from the construction and maintenance of a transmission line are the relatively mature forests, as indicated by the typical height and coverage of the tree canopies. All forests with a "closed" canopy (i.e., those having greater than 80 percent tree cover) are considered a high constraint. With the exception of reforestation projects, these are the areas which support the greatest diversity and abundance of plant species and where a greater number of indigenous species are found.

Also, more open-canopy forests (40 to 80 percent cover) with a typical canopy height greater than 30 feet are a high constraint because a transmission line through such areas may require extensive clearance of vegetation.

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25. B. Scott-Walton, K. M. Clark, R. B. Holt, D. C. Jones, S. D. Kaplain, J. S. Crebs, P. Poulson, R. A. Shepherd, J. R. Young, Potential Environmental Effects of 765 kV Lines, prepared by SRI for the U. S. Department of Energy, Report No. DOE/EV-0056, November, 1979; J. E. Bridges, "Environmental Considerations Concerning the Biological Effects of Power Frequency (50 or 60 Hz) Electric Fields," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-97, #1, Jan./Feb., 1978; New York Public Service Commission, Opinion No. 78-13, Case 26529 and 26559: Common Record Hearings on Health and Safety of Extra-High Voltage Transmissio Lines, June 19, 1978.

Vegetation may be cleared initially in order to construct the transmission line and vegetation is maintained in a cut back manner to clear transmission lines. For this project, the minimum clearance between the lowest point of the transmission line and the ground has been specified to be 30 feet.

The following describes the relative constraints pertaining to vegetation for transmission line routing at the regional scale.

VEGETATION

DEGREE OF CONSTRAINT	CRITERIA
High	All closed-canopy (greater than 80% cover) forests; open-canopy (40-80% cover) forests with tall stature trees (greater than 30 feet)[26].
Medium	All forest areas with an open-canopy and medium statute trees (6 to 30 feet tall).
Low	All remaining areas, including agricultural and urban uses and barren lava flows.

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26. Approximates classifications used in James D. Jacobi, Mapping the Natural Vegetation of the Hawaiian Islands, March 7, 1983. Only a portion of the study region has been mapped according to this classification system. For the remaining areas, maps were produced by DHM inc. based on aerial photo interpretation and field work by Lee Hannah and Linda Cuddihy, using simplified version of the Jacobi system to classify vegetation zones according to tree species and forest type.

EXHIBIT IV–4
VEGETATION

Constraints

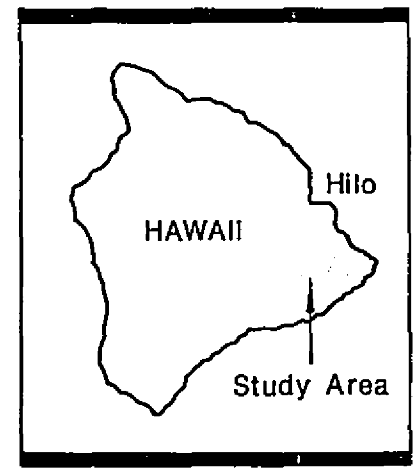
H — All closed-canopy forests; open-canopy forest with typical tree height above 30′.

M — Open-canopy forests with typical tree height between 6′ to 30′.

L — All remaining areas, including agricultural and urban uses and barren lava flows.

Source

- James D. Jacobi, *Mapping the Natural Vegetation of the Hawaiian Islands,* March 7, 1983.
- U.S. Fish and Wildlife Service, *Jacobi System Vegetation Maps— Advance Prints,* 1979-1984.
- U.H. Environmental Center, Lee Hannah, and Linda Cuddihy, Vegetation Maps based on Jacobi System for Kapoho and Pahoa South Quads, 1984.
- DHM inc.



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2. Wildlife

In the study area, the focus of wildlife concerns relative to a transmission line route is on birds or flying mammals and their habitats. This is because of the presence of native rain forests, particularly in the Nanawale Forest Reserve, but also, perhaps, in the extensive Ohia forests in the Puna area. Indigenous land mammals are of relative insignificance. The Hawaiian Bat (Lasiurus cinereus semotus), listed as an endangered species, is the only endemic terrestrial mammal that may be found in the region. Since it depends upon flight, its relationship to transmission line concerns is more similar to that of birds than of other land mammals. Common mammals such as the mongoose and the feral pig, goat and sheep destroy some of the best bird habitats and often prey on birds or compete with them for forage[27]. Endemic insects and land snails are to be found in the same habitats as the native bird species, since both are dependent on the same ecosystem.

The definition of constraint areas for bird habitats is closely related to vegetation zones. The most readily defined habitat for rare and endangered bird species is the closed-canopy native rain forest. The rain forest offers a greater diversity and volume of habitat for forage and can therefore support a greater number of bird species and a greater density of birds. It is here that endangered species of the Hawaiian Honeycreeper sub-family (Drepanidinae) can be found; such as the Akiapola au (Hemignathus munroi) the Hawaii Akepa (Loxops coccineus coccineus), the Hawaii Creeper (Loxops maculatus mana) and the Ou (Psittirostra psittacea). There are several other *endemic birds*, which, while not designated as rare and endangered species, are dependent on native forests; these include the Amakihi (Hemignathus virens virens), the Elepaio (Chasiempis sandwichensis sandwichensis), the Omao (Phaeornis obscurus obscurus), and the Apapane (Himatione sanguinea sanguinea)[28].

The Io, or Hawaiian Hawk (Buteo solitarius), is an endangered species that can also be found in the study region. It has a wide range and is not strictly dependent on the native forest[29]. However, since it tends to areas dominated by native vegetation and avoids rockland communities, it is included here as requiring habitats similar to those of other species totally dependent on native forests.

A transmission line route through a closed-canopy native forest would require the removal of vegetation, thereby reducing habitat. Disturbance to the forest and an opening in the canopy would also promote the introduction of competing plant species and access by feral mammals and humans, which

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27. J. K. Baker and C. A. Russell, "Mongoose Predation on a Nesting Nene", Elepaio (40:51-52) 1979. d. Mueller-Dombois and G. Spatz, "The Influence of Feral Goats of the Lowland Vegetation in Volcanoes National Park", Phytocoelogia (3:1-29) 1975. G. Spatz and D. Mueller-Dombois, "Succession Patterns after Pig Digging in Grassland Communities on Mauna Loa, Hawaii, Phytocoelogia (3:346-373) 1975.

28. J. M. Scott and J. D. Jacobi, Hawaii Forest Bird Survey (Honolulu: U. S. Fish and Wildlife Service) 1981.

29. Hawaii Audubon Society, Hawaii's Birds, Second Edition (Honolulu: Hawaii Audubon Society) 1978.

would have a long-term adverse effect on the quality of the habitat. Moreover, the presence of transmission lines in these forests creates a potential collision hazard.

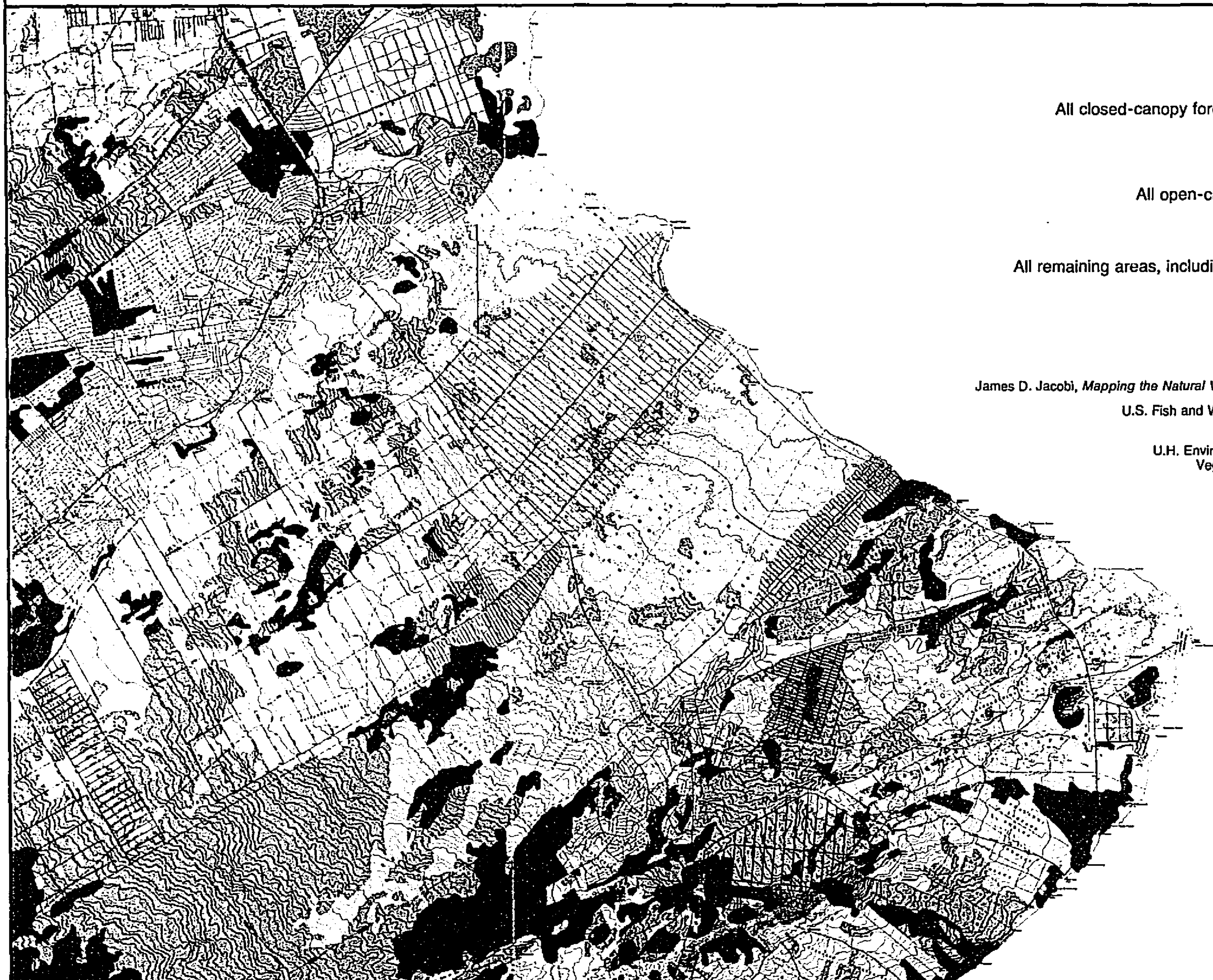
The relative wildlife constraints can, therefore, be defined as follows:

WILDLIFE

DEGREE OF CONSTRAINT	CRITERIA
High	All closed-canopy forests (greater than 80% cover).
Medium	All open-canopy forests (40-80% cover).
Low	All remaining areas, including agricultural and urban uses and barren lava flows.

EXHIBIT IV-5

WILDLIFE



Constraints

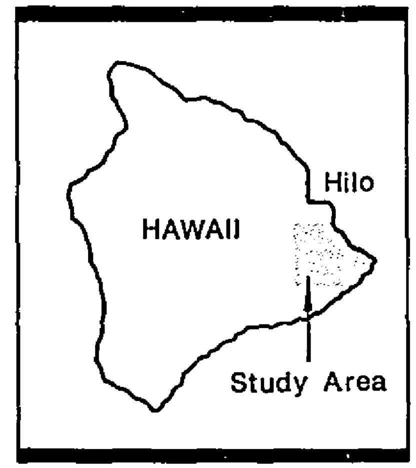
All closed-canopy forests (greater than 80% cover). **H**

All open-canopy forests (40-80% cover). **M**

All remaining areas, including agricultural and urban uses and barren lava flows. **L**

Source

- James D. Jacobi, *Mapping the Natural Vegetation of the Hawaiian Islands*, March 7, 1983.
- U.S. Fish and Wildlife Service, *Jacobi System Vegetation Maps—Advance Prints*, 1979-1984.
- U.H. Environmental Center, Lee Hannah, and Linda Cuddihy, Vegetation Maps based on Jacobi System for Kapoho and Pahoa South Quads, 1984.
- DHM inc.



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E. SOCIO-ECONOMIC FACTORS

Socio-economic considerations in the routing of the proposed transmission lines relate to human uses of land in the study region. As previously noted, scientific evidence indicates that the electromagnetic fields of 69 kV ac transmission lines do not cause adverse biological effects on human beings. Nevertheless, the public seems to have negative perceptions of transmission lines based on aesthetic values and uncertainty regarding potential health risks.

There are also certain nuisance factors associated with transmission lines. For example, a transmission line easement which bisects a property may be seen as detracting from the property's future use potential. A more direct nuisance effect is the potential interference with AM radio and television reception under certain conditions due to sparking and corona discharge from transmission lines. This problem can be eliminated by proper design, installation and maintenance of the transmission line.

It is characteristic of the following socio-economic factors that the constraints are based at least as much on human perceptions of transmission lines and their effects as they are on any inherent physical qualities. There are, however, some opportunities for routing the lines in the network of existing linear corridors for transportation and utilities in the study region. These corridors identify areas where an additional transmission line may be perceived as less of an encumbrance.

Although the visual aspect of a transmission line is often a key feature in human perceptions, visual constraints are discussed later, in Chapter VI, Detailed Alignment, because of the site-specific nature of their effects.

1. Recreation

While transmission lines often co-exist with recreational areas, they are sometimes perceived as an encumbrance. This may tend to constrain the recreational value of an area underneath and to either side of the transmission line, but the degree of constraint varies according to the type of recreation area. Beach parks and playgrounds designed for active recreation use, such as organized games and sporting events, are usually smaller in size and exposed to more frequent and intensive use than are wilderness parks. Therefore, a transmission line easement would tend to consume a greater percentage of these recreation areas and be perceived as a greater encumbrance. In a large wilderness park, however, the easement would take a smaller percentage of the total recreation area and the opportunities for camouflaging or locating the line itself to avoid or minimize exposure to park users are greater.

Existing and proposed public recreation areas - County, State and Federal - have been identified in a technical supplement to the State Comprehensive Outdoor Recreation Plan (SCORP)[30]. This document also rates the intensity of use for these recreation areas as high, moderate, medium, low and no value[31]."

High" constraint areas (which include high and moderate from the SCORP categorization) involve active recreational use and often a high frequency of use, frequently in an urban area. These areas include a beach park, boat launching ramp or areas where there are special natural or cultural resources.

"Medium" constraint areas (or medium and low from the SCORP categorization) include "back country" or naturally pristine lands where the use is dispersed or "controlled" and where nature and solitude may be enjoyed.

All other areas have "low" constraints.

RECREATION

DEGREE OF CONSTRAINT	CRITERIA
High	High and moderate[32] recreation use such as active beach parks, boat harbors and urban parks.
Medium	Medium and low[33] recreation use such as "back country" and controlled use in pristine areas.
Low	All remaining areas or areas of "no value" as identified in SCORP.

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30. See State of Hawaii, Department of Land and Natural Resources, State Recreation Plan Technical Reference Document, Honolulu, September, 1980, pp. 215-226.

31. The definitions and descriptions of recreational use provided in this report are taken from SCORP. SCORP's "High" and "Moderate" are equivalent to a "High" constraint; "Medium" and "Low" equal a "Medium" constraint; "No Value" equals a "Low" constraint.

32. SCORP classifications

33. SCORP classifications

EXHIBIT IV-6

RECREATION

Constraints

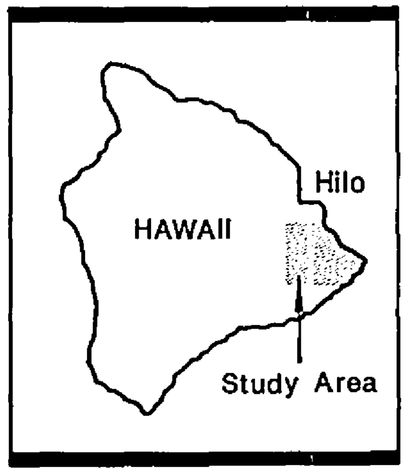
High and moderate recreation use. **H**

Medium and low recreation use. **M**

All remaining areas. **L**

Source

State of Hawaii, Department of Land and Natural Resources, • *State Recreation Plan Technical Reference Document*, 1980.



POHOIKI GEOTHERMAL TRANSMISSION LINE ROUTING STUDY • DHM inc.

2. Land Use

Land uses described in this report are based on the General Plan[34] of the County of Hawaii, zoning[35] applied by the County of Hawaii, Land Use Districts[36] administered through the State Land Use Commission and the Department of Land and Natural Resources, and certain agricultural areas delineated on the State's Agricultural Land Use Map[37].

Because the most intense use by the population occurs in urban or developing areas, all lands zoned by the County for urban use or designated by the State as Urban Districts are classified as a "high" constraint for the location of a transmission line. In some areas, one of the County's agricultural zoning classifications [A - Agriculture (1a), which permits one-acre lots] is also designated for urban use on the County General Plan or is in the State Urban District. Such areas are considered a "high" constraint.

Industrial areas are considered a "medium" constraint because the perceived hazards and nuisances of industrial activities are often as great or greater than those of a transmission line. Agricultural subdivisions with a minimum lot sizes of one to three acres [A - Agricultural (1a), A - Agricultural (3a)] as zoned by the County also are considered to have a "medium" constraint, primarily because these areas tend to be residential in character.

In the study area there are a variety of other agricultural uses, zoning and General Plan allocations. Minimum lot sizes vary from one to 20 acres. Puna has the largest area of papaya orchards in the County of Hawaii and also extensive macadamia nut orchards. There are numerous small cut-flower nurseries and a variety of truck farming operations. There are also some grazing and ranching operations on a small scale. These active and productive uses are considered a "medium" constraint. The agricultural uses described above do not include all lands in the State Agricultural District because not all agricultural lands are productive.

Former Puna Sugar Plantation lands are included as "medium" constraints because the land is continuing in active agricultural production. Much of the former sugar land is being placed in macadamia nuts or other orchard crops which may include cocoa.

All other areas have a "low" constraint.

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34. County of Hawaii, The General Plan, (Adopted by Ordinance No. 439 on December 15, 1971, revised 1986).

35. Department of Planning, County of Hawaii, Zoning Maps, 1986.

36. Land Use Commission, State of Hawaii, Land Use District Boundaries, Honolulu, Hawaii, 1987.

37. Department of Agriculture, State of Hawaii, Agricultural Land Use Maps, 1982.

LAND USE

DEGREE OF CONSTRAINT	CRITERIA
High	Areas zoned for residential and commercial uses; one-acre agricultural lots that are in the State Urban Land Use District or are designated for urban use on the County General Plan[38].
Medium	Areas zoned for industrial use and one, two and three-acre agricultural lots that are not in the State Urban Land Use District or are not designated for urban use on the County General Plan[39]; areas in agricultural production[40]; former Puna Sugar Plantation lands.
Low	All remaining areas.

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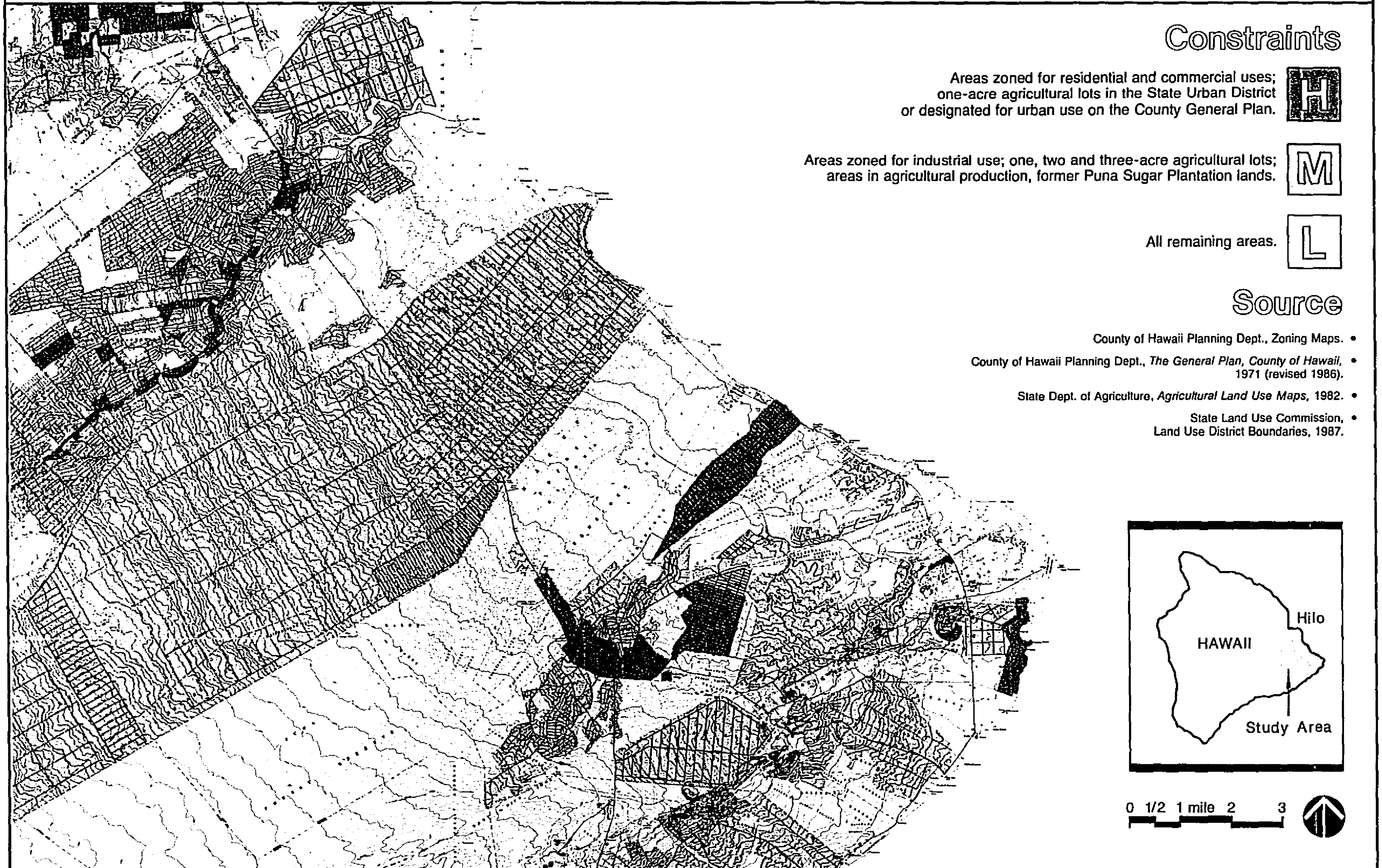
38. County of Hawaii zoning classifications: RS - Single Family Residential (10, 15, 20); RM - Multi-Family Residential (2); RA - Residential Agriculture (.5a); A - Agriculture (1a) if designated on County of Hawaii General Plan for urban use or included in a State Urban Land Use District; CV - Village Commercial (10); CN - Neighborhood Commercial (10).

39. County of Hawaii zoning classification: ML - Limited Industrial (20); A - Agriculture (1a, 3a) if not in State Urban Land Use District or designated urban on General Plan.

40. Areas delineated on Agricultural Land Use Map prepared by the State of Hawaii Department of Agriculture, current as of 1982.

EXHIBIT IV-7

LAND USE



POHOIKI GEOTHERMAL TRANSMISSION LINE ROUTING STUDY • DHM inc.

3. Transportation and Utilities

The study area's network of roadways, power lines and a former railroad alignment were reviewed to assess the opportunities they may offer for locating transmission lines because utilities and roads often occupy the same corridors. In some cases there are existing easements or rights-of-way which may allow for installation of new transmission lines.

The major advantage of conforming to existing roadway or utility alignment patterns is that new lines can be readily incorporated into the existing features of these areas. In the study area, transmission or power lines tend to be located near or within existing highway or road rights-of-way. In the case of the former railroad, only a short length of the former route has a single owner. The remainder of the route is held by adjacent property owners except through Hawaiian Paradise Park where the former railroad easement is owned by each of the lot owners of the entire subdivision[41]. Therefore the former railroad route represents no advantage (in terms of an available right-of-way) over any other route.

For this factor, areas are evaluated in terms of "high" and "low" constraints only. Areas without any linear easements, or without existing roads or power lines, are considered a "high" constraint. Specifically, this means that "high" constraint areas are more than 1/4 mile from existing paved or well-maintained unpaved roads which are passable under most weather conditions. Areas with "low" constraints are those lands less than 1/4 mile from existing paved or well maintained unpaved roads.

HELCO requires that the two proposed 69 kV lines be separated by one-half (0.5) mile[42] in order to reduce the risk of failure of both lines at one time due to a natural catastrophe such as an earthquake, lava flow, brush fire, or hurricane. This requirement might be reduced if each of the proposed 69 kV lines could be placed on either side of a major road. This is because a major road could be considered as a firebreak which could prevent a dual line outage caused by fire.

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41. Letter to editor, Puna/Kau Independent News, 11:11:6, November 1986. According to Ms. Kiki Shappell "...the Railroad roadways in increment I are indeed owned by the lot owners in common, with each lot owner holding title to 1/5750 of all the roadways. No one owns any particular piece of road. Every part is owned jointly by all of the lot owners in increment I."

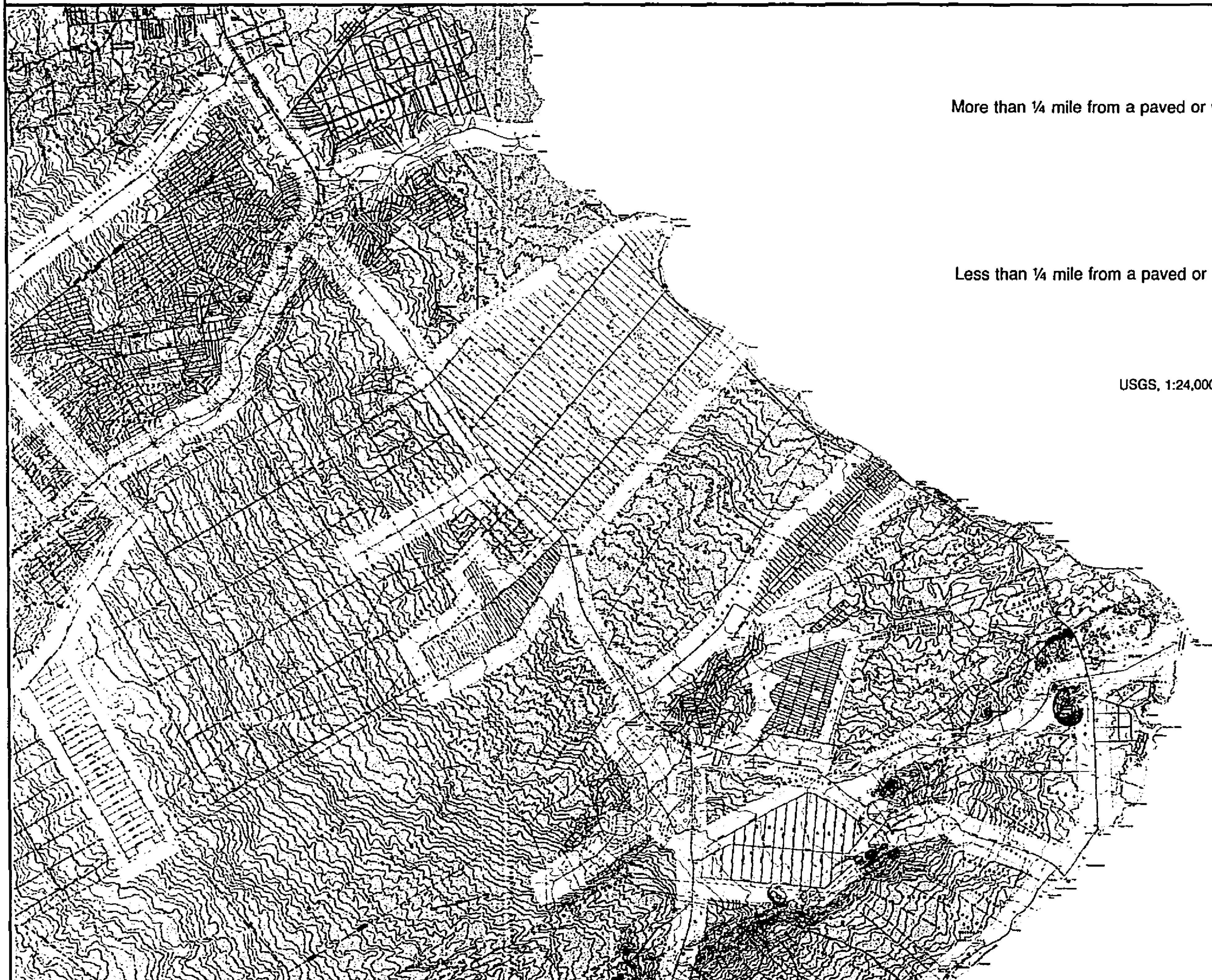
42. The minimum separation distance is considered to be 0.5 miles unless a major road is between the two proposed 69 kV lines. If so, then the separation distance could be less, but not less than the PUC requirement of 3/4 the pole height.

TRANSPORTATION AND UTILITIES

DEGREE OF CONSTRAINT	CRITERIA
High	More than 1/4 mile from a paved or well-maintained unpaved road which is passable under most weather conditions.
Medium	Not Applicable.
Low	Less than 1/4 mile from a paved or well-maintained unpaved road which is passable under most weather conditions.

EXHIBIT IV-8

TRANSPORTATION AND UTILITIES



Constraints

More than ¼ mile from a paved or well-maintained unpaved road. **H**

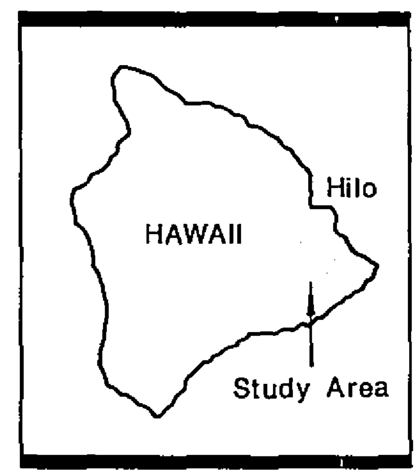
Not Applicable. **M**

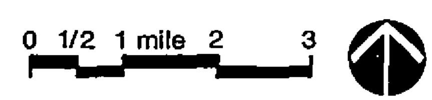
Less than ¼ mile from a paved or well-maintained unpaved road. **L**

Source

USGS, 1:24,000 scale Topographic Quadrangle Maps, 1980-1983. •

DHM inc. •





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4. Land Ownership

For safety and access, typical rights-of-way up to 50 feet wide[43] are required for 69 kV transmission lines. The acquisition of a right-of-way would have a more significant impact on the potential use of small parcels than it would on large ones. Landowners are primarily concerned that transmission line right-of-way acquisitions do not create small, irregularly shaped remnant parcels that reduce the value of their property. On smaller properties, this often means locating the easement adjacent to the property boundary, which can result in a very indirect route that zig zags through areas with numerous such parcels.

"High" constraints exist where there are private land holdings of 10 acres or less. When there are a high number of landowners within a proposed right-of-way easement the public costs become greater and are eventually reflected in higher utility rates. When the utility company must negotiate with many property owners to acquire a right-of-way easement, the documentation and procedural requirements are more extensive and more costly. Thus, there is a greater constraint where there is a substantial degree of parcelization. Much of the Puna region has been subdivided into residential and agricultural lots of 10 acres or less in size.

Hawaiian Homes Lands under the jurisdiction of the Hawaiian Homes Commission (HHC) are considered a "medium" constraint. These lands pose a unique situation because of Federal and State statutory restrictions which limit the period for the granting of easements across these lands to a maximum of 21 years. Utility companies normally seek a perpetual easement. Moreover, the HHC is obligated to use these lands to the benefit of native Hawaiians. Recent litigation by Hawaiians against the Commission has clouded the land use plans for any agency wishing to use Hawaiian Home Lands. The use rights for these lands can be difficult to acquire.

The Department of Hawaiian Home Lands recognizes the potential for rural residential use in the areas straddling the Pahoa-Keaau Highway and recreational use of the parcel along the shoreline[44]. The Commission has recently created a subdivision of 2- and 5-acre lots[45] in the Lands of Makuu on both sides of the highway which further parcelizes their holdings. The lots are leased to native Hawaiian beneficiaries.

Portions of the study region are comprised of extensive private estates and public lands. Amfac, Bishop Estate, Shipman Estate, Kapoho Land and Development Company, Tokyu Land Development, and the State of Hawaii are major landowners in the region. These private land holdings of more than 10 acres are considered to have a "medium" constraint for a transmission corridor.

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43. The precise right-of-way (ROW) may vary depending on pole spacing. Pole spacing of 600 feet requires a 50-foot ROW; lesser pole spacig requires a lessor ROW width.

44. State of Hawaii, Department of Hawaiian Home Lands, General Plan, Honolulu, 1975.

45. Telephone communication, Department of Planning, County of Hawaii, 1986.

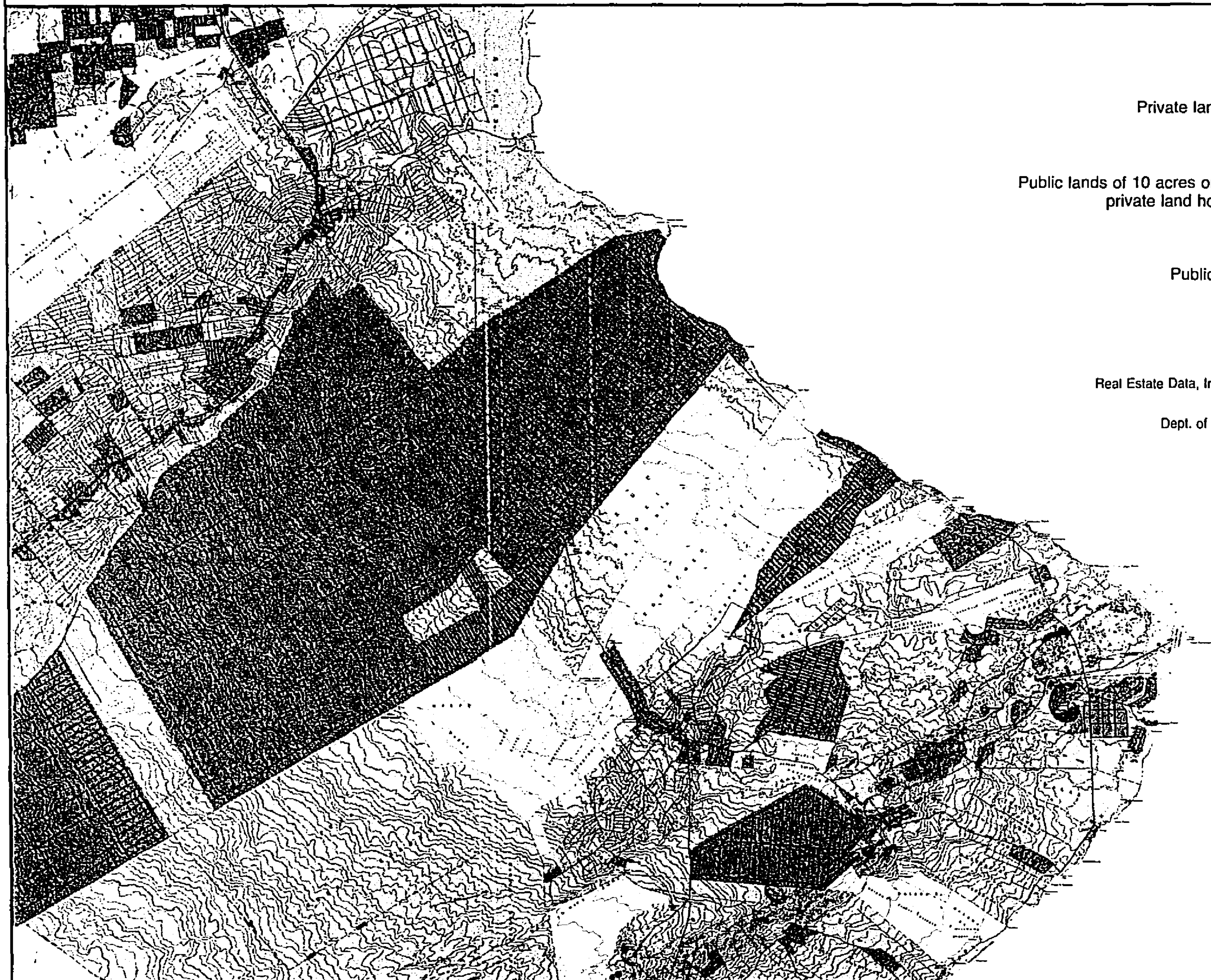
In the study area, large parcels of state land represent an opportunity for a transmission route because these lands are generally not intensively used and there is no expectation of future profitable use, as in the case of private landowners. For this reason, State lands of more than 10 acres are classified as a "low" constraint.

LAND OWNERSHIP

DEGREE OF CONSTRAINT	CRITERIA
High	Private landholdings of 10 acres or less.
Medium	Public lands of 10 acres or less; Hawaiian Home Lands; private land holdings of more than 10 acres.
Low	Public lands of more than 10 acres.

EXHIBIT IV-9

LAND OWNERSHIP



Constraints

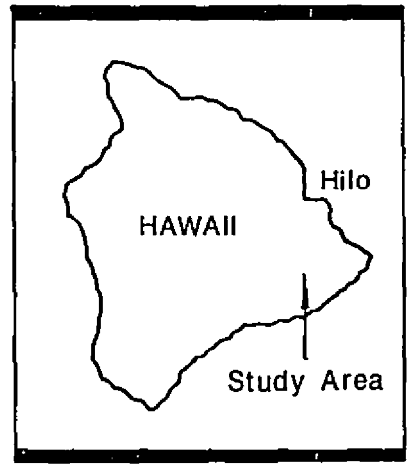
H — Private landholdings of 10 acres or less.

M — Public lands of 10 acres or less; Hawaiian Home Lands; private land holdings of more than 10 acres.

L — Public lands of more than 10 acres.

Source

- Real Estate Data, Inc., *Real Estate Atlas of Hawaii, County of Hawaii, Map Volume Zone 1,* 1986.
- Dept. of Hawaiian Home Lands. Map of Maku'u Farm Lots.



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5. <u>History and Archaeology</u>

The construction of a transmission line may detract from the research, cultural or sacred value of a historic property or archaeological site which lies in or very near its path.

In Hawaii, a distinction is generally made between cultural properties which pre-date (pre-historic) the arrival of Captain James Cook in Hawaii in 1778 and those which are more recent (historic) in origin. The study region's three major areas of historic interest are the towns of Mountain View, Keaau and Pahoa. Their location and historic characteristics are well-defined[46]. The pre-historic sites which have been identified in the study region consist of the archaeological remains of Hawaiian settlements, <u>heiau</u>, petroglyphs, burial grounds and ancient trails[47].

All of the sites from both periods which have been located, described and assigned a site number by the State Historic Preservation Office are considered "high" constraint areas. Some sites, however, are so small in size that their areal coverage must be exaggerated somewhat in order to be distinguishable on a regional scale map. Such sites can be delineated more precisely in a more detailed analysis if they should appear in a potential transmission line corridor.

In addition to the known historic sites, there is a possibility of undiscovered archaeological remains in the region. The probability of a large number of such sites in this region is limited by several factors. Large areas of the region have been covered by lava flows in the past 500 years, which has both discouraged human settlement of the area and destroyed much of what evidence there might have been of human use[48]. In addition to natural disturbances, urbanization and agriculture in the post-Cook period may have destroyed archaeological remains in some areas.

Nevertheless, there are some relatively undisturbed areas which can be rated a "medium" constraint, in recognition of the relatively greater possibility of undiscovered archaeological remains there.

The remainder of the study area is considered a "low" constraint in terms of historic and archaeological resources. It should be noted that the designation of areas by degree of constraint does not eliminate the necessity of conducting a more detailed analysis at later stages of route selection and project planning. A field study of potential corridors and of areas that may be disturbed in transmission line construction will mitigate against the

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46. The entire towns have been described as historic areas and have been assigned site numbers by the State Historic Preservation Office, although none is on the official State or Federal registers of historic places.

47. State Historic Preservation Office, file of site descriptions.

48. Comments on lava flow coverage attributed to Richard B. Moore, former Survey Geologist with the U. S. Geological Survey at Hawaiian Volcano Observatory.

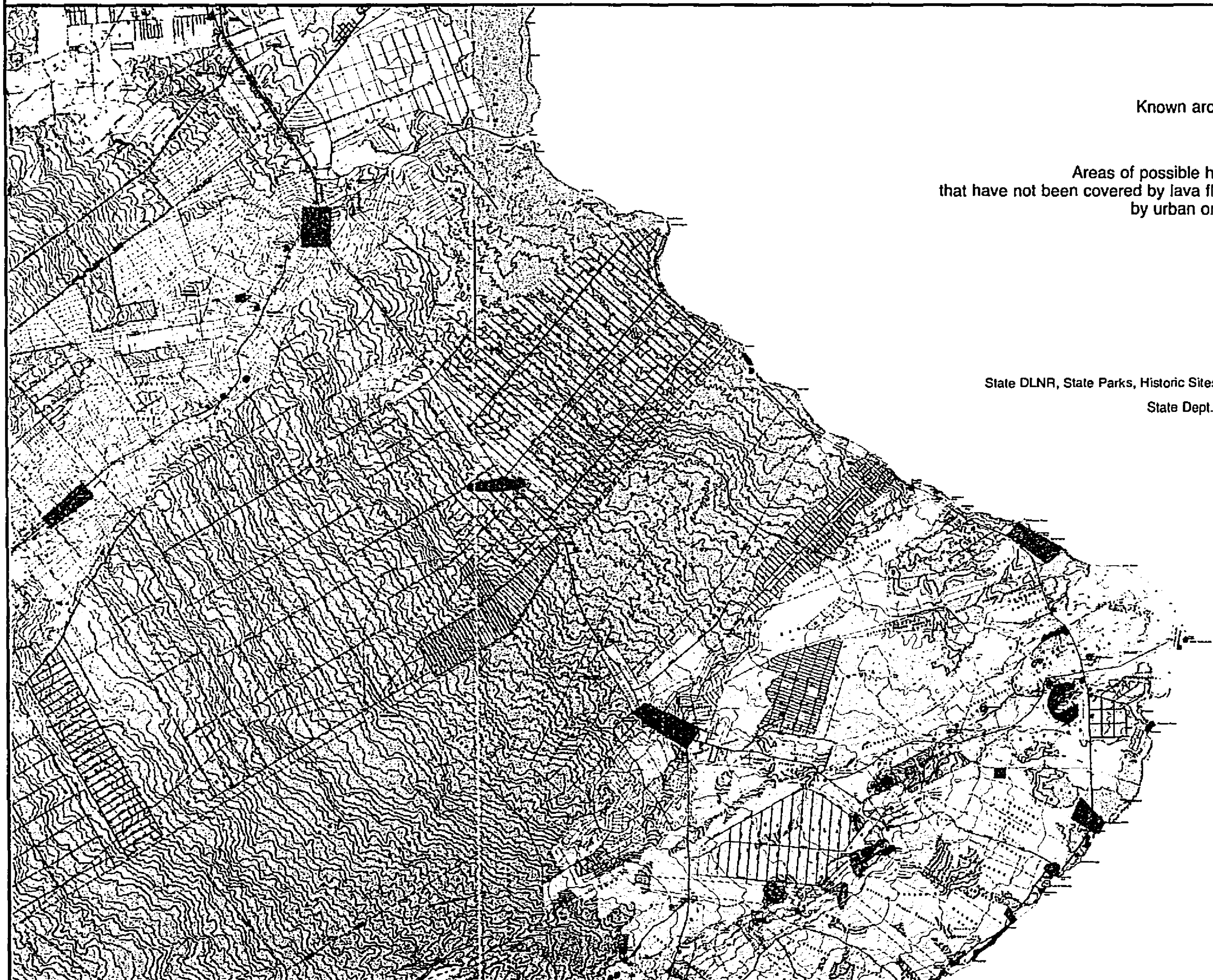
destruction of a previously undiscovered archaeological site. During initial planning, the constraint analysis at the regional scale is intended to avoid areas where sites are known to exist or where the possibility of their existence is relatively greater.

HISTORY AND ARCHAEOLOGY

DEGREE OF CONSTRAINT	CRITERIA
High	Known archaeological and historic sites.
Medium	Areas of possible human use in pre-Cook period that have not been covered by lava flows or substantially disturbed by urban or agricultural uses since 1778.
Low	All remaining areas.

EXHIBIT IV-10

HISTORY AND ARCHAEOLOGY



Constraints

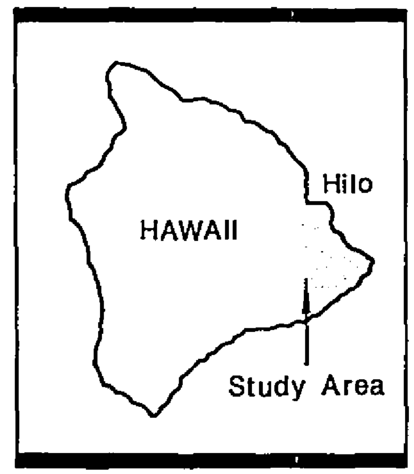
Known archaeological and historic sites. **H**

Areas of possible human use in pre-Cook period that have not been covered by lava flows or substantially disturbed by urban or agricultural uses since 1778. **M**

All remaining areas. **L**

Source

- State DLNR, State Parks, Historic Sites Section, Historic and Archaeological Sites Maps.
- State Dept. of Agriculture, Agricultural Land Use Maps, 1982.
- Richard B. Moore, *Preliminary Geologic Map of Kapoho and Pahoa South Quads*, 1981.
- DHM inc.



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6. Land Regulation

There are some areas where the construction of a transmission line would be discouraged by regulatory controls designed to protect special resource values. The controls are not so restrictive that they eliminate these areas from further consideration, such as the Exclusion Areas which were described earlier. Nevertheless, a permit application for a proposed transmission line through these areas would be evaluated in terms of the line's possible conflicts with special resource values.

There is a ring of land area encircling the island which has been designated the Special Management Area (SMA) as part of the State's Coastal Zone Management Program[49]. The County reviews permit applications for development within the SMA in terms of a number of policies and guidelines. One of these policies is to "protect the shoreline of the County where needed from encroachment of man-made improvements and structures[50]. The SMA is considered a "high" constraint area.

The State Conservation District contains several subzones and special districts representing a range in degree of restrictiveness[51]. The most restrictive area is the Protective Subzone, which has previously been described as Exclusion Areas. Next in the hierarchy of restrictiveness are the Limited and Resource subzones. While regulations governing these subzones would not preclude a transmission line, their stated objectives and narrow range of permitted uses for these areas suggest a "high" regulatory constraint. The General Subzone of the Conservation District is more permissive, and can be considered a "medium" constraint. A transmission line route through any portion of the Conservation District would require the review and approval of the State of Hawaii Board of Land and Natural Resources.

LAND REGULATION

DEGREE OF CONSTRAINT	CRITERIA
High	Limited and Resource Subzones of the State Conservation District. Special Management Area of the coastal zone.
Medium	General Subzone of the State Conservation District.
Low	All remaining areas.

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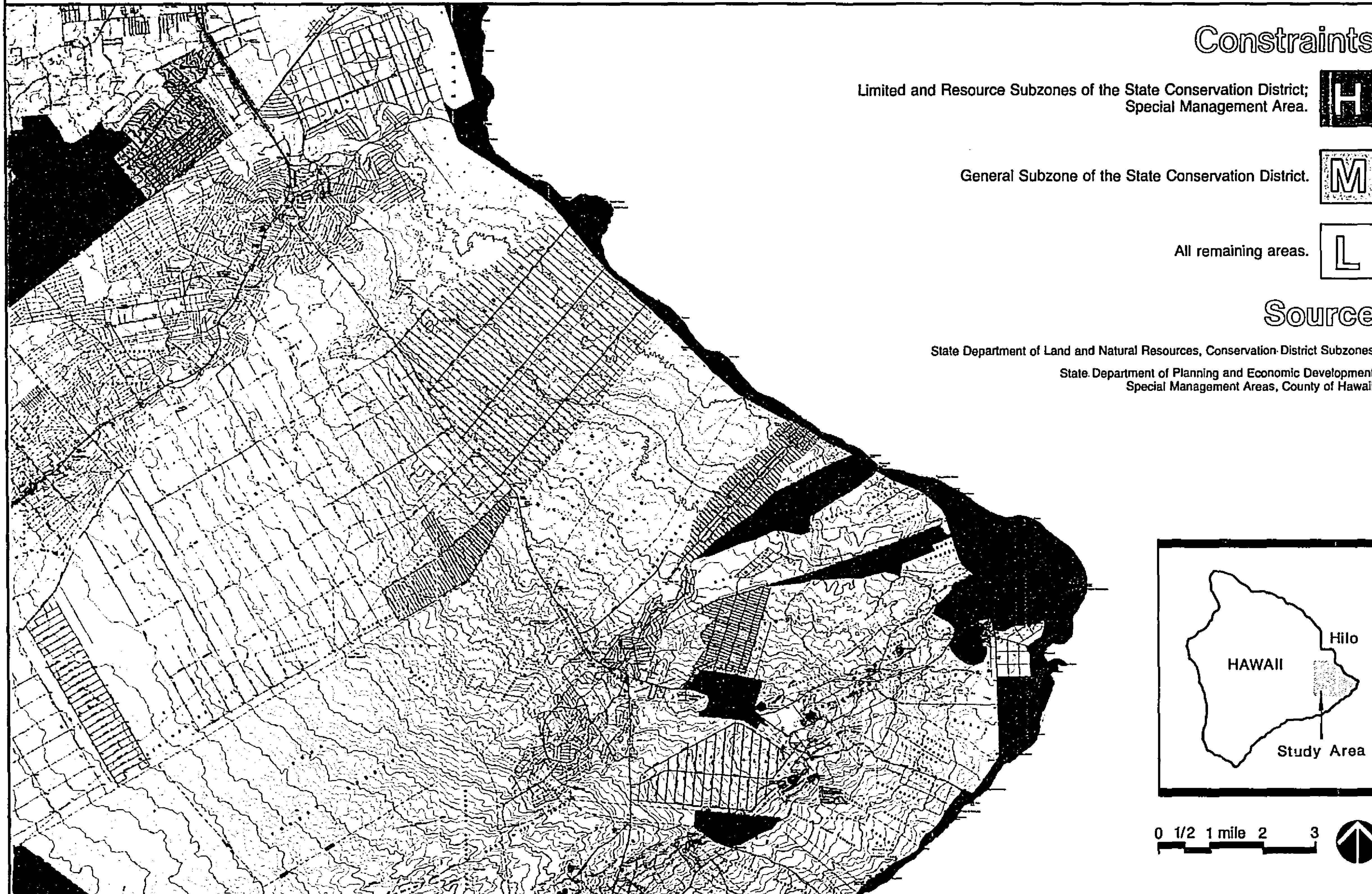
49. State of Hawaii, Department of Land and Natural Resources, Regulation No. 4 pursuant to Chapter 183-41, Hawaii Revised Statutes, Honolulu, Hawaii, May, 1978.

50. County of Hawaii Planning Department, "Rules Relating to Administrative Procedures: Planning Commission," Hilo, Hawaii, October, 1975.

51. County of Hawaii Planning Department, "Rule Relating to Administrative Procedures: Planning Commission," Hilo, Hawaii, October, 1975.

EXHIBIT IV-11

LAND REGULATION



Constraints

- H — Limited and Resource Subzones of the State Conservation District; Special Management Area.
- M — General Subzone of the State Conservation District.
- L — All remaining areas.

Source

- State Department of Land and Natural Resources, Conservation District Subzones.
- State Department of Planning and Economic Development, Special Management Areas, County of Hawaii.

POHOIKI GEOTHERMAL TRANSMISSION LINE ROUTING STUDY • DHM inc.

F. COST FACTORS

The cost of constructing and maintaining the proposed transmission lines is a concern not only to the utility company but to all Island of Hawaii residents and businesses who are supplied with electric power by the utility, since these costs are eventually borne by customers through the utility's rate base.

Route length is an obvious determinant of cost. This has been taken into account by restricting the study region to the southeast portion of the island, which still permits a very large number of routing alternatives, some of which could be quite indirect. No additional route length criteria are considered in the broadscale analysis, but the length of the route can be a factor in the identification of specific routing alternatives and the selection of a preferred route.

Transmission line costs at the regional scale of analysis are influenced primarily by relative land values, various physical conditions which impinge on access to the transmission lines, and certain land uses and physical elements that effect the amount of maintenance required by the line.

1. Land Value

Land value has a direct impact on the cost of acquiring an easement for a transmission line. Utility companies usually pay private property owners a consideration based on an appraised value for transmission line easements. In recent years, the State government also has tended to demand compensation for the use of public lands, although not necessarily at a rate comparable to private lands.

Land values are usually negotiated. While the utility company has power of eminent domain, this is used only as a last resort because the proceedings for this form of acquisition add to costs in terms of legal fees and project delays.

The present and potential use of a property is the most significant influence on its value. Potential use can be determined by the property's location, physical characteristics and zoning designation. The land use classifications used for real property assessment purposes in Hawaii take potential use into account; e.g.; there is a separate classification for "unimproved residential" land[52]. Assessed valuation provides the most comprehensive available indicator of land value according to present and potential use. It is possible, on the basis of public records, to determine the average valuation per acre for different categories of existing and potential use[53].

Assessed valuations for these categories fall into three distinct groups, corresponding closely to the State Land Use District categories. The Urban District is the high-value category. The Rural and Agriculture District are medium-value and the Conservation District is a low-value category.

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52. Hawaii uses the code system established by the "Pittsburgh Law" of differential tax rates for real property assessment and taxation. Cf., Chapter 246, Hawaii Revised Statutes.

53. City and County of Honolulu Department of Finance, Real Property Assessment Division, "Real Property Tax Valuations, Tax Rates and Exemptions, 1983-1984 Tax Year, State of hawaii," Honolulu, 1984. The City's Department of Finance compiles property tax data for all of Hawaii's counties.

Market value alone, however, does not determine the cost of a transmission line easement. HELCO has found, for example, that large landowners are often willing to provide easements at a minimal cost. Sometimes, the transmission line is a benefit to these landowners and can result in an increase in value of certain portions of their properties which they wish to develop. On the other hand, small property owners are less likely to reap these benefits and are more likely to expect compensation from the utility company.

The utility company can usually obtain easements across public land at lower cost than on comparable private land, particularly if the property is located in the State Conservation or Agricultural District. Urban District land is usually more expensive, since an appraiser bases the cost on a percentage of market value. The percentage represents the diminished utility which is a reflection of a property's inability to fulfill its highest and best use.

LAND VALUE

DEGREE OF CONSTRAINT	CRITERIA
High	Urban District lands; private, public, and Hawaiian Home Lands properties of 10 acres and less.
Medium	Private properties of more than 10 acres in the Agricultural and Rural Districts.
Low	All remaining areas.

EXHIBIT IV-12

LAND VALUE

Constraints

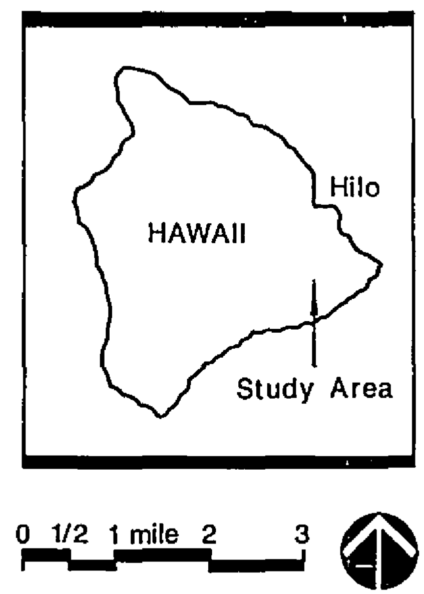
Urban District lands; private, public and Hawaiian Home Land properties of 10 acres and less. **H**

Private properties of more than 10 acres in the Agriculture and Rural Districts. **M**

All remaining areas. **L**

Source

- State Land Use Commission, State Land Use District Boundaries, 1987.
- Real Estate Data, Inc., *Real Estate Atlas of Hawaii, County of Hawaii, Map Volume Zone 1*, 1986.
- Dept. of Hawaiian Home Lands, Map of Maku'u Farm Lots.



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2. Maintenance

A major consideration in maintenance costs is the need for clearance between the transmission conductors and nearby objects such as trees. HELCO's engineering standards require that all areas within 10 feet of the transmission lines be kept free of vegetation. The specified minimum ground clearance (at the point of maximum line sag) of the proposed power line is 30 feet. This means that vegetation would be maintained at a maximum height of 20 feet (30 foot high power line - 10 foot clearance = 20 foot high vegetation) within the transmission line easement. Because of this standard, forest areas with canopy heights in excess of 30 feet pose a constraint because of the high cost of severe pruning. Both closed- and open- canopy forests with trees greater than 30 feet in height are considered as "high" constraints.

Salt spray, which occurs up to 1/2 mile[54] from the shoreline inland, poses a "high" constraint. Salt spray can cause flashovers at insulators and is generally corrosive to electrical systems and to hardware. Therefore, transmission lines within this area incur high maintenance costs.

Considerations stemming from human activities can also affect the maintenance of a transmission line especially where vandalism by hunters may occur. Hunter vandalism is associated with the discharge of firearms and the use of the transmission line insulators and conductors for target practice. This generally occurs in or near areas where game hunting is common. Game hunting areas are considered a "high" constraint.

Open-canopy forests with medium stature trees (6 to 30 feet tall) are a "medium" constraint because of potential pruning costs to keep vegetation clear of transmission lines.

It should be noted that in general, Puna has a somewhat higher incidence of fires, especially during dry periods, than have less developed areas on the Island of Hawaii[55]. However, mapped data is unavailable. For the purposes of this study, it is assumed that the fire hazard is relatively equal throughout the district.

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54. Based on information provided by HELCO.

55. Based on communications with staff, Department of Land and Natural Resources, Division of Forestry, September, 1986.

MAINTENANCE

DEGREE OF CONSTRAINT	CRITERIA
High	All closed-canopy forests (i.e., more than 80% cover); open-canopy (40 to 80% cover) forests with trees greater than 30 feet[56]; designated salt spray areas; game hunting areas.
Medium	Open-canopy forests with trees 6 to 30 feet tall.
Low	All remaining areas.

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56. Jacobi, James D., Mapping the Natural Vegetation of the Hawaiian Islands, March 7, 1985.

EXHIBIT IV-13

MAINTENANCE

Constraints

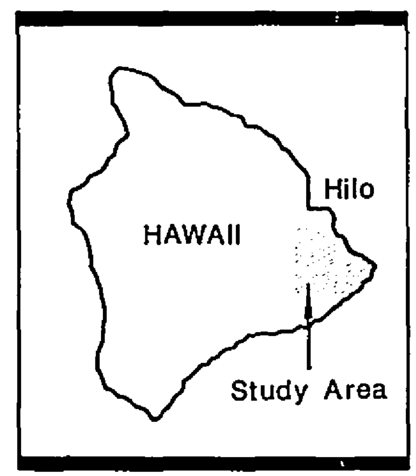
All closed-canopy forests; open-canopy forests with trees 30′ or greater; designated salt spray areas; hunting areas. — H

Open-canopy forests with trees 6′-30′ tall. — M

All remaining areas. — L

Source

- U.S. Fish and Wildlife Service, *Jacobi System Vegetation Maps*, 1979-1984.
- State DLNR, *State Recreation Plan Technical Reference Document*, 1980.
- HECO, Inc., *Insulation Areas, Engineering Data*.
- DHM inc.



0 1/2 1 mile 2 3

3. Access

The cost of constructing and maintaining a transmission line is affected by the degree of its accessibility. Areas which are distant from existing roads or characterized by rugged terrain or other physical barriers or difficulties, such as steep slopes, subsurface lava tubes and dense vegetative cover are the most costly sites for the construction and maintenance of transmission lines. To some extent, proximity to roads and geophysical characteristics are interdependent criteria, since roads tend to be aligned in areas with less difficult physical conditions. This is generally the case in the study area, therefore "access" constraints are mapped based on distances from existing areas.

Areas which are more than 1/2 mile to either side of a paved road or improved and well maintained road which may be unsurfaced are considered "high" constraints. Also areas more than 1/4 mile from unpaved, poorly maintained roads such as jeep trails or agricultural lot access roads are considered "high" constraints.

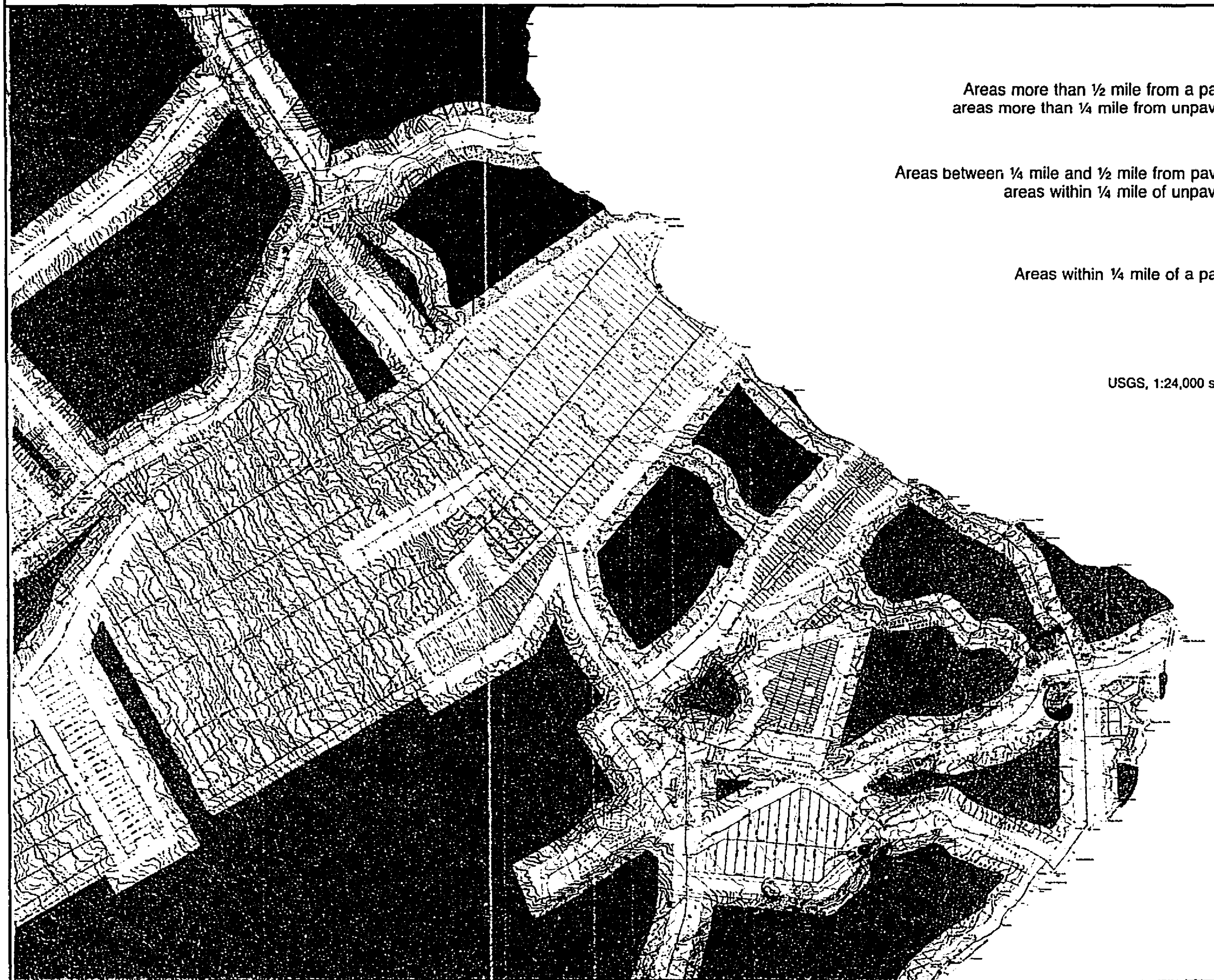
Areas between 1/4 and 1/2 mile from paved or improved and well maintained roads and areas within 1/4 mile of unpaved, poorly maintained roads are considered "medium" constraints.

Areas within 1/4 mile of a paved or improved well maintained road which may be unpaved are considered to have "low" or the least amount of constraints for access to construct and maintain transmission lines.

ACCESS

DEGREE OF CONSTRAINT	CRITERIA
High	Areas more than 1/2 mile from a paved or improved, well maintained road; areas more than 1/4 mile from unpaved, poorly maintained roads such as jeep trails.
Medium	Areas between 1/4 mile and 1/2 mile from a paved or improved, well maintained road; areas within 1/4 mile of unpaved, poorly maintained roads such as jeep trails.
Low	Areas within 1/4 mile of a paved or improved, well maintained road.

EXHIBIT IV-14
ACCESS



Constraints

H — Areas more than ½ mile from a paved or well maintained road; areas more than ¼ mile from unpaved, poorly maintained roads, such as jeep trails.

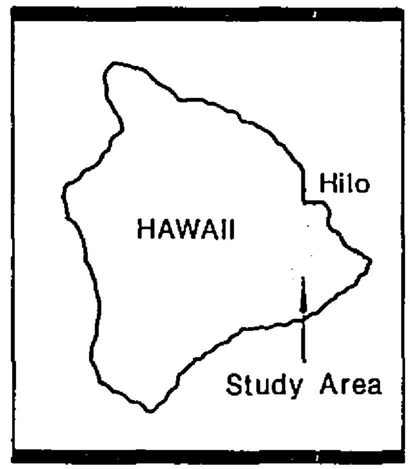
M — Areas between ¼ mile and ½ mile from paved or well maintained roads; areas within ¼ mile of unpaved, poorly maintained roads, such as jeep trails.

L — Areas within ¼ mile of a paved or well maintained road.

Source

USGS, 1:24,000 scale Topographic Quadrangle Maps, 1980-1983. •

DHM inc. •



CHAPTER V

CHAPTER V: IDENTIFICATION OF CORRIDORS AND POTENTIAL ROUTES

A. COMPOSITE MAPS

In order to present an overall view of the constraints and opportunities for the transmission line route, a composite overlay map was prepared for each data category (geophysical, biological, socio-economic, and cost factors). The composite maps represent the combined constraints of all the data factors in each data category and identify the areas of less constraint for each category.

Composite maps for the data categories of geophysical, biological, socio-economic and cost factors are shown in Exhibits V-1, V-2, V-3 and V-4. In Exhibit V-5, the four composite maps and the Exclusion Areas map are laid over one another. One can see color tones ranging from black (Exclusion Areas), through dark grey (high constraint) to light grey (low constraint). The "relatively" lighter areas are mapped as areas of less constraint, and are viewed as opportunities for transmission line corridors. The areas of less constraint are mapped in Exhibit V-6.

Potential corridors are identified by linking the areas of less constraint to provide a continuous connection between the geothermal power plant site and the Puna Substation area at Keaau. This was done using the areas of less constraint as the main guide and linking them where they did not join. Linkages were normally made across the shorter route and if possible along an existing road or jeep trail. Urban and Conservation District lands were avoided. Where necessary, the corridors were widened to allow for alternative alignments if the widening did not affect environmentally sensitive areas such as Urban or Conservation Districts. Through large areas of less constraint, such as agricultural subdivisions and the mauka lands, the most direct route was chosen between the identified corridor on either side. The potential corridors are shown on Exhibit V-7. The width of the corridors is one-quarter to three-quarters of a mile to permit a choice of alignments.

B. POTENTIAL CORRIDORS

The corridors identified for further evaluation have been divided into five segments (as shown on Exhibit V-7) for review purposes. The segments may be combined to form three primary corridors from the Pohoiki geothermal plant to the Puna substation:

Corridor AB	Nanawale/Railroad Corridor
Corridor ACE	Nanawale/Highway Corridor
Corridor DE	Leilani/Highway Corridor

Below is a brief description of the five segments:

Segment A - This segment, referred to as the Nanawale segment, is common to both the Nanawale/Railroad corridor and the Nanawale/Highway corridor. It originates at the geothermal plant site and proceeds north across Nanawale Farm Ranch Lands, then west along the edge of Nanawale Estates Subdivision. It terminates at the State-owned lands of Keonepoko Ki ahupuaa, near the mauka corner of Hawaiian Beaches Subdivision.

Segment B - This segment originates along Kahakai Road near Hawaiian Beaches Subdivision and proceeds along the northern boundary of the subdivision to the former railroad alignment, which it then follows north to the Puna Substation. Proceeding towards the substation, the first 4 1/2 miles of this segment cross vacant State-owned lands of tall grasses and scattered Ohia trees. The segment then passes through Hawaiian Paradise Park, a one-acre agriculture lot subdivision, for close to 4 miles. This portion of the subdivision is sparsely populated with between 25 and 50 developed parcels. The final 3 1/2 miles of the segment continue to follow the railroad route through scrub Ohia trees and the Puna Sugar lands to the substation.
Segment C - This segment is a "connector" between the Nanawale segment and the Highway segment. It primarily follows Kahakai Road between Hawaiian Beaches and Pahoa town, and encompasses State-owned land, including the Pahoa Agricultural Park. It does not include the lands of Keonepoko Homesteads along the highway. Segment C terminates near the Pahoa landing strip.

Segment D - This segment is referred to as the Leilani segment because it originates at the Pohoiki geothermal plant site and heads west, along the northern edge of Leilani Estates Subdivision. It completely avoids the State conservation lands of Nanawale Forest Reserve on the right. The segment heads north for a short distance spanning Kalapana Road, then veers off to the northwest across former sugar lands and vacant State-owned lands on the west side (mauka) of Pahoa. This segment terminates across Pahoa Highway (Highway 130) from the Pahoa landing strip and segment C.

Segment E - The highway segment is common to both the Nanawale/Highway corridor and the Leilani/Highway corridor. It extends along Pahoa Highway from the Pahoa landing strip to just south of Keaau, at which point it continues northeast to the Puna Substation. Near its origin, segment E passes through the Maku'u parcel of Hawaiian Home Lands, portions of which have been subdivided and leased to native Hawaiian beneficiaries. It then crosses the eastern tip of Ainaloa Subdivision and 3-1/2 miles of Orchid Land Estates three-acre agriculture lot subdivision on the mauka side of the highway. On the makai side, this corridor segment passes through 3-3/4 miles of Hawaiian Paradise Park one-acre agriculture lot subdivision. North of the subdivisions, the corridor segment includes vacant scrub Ohia lands and former sugarcane fields, terminating at the substation near the Puna Sugar Mill.

C. CORRIDOR EVALUATION

To generate a rating for each corridor to serve as a basis for comparing the corridor alternatives, "test routes" were identified by going through the lightest areas of the composite maps. The test results provide a point of reference to evaluate each segment against all the previously mapped data factors. These test routes were overlaid on each broadscale data factor constraint map. Each time the test route passed through either a high or medium constraint area, the linear distance through the constraint area was measured in inches. The unit of measurement is a relative figure, depending upon the scale of the map or, the actual conditions in the field. Therefore the measurement of constraint becomes the "score" for that data factor in the particular segment where it was encountered. Exhibit V-8 shows a map of the test routes and V-9 shows the scores for each data factor and each segment of the test routes. The table shows a total score for each route.

In calculating the total score, each high constraint score was multiplied by three to reflect its relative importance while each medium score was recorded as it was measured. The test route with the least constraints (the lowest total score) was "D" - the one just mountainward of the State Highway. The next lowest score was "AC" - the one just seaward of the State Highway. Potential route "AB" - the former railroad alignment - had the highest score but is still considered an acceptable alternative because its score is not significantly greater than the other two potential routes.

Note that the three total scores are quite close in value which reflects the overall similarity of the study area in general. Because of this, it was decided to study all the corridors in the detailed analysis phase. The results of this study are described in Chapter VI.

EXHIBIT V-1

COMPOSITE CONSTRAINTS: GEOPHYSICAL FACTORS

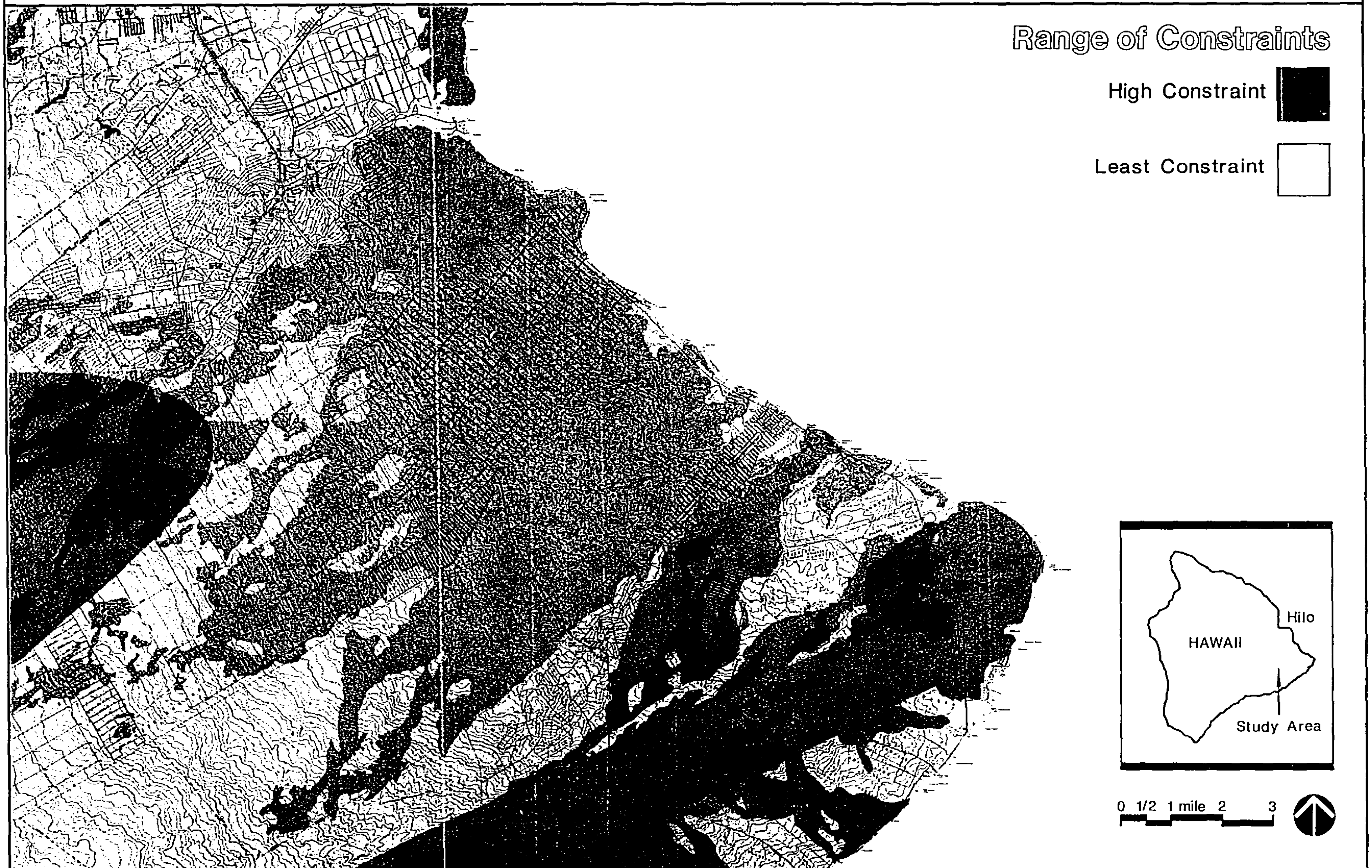


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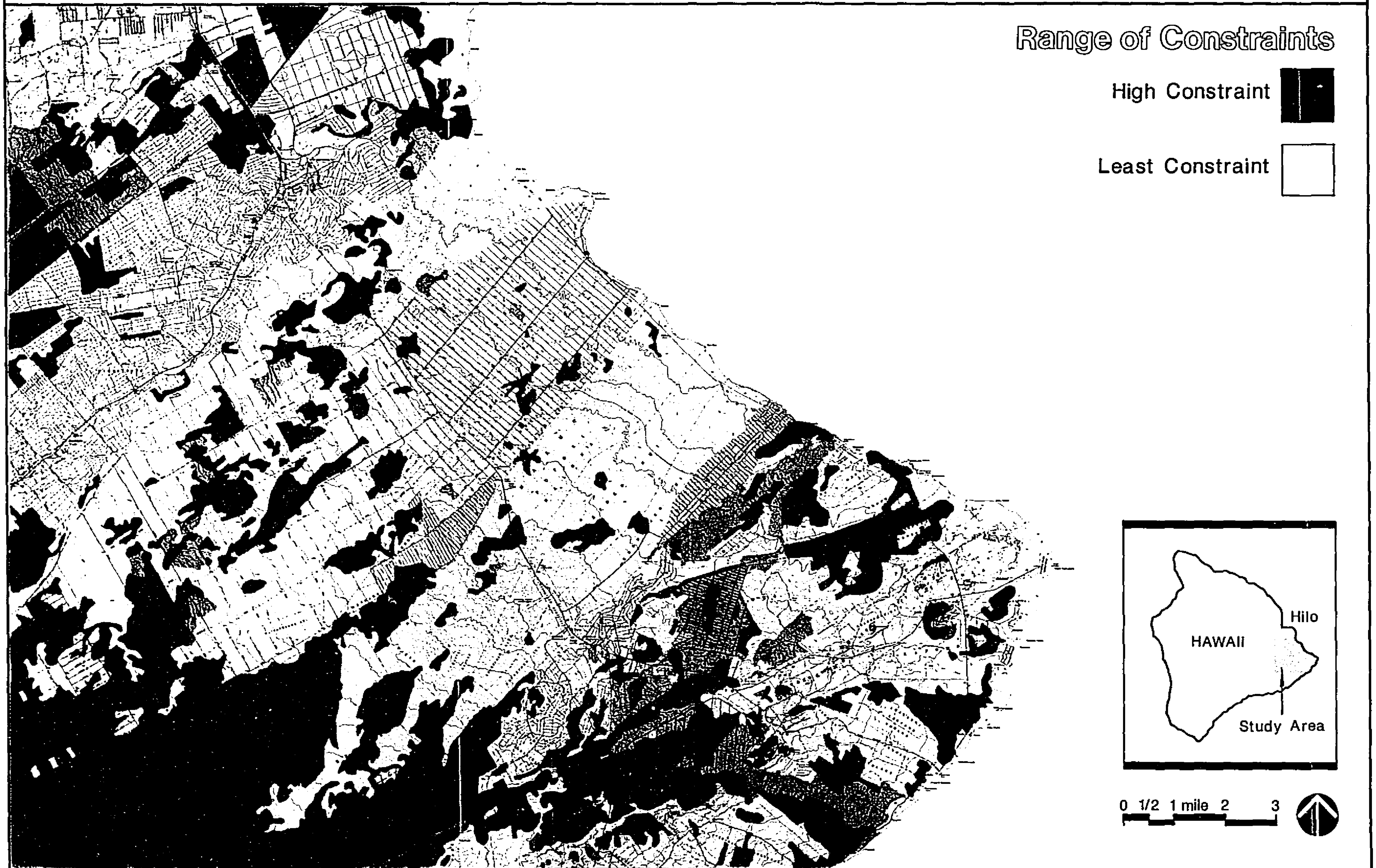
EXHIBIT V-2

COMPOSITE CONSTRAINTS: BIOLOGICAL FACTORS



POHOIKI GEOTHERMAL TRANSMISSION LINE ROUTING STUDY • DHM inc.

EXHIBIT V-3

COMPOSITE CONSTRAINTS: SOCIO-ECONOMIC FACTORS

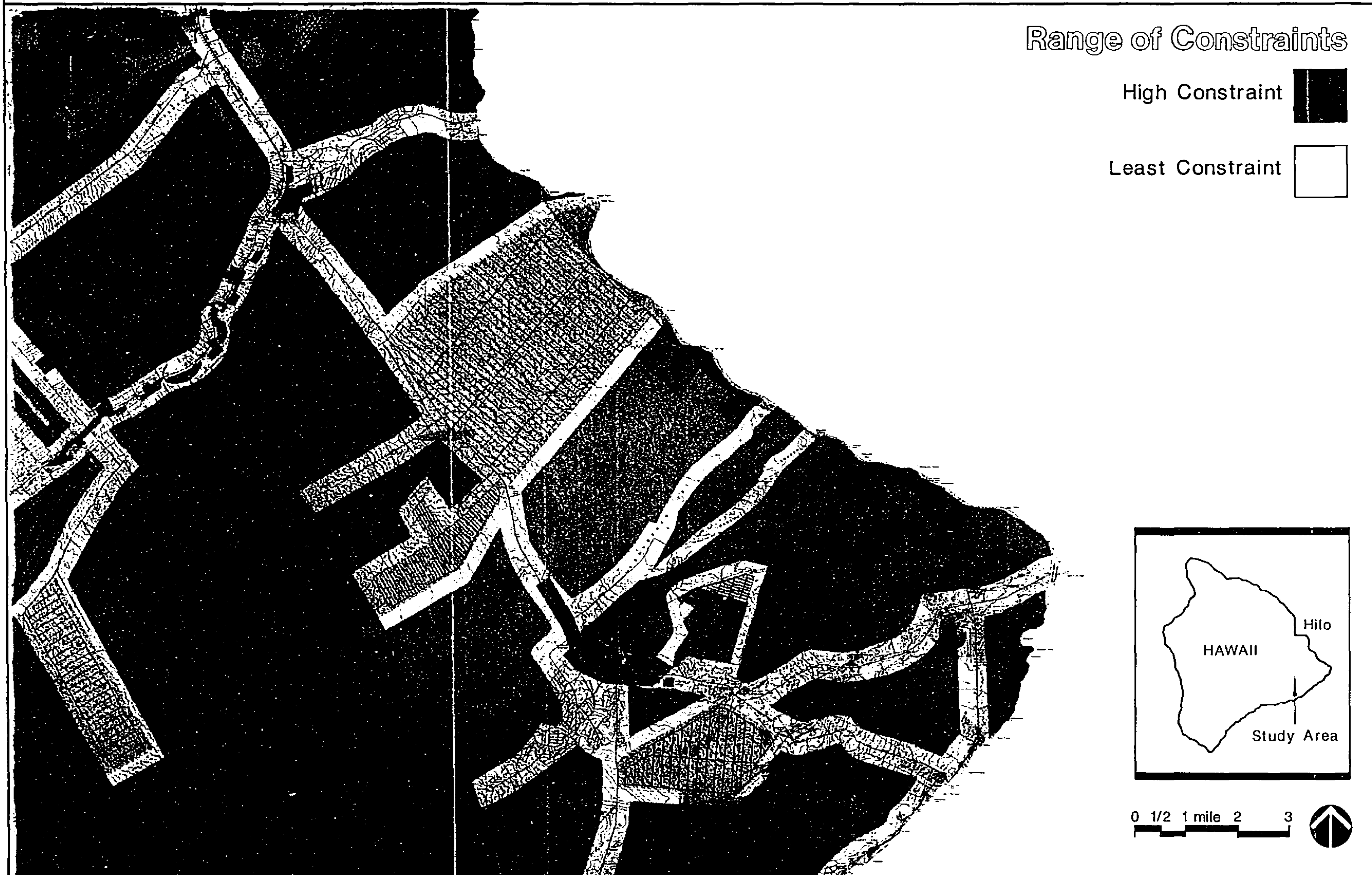


EXHIBIT V-4

COMPOSITE CONSTRAINTS: COST FACTORS

POHOIKI GEOTHERMAL TRANSMISSION LINE ROUTING STUDY • DHM inc.

EXHIBIT V-5

COMPOSITE CONSTRAINTS: ALL DATA CATEGORIES

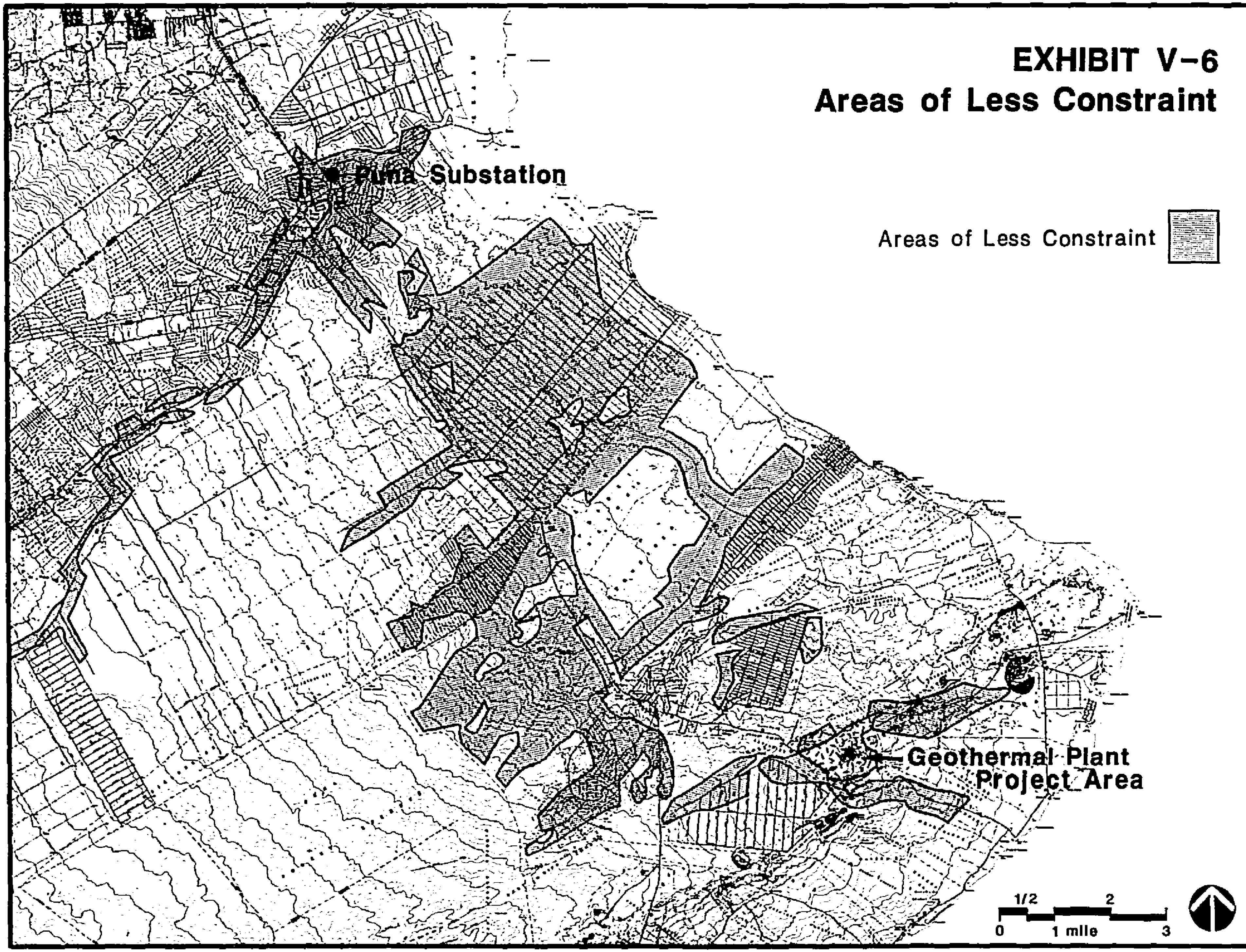


EXHIBIT V-6
Areas of Less Constraint

DHM inc.

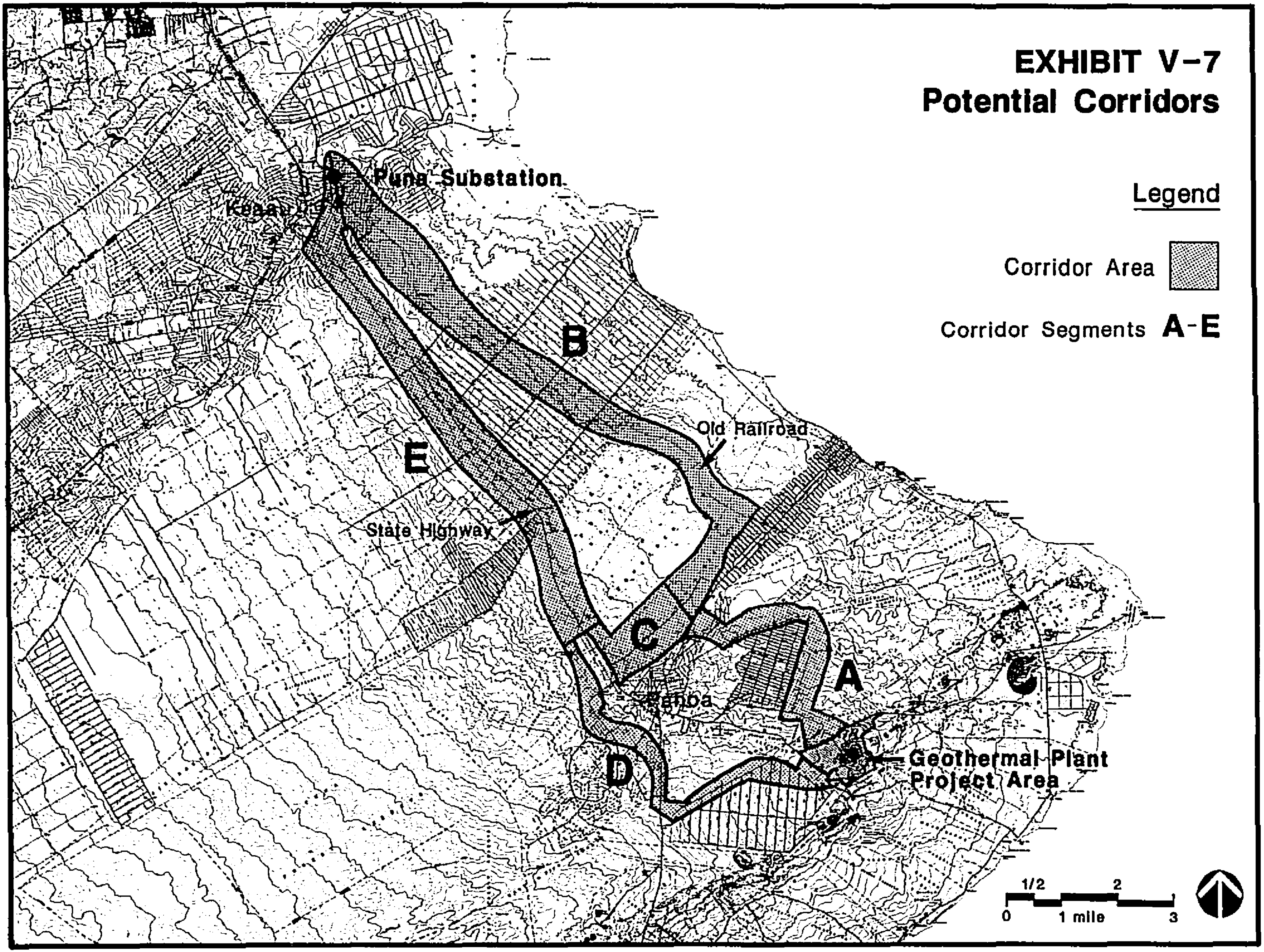


EXHIBIT V-7
Potential Corridors
Puna Substation
Keaau
Legend
Corridor Area
Corridor Segments A-E
B
E
Old Railroad
State Highway
C
A
C
Pahoa
D
Geothermal Plant
Project Area
1/2
2
0
1 mile
3

DHM inc.

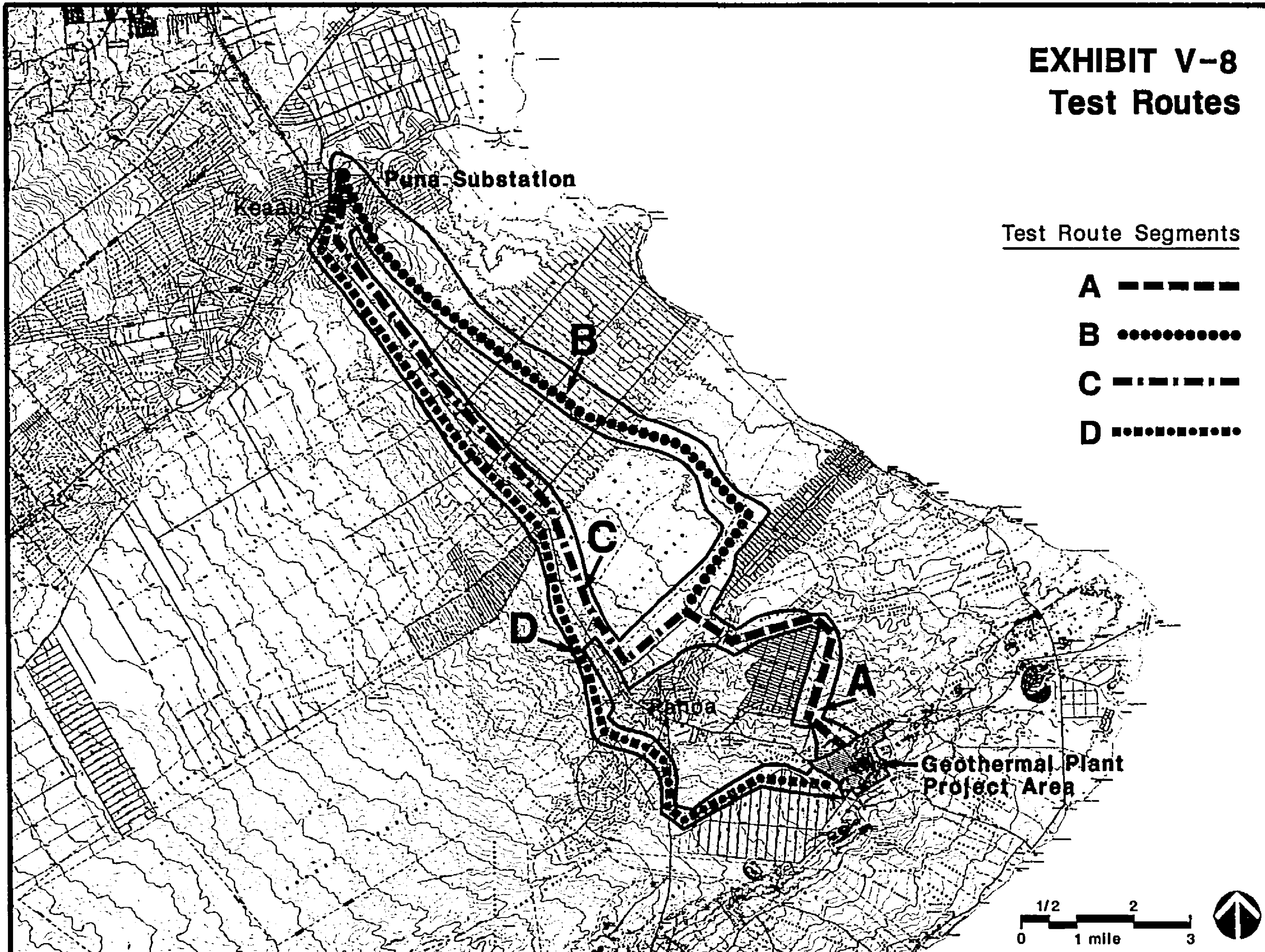


EXHIBIT V-8
Test Routes
Test Route Segments
A
B
C
D
Puna Substation
Keaau
B
C
D
A
Pahoa
Geothermal Plant
Project Area
1/2
2
0
1 mile
3

DHM inc.

EXHIBIT V-9

CONSTRAINT SCORES FOR TEST ROUTE SEGMENTS, BY DATA FACTOR

Numbers represent the length of constraint area crossed by a test route.

DATA FACTOR	TEST ROUTE SEGMENT A	B	C	D
GEOPHYSICAL				
1. Slope and Soils				
High				
Medium	3.30	16.83	18.28	18.96
2. Geologic Hazards				
High	7.12			5.73
Medium	1.41	20.91	20.91	23.54
BIOLOGICAL				
1. Vegetation				
High	0.56	1.17	1.94	4.60
Medium	2.94		0.36	0.20
2. Wildlife				
High		0.57		0.30
Medium	3.57	0.60	1.86	4.74
SOCIO-ECONOMIC				
1. Recreation				
High				
Medium	0.12			0.35
2. Land Use				
High				
Medium	6.64	10.08	12.00	16.68
3. Transportation and Utilities				
High	1.44	8.56	3.40	0.88
4. Land Ownership				
High	2.32	6.50	6.78	11.28
Medium	6.94	6.07	11.69	14.36
5. History and Archaeology				
High				0.46
Medium	0.82	17.34	10.58	13.66

DATA FACTOR	TEST ROUTE SEGMENT A	B	C	D
6. Land Regulation				
High	0.11			0.48
COST				
1. Land Value				
High	2.36	6.52	10.69	12.32
Medium	7.02	6.10	6.81	12.03
2. Access				
High		1.84		
Medium	1.60	7.60	2.44	4.60
3. Maintenance				
High	0.66	1.17	1.94	5.00
Medium	2.67		0.37	0.48
HIGH (3x) + MEDIUM	80.74	164.52	159.50	232.75

RATINGS FOR THREE TEST ROUTES

H (3x) + M

1. A+B = 245.26
2. A+C = 240.29
3. D = 232.75

CHAPTER VI

CHAPTER VI: DETAILED ANALYSIS

A. MAP FORMAT AND DATA

The detailed analysis of conditions in the study corridors requires a larger map scale. The Phase 2 mapping scale is 1:24,000 (1 inch = 2,000 feet), whereas the Phase 1 (Broadscale) analysis scale is 1:36,000 (1 inch = 3,000 feet). Both phases use USGS quadrangle sheets for their base. The study corridors are divided into four sections for suitable page-sized display in this report, beginning at the geothermal plant project area in Section 1 and terminating near the Puna substation in Section 4. The segments are shown in Exhibit VI-1.

Air photos[57] were used to provide additional information on land use, man-made and natural features such as vegetation, roads, developed lands. Data from these were verified by field surveys. Consequently, much of the data shown on the large scale maps is new information collected during field surveys (see Appendices B-F) expressly for this project. Field surveys were performed by scientists and professional experts to identify the following detailed information: archaeology and history, ornithology, entomology, botany, geology and soils, and visual resources.[58] Other relevant data was also mapped, including existing telephone lines, existing electric transmission and distribution lines, a new Hawaiian Home Lands subdivision on both sides of Highway 130, lands in agriculture production, and land ownership.

Above data are shown in two data maps for each section: (1) Physical Conditions and (2) Visual Resources. The following paragraphs describe the data factors placed on each map, and their relative constraints and opportunities for transmission line alignment.

B. PHYSICAL CONDITIONS

1. Land Use

Land use factors mapped in the study corridors include urban lands, productive agriculture lands, residential agriculture lands, existing utility line and road rights-of-way, the planned Pahoa By-pass Highway, and archaeological and historic sites.

Productive agricultural lands are typically used for field crop cultivation which includes nurseries, orchards, or other diverse crops. While these lands are not a highly restrictive constraint to a transmission line route, they are more constraining than vacant or pasture lands due to the level of human activity and land value. These lands are identified on the detailed analysis maps based on field checks of productive agricultural lands mapped by the State Department of Agriculture (as described in Phase 1).

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57. Air photos are dated 1977. Field checks were used to update the air photo information and to verify changes in land uses.

58. Field surveys were conducted of the entire study corridors with the exception of the agricultural subdivisions of Orchid Land Estates, Ainaloa, and Hawaiian Paradise Park as these areas have been physically disturbed.

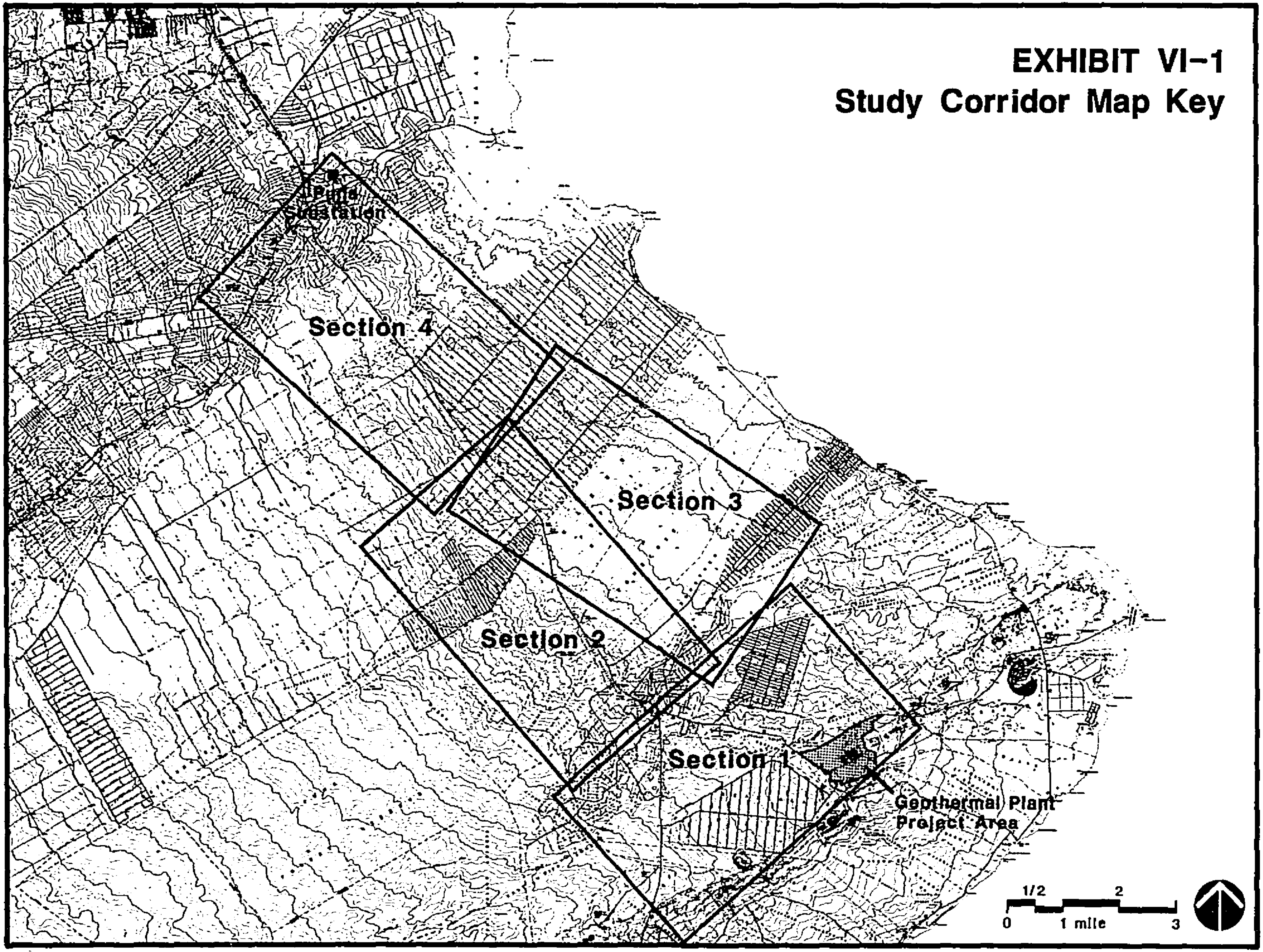

EXHIBIT VI-1
Study Corridor Map Key

DHM inc.

There are four agriculture-zoned subdivisions in the corridors (Hawaiian Paradise Park, Orchid Land Estates, Ainaloa Estates and Hawaiian Home Lands) which, for the most part, are not in agricultural use, but are more residential in character. The agricultural subdivisions form a wide block of land from the ocean to the slopes of Kilauea over which a transmission line must cross if it is to connect the Pohoiki geothermal power plant with the Puna substation. These subdivisions and two small areas of urban land in Keaau which extend into the corridor, are a general constraint due to the degree of human activity there.

The existing system of roads within the corridors are opportunities for alignments because of direct access available for transmission line construction and maintenance. This includes Highway 130 between Keaau and Pahoa and the agricultural subdivision roads. Former sugarcane roads, jeep trails, and the former railroad alignment (now a jeep trail except through Hawaiian Paradise Park where it is a road), offer similar opportunities for a transmission line alignment because of the access they could provide through otherwise difficult access areas.

The opportunities associated with existing utility lines are contingent upon many factors including road rights-of-way, utility (HELCO) rights-of-way, and technical aspects. For example the existing 34.5 kV transmission line and telephone line along Highway 130 are located within the highway right-of-way. However, the right-of-way width is not sufficient to allow an additional transmission line adjacent to the existing line, and installation of the 69 kV line on the same 34.5 kV poles would cause considerable outages to the present customers throughout Puna during construction. Therefore, the existing 34.5 kV line is considered a constraint for alignment selection. Hawaiian Paradise Park, Orchid Land Estates, and Ainaloa appear to provide opportunity for construction of the 69 kV line within an existing HELCO right-of-way by installing higher poles with the new transmission lines on top and the existing distribution lines underneath. Outages to the distribution line would occur during construction, however the customers affected would be limited to those within about a half-mile area.

Pahoa By-pass Highway, a change in Highway 130 which is scheduled for construction in 1988, will by-pass Pahoa to the east. Its route is through agricultural land with few or no residences, however, it presented no real opportunities for a powerline alignment.

Some archaeological and historic sites[59] are located in the corridors and are a constraint in that although the conductors of the line may be allowed to cross overhead, specific pole sites must not disturb them.

2. Biological

Based on air photos, areas of dense trees were identified because these may affect powerline construction and maintenance by requiring extensive cutbacks. The botanical survey (Appendix C) identified an area of diverse plant growth which is shown on the detailed analysis maps. Although there is a moderate coverage of Ohia trees throughout Puna, much of the growth is

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59. Appendix B, Archaeological Survey.

stunted, sparse and immature. Because of the relative youth of Ohia in the study area, the plant communities have only a few of the potential number of species which would develop in a mature forest. Overall, "the floristic quality was consistently poor and the same species composition was repeatedly expressed"[60] in the study areas.

The ornithological survey identified the presence of three native birds and several common non-native species (see Appendix D). The native birds found were the 'Elepaio, the 'Io (Hawaiian Hawk), and the Hawaiian Stilt. The Hawaiian Stilt were sighted on small ponds in the vicinity of the Puna Substation. The 'Elepaio and the 'Io were seen in the makai corridor above Nanawale Farm Ranch Lands, however specific locations for them are not mapped because these birds apparently use broad areas in Puna District and are not dependent on any specific locations, although they favor forests at the higher elevations. The survey report notes that the environments in the study corridors are not particularly hospitable towards native species and that although they "...may occasionally use these areas, it is not likely that they are dependent upon them".[61]

The entomological survey (see Appendix E) found several native species of insects. Their habitats are all below ground in caves or lava tubes. From highest to lowest significance, the areas are: "...1) Pahoa Cave, both upper and lower caves, 2) The kipuka area south of Pahoa..., 3) The Seaview Road site".[62] Generally, the presence of insects is determined by the surrounding vegetation. An important insect habitat in the caves are Ohia roots which enter the cave roof from the ground surface. The report notes that in order to preserve the insects, the surrounding vegetation must be protected, especially from herbicides which may be used to control vegetation as part of power line maintenance practices. Also there is a potential for the infiltration of herbicides into the caves which could present a serious threat to the fragile ecosystems there.

3. Geophysical

The major finding of the field survey (see Appendix F) is that there is a high probability of encountering lava tubes and caves which ultimately will affect pole foundations and the precise alignment. The caves are ubiquitous to the area and are often obscured by vegetation. With the exception of the larger underground formations described above in the biological section, the caves or lava tubes will generally need to be identified during construction and avoided.

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60. Appendix C, Botanical Survey.

61. Appendix D, Ornithology Survey Report, p. 9.

62. Appendix E, Entomology Survey, p. 6.

4. Land Ownership

Land ownership was mapped from tax key maps which identify each parcel of land, its owner, size and geographic location. Major land owners include the public[63], Hawaiian Home Lands, and private entities.
State lands consist mostly of large parcels (greater than 10 acres) although there are some small leased parcels.

Hawaiian Home Lands are on both sides of Highway 130, just south of Hawaiian Paradise Park and Ainaloa Estates. More than half of these lands have been divided into agricultural lots of 5-acres (on the makai side of Highway 130) and 2-acres (on the mauka side of Highway 130).

Privately owned lands consist of large vacant or agriculture parcels as well as small residential parcels in urban areas or agricultural subdivisions.

C. VISUAL RESOURCES

A primary aesthetic consideration in the siting of a transmission line is the extent to which the poles and conductors are screened from view at important vantage points by vegetation, natural landforms and buildings or structures. In the case of the study corridor, the area within visual range of the major roadways gets the most frequent view exposure since these roadways act as a continuous vantage point for motorists and passengers. These viewers include local residents, island-wide residents, and visitors to the island.

1. Visual Screens

The physical features which screen views from major vantage points are indicated on the detailed analysis maps. Four types of screens are noted: 1) solid vegetation, which consists of a thick growth of trees near the road, 2) partial vegetation, which is thinner or lower vegetative growth that allows occasional or penetrated views, 3) urban, which is usually created by the buildings and vegetation of an urban environment, and can be either partial or solid in effect, and 4) berms, which may be either man-made road cuts or natural earth formations that limit all or part of the view from the road.

Partial vegetation screens and urban screens may allow occasional or penetrated views to a transmission line. The effectiveness of a berm as a screen depends upon berm height, distance from the road, vegetation cover, and the slope of the ground beyond it. The major constraint for all types of screens is if they are not tall enough to screen the entire pole, all or portions of the poles may be silhouetted against the sky, resulting in a highly visible contrast of form and color.

Urban screens and residential areas can be a constraint if the line is highly visible from the urban or residential area itself.

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63. Nearly all public land in the corridors belongs to the State of Hawaii, only a small parcel along Highway 130 near Keaau belongs to the County of Hawaii. There is no federally owned land.

On the other hand, solid vegetation screens offer the best opportunity for masking the view of a transmission line. Solid screens virtually block one's view at the edge of the road, creating an enclosure and directing the line of sight away from the screen. A transmission line beyond the screen or well within it would not be visible from the road. Partial vegetation screens are effective if the line is set back far enough to appear no taller than the screen itself, and so views of the line are sufficiently diffused by the vegetation.

The urban screens of Pahoa and Keaau are wide enough that the corridors beyond are not visible from the main roads. The agriculture subdivisions and lands in agriculture production serve as partial screens in some locations along the major roads.

The majority of the berms mapped are the result of man-made road cuts and are immediately adjacent to the road. They can serve as solid screens if the line is located far enough back so that it appears no taller than the berm itself. Berms are also effective screens if they are covered with trees or if the ground beyond slopes away. These conditions can vary considerably over short distances however.

2. Views

Views of the corridor from major roads are indicated on the detailed analysis maps along with a verbal description for each in terms of openness *and viewgrounds (ie. foreground, middleground, background).*[64]

All views are constraints to the extent that they allow a transmission line to be fully visible from a major vantage point. Rights-of-way of major roads are a visual constraint because lines adjacent to major roads are highly visible, often silhouetted, and visually exposed to large numbers of people. Existing utility lines (electric and/or telephone) in road rights-of-way are an additional constraint because of the cluttered effect which may be created by adding another line. Transmission lines would be very visible and difficult to conceal when crossing major roads, so the number of road crossings should be minimized. If the line must cross a major road, it should do so at a right angle, if possible, in order to shorten the visible length of the line.

Although much of the existing urban and residential land in the corridor is heavily vegetated, thereby providing screening opportunities for a transmission line, there is also potential for significant views of the line. Open views are predominant along existing roadways and in areas with little vegetation or cleared of vegetation. Site-specific screening and view constraints are not mapped for these areas; all urban and residential lands are considered equally as a constraint in terms of visual resources.

Generally, views of the corridor from major roadways are infrequent and short in duration, especially considering the speed of passing motorists and passengers. Thus, the visual impact of views to the transmission line can be minimized by careful alignment within the viewplane. In the case of open views where a vista of the foreground, middleground and background is

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64. DHM Planners, inc. for Parsons Hawaii et. al., Visual Impact Analysis of Proposed 300 kVdc Line, Hawaii Deep Water Cable Program, January 1987.

present, it is preferable to locate the transmission line either directly in front of a total backdrop to avoid having poles and conductors silhouetted against the sky, or at a distance far enough away that the line is visually absorbed by the landscape. Where only a foreground is visible, the line can be placed immediately behind the screen which blocks the middleground and background. Alternately, it can be placed immediately in front of the screen, using it as a backdrop to minimize visual impact.

When there is more than one utility line along a major roadway, placement of the separate lines on a single pole minimizes the visual impact and cluttered appearance of several lines.

D. DESCRIPTION OF ALIGNMENTS

On the basis of these constraint analyses, a preferred alignment was delineated. The path of this alignment, in relation to the various data factors for all four (4) map sections, is shown in Exhibits VI-2 through VI-9. Also shown are alternative alignment segments. A narrative accompanying each map section describes the conditions encountered by the preferred alignment travelling northwest, and explains the reasons why it was selected over alternative alignments.

SECTION 1 (Exhibits VI-2 and VI-3)

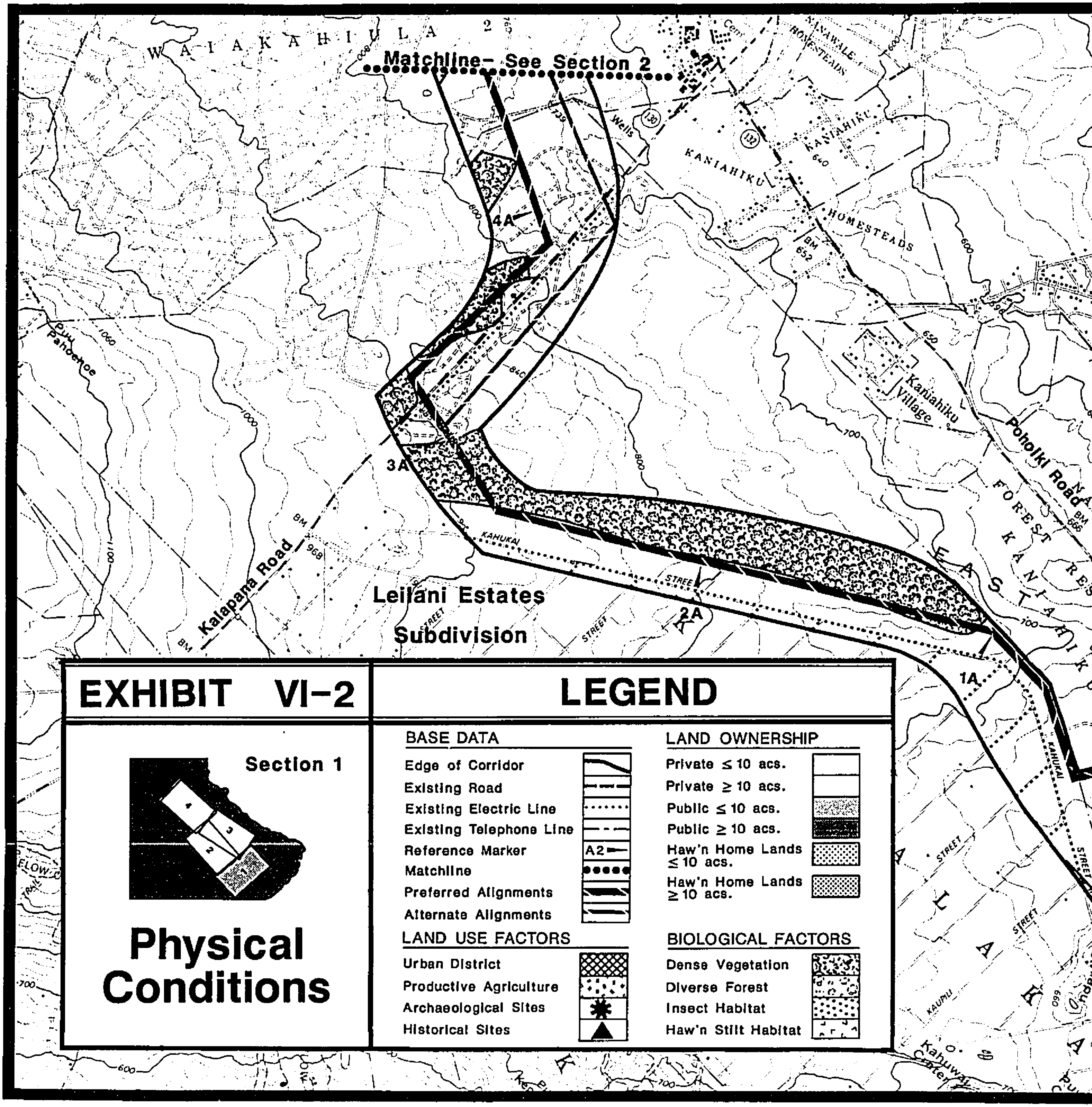
Alignment "A": This alignment originates on the western edge of the geothermal plant project area at Pohoiki Road. The alignment crosses Pohoiki Road and follows the western property lines of Pohoiki Bay Estates, a partially subdivided subdivision. At the southwest corner of Pohoiki Bay Estates, the alignment heads west along the outside edge of Nanawale Forest Reserve, at no time entering the respective Conservation District. At Reference Marker 1A, as shown on the map, the alignment turns southwest to follow a dirt road located on the northwest edge of Leilani Estates Subdivision, parallel to Kahukai Street. This dirt road is also marked by the dense vegetation along it, consisting of early stage Ohia forest and thick undergrowth of Uluhe fern. The alignment is located on Puna Sugar Company land to avoid crossing the numerous one-acre lots of Leilani Estates. Before Reference Marker 3A, the alignment unavoidably passes through the dense trees (which continue beyond the corridor) and crosses Kalapana Road at a right angle to minimize visual impacts. This is the first point at which the line is openly visible from a road since it originally crossed Pohoiki Road near the geothermal site. Once across Kalapana Road, the alignment parallels the road with a sufficient setback to be screened by the vegetation along the road and, where visible, allow the solid vegetation screen in the middleground serve as a backdrop to the line. At approximately Reference Marker 4A, the alignment heads northwest across former sugarcane fields to the end of Section 1.

An alternative alignment segment begins at Reference Marker 3A and parallels Kalapana Road on the east side. This alternative crosses the former sugarcane fields of Puna Sugar Company to the edge of the corridor where it turns to cross Kalapana Road. Although the alternative is set back 500 feet from the road, it is still within the open foreground view, thus visually less preferable.

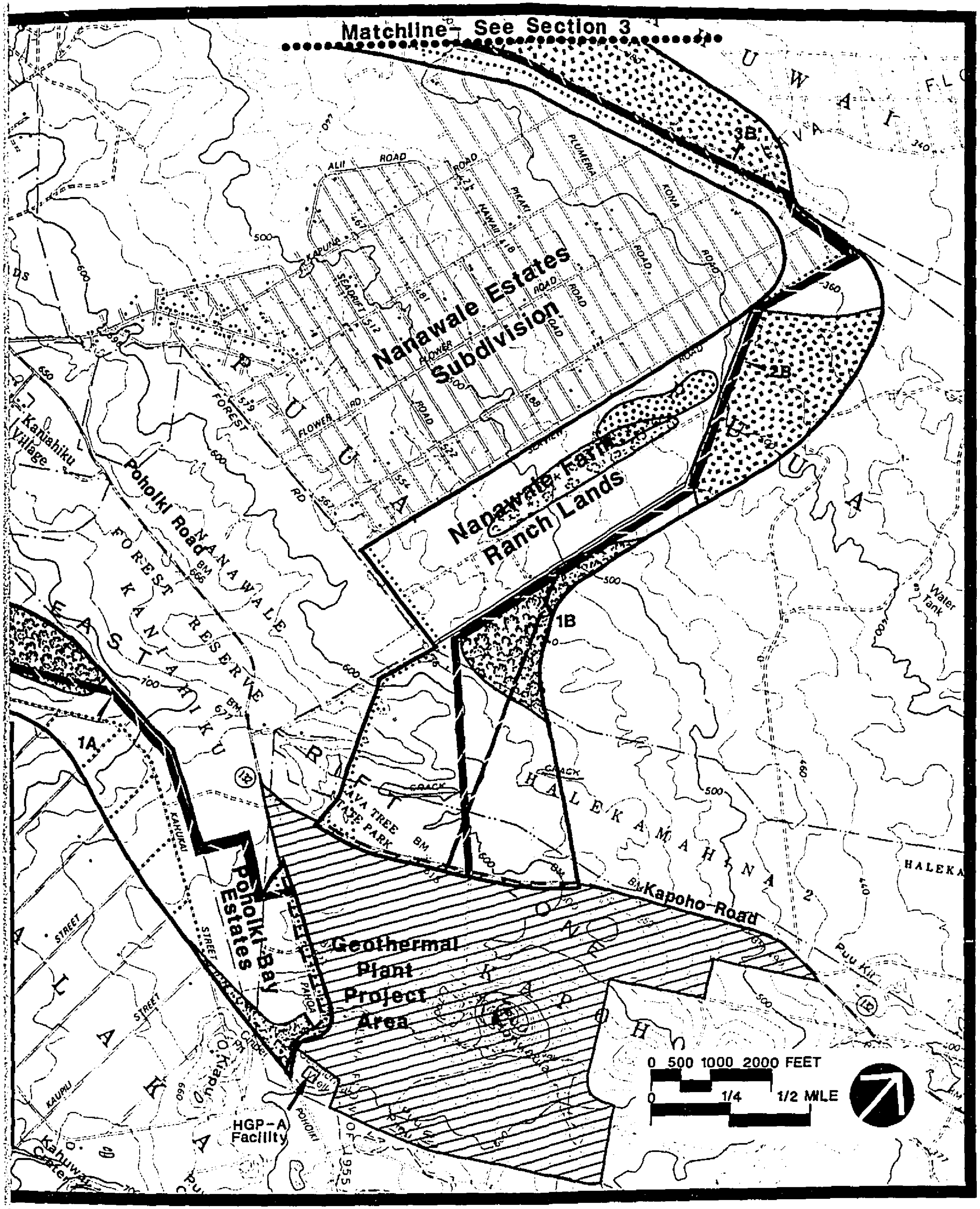
Alignment "B": Preferred alignment "B" originates on the northern edge of the geothermal plant project area at Kapoho Road. Thermal Power intends to route the transmission line along the existing dirt road from the proposed power plant site near Puu Honuaula to Kapoho Road. From this point, the preferred alignment crosses Kapoho Road and heads northwest across open herbaceous weedland to the edge of Nanawale Farm Ranch Lands, avoiding an area of dense tree growth to minimize environmental disturbance and additional construction and maintenance costs. Likewise, by following an existing dirt road along the east side of the Ranch Lands, considerable disturbance to the forest area is avoided. Views to the alignment are screened by a berm and dense vegetation along Kapoho Road. The preferred alignment continues outside the west and north boundaries of the Nanawale Farm Ranch Lands to avoid the numerous subdivided parcels and areas of diverse forest and unique insect habitat identified during biological field surveys. Near Reference Marker 2B, the alignment is on the edge of productive orchard lands as identified by the State Department of Agriculture.

Between Reference Marker 2B and edge of Section 1, the alignment runs adjacent to the northern edge of Nanawale Estates Subdivision. Only at the northeast corner of the subdivision (about halfway between Reference Marker 2B and 3B) is the preferred alignment located inside the subdivision property line, along an existing road. This is necessary to avoid routing the line through the Conservation District lands of Nanawale Forest Reserve. Once past the Forest Reserve, the alignment is located in State land which is leased to a large papaya growing company and is identified as productive agricultural land. By keeping the alignment close to the property line, it will have minimal impact to agricultural use of the land and will not be visible from the subdivision due to the dense vegetation screen along the road.

An alternative alignment segment also originates at Kapoho Road, a few hundred feet west of the preferred alignment, in order to cross the road and follow a property line between two large (50 acre) flag lots. This alignment avoids bisecting individual privately owned parcels, however it crosses through nearly a half mile of dense vegetation. Since all the parcels affected by the preferred alignment have the same owners and leasee, it was selected over this alternative. However, the final alignment is dependent on negotiations with the landowners involved.



POHOIKI GEOTHERMAL TRANSMISSION LINE



N LINE ROUTING STUDY ○ DHM inc.

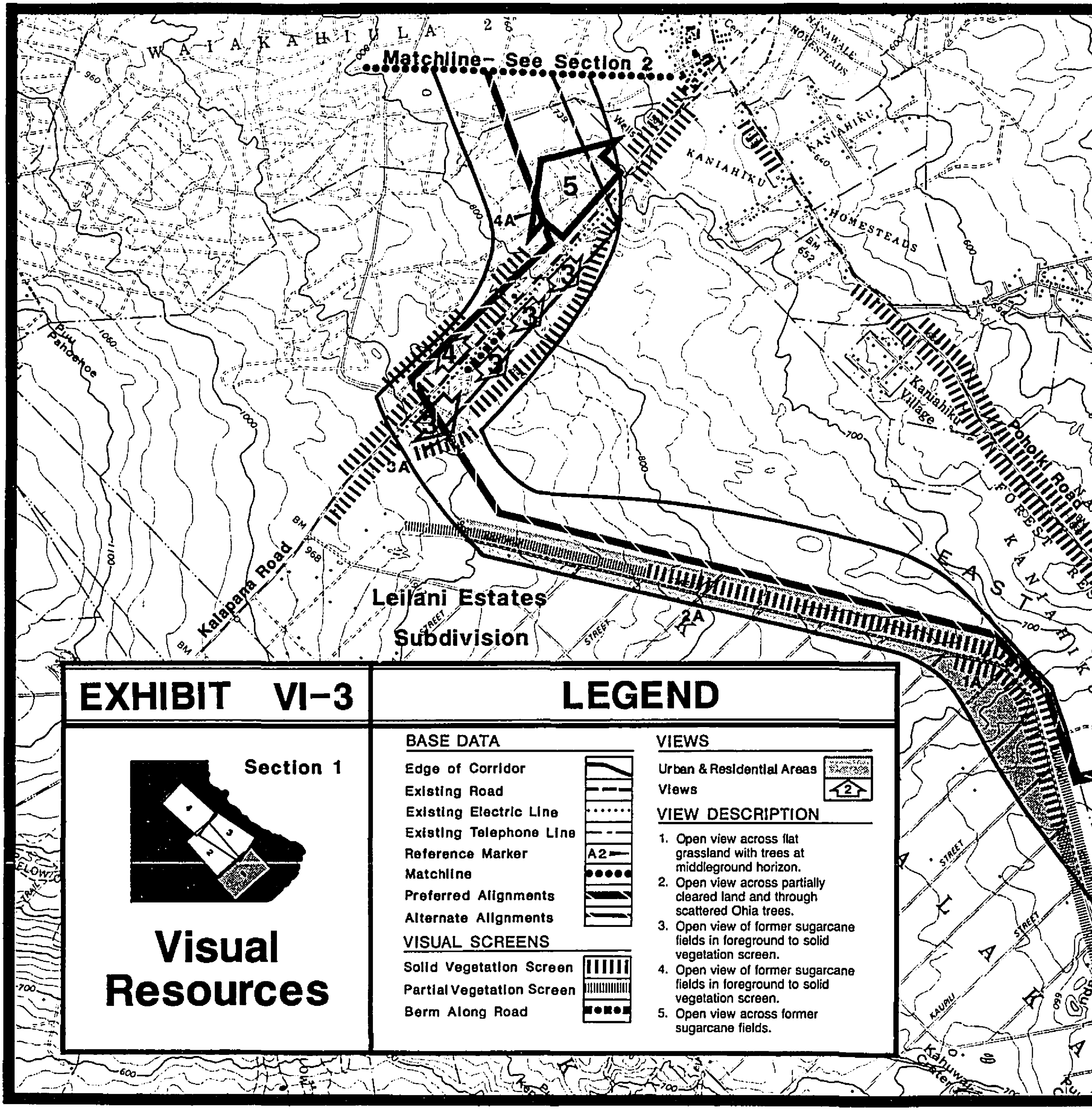


EXHIBIT VI-3

Section 1

Visual Resources

LEGEND

BASE DATA

- Edge of Corridor
- Existing Road
- Existing Electric Line
- Existing Telephone Line
- Reference Marker
- Matchline
- Preferred Alignments
- Alternate Alignments

VISUAL SCREENS

- Solid Vegetation Screen
- Partial Vegetation Screen
- Berm Along Road

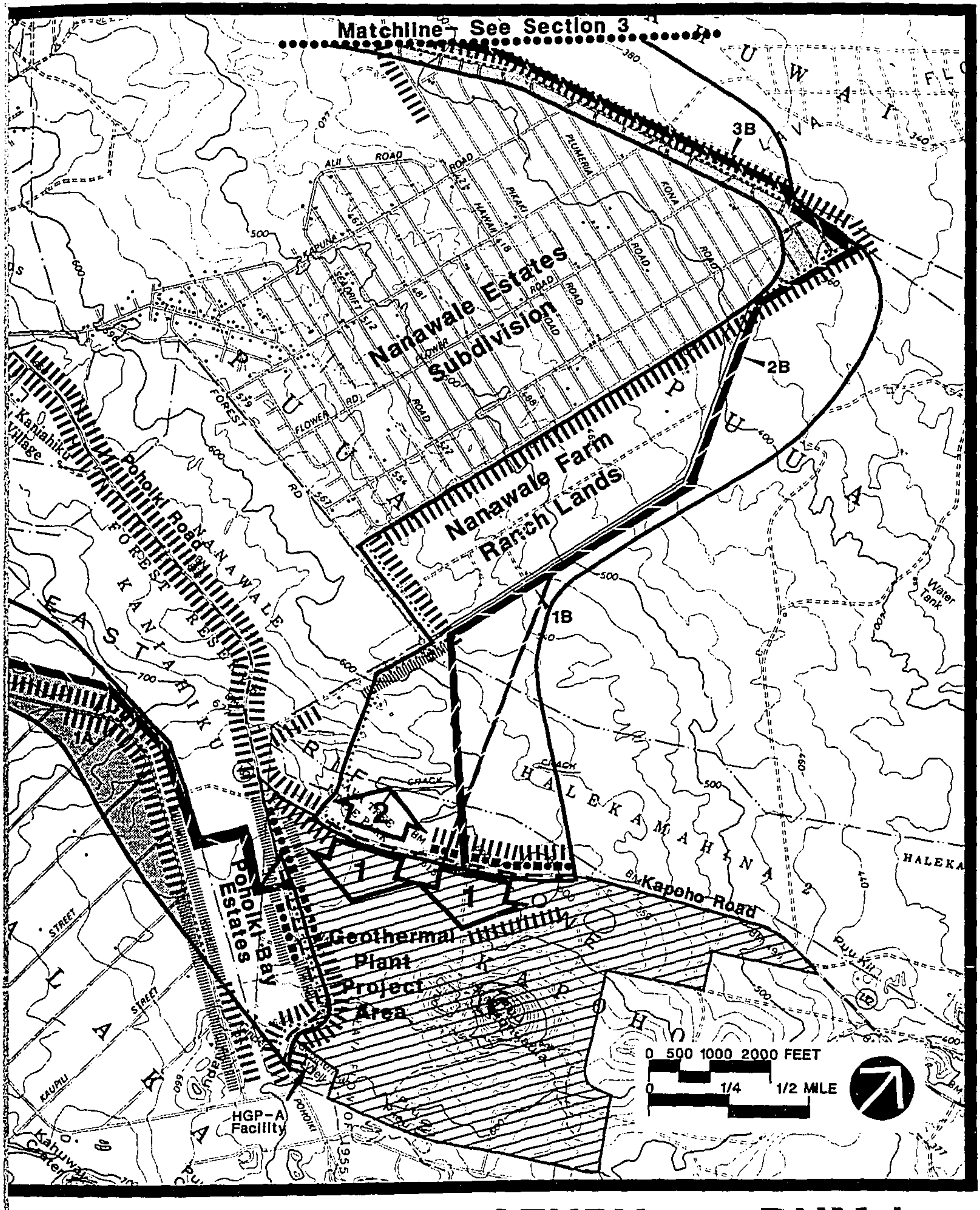
VIEWS

- Urban & Residential Areas
- Views

VIEW DESCRIPTION

1. Open view across flat grassland with trees at middleground horizon.
2. Open view across partially cleared land and through scattered Ohia trees.
3. Open view of former sugarcane fields in foreground to solid vegetation screen.
4. Open view of former sugarcane fields in foreground to solid vegetation screen.
5. Open view across former sugarcane fields.

POHOIKI GEOTHERMAL TRANSMISSION LINE



N LINE ROUTING STUDY ○ DHM inc.

SECTION 2 (Exhibits VI-4 and VI-5)

Alignment "A": The preferred alignment "A" continues across the former sugarcane fields, skirting a small kipuka of native forest which is a significant insect habitat. Near Reference Marker 5A, the alignment heads north along the existing Pahoa Bypass Road. The alignment is kept on the makai side of the road because of the Pahoa solid waste station and a burial cave archaeological site on the mauka side.

The alternative alignment to the north meets the preferred alignment near the solid waste station.

From the waste station until nearly Reference Marker 7A, the preferred alignment crosses State-owned land which is basically vacant lava land, overgrown with weeds and scattered scrub Ohia trees. Unavoidably, the alignment crosses the upper portion of Pahoa Cave which was identified during the field surveys as a sensitive insect habitat. The cave is believed to extend far upland, therefore, even a transmission line route outside the study corridor may not avoid crossing it. Significant care must be taken during design and construction of the line to avoid damaging the cave or exposing it to increased access.

Through the Hawaiian Home Lands of Maku'u (between Reference Marker 7A and Ainaloa), the alignment is located near the mauka edge of the study corridor to by-pass the newly subdivided 2-acre lots which are leased to native Hawaiian beneficiaries.

The alignment route through Ainaloa Subdivision was based on the location of the *preferred alignment in Orchid Land Estates. In Orchid Land, the alignment follows* 35th Avenue because it has the greatest length of existing distribution lines, thus existing utility rights-of-way. Also, 35th Avenue is a continuous road through the subdivision and has fewer existing homes along it than does 34th Avenue. In Ainaloa Subdivision however, the extension of 35th Avenue is a densely populated road with an existing distribution line.

There is native Ohia forest of short, pole-like habit on both sides of the highway through this section. Guava, mango and other alien trees are interspersed among the Ohia and the understory consists of weeds. The presence of the numerous houselots and agriculture lots disrupt the integrity of the forest, and as a result there is no continuity to plant formations.[65] This is the case throughout the subdivision areas in all corridor sections.

The alternative alignment through Ainaloa Subdivision follows a deadend, sparsely populated road with no existing utility ROW, to meet with 34th Avenue in Orchid Land Estates. This alternative is so located because in Section 4 it joins Highway 130.

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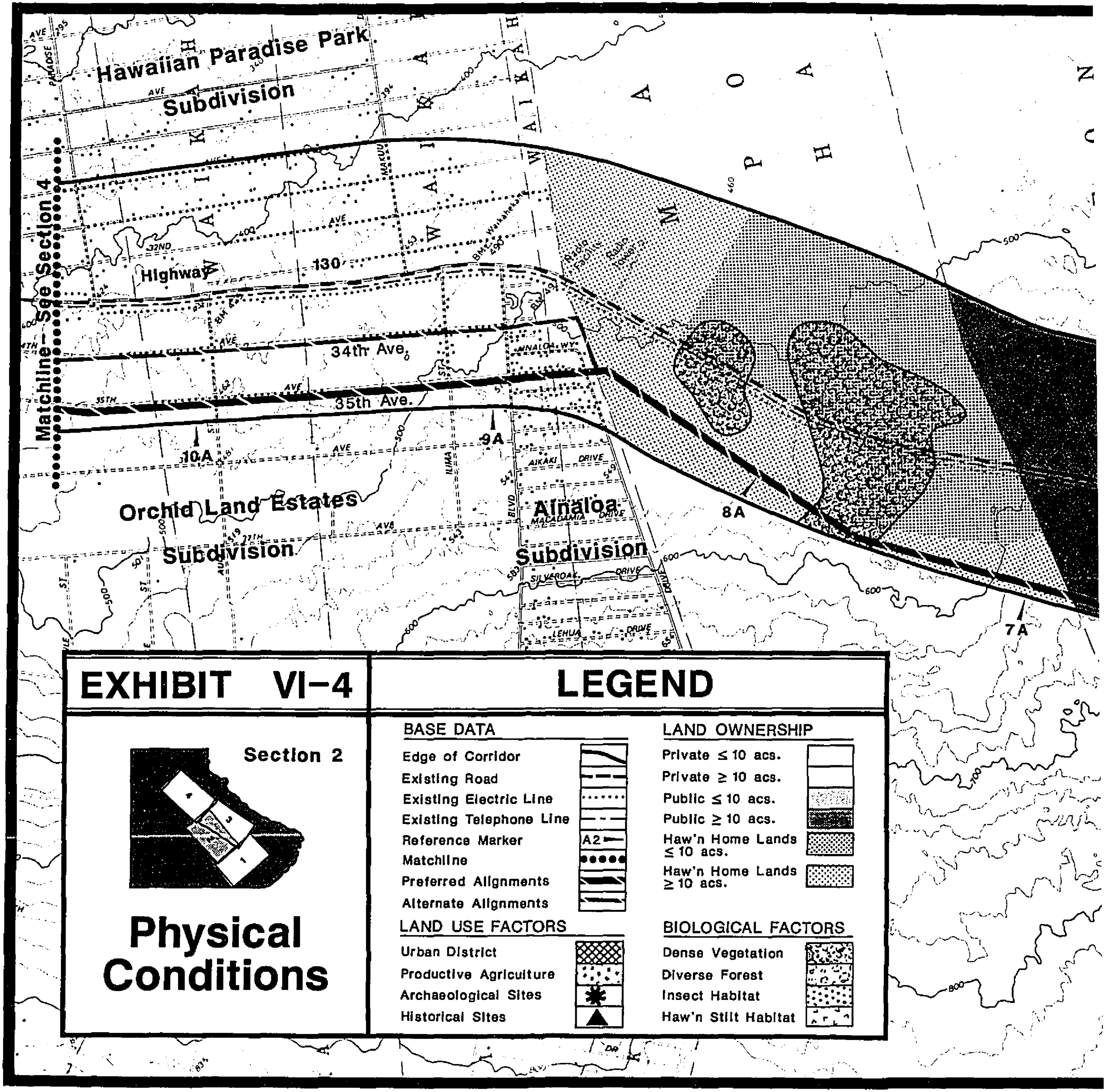
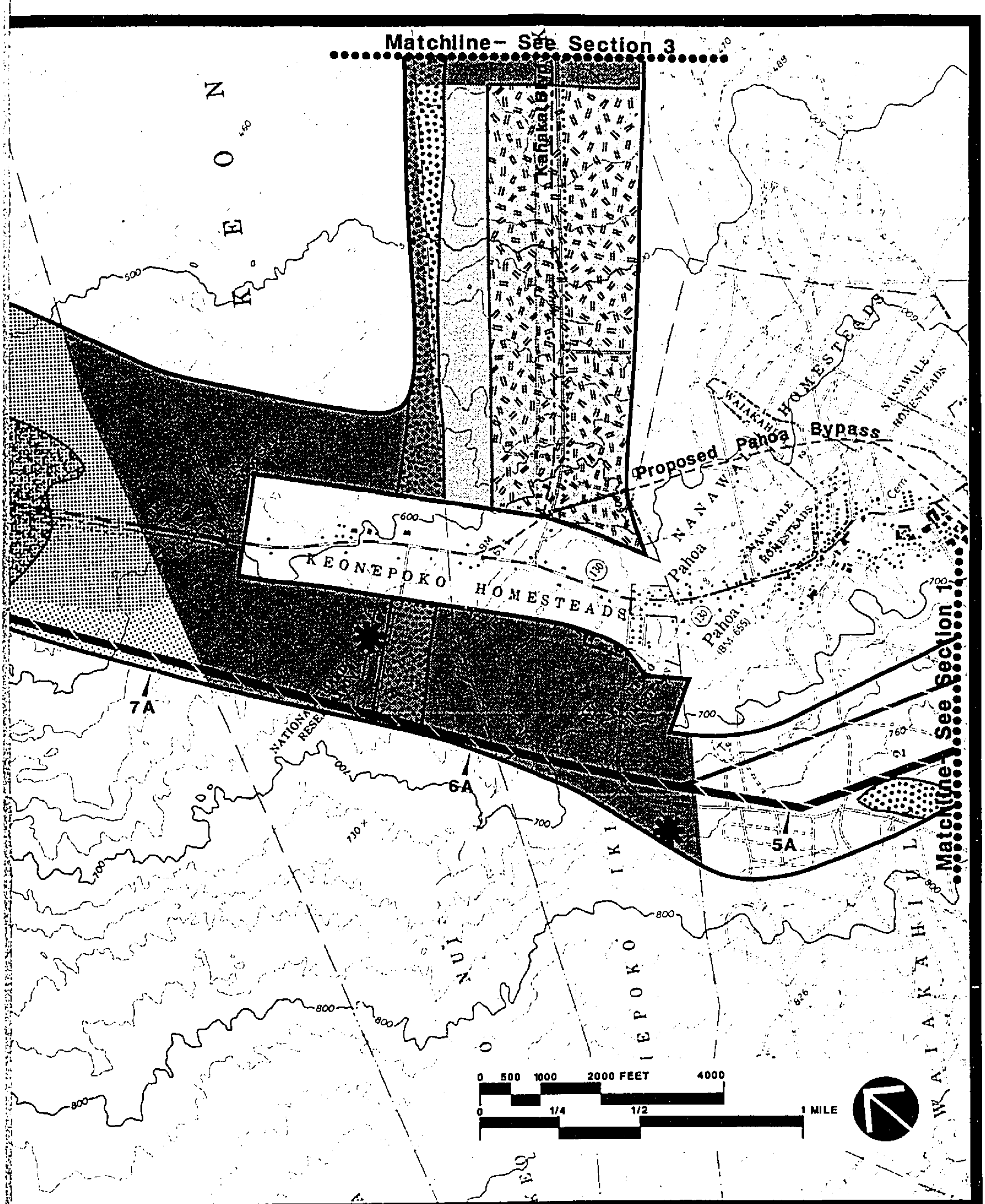
65. Appendix C, Botanical Survey.



POHOIKI GEOTHERMAL TRANSMISSION LINE R



N LINE ROUTING STUDY ○ DHM inc.

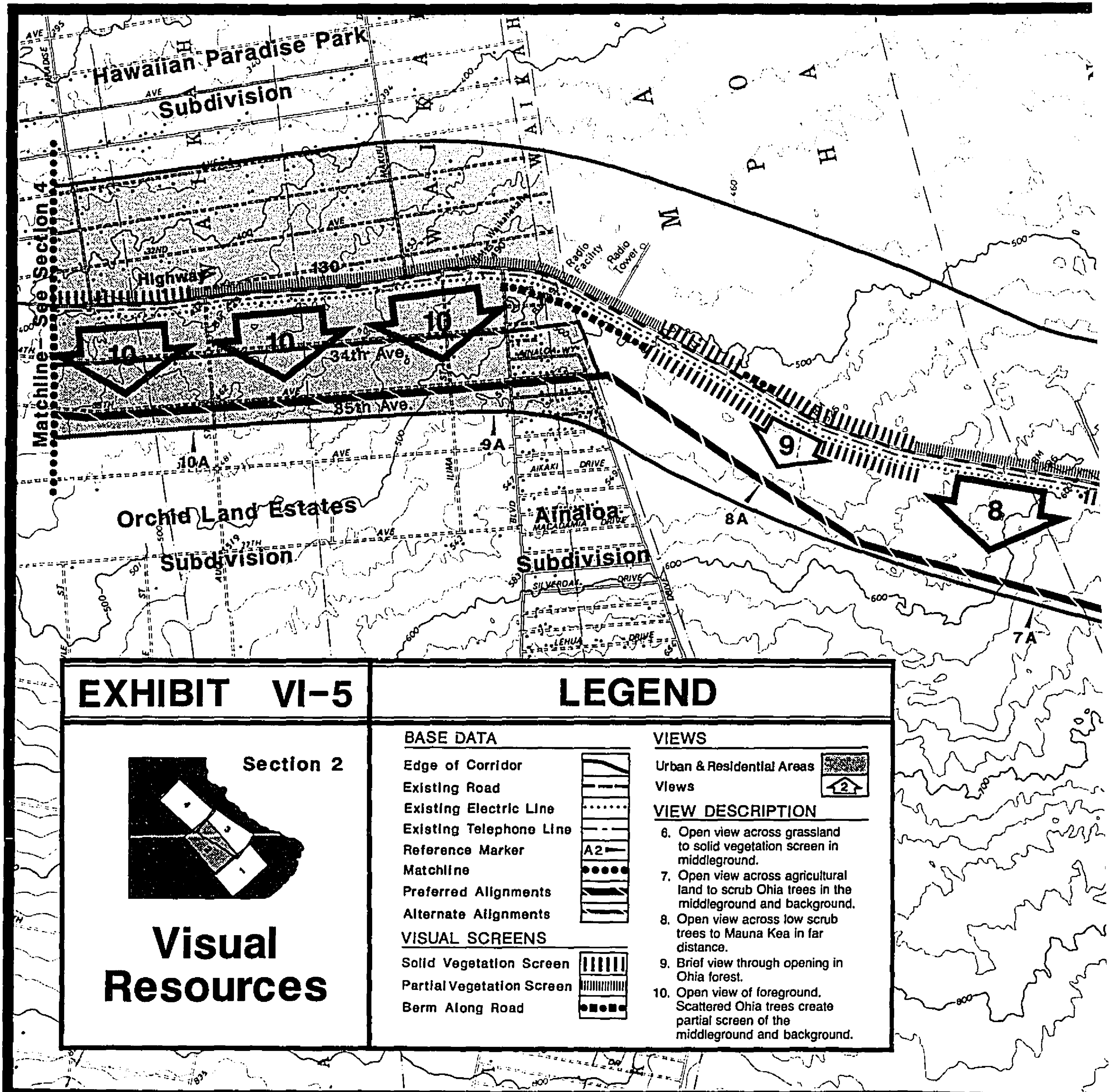


EXHIBIT VI-5

Section 2

Visual Resources

LEGEND

BASE DATA

- Edge of Corridor
- Existing Road
- Existing Electric Line
- Existing Telephone Line
- Reference Marker (A2)
- Matchline
- Preferred Alignments
- Alternate Alignments

VISUAL SCREENS

- Solid Vegetation Screen
- Partial Vegetation Screen
- Berm Along Road

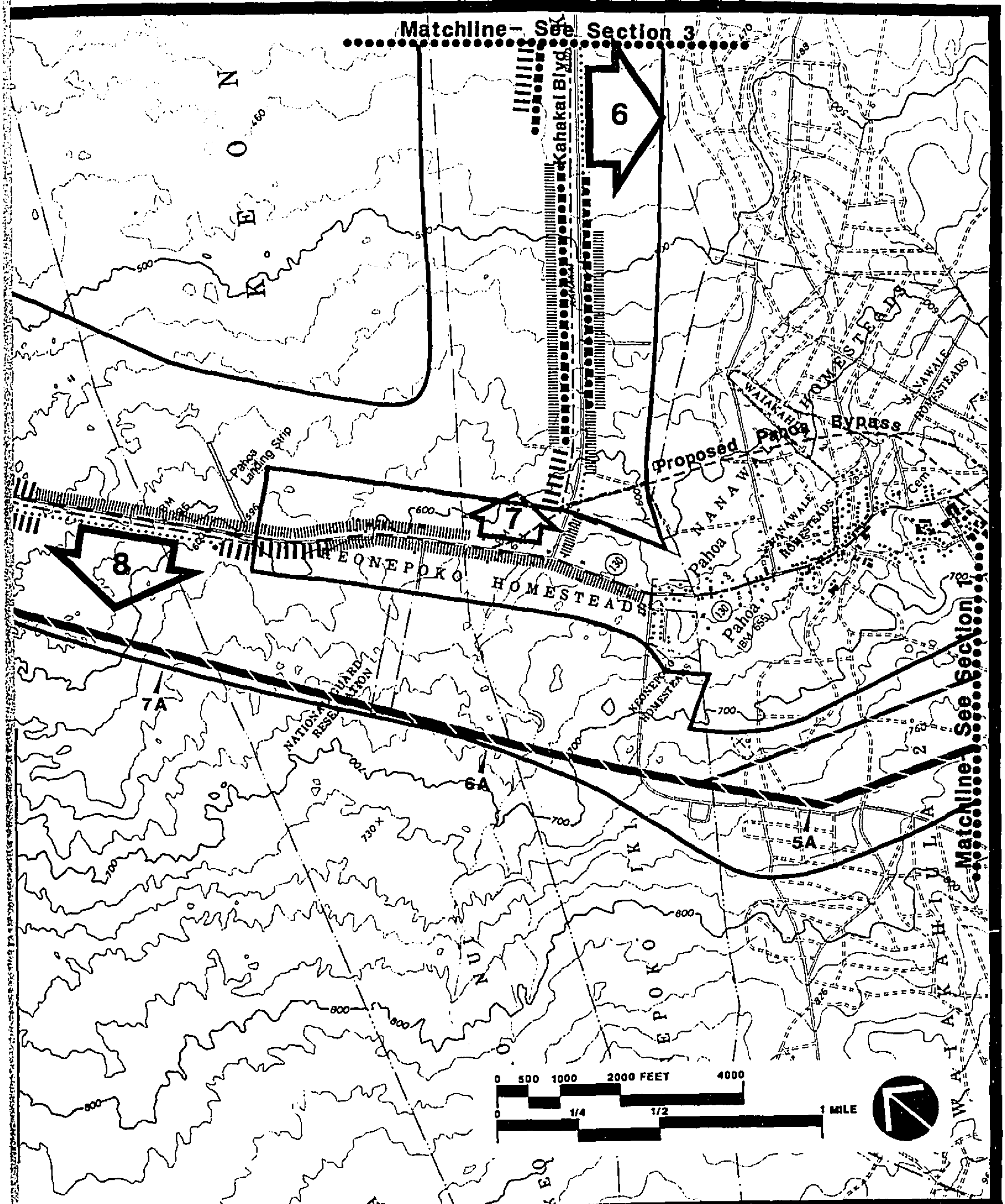
VIEWS

- Urban & Residential Areas
- Views (2)

VIEW DESCRIPTION

6. Open view across grassland to solid vegetation screen in middleground.
7. Open view across agricultural land to scrub Ohia trees in the middleground and background.
8. Open view across low scrub trees to Mauna Kea in far distance.
9. Brief view through opening in Ohia forest.
10. Open view of foreground. Scattered Ohia trees create partial screen of the middleground and background.

POHOIKI GEOTHERMAL TRANSMISSION LINE



N LINE ROUTING STUDY ○ DHM inc.

SECTION 3 (Exhibits VI-6 and VI-7)

Alignment B: From the matchline with Section 1, the preferred alignment turns away from the boundary of Nanawale Estates heading northwest across private-owned agricultural parcels and former sugar lands. At the western tip of Hawaiian Beaches Subdivision, near Reference Marker 5B, the alignment passes close to an existing water tank, and between two archaeological sites identified in the field survey. There is sufficient distance between the line and the sites to avoid any disturbance to them. The site closest to the subdivision is a cluster of petroglyphs and the site south of the alignment is a burial cave.

The alignment continues northwest across the State-owned grassland terrain in Keonepoko Iki land division. From Kahakai Boulevard, which the alignment crosses, there is an open view to the north, but a partial screen looking south. The lower portion of Pahoa Cave, an important insect habitat, is unavoidably crossed by the alignment, but is crossed at a right angle to minimize the distance. The final alignment may be adjusted once the cave is accurately surveyed. Beyond the cave, the alignment hugs the Keonepoko boundary to the former railroad right-of-way, keeping the maximum distance between the line and Hawaiian Beaches Subdivision.

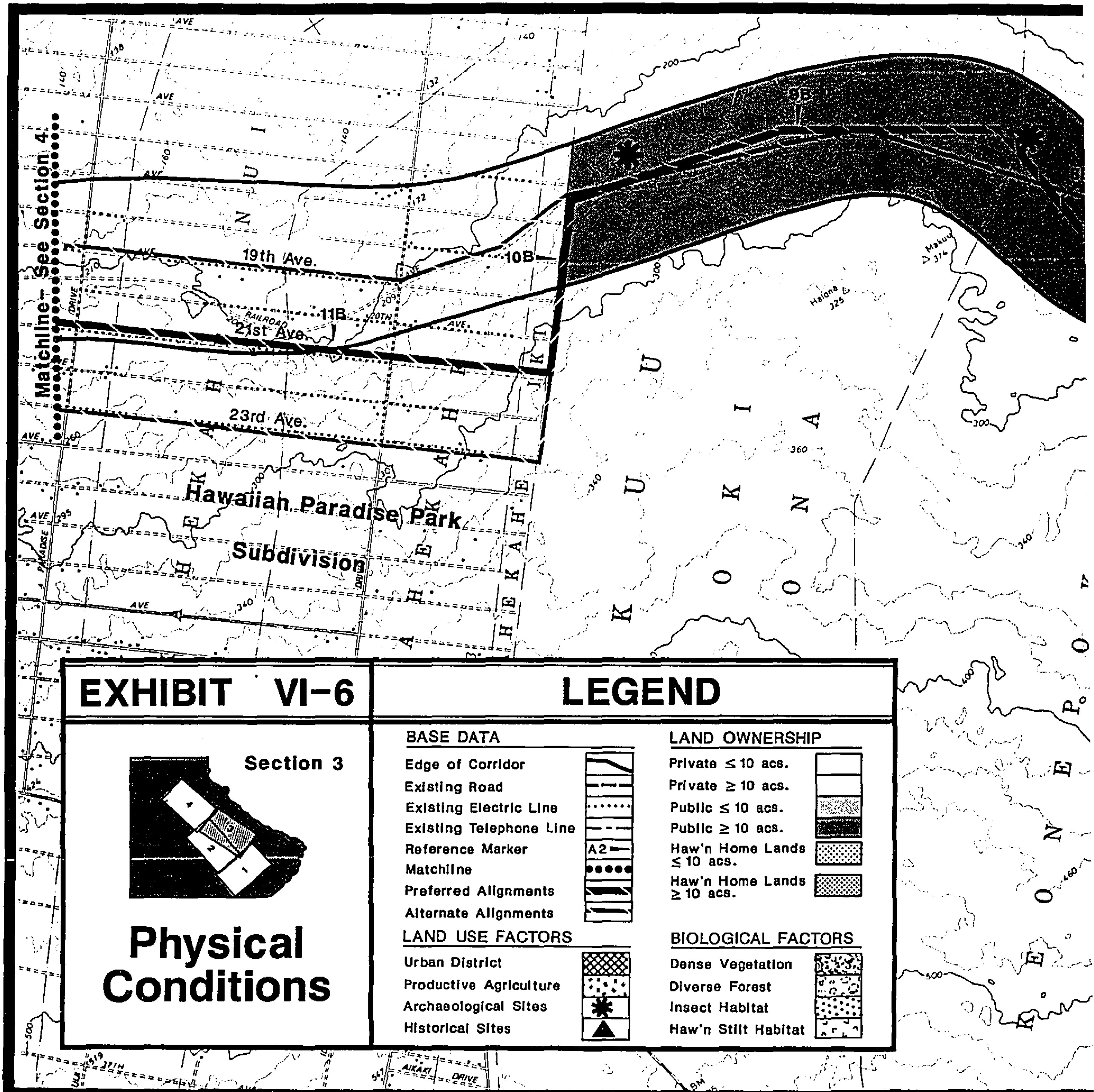
Along the former railroad right-of-way, the preferred alignment follows the existing jeep trail closely to take advantage of the accessibility provided and to minimize unnecessary disruption to the surrounding environment. It also avoids interfering with two archaeological sites near the old railroad route.

Throughout this area (State-owned land) the landscape is very homogeneous, consisting of andropogon grassland with scattered Ohia snags, apparently previously burned.

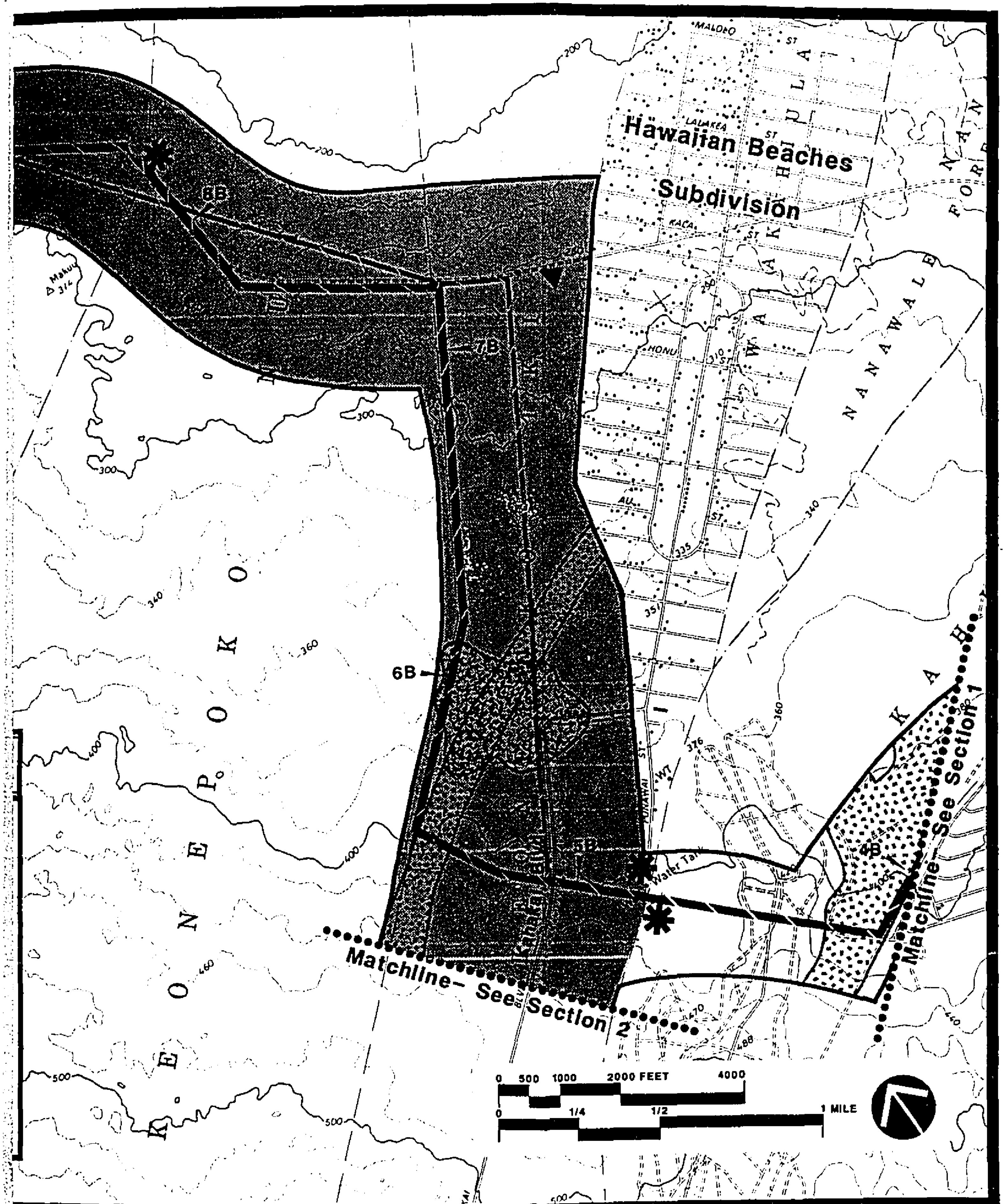
Where the railroad meets Hawaiian Paradise Park Subdivision (Reference Marker 10B), the preferred alignment turns and follows the subdivision boundary to 21st Avenue, where it turns and continues on 21st Avenue through the subdivision to the matchline with Section 4. 21st Avenue is the preferable route because it has an existing distribution line and 40-foot wide HELCO easement along much of it.

An alternative alignment segment heads north toward the railroad ROW along the north side of Kahakai Boulevard (near Reference Marker 5B). While this increases the ease of access, it also makes the line more visible from the boulevard and possibly from Hawaiian Beaches Subdivision. When this alternative meets the railroad ROW however, it follows a straight-line route, minimizing line length and the number of changes in direction, but diverging up to 700' from the jeep trail.

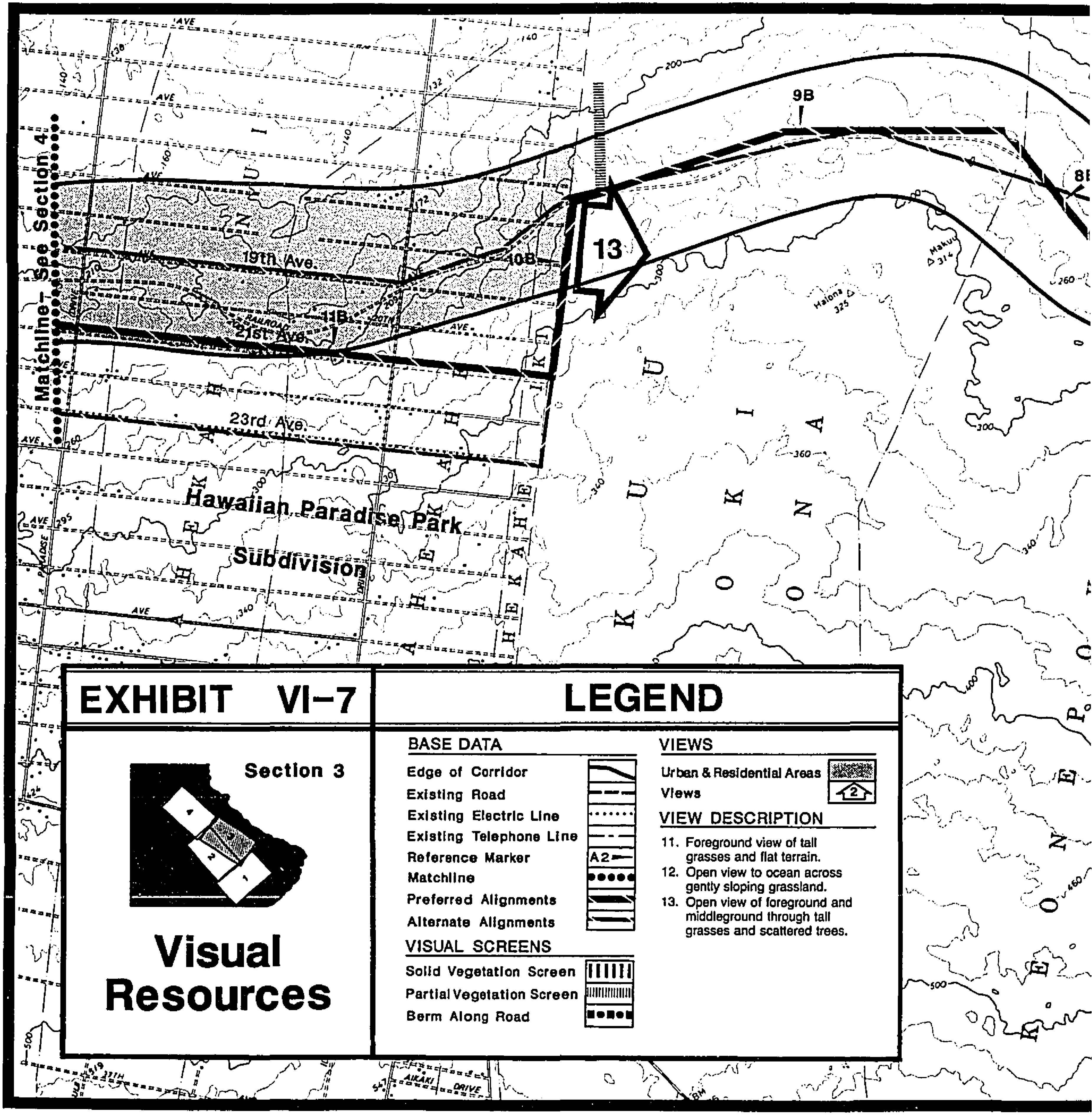
There are two alternatives through Hawaiian Paradise Park. The makai alternative follows Railroad Avenue to 19th Avenue, along which there are large sections with existing distribution lines. The mauka alternative is along 23rd Avenue which also has distribution lines, but is entirely outside the corridor. The corridor boundaries through the subdivision define the most direct route between the areas of less constraint on either side. (Refer to Chapter IV and V).



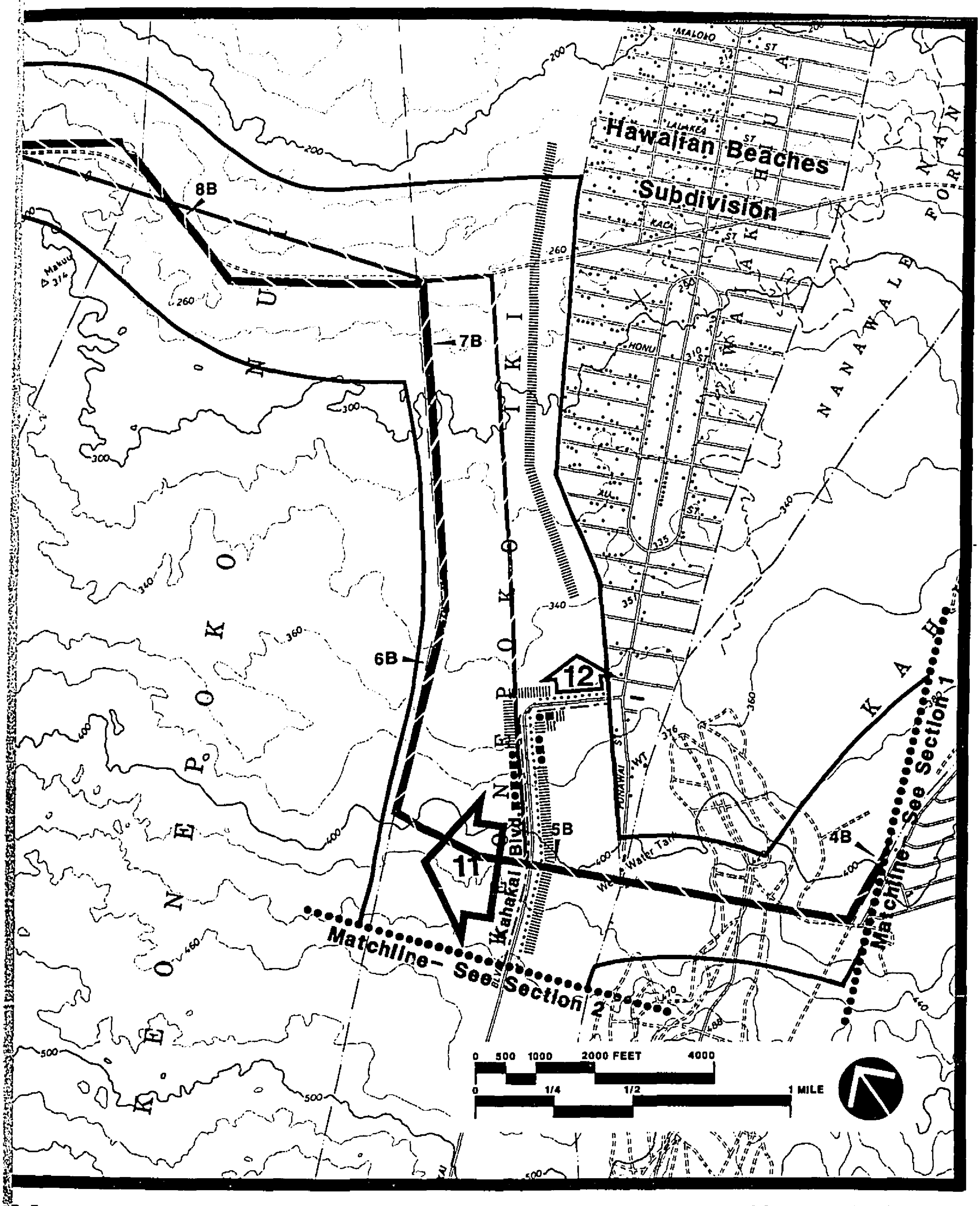
POHOIKI GEOTHERMAL TRANSMISSION LINE



ON LINE ROUTING STUDY ○ DHM inc.



POHOIKI GEOTHERMAL TRANSMISSION LINE



N LINE ROUTING STUDY ◦ DHM inc.

SECTION 4 (Exhibits VI-8 and VI-9)

Alignment "A": From the match line with Section 3, the preferred alignment continues on 35th Avenue through Orchid Land Estates to the edge of the subdivision. There is an existing distribution line and utility easement along most of 35th Avenue in this section, and very few of the 3-acre lots have existing houses. The road itself is an unmaintained dirt road.

North of the subdivision, the preferred alignment crosses a small area of former sugarcane fields (Reference Marker 13A). Although there is an open view of the fields from Highway 130, the alignment is set back far enough that it will not be visually prominent. As the preferred alignment continues northward across vacant lava land and scrub vegetation, the distance effect and the existing berm and partial vegetation screen along the highway eliminate any adverse visual impacts. The alignment remains set back from the highway as it crosses through more abandoned cane fields near Reference Marker 15A, in order to pass behind (mauka of) the plantation manager's estate, which is identified as an historic site.

The preferred alignment crosses Highway 130 south of Keaau at the intersection with a paved sugarcane road. The alignment then follows this road northeast and then north to meet the existing 69 kV line which leaves Puna Substation heading for Kaumana. The alignment avoids all urban and residential lands of Keaau and the community of "8-1/2 Mile Camp". The proximity of the alignment to the existing paved road provides convenient access for construction and maintenance and eliminates the need to construct a special access road.

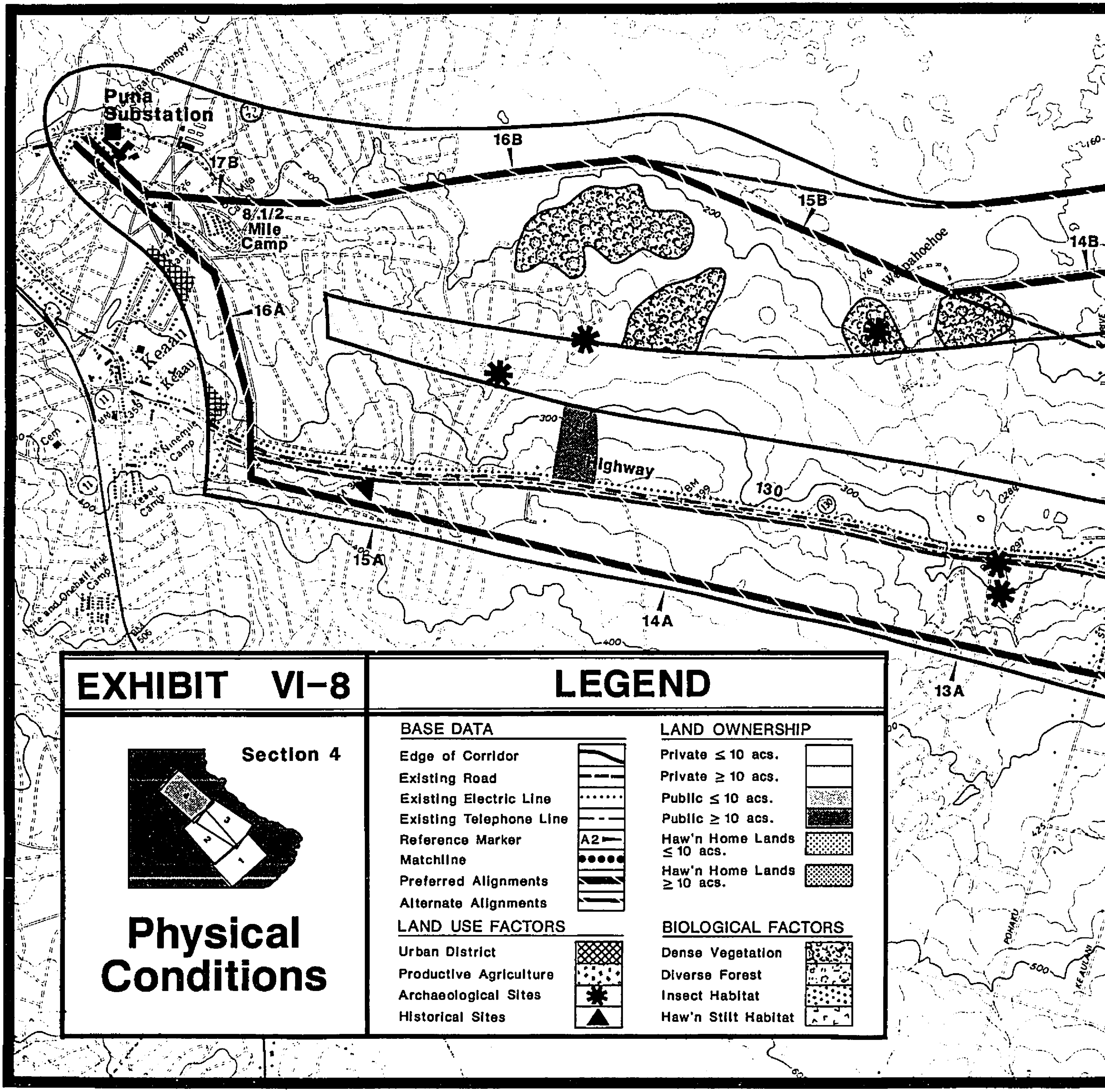
Although the alternative alignment segment shown in Section 4 avoids traversing the subdivisions, it has 3 major disadvantages: visual impacts, and environmental and technical problems. The alternative is located within the right-of-way of Highway 130, mauka of the road, for nearly 5 miles. The adverse visual impact created by this alignment would be significant, especially considering the existing 34.5 kV transmission line on the makai side of the road. If the alignment could be set back to take advantage of the existing vegetation screens along the highway, the visual impacts could be reduced considerably. Environmentally, this alternative crosses one archaeological site of agricultural terraces near Reference Marker 13A and passes between the highway and the historic plantation manager's house near Reference Marker 15A. Careful placement of the poles may avoid disturbing the archaeological and historic sites. From the technical aspect, there is currently a telephone line in the highway right-of-way mauka of the road. Because of limited right-of-way width, arrangements would have to be made between HELCO and Hawaiian Telephone to share poles.

Alignment B: Preferred alignment "B" continues through Hawaiian Paradise Park along 21st Avenue, within existing utility ROW where it exists, until 21st Avenue ties into Railroad Avenue. The alignment then follows Railroad Avenue out of the subdivision, where the railroad ROW is again a jeep trail. Crossing rough lava terrain, scrub vegetation, and former sugarcane lands, the alignment stays close to the railroad trail until Reference Marker 17B. At this point it takes the most direct route to meet the existing 69 kV line west of Puna Substation.

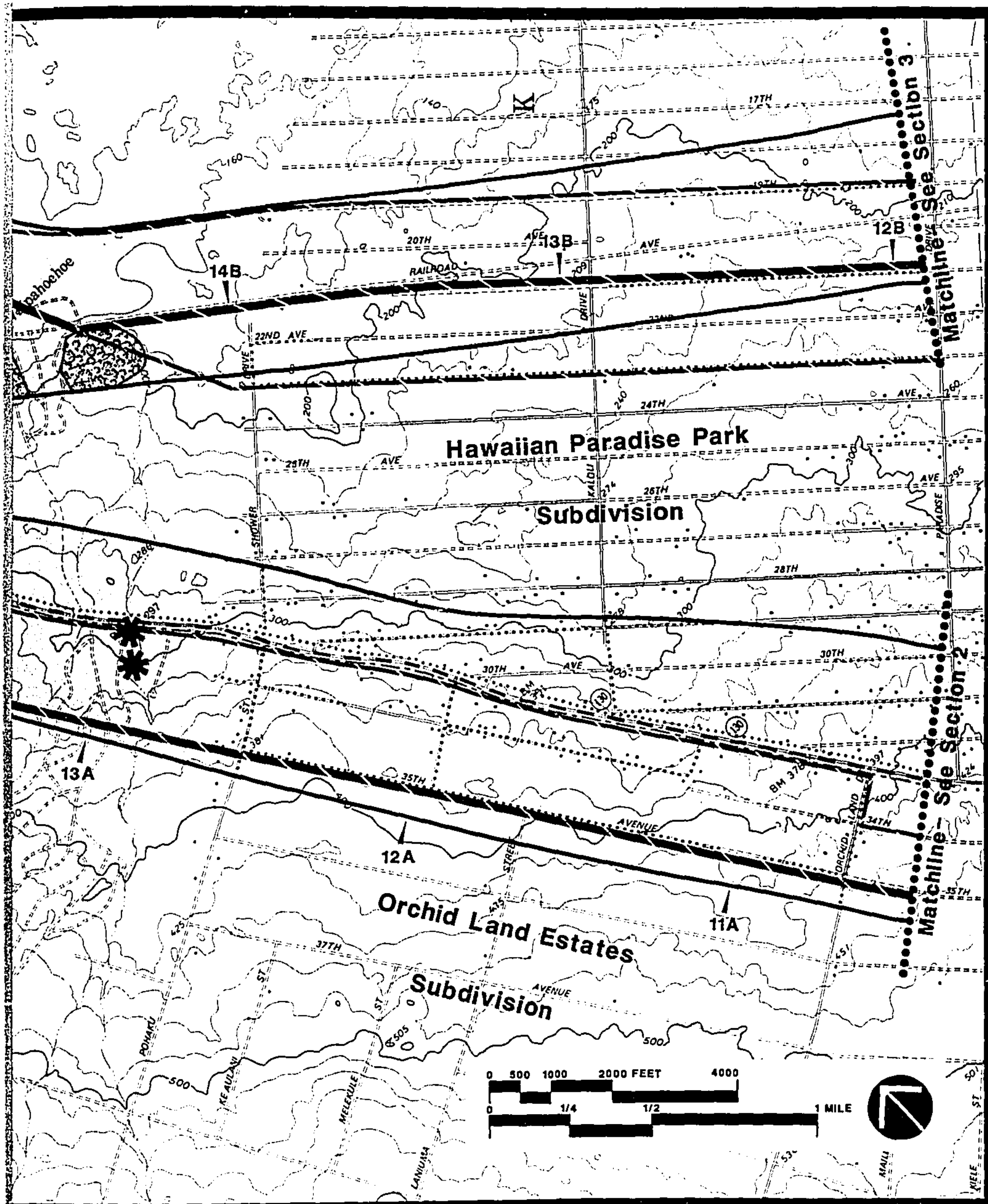
The makai alternative follows 19th Avenue to the end of the subdivision and continues northwest across the vacant lava/scrub land to meet the railroad trail. This alternative would require a mile-long access road beneath it because of its distance from the railroad and the rough terrain it crosses.

The mauka alternative through the subdivision follows 23rd Avenue outside the corridor, and meets the preferred alignment near Waipahoehoe, between Reference Markers 14B and 15B.

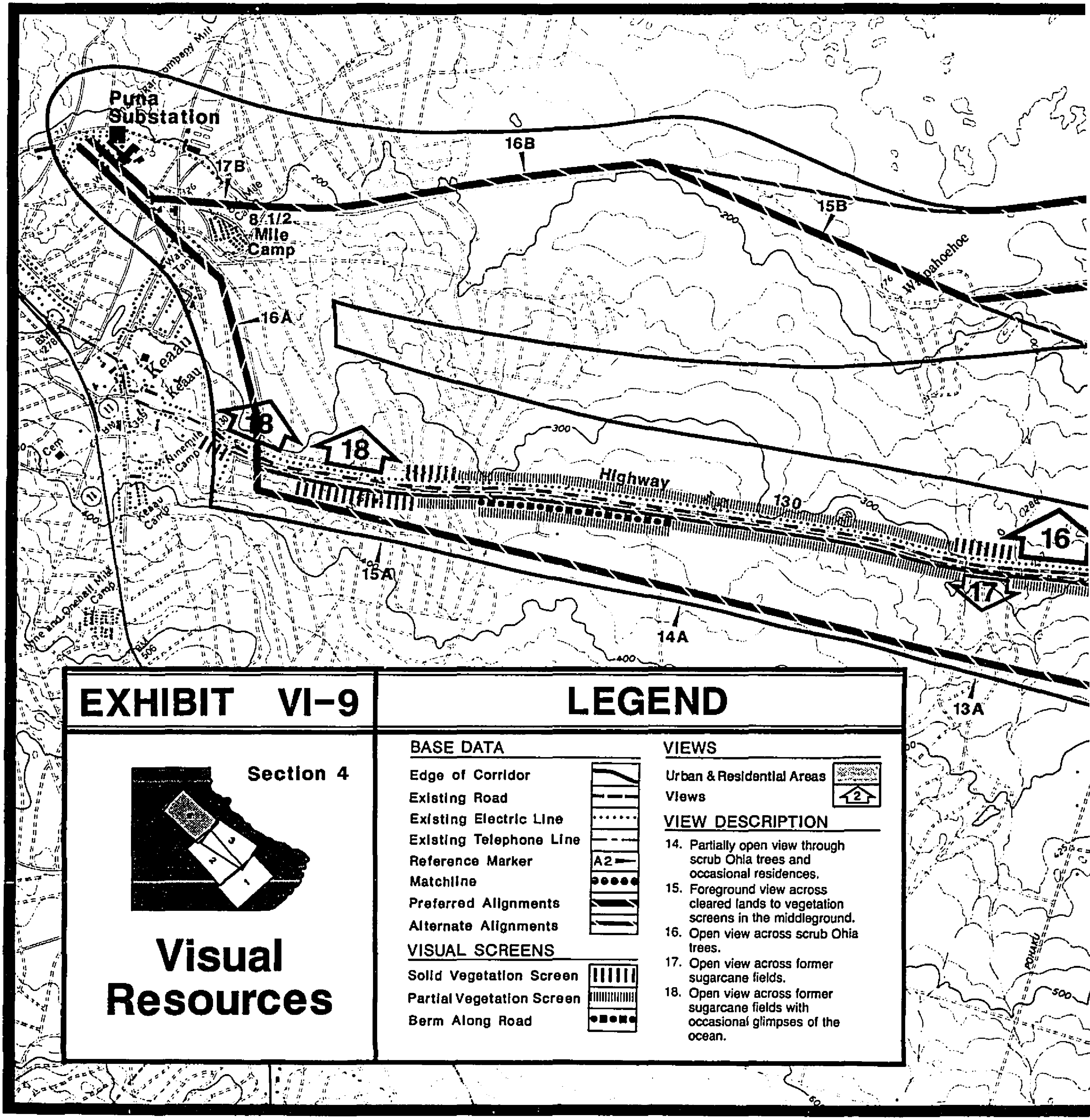
The overall alignments of preferred and alternative "A" and "B" are shown in Exhibit VI-10.



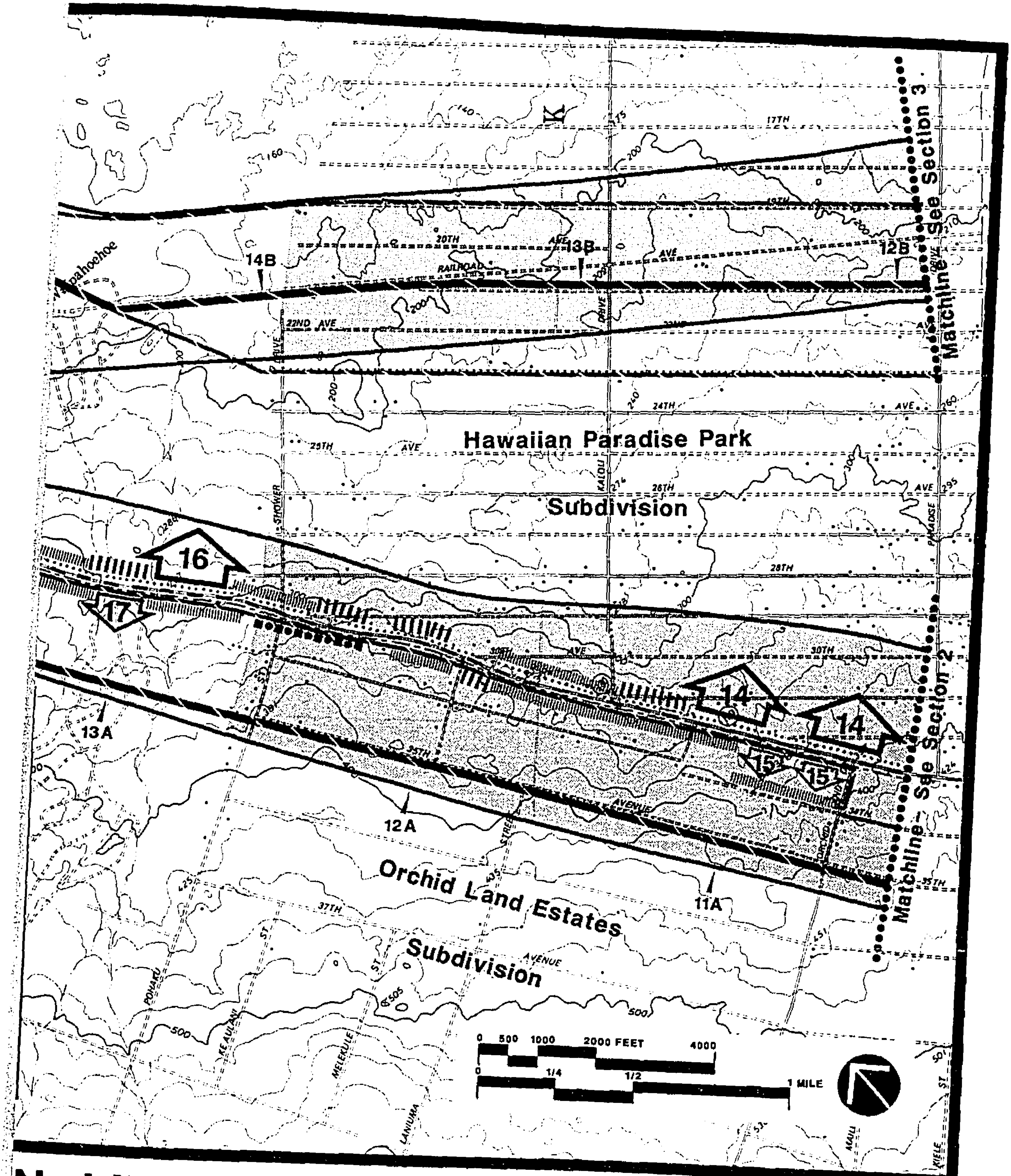
POHOIKI GEOTHERMAL TRANSMISSION LINE F



N LINE ROUTING STUDY ○ DHM inc.



POHOIKI GEOTHERMAL TRANSMISSION LINE



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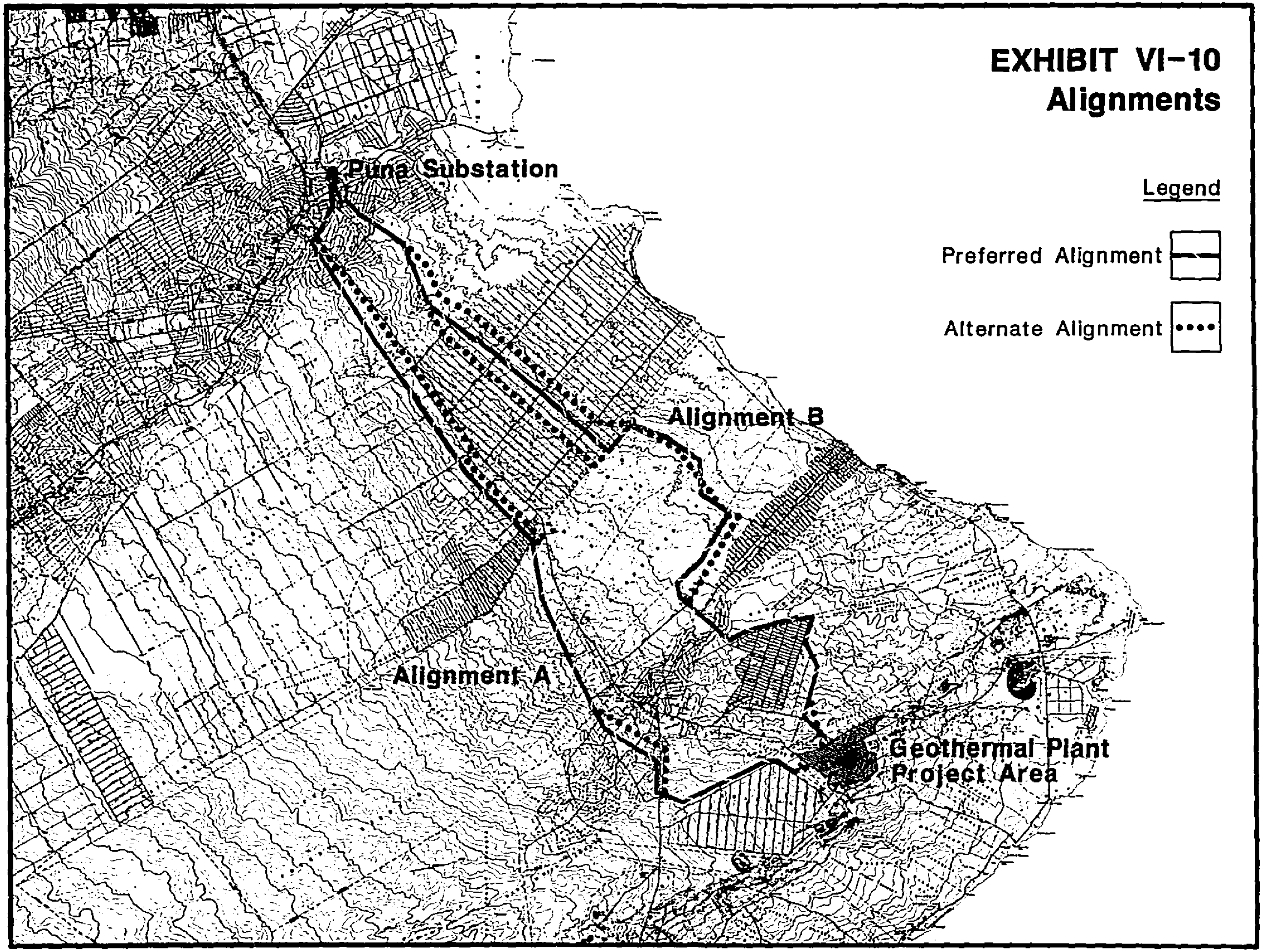

EXHIBIT VI-10
Alignments

DHM inc.

APPENDIX A

APPENDIX A

SUMMARY OF FIRST COMMUNITY WORKSHOP

Pahoa Community Center
Pahoa, Hawaii
Wed., November 12, 1986
7:00 p.m.

Twenty five residents attended the workshop in Hilo, as shown on the attached list. The workshop began with a presentation by HELCO on its system planning requirements and the need for the proposed transmission line. HELCO also explained why they are involved with the proposed geothermal plant, and indicated that Thermal Power Company will be holding separate workshops related to the general plant itself in the near future. This was followed by a presentation by DHM inc. on transmission line routing methodology and samples of broadscale data factor maps from a previous transmission line routing study.

After these presentations, workshop attendees were asked to comment on or suggest revisions to the criteria or methodology for the routing study. They were also invited to raise questions and concerns related to the description and rationale for the project.

Specific issues raised during the question and answer period were:

1. Project Need and Description

    a. Will the new poles be shared with other utilities such as telephone?

    b. What "class" of pole will be used?

    c. When making right-of-way acquisitions, will you be contacting individual landowners?

    d. What kinds of projections does HELCO make for future energy demands?

    e. How long will the proposed 2 transmission lines be adequate to meet the projected demands?

    f. What is the capacity of the geothermal resource?

2. Routing/Environmental Considerations

    a. Will the old railroad right-of-way be a possible route?

    b. Does the proposed line have to go through Pahoa Town?

    c. Where is State Conservation land?

    d. Is it more difficult to go through Hawaiian Homes Land?

Most of these questions received immediate responses. Participants were told that additional information and the potential study corridors will be presented at the second round workshops to be held December 11th.

Twelve of the questionnaires distributed at the workshop were completed and returned. Attached is a summary sheet showing the various rankings that each routing factor received. If factors were "x"'d instead of given numerical rankings, the "x"'s have been translated to number "1" rankings. It is interesting to note that, based on this small sample, the highest priorities for routing considerations include residential areas, preservation lands, impacts on wildlife and native forest areas, using small private priorities, and areas with archaeological sites.

FIRST COMMUNITY WORKSHOP ATTENDEES

PERSON	AFFILIATION
Daniel Elia	
Raymond K. Elia	
William S. Gardner	
David T. Hess Sr.	
Patricia Hess	
Lorna Worswick	
Virginia Spencer	
Gordon Souder	
S. P. Gibbons	
Carl Davidson	
Betty Davidson	
Frank J. Mulec	
Peter K. Hauanio	
Wim (Pappy) Warren	
Mae E. Mull	Hawaii Audubon Society
Robert E. Cooper	W. H. Shipman Ltd.
Wallace T. Oki	
Gregory J. Plescia	
Sydney Keliipuleole	Kamehameha Schools/Bishop Estate
Lee Kenty	
M. Kenty Chamberlin	
Marguerite Kenty	
W. H. Kenty	
R. W. Pulcare	
Russell Kokubun	County Council Representative
Fred Karimoto	HECO
Anna Lau	HECO
Eugene Yoshimi	HECO
Scott Shirai	HECO
Clyde Nagata	HELCO
Dennis Tanigawa	HELCO
Duk Hee Murabayashi	DHM inc.
Wendie McAllaster	DHM inc.
Eugene Dashiell	DHM inc.

QUESTIONNAIRE
COMPOSITE SCORES AND RANKS

Instructions:

We would appreciate your taking the time to fill in this questionnaire. We want to know what you think are the most important things to consider in selecting a transmission line route.

Please read the list of factors which can be considered in routing a transmission line. Then rank them by putting a "1" in the blank space to the left of the factor which you consider most important, a "2" next to the second most important factor, and so on. You may give two or more factors the same ranking if you feel they are equal in importance and you may omit ranking any factor which you think is not important.

If something you are concerned about is missing from this list, please add it at the bottom of the list and show how you would rank that concern.

A TRANSMISSION LINE ROUTE SHOULD AVOID:

RANK	FACTOR
4, 8, 1, 1, 2	SOIL EROSION AND USE OF STEEP SLOPES.
4, 2, 5, 1, 2, 1	DAMAGE TO THE LINE AND INTERRUPTION OF SERVICE DUE TO LAVA FLOWS AND OTHER NATURAL DISASTERS.
1, 1, 6, 1, 1, 1	IMPACTS ON WILDLIFE AREAS, ESPECIALLY NATIVE BIRD HABITATS.
1, 1, 4, 1, 1, 1	IMPACTS ON NATIVE FOREST AREAS.
2, 3, 1, 2, 2	RECREATION AREAS, INCLUDING HUNTING AREAS.
3, 1, 3, 1, 1, 1, 1, 3, 2, 2	RESIDENTIAL AREAS.
3, 5, 1, 1, 3	PRIME AGRICULTURAL LAND.
2, 1, 1, 2, 1, 1, 1, 1	PRESERVATION LANDS.
4, 7, 2, 1, 4, 2	USING LAND OUTSIDE OF EXISTING ROAD OR UTILITY EASEMENTS.
4, 1, 1, 1, 5, 1	USING SMALL PRIVATE PROPERTIES.
3, 2, 1, 2	VISIBILITY OF THE LINES FROM HEAVILY TRAVELLED ROADS.
3, 2, 4, 3, 1, 1, 1	AREAS WHERE ARCHAEOLOGICAL SITES ARE KNOWN TO EXIST.
1, 5, 1, 10, 1, 2	HIGHER COSTS FOR CONSTRUCTING THE LINE.
2, 5, 10, 1	HIGHER COSTS FOR MAINTAINING THE LINE.
8	LARGE AREA BUSINESS HOLDINGS OF PRIME AG.*
3	SMALL FARMS WITH PRIME AG.*

WHICH COMMUNITY DO YOU LIVE IN?

1	KEEAU	1	HAWAIIAN PARADISE PARK
	ORCHID LAND ESTATES		HAWAIIAN ACRES
	AINALOA ESTATES	3	HAWAII BEACHES ESTATES
4	PAHOA		NANAWALE ESTATES
1	VOLCANO	1	KOAE
1	OTHER		

SUMMARY OF FIRST PUBLIC AGENCY WORKSHOPS

Auditorium
Hawaiian Electric Co. Inc.
Honolulu, Hawaii
Wed., Nov. 12, 1986
10:00 a.m.

Auditorium
Hawaii Electric Light Co., Inc.
Hilo, Hawaii
Thurs., Nov. 13, 1986
9:30 a.m.

HONOLULU SESSION

Five representatives from State agencies were present at the workshop, as shown on the attached list. The workshop began with a presentation by HELCO on its system planning requirements and the need for the proposed transmission line. HELCO also explained why they are involved with the proposed geothermal plant, and indicated that Thermal Power Company will be holding separate workshops related to the geothermal plan itself in the near future. This was followed by a presentation by DHM inc. on transmission line routing methodology and samples of the broad-scale data factor maps from a previous transmission line routing study.

After these presentations, workshop attendees were invited to raise questions regarding any of the material presented.

Issues raised during the question and answer period were:

1. Puna Natural Area Reserve is no longer designated as a natural area reserve.

2. Has the option to place part or all of the transmission line underground already been foreclosed?

Immediate responses were made to these comments. Participants were told that the potential study corridors will be presented at a second workshop, scheduled for December 10, 1986. The workshop adjourned at 11:00.

HILO SESSION

Four agency representatives attended the workshop in Hilo. The presentation was identical to that in the Honolulu session the day before. No comments or questions were raised by participants.

CORRECTION

THE PRECEDING DOCUMENT(S) HAS BEEN REPHOTOGRAPHED TO ASSURE LEGIBILITY
SEE FRAME(S)
IMMEDIATELY FOLLOWING

SUMMARY OF FIRST PUBLIC AGENCY WORKSHOPS

Auditorium
Hawaiian Electric Co. Inc.
Honolulu, Hawaii
Wed., Nov. 12, 1986
10:00 a.m.

Auditorium
Hawaii Electric Light Co., Inc.
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9:30 a.m.

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HILO SESSION

Four agency representatives attended the workshop in Hilo. The presentation was identical to that in the Honolulu session the day before. No comments or questions were raised by participants.

FIRST PUBLIC AGENCY WORKSHOP ATTENDEES

PERSON	AFFILIATION
Honolulu Session	
George Krasnick	Parsons Hawaii
Anne Lo-Shimazu	Department of Land & Natural Resources - OLEA
Nobuo Honda	Department of Land & Natural Resources - Division of Forestry & Wildlife
John D. Nakagawa	Department of Planning and Economic Development - CZM Program
Gerald Lesperance	Department of Planning and Economic Development - Energy Division
Faith Miyamoto	Office of Environmental Quality Control
Maurice Richard	Thermal Power Company
Fred Karimoto	HECO
Anna Akamu	HECO
Eugene Yoshimi	HECO
Keith Kobuke	HECO
Jake Fernandez	HECO
Andy Chang	HECO
Scott Shirai	HECO
Chuck Freedman	HECO
Ken Morikami	HECO
Clyde Nagata	HELCO
Dennis Tanigawa	HELCO
Duk Hee Murabayashi	DHM inc.
Wendie McAllaster	DHM inc.
Hilo Session	
Rodney T. Oshiro	Division of Forestry & Wildlife
Ilima Piianaia	County Planning Department
Brian Nishimura	County Planning Department
Cheryl Ramos Blyth	Legislative Auditor - County Council
Fred Karimoto	HECO
Anna Akamu	HECO
Eugene Yoshimi	HECO
Scott Shirai	HECO
Clyde Nagata	HELCO
Dennis Tanigawa	HELCO
Mark Gushiken	HELCO - Land
Alex Gentry	HELCO - Land
Duk Hee Murabayashi	DHM inc.
Wendie McAllaster	DHM inc.
Eugene Dashiell	DHM inc.

SUMMARY OF SECOND COMMUNITY WORKSHOP

Pahoa Community Center
Pahoa, Hawaii
Wed., December 10, 1986
7:00 p.m.

Thirteen residents and landowners attended the workshop. (See the attached list.) The content of the workshop was the same as for the agencies. DHM described the corridor evaluations by briefly discussing each factor and showing a map of the composite factors, the corridors and the typical alignment being used for the surveys.

The following questions and concerns were raised:

1. Can you put the transmission lines along the highway?

   Response: Three lines along the highway would be difficult to construct.

2. Ownership of the former railroad alignment in Hawaiian Paradise Park is in dispute. The community association may not own it. It appears to be owned by each of the landowners in Hawaiian Paradise Park. Thus each person may own 1/5750 of the former alignment through HPP.

3. Why is the voltage so low? Why not 138 kv?

   Response: The voltage is 69 kv ac because that is adequate for the purpose and because the remaining HELCO grid is 69 kv ac also.

4. Why are two lines needed?

   Response: Two lines are required to provide a reliable system. Because this line would provide about 25 percent of Hawaii's power, an outage of the entire 25 MW could adversely affect the entire system. If there are two lines, it is more likely that an outage would affect only one line and power would be restored much more rapidly.

SECOND COMMUNITY WORKSHOP ATTENDEES

PERSON	AFFILIATION
Jenny Allen	
Betty Vincent	
Tsune Matsumoto	Amfac Property
Sally Wang	
Michael McMillan	Paradise Anui Kanalike HPP
Tadashi Higaki	
Ted Shepherd	Hawaiian Acres C. C.
Will Sutherland	
Frank Hicks	Paradise Park
David Ford	
Robert Cooper	W. H. Shipman Ltd.
Fred Karimoto	HECO
Anna Akamu	HECO
Eugene Yoshimi	HECO
Scott Shirai	HECO
Clyde Nagata	HELCO
Dennis Tanigawa	HELCO
Duk Hee Murabayashi	DHM inc.
Eugene Dashiell	DHM inc.

SUMMARY OF SECOND PUBLIC AGENCY WORKSHOP

Auditorium
Hawaiian Electric Company, Inc.
Honolulu, Hawaii
Wed., December 10, 1986
10:00 a.m.

HONOLULU SESSION

Six representatives from State and County agencies attended the workshop (see the attached list). Dennis Tanigawa, of HELCO, chaired the meeting. He noted that this was the second in a series of three meetings, that the third would be held in May with the proposed transmission alignment as the subject. DHM inc. presented the corridor identification analysis and described the methodology and the findings. DHM showed maps of the corridor and the possible routes which are being more fully investigated during field work beginning this month. DHM described the extent of the alignment investigations which are now beginning.

Attendees asked the following questions:

1. Bruce Anderson of DOH expressed concern that the report and the EIS include a discussion of the available information which describes scientific findings regarding the effect on human health of similar transmission lines. He offered to provide a list of reference and copies of some of the current articles.

   Response: DHM noted that the report and EIS will include discussion of these materials, but that our present understanding is that transmission line voltages of 69 kv ac are relatively low and that most scientific studies are concerned with lines of much higher voltage, perhaps 200 to 400 kv. Anderson agreed. DHM will follow-up with Anderson's offer.

2. Nobuo Honda of the Division of Forestry expressed concerns over the height of vegetation when considering maintenance or corridors. He felt that the analysis should reflect the actual species of the tree rather than just present heights because even though they may be short now some species may grow to be taller.

   Response: DHM noted that we are using the Jacobi maps which recognize this concern and identify species.

HILO SESSION

Nine persons from State and County agencies attended the workshop. The presentation was identical to that in Honolulu.

The following questions were asked:

1. How many transmission lines will eventually be built in the Puna region? What are the future plans regarding transmission lines?

   Response: HELCO is planning for 69 kv for the 25 MW geothermal power plant development. Although a feasibility study for a 300 kVdc transmission is a part of the Hawaii Deep Water Cable Program, HELCO is not planning for the project.

   Hurricane Iwa caused transmission line planners to be concerned about creating an energy corridor in which all transmission lines are located. They are concerned about the system reliability. As a result, HELCO set up a policy of 0.5 mile separation between the proposed 69 kv and other transmission lines.

2. How many alignments will be selected and will you rank them?

   Response: DHM will suggest two alignments to HELCO. There will be no ranking.

3. Can the 2 lines handle 50 MW if Thermal Power wants to build more generating units?

   Response: No.

4. Will your EIS cover other than State lands?

   Response: Yes. It will cover the full length of the selected alignments.

5. Are you seeking a Conservation District Use Application (CDUA) permit or a boundary amendment?

   Response: No CDUA permit will be required if we can avoid crossing the Conservation land. No boundary change is needed. We will be preparing an EIS because of a potential easement request from the State due to the transmission lines crossing the State-owned land areas.

6. When will additional lines be required?

   Response: When more than 25 MW is required.

7. How many lines can you get in a corridor?

   Response: It depends on how wide a corridor is. It will also depend on the right-of-way width of 50 feet for a 69 kv line and a minimum separation of pole height length. In addition, a minimum of 0.5 mile separation between two transmission lines is required by HELCO at this time.

SECOND PUBLIC AGENCY WORKSHOP ATTENDEES

PERSON	AFFILIATION
Honolulu Session	
Colleen Spiering	Department of Health
Bruce Anderson	Department of Health
Dean Nakano	Department of Land & Natural Resources
Rick Nabarrete	Hawaiian Homes
Nobuo Honda	Department of Land & Natural Resources, Division of Forestry
Gerald O. Lesperance	Department of Planning and Economic Development, Energy Division
D. H. Mason	Thermal Power Company
Maurice Richard	Thermal Power Company
Fred Karimoto	HECO
Anna Akamu	HECO
Eugene Yoshimi	HECO
Scott Shirai	HECO
Ken Morikami	HECO
J. Oda	HECO
Clyde Nagata	HELCO
Dennis Tanigawa	HELCO
Duk Hee Murabayashi	DHM inc.
Eugene Dashiell	DHM inc.
Hilo Session	
Bruce McClure	County of Hawaii Department of Public Works
David Murakami	County of Hawaii Department of Public Works
Rodney Nakano	County of Hawaii/Planning
Andrea Gill Beck	Hawaii Energy Extension Service
Ronald Bachman	State Department of Land and Natural Resources, Wildlife
Rodney T. Oshiro	Division of Forestry/Wildlife
Charles K. Wakida	Division of Forestry/Wildlife
Russell Kokubun	County Councilman
Cheryl Ramos Blyth	Legislator Auditor-County Council
Clyde Nagata	HELCO
Dennis Tanigawa	HELCO
Fred Karimoto	HECO
Anna Akamu	HECO
Eugene Yoshimi	HECO
Scott Shirai	HECO
Duk Hee Murabayashi	DHM inc.
Eugene Dashiell	DHM inc.

SUMMARY OF THIRD COMMUNITY WORKSHOP

Pahoa Community Center
Pahoa, Hawaii
Thurs., September 3, 1987
7:00 p.m.

Approximately one hundred residents attended the workshop, as shown on the attached list. The Public Utilities Commission attended the workshop and served as a moderator.

The meeting was organized into three sections. First, HELCO and their planning consultant, DHM inc., presented the two selected alignments for the proposed 69 kV transmission lines. DHM inc. described the types of factors which were mapped and evaluated in the process of identifying the alignments. They also described the proposed route of each alignment across the Puna area.

The second portion of the meeting was an opportunity for the residents to ask specific questions about the DHM inc.'s presentation, the proposed alignments, and their selection. Questions were raised concerning such issues as:

- late notice about the project to affected property owners
- the density of Ainaloa subdivision
- why the transmission lines were a separate issue from the geothermal power plant
- will the subdivision(s) affected by the lines get electricity from them
- impacts on property values
- consideration of undergrounding the lines
- consideration of human beings and their homes
- easement width and compensation to property owners
- consideration of using large landowners' property
- constraints given to the consultant by HELCO

The questions were responded to by HELCO or DHM inc.

During the final portion of the meeting, the residents were encouraged to voice their general concerns and opinions about the proposed project to the Public Utility Commission and HELCO. Several residents spoke, and their concerns are summarized below. Speakers were encouraged to submit their comments in written form to HELCO with a copy to the Commission.

- Ainaloa is a densely populated subdivision with small lots and private roads.

- How much will the line cost and what would it cost to go underground?

- Why can't the line(s) go along the highway?

- What kind of improvements will be made to 35th Ave. if the line goes there?

- Put the line in the mauka part of Ainaloa where it is less populated and the residents need power.

- What would be the affect of the line on property value.

- Alignment selection needs to consider fire hazards and salt corrosion.

- The former railroad is more of a hiking path than a jeep trail.

- Safety.

- There is no fire access to the railroad area and Hawaiian Paradise Park.

The attendees were informed that HELCO will continue to work with the subdivision associations in attempts to come to mutually agreeable locations for the alignments within the respective subdivisions.

WORKSHOP ATTENDEES

NAME	NAME	NAME
Catherine Ford	Diana & Londo Londi	Fred C. Gills
Fern Gilchrist	Sue Clark	R. W. Pulcare
Daisy U. Smith	Dick Miner	S. Meneles
Jessie E. Daskam	Ron Phillips	B. M. DenCause (sp.?)
Robin M. Daskam	Mike Greenlaw	J. Armstrong
Peg J. Daskam (sp.?)	Paul Alan	Sherrie Moore
Kile Golden	Russell Kokubun	
Peggy Golden	Donna Licata	Fred Karimoto
Don Tinker	Richard Hahn	Anna Lau
Tesse Tinker	H. H. Huret	Eugene Yoshimi
Marilyn Lusareta	Ralph V. Kelly	Scott Shirai
William G. Lusareta	Michael McMillan	Clyde Nagata
Rocky J. Nunes	Eric Bushu (sp.?)	Dennis Tanigawa
Debra L. Nunes	Bud Ahrender (sp.?)	
Ruth Sleightholm	Thomasine Deitch (sp.?)	Duk Hee Murabayashi
June Shamwell	Violet Santiago	Wendie McAllaster
Vicky Jacobs	Morgen M.E. Bahurinsky	
Edward Jacobs	John A. Wassell	
Gordon Souder	John, Jackie, Cartor (sp.?)	
Mary J. Owens	Patrick McHugh	
Kini L. Pea	B. Aloha McHugh	
Jim E'more (sp)	Kay Wiley	
William Reich	Del Pranke	
Nelson Ho	Deborah Pranke	
James H. Green	Milton Papineau	
Bill Milks	Rubye Papineau	
David A. Kikau Sr. (sp.?)	Esther Kayl	
Jeam Mayberry	Jeanne Fuller	
Douglas Mayberry	Charles Boehnke	
Doug Bell	Virginia Boehnke	
Chuck Sperry	Peter Yost	
Frank Dewater	Carolyn Yost	
Marvin Watts	Ralph Yost	
Lewis Goldenberg	Carl Neely	
Michael Gurr	Norma Neely	
Shirley Gil	Barbara Hogan	
Shirley Chaekowski (sp.?)	Tom Henderson	
W. Mastenbrook	Eve Henderson	
Norma Mastenbrook	Barbara Novak	
Sally Wang	L. J. Novak	
Rex Ivan Delden	W. W. Boysel	
H. L. Kenty	Ralph W. Frink	
Marge Chamberlin	Lola R. Frink	
Gerald & Deborah Hay	Alice D. Boysel	
Peggy Rosendahl	Moira Kokkolio-Bright(sp.?)	
Lynne Goldestein	James K. Bright	
Patrick W. Goldstein	James Smith	
Kathleen Furtado	W. B. Mason	

(sp.?) Spelling may be incorrect due to handwriting on attendance list.

SUMMARY OF THIRD PUBLIC AGENCY WORKSHOPS

Auditorium
Hawaiian Electric Co. Inc.
Honolulu, Hawaii
Thurs., Sept. 3, 1987
10:00 a.m.

Auditorium
Hawaii Electric Light Co., Inc.
Hilo, Hawaii
Fri., Sept. 4, 1987
10:00 a.m.

HONOLULU SESSION

The fourteen individuals that attended the workshop included six representatives from State agencies as shown on the attached list.

DHM inc., HELCO's planning consultant, presented the two selected alignments for the proposed 69 kV transmission lines. They described the types of factors which were mapped and evaluated in the process of identifying the alignments, and also described the proposed route of each alignment across the Puna area.

HILO SESSION

Four agency representatives attended the workshop in Hilo. The presentation was identical to that in the Honolulu session the day before.

THIRD PUBLIC AGENCY WORKSHOP ATTENDEES

PERSON	AFFILIATION
Honolulu Session	
J. Kirkham M.D.	Department of Health
Ronald L. Walker	Dept. of Land & Natural Resources, Division of Forestry and Wildlife
Mike Shimabukuro	Dept. of Land & Natural Resources,
Y. Miyashiro	Division of Land Management
Dean Nakano	Dept. of Land & Natural Resources, Division of Water & Land Development
J. Hendrickson	Ainaloa Subdivision
June Peter	
Clarence Edwards Sr.	
Lawrence Dawson	Bodissage Hawaii, Inc.
Allan Kawada	True Geo Energy Co.
Doug Bell	Thermal Power Company
Dan Mason	Thermal Power Company
Ralph Patterson	Thermal Power Company
Fred Karimoto	HECO
Anna Lau	HECO
E. Yoshimi	HECO
Ken Morikawa	HECO
Andy Chang	HECO
Kevin Doyle	HECO
Ann Yamamoto	HECO
Scott Shirai	HECO
Clyde Nagata	HELCO
Dennis Tanigawa	HELCO
Duk Hee Murabayashi	DHM inc.
Wendie McAllaster	DHM inc.
Hilo Session	
Jim Lui-Kwan	County Planning Department
Virginia Goldstein	County Planning Department
B. McClure	County Dept. of Public Works
Ron Ibarra	Mayor's Office
John and Mary Davis	
Doug Bell	Thermal Power Company
Fred Karimoto	HECO
Anna Lau	HECO
Eugene Yoshimi	HECO
Scott Shirai	HECO
Clyde Nagata	HELCO
Dennis Tanigawa	HELCO
Duk Hee Murabayashi	DHM inc.
Wendie McAllaster	DHM inc.

PARTIES PERSONALLY NOTIFIED OF PUBLIC AGENCY AND COMMUNITY WORKSHOPS

COUNTY OFFICIALS

Mayor Dante Carpenter
Councilman Robert Herkes
Councilwoman Merle K. Lai
Councilman Stephen K. Yamashiro
Councilman Takashi Domingo
Councilman James Dahlberg
Councilman Spencer Kalani Schutte
Councilman Russell Kokubun
Councilwoman Lorraine Jitchaku-Inouye
Councilman Frank De Luz III

COUNTY AGENCIES

Department of Public Works
Office of the Mayor
Planning Department

STATE REPRESENTATIVES

The Honorable Harvey Tajiri
The Honorable Dwight Takamine
The Honorable Virginia Isbell
The Honorable Wayne Metcalf
The Honorable Andrew Levin

STATE SENATE

The Honorable Malama Solomon
The Honorable Richard Matsuura

STATE AGENCIES

- Department of Agriculture
- Department of Business and Economic Division
- Department of Hawaiian Home Lands
- Office of Hawaiian Affairs
- Department of Health
- Department of Land and Natural Resources
  - Aquatic Resources Division
  - Conservation and Resources Enforcement
  - Forestry and Wildlife Division
  - State Parks, Outdoor Recreation and Historic Site Division
  - Water & Land Development Division
- Office of Environmental Quality Control
- Department of Transportation
- University of Hawaii
  - Environmental Center
  - U.H.H. Division of Natural Science
  - U.H. Cooperative Extension Service

FEDERAL AGENCIES

Department of Agriculture
  Soil Conservation Service
Department of Interior
  Fish & Wildlife Service
  Geological Survey
  National Park Service

COMMUNITY ORGANIZATIONS

Ainaloa Community Association
Aloha Association
AMFAC Sugar Company
Big Island Committee on Municipal Power
Big Island Papaya Growers Association
Conservation Council for Hawaii
Fern Acres Community Association
Golden State Hawaiian Corporation
Hawaii Anthurium Growers Cooperative
Hawaii Audubon Society
Hawaii Energy Extension Service
Hawaii Island Chamber of Commerce
Hawaii Redevelopment Agency
Hawaiian Beaches Community Association
Hawaiian Beaches Hui Kahakai
Hui Hana Like
Hui Hanalike Community Association
Hui O Puna Jaycees
Hui O Puna Jayceettes
Hui O Puna Nui
ILWU
Kalapana Community Association
Kalapana Gardens Community Association
Kalapana Star of the Sea
Kamehameha Lodge
Kamehameha Schools/Bernice Pauahi Bishop Estate
Keaau School PTA
Leilani Community Association
Lions Club
Nanawale Community Association
Opihikau Church
Orchidland Community Association
Pahoa Filipino Club
Pahoa Nikkei Jin Kai
Pahoa School PTSA
Paradise Park Hui Hanalike
Puna Community Forum
Puna Geothermal Committee
Puna Hui 'Ohana
Puna Lions Club
"Puna Reflections"
Puna Soil and Water Conservation District
"Puna Speaks"
W. H. Shipman, Ltd.
Tokyu Land
"Volcano Views"
Waawaa Community Association

HEI

October 17, 1986

Puna Geothermal Committee
Post Office Box 370
Volcano, Hawaii 96785

Gentlemen:

Subject: Proposed Pohoiki-Puna Transmission Line

Hawaii Electric Light Company has conducted a thorough study of how we might best transmit the potential electric power produced at the Pohoiki geothermal plant. After studying all the possible alternatives, we have concluded that it will be necessary to construct new transmission lines between substations at Pohoiki and Puna.

The route of this transmission corridor is an obvious concern of the people of the Puna district, and we intend to involve community residents in the planning process. For this reason, we would like to extend a special invitation to you to attend the first of several public workshops that will be held on the transmission line project in the next several months.

The workshops will be conducted by OHM Planners, Inc., a consultant, and will explain the approach we are using in the routing study and respond to comments from the public. It will also include a brief description of the proposed geothermal development. I must emphasize that routes have not yet been selected and that the final placement of the transmission line corridor will depend a great deal on the comments and preferences expressed by the public at the workshops.

The first session in November will be held at the Pahoa Neighborhood Center on ~~Thursday~~ Wednesday, November 12, 1986, at 7:00 p.m.

Your participation will be greatly appreciated, and our agenda is enclosed for your reference. If you would like more information about the workshop, please call Mr. John Corbelli at 935-1171, ext. 122, or Dennis Tanigawa at 935-1171, ext. 351.

Sincerely,

Norman A. Oss
President

NO:md
Enclosure

A Hawaiian Electric Industries Company

Dear Big Island Customer,

Helco welcomes your help in planning the best possible route for new electric transmission lines between Pohoiki and our Puna substation. The two lines are needed to transmit electric power to our Big Island customers from the new geothermal plant that will be built at Pohoiki by Thermal Power.

Like you, Helco is concerned about keeping the cost of the project as low as possible, protecting the environment, and minimizing the project's visual impact.

At 7pm on November 12, in the Pahoa Neighborhood Center, we will hold the first of several public workshops to help us identify the best corridor for these lines.

Because selection of a route will depend a great deal upon comments, preferences, and suggestions received at these workshops, your input would be greatly appreciated.

Please call Helco's Dennis Tanigawa at 935-1171 if you want more information. Mahalo.

The people of
Hawaii Electric Light Company

Helco plans to string up Puna line

By Leigh Critchlow
Tribune-Herald

Hawaii Electric Light Co. announced today it plans to construct a new transmission line between Thermal Power Company's proposed geothermal plant at Pohoiki and Helco's Puna substation next to the old Puna Sugar Co. plant.

A study of all possible alternatives by Helco has determined that the new 69,000-volt transmission line is required to serve Big Island customers, explained Helco president Norman Oss.

Helco earlier this year signed a contract with Thermal Power to purchase up to 25,000 kilowatts of geothermal-produced power by 1993, enough electricity for about 8,300 Big Isle homes.

The power will be provided in two increments of 12,500 kilowatts — the first by 1989 and the second by 1993.

Oss said Helco will be seeking public involvement in determining the route for the new transmission line.

"The placement of any transmission line is a concern to people in the affected areas. There are geophysical, biological, economical, and social concerns, to name a few, Oss said.

"For these reasons, we wish to invite the public, not just to attend but also to give us their input, at a series of informational workshops scheduled over the next several months.

"We want the community to help us determine a final route for this important project," Oss said.

Helco will pick the route judged to be the "least environmentally objectionable," said Alva Nakamura, manager of Helco's engineering department, at a press conference this morning in Hilo.

Oss said the route for the transmission line will use existing roadways wherever possible. The project could benefit residents of some rural areas who are far from electricity, he said.

The first public meeting will be held at 7 p.m. Nov. 12 in the Pahoa Community Center.

The session will be conducted by DHM Planners, Inc., whose representatives will explain the approach being used in the routing analysis and answer questions from participants.

There also will be a brief description offered of the proposed geothermal development.

Community involvement in planning the transmission line's route is important in order that every environmental concern is addressed and resolved during the route selection process, which subsequently will be described in an environmental impact statement Oss said.

—T-H photo by Larry Kadooka

PLANS FOR PUNA — Helco officials this morning announced plans for a new 69,000-volt transmission line in Puna. From left are Alva Nakamura, manager of the engineering department; Helco president Norman Oss, engineer Clyde Nagata; and engineer Dennis Tanigawa, the project manager.

Tribune-Herald 11-6-86

A-20

HEI

November 26, 1986

Big Island Committee on Municipal Power
c/o Alex Smyklo
Post Office Box 1412
Pahoa, Hawaii 96778

Gentlemen:

Subject: Proposed Pohoiki-Puna Transmission Line

Last month, we held the first round of public workshops concerning the proposed 69 KV transmission line project which will connect Thermal Power's proposed geothermal power generating plant at Pohoiki to HELCO's 69 KV grid at the Puna Substation.

At those workshops, we apprised you of the transmission line project and the method by which the transmission line corridors will be selected.

The second round of public workshops will be held this month. At the workshops, you will be apprised of the areas which have been identified as potential corridors and how these corridors were selected. The preferred corridors will also be identified. The workshops will be conducted by DHH Planners, Inc.

We extend a special invitation to you to attend the workshop which will be held on Wednesday evening, December 10, 1986, at 7:00 P.M., at the Pahoa Neighborhood Center.

If you have any questions about the workshop, please call HELCO at 935-1171 and ask for Mr. John Corbelli or Mr. Dennis Tanigawa.

Sincerely,

Norman A. Oss
President

NAO:md

A Hawaiian Electric Industries Company

Hawaii Electric Light Company, Inc. • PO Box 1027 • Hilo HI 96721-102

RESIDENT'S LETTER - 3,954 MAILED

August 20, 1987

Dear Neighbor:

About fourteen years ago, the National Science Foundation and the State of Hawaii envisioned a day when renewable energy might provide us with all the heat and light we needed and financed a University of Hawaii proposal to explore for geothermal energy at Pohoiki. Not only were the results successful, but today that small, exploratory well supplies enough electricity for about 800 Big Island homes.

The prospects that geothermal energy may provide more Big Island homes with electricity rose even higher this year when HELCO signed an agreement to purchase up to 25,000 kilowatts of geothermal-produced energy from Thermal Power Company, beginning in late 1989. This means that some 8,000 more Big Island homes will be getting their electricity from geothermal energy.

In a few months, we will begin construction of a new 69,000 volt transmission line between Thermal Power's proposed geothermal plant at Pohoiki to our substation in Keaau. Construction of this line will enable us to transport this geothermal-produced energy for use solely on the Big Island.

In order to plan the best route for the transmission line, we solicited public input and comments. At these meetings, some people understandably expressed a number of concerns, and a few did not like our plans at all. And, while we had the answers to most of the questions, we thoroughly investigated those we didn't.

Because some of those who are disenchanted with our plans have been making misleading statements, we'd like to set the record straight and share with you the results of our research.

I would also like to invite you to tune in when Clyde Nagata, our Manager of Engineering, and I discuss these important issues from 6:30 to 7:00 P.M., Thursday, August 27, on "Big Island Issues and Answers", KHBC, Channel 2.

You are also invited to a public informational meeting, which will be held at 7:00 P.M., September 3, 1987, at the Pahoa Neighborhood Center. The final transmission line alignments will be shown at this meeting.

Should you have any questions after reviewing either the materials or the show, please feel free to call Dennis Tanigawa at 935-1171.

Thank you for your interest and consideration.

Sincerely,

Norman A. Oss
President

An HEI Company

(ATTACHMENT SENT WITH ALL LETTERS)

QUESTIONS AND ANSWERS
Pohoiki - Keaau 69,000 Volt Transmission Line

Question: Do transmission voltages increase the danger of injury and fire if a line falls to the ground?

Answer: Transmission lines are actually better designed for automatic protection than lower voltage distribution lines. By the time a transmission line falls to the ground, they are normally already de-energized by automatic protective devices which also signal an interruption to our system operations personnel.

During the February 1986 windstorm, for example, several of our 69,000 volt (69 kv) transmission lines fell and were automatically de-energized by protective devices. No injuries or fires resulted.

To our recollection, there have been no injuries or fatalities on the Big Island due to downed transmission lines. The tragic fatality earlier this year in Nanawale Estates involved a 12 kv line, a distribution voltage.

Question: Will the electromagnetic field (EMF) created by a transmission line cause adverse health effects, particularly in children?

Answer: J. Michael Silva is a professional engineer and president of Enertech Consultants and has performed many studies on this subject. According to Silva, EMF from a 69 kv transmission line can be even less than that generated by some typical household appliances. His analysis, including field measurements and computer calculations indicate no significant effects from EMF on human health.

HELCo has always been concerned about this matter and continues to support research efforts of the Electric Power Research Institute (EPRI). To date, none of EPRI's studies over the past decade has found any correlation between EMF and human health.

Nonetheless, we recognize the need for additional research. EPRI has expanded its research program and has asked 15 experts from the scientific community and industry to serve on an oversight committee to review and to make recommendations on their research program.

Question: Will EMF cause interference with TV, radio, telephone, and emergency communications?

Answer: This usually doesn't occur, since interference can be minimized through proper design and the use of appropriate hardware, its primary cause. When it does, as was once the case on a part of our Hamakua 69 kv line, the introduction of special hardware immediately cleared up the problem.

Question: Can future power lines from geothermal fields be master-planned to minimize adverse effects on the community?

Answer: Thermal Power Company appears to be the only active geothermal developer in Puna. Although it is possible that others may eventually produce geothermal power there, we have no knowledge of further developments. This makes master-planning of transmission lines extremely difficult, if not impossible.

In the meantime, our power needs are rapidly approaching the critical state. We need more generation and we need to proceed to plan and build the lines needed to tie Thermal's proposed plant to our system.

Question: What about the visual intrusion the electrical power structures will have on views of the ocean, mountains, and landscape?

Answer: Contrary to what some people think, we will not be installing steel tower structures. What is being installed are 65- to 70-foot wooden poles, with 7 to 8 feet buried in the ground.

In addition, it is our experience that the issue of aesthetics is generally subjective. While one person may greatly dislike a utility pole in his view, another may be indifferent about it because he values other factors about his surroundings more.

Question: What effect would the presence of a transmission line have on property values?

Answer: There are a number of 69 kv lines already around the Big Island, including through some residential areas as Kawailani Street. Research by the County tax office established that there was no evidence of decrease in property values.

There is also the argument that values may increase in many sections of subdivisions currently lacking electricity, since distribution lines could be installed on the same 69 kv poles, making it more economically affordable for residents to obtain line extensions, especially in conjunction with our new Special Subdivision Project Provision Program (SSPP).

Question: What effect, if any, would a 69 kv transmission line have on my home insurance premiums?

Answer: The insurance companies we contacted unanimously agreed that there would be no effect. In fact, they reported that premiums are sometimes lower in homes served by electric utility service rather than by their own generators. Some companies reported that they would not insure a house that didn't have electric service from a utility.

Question: Could the transmission line be placed underground instead?

Answer: It could, but the cost would be approximately 6 times greater than an overhead line and would create an unfair and unnecessary financial burden on all our Big Island customers. In this case, it would cost $4 million for one overhead 69 kv line, compared to $22 million for one underground line.

There is pro and con to most situations and this is no exception. Because underground lines are buried and not visible, maintenance and restoration of power due to cable failure takes considerably more time. Depending on the severity, repairs may take several days. Also, since there are no poles on an underground line, they would have to be installed later, anyway, whenever line extensions are necessary to serve customers requesting electric service to areas currently without it.

Question: How wide will the easement for the line be?

Answer: Although the "corridors" we have been studying are quite wide, we normally require a maximum of only 50 feet for the actual alignment for a 69,000 volt line. However, if the line is located along a roadway (which is a likely case), we would be satisfied with an easement covering the width of the roadway. Then we would not have to ask for easements within individual lots except for anchors wherever the line changes direction.

APPENDIX B

BISHOP MUSEUM

1525 BERNICE STREET • P.O. BOX 19000-A • HONOLULU, HAWAI'I • 96817-0916 • (808) 847-3511

CULTURAL AND BIOLOGICAL RESOURCES SURVEY
OF THE POHOIKI TO PUNA-SUBSTATION
69KV TRANSMISSION CORRIDOR
KAPOHO TO KEA'AU, PUNA, HAWAI'I ISLAND

Final Report:
Archaeological Survey
Department of Anthropology
Bernice Pauahi Bishop Museum

ORIGINAL

CULTURAL AND BIOLOGICAL RESOURCES SURVEY OF THE POHOIKI TO PUNA-SUBSTATION 69KV TRANSMISSION CORRIDOR KAPOHO TO KEA'AU, PUNA, HAWAI'I ISLAND

Final Report:

Archaeological Survey

April 30, 1987

Eric K. Komori

Appendix:

Literature Review of
Previous Archaeological Work,
Previous Historic Land Use, and
Legends and Traditions

Ingrid R. Peterson

Prepared for:

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1188 Bishop Street
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Department of Anthropology
Bernice P. Bishop Museum
Honolulu, Hawai'i

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ABSTRACT

Thirty six archaeological transects of inland portions of Puna district on the the island of Hawai'i were conducted to locate archaeological sites and assess the potential for additional resources in the area. The purpose of the study is to provide data for an environmental impact statement on a transmission line.

The number of sites located is very low (11 prehistoric-type and 3 historic-type sites), however, the findings support a settlement pattern model for the area that predicts the occurrence of extensive prehistoric-type agricultural fields, and sites that reflect adaptation to the physiographic features in the area. Historic-type sites were associated with the sugar industry.

Previous geologic research provides estimates of the age of the substrates in the study area that allow tentative generalized interpretations of the archaeological sites. The hypothesis that expansion of Hawaiian settlements away from initial foci after A.D. 1100 is supported by estimated dates of no older that A.D. 1450 for the sites. The estimated age and type of a small number of petroglyphs located supports the findings of previous research that indicates a change in stylistic preference.

Preservation of all sites located is recommended and further archaeological survey once a particular alignment is chosen is specified.

INTRODUCTION

This report presents the results of an archaeological study of alternate routes for the proposed Pohoiki-Kea'au Transmission Line Corridor located in the district of Puna on the island of Hawai'i. The study was conducted under contract to DHM, Inc. by the Department of Anthropology, Bernice. P Bishop Museum. The archaeological fieldwork was conducted between February 9-20, 1987 by the author, William Fortini, Elaine Rogers-Jourdane, and Jeffery Yasauchi. All records and data are deposited in the Department of Anthropology, Bernice Pauahi Bishop Museum. I would like to express my appreciation to Mr. Timothy Lui-Kwan (Hawai'i County Planning Department), Mr. Bruce Butts (Hawai'i County Civil Defense), Mr. Sonny Kinney (Alu Like, Inc.), and Mr. Clarke Wallace (Aafac Inc.) for providing valuable assistance and information during the course of the fieldwork.

The primary objective of this study is to provide data for an environmental impact statement on the transmission line corridors. The tasks undertaken were:

1. Identification and evaluation of archaeological resources found in the area through field survey and literature search.

2. Assessment of potential for the existence of additional archaeological resources in the area.

3. Evaluation of possible effects of the proposed transmission line on archaeological resources in the area.

A literature search on the legends and traditions, previous archaeological research, and historical data concerning the general Puna area was also conducted and is included as an appendix.

GEOGRAPHIC SETTING

The study area consists of three discontinuous corridors that begin near the Puna Sugar Mill (east of the town of Kea'au), continues to the Pahoa town area, and end near the existing geothermal plant at Pu'u Honuaula, in Pohoiki (fig. 1). The corridors generally follow existing roads, range from 450 to

850 meters (1500-3000 feet) in width and are approximately 42 kilometers (26 miles) in total length. For the purposes of this report the corridors have been divided into nine segments "A" through "I" (fig. 1).

The corridors are entirely located in the traditional Hawaiian district of Puna and cross twelve ahupua'a (traditional Hawaiian land divisions). The ahupua'a crossed are: (roughly north to south)

1	Kea'au	5	Keonepoko Nui	9	Halekamahina 2
2	Waku'u	6	Keonepoko Iki	10	Kapoho
3	Popoki	7	Kahuwai	11	Kaniahiku
4	Halona	8	Puua	12	Keahialaka

During the "Mahele" in the mid-1800's, when the traditional Hawaiian land tenure system was overthrown, only fourteen land awards were recorded in the Puna area. Of these three were for less than 20 acres, the other awards (primarily to chiefs) range from 1,110 to 64,275 acres in area (Indices 1929).

B-4

Modern activities in the area include: geothermal and biomass electrical energy plants, papaya plantations, cut-flower farms, sugar cane plantations (now abandoned) and large scale land developments.

ENVIRONMENTAL SETTING

The study area is located on the windward slopes of Kilauea Volcano one of the best known and intensively studied (geologically) volcanoes in world (Holcomb 1981:2). Kilauea volcano is highly active and recent eruptions such as those in 1955, 1840 and circa 1790, have affected portions of the southeastern limits of the study area (Ibid:plate 3). The elevation of the corridor ranges from 61 to 274 meters (200 to 900 feet) above sea level and rainfall is from about 318 to 445 centimeters (125 to 175 inches) per year (Stearns and MacDonald 1946:212).

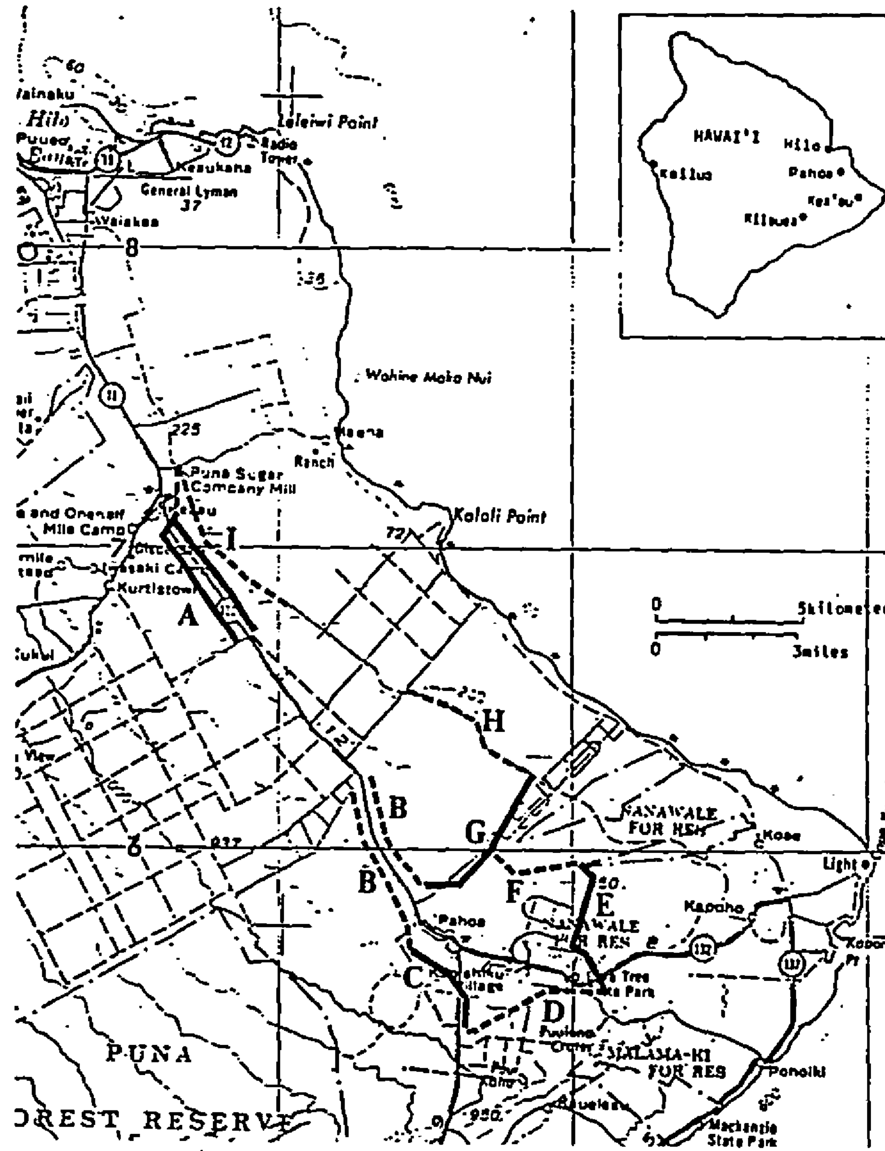

FIGURE 1. Map of Project Area with Corridor Segments and Locations.

Geology

The deeper soils in the area are represented by limited areas of ash deposits and weathered 'a'a. Virtually all of these areas have been used for sugar cane fields or pasture land and are extensively disturbed. These deposits are surrounded by a large number of extensive, more recent lava flows that have little or no soil development (Soil Conservation Service 1972; Holcomb 1981).

The high frequency of diverse, recent lava flows in the study area has resulted in a topography that is highly variable and closely linked to flow morphology. A recent study that details the chronology of the surficial lava flows of Kilauea volcano shows that much of the study area is covered with recent pahoehoe lavas less than one thousand years old, with pockets of 'a'a lava that are generally older (Holcomb 1981:plate 3). Utilizing data such as radiocarbon dates, paleomagnetic data, stratigraphic relationships, or historic accounts, Holcomb arranged the lava flows into nine age groups. The age intervals for the groups range from 100 to 500 years, with the most recent lavas being from the twentieth century and the earliest lavas being older than 1500 years B.P. (Ibid).

B-5

Two basic types of lava flows, surface-fed and tube-fed are distinguished for Kilauea Volcano. The surface morphology, however, is influenced by many factors such as its physical properties, the environment into which it is introduced, rate of flow, and duration. The large number of factors result in a variety of surface textures that range from relatively smooth flat surfaces, to broken plate-like structures, to extremely rough 'a'a lava (Ibid:77-98).

Flora

Forested areas that are undisturbed by modern agricultural or urban activities are dominated by 'ohi'a (Metrosideros collina) with an understory that includes an assortment of ferns and shrubs. More exposed areas range from less dense 'ohi'a forests with a ground cover of thick matted uluhe ferns (Dicranopteris sp.) to open grassy areas commonly called "'ohi'a dieback". Variations in vegetation in these unaltered areas appear to be closely related to substrate type and age.

Although poorly represented, plants found in the study area that are commonly associated with prehistoric-type Hawaiian activity include kukui (Aleurites moluccana), hala (Pandanus odoratissimus), 'ulu (Artocarpis communis) and ki (Cordyline terminalis) Small numbers of recent introductions such as guava (Psidium guajava), siris (albizia lebbeck), koa haole (Leucaena glauca), and mango (mangifera indica) are frequently found, clustered in relatively unaltered areas. (For a complete listing, the reader is referred to concurrent research by Takeuchi and Imada for DHM, Inc.)

Fauna

Indications of the presence of feral pigs (Sus scrofa) was noted throughout the study area, however, only one deceased juvenile was seen. Cows and horses are also present, however, no feral examples of large mammals other than pigs were observed. Doves and myna birds are common in the area and egrets were occasionally seen. (For further information on the ornithology of the area the reader is referred to concurrent research by Fleischer for DHM, Inc.; entomological resources in the area are covered in Nishida et al. for DHM, Inc.)

TERMINOLOGY

The present research is primarily intended to provide an assessment of archaeological resources in the study area based previous documentation and sampling of surface remains. Therefore, in order to avoid ambiguity since the cultural and chronological associations ascribed to each site is based on limited data, terms used for site interpretation must be well defined. Of principal concern are the dichotomies of prehistoric - historic (Hawaiian vs. non-Hawaiian), and archaeological - historic (mainly concerned with methodology).

Prehistoric - Historic

The discovery of the Hawaiian Islands by westerners in A.D. 1778 (technically ending the "pre-historic" period) was not accompanied by an immediate end to pre-contact Hawaiian culture. It must be recognized, therefore, that well into the "historic" period sites were being formed within a traditional Hawaiian context. The terms historic and prehistoric are not used here as they imply a sharp chronologic break. Instead the site interpretations use the terms: prehistoric-type to imply association with traditional Hawaiian culture, historic-type to imply association with later cultures, and prehistoric/historic-type when an interpretation cannot be made. In cases where more than one type of interpretation can be made multiple terms are used.

In the absence of excavated data, the site attributes of prehistoric-type and historic-type are based on three characteristics that are observable through examination of surface features:

1. Artifact and midden types.

2. Construction techniques and structural configuration.

3. Spatial associations.

Of these, the interpretation of artifacts and midden is usually the most reliable means of site evaluation.

B-6

The methodology for analysis of construction techniques, structural configurations and spatial associations, based on surface characteristics is not systematized for Hawaiian sites. However, although site interpretations based solely on these characteristics are less explicit, they comprise a useful basis for subsequent investigations.

Archaeological Site - Historic Site

Another potential source of confusion are the terms: archaeological site, and historic site. For the purposes of this study archaeological and historic sites are differentiated based on the potential for reliable documentation (i.e. oral history or or coeval documentation). This criteria will determine the primary research methodology, archaeological for an archaeological site or historical for a historical site.

Sites that are primarily associated with prehistoric-types of activities are unlikely to have coeval documentation and are therefore called archaeological site. Sites that are associated with historic-types of activities are called historic site if the site has coeval documentation, or archaeological site if such documentation is lacking.

PREVIOUS ARCHAEOLOGICAL WORK

This section is principally concerned with the study area proper, a more generalized report covering previous archaeological research in the Puna area is included as an appendix.

Archaeological research regarding the inland areas of Puna has been extremely limited. Most study areas have been limited in size and frequently concerned with only one site. A notable exception, although no fieldwork was conducted, is a comprehensive analysis of archaeological and historical literature concerning the Puna area (McEldowney 1979), that is utilized in the development of the research design for the present study (see below).

Although the present study area is quite extensive only one project involving archaeological fieldwork had been previously conducted in the area (Bordner 1977). This project resulted in the location of one, possibly prehistoric-type site (State of Hawai'i Site 50-10-46-6417a) (Ibid). This site is an ahu (stone mound) located approximately 91 meters (300 feet) east of Highway 130, approximately 5.5 kilometers (3.4 miles) northwest of Pahoa town. This site was not relocated during the present survey and may have been destroyed by subsequent construction activities.

Pahoa town, (State of Hawai'i Site 50-10-55-7380) and the former right-of-way for the Hawai'i Consolidated Railway, are the only previously identified historic-type sites within the corridors.

Prehistoric-type sites located in the general vicinity of the proposed corridors consist of four lava tube sites: Shipman's Cave (50-Ha-A1-11), Kapo Kohe Lele Cave, Pahoa Cave, and a "modified lava tube" (see appendix). With the exception of the "modified lava tube," these all contain human skeletal remains. Pahoa Cave and Shipman's Cave are thought to be refuge caves as well (see appendix). These caves (lava tube segments) are part of an extensive system of lava tubes that occur in many sections of the study area and may be connected to lava tube sites located during the present fieldwork.

Historic-type sites located near the corridor are for the most part related to sugar plantation activities in the area. The closest example is

Kea'au District (State of Hawai'i site 50-10-44-7389) which encompasses most of Kea'au town.

RESEARCH DESIGN

The study objectives outlined in the introduction are primarily related to the development an environmental impact statement concerning the proposed activity and not necessarily related to general archaeological research goals. Since the study area covers a large area that has not been previously examined through extensive fieldwork, it is necessary to relate the present research activities to the context of the general Puna area.

Settlement Pattern Model

The research design for the present study focuses on prehistoric-type activity in the study area and utilizes a settlement pattern model based on analysis of archaeological data from previous studies and literature from the early historic period (McEldowney 1979). The analysis was primarily concerned with the east Puna region between the town of Hilo and Cape Kumukahi to an altitude of 2900 meters (9,500 feet), and included the present study area. McEldowney identified five zones of prehistoric-type Hawaiian settlement and land use roughly corresponding to elevation:

I. Coastal settlement (0-50 ft.)
II. Upland agriculture (50-1,500 ft.)
III. Lower forest (1,500-2,500 ft.)
IV. Rainforest (2,500-5,500 ft.)
V. Sub-alpine (5,500-9,500+ ft.)

Substantial prehistoric-type settlements were found to have occurred on the coast, with extensive agricultural fields located in areas of Zone II. The higher elevation areas of Zones III, IV, and V were have been utilized for exploitation of a large variety of forest resources such as trees, fibers, birds, etc. and trails (McEldowney 1978:15-33).

McEldowney noted that differing land use patterns, although closely related to elevation (i.e. proximity to coastal areas and primary settlements) are also related to variability in physiography (geologic morphology, and

B-7

vegetation) within each zone (Ibid:3, 4, 14). Two extremes in geologic variability are represented by thick, older, volcanic ash deposits from Mauna Loa volcano (relatively well developed soils), and the recent lavas of Kilauea volcano (little or no soil development).

McEldowney illustrated specific adaptations to the environment of the region utilizing data from early historic descriptions and previous archaeological research:

> [on the ash deposits]...the land use patterns were unform [uniform], consisting of more concentrated settlements on gulch or valley floors near the coast and of widely spaced plantations and huts scattered across an "unwooded," gentle slope up to 2,000 ft elevation (Ellis, 1963:349; Macrae, 1922:48-49; Menzies, 1920:51). [on recent lavas]...adaptation patterns centered around maximizing use of a frequently changing landscape with a rough, uneven, and highly variable surface having little soil development. Practices typical of the area, such as the modification of lava tubes and outcrops for shelter, the use of mounds and mulching for planting, ...typify this adaptation [McEldowney, 1979:14, 15].

In terms of overall site frequency in Zone II McEldowney suggests that few prehistoric-type sites are to be expected in areas of recent lavas, and that undisturbed volcanic ash deposits and older lava flows have a higher potential (Ibid:19).

Research Goals

General research problems addressed by the present study are related to the prehistoric-type settlement pattern model presented by McEldowney. Although the study area is limited by "artificial constraints" (i.e. the study area boundaries are not congruent with archaeological research considerations), the study must be conducted within the context of regional considerations.

The following research problems or questions are addressed by fieldwork in the present study area:

1 Previous archaeological work has not resulted in the location of agricultural features in areas of Zone II as predicted by the settlement model. Is this the result of inadequate sampling or are weaknesses in the model the source of the discrepancy?

2 What kinds of prehistoric-type activities other than agriculture are indicated by archaeological sites in the areas of Zone II studied, and what is their distribution.

3 The effects of volcanic activity especially during the prehistoric period.

Although historic-type sites are not evaluated here in the context of research goals, identification and evaluation of these resources is included as one of the objectives of the study.

Sampling Design

Due to the dense vegetation, rough topography, and large size of the study area a surface survey of 100 percent of the area was considered unfeasible. Thus, the adoption of a sampling strategy was necessary. Although no large scale ground surveys had been previously conducted within directly comparable areas, research in nearby areas suggest the occurrence of archaeological sites in association with certain physiographic features. Therefore a stratified sampling strategy was chosen (McEldowney 1979).

Compared to a more random design, a stratified sampling strategy increases the probability of obtaining a representative sample if relevant distributional factors are known. The parameters adopted for the stratified sampling are untested, therefore, a set interval strategy is incorporated into the overall stratified design.

For the present study this means that within each physiographic area identified for sampling, more than one transect was performed and that the transects were, in general, evenly spaced.

Methodology

The sample areas identified, utilizing aerial photos, geologic and topographic maps, and helicopter reconnaissance, consist of various lava flows, ash deposits and associated vegetation. These large physiographic areas are well defined although internally, numerous small scale variations in the terrain and vegetation occur.

Approximate locations for transects were set at central and/or peripheral portions of each physiographic area. Selection of the precise location of each transect, however, was often influenced by degree of accessibility and localized variations in terrain. It should be noted that the considerable physiographic variability of the study area resulted in a set interval pattern of transect placement for the whole area (fig. 1). Transects were generally oriented perpendicular or parallel to the survey corridors, however, other orientations were selected as necessary (e.g. at the border of two physiographic areas transect were oriented to include both). Table 1 summarizes information on each transect.

Surveys were conducted using systematic sweeps oriented to compass bearings. Personnel were usually spaced 25 meters apart and transect widths were generally 100 meters, except in areas of extremely rough terrain or unusually dense vegetation. When features were found an intensive search of the vicinity was conducted for other features. Verbal descriptions were written for each sites and all site locations plotted on 1:24,000 scale maps (U.S.G.S). Time constraints did not allow for the mapping of all the sites located, however, sketch maps were drawn and photographs taken whenever feasible. Artifacts and samples were not collected during the survey.

TABLE 1
TRANSECT SUMMARY

Transect	Substrate Type	*Substrate Age	Site
1	Ash	>1500	-----
2	Ash	>1500	A1-45
3	TF pahoehoe	350-500	-----
4	TF pahoehoe	350-500	-----
5	'A'a soil	>1500	A1-48, 49
6	Ash	>1500	-----
7	Ash	>1500	A1-46
	TF pahoehoe	350-500	-----
8	'A'a soil	>1500	A1-47
	TF pahoehoe	350-500	-----
9	TF pahoehoe	350-500	-----
10	TF pahoehoe	350-500	**50-10-46-6417
11	TF pahoehoe	750-1000	-----
12	TF pahoehoe	350-500	-----
13	TF pahoehoe	350-500	-----
14	TF pahoehoe	350-500	A4-68
15	TF pahoehoe	350-500	A4-69
	TF pahoehoe	750-1000	-----
16	TF pahoehoe	750-1000	-----
	'A'a soil	750-1000	-----
17	TF pahoehoe	750-1000	-----
	'A'a soil	750-1000	-----
18	S pahoehoe	19th century	-----
	Rampart	19th century	-----
19	S pahoehoe	17th century	-----
20	S pahoehoe	16th century	-----
21	S pahoehoe	17th century	-----
22	'A'a soil	16th century	-----
23	S pahoehoe	19th century	-----
24	'A'a soil	750-1000	-----
25	S pahoehoe	19th century	-----
26	S pahoehoe	19th century	-----
27	'A'a soil	16th century	-----
28	TF pahoehoe	350-500	A4-70, A5-18
	'A'a soil	>1500	-----
29	TF pahoehoe	350-500	-----
30	TF pahoehoe	350-500	-----
31	TF pahoehoe	350-500	-----
	TF pahoehoe	750-1000	-----
32	TF pahoehoe	350-500	TH-2
33	TF pahoehoe	350-500	-----
34	TF pahoehoe	350-500	A4-67
35	TF pahoehoe	350-500	-----
36	TF pahoehoe	350-500	A3-28

TF pahoehoe = tube fed pahoehoe
S pahoehoe = surface pahoehoe
*Age ranges are given in years B.P.
**State site 50-10-46-6417 was not relocated.

SURVEY RESULTS

Eleven archaeological and three historic sites were located during the survey (fig. 2a, 2b attached at end of report).

Historic-type sites have been assigned temporary numbers prefaced by "TH-". All sites that contain probable prehistoric components have been assigned site numbers following the established Bishop Museum system:

50 = State of Hawai'i
Ha = Island of Hawai'i
A = Puna
1 = _ahupua'a_ of Kea'au
3 = _ahupua'a_ of Maku'u, Popoki, Halona
4 = _ahupua'a_ of Keonepoko Nui, Keonepoko Iki
5 = _ahupua'a_ of Waikahiula

The terminal number is a discrete site number assigned in order of recordation within each _ahupua'a_.

Archaeological Sites

Tentative determinations of site functions based on comparisons with structures analyzed in previous studies have been summarized, with environmental data, in Table 2. The age of the geologic substrates are based on data from Holcomb's study of the chronology of surficial lava flows in the area (Holcomb 1981).

With one exeception (TH-2), all the archaeological sites below have associations with prehistoric-type activities. Site 50-Ha-A4-69, a burial cave, contains human skeletal material associated with early historic artifacts as well as skeletal remains without similar associations and is interpreted as both prehistoric-type and historic-type (see above Terminology).

Site 50-Ha-A1-45

This site consists of a stone platform and a ditch that are located in a steep gulch that is situated in the midst of extensive sugar cane field. The platform constructed of stacked, angular stone measures 3 by 4 meters and

TABLE 2
PREHISTORIC-TYPE ARCHAEOLOGICAL SITE
FUNCTIONAL INTERPRETATIONS AND SUBSTRATE DATA

Site	Type	Functional Interpretation	Substrate Type	*Substrate Age	Corridor Section
A1-45	Irrig. ditch, platform	Agriculture	Ash soil	>1500	A
A1-46	Walls, terraces, clearings	Agriculture	Ash soil Pahoehoe	>1500 350-500	I
A1-47	Terraces, mod. outcrops	Agriculture	'A'a soil Pahoehoe	>1500 350-500	I
A1-48	Terraces	Agriculture	'A'a soil	>1500	A
A1-49	Terraces	Agriculture	'A'a soil	>1500	A
A3-28	Platform	Boundary/Trail	Pahoehoe	350-500	H
A4-67	Terraced platform	Boundary/Trail	Pahoehoe	350-500	H
A4-68	Modified cave	Refuge	Pahoehoe	350-500	B
A4-69	Burial cave	Burial	Pahoehoe	350-500	C
A4-70	Petroglyphs	Petroglyph	Pahoehoe	350-500	G
A5-10	Burial cave	Burial	Pahoehoe 'A'a	350-500 >1500	G

* Substrate age in years B.P.

B-10

stands 100 centimeters high. The ditch is approximately 23 meters long, 2 to 3 meters wide and 30 centimeters deep. Recent debris, including bottles, metal fragments and pieces of plastic were found. Soils in the area are deep and the vegetation includes guava, 'ulu and banyan (Ficus sp.).

Site 50-Ha-A1-46

Located at the boundary between former sugar cane fields and an 'ohi'a forest, this complex of stacked stone structures occupies an area of approximately 150 x 40 meters. The principal feature in the area is a stacked stone wall that appears to extend over the entire length of the area. A large number of terraces, clearings, and small wall segments appear to form a continous series of structures that occupy the entire area. No artifacts or midden were found, although remnants of a modern fence was present. The dense vegetation includes guava, 'ulu, banyan and siris. The substrate appears to be a mixture of the deep soils of the sugar cane fields and the rocky surface of the 'ohi'a forest.

Site 50-Ha-A1-47

Occupying an area that measures approximately 100 x 30 meters, this complex of structures is bounded on the west by one of the sugar cane fields at Waipahoehoe and on the east by forest (fig. 3). Numerous modified outcrops, clearings and small terraces (less than five meters long) were found in the area. A long, narrow depression, 15 meters long, 1 meter wide and 20 centimeters deep is located near the eastern boundary of the area. This structure is oriented 240 degrees east of magnetic north, bounded by 1-2 courses of angular stone and its shallow interior consists of a deposit of sediments. No artifacts or midden were observed.

The vegetation includes guava, 'ulu banyan and siris. As at site A1-46 the substrate in this area appears to be a mixture of the deep soils of the sugar cane fields and the rocky surface of the 'ohi'a forest.

In 1846 Chester Lyman traveled to Waipahoehoe and described a "little village" in the area (Lyman 1846:108).

Site 50-Ha-A1-48

This structure consists of a five meter long terrace situated at the top of the steep southeast bank of an intermittent stream. The terrace is located

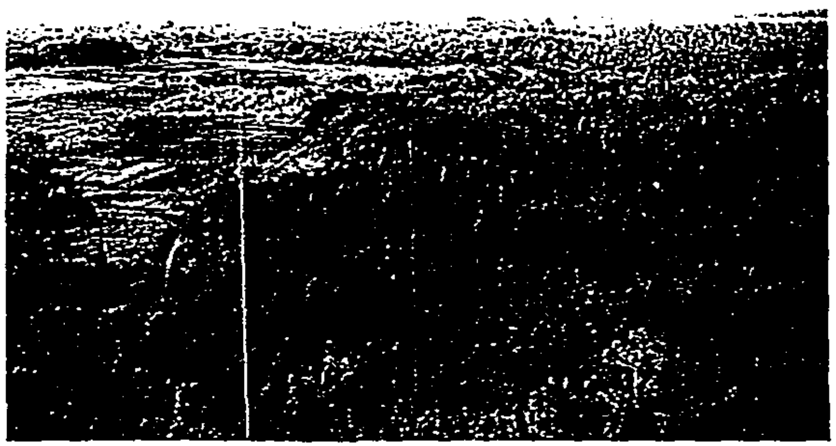

FIGURE 3. Aerial View of Topography near Site A1-47. (agricultural complex)

in a dense, narrow stand of hau (Hibiscus tileaceus) that follows the stream and between two sugar cane fields. The terrace is constructed of stacked angular stones, two to three stones high (60 centimeters) and oriented approximately 10 degrees east of magnetic north. No artifacts or midden were observed. Disturbed remnants of additional terracing were found nearby and the soil in the area is deep.

Site 50-Ha-A1-49

Situated about 150 meters northeast of A1-48, along the same bank of the stream, this structure is a segment of terracing 25 meters long. Constructed of 4-5 courses (75-100 centimeters high) of stacked angular stone, the structure is oriented approximately 355 degrees east of magnetic north. The site has been disturbed by bulldozing of the deep soils of the adjacent sugar cane field and is covered with guava. No artifacts or midden were observed.

Site 50-Ha-A3-28

This structure is a low terrace or platform situated at the base of a pressure ridge system in an open pahoehoe flow. The structure is ill-defined, however, it appears to be constructed of 1-2 courses of stacked angular stone and measures 2.4 by 1.8 meters. No midden or artifacts were observed. A modern hunter's blind constructed of lumber was found nearby. The site is situated in the "'ohi'a dieback" an open grass areas with sparse 'ohi'a, but ki, hala and guava were found clustered along the pressure ridge.

Site 50-Ha-A4-67

Located immediately adjacent to the railroad bed, this structure is a stepped stone platform constructed of stacked stone facings with an interior fill of smaller stone (fig. 4, 5). No artifacts or midden were found on the structure. This site is located in the "'ohi'a dieback" area, very close to the boundary between the ahupua'a of Halona and Keonepoko Nui. The substrate is relatively bare pahoehoe.

Site 50-Ha-A4-68

This site consists of a collapsed lava tube sink roughly 30 meters in diameter and 5 meters deep that has been extensively modified. Entry into an extensive network of lava tubes that is accessible from the sink has been restricted by the construction of stacked stone walls and platforms that block the tube openings (fig. 6). An interesting feature at the west end of the

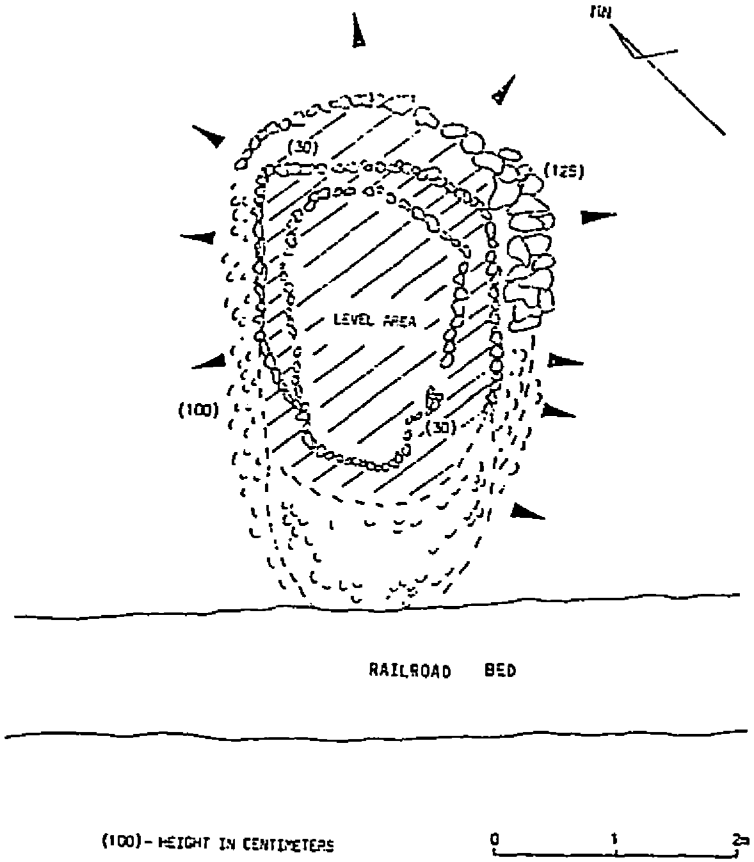

FIGURE 4. Sketch Map of Site A4-67 (terraced platform).

FIGURE 5. Site A4-67 (terraced platform), in "'ohi'a dieback" Area. View to North.

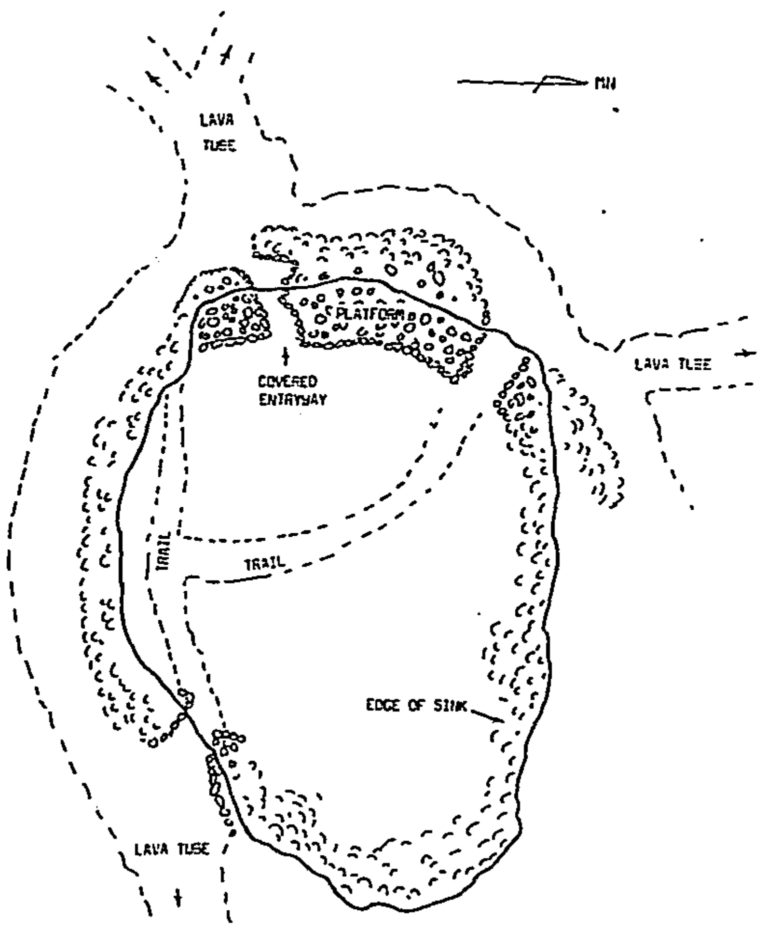

FIGURE 6. Rough Sketch of Site A4-68 (refuge cave). Not to Scale.

B-13

sink is a passageway that allows access to the lava tubes. This entry is a small constructed opening 60 centimeters high and 75 centimeters wide, faced on both sides and ceiling, that continues for a distance of about four meters.

Prehistoric-type midden material consists of marine shell and burnt <u>kukui</u> nuts. There is a deep deposit of sediments on the bottom of the sink area and the excavation potential is good. The lava tubes were followed for approximately 400 meters and no interior structures were located, however, the system continues for an unknown distance and is probably related to the system associated with the "Pahoa Cave" (Yent 1983).

The sink is located in an area of pahoehoe lava with little soil development. Vegetation in the area is dominated by <u>'ohi'a</u> and dense <u>uluhe</u> . Solitary <u>kukui</u> and banyan trees were found growing in the sink (fig. 7).

This lava tube had been previously designated as a Civil Defense shelter and there is evidence of recent modifications to the site. Stones have been removed from walls and platforms, a path constructed into the sink, and pipes and lumber are scattered on the surface. Civil Defense shelter maps show another lava tube cave located east and across the highway from A4-68, however, it could not be relocated

<u>Site 50-Ha-A4-69</u>

This site is a collapsed lava tube sink that has no structural modifications and very little soil development. The sink is about 10 meters in diameter and 5 meters deep, with openings into lava tubes that extend to the north and south. The badly disturbed skeletal remains of approximately five individuals were found scattered for approximately 100 meters along both tubes. The tubes were not completely explored due to time constraints and additional skeletal remains may exist.

No prehistoric-type artifacts or midden were found in the tubes. Artifacts from with the early historic period (e.g. square shank nails, bottles with hand formed lips, bone buttons), however, appear to be associated with certain concentrations of bone and it is likely that both prehistoric-type and historic-type interments are represented (fig. 8). Modern artifacts such as pieces of corrugated iron and a bottle with "Territory of Hawaii"

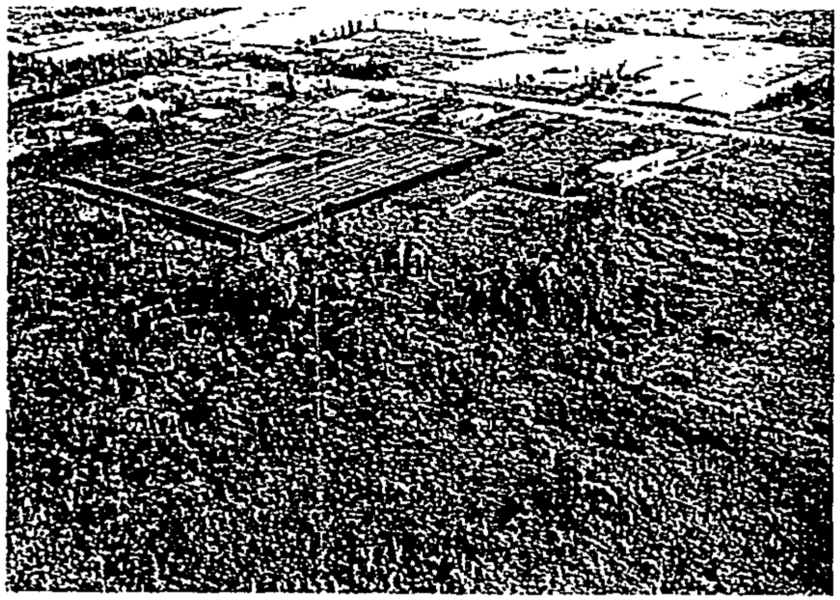

FIGURE 7. Aerial View of Topography near Site A4-66 (refuge cave).

FIGURE 8. Interior of Site A4-69 (burial cave). View to West.

embossed on it were also found, inferring relatively recent activity at the site.

The site is located in an area covered with dense uluhe and sparse 'ohi'a.

Site 50-Ha-A4-70

This site is a cluster of 18 petroglyphs located on a smooth pahoehoe lava flow in an area covered with dense uluhe and sparse 'ohi'a. Nine figures are anthropomorphic, the others being triangular, circular or irregular in shape (fig. 9, 10, 11).

Hidden under a dense mat of organic material the petroglyphs were discovered by the landowner while clearing a large area with hand-tools. Therefore, even though no additional petroglyphs were found in nearby areas, other figures may exist. The landowner said that children had found "bones" in a nearby lava blister, however, no such materials could be located.

B-15

Site 50-Ha-A5-10

Located approximately 150 meters south of A4-70, this site is a collapsed lava tube sink that is 20 meters wide, 7.5 meters long and 6 meters deep. A large number of human skeletal remains were found near the sink opening, including two crania, a pelvis, long bones, vertebrae, ribs, etc.. The remains had been disturbed and were scattered in crevices and along lava tubes that branched from the sink. No artifacts of any kind nor any midden was found and there is little or no soil development. The site is located in an area covered with dense uluhe and sparse 'ohi'a (fig. 12).

TH-2

Located near the southwest end of corridor segment "I" this site consists of two structures, a 6 by 5 meter cement foundation and a 1 by 1.5 meter stone and cement structure 1.8 meters high, that are situated directly on the railroad right-of-way. A large amount of historic-type debris including porcelain bowl fragments, 20th century glass bottles, etc. are present in the vicinity of the structures. Ten mango and four coconut (Cocos nucifera) trees are located at the site, which is otherwise situate in an area of "'ohi'a dieback".

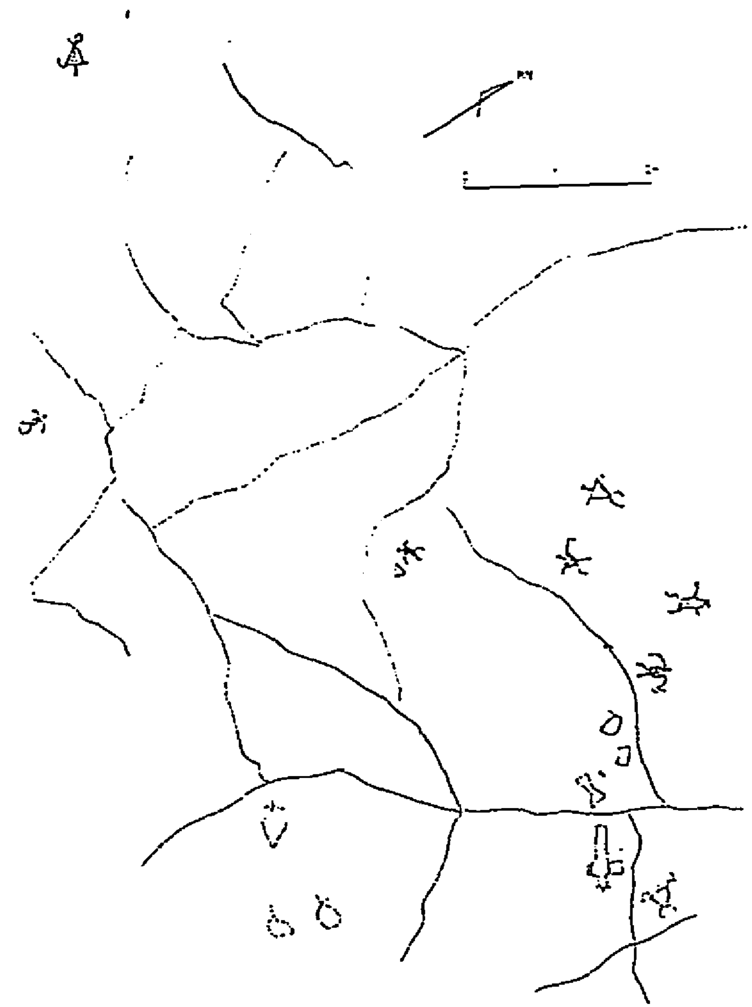

FIGURE 9. Sketch Map of Site A4-70 (petroglyphs).

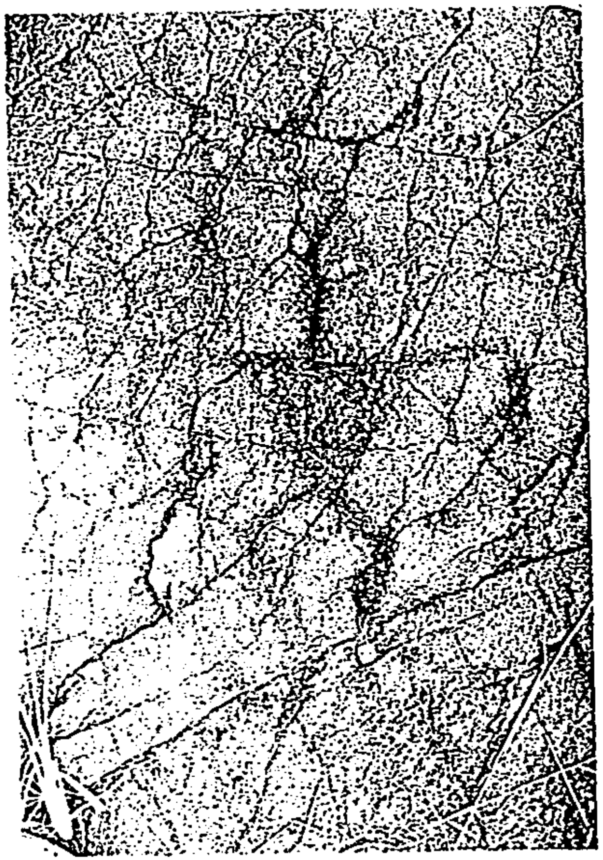

FIGURE 10. Petroglyph Site A4-70, Triangular Human Figure.

FIGURE 11. Petroglyph Site A4-70, Triangular Human Figure.

FIGURE 12. Vegetation at Site A45-10 (burial cave). View to South.

Historic Sites

TH-1

This site is the right-of-way of the Hawaii Consolidated Railway, that extends from Hilo bay to the Kapoho area in south Puna. The tracks were removed in the early 1920's and many portions, especially in the Hilo area and the subdivided areas in Puna have been utilized for modern roads, however, the railroad bed itself is relatively intact. (see appendix for further information on this site)

TH-3

The Olaa Sugar Company, plantation manager's estate is located approximately 1.2 kilometers (3/4 mile) south of Kea'au town along Highway 130. This site is directly associated with Kea'au District (State of Hawai'i site 50-10-44-7389), which includes much of the plantation town of Kea'au, and appears to be in relatively good condition.

DISCUSSION

The limited scope of the present study makes interpretations very tentative, however, the settlement pattern model presented in the research design is generally supported by the results of the survey. The predicted occurrence of extensive agricultural fields and adaptation patterns closely related to physiographic features is supported by the current data.

It should be noted that the present study area covers only the central portions of Zone II (discussed in the Research Design). The underlying question of where the "inland" areas begin, with regard to prehistoric-type site distribution is not addressed by the present study.

Agricultural Sites

Five sites are related to prehistoric-type agricultural activities and are located near the northwest boundary of the study area, where deeper soils occur. These soil deposits were used for modern agriculture and the terrain has been extensively altered. Therefore, although the sites are limited in extent it is likely that the features are remnants of large, permanent agricultural complexes described by early historic visitors.

Two of these sites are agricultural complexes that are situated in areas where the deep soils derived from volcanic ash, or weathered 'a'a are mixed with more recent lava flows. Although the ash is older than 1500 years, the relatively unweathered lava was formed 350-500 years B.P., therefore, a tentative limit of 500 years is suggested for the age of these features. The other agricultural sites are all located in nearby areas and are probably closely related to the two complexes.

It should be noted that although a large number of agricultural features were destroyed when the areas with deep soils were plowed for sugar cane fields, another source of disturbance for features in the area may have been recent lava flows. Many of the flows in the area are less than 1000 years old (well within the period of human occupation for Hawai'i), and may cover earlier sites in the area. The substrates on which the other types of sites are located were formed between 350-500 years B.P. indicating that they too were utilized within the last 500 years.

Refuge Caves

The refuge cave located during the present study is probably part an extensive network of lava tubes located northwest of Pahoa town that probably extend to coastal areas. It is highly likely that additional lava tube sites, possibly connected with this refuge cave, are present in areas with similar geologic morphology since two other refuge caves have been located in the general area. Although traditional histories ascribe a secondary political role for Puna, the lands were considered valuable and the conflict implied by the presence of refuge caves may be related to control of local resources.

Burial Cave

The skeletal material located at the two burial caves, were extensively disturbed and only minimal interpretations regarding possible age of the burials is made. The remains found in one of burial caves appear to be from both the historic and prehistoric period and may indicate continual use of the cave over a period of time spanning the transition from prehistoric-type to historic-type activities. The other cave may be related to prehistoric-type activities only. Traditional Hawaiian burials are frequently associated with habitation areas, however, no known prehistoric-type habitation sites are situated near these sites. One explanation is that some burial sites, usually for high ranking persons were secreted in remote areas. The other possibility is that many sites have been destroyed by modern activities and features that remain are difficult to locate.

Platforms

Two of the sites are platforms located in open areas of smooth pahoehoe. Since both of the structures are located near boundaries between two <u>ahupua'a</u> a tentative interpretation is that they may be territorial boundaries or trail markers.

Petroglyphs

The petroglyphs found at site A4-70 are similar to figures found at other sites in Hawai'i. The importance of the carvings is that an age limit of no older than 500 years (the estimated age of the lava flow on which they have been inscribed) can be placed on them. To this author's knowledge, only one other site, the Hilina Pali Petroglyph Cave (Bishop Museum site 50-Hv-363) has produced direct chronological associations for Hawaiian petroglyphs.

The research at the Hilina Pali site indicates that there was a stylistic change in human figure petroglyphs at about A.D. 1600. Human figures carved when the cave was first occupied (circa A.D.1600) are dominated by linear figures (60%), with few open-bodied (10%) and triangular figures (10%). Based on inferential data a hypothesis that there was a subsequent change in preference for triangular forms as opposed to linear figures, was proposed, however, further research was considered to be necessary (Cleghorn 1980).

At site A4-70 all of the nine human figures are either triangular or open bodied, no linear figures were found. Although the sample is small the complete absence of linear figures in a cluster of petroglyphs produced after circa A.D. 1500 lends support to Cleghorn's hypothesis.

Summary

The period of time suggested for occupation of the sites located during the present study is from circa A.D. 1450 to the present. In terms of the prehistoric Hawaiian occupation of the islands this spans the latter part of the Expansion Period (A.D. 1100-1650) and the entire Proto-Historic Period (A.D. 1650-1795) as proposed by Kirch for the evolution of Hawaiian culture (Kirch 1985). During these periods the population increased rapidly, settlements expanded from valley foci, and social systems underwent significant changes, resulting in the advanced culture encountered by Europeans in the late eighteenth century (Ibid).

The hypothesis that settlements expanded from primary contexts into other (presumably less desirable areas) after A.D. 1100 is supported by the results of the present study. The establishment of agricultural complexes, far from the primary areas used for settlement on the coast (circa 5 km.) sometime after A.D. 1450 is consistent with Kirch's model for the development of Hawaiian culture.

B-19

RECOMMENDATIONS

This section contains general recommendations regarding selection of the transmission line corridor and specific recommendations regarding the treatment of archaeological and historic sites located during the survey. The recommendations for corridor selection are based on the potential for existence of additional archaeological sites in each corridor section ("A" through "I") and recommendations for specific sites are based on site evaluations and possible impacts the construction of the transmission line may have on the features located.

General Recommendations

The results of the survey indicate that the archaeological sites located in the survey area are of limited areal extent. There is a high probability, however, that isolated sites are present throughout the study area. Therefore, when a specific alignment for the corridor is selected additional archaeological research should be conducted in areas to be disturbed. The dense vegetation and rugged terrain of many parts of the study area make location of archaeological sites such as lava tube caves very difficult. If the the area to be studied is well-defined, concentrated efforts to locate sites can be made.

Archaeological Site Evaluations and Recommendations

Evaluations of condition, research potential and interpretive value of each archaeological site are listed in Table 3. The terms used are hierarchical and consist of: excellent, good, fair, or poor.

The condition of the site is evaluated through a qualitative assessment of the site's structural integerity. Research potential is related to the possibility that the site may contain data important to the prehistory or history of the area, region, or Hawaiian archaeology in general. Interpretive value is based on the potential of a site for public use or display. Site qualities taken into consideration include: uniqueness in the region , site condition, accessibility, and public interest.

The archaeological sites identified during the present study are assessed as having either good or excellent research potential. Since the present study indicates that very few prehistoric-type sites remain in the area, the

TABLE 3
ARCHAEOLOGICAL SITE EVALUTATIONS

Site	Description	Condition	Research Significance	Interpretive Potential
A1-45	Irrig. ditch, platform	Fair	Good	Poor
A1-46	Walls, terraces, clearings	Good	Excellent	Good
A1-47	Terraces, mod. outcrops	Fair	Good	Poor
A1-48	Terrace	Fair	Good	Poor*
A1-49	Terrace	Poor	Good	Poor
A3-28	Platform	Fair	Good	Poor
A4-67	Terraced Platform	Good	Good	Fair
A4-68	Refuge cave	Fair	Good	Poor
A4-69	Burial cave	Fair	Good	Poor
A4-70	Petroglyphs	Fair	Good	Fair
A5-10	Burial cave	Fair	Good	Poor
TH-2	Cement/stone foundation	Poor	Good	Fair

* Access to these sites should be limited, therefor interpretive value assessed as poor.

B-20

importance of known features to future research is very high since their research potential is enhanced. The historic-type site TH-3 is probably a railroad depot, however, in the absence of specific historical data this interpretation is tentative and further research is necessary.

In most cases the placement of foundations for transmission line poles allow enough flexibility to avoid all sites.

It is recommended, therefore, that all of the located sites be preserved.

Historic Site Recommendations

Most of the previously identified historic sites in the Puna area were evaluated during the Statewide Inventory of Historic Places conducted in the early 1970's. The majority of the sites are associated with sugar plantations and, based on such factors as architectural uniqueness, historical background and representative style, have been assigned reserve status (the four terms available were high value, valuable, reserve, and marginal).

Although detailed information on the plantation manager's estate, site TH-3, is presently unavailable, it may be eligible for nomination for registration as a historic place. The estate area is well defined and of limited area, and should be avoided by the proposed construction activities.

The formulation of specific recommendations regarding the railroad right-of-way is problematic due to its extreme length. Although preservation of portions of the railway foundation that remain is desirable, the specific parts to be preserved is difficult to determine. However, two sections that should be preserved are the portions near sites TH-2 and A3-28, both located immediately adjacent to the railway bed.

The proposed construction activities are unlikely to affect significant portions of the railway bed, however, specific construction activites should be reviewed with regard to possible extensive alterations.

Corridor Evaluations

In order to facilitate description the corridors have been divided into nine sections, "A" through "I" (fig. 1).

Segments "A" and "I"

Portions of the northwest and southeast limits of these segments are situated in areas utilized for sugar cane fields and modern house lots. However, restricted areas such as small gulches and the margins of the sugar cane fields may contain additional archaeological sites such as the five agricultural sites (A1-45 through 49) located. No sites were located in the central parts of this segment, however, it is likely that lava tube systems are present in the pahoehoe substrate of these areas and cave sites may exist.

Segment "B"

An extensive lava tube system is known to be located in the pahoehoe substrate in this area. It is highly likely that additional sites such as the burial (A4-69) and refuge caves (A4-68) located are present in the area. These sites are very difficult to locate but are usually of limited extent.

B-21

Segment "C"

This segment crosses terrain that has been extensively disturbed by intensive modern agricultural activities. No sites were located in these areas and the potential for sites is very low.

Segment "D"

The substrate in this area is extremely rocky and irregular, and less than 400 years old with very little soil development. The eastern part of the segment has been extensively disturbed by modern agricultural activities. No sites were located in this area and the potential for sites is very low.

Segment "E"

Portions of this segment are covered by lava flows that occurred in the 19th century, other areas with older substrates have been extensively distubed by modern agricultural activities. No sites were located in this area and the potential for sites is very low.

Segment "F"

The east part of this segment has been extesively disturbed by modern agricultural activities. No sites were located in these areas by the present survey and the potential for sites is very low. The northwest end, however, at the intersection with segment "F" is situated on an undisturbed pahoehoe flow where petroglyphs (A4-70) and a burial cave (A5-10) was located. Although these sites are of very limited extent, there is a possibility that additional, similar sites may be present.

Segment "G"

It is likely that an extensive lava tube system exists in the pahoehoe substrate of this area. Therefore, although the only site located along this segment is site TH-2 (possible railway depot), there is a possibility that cave sites may be present.

Segment "H"

The substrate in this area is similar to that in segment "G" and there is a possibility that cave sites are present. Two isolated platforms (A3-28, A4-67) were located along this segment by the present survey and additional, similar sites may exist.

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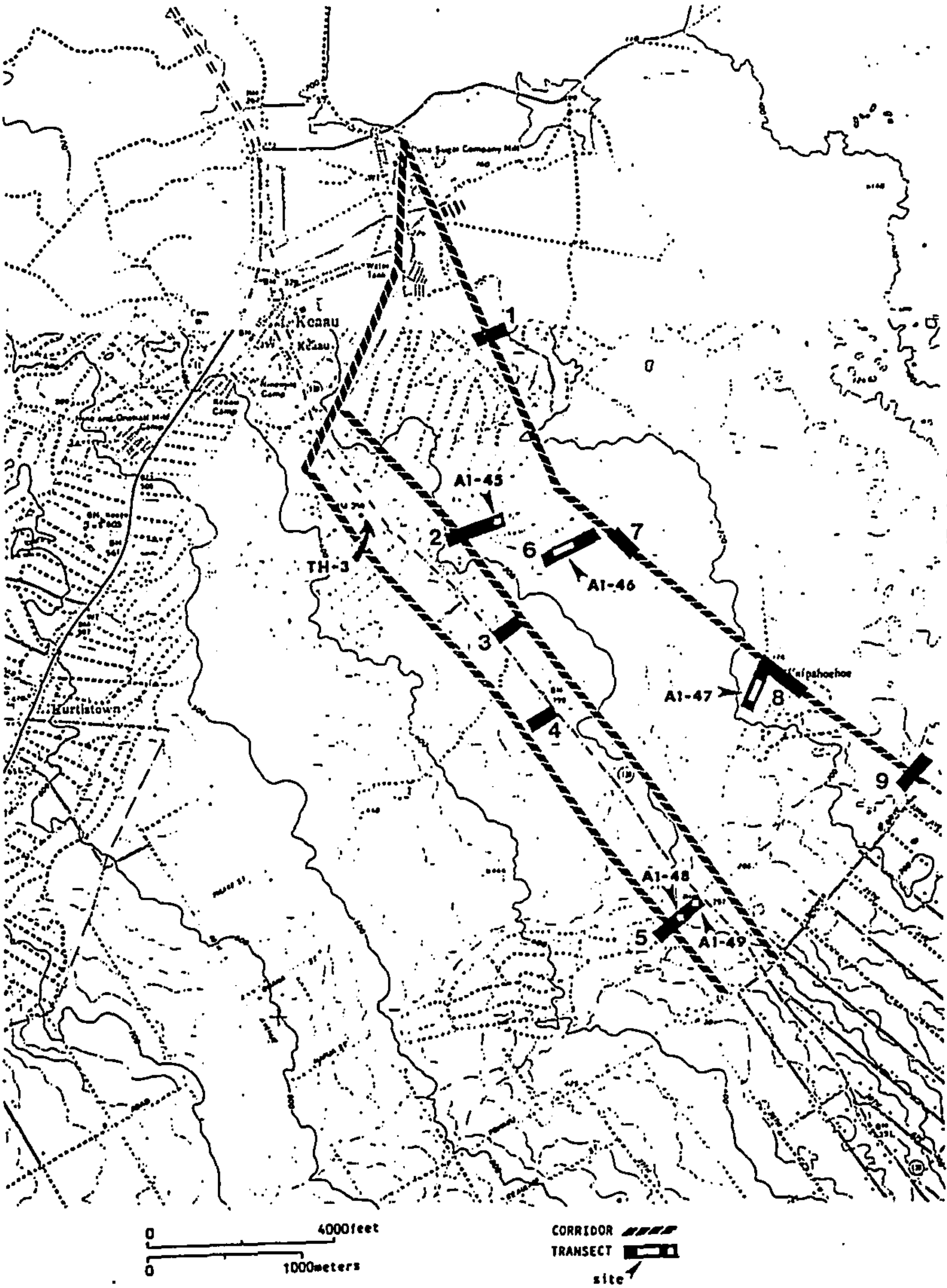

FIGURE 2a. Site Location Map with Transect Locations.

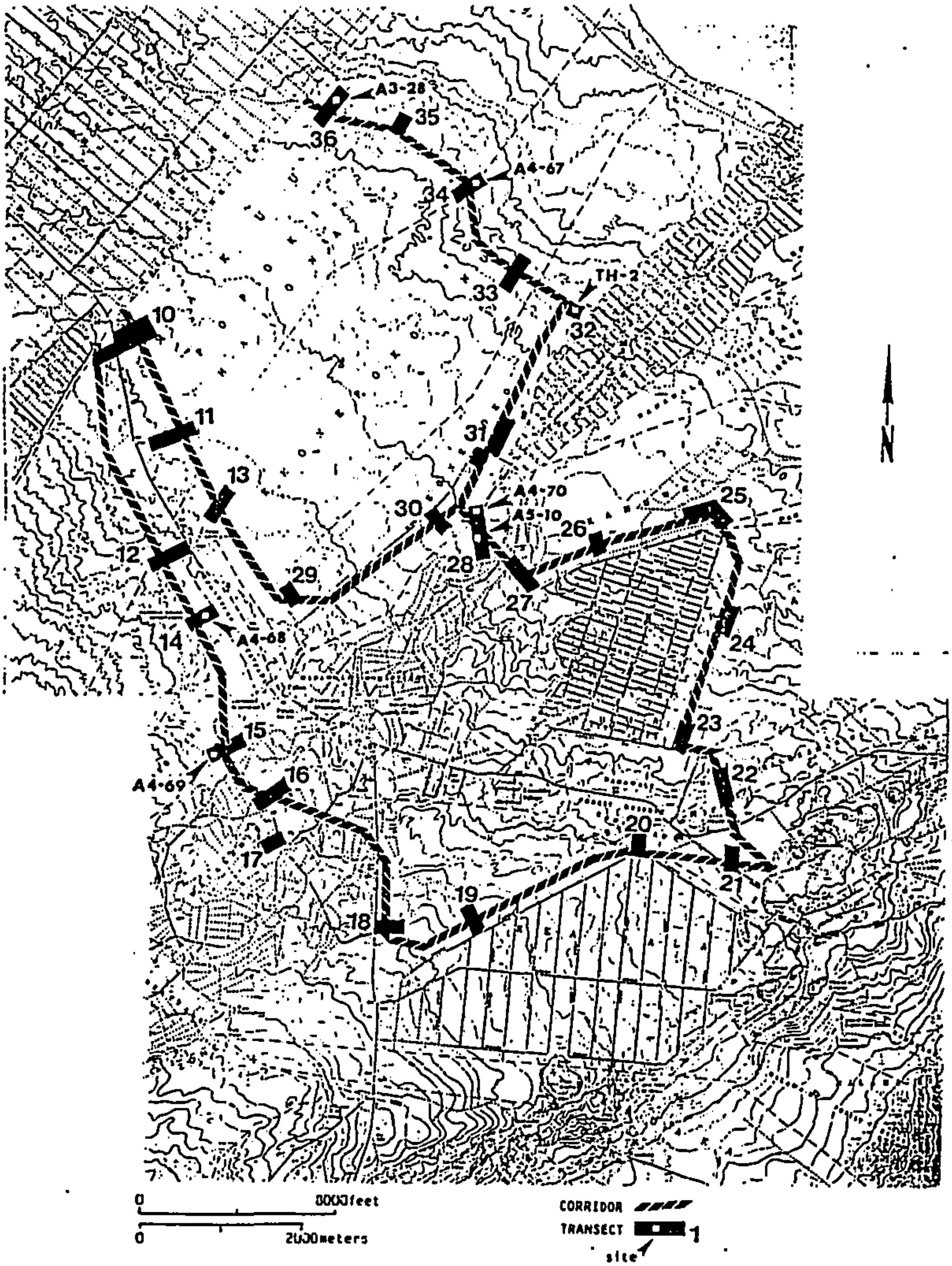

FIGURE 2b. Site Location Map with Transect Locations.

Appendix

LITERATURE REVIEW

of

**PREVIOUS ARCHAEOLOGICAL WORK,
PREVIOUS HISTORIC LAND USE AND
LEGENDS AND TRADITIONS**

by

Ingrid R. Peterson

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PREVIOUS ARCHAEOLOGICAL WORK

Archaeological research in the study area was first conducted in the early 1900s. Early research focused on heiau. More comprehensive surveys of archaeological sites began in the 1930s. However, the bulk of the research has been conducted in coastal areas. Studies of inland areas have been conducted in only very limited areas, investigating either specific archaeological sites or specific small areas slated for development.

The previous archaeological work for the Puna district pertinent to the study area is summarized below. See Table 1 (at end of report) for an inventory of archaeological and historical sites in the study area.

DATE	RESEARCHER	DESCRIPTION
1906	J. F. G.Stokes	A surface survey of the prominent religious structures of Hawai'i.
1907	T. G. Thrum	Description of Kukii Heiau, in Kapoho and its construction.
1930-1932	A. E. Hudson	Conducted archaeological reconnaissance survey on the east coast of Hawaii. Hudson's record provides good general information on the Puna area and was the most comprehensive survey of Puna at that time.
1945	K. P. Emory	Explored Shipman's Cave in Keaau, Puna.
1959	K. P. Emory et al.	Staff of the Bishop Museum conducted research on the natural and cultural history of the Kalapana extension of Hawaii Volcanoes National Park. The report provides good information on the land and traditional history of the Puna district.

DATE	RESEARCHER	DESCRIPTION
1963	L. J . Soehren	Conducted archaeological reconnaissance survey of Kahuwai Village, Puna.
1966-1968	V. Hansen	Conducted archaeological reconnaissance surveys in the Puna area, and recorded, mapped, and located numerous sites for the district.
1970	V. Loo and W. Bonk	Anthropological Research International compiled an inventory of historical sites in the northern portion of the island of Hawai'i, with a good review of the Puna district, in conjunction with Dept. of Planning, County of Hawai'i.
1971	N. Crozier and D. Barrere	Staff of the Bishop Museum conducted archaeological reconnaissance survey and historical research of Pu'ala'a, Puna, in conjunction with Bishop Estate.
1972	R. Bevaqua and T. Dye	Staff of the Bishop Museum conducted archaeological reconnaissance survey of the proposed Kapoho to Kalapana highway, in conjunction with Sam O. Hirota Inc. and Dept. of Public Works, County of Hawaii.
1973	N. Ewart and M. Luscomb	Staff of the Bishop Museum conducted archaeological reconnaissance survey of the proposed Kapoho to Keaukaha highway, in conjunction with Sam O. Hirota Inc. and Dept. of Public Works, County of Hawaii.

1977	R. M. Bordner	Archaeological Research Center, Inc. conducted archaeological reconnaissance survey of a proposed radar beacon system in Maku'u, Puna, in conjunction with Federal Aviation Administration.
1979	Fed. Hwy. Adm.	Federal Highway Administration and the Land Transportation Division of State of Hawaii Dept. of Transportation discovered two sites in preparing an Environmental Impact Statement for proposed Pahoa By-Pass for Keaau-Pahoa Road in Kaniahiku, Puna.
1979	H. McEldowney	Staff of the Bishop Museum conducted archaeological survey, historical research, and compiled site inventory of southern Hilo and northern Puna Districts, in conjunction with U.S. Army Corps of Engineers.
1980	W. Bonk	Conducted archaeological reconnaissance surveys of small _mauka_ areas in Keahialaka and Pohoiki, Puna, in conjunction with Geothermal Exploration and Development Corp.
1980-1981	E. J. Ladd	Conducted archaeological reconnaissance survey of Cape Kumukahi, in conjunction with U.S. Coast Guard.
1982	M. Yent and J. Ota	Staff of Division of State Parks and Historic Sites, Dept. of Land and Natural Resources, State of Hawaii conducted archaeological reconnaissance survey of a _makai_ part of the Nanawale Forest Reserve in Halepua'a, Puna, in conjunction with Division of Forestry.

1983	M. Yent	Staff of Division of State Parks and Historic Sites, Dept. of Land and Natural Resources, State of Hawaii conducted archaeological reconnaissance survey of a lava tube in Halona, Puna, in conjunction with Division of Forestry.
1983	D. Cox	Conducted archaeological reconnaissance survey of the proposed Cape Kumukahi Small Craft Navigation Improvements Project, in conjunction with U.S. Army Corps of Engineers.
1984	E. Rogers-Jourdane and B. Nakamura	Staff of the Bishop Museum conducted archaeological reconnaissance survey and historical research in Kapoho, Puna, in conjunction with Geothermal Development by the Thermal Power Company.

The vast majority of recorded sites have been found within 1 mile of the coastline. The only prehistoric sites in the study area that are definitely farther inland are three lava tube sites, one _ahu_, and six sites along the east rift zone. The "Pahoa Cave" lava tube site, located in Halona and listed in the inventory, is actually slightly inland of the study area. The three lava tube sites are: "Shipman's Cave," located in Kea'au (site 50-Ha-A1-11); the unnumbered site in the Kaniahiku area of Halepuaa-Kanekiki-Puua (Federal Highway Administration 1979); and the unnumbered site in Pohoiki (Bonk 1980b). The _ahu_ is located in Maku'u (State of Hawai'i site 50-10-46-6417a).

Two of the east rift zone sites are in Kula: Kukii Heiau (site 50-Ha-A8-1) and a grave (Hudson site 107). Three sites are in Kapoho: the Kapoho petroglyphs (50-Ha-A9-1), the _holua_ slide site Ka Holua O Kahawali (50-Ha-A9-2), and the unnumbered site of male and female sacred stones (Hudson site 108). In Pu'ala'a is the site of a destroyed _holua_ slide and partially destroyed agricultural patches (50-Ha-A10-6).

In addition, some of Ewart and Luscomb's unmapped Kea'au sites that are in our study area and north of Kaloli Point may be up to 2 miles inland (Ewart and Luscomb 1974:3), and some of Yent and Ota's prehistoric sites in Halepua'a may be up to 1.75 miles inland (Yent and Ota 1982:11).

For an area including the study area, McEldowney asserts that the combined results of archaeological studies alone "...do not provide an adequate basis for predicting site distribution...Coverage of even the most extensively examined coastal area remains incomplete" (McEldowney 1979:8). However, based on early historic accounts, McEldowney describes land use zones at the time of Western contact and possibly earlier, and she makes some comments on site distribution. Her Coastal Settlement Zone, extending 1 mile inland, and her adjacent Upland Agricultural Zone include the study area (Ibid.:14,48,64).

She finds the highest number of people of the early historic period, and therefore the highest site probabilities, are in the Coastal Settlement Zone.

> Early descriptions, as well as the distribution of known sites, suggest that structures representing both permanent and/or temporary use occur along the entire coast....The occurance of...the better developed organic soils important to crops, of potable fresh and brackish water, of local coastline formations amenable to sea exploitation, and of ponds or streams for acquaculture and/or marshland taro cultivation...appear to be major factors associated with population concentrations (Ibid.:15).

Structures occur singularly, clustered in small, widely-spaced groups, or concentrated in the six villages mentioned in early historic literature (Kea'au or Haena, Maku'u, Wai'akahiula, Honolulu, Kahuwai, and Kula or Koa'e) (Ibid.:15-16).

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Agricultural areas were nearby and/or slightly inland in the Upland Agricultural Zone. McEldowney states, "Within this zone, the possibilities of remnant agricultural complexes could be high on both ash and older aa or pahoehoe substrates that have not been disrupted by historic agricultural practices (Ibid.:19). She also notes that land use in this zone may have focused also on the lava tubes underlying the pahoehoe flows.

Cordy makes some predictions on potential site patterns based on historical and archaeological records for two areas of Puna in the study area. In Maku'u-Popoki-Halona, he suggests a high concentration of sites in the coastal area up to 1.75 miles inland, where permanent settlement was likely to be near the shore, with agricultural areas nearby and slightly inland. Farther inland he predicts a sparse distribution of sites, with burials or transit campsite remains in lava tube caves or transit campsite remains in surface walled shelters (Cordy 1986a).

In discussing Kapoho Ahupua'a, Cordy notes that in the surrounding areas a general pattern appears to exist of most permanent housing and associated <u>heiau</u> nearest the coast (0-1 miles inland) and agricultural areas nearby the houses and just inland from them. Farther inland he predicts sporadic land use and few sites, which might be shelters in caves or surface enclosure walls or burials in caves or in platforms on cinder cone slopes (Cordy 1986b).

PREVIOUS HISTORIC LAND USE

Railroad

A railroad operated in Puna from 1899 to 1946. The development of the sugar, lumber, and rock industries in and around the study area is tied in with the building of this railroad and the development of the companies that ran it. Hilo Railroad Company operated the railroad from the time of its incorporation in 1899 until its reorganization in 1916. From 1916 until 1946 Hawaii Consolidated Railway, Ltd. ran the railroad (Kelly et al. 142).

The major promoters of Hilo Railroad Company were Honolulu businessmen Benjamin F. Dillingham and Lorrin A. Thurston. They were also the major promoters of Olaa Sugar Company, incorporated in 1899, and Puna Sugar Company, incorporated in 1900 (ibid.144, 131). Hilo Railroad company arranged a 40-year contract to transport all Olaa Sugar Company freight (Ibid. 144). The first product of Olaa Sugar Company was 'ohi'a wood, obtained in clearing forests in the 'Ola'a area.

In 1900, Hilo Railroad Company built about 8.3 miles of railroad line from a terminal and harbor facilities at Waiakea, Hilo to the Olaa Sugar Company mill near Kea'au, Puna (ibid.). Raw sugar was transported from Olaa mill to Hilo Harbor on this line. By the end of 1901, the line was extended farther south to Kapoho with a 5-mile branch to Pahoa, for a total of 25.1 miles. Another 10 miles were also completed from Olaa Mill to Kea'au and up to Mountain View. Together these lines made up the "Hilo Division" (Ibid. 147). Sugar was cultivated in areas near the terminals at Kapoho, Pahoa, and Mountain View (Ibid. 132, 147 162; 164, see also Hawaii Survey 1906).

By 1910, the railroad also served Pahoa Lumber Mill in Pahoa. The mid-1910 annual report for Hilo Railroad Company describes the expediency of changing the rails on the Pahoa branch to 60 pounds and practically reconstructing the line due to heavy traffic from the lumber company freight and sugar cane (Kelly et al. 162). In 1909, Pahoa Lumber Mill "had about 10 miles of railroad track"

(Ibid. 114). The arrangement between the lumber company and the railroad company concerning the railroad in the Pahoa area was not determined.

The railroad also carried rock for the Hilo breakwater from quarries in Kapoho from 1908 to 1925 (Ibid. 193).

In mid-1910, the annual report of Hilo Railroad Company described an extension reaching 7 miles southwest of Kapoho to Kaueleau and a lumber mill there. (Kaueleau is outside the study area.) The company secured the right to operate over the portion of the railroad grade and tracks owned by Puna Sugar Company. The extension also reached the rubber plantation of Pacific Development Company (Ibid. 162, 164). (Whether the rubber plantation was located within the study area was not determined.) A 1906 map shows sugar cultivation just west of where the extension terminated (Hawaii Territory Survey 1906). Perhaps the extension was also used to carry this sugar.

Hawaii Consolidated Railway was controlled by the owners of the sugar plantations it served in Hilo and adjoining districts (Ibid. 142, 165). In 1946, after a tidal wave caused a great deal of damage to Hawaii Consolidated Railway, the company liquidated (Ibid. 175).

A map of southern Puna shows railroad tracks, including a branch to Pahoa, an extension from Kapoho to Kaueleau, and an additional branch, apparently not described above, in Kapoho that terminated near Pu'u Honuaula (Hawaii Territory Survey 1952). This branch probably served Puna Sugar Company fields in Kapoho and the Kapoho quarries. Only a very short part of its appears on a 1902 map (Hawaii Territory Survey 1902).

In northern Puna, a 1917 Olaa Sugar Company field map shows two branches off the main railroad line. One branch extends east from Olaa through sugar in Kipuka 4. The other branches off the main line south of the mill at Kaipahoehoe, passing through sugar at Kipuka 2 and terminating at Kipuka 1 ("Field map, Olaa Sugar Co., July 1917" in Conde and Best 1973:95, see also Hawaiian Territorial Survey 1930).

Sugar

"The incorporation of the Olaa Sugar Plantation in 1899 marked the beginning of sugar cultivation in the Puna District" (Kelly et al. 1981:144). In the 'Ola'a area, the company took over land formerly cultivated with coffee and cleared land covered in 'ohi'a forest. In 1900 the plantation covered about 19,500 acres, forming one of the largest sugar plantations in the Territory (Kelly et al. 1981:144). By 1902, the plantation stretched 14 miles mauka from the mill (Kelly et al. 1981:147, see also Hawaii Survey 1906), extending far outside the study area. By 1905, Olaa Sugar had 7,676.4 acres under sugar cultivation (Kelly ot al. 131). In a 1917 Olaa Sugar Company field map, sugar cultivation in the study area can be seen in the are around Olaa Mill, in a smaller area to the east along a road branch (Kipuka 4), and in two smaller areas south of the mill on the Waipahoehoe railraod branch (Kipuka 1 and2) ("Field Map, Olaa Sugar Co., July 1917" in Conde and Best 1973:95, see also Land Court Map 1930).

Puna Sugar Company was established in 1900 by the same people who developed Olaa Sugar Company (Kelly et al. 1981:131). It had no mill, but sent its cane to Olaa Mill (Kelly et al. 1981:154). "By 1905, Puna Plantation was taken over by Olaa Sugar Plantation" (Kelly et al. 1981:131). However, it was not until 1936 that Olaa Sugar Company officially bought out Puna Sugar Company (Kelly et al. 1981:131).

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Puna Sugar Company cultivated sugar in Kapoho (Kelly et al. 1981:164, Conde and Best 1973:99) and near Pahoa (Kelly et al. 1981:162, 164). A 1906 map shows these areas and another sugar plantation area which is west of Kaueleau (and outside the study area) (Hawaii Survey 1906). In 1907, Hawaiian Mahogany Lumber Company of Pahoa, later known as Pahoa Lumber Company, cleared 'ohi'a forests on Puna Sugar Company land. This land was then to be planted in cane (Conde and Best 1973:101). By mid-1910, the Hilo Railroad Company annual report spoke of a great increase in the amount of cane passing over the Pahoa branch line (Kelly et al. 1981:162).

In 1955, a volcanic flow at Kapoho eliminated 1,400 acres of cane area belonging to Olaa Sugar Company, Ltd. (Kelly et al. 1981:132). By 1956, the company had 9,400 acres planted in sugar cane (Kelly et al. 1981:131). Its name was officially changed to Puna Sugar Company, Ltd. in 1960 (Conde and Best 1973:94). In 1979, the company harvested 6,944 acres of cane and had a total of 16,145 caneland acres (Kelly et al. 1981:119).

Coffee

In the 1890s, coffee plantations were established in 'Ola'a district (between the present Puna and South Hilo districts) (Cordy 1978:4). It may be that all of these plantations were far from mauka of the later Olaa Mill (see Olaa Title Map 1900) and therefore out of the study area. In 1900, Olaa Sugar Company took over land from former 'Ola'a coffee homesteaders (Kelly et al. 1981:131, 144). "Unfortunately the coffee boom in Hawaii ended soon after it began and by 1902, Hawaiian coffee growers could no longer compete with foreign growers" (Cordy 1978:4).

"In the more remote district of Puna, the coffee industry was undeveloped except for a coffee plantation and mill established at Pohoiki by Robert Rycroft in or before 1894 (Cordy 1978:4). Rycroft had planted 35 acres (Cordy 1978:4). His mill was near the coast at Pohoiki and therefore out of the study area, but his coffee fields were about 3 miles mauka (Cordy 1978:4, see Loebenstein 1895, Hawaii Territory Survey 1952). "It is not known when Robert Rycroft abandoned his coffee plantation at Pohoiki, but other records show he had established a soda works manufacturing plant in the Sheridan Tract of Kakaako, Honolulu in 1900" (Cordy 1978:4). By 1927, coffee was no longer being cultivated in Puna district (Cordy 1978:4).

Lumber

In 1907, Hawaiian Mahogany Lumber Company of Pahoa cleared 'ohi'a forests on Puna Sugar Company land (Conde an Best 1973:101). By 1909, it had a contract to provide Santa Fe Railway Company with ties (Kelly et al. 1981:164). In 1909, Hawaiian Mahogany Lumber Company was taken over by Pahoa Lumber Company, also known as Pahoa Lumber Mill. The ties were to be shipped directly to California from Hilo port (Kelly et al. 1981:114).

From April to December 1909, the mill turned out 91,407 standard ties, about 622,662 ft of small ties, and 101,202 ft of lumber. The mill operated its own plant for building railway cars and repairing machinery. It had about 10 miles of railroad track, four locomotives, forty-five cars, and nine logging donkeys. In addition to railroad ties, which were in high demand in the Islands as well as on the Mainland, the company expected increased business in shingles and lumber for cars, wagons, carriages, etc. (Ibid.).

In 1910, Pahoa Lumber Mill secured the "right to lumber the forest on a tract of unleased government forest land in Puna, adjoining the Kaohe Homesteads at Pahoa, and having an approximate area of 12,000 acres" (Conde and Best 1973:183).

Later the company was known as Hawaii Hardwood Company, which folded in 1918 (Conde and Best 1973:181).

Rock

"Construction of the Hilo breakwater began in 1909 with the building of a rock fill.... In the first several years of breakwater construction, the railroad hauled all of the rock: most was from the Kapoho quarry in Puna" (Kelly et al. 1981:157). There was also an Olaa quarry.

From 1908 to 1910, 148,200 tons of rock for the Hilo breakwater were quarried from the Kapoho, Waiakea, and Olaa quarries. From 1910 to 1912, 95,577 tons of rock for the project were quarried from the Kapoho and Waiakea quarries. From 1924 to 1925, 88,657 tons of rock for the breakwater were quarried from the Kapoho quarries (Kelly et al. 1981:193).

Ranching

In Puna the "native agricultural system began to decline around 1840 as the population declined. At this time, there was a shift to ranching, coffee, and sugarcane" (Yent and Ota 1972:12). Evidence of ranching was found in Nanawale Forest Reserve near the coast in the ahupua'a of Halepua'a (Yent and Ota 1972:15-16). Enclosures that were through to be former cattle pens were found in the ahupua' of Kea'au and in the ahupua'a of Maku'u-Popoki-Halona (Ewart and Luscomb 1974:16-19, 26). There was a Shipman Ranch in Kea'au (Emory 1945). An 1895 map shows "Lyman's Ranch Paddock" in Kapoho between Kapoho Crater and Pu'u Kuki'i (Loebenstein 1895). A 1923 Hawaii Consolidated Railway map shows cattle ranching in an undefined large area makai of the railroad and between Olaa Mill and branch of the railroad leading to Pahoa (Kelly et al. 1981:164).

LEGENDS AND ORAL TRADITIONS

Traditonal History of Politics and Religion

In recounting the traditional political history of Puna, Barrere states:

> ...that Puna, as a political unit, played an insignificant part in shaping the course of the history of Hawaii island. Unlike the other districts of Hawaii, no great family arose upon whose support one or another of the chiefs seeking power had to depend for his success. Puna lands were desirable, and were eagerly sought; but their control did not rest upon the conquering of Puna itself, but rather upon control of the adjacent districts, Ka'u and Hilo. An attempt to follow in detail the course of Puna's history is meaningless, since her history is bound up with the fortunes of the ruling families on either side of her (Barrere 1959:15).

Barrere does, however, describe events that were significant to Puna itself.

Around 1475 A.D., Puna was one of six districts of Hawai'i Island whose chiefs acknowledged Liloa as their supreme chief. The unity of the districts was temporarily destroyed with the death of Liloa. At this time Hua'a was the chief of Puna. 'Umi, a son of Liloa, but not the acknowledged heir to his position of supreme chief, reunited the kingdom. The Hawaiian historian S. M. Kamakau describes the death of Hua'a on the battlefield of Kuolo in Kea'au during the conquest of Puna by 'Umi (Barrere 1959:15-16). Other political events relating specifically to Puna from the time of 'Umi up until the time of Kamehameha's conquest of Hawai'i Island are also described by Barrere (1959; see Appendix A).

The Kings' Pillars (#50-Ha-A8-2), the stone cairns at the tip of Cape Kumukahi, "are said to have been built by the various monarchs of the Hawaiian kingdom upon assuming the throne" (Hudson 1932:325). Others say the rock piles

are funeral cairns or that they are built to signify that one's illness is being left behind (Mary Kawena Pukui in Emory et al. 1959:60).

Puna had importance as a center in the development of Hawaiian religion. It was in Puna that the priest Paao first established his line of priesthood. The line continued until after Kamehameha I's death in 1819 (Beckwith 1979:371-375). The first <u>heiau</u> constructed by Paao was in a part of Puna outside the study area (Thrum 1907a:48). According to tradition, Kukii Heiau (#50-Ha-A8-1) on the summit of Kukii Hill in Kapoho was built by 'Umi, ruler of Hawai'i Island, who was devoutly religious. Kukii Heiau was one of the <u>heiau</u> erected by 'Umi on his tour around the island after he came to power. Each of these <u>heiau</u> was said to have been distinguished by its dressed- or hewn-stone construction (Fornander 1969:101-102). It was said there was once an important <u>heiau</u> in Pohoiki called Oolo, but it was entirely destroyed by 1907 (Thrum 1907b).

Legends

Many of the legends of Puna refer to an early time when the area was famous for its long stretch of sand, its fertile plains, and its hala trees. Numerous legends describe Pele's anger causing lava to cover either large areas of the region or more limited sections of it. It has been pointed out that traditions imply that Puna "was once Hawaii's richest agricultural region and that it is only in relatively recent time that volcanic eruption has destroyed much of its best land" (Handy and Handy 1972:542).

Puna, or some say the eastern side of the district (Green 1928:10-11 in "The Story of Kalaikini), was known as <u>ka paia 'ala i ka hala</u>, which means "the forest bower or wall scented by hala" (Pukui and Elbert 1971:270). Hala grew abundantly in Puna and people tucked hala blossoms in the walls of their houses and in their sleeping mats. Puna was also famous for the fine mats people made of the short white husks of hala blossoms and for the soft breeze that in the old days was scented by hala and lehua blossoms 62).

In the legend of Puna'aikoa'e ((Mary Kawena Pukui in Emory et al. 1959:37), Pele covers most of the land of Puna, including most of its long beach, with lava. In the legend of Keliikuku (Westervelt 1916:31-32), Pele covers houses, fertile plains, and forests, including hala, with burning lava. Several other Puna chiefs anger Pele, causing lava to cover parts of their land.

Listed below are some of the legends referring to Puna generally or more specifically to Puna lands within the study area. Given the size of the area and the close connection between Pele and the volcanically active land of Puna, there are surely additional references to this area of Puna which are not mentioned here.

Legend of Iwa (Elbert 1979:18-30)

In the legend of Iwa a man named Kea'au, who lives in that region, owns two leho shells (cowries) called Kalokuna. He treasures the shells for their exceptional power as bait for squid fishing. One has only to expose them and squids come up and enter the canoe. 'Umi, chief of Hawai'i Island, who is then living in Kona, hears of Kea'au's shells and sends his messengers to demand that they be turned over to him. Kea'au complies, but then yearns for his shells. He brings the infamous boy thief Iwa from O'ahu to recover the shells from 'Umi for him. This Iwa does, but soon after he steals them back from Kea'au for 'Umi. Iwa then performs other feats of thievery for 'Umi, and Kea'au is left without his shells and living in Leleiwi, "the point of land adjoining Kumukahi, between Puna and Hilo" (Elbert 1979:22).

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The Story of Kalaikini (Green 1928:10-15)

In this story of Kalaikini, the traveling kupua or sorcerer from Tahiti, he is defeated in battle with another sorcerer, Pohakuolekia, at Kapoho Crater. Pohakuolekia is now a magic slab-like rock on the rim of the crater. His wife, the scorceress Pohaku o Hanalei, is a magic rock on the opposite side of the crater. (These rocks appear to be Hudson's site #108.) In the legend, they were standing in these positions when Kalaikini comes upon them. Kalaikini creates a column of dust in almost digging up Pohakuolekia from his firmly planted stance. At his wife's tears and cries of love, Pohakuolekia twists and squirms until he is so deeply rooted in the earth's foundations that Kalaikini abandons his efforts to dislodge his foe.

Legend of Halemano (Elbert 1979:258-290)

In this complicated romance, handsome Halemano of O'ahu falls deeply in love, through dreams, with Kamalalawalu, the beauty of Puna. She is the daughter of the chiefs of Kapoho, and has been brought up with her favorite brother Kumukahi as her only companion and eight hundred dogs to guard and serve her. Hua'a, the chief of Puna, and Kulukulua, the chief of Hilo, court her without success (Elbert 1979:258).

With the help of his older sister, the sorceress Laenihi, Halemano travels to Puna and lures Kamalalawalu to his canoe. Halemano and Laenihi arrive off of Haku'u and Popoki (Elbert 1979:256), where they use specially prepared playthings to entice Kumukahi, who in turn summons his sister. Both are abducted to O'ahu by Halemano and Laenihi. Halemano and Kamalalawalu marry there, and she sends Kumukahi back to Hawai'i to live with their parents (Elbert 1979:260).

Later in the story when Halemano and Kamalalawalu are living in Waiakea, Hilo, she is taken to Hua'a, chief of Puna. She tells her brother to take good care of Halemano. Kumukahi and Halemano live together for eighty days (Elbert 1979:266).

Later still, in trying to win back Kamalalawalu, Halemano chants to her of their days in Puna, mentioning Cape Kumukahi and ke ahi a Laka ("the fires of Laka") (Elbert 1979:276).

At the end of the legend Kamalalawalu is living on O'ahu as the wife of a chief. Hua'a, the chief of Puna, and the chief of Hilo sail to O'ahu with an army, defeat the O'ahu chiefs, and bring Kamalalawalu back to Hawai'i (Elbert 1979:290).

Kumukahi from Kahiki (Mary Kawena Pukui in Emory et al. 1959:61-62)

Kumukahi and his brother Palamoa came from Kahiki to Hawai'i long ago in the time the gods still walked on earth. Some say he was a relative of Pele (Beckwith 1979:119). Others say he came with his older brother, the great chief Moikeha (Fornander 1918 4:114). With their sister Kahikinaakala ("the sunrise"), they took the form of mortals and settled in Puna at the most easterly point of land in the Hawaiian Islands (Cape Kumukahi).

Kumukahi had four wives: Kanono, Pa'upo'ulu, Ha'eha'e, and Hanaka'ulua. (Some say Ha'eha'e was Kumukahi's younger brother [Fornander 1918 4:114].) The wives manipulated the seasons by pushing the sun back and forth. They were later seen as four large stones spaced evenly apart at Cape Kumukahi, and were used to calculate the solstices of the sun. Cape Kumukahi is known therefore as the "Ladder of the Sun" and the "Source of the Sun." The literal translation of "Kumukahi" is "first beginning" (Pukui et al. 1976:124).

Sun worshipers brought their sick to be healed at Cape Kumukahi. Along with the lake at Kapoho Crater, it was one of the stops on "the journey of health" frequently made by those who had recovered from illness (Westervelt 1916:28-29).

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At some point Pele destroyed Kumukahi and his family as mortal beings. However, they were powerful 'aumakua. Kumukahi could take the form of a man or a kolea bird (the migrant plover). Palamoa could take the form of a rooster.

Legend of Kumukahi, a Chief of Puna (Westervelt 1916:27-28)

There are several legends about chiefs of Puna who angered Pele. Kumukahi is also the name of one of these chiefs. He was a handsome man who loved the ancient games. He pleased Pele, but when she came to him as an old woman demanding to join the games, he ridiculed her. She chased him to the sea, covering him with lava, forming the cape called Kumukahi.

Legend of Kahawali (Thrum 1912:39-42)

In this legend, Kahawali, chief of Puna, and Ahua (Westervelt 1916:41), one of his favorite companions, are racing with their holua (sleds) down the side of a hill in Kapoho (Ka Holua o Kahawali, #50-Ha-A9-2). At the bottom of the race course, Kahawali sticks his broad spear into the ground, and then climbs the hill called Kahaleokamahina (Westervelt 1916:40) (or Halekamahina).

Back at the top of the slide, Pele, in the form of a woman, challenges Kahawali to a race and loses. She then asks him for his sled. Not realizing her identity, Kahawali abruptly refuses and sleds off down the hill. Enraged, Pele stamps her foot, causing an earthquake and an opening in the hill. She transforms into her supernatural state and chases Kahawali with streams of lava.

At the bottom of the hill, Kahawali looks back and sees Pele. He grabs his spear and with Ahua flees for his life. The spectators and entertainers at the race are overwhelmed by Pele's lava as she pursues Kahawali. In his flight, he pauses at Pu'ukea, where he throws off his ki leaf cloak. He then bids farewell to his favorite pig Alo'ipua'a (Westervelt 1916:43), to his mother at Kuki'i, to his wife Kanakawahine, to his children Poupoulu and Kaohe, and finally, after crossing a deep chasm, to his sister Koai in Kula. Kumukahi and Ahua escape in a canoe, despite the large rocks Pele throws at them from the shore.

Legend of Papalauahi (Westervelt 1916:29-30)

The chief of Puna, Papalauahi, was also challenged to a holua race by Pele, appearing this time in the form of a beautiful woman. He won and Pele stamped on the ground, letting loose floods of lava. Papalauahi and many of the neighboring chiefs attending the games were destroyed as they fled, and the spectators on the plains below were turned into pillars of lava.

Legend of Keliikuku (Westervelt 1916:31-32)

This legend tells of a chief of Puna, Keliikuku, who is very proud of his homeland. While on O'ahu he boasts to a prophet of Pele, Kaneakalau, "My country is charming. Abundance is found there. Rich, sandy plains are there, where everything grows wonderfully" (Westervelt 1916:31). The prophet ridicules him, saying tht Pele has desolated Puna. "The trees have descended from the mountains to the sea. The ohi'a* and puhala are on the shore. The houses of your people are burned. Your land is unproductive. You have no more people" (Westervelt 1916:31-32). Keliikuiu heads home. He comes around the eastern side of Hawai'i, lands his canoe, and climbs the highest point for a view of Puna. He sees his fertile plains covered with black lava still pouring out clouds of smoke. The remnants of forests are still burning. Pele has heard

Keliikuku boasting and has demonstrated that the land around her pit of fire is not secure against her will. Keliikuku hangs himself.

Legend of Kapapala (Westervelt 1916:33-34)

Kapapala was a Puna chief who went up to the crater to see Pele. They enjoyed each other's company until Kapapala dared to surf her lake of fire. Pele caused him to fall off his board into the flames.

Legend of Kealohalani and Honolulu (Mrs. Anne Hall in Emory et al. 1959:42-43)

In this legend a Puna chief named Kealohalani angers Pele by courting one of her sisters. Pele chases him and, as he dives into the ocean, his helmet falls off onto a sand hill. Pele changes man and helmet into stone. Kealohalani can be seen below the sand hill as the red stone formation of a man lying in the water.

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The sand hill became known as Honolulu, because the chief Honolulu, one of Kealohalani's retainers, composed the chant of this story. Later he settled on O'ahu.

The helmet stone, also called the Honolulu stone or the bell stone for its shape, was moved first to Kalapana and then to Olaa.

Legend of Puna'aikoa'e (Mary Kawena Pukui in Emory et al. 1959:37)

Before Pele and her family came to Hawai'i, Ka'u and Puna were beautiful lands with only earth from one end to the other and no lava beds. A very long stretch of sand, called Keonelau'enaakane, stretched from Waiakea in Hilo to Panau in Puna.

In the legend of Puna'aikoa'e, Pele and Wakakeakaiilawai, the mo'o (lizard) goddess, have a great battle over their husband Puna'aikoa'e. He was a supernatural man with a koa'e (tropic bird). He lived at Pu'ula, Puna, near a place called Koa'e (Pukui and Elbert:397). The fighting between Pele and Waka extended from Punalu'u in Ka'u to Waiakea in Hilo, covering most of Puna in

lava. Only traces of the long beach remain. Pele destroyed Waka and Puna'aikoa'e in her fires. (See also Thrum 1923:185-196.)

Legend of Pele and Hi'iaka (Emerson 1915)

In this long, complex legend there are many mentions of Puna (e.g., Emerson 1915:200, 209, 211). References to specific place names in Puna include mentions of Pu'ulena (Emerson 1915:193, 203, 213), Keahialaka (Emerson:189, 211), Kea'au (Emerson 1915:223) and Ha'eha'e (Emerson 1915:189).

TABLE 1

INVENTORY OF ARCHAEOLOGICAL AND HISTORICAL SITES IN THE STUDY AREA

B.P.B.M.=Bernice P. Bishop Museum, Dept of Anthropology
S.H.P.O.=Hawaii State Preservation Office
Site numbers are B.P.B.M. site numbers unless otherwise noted.
Page numbers are given only when references to sites are not easily located by site numbers.

Site Number/Name	Site Type	Features	References
AHUPUA'A A1: KULA, OLAA			
50-Ha-A1-11= Shipman's Cave	sections of burial-refuge lava tube	>1	Emory 1945 McEldowney 1979
50-Ha-A1-12	enclosure, kerbed trail	2	B.P.B.M. Site Card Ewart and Luscomb 1974 Apple 1965:31-39 McEldowney 1979
50-Ha-A1-13	burial lava tube	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-17	historic habitation-agricultural complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-18	possibly historic habitation-agricultural complex	>9	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-21	complex	3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-22	enclosure, probably historic cattle pen	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-24	mound	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-25	historic L-shape structure	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979

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Site Number/Name	Site Type	Features	References
50-Ha-A1-26	enclosure, probably historic cattle pen	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-27	complex, probably historic cattle enclosures	>6	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-28	wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-29	small complex	3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-30	complex	>7	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-31	facing	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-34	possibly historic cattle enclosure	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-35	complex	6	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-40	facings, wall	>2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-41	mounds, platform	>2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-42	enclosure	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-43	small complex	>2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-44	short wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A1-64 Ha'ena Pond	pond	1	McEldowney 1979 Kikuchi 1973:31, 25

Site Number/Name	Site Type	Features	References
50-Ha-A1-65 Ha'ena Complex	partly historic complex	?	McEldowney 1979
State 10-44-7389 Kea'au District	historic commercial, domestic, religious, and plantation-related structure	>1	S.H.P.O. Site Folder McEldowney 1979
AHUPUA'A A2: WAIKAHEKAHE NUI, WAIKAHEKAHE IKI			
50-Ha-A2-1	complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A2-2	probably habitation-agricultural complex	>9	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A2-3	complex, including possible heiau	>8	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
AHUPUA'A A3: MAKUU, POPOKI, HALONA			
50-Ha-A3-1	possibly agricultural complex	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-2	wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-3	possibly agricultural complex	>4	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-4	complex, at least partly historic cattle pen	>1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-5	probably agricultural walls and mounds, historic walls	>4	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-6	historic petroglyphs	2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-7	mostly historically modified complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979

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Site Number/Name	Site Type	Features	References
50-Ha-A3-10	probably habitation-agricultural complex	>9	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-14	historic wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-15	depressions in lava, possibly for food preparation	2	McEldowney 1979 Hudson 1932, #60
50-Ha-A3-16	trail	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-17	at least partly historic burial platforms	2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-18	partly historic habitation-agricultural complex	>9	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-19	possible habitation-agricultural complex	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-20	ahupua'a boundary wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-24	probably prehistoric petroglyph field	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979 Hudson 1932:308 S.H.P.O. Folder #4222
50-Ha-A3-25	at least partly historic petroglyph field	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979 Hudson 1932:308
50-Ha-A3-26	probably burial mound	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-27	stone-lined depression, possibly animal enclosure	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A3-28	platform	1	McEldowney 1979 Hudson 1932, #62

Site Number/Name	Site Type	Features	References
Hudson #81	platforms, walls, enclosures	>5	Hudson 1932
State 10-45-4222 Naku'u Petroglyphs	historic petroglyphs	1	S.H.P.O. Folder Ewart and Luscomb 1974:29 McEldowney 1979
State 10-45-7476	historic domestic structure	1	S.H.O.P. Folder McEldowney 1979
State 10-46-6417a	ahu	1	Bordner 1977
Pahoa Cave	burial-refuge lava tube	1	Yent 1983
AHUPUA'A A4: KEONEPOKO NUI, KEONEPOKO IKI			
50-Ha-A4-1	mound	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-2	at least partly historic small complex	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-3	complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-4	platform	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-5	historic small complex	2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-6	retaining wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-7	possibly agricultural complex	6	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-10	complex, platforms and probably agricultural walls	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-11	possibly agricultural complex	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979

Site Number/Name	Site Type	Features	References
50-Ha-A4-12	probably windbreak wall, mound	2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-13	trail	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979 Hudson 1932, #83
50-Ha-A4-14	C-shape structure	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-15	probably ahupua'a boundary ahu	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-16	probably historic wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-19	historic small complex	12	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-21	faced depression	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-22	disturbed burial mound	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-23	possibly burial mound	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-24	possibly agricultural complex	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-25	wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-26	platform	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-27	stone outline	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979

Site Number/Name	Site Type	Features	References
50-Ha-A4-28	faced depression	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-29	wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-30	small complex	3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-31	complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-32	probably agricultural complex	>2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-33	wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-34	possibly burial mound	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-35	faced depression	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-36	faced rise	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-37	complex	>2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-38	probably agricultural complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-39	probably agricultural complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-40	possibly agricultural complex	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979

Site Number/Name	Site Type	Features	References
50-Ha-A4-41	small complex	3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-42	complex of walls	>1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-43	possibly habitation complex	>6	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-44	complex	>1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-45	complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-46	probably burial mound	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-47	small complex	2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-48	possibly agricultural complex	>6	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-49	complex	4	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-50	possibly shelter wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-51	complex	6	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-52	complex	3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-53	faced pit, ravine	2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979

Site Number/Name	Site Type	Features	References
50-Ha-A4-54	enclosure	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-55	faced slope	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-56	wall, possibly burial mounds	3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-57	cemetery	5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-58	faced depression	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-59	possibly agricultural complex	4	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-60	complex	>5	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-61	retaining wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-62	possibly agricultural small complex	>1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-63	complex	>1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-64	possibly burial mounds	2	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A4-66	small complex	3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney
50-Ha-A4-67	complex	>1	McEldowney 1979 Hudson 1932, #84

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Site Number/Name	Site Type	Features	References
AHUPUA'A A5: WAIAKAHIULA, HONOLULU			
50-Ha-A5-1	canoe shed	1	Photos H-680/14 & 15 (B.P.B.M. Anthro. Dept.) B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-2	possibly destroyed trail	1	Photo H-680/17 (B.P.B.M. Anthro. Dept.) B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-3	possibly destroyed bait cup	1	Photo H-680/16. (B.P.B.M. Anthro. Dept.) B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-4	possibly agricultural complex	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-5	possibly burial or houre site platform	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-6	wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-7	wall	1	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-8	possibly habitation-agricultural complex	>3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-9	small complex	3	B.P.B.M. Site Card Ewart and Luscomb 1974 McEldowney 1979
50-Ha-A5-10**	wall	1	McEldowney 1979 Hudson 1932, #85 Loo and Bonk 1970, #71

Site Number/Name	Site Type	Features	References
State 10-45-4221 Honolulu Landing	probable habitation complex, probable well	>7	S.H.P.O. Folder Hudson 1932, #65 Hansen 1967
State 10-55-7388 Pahoa District	historic commercial, domestic, religious, community, and school structures	>29	S.H.P.O. Folder
AHUPUA'A A6: KANAWALE, WAAWAA, KAHUWAI			
50-Ha-A6-1	habitation complex	>7	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #93 Barrere 1962 Orr 1963a Orr 1963b McEldowney 1979
50-Ha-A6-2	paved trail	1	B.P.B.M. Site Card Hudson 1932, #86 McEldowney 1979
50-Ha-A6-3 Kanawale Village	habitation walls, partly destroyed	>1	B.P.B.M. Site Card Hudson 1932, #86 Wilkes 1845:189 McEldowney 1979
50-Ha-A6-4	canoe shed	1	B.P.B.M. Site Card Hudson 1932, #87 McEldowney 1979
50-Ha-A6-5	platform	1	B.P.B.M. Site Card Hudson 1932, #89 McEldowney 1979
50-Ha-A6-6	possibly burial platforms, burials	7	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #90 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979
50-Ha-A6-7	sloped pavement, possibly a meeting place	1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #91 Orr 1963a Orr 1963b McEldowney 1979

Site Number/Name	Site Type	Features	References
50-Ha-A6-8	canoe sheds	2	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #92 Orr 1963a Orr 1963b Ahue 1963 Barrere 1962:164-165 McEldowney 1979
50-Ha-A6-9	enclosure, possible heiau	1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #94 Orr 1963a Orr 1963b Ahue 1963 McEldowney 1979
50-Ha-A6-10	possibly habitation-agricultural complex, destroyed	>3	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #95 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979
50-Ha-A6-11	habitation-agricultural complexes	>5	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #96 Orr 1963a Orr 1963b McEldowney 1979
50-Ha-A6-12	platforms	3	B.P.B.M. Site Card Barrera 1974 Hudson 1932, #97 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979
50-Ha-A6-13	platforms	6	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #98 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979

Site Number/Name	Site Type	Features	References
50-Ha-A6-14	probably burial platform	1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Orr 1963a Orr 1963b McEldowney 1979
50-Ha-A6-15	possibly burial platform	1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Orr 1963a Orr 1963b McEldowney 1979
50-Ha-A6-16	burial	1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979
50-Ha-A6-17	possibly burial platform	1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979
50-Ha-A6-18	possibly house platform	1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979
50-Ha-A6-19	grave	1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979
50-Ha-A6-20	trail	1	B.P.B.M. Site Card Bishop Estate Map 2432 Barrera 1974 S.H.P.O. Folder #4278 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979

Site Number/Name	Site Type	Features	References
50-Ha-A6-21	cyst burials	2	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Hudson 1932, #95 Orr 1963a Orr 1963b Soehren 1963 McEldowney 1979
50-Ha-A6-22	burials	>1	B.P.B.M. Site Card Barrera 1974 S.H.P.O. Folder #4278 Soehren 1963 McEldowney 1979
50-Ha-A6-23	possibly house platform	1	B.P.B.M. Site Card Barrera 1974 Orr 1963a McEldowney 1979
50-Ha-A6-24	grave	1	B.P.B.M. Site Card Barrera 1974 Orr 1963a McEldowney 1979
50-Ha-A6-25	grave	1	B.P.B.M. Site Card Barrera 1974 Orr 1963a McEldowney 1979
50-Ha-A6-26	house platform	1	B.P.B.M. Site Card Barrera 1974 Orr 1963a McEldowney 1979
50-Ha-A6-27	walled house site with paving	1	B.P.B.M. Site Card Barrera 1974 Orr 1963a McEldowney 1979
50-Ha-A6-28	walled house site	1	B.P.B.M. Site Card Barrera 1974 Orr 1963a McEldowney 1979
50-Ha-A6-29	alignment	1	B.P.B.M. Site Card Hudson 1932, #88 McEldowney 1979

Site Number/Name	Site Type	Features	References
State 10-46-4270 Kahuwai Village Complex***	partly historic habitation-agricultural complex	>56	S.H.P.O. Folder B.P.B.M. Site Cards A6-1, -6 through -11, -13 through -22 Hudson 1932, #90-98 Loo and Bonk 1970, #70
AHUPUA'A A7: HALEPUAA, KANEKIKI, PUUA			
50-Ha-A7-1	probably shelter platform, possibly destroyed	1	McEldowney 1979 Hudson 1932, #99
50-Ha-A7-2	petroglyphs, destroyed	3	McEldowney 1979 Hudson 1932, #100
State 10-45-	historic church	1	S.H.P.O. Site Folder
none	traditional agricultural complex, plus probably historic enclosures and walls	>9	Yent and Ota, 1982
none	historic slaughterhouse	1	Federal Highway Administration 1979
none	modified lava tube	1	Federal Highway Administration 1979
AHUPUA'A A8: KULA, HALEKAMAHINA (see note below)			
50-Ha-A8-1 State 10-46-2500 Kukii Heiau	<u>heiau</u>	1	B.P.B.M. Site Card S.H.P.O. Folder Hudson 1932, #106 Thrum 1907a:40 Thrum 1907b:55 Stokes n.d.:588 Bevacqua and Dye 1972 Loo and Bonk 1970, #69 Rogers-Jourdane 1984:I-4
50-Ha-A8-2 State 10-46-4250 Kings' Pillars/ Kii Pohako Alii	cairns, 1 destroyed	3	B.P.B.M. Site Card S.H.P.O. Folder Hudson 1932, #103 Cox 1983a, #1 Rogers-Jourdane 1984:I-4
50-Ha-A8-4	platform, destroyed	1	McEldowney 1979 Hudson 1932, #101
50-Ha-A8-5	platform, destroyed	1	McEldowney 1979 Hudson 1932, #102

Site Number/Name	Site Type	Features	References
Loo & Bonk #68 Kumukahi Gravesites?	historic platforms	2	Loo and Bonk 1970 S.H.P.O. Folder #4251 Cox 1983a, #6
State 10-46-4251 Kumukahi Gravesites	possibly burial platforms	2	S.H.P.O. Folder Loo and Bonk 1970, #68 Cox 1983b, State #10002 Cox 1983a, #6 or #7+#8 Rogers-Jourdane 1984:I-4
State 10-46-10002	clusters of platform-like features	2	Cox 1983b Cox 1983a, #7 and #8 S.H.P.O. Folder #4251
Cox #6	platform, possible <u>ko'a</u> platform	2	Cox 1983a Loo and Bonk 1970, #68 S.H.P.O. Folder #4251
Cox #2	historic petroglyphs	2	Cox 1983a
Cox #3	old trail	1	Cox 1983a
Cox #4	lava blister shelter caves	2	Cox 1983a
Cox #5	pond, probably modified	1	Cox 1983a
Cox Cluster A	terraced platforms	2	Cox 1983b
Cox Cluster B	complex	6	Cox 1983b
Cox Cluster C	hollow with vertical slab	2?	Cox 1983b
Cox Cluster D	platforms	4	Cox 1983b
Cox Cluster E	platforms	3	Cox 1983b
Cox Cluster F	platforms, paved area	9	Cox 1983b
Cox Cluster G	platforms, 2 with burial	5	Cox 1983b
Cox Cluster H	platform	1	Cox 1983b
Cox Cluster I	platform, pavements	>2	Cox 1983b
Ladd Area A	historic platform	1	Ladd 1981
Ladd Area B	historic petroglyphs	2	Ladd 1981
Ladd Area C	<u>ahu</u>	2	Ladd 1981

Site Number/Name	Site Type	Features	References
Ladd Area D	probably shelter lava bubble	1	Ladd 1981
Hudson #102	platform, cairns, platform graves	>4	Hudson 1932
Hudson #104	shelter, adjoining platform	2	Hudson 1932
Hudson #105	canoe house	1	Hudson 1932
Hudson #107	cyst-type grave	1	Hudson 1932
Hudson #112	trail, small enclosures, agricultural workings	>4	Hudson 1932
Hudson #113	enclosure	1	Hudson 1932
Hudson #114	enclosure	1	Hudson 1932
Hudson #115	paved area, possibly house site	1	Hudson 1932
Hudson #116	canoe house, trails, walks, shallow pits, small pens	>6	Hudson 1932
Hudson #117	probably house site platform, trail, terraces	>3	Hudson 1932
Hudson #118	paved area, probably house site	1	Hudson 1932
Hudson #119	paved area, faced hole	2	Hudson 1932
Hudson #120	platform	1	Hudson 1932
Hudson #121	enclosures	2	Hudson 1932
Hudson #122	canoe house	1	Hudson 1932
Hudson #123	terraced platform	1	Hudson 1932
Hudson #124	probably historic windbreak wall	1	Hudson 1932
Hudson #125	enclosure on terrace	2	Hudson 1932
Hudson #126	platform	1	Hudson 1932
Hudson #127	wall windbreak	1	Hudson 1932

Site Number/Name	Site Type	Features	References
Hudson #128	enclosure	1	Hudson 1932
Hudson #129	paved area	1	Hudson 1932
Hudson #130	probably canoe house	1	Hudson 1932
Hudson #131	terraced platform	1	Hudson 1932
Hudson #132	house platform	1	Hudson 1932
Hudson #133	trail	1	Hudson 1932
Hudson #134	probably historic circular shelter	1	Hudson 1932
Hudson #135	wall windbreaks	2	Hudson 1932
Hudson #136	possible platform, probably for house	1	Hudson 1932
AHUPUA'A A9: KAPOHO			
50-Ha-A9-1 State 10-46-2501 Kapoho Petroglyphs	clusters of petroglyphs	>1	B.P.B.M. Site Card S.H.P.O. Folder Bevaqua and Dye 1972 Rogers-Jourdane 1984:I-4
50-Ha-A9-2 State 10-46-5245 Ka Holua o Kahawali	holua slide	1	B.P.B.M. Site Card S.H.P.O. Folder Hudson 1932:332 Rogers-Jourdane 1984:I-4
State 10-46-4254 Kapoho Point Platform	platform	1	S.H.P.O. Folder Rogers-Jourdane 1984:I-4 Hudson 1932, #137
State 10-46-7492 Lyman Marker	historic rock marker	1	S.H.P.O. Folder
Hudson #108	male and female sacred stones	2	Hudson 1932
AHUPUA'A A10: PU'ALA'A, AHALANUI, LAEPAOO, ONELOA			
50-Ha-A10-6 State 10-46-4295 Pualaa Complex 2	destroyed holua slide, agricultural patches, some remaining	>4	B.P.B.M. Site Card S.H.P.O. Folder Hudson 1932:82 Hudson 1932, #109,110,111 Crozier and Barrere 1971 Loebenstein 1895

TABLE 1 (contd.)

Site Number/Name	Site Type	Features	References
AHUPUA'A A11: POHOIKI, KEAHIALAKA			
50-Ha-A11-2**** Oolo Heiau	destroyed heiau	1	B.P.B.M. Site Card Thrum 1907a:39 Nakamura 1984:II-2
none	possibly burial-refuge lava tube	1	Bonk 1980b
THROUGH MANY AHUPUA'A:			
Hawaii Consolidated Railway	destroyed railroad	>1	Kelly et al. 1981: 142-177 Hawaii Survey 1952 USGS Pahoa North Quad USGS Kapoho Quad McEldowney 1979
Hilo to Puna Trail	partially destroyed trail	>1	Hudson 1932:246-249 Loebenstein 1895 USGS Kea'au Quad USGS Pahoa North Quad USGS Kapoho Quad McEldowney 1979

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* B.P.B.M. Site Card A1-11 describes a diffferent lava tube site which is out of the study area, but also refers to Emory's manuscript on Shipman's Cave. McEldowney lists Shipman's Cave as site A1-11 in her inventory.

** This well may be the one mentioned at State 10-45-4221.

*** This site includes many previously listed sites.

**** This site was probably not in our study area. Its former location is known only as being in Pohoiki.

(note) Some sites may be listed more than once. There is much uncertainty as to whether different archaeologists are describing the same sites in the areas of Cape Kumukahi and the Kumukahi Gravesites. Some Hudson sites (#102, 104, 105, 112-136) may be destroyed by lava.

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CORRECTION

THE PRECEDING DOCUMENT(S) HAS BEEN REPHOTOGRAPHED TO ASSURE LEGIBILITY
SEE FRAME(S)
IMMEDIATELY FOLLOWING

Site Number/Name	Site Type	Features	References
Ladd Area D	probably shelter lava bubble	1	Ladd 1981
Hudson #102	platform, cairns, platform graves	>4	Hudson 1932
Hudson #104	shelter, adjoining platform	2	Hudson 1932
Hudson #105	canoe house	1	Hudson 1932
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AHUPUA'A A9: KAPOHO			
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50-Ha-A9-2 State 10-46-5245 Ka Holua o Kahawali	<u>holua slide</u>	1	B.P.B.M. Site Card S.H.P.O. Folder Hudson 1932:332 Rogers-Jourdane 1984:I-4
State 10-46-4254 Kapoho Point Platform	platform	1	S.H.P.O. Folder Rogers-Jourdane 1984:I-4 Hudson 1932, #137
State 10-46-7492 Lyman Marker	historic rock marker	1	S.H.P.O. Folder
Hudson #108	male and female sacred stones	2	Hudson 1932
AHUPUA'A A10: PU'ALA'A, AHALANUI, LAEPAOO, ONELOA			
50-Ha-A10-6 State 10-46-4295 Pualaa Complex 2	destroyed <u>holua</u> slide, agricultural patches, some remaining	>4	B.P.B.M. Site Card S.H.P.O. Folder Hudson 1932:82 Hudson 1932, #109,110,111 Crozier and Barrere 1971 Loebenstein 1895

TABLE 1 (contd.)

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Hilo to Puna Trail	partially destroyed trail	>1	Hudson 1932:246-249 Loebenstein 1895 USGS Kea'au Quad USGS Pahoa North Quad USGS Kapoho Quad McEldowney 1979

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APPENDIX C

CULTURAL AND BIOLOGICAL RESOURCES SURVEY OF THE
POHOIKI-TO-PUNA SUBSTATION 69 KV TRANSMISSION CORRIDOR
KEA'AU TO KAPOHO, PUNA, HAWAI'I ISLAND

Final Report:

Botanical Survey

22 April 1987

Wayne N. Takeuchi
Clyde T. Imada
Department of Botany
Bernice Pauahi Bishop Museum

Prepared for:

DHM, Inc.
1188 Bishop Street
Suite 2405
Honolulu, Hawai'i 96813

Department of Botany
Bernice Pauahi Bishop Museum
Honolulu, Hawai'i

INTRODUCTION

To simplify botanical description of the project terrain, the following narrative is keyed to the individual parcels into which our field survey was divided. Sectors have been delimited from the total territory on the basis of logical considerations relating to spatial continuity and approximate homogeneity of forest/community condition. Geographic north is indicated for each of the various diagrams. Except for zone 6 (where the map reference is self-evident), the interrelation of the various subunits is depicted in figure 1.

Representative species lists are provided for most of the survey sections. The following symbols are employed in the enumeration:

E = endemic; a plant whose natural range is restricted to the Hawaiian Islands.

I = indigenous; a plant native to the Hawaiian Islands, but also with natural occurrences elsewhere.

A = alien; introduced by man, accidentally or by design.

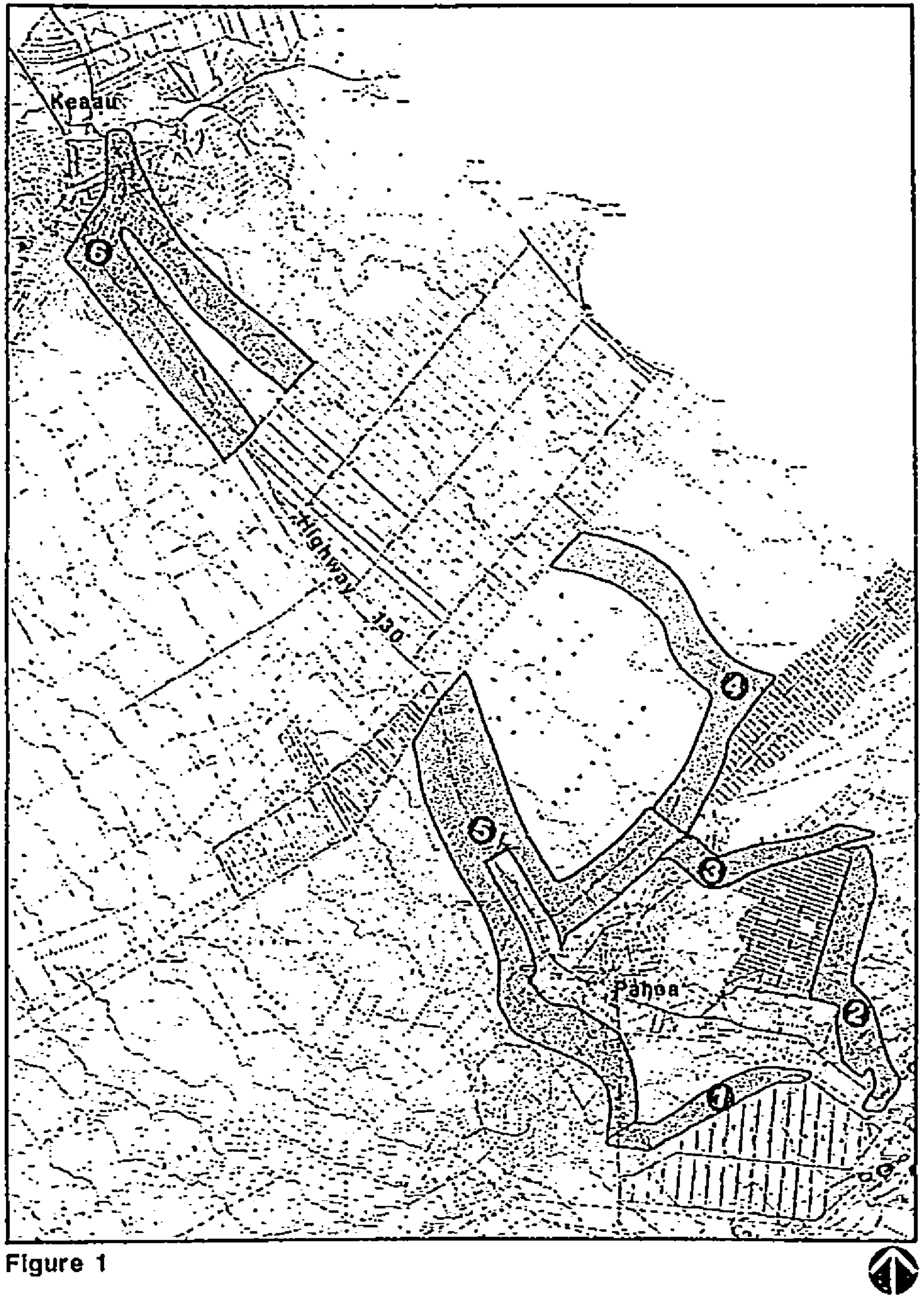


Figure 1

DESCRIPTION OF ZONES

ZONE 1: Kahukai Street Corridor at Keahialaka

The proposed track along Kahukai Street extends through an early stage forest consisting primarily of Metrosideros polymorpha and Dicranopteris linearis. A fissured substrate of undecomposed a'a underlies most of the area. Due to the hazards presented by unsettled clinker, reconnaissance was necessarily limited to a few discretionary off-road penetrations. But in any event, the structure of this forest type proved capable of characterization without intensive coverage.

The Kahukai corridor has a monotypic Metrosideros canopy topping at a height of 7-8 m. Trees are widely spaced, so direct insolation passes unimpeded into understory strata. Such light-intense environments are very favorable to Dicranopteris linearis (i.e. uluhe fern), and the thicket-forming heliophyte now envelops most of the sector in a 2 m high tangle. The uluhe congests the ground interval so effectively that few plants can penetrate the stratum. Diversity is thus severely suppressed. Among native species, Sadleria cyatheoides and Pipturus albidus are the most consistent emergents from the Dicranopteris matrix. Where disruption of the native groundcover has occurred through natural or manmade agency, weedy volunteer crops of varied composition are frequently released. Many aliens were registered from roadsides and houselot margins, but only Melastoma candidum appears to pose an environmental threat.

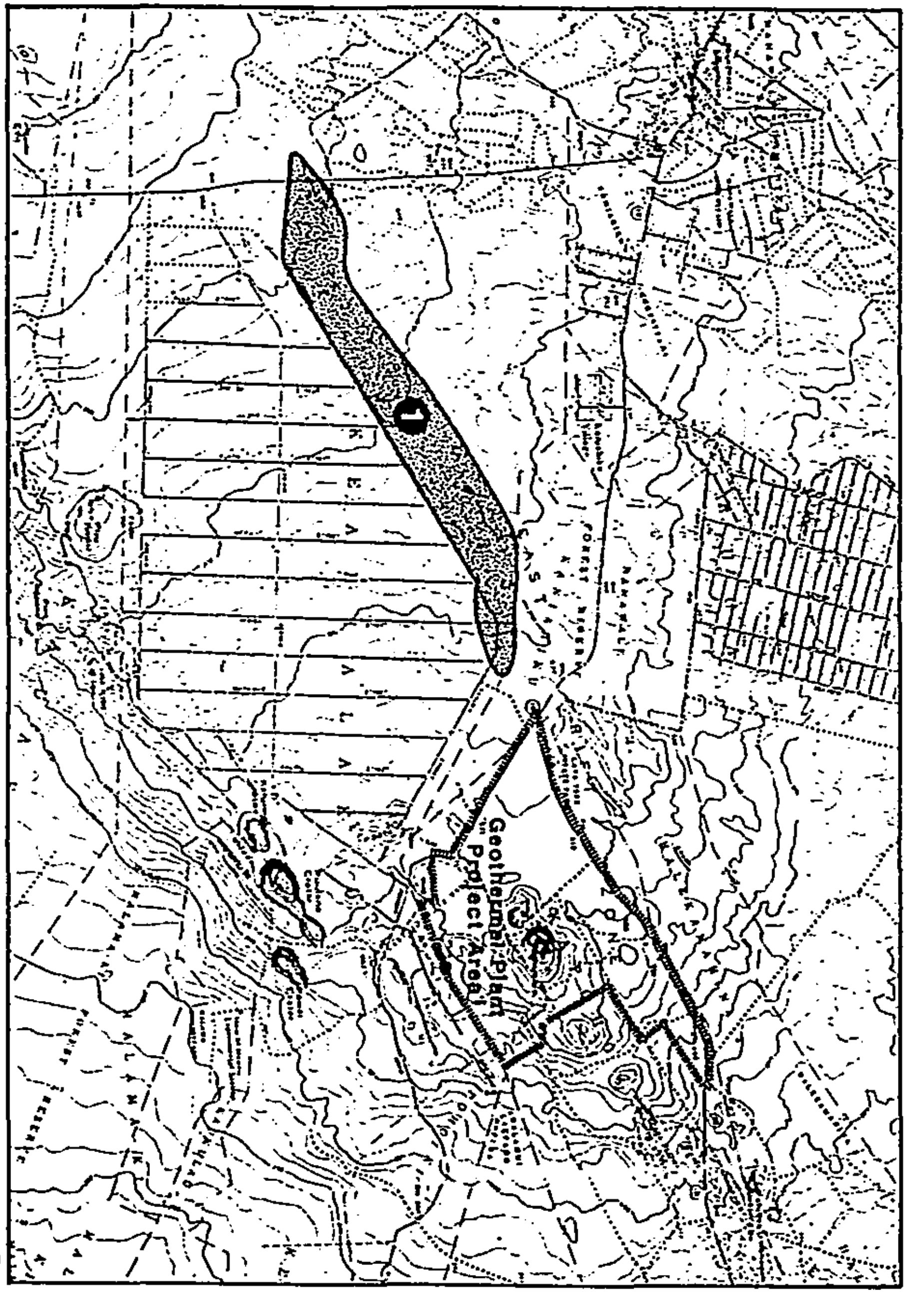
Towards the NE end of the tract, the Metrosideros-Dicranopteris formation passes rather sharply into a forest of greater maturity. The abruptness of transition indicates that the floristic demarcation is probably a historical flow boundary. With passage across this structural line, certain features of successional process are displayed. In the forest of contrasting condition, the Metrosideros canopy assumes higher stature, and lateral elaboration of individual crowns has produced an interlocking overstory. The resulting reduction of subcanopy light is associated with the replacement of uluhe fern by a shade-adapted assemblage dominated by Cibotium chamissoi and Ophioglossum pendulum.

Within the mature acreage there is also a noticeable increase in species count, with Diospyros sandwicensis, Myrsine lessertiana, and Psychotria hawaiiensis var. hawaiiensis achieving significant frequencies in a normally depauperate canopy. The appearance of additional taxa results in a more equitable occupation of the different height increments, so that a solid front of plant growth confronts the observer. There is no disjunction between vegetation layers as is obvious in the Metrosideros-Dicranopteris association.

In addition to the species mentioned in the text, the following plants were recorded from zone 1:

Albizzia sp. (A), Melochia umbellata (A), Psidium cattleianum (A), Psidium guajava (A), Aleurites moluccana (A), Persea americana (A), Bambusa sp. (A), Musa acuminata (A), Cecropia obtusifolia (A), Pluchea symphytifolia (A), Buddleia asiatica (A), Ardisia crispa (A), Alyxia oliviformis (E), Freycinetia arborea (I), Cordyline terminalis (A), Rubus rosifolius (A), Impatiens sultani (A), Commelina diffusa (A), Psilotum nudum (I), Pleopeltis thunbergiana (E), Begonia hirtella (A), Stachytarpheta dichotoma (A), Cyperus sp. (A), Cyperus halpan (A), Castilleja arvensis (A), Youngia japonica (A), Ageratum conyzoides (A), Ageratum houstonianum (A), Mitracarpus hirtus (A), Spermococe assurgens (A), Polygala paniculata (A), Lindernia crustacea (A), Sacciolepis indica (A), Digitaria violascens (A), Paspalum dilatatum (A), Paspalum scrobiculatum (A), Cannabis sativa subsp. indica (A), Coprosma menziesii (E), Machaerina angustifolia (I), Machaerina mariscoides (I), Coix lachryma-jobi (A), Arundina bambusifolia (A), Spathoglottis plicata (A), Nephrolepis sp., Cocculus trilobus (I), Chamaesyce hirta (A), Andropogon virginicum (A), Pityrogramma calomelanos (A), Lycopodium cernuum (I), Chamaesyce prostrata (A), Sphenomeris chinensis (I), Paederia scandens (A), Phymatosorus scolopendria (A), Melaleuca quinquenervia (A), Elaphoglossum crassifolium (E), Christella parasitica (A), Adenophorus sp. (E), and Peperomia sp. (E).

Zone 1



Zone 1. Metrosideros forest with dense understory of Dicranopteris linearis. A common community type throughout the Hawaiian Islands.

ZONE 2: Corridor Between Puua and the Geothermal Plant

This sector is recognized primarily for purposes of report convenience rather than vegetation homogeneity. A number of distinct community entities are actually included within zone 2, but the various elements tend to be of such small area that their individual description would be cumbersome. Comment is thus limited to statements of general pattern, with attention directed to specific parcels only when warranted by some salient site feature.

Zone 2 spans the full range of developmental states from near-barren lava to mature forest.

An example of vegetation in the first stages of successional recovery from volcanism is found immediately around the geothermal facility. There the plant life is exceedingly sparse, with much of the landscape consisting of nothing more than lichen-encrusted rocks. A scattering of Metosideros saplings provides the only significant cover. Nephrolepis multiflorum (A), Arundina bambusifolia (A), Andropogon virginicum (A), Styphelia tameiameiae (I), Pluchea symphytifolia (A), Waltheria indica (I), Phymatosorus scolopendria (A), Buddleia asiatica (A), Albizzia sp. (A), Mitracarpus hirtus (A), Hyparrhenia rufa (A), and Spathoglottis plicata (A), compose the remainder of an extremely abbreviated flora.

Moving north towards highway 132, the terrain becomes an open weedland with herbaceous pests such as Melinis minutiflora (A), Mimosa pudica (A), Arundina bambusifolia (A), Phymatosorus scolopendria (A), Buchnera sp. (A), Sporobolus indicus (A), Dissotis rotundifolia (A), Desmodium triflorum (A), Brachiaria mutica (A), Hyptis pectinata (A), and Paederia scandens (A). Canopy is absent, but small shrubs of Melochia, Pipturus, and Cecropia spike intermittently through the ground tangle.

Near Lava Tree State Park, a developing forest of juvenile Metrosideros forms the dominant cover. The understory is occupied by discontinuous patches of Dicranopteris linearis (E), Melastoma candidum (A), Machaerina angustifolia (I), Desmodium cajanifolium (A), and a host of the same weeds to be found in virtually all of the zones surveyed. The early stage forest covers essentially the entire remaining territory parallel to Seaview Road. Hibiscus tiliaceus (I), Pandanus tectorius (I), and Cecropia obtusifolia (A) can achieve dominance through localized areas, but the Metrosideros-Dicranopteris combination is clearly the major association.

In a preliminary report, specific mention was made of the narrow strip of forest running down the center of the Seaview Road parcel. The strip is very distinct on a wide range of community descriptors and is undoubtedly the best example of native forest encountered within the project area. This assessment represents only a relative judgment however. Compared to survey sections elsewhere, the parcel is richer by comparison, but is still mundane on any absolute measure of vegetation quality. Occurrences of Tetraplasandra hawaiensis, an indeterminable Cyrtandra, and an elevated species count, are collectively deserving of note--though not so significant as to merit special dispensation for the site. Species recorded from this strip include: Psychotria hawaiiensis var. hawaiiensis (E), Tetraplasandra hawaiensis (E), Myrsine lessertiana (E), Dicranopteris linearis (I), Pipturus albidus (E), Antidesma platyphyllum (E), Diospyros sandwicensis (E), Freycinetia arborea (I), Metrosideros polymorpha (E), Asplenium nidus (I), Vittaria elongata (E), Cibotium chamissoi (E), Thelypteris hudsonianum (E), Vandenboschia sp. (E), Ophioglossum pendulum subsp. falcatum (E), Adenophorus tamariscinus (E), Alyxia oliviformis (E), Cyrtandra sp. (E), Melastoma candidum (A), Oplismenus hirtellus (A), Cecropia obtusifolius (A), Spathoglottis plicata (A), Psidium cattleianum (A), Blechnum occidentale (A), Mimosa pudica (A), Rubus rosifolius (A), Ageratum houstonianum (A), Psilotum nudum (I), Trema orientalis (A), Persea americana (A), Musa xparadisiaca (A), Pluchea symphytifolia (A), Paederia scandens (A), Impatiens wallerana (A), Nephrolepis sp., Cordyline terminalis (A), Arundina bambusifolia (A), Christella sp., Plectranthus scutellarioides (A), Desmodium sp. (A), Setaria palmifolia (A), Dissotis rotundifolia (A), Cocculus trilobus (I), Phymatosorus scolopendria (A), Lycopodium phyllanthum (E), Wikstroemia sandwicensis (E), Pandanus tectorius (I), Hibiscus tiliaceus (I), and Peperomia sp. (E)

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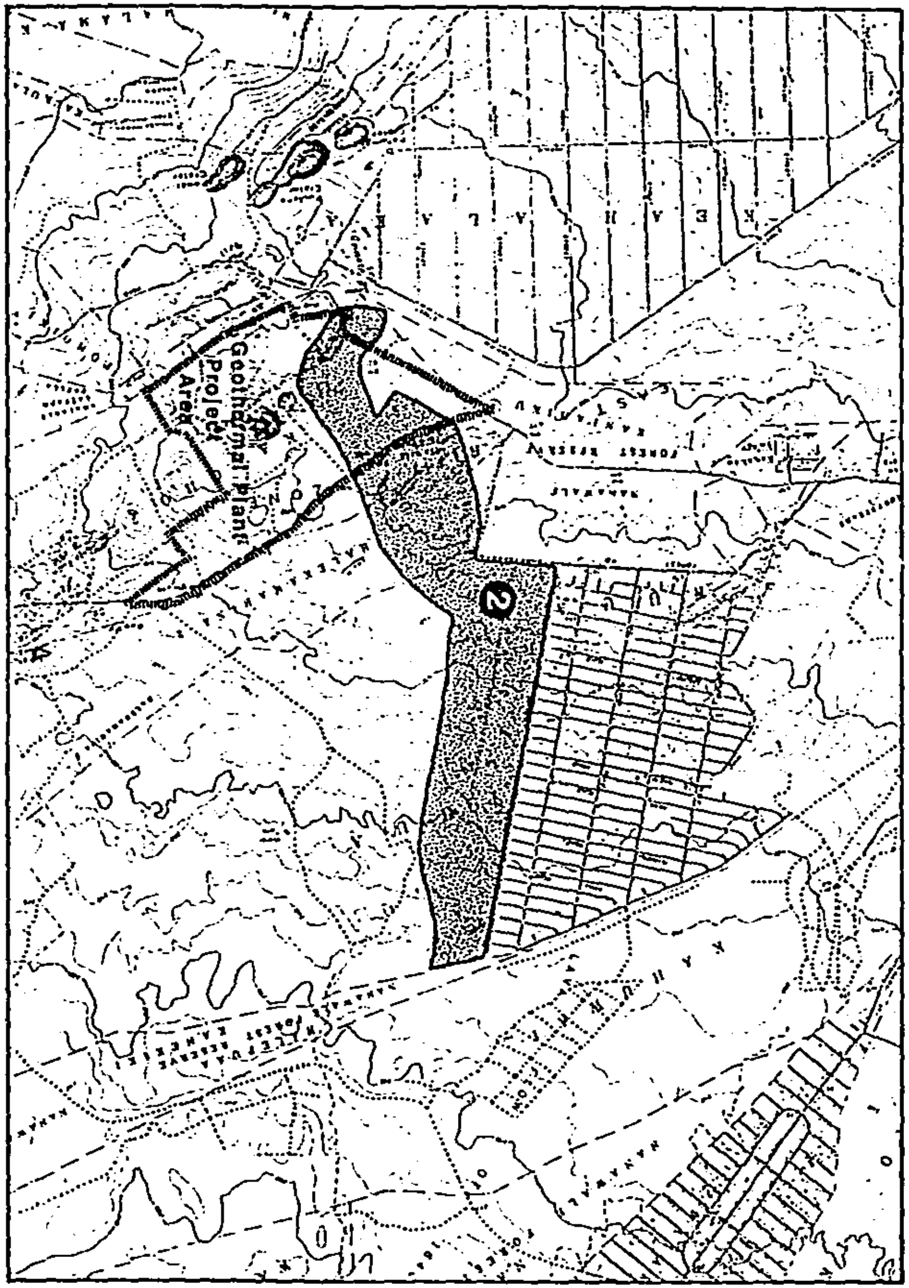
Zone 2



Zone 2. Top: 1955 lava flow near the geothermal facility. Bottom: Herbaceous weedland adjacent to route 132.

ZONE 3: Kahuwai Corridor

The Kahuwai corridor is the narrow trace along the northern boundary of the Puua subdivision. The early successional association of *Metrosideros* - *Dicranopteris* is again the dominant vegetation cover. Although the species mix is primarily of native character, diversity is very low and consists essentially of common plants found in many other regions of Hawaii.

Overall, the community in zone 3 is poorly developed. Most of the *Metrosideros* are mere scrub-sized individuals scattered over relatively fresh clinker. The living biomass is composed almost entirely by just *Metrosideros* and *Dicranopteris*.

Moving toward the western end of the strip, the land supports an increasingly weedier and taller forest with *Eucalyptus* and *Cecropia* as stature dominants. As with other survey sections exhibiting similar cover, there is nothing of real botanical value in this area. The species compilation for the zone was much smaller than comparable sites in units 1 and 2, and with no new additions of consequence.

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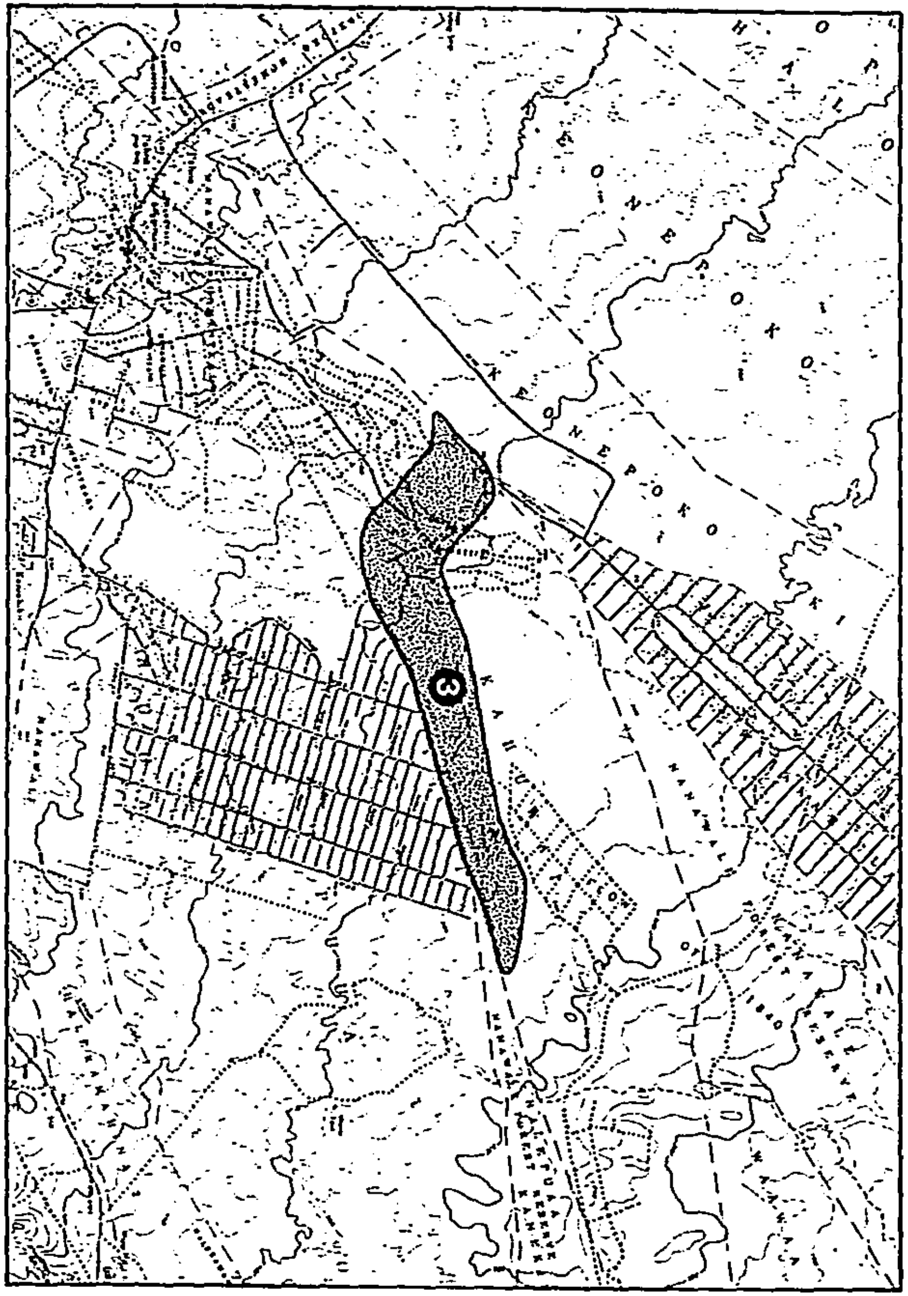
Zone 3



Zone 3. Showing the principal vegetation of Metrosideros and Dicranopteris.

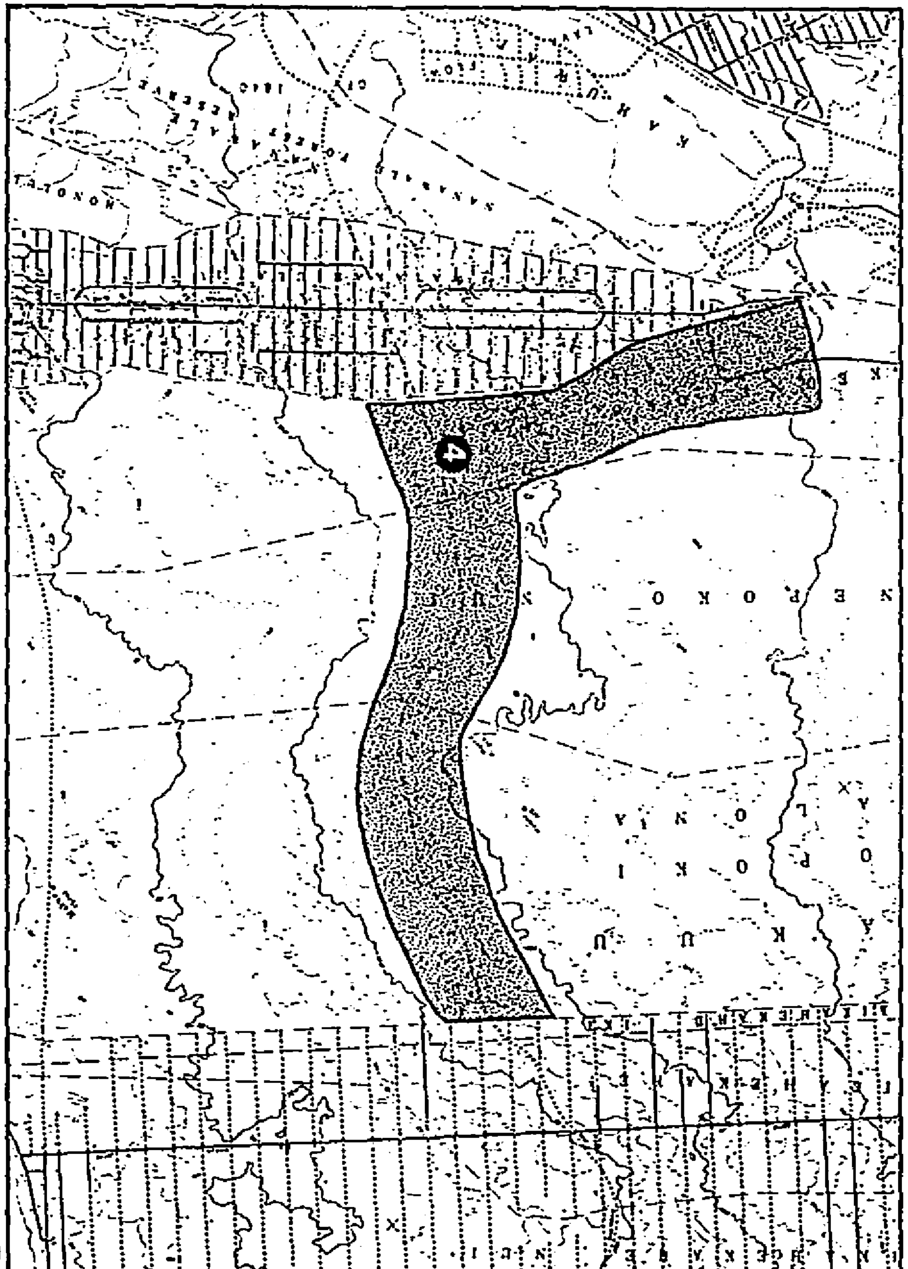
ZONE 4: Railroad Avenue near Keonepoko

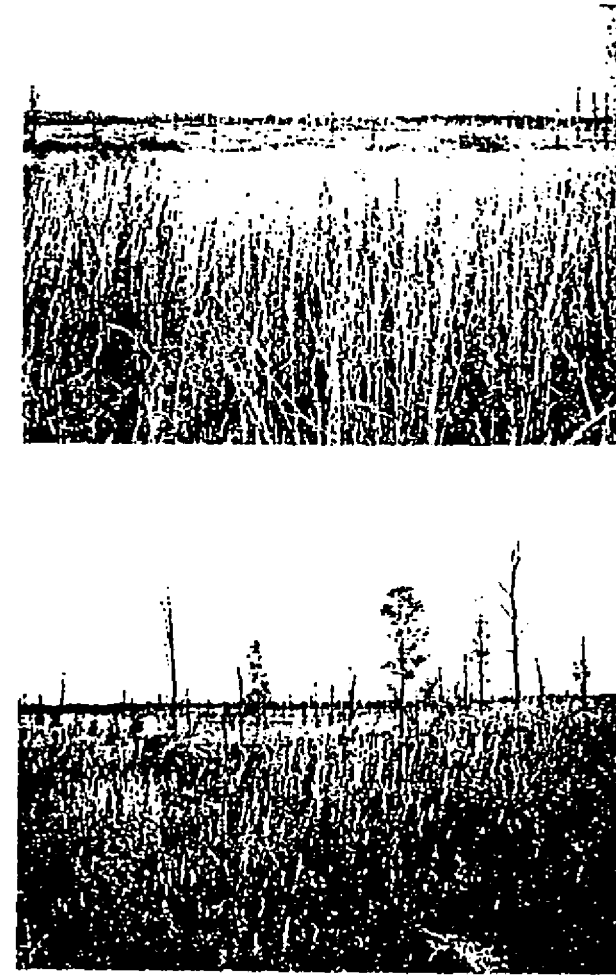
The Keonepoko parcel is the survey unit formed by portions of Railroad Avenue and the lane extending from Kahukai Boulevard. This sector is extremely homogeneous floristically, as it consists of a virtually unbroken expanse of Andropogon virginicum grassland. Judging from the large number of standing snags, an open canopy of Metrosideros must have once extended the full length of the zone. A wide range of snag condition was noted, with dead trees ranging from states of advanced decomposition to freshly dead boles without bark exfoliation or twig drop. The canopy dieback process in this tract was apparently very prolonged and only recently completed. Live Metrosideros was recorded mainly at the northwestern end of the Railroad Avenue segment and then only with individuals of low vigor.

The entire area, or at least sections of it, are likely under burn influence. Grazing is probably not responsible for grassland maintenance since the property is unfenced and cattle was not seen. At least one dieback section had signs of fire scarring on standing wood and ash residue on the ground.

Besides Metrosideros polymorpha (E) and Andropogon virginicum (A), the following are the notable species in zone 4: Osteomeles anthyllidifolia (E), Pluchea symphytifolia (A), Arundina bambusifolia (A), Passiflora foetida (A), Waltheria indica (I), Chamaecrista nictitans subsp. patellaria var. glabrata (A), Wikstroemia sandwicensis (E), Cassytha filiformis (I), Indigofera suffruticosa (A), Spathoglottis plicata (A), Mimosa pudica (A), Psidium guajava (A), Psidium cattleianum (A), Mangifera indica (A), Cocos nucifera (A), Melinis minutiflora (A), Nephrolepis multiflora (A), Centella asiatica (A), Stachytarpheta urticifolia (A), Crotalaria spectabilis (A), Crinum sp. (A), Thunbergia fragrans (A), Crassocephalum crepidioides (A), Desmodium incanum (A), Pennisetum setaceum (A), Hyptis pectinata (A), Themeda gigantea (A), Albizzia sp. (A), Emilia fosbergii (A), Erechtites valerianifolia (A), Cyperus sp., Machaerina mariscoides (I), Trema orientalis (A), Scleria testacea (E), Castilleja arvensis (A), and Pityrogramma calomelanos (A).

Zone 4





Zone 4. Andropogon grassland with dead snags from a former Metrosideros forest. Foliated trees in bottom frame are Eucalyptus.

ZONE 5: Highway Parcels near Pahoa

The survey units near Pahoa occur primarily on agricultural or residential land bracketing major roads. Human activity has fragmented the vegetation into a mosaic of contrasting types difficult to bring under common description, other than with the fact that they are universally of minimal botanical value.

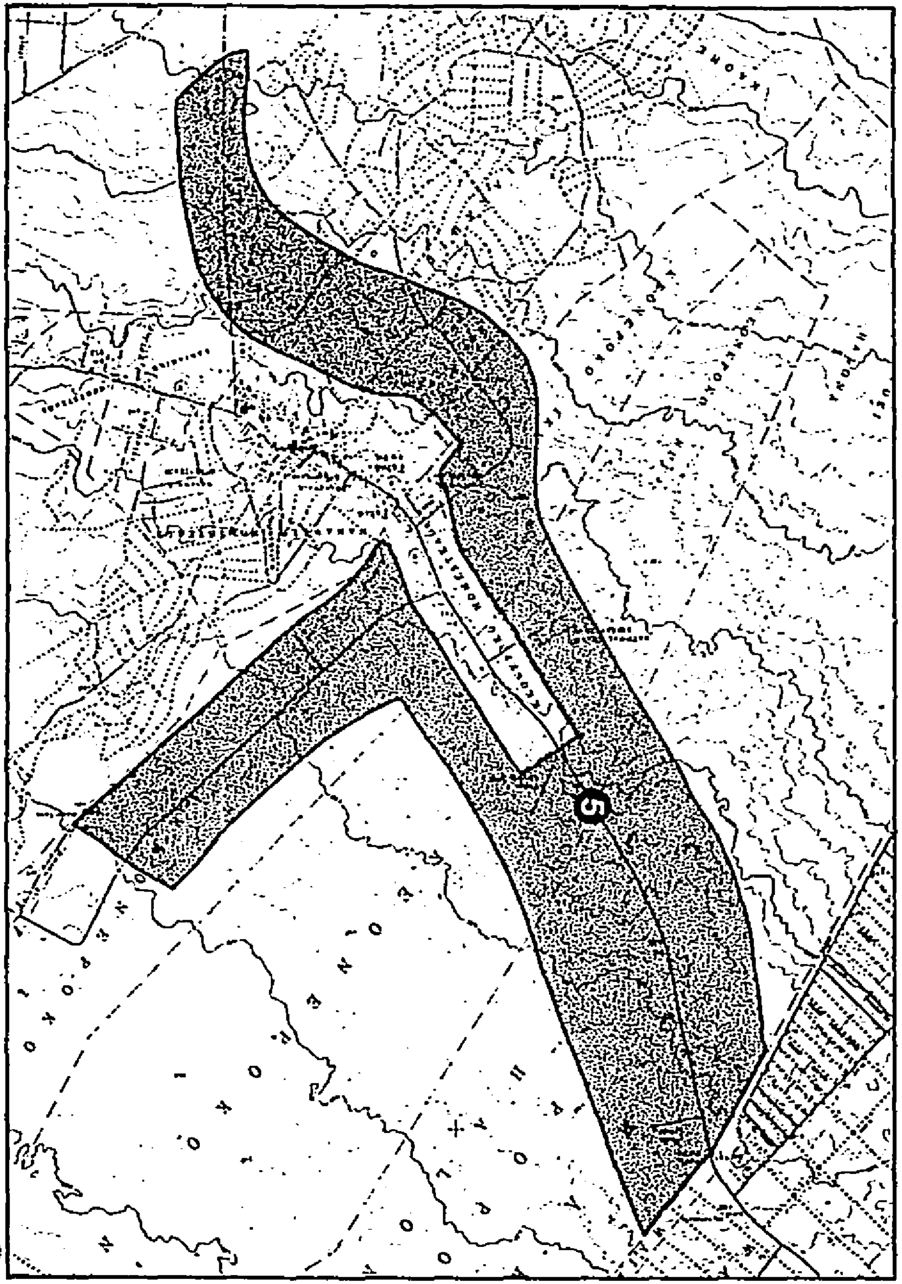
In general, the largest area of native forest is the fraction on both sides of highway 130 (toward Keaau). Short-statured Metrosideros of pole-like habit is the dominant cover in the area. However the understory component is frequently infested with weeds such as Melastoma candidum (A), Andropogon viriginicum (A), Polygonum capitatum (A), Castilleja arvensis (A), Eragrostis unioloides (A), and Arundina bambusifolia (A). Alien communities of (primarily) Psidium cattleianum, Psidium guajava, Mangifera indica, Pluchea symphytifolia, Albizzia sp., and Cecropia obtusifolia are also interspersed throughout the section. Due to the presence of numerous houselots and agricultural plots, there is no continuity to the plant formations.

This same pattern is repeated in the properties along Kahukai Boulevard. Substantial patches of the Metrosideros-Dicranopteris association are distributed through the strip but the residential and commercial farm lots completely disrupt the integrity of forest. Melochia umbellata, Pluchea symphytifolia, Buddleia asiatica, and Psidium guajava are common pests.

The lane forming an arc to the west of Pahoa is similarly of low botanical quality. Much of the area consists of abandoned canefields, pastureland, or weedy borderland. When native communities are present, they are nearly always of the ubiquitous pioneer type composition. Exceptions such as the kipuka by Pahoa Dump may contain a richer-than-usual species suite but the taxa recorded are still common items to be found almost anywhere.

Relictual stands of Metrosideros-Psychotria forest were encountered along the portion of route 130 which runs south from Pahoa. Certain sites have higher species counts than the survey norm but again the plants involved are common throughout Hawaii.

Zone 5



Zone 5. Two views of the Metrosideros forest near Keonopoko Homesteads. Foreground: the alien shrub Melastoma candidum as an aggressive invader.

ZONE 6: Puna Substation

The survey section near the Puna substation extends to the SE in a double-lane configuration, with one arm passing through Waipahoehoe and the second superimposed upon the Keaau-Pahoa highway. Most of this area has had a long history of intensive agricultural use. Native plant cover is absent from a wide territory, especially in the region adjoining the substation.

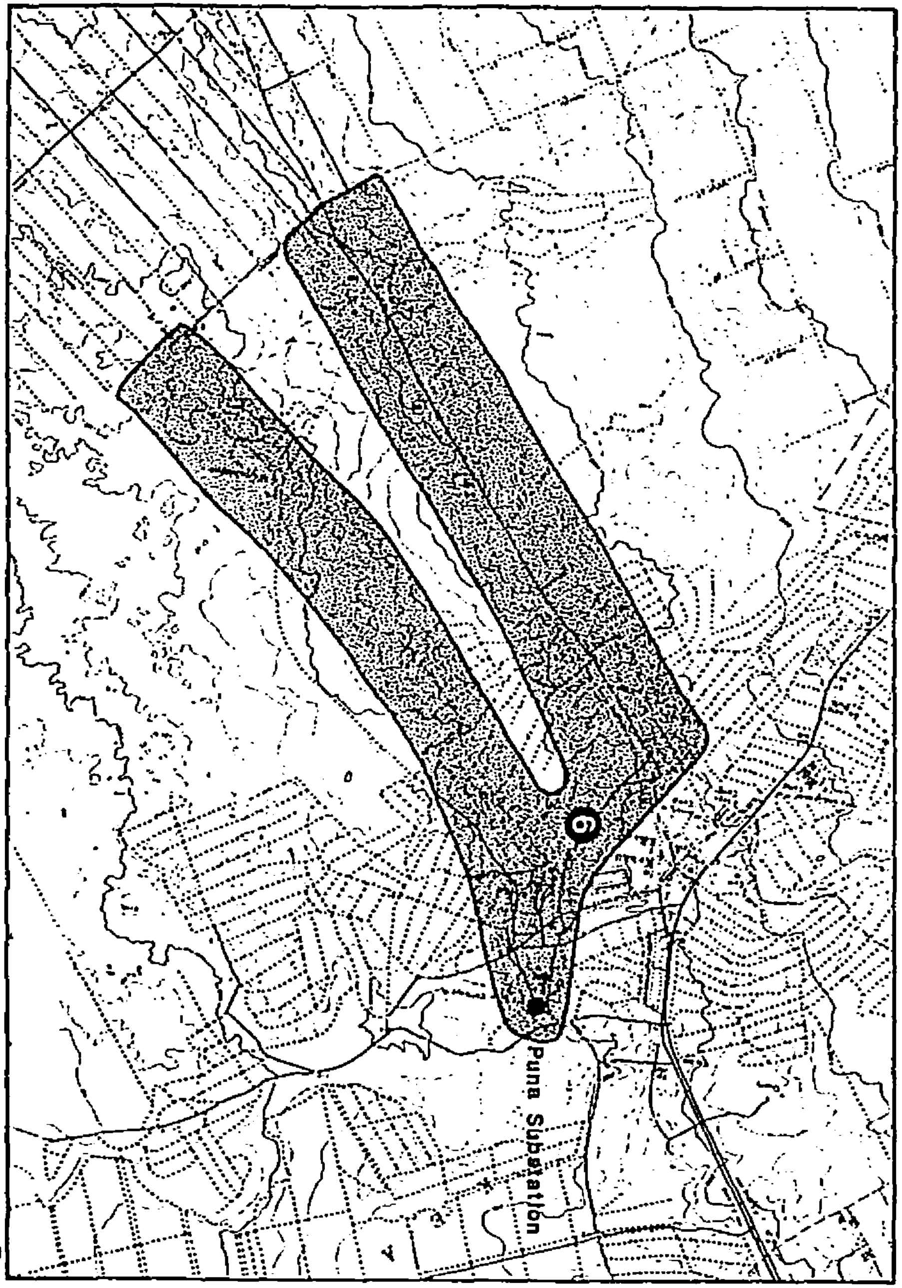
Due to the failure of the sugar industry around Keaau, former plantation acreages are now in the process of converting to weedy wastelots. Although Saccharum officinarum (i.e. sugar cane) remains the dominant species in abandoned tracts, Cecropia obtusifolia and Melochia umbellata are invading. From present indications, the untended fields should eventually develop into an alien forest dominated by Psidium cattleianum--if the land is allowed to continue on a free running sequence.

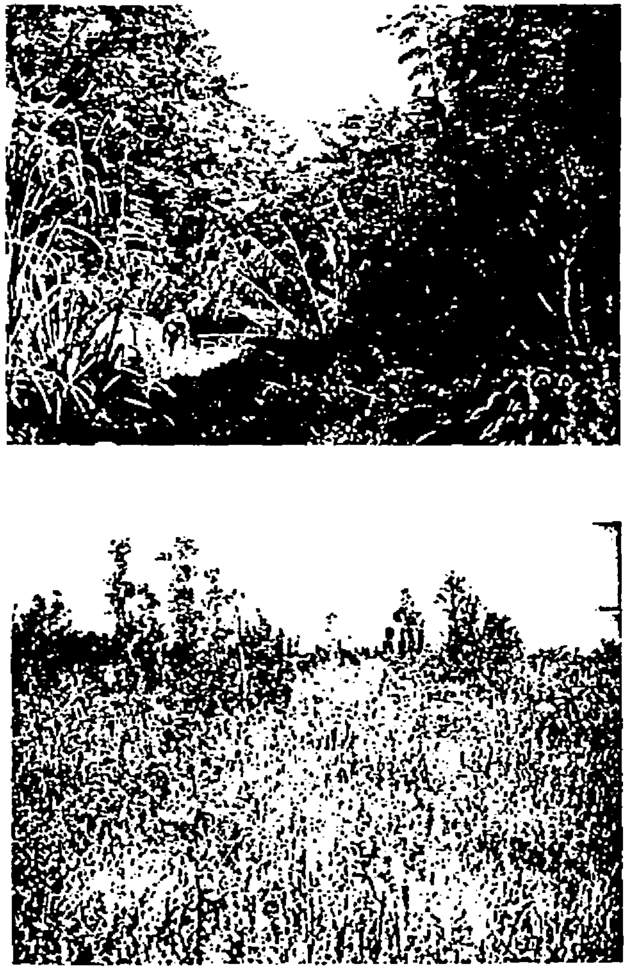
A large number of sites in zone 6 are presently invested in small scale cultivation of alternative crops. Many agricultural plant pests and incidental ephemerals are associated with the farm plots. No attempt was made to compile a botanical inventory of the occurrences since they represent disturbance formations irrelevant to the proposed project.

Near Waipahoehoe, a second growth forest of Trema orientalis and Cecropia obtusifolia is distributed in discontinuous fashion among agricultural clearings. Further to the southeast this vegetation gives way to an Andropogon virginicum-Arundina bambusifolia rangeland. Pluchea symphytifolia, Psidium guajava, Desmodium cajanifolium, Clusia rosea, Mangifera indica, Cordyline terminalis, and Melinis minutiflora are conspicuous weeds in the rangeland community.

As a general pattern, deep-soil habitats in zone 6 are associated with the kind of weedy plant assemblages to be expected from past or present agricultural use. Patches of native forest are present only over terrain which has been renewed by relatively recent volcanic activity. In the latter situation, an open Metrosideros-Dicranopteris community develops as a successional pioneer on the unweathered lava. Examples of the pioneer forest are present along stretches of route 130 but the communities are heavily infiltrated by aliens such as Andropogon, Arundina, and the serious pest Psidium cattleianum.

Zone 6





Zone 6. Top: Secondary forest near Waipahoehoe, abundantly vegetated by all manner of plant pests. Canopy of Trema orientalis and Cecropia obtusifolia. Bottom: Andropogon-Arundina rangeland to SE of Waipahoehoe.

SUMMATION

Our examination of the routes under consideration indicates that the botanical impact of the intended project would be very minimal. Many of the areas submitted for review are managed landscapes which have already been highly altered by man. Even in cases where native forest was encountered, the floristic quality was consistently poor, and the same species composition was repeatedly expressed.

An ecological comment of general application can be made of this study terrain:

As a vegetation matures, it normally progresses through a continuous series of changes known collectively as succession. In Puna environments, the program of change is initiated when an existing plant cover is erased by lava flows, the terrain subsequently recovering its vegetation through stages of incremental repopulation. Though of wide spatial extention, the ohia stands in the survey tract are consistently at an early stage in the successional process. Volcanism in the district is so active that the maturation sequence is constantly being truncated, and both the landscape and the plant communities are kept youthful by continual resetting to the starting point in the development cycle. Due to their incipient status, the plant communities contain only a small fraction of the species diversity which can be potentially exhibited by forests of their type. The biological value is diminished accordingly.

Rare and endangered taxa of Metrosideros forests are primarily associated with the mature, dense-shade environments produced by old stands. Youthful communities like the ones common over geologically active terrain are not likely to harbor plant rarities. It is physically impossible to inspect the contents of every patch of native forest with occurrence inside the project boundary. But just on general ecological principles, it is highly improbable that some outstanding botanical find could ever be retrieved from the kind of forests prevailing in the Puna district.

We recommend that botanical concerns be omitted from the evaluation process for final route selection. There is no compelling basis for altering or abandoning any of the intended tracks on the basis of vegetation considerations.

APPENDIX D

CULTURAL AND BIOLOGICAL RESOURCES SURVEY OF THE POHOIKI TO PUNA-SUBSTATION 69KV TRANSMISSION CORRIDOR KEA'AU TO KAPOHO, PUNA, HAWAI'I ISLAND

Final Report:

Ornithological Survey

15 April 1987

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Introduction

A survey of birds was conducted under contract to DHM, Inc., during the period 18-23 December 1986 in the proposed 69KV transmission corridor between Pohoiki and Puna-Substation in the Puna District, Hawai'i Island. The study area consists of corridors of land roughly 26 miles in length surrounding the proposed transmission aliignments (see Fig. 1). The primary goal of the study was to document the presence of avian species that might be affected by the construction and continued presence of the power line. In particular, I attempted to document species that are currently threatened, endangered or are in some other way of concern (e.g. non-endangered native forest birds). The elevation of the study area (< 300 m), and the lack of a significant amount of wetland habitat made it unlikely that such species would be found, and this was largely confirmed. I report below my methods of surveying the study area, the results tabulated for various sections of the study area, and a discussion of the potential impact the power line might have on avian species in general, and on threatened or endangered ones in particular.

Study Site and Habitats

The study area was located between the Puna Substation and the geothermal plant located at Pohoiki (see Fig. 1).

Several potential routes were specified, and coverage of the study area included all of these. The corridors were divided into 23 subsections and six major sectors (see Fig. 1 and Tables 1 and 2). The sectors were combined from the subsections as follows: Puna West: A, G, E, F; Puna East: B, C, D, E, F; Old RR: H, R; Southeast: Q, T, I, O, J, N; 130 East: L, M1, M2, PL; 130 West: L, PR, K1, K2, S, N. As can be seen, some subsections are found in more than one sector. This is primarily because of overlap of separate "corridors" at the ends of the transmission line (i.e., Puna Substation and Pohoiki plant; see Figure 1). Bird species numbers were summarized for each subsection and then for each sector. The six sectors can be variously combined to provide summary data for each of the three most likely transmission line corridors.

Habitats were varied in the study area, and included sugarcane fields (mostly in the Puna east and west sectors; Fig. 1); 'ohia forest (mostly in the "southeast" and "Old RR" sectors); mixed 'ohia and introduced tree forests and savannas, and residential areas (mostly in the "130 West" sector). Many of the 'ohia trees were in bloom during the survey period, so nectar resources were available for native honeycreepers, if they were present in the area. The underlying substrate was fairly rough and rocky, and in some areas a thick understory of grass and thorny shrubs limited

our access. (See the report from the B. P. Bishop Museum's botanical survey for a more detailed description of the vegetation types available for birds.)

Methods

All fieldwork was conducted during the period 18-23 December 1986. Surveys were generally conducted from about sunrise (about 6:30 a.m.) to about 3:00 or 4:00 p.m. Our methodology involved making counts at least every 0.2 miles along each transect. Counts were conducted at stations from which most or all of the corridor area was visible for at least 0.1 miles. This was also a distance within which songs of most avian species could be heard. Therefore, coverage of the corridor was fairly close to 100%. The numbers of each species of bird seen or heard during a five-minute period was recorded into field notebooks at each station. Habitat types at each station were also noted. The number of birds for each sector was summed from the stations within each sector. I and my field assistant attempted to be as realistic as possible in estimating the number of birds seen or heard. We spent the first day of the study (18 December) visiting the entire study area, both to determine the best plan for conducting the survey and to familiarize or refamiliarize ourselves with the types of birds present in the study area and their songs.

Results and Discussion

Raw summaries of the survey results are presented in Table 1. A total of 1254 individuals of 16 species of birds were counted during the survey. Five species were found in no more than one of the 23 subsections, and an additional four species were found in fewer than half of the 23 subsections (Table 1). Table 2 and all subsequent analyses summarize the results by sector for each of the seven species found in more than 50% of the subsections (Common Myna, Acridotheres tristis; Northern Cardinal, Cardinalis cardinalis; Japanese White-eye, Zosterops japonicus; Nutmeg Mannikin, Lonchura punctulata; House Finch, Carpodacus mexicanus; and the two dove species [Spotted Dove, Streptopelia chinensis; and Zebra Dove Geopelia striata] combined into a single "doves" category). There is also a separate category with all of the other species combined. All seven of the species found in more than 50% of the subsections ("common species") are exotics.

D-3

The relative abundance of the common species in each major sector is plotted in Figure 2. As can be seen, Nutmeg Mannikins and Common Mynas were most common in the agriculturalized Puna East and Puna West sectors, whereas Northern Cardinals and House Finches were more abundant in the wooded habitats of all sectors other than Puna East and Puna West. Japanese White-eyes and the doves were more

evenly distributed among all of the sectors. Similar trends can also be identified in Figure 3. The "others" that are so common in the Puna sectors are primarily ducks (see below).

Of the remaining nine "other" species, three are introduced exotic species (Eurasian Skylark, Alauda arvensis; Melodious Laughing-Thrush, Garrulax canorus; and House Sparrow, Passer domesticus), three are migrants (Northern Pintail, Anas acuta; Lesser Scaup, Aythya affinis; and Golden Plover, Pluvialis dominica) and three are natives of special concern (the 'Io or Hawaiian Hawk, Buteo solitarius; the Hawaiian Black-necked Stilt or Ae'o, Himantopus mexicanus knudseni; and the 'Elepaio, Chasiempsis sandwichensis). The 'Io and the Stilt are both endangered species (Pyle 1983); the 'Elepaio is not endangered but is not a common bird at these elevations on Hawaii (Pratt 1980).

The two duck species and the stilts occurred only in some small ponds at the edge of the corridor in subsection F (Fig. 1). These ponds were checked a total of four times during the survey to determine how often they were being used by the waterfowl and stilts. The stilts were seen on only one occasion, the ducks on three of the four visits. The ponds and their inhabitants are not likely to be affected greatly by construction of the power line because they are on the very edge of the corridor (> 200 m from the probable position of the power line). However, if this route is chosen, care should be taken to disturb these habitats as little as possible.

The single 'Io was seen soaring high above the abandoned railway track in subsection J. This endangered species feeds primarily on rodents, insects and birds (Berger 1981, Griffin 1984). They hunt mostly from stationary perches but also while soaring (Griffin 1984). Thus, it is unlikely that the power line would hinder their activities, in fact, the poles or lines might provide appropriate hunting perches for the hawk (assuming precautions are taken to eliminate the risk of electrocution). In addition, the destruction of forested or second growth habitat associated with establishment of the power line would increase open areas, which the hawk is known to use to find food (Griffin 1984). All care should be taken during construction and/or maintenance of the line not to interfere with breeding attempts by the hawk. 'Io breed between March and September (Griffin 1984).

The 'Elepaio was the only other endemic form found during the survey, and is the only native passerine that could normally be expected at this low elevation on Hawaii (Scott et al. 1986). Although 'Elepaio are not listed as an endangered species by the U.S. Fish & Wildlife Service,

their numbers have appeared to decrease in recent years (Scott et al. 1986). The birds were sighted in subsection D (Figure 1, Table 1). Other native passerines were carefully listened and searched for (e.g. Apapane, *Himatione sanguinea* and Common Amakihi, *Hemignathus virens*), but none were noted. It is possible that during other times of the year (perhaps when more 'ohia are in bloom) these species do come down to lower elevations. A literature search through *The 'Elepaio* and other sources failed to find any evidence that these honeycreepers do or have in recent times occupied this specific area.

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Conclusions and Recommendations

The 'Elepaio, the 'Io, and the Hawaiian Stilt were all found along the same corridor (sectors Puna East, Old RR and Southeast combined). I therefore suggest that developing one of the two alternate routes (i.e., the two along the highway) would be best to minimize impact to these native birds. Only non-native (and mostly pest) species were found along the alternate corridors during the surveys (Table 1, Figure 1). I believe that our coverage of the sites was adequate to document whether native species of birds occur along these corridors. Such native birds may occasionally use these areas, but it is not likely that they are dependent upon them. I also do not feel that populations of the introduced, pest species would be extraordinarily affected by the construction and maintenance of the power line.

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Table 2. Total of species grouped by sector.

Species:	Puna West	Puna East	Old RR	South -East	130 East	130 West
Common Myna	70	73	11	39	26	39
Northern Cardinal	15	12	17	13	41	44
Japanese White-eye	68	61	36	73	77	98
Nutmeg Mannikin	117	149	6	0	18	18
House Finch	8	9	48	66	64	81
"Doves"	8	15	17	15	23	15
Others	46	49	1	5	10	5
Total	332	368	136	211	259	300
%	(26.5)	(29.3)	(10.9)	(16.8)	(20.7)	(23.9)
Total # Species	14	14	8	9	9	8

Table 1. Total number birds by area and species

SPECIES	A	B	C	D	E	F	G	H	I	J	K1	K2	L	M1	M2	N	O	PL	PR	Q	R	S		TOTAL
										SECTIONS														
Pintail	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Lesser Scaup	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hawaiian Hawk	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Golden Plover	0	1	8	0	3	1	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	17
Hawaiian Stilt	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Spotted Dove	0	1	2	0	0	1	0	6	0	3	4	0	2	1	5	2	3	2	6	1	7	2	0	48
Zebra Dove	4	5	4	0	2	0	1	1	0	0	0	0	2	0	11	1	2	0	2	2	3	0	1	41
Eurasian Skylark	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Common Myna	13	4	24	0	37	8	12	3	5	4	2	2	10	5	5	19	10	6	10	1	8	0	0	188
Melodius Laughing-thr	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	5
House Sparrow	4	1	0	0	0	0	3	0	0	0	0	0	2	0	6	3	0	0	2	0	1	0	0	22
Northern Cardinal	9	8	1	1	2	0	4	8	7	0	4	1	20	4	6	0	2	11	17	2	9	8	2	126
Japanese White-eye	35	17	8	22	10	4	19	25	5	22	22	13	24	20	15	21	7	18	25	9	11	0	9	361
Nutmeg Mannikin	6	24	5	11	89	20	2	6	0	0	0	0	0	0	0	0	0	18	2	0	0	0	0	183
House Finch	6	4	0	5	0	0	2	37	0	12	7	2	5	17	26	40	5	16	12	3	11	11	6	227
Elepaio	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
TOTAL	79	65	52	41	146	64	43	86	17	43	39	18	65	47	76	86	29	71	80	18	50	21	18	1254
PERCENT OF TOTAL	6.3	5.2	4.1	3.3	11.6	5.1	3.4	6.9	1.4	3.4	3.1	1.4	5.2	3.7	6.1	6.9	2.3	5.7	6.4	1.4	4.0	1.7	1.4	

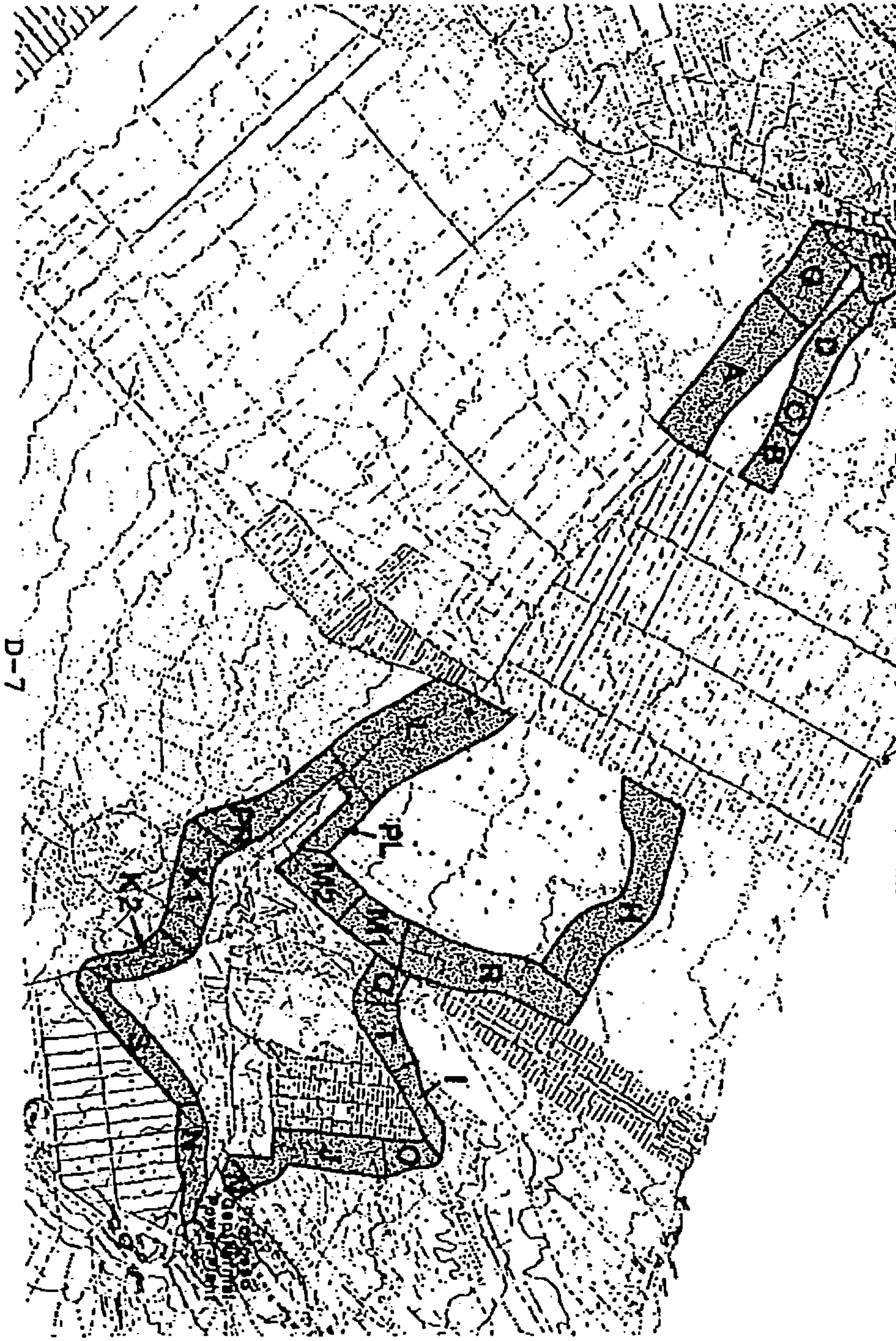

Figure 1: Map of the study area for the Pohoiki to Puna Substation Transmission Corridor. The study area was divided into 23 subsections (A-T). These subsections were combined into six sectors (see text and Table 2).

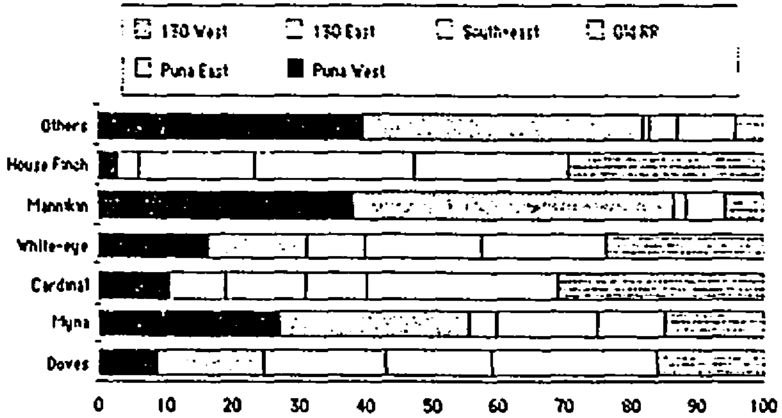

FIG. 2. Species groups by area.

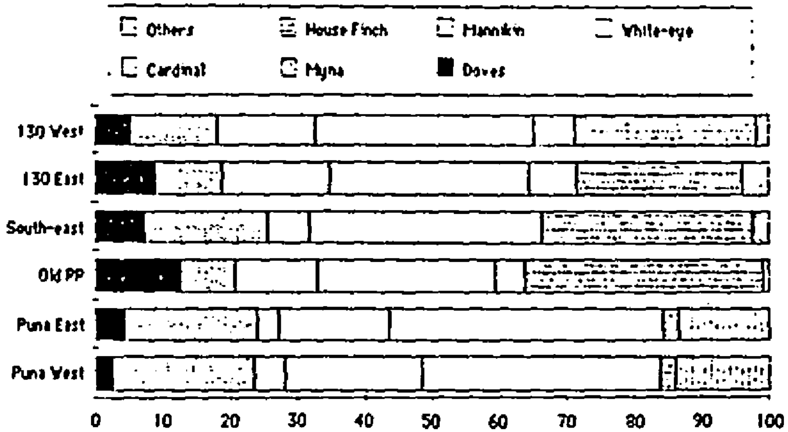

Fig. 3. Areas by species group.

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APPENDIX E

Final Report of the Pohoiki to Puna Powerline EIS:

Terrestrial arthropods

by G.M. Nishida and W.C. Gagné

The Department of Entomology of Bishop Museum conducted entomological field surveys of the Pohoiki to Puna proposed powerline alignments, on 5-11 February, based on maps provided by DHM, Inc. Eighteen promising locations were sampled during this period. Sampling methods included sweeping, beating, and hand collecting during both day and night. During the evenings, a mercury vapor lamp was used to attract insects. Lists of the insects and other arthropods collected from the areas outlined by DHM and identified are found in Appendix 1.

Three areas of important concentrations of native species were found during the survey, one of critical importance. These areas are outlined in Appendix 2. A critical fourth area, though not included in the survey, will be crossed by the powerline using either of the alternate routes.

The following narrative will begin from the Puna Substation and work south and east toward the geothermal plant following the two nearly parallel alternative routes marked on the DHM maps. One route followed the old railroad track bed. The other paralleled the Keeau to Pahoa Road. Divergences to these basic routes occurred at and beyond Pahoa.

The survey areas just to the south and southeast of the Puna Substation contained introduced species or common species of native insects. The railroad bed route was surrounded by mostly sugar cane and weeds and populated by non-native insect species. The road route was mostly late flow lava vegetated with o'hia trees and uluhe fern and populated by non-native or common native insect species.

The survey map provided by DHM shows a coverage gap between Shower Drive to slightly beyond Makuu Drive. Accordingly, this area was not formally surveyed. However, the area was driven through and visually surveyed. Superficially, there appears to be not much entomologically that would be affected by a powerline across this subdivision. However, we are concerned, as this "non-survey" area crosses above Kazumura Cave, the restricted habitat for a number of remarkable cave-adapted organisms (Gagné and Howarth 1975, Gurney and Rentz 1978, Bellinger and Christiansen 1974, Gertsch 1973). Kazumura Cave has been previously studied and much Hawaiian lava tube research has taken place there (Howarth 1973).

South of Makuu Road, the Keeau to Pahoa Road route diverges just before Pahoa town. One fork skirts Pahoa to the south. The other fork makes a sharp bend at Kahakai Boulevard and joins with the abandoned railroad route, which has made a similar bend (but in the opposite direction). At this location, the railroad route crosses an area of scattered o'hia that appears to have been previously burned. Nothing of entomological significance was

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found along the surface of this route. The route following the road was, again, populated by non-native or relatively common native species.

Perpendicular to the outlined survey areas and paralleling Kahakai Boulevard is the most significant habitat located within the survey parameters (see Appendix 2). This is the general location of Pahoa Cave. Collected and observed in this cave were unique cave-adapted creatures. Many have adapted so well to the environment as to have become eyeless, using other means to communicate with each other. These unique cave animals, found only in this cave, included cixiid bugs, crickets, crane flies, moths, millipedes, sow bugs, silverfish and centipedes. A major scientific study of the cixiid bugs from Pahoa Cave is currently underway, with important discoveries on the behavior of these bugs (Hoch and Howarth, pers. communication). Pahoa Cave crosses underneath both alternative routes including both forks of the alternate route on either sides of the Keeau to Pahoa Road. Concern about this extremely important biological resource is not focused only on possible physical damage to the cave during construction or possible exposure of the cave to increased access and thus pressure on the fragile habitat of these animals, but also extends to general maintenance of powerlines. A common practice of powerline maintenance is to use herbicides to control the vegetation beneath the lines. This practice of spraying would be extremely dangerous to the cave animals, as the herbicide would kill the host plants - the major energy sources

for the cave animals. The herbicide is also likely to percolate down into the caves, directly affecting the animals.

Continuing first with the southernmost fork of the roadway alternative, the proposed route skirts Pahoa to the south and west. The fauna around the solid waste disposal site is very similar to the previously mentioned roadway faunas, with nothing unique. Traveling south and east, the area is mostly sugar cane and weeds without any entomological significance. However, a small _kipuka_ of native forest does appear at the edge of this fork, on the map appearing beside and below the last "A" in Waiakahiula (see Appendix 2 for location). This area produced a significant number of native species, including several that are probably new and undescribed. This _kipuka_ is relatively small and located in the midst of sugar cane. It could be easily skirted by the proposed powerline if the alignment was placed directly in the middle of the alternative route or moved somewhat closer to Pahoa.

Further along, this alternative goes south along State Route 130 for a short section, then proceeds east paralleling Kahukai Street in the Keahialaka Subdivision before it takes a turn towards the geothermal facility. Some native insects were collected along Kahakai Street, but most species were of general distribution.

Returning to the railway route, after the two forks combine along Kahakai Boulevard, we find that the route parallels the northern edge of Puna Subdivision, makes a sharp right-angle turn, and parallels Seaview Road along an unnamed dirt road. The route then skirts Nanawale Forest Reserve and Lava Tree Molds State Park before heading towards the geothermal plant. Another area of significance was discovered along the east side of the dirt road paralleling Seaview Road (see Appendix 2). This site is approximately outlined by the dirt road to the east, Seaview Road to the west, Plumeria Road extended to the north, and Hawaii Road extended to the south. The dominant native tree, *lama* (*Diospyros hawaiiensis*), made up the canopy of a comparatively diverse community of native plants.

In many of the other sites, *Anoplolepis longiceps*, the long-legged ant, was found in abundance. This introduced alien species apparently heavily impacts resident insect populations, thus areas foraged by this ant yield significantly fewer native species than might be expected. This ant was also found in abundance in the Seaview Road site, and indeed, day collecting was not as productive as might have been expected. However, collecting at night using a mercury vapor lamp attracted many natives including 14 species of native moths (*Hyposmocoma*) alone, despite the occupation by the long-legged ant. This area is one of the lowest elevation patches of remaining lowland native forest with surviving native species.

Based on Appendix 1, the species totals are as follows:

Endemic species	44
Indigenous species	3
Exotic or Alien species	70
Species new to Big Island	12

The total for the endemic and indigenous species as compared to the alien species is significant especially in light of the occupation by the long-legged ant. The other surprising total was the large number of species previously unknown from the Big Island.

In summary, the areas of entomological significance, in probable order of significance are: 1) Pahoa Cave, both upper and lower caves, possibly extending to the ocean. 2) The *kipuka* area south of Pahoa near the last "A" in Waiakahiula. 3) The Seaview Road site. The latter two sites provided a living laboratory insight as to the impact of long-legged ants on native arthropods in that one *kipuka* had ants and the other didn't. The native arthropod composition of these two sites were dramatically different. This provided the first comparison of the impact of this recently introduced ant on the island of Hawaii. In addition, the area crossed by Kazumura Cave not included in this survey is extremely significant.

In general, the alignments could probably be adjusted to skirt or skip the significant sites. Pahoa Cave and Kazumura Cave are extremely important living biological laboratories and great care should be extended when passing over these caves. Our recommendation is that someone with knowledge of the caves be added as a consultant when the final alignment is decided, to provide input as to the best possible way to cross the caves with the least possible perturbation. We would suggest Dr. Fred Stone of the Department of Geology at the University of Hawaii at Hilo, and one knowledgeable about Hawaiian cave biotas, as a possible consultant.

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Acknowledgements:

Basic support was provided by the Department of Entomology of the Bishop Museum. Identification support was provided by G.A. Samuelson, F.G. Howarth, N.L. Evenhuis, and J.C.E. Riotte of the J.L. Gressitt Center for Research in Entomology; M. Asche of Marburg University, West Germany, and C.W. Sabrosky of the U.S. National Museum.

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Appendix 1.

INSECTS COLLECTED ON POWERLINE SURVEY
February 1987

E = endemic
I = indigenous
* = species previously not recorded from Hawai'i island

ORDER DICTYOPTERA

Family Ectobiidae

	Lupparia notulata (Stal)	Stops 2, 3, 5, 8

Family Blattellidae

	Blattella lituricollis Walker	Stop 8

Family Blattidae

	Melanozosteria soror (Brunner)	Stops 4, 8
	Periplaneta australasiae (Fabricius)	Stop 8

Family Panchloridae

	Pycnoscelis surinamensis (L.)	Stop 8

Family Mantidae

	Orthodera burmeisteri Wood-Mason	below sugar mill

ORDER ORTHOPTERA

Family Tettigoniidae

	Phaneroptera furcifera (Stal)	Stops 4, 8
	Conocephalus saltator (Saussure)	Stops 4, 5

Family Gryllidae

*	Myrmecophila quadrispina Perkins	Stop 5
	Acheta oceanicum (Le Guillou)	Stop 8
E	Paratrigonidium sp.	Stop 9
E	Caconemobius sp.	Pahoa Cave

ORDER DERMAPTERA

Family Chelisochidae

	Chelisoches morio (Fabricius)	Stops 2, 5, 9
	Sparattina nigrorufa (Burr)	Stop 5

ORDER HETEROPTERA

Family Anthocoridae

	Orius sp.	Stop 5

Family Miridae

E	Hyalopeplus pellucidus (Stal.)	Stop 3
E	Orthotylus n. sp. near kanakanus Kirkaldy	Stop 7
E	Orthotylus n. sp. near perkinsi	Stop 9

Family Reduviidae

	Oncocephalus pacificus (Kirkaldy)	Stops 5, 8

ORDER HOMOPTERA

Family Cicadellidae

E	Balclutha hospes (Kirkaldy)	Stops 5, 8, 10, 11
E	Nesophrosyne (Nesoreias) oceanides Kirkaldy	Stop 9
E	Nesophrosyne (N.) silvicola Kirkaldy	Stop 9

Family Cixiidae

E	Iolania perkinsi Kirkaldy	Stops 3, 5

Family Delphacidae

E	Nesothoe sp. near maculata (Muir)	Stop 1
	Sogatella kolophon (Kirkaldy)	Stops 5, 8, 10

Family Flatidae

	Melormenis antillarum Kirkaldy	Stop 5
	Siphanta acuta (Walker)	Stops 1, 3, 4, 8, 9

Family Membracidae

	Vanduzea segmentata (Fowler)	Stops 3, 4, 5, 11

Family Psyllidae

E	Kuwayama minuta Crawford	Stop 8
E	Kuwayama nigricapitata Crawford	Stop 8
E	Trioza sp. cf. hawaiiensis Crawford	Stop 8
E	Trioza sp. cf. lanaiensis Crawford	Stop 8
E	Trioza ohiacola Crawford	Stop 8
E	Trioza sp. nr. pullata Crawford	Stops 4, 5, 8

ORDER HYMENOPTERA

Family Formicidae

	Anoplolepis longipes (Jerdon)	Stops 2, 4, 5, 10
	Monomorium sp. prob. destructor (Jerdon)	Stop 8

ORDER LEPIDOPTERA

Family Carposinidae

E	Carposina sp.	Stop 5

Family Gelechiidae

	Anatrachyntis incertulella (Walker)	Stop 5
	Autosticha pelodes (Meyrick)	Stop 5
E	Hyposmocoma (Euperissus) sp. cf. hirsuta (Walsingham)	Stop 5
E	Hyposmocoma sp. 1	Stop 5
E	Hyposmocoma sp. 2	Stop 5
E	Hyposmocoma sp. 3	Stop 5
E	Hyposmocoma sp. 4	Stop 5
E	Hyposmocoma sp. 5	Stop 5
E	Hyposmocoma sp. 6	Stop 5
E	Hyposmocoma sp. 7	Stop 5
E	Hyposmocoma sp. 8	Stop 5
E	Hyposmocoma sp. 9	Stop 5
E	Hyposmocoma sp. 10	Stop 5
E	Hyposmocoma sp. 11	Stop 5
E	Hyposmocoma sp. 12	Stop 5
E	Hyposmocoma sp. 13	Stop 5
	Stoeberhinus testaceus	Stop 5
	?Stoeberhinus sp.	Stop 5

Family Gracillaridae

E	Philodoria (P.) sp.	Stop 5

Family Lycaenidae

	Strymon bazochii Godart	Stop 4

Family Noctuidae

	Autographa chalcites (Esper)	Stop 5
	Bocana manifestalis Walker	Stop 5
	Eublemma anachoresis (Wallengren)	Stop 5
	Hypocala deflorata (Fabricius)	Stop 5
	Leucocosmia nonagrica (Walker)	Stop 5
	Ophiusa indiscriminata (Hampson)	Stop 5
E	*Schrankia* n. sp. 1	Stop 5
E	*Schrankia* prob. n. sp.	Stop 6
	Simplicia lantokiensis (Prout)	Stop 5
	Spodoptera exempta (Walker)	Stop 5

Family Nymphalidae

E	*Vanessa tamehameha* (Escholtz)	Stop 5, 9

Family Pyralidae

	Bocchoris fatualis Munroe	Stop 5
E	*Eudonia* sp. #1	Stop 5
E	*Eudonia* sp. #2	Stop 5
E	*Eudonia* sp. #3	Stop 5
E	*Hedylepta localis* (Butler)	Stop 5
	Paraponyx fluctuosalis (Zeller)	Stop 5
E	*Udea* sp.	Stop 5

Family Sphingidae

	Macroglossum pyrrhostictum (Butler)	Stop 5

Family Tineidae

	Decadarchis simulans (Butler)	Stop 5

Family Yponomeutidae

	Plutella sp. prob. *xylostella* (Linn.)	Stop 5

ORDER NEUROPTERA

Family Chrysopidae

	Chrysopa sp.	Stop 9

ORDER ODONATA

Family Libellulidae

I	*Pantala flavescens* (Fabricius)	Stop 5

ORDER TRICHOPTERA

Family Hydropsychidae

	Cheumatopsyche analis (Banks)	Stop 5

ORDER COLEOPTERA

Family Anthribidae

	Araecerus sp.	Stop 8

Family Carabidae

*?	*Perigona nigriceps* Dejean	Stop 8

Family Cerylonidae

*	unidentified	Stop 5

Family Coccinellidae

	Scymnus bilucernarius Mulsant	Stop 1

Family Colydiidae

*?	*Penthelispa rufipennis* Montrouzier	Stop 5

Family Cucujidae

I*?	*Moanus crenatus* Sharp	Stop 3
I*?	*Psammoecus pallidipennis* (Blackburn)	Stop 8

Family Elateridae

E*?	*Anchastus swezeyi* VanZwaluwenburg	Stops 2, 4
	Conoderus exsul (Sharp)	Stop 8

Family Lathridiidae

*?	*Corticaria* sp.	Stop 8

Family Nitidulidae

	Haptoncus ocularis (Fairmaire)	Stop 8

Family Staphylinidae

*?	*Carpelimus* sp.	Stop 8

ORDER DIPTERA

Family Stratiomyidae

Hermetia illucens (L.)

Family Syrphidae

Ornidia obesa (Fabricius)
Mesograpta marginata (Say)
Ischiodon grandicornis (Macquart)
Syritta orientalis (Macquart)

Family Dolichopodidae

E *Chrysosoma fraternum* Van Duzee
E *Chrysotus pallidipalpis* Van Duzee

Family Drosophilidae

Genus #1
Genus #2

Family Lauxaniidae

Homoneura spp.

Family Chloropidae

Rhodesiella scutellata (de Meijere)
Desmometopa sp.
* *Monochatoscinella* sp.

Family Sciaridae

unidentified

Family Chironomidae

unidentified

Family Tipulidae

Limonia (*Libnotes*) *perkinsi* Grimshaw

Family Sphaeroceridae

Limosininae, ?Genus 1
Leptocera abdominiseta Duda
Pterogramma brevivenosa (Tenorio)

Family Psycodidae

Psychoda alternata Say
Telmatoscopus albipunctatus (Williston)

Family Tephritidae

Dacus (*Bactrocera*) *dorsalis* Hendel
Acinia picturata (Snow)
Procecidochares alani Steyskal

Family Muscidae

Musca domestica (L.)

Family Culicidae

Aedes prob. *albopictus* (Skuse)

Family Sarcophagidae

Boettcherisca peregrina (Robineau-Desvoidy)

Family Cecidomyiidae

unidentified

Family Periscelididae

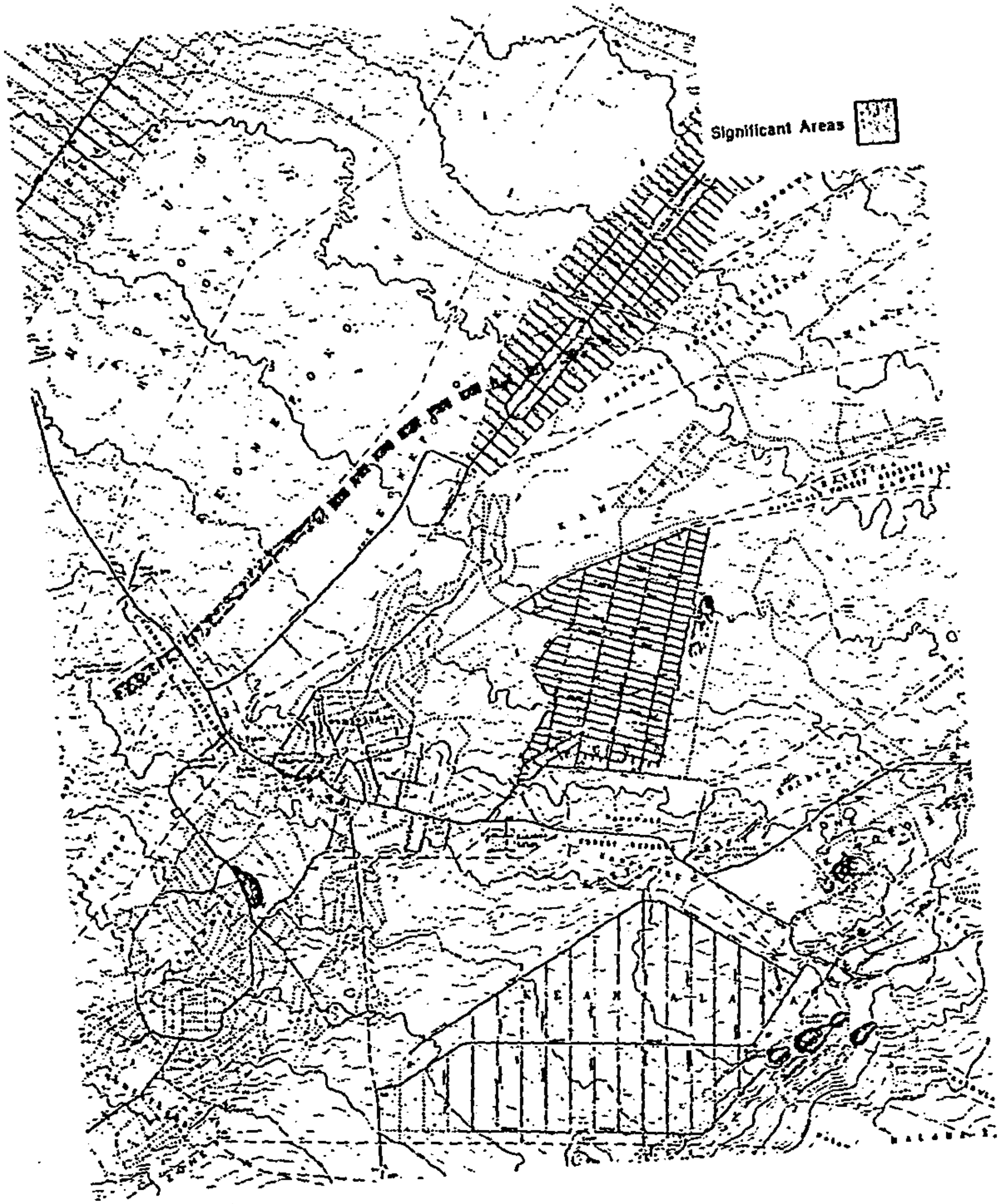
* *Stenomicra* (*Podocera*) *distinctipennis* Collin

Family Scatopsidae

* genus near *Rheqmoclemina*

Family Sphaeroceridae

unidentified



Appendix 2.

APPENDIX F

FINAL REPORT

GEOLOGIC CONSULTATION

PROPOSED PUNA-POHOIKI TRANSMISSION LINE

PUNA, HAWAII, HAWAII

FOR THE HAWAII ELECTRIC LIGHT COMPANY

May 11, 1987

SUMMARY

Geologic conditions would not appear to be a significant factor in the choice among proposed transmission line alignments. Very similar geology is found along the proposed corridors and generally the same soil and geologic conditions would be encountered along each alignment.

Significant geologic hazards appears to be lava tubes and cavities, and lava flows. Lava tubes and cavities are present along all of the candidate alignment corridors, and any immediately adjacent to transmission line foundations would need to be located and repaired.

The potential for lava flows overrunning the transmission line appears to be equal for all corridors. Many lava flows from the Kilauea summit have crossed the alignment corridors within the last 1500 years, the last at least 350 years ago. The last lava flow from Mauna Loa to enter any of the corridors occurred over 1500 years ago. Kilauea's east rift zone has emitted most of the recent flows in the region, including an 1840 flow which crossed a section of a proposed corridor, and a 1955 flow which occurred near the Geothermal Plant terminus of the alignments.

INTRODUCTION

This report summarizes our findings and recommendations regarding the potential corridors for the Puna-Pohoiki transmission lines, Puna, Hawaii, Hawaii. The general location of the corridors are indicated on the Map of Area, Plate 1. The specific corridors are shown on the Plot Plan, Plate 2. The corridor segments have been labeled as shown on the Plot Plan (A, B, C, D, & E) to facilitate discussion of these segments.

Dames & Moore was retained to provide geological consulting services for the corridors and alignments selection and to provide geologic input for the subsequent Environmental Impact Statement (EIS). Our scope of work was defined in our revised proposal dated October 22, 1986.

OUR UNDERSTANDING OF THE PROPOSED PROJECT

DHM Inc. has been charged by HECO/HELCO to select two 69 kv alignments for transmitting 25 MW of electricity, to be generated by Thermal Power in the Pohoiki area, to the Puna substation.

For these two transmission lines, two quarter-mile wide corridors would be selected based upon environmental conditions, land use, and socioeconomic constraints. Geological conditions within these corridors would be one of the environmental conditions evaluated for corridor suitability.

The results of the selection team efforts would be published in a transmission line corridor selection report, and used in subsequent environmental studies.

SCOPE OF WORK

The purpose of our geologic consultation is to provide geologic information for use in optimizing transmission corridor and right of way selection from the standpoint of geologic hazards, suitability and ease of construction. To accomplish this purpose the following tasks were performed.

1. Review of Project Description and Relevant Literature - We reviewed the description of the proposed project provided by DHM to familiarize ourselves with geological routing and design requirements and to identify key issues relevant to our subsequent services. We also reviewed regional geological information in our files.

2. Field Investigation of Selected Corridors - We conducted our field investigation of the selected corridors in two parts. The first part was a helicopter fly-over of the two corridors with the project team. The fly-over was recorded with a video camera to assist in later review of relevant features and to assist with subsequent field work.

   Following the fly-over, an on-the-ground field study of the two selected corridors was conducted. The field investigation included sampling of near surface soils for classification and limited test pit excavation to determine the depth of surface soils at selected locations.

Analysis and Report Preparation - We evaluated data collected in the field and obtained during the literature review. The analysis considered topography, geology, and natural hazards as well as the effect of surface

hydrology on erosion and construction techniques. Anticipated foundation conditions were also factored into our analysis. Our findings and recommendations are presented in this draft report. Following DHM review of our draft report, a final report will be prepared, incorporating your comments.

SURFACE CONDITIONS

TOPOGRAPHY AND MORPHOLOGY

The proposed alignment corridors are located on the lower east slopes of Kilauea and Mauna Loa volcanoes. The ground slopes downward towards the northeast across the corridors at an average gradient of 2 percent. The ground elevation across the corridors rises from +200 feet to +400 feet near the site of the Puna substation and from +340 feet to +920 feet near the site of the geothermal plant. The ground elevation rises from +200 feet to +610 feet over a distance of about 13.5 miles between the sites of the Puna substation and geothermal plant.

Access through the corridor region is provided through a network of mapped public and private, paved and non-paved roads through agricultural, residential, and forest reserve lands.

The topography within the corridors is controlled by the morphology of landforms created by basaltic lava flows. In general, lava flows throughout the region either exist at the surface or underlie shallow soil cover. Lava flows in this region originate from Hawaiian-type eruptions, which are characterized by very fluid lavas with flows usually less than 15 feet thick and capable of spreading great distances from their vents creating very gentle slopes. Some of the flows have advanced as sheets forming nearly flat surfaces sometimes extending hundreds of yards. Most of the flows, however, have advanced as uneven, separate flow units characteristic of flows that have traveled far from their vents. In general, as these flows continue to spread and cool, they undergo divergence often resulting in a distribution of thickened lobes piled upon one another or upon older flows creating an irregular, rugged landscape. Continued cooling and thickening eventually transforms the flow from pahoehoe to a'a. Landforms such as spatter cones, collapsed lava tubes, and fissures contribute to the irregular landscape. Other common landforms include tumuli, pressure ridges, and pressure plateaus, which are cracked, dome-shaped hillocks occasionally greater than 20 feet in height. The lava flows in this region have created a topography that, on a large scale measured over several square miles, consists of a very gentle slope rarely greater than 10 percent in average gradient and, on a smaller scale, consists of an irregular, undulating landscape with variations in topographic relief up to about 20 feet.

SOILS

Soil data gathered during this investigation are summarized on Plate 3, Soil Map. Test Pit logs are presented in the Appendix, as are laboratory test data. Test pit locations are mapped on Plate 2.

Most of the central portion of the corridor region has little or no soil cover above the lava flows with vegetation consisting of scattered ohia trees, moss, grass, and ferns. In areas of soil cover, the soil is typically less than 1.5 feet thick. Soil cover has removed the smaller irregularities from the lava flow landscape. Larger lava flow landforms exist either as hillocks and nobs covered by soil or as rock outcrops.

Areas with soil greater than 1.5 feet thick over the lava are generally limited to the two ends of the corrider alignments (See Soil Map, Plate 3). At the Puna end, Olaa silty clay loam, up to 25 inches thick, is predominant,

with limited areas of Hilo silty clay loam which is over 5 feet thick. There are limited areas of Olaa silty clay loam at the Pohoiki end of the alignments.

Thirteen test pits were excavated in soil areas along the alignments, to assist in checking mapped soil classification information. All encountered basalt rock within 1.5 feet of the ground surface, except for test pits 9 and 11, which were located within Hilo silty clay loam areas.

Organic soils overlying older lava bedrock and silty clay loams formed from volcanic ash are the two basic soil types found in the corridor region.

The organic soils are typically very rocky, less than 6 inches thick and support a natural vegetation consisting of ohia, dense growths of uluhe fern, guava, and grass. These lands are mainly used for woodland, pasture, and homesites.

The silty clay loams are often very stony and usually less than 1.5 feet thick. One type of loam occurring near Keaau, called the Hilo Series Silty Clay by the USDA Soil Conservation Service (SCS) can extend to depths greater than 5 feet. Lands consisting of loams support a natural vegetation of Hilo grass, California grass, guava, ohia, and tree fern. Loam areas are used for sugarcane, truck crops, and pasture.

Both the organic soils and silty clay loams have rapid permeability, slow runoff, and support vegetation with roots that, unless the soil is very deep, pass through to the bedrock. The chance of erosion in these soils is rated by the SCS as slight.

Laboratory testing (see Appendix) indicates that the soils are generally gravelly silty clays or organic soils. The organic soils are only suitable for possible use as topsoil. The gravelly silty clays are suitable for use in near surface backfill for transmission tower or pole foundations. Along most of the alignments, very little soil is available for construction purposes.

SURFACE DRAINAGE

Only two stream channels pass through the corridor region. Both streams are dry and both are part of the Waipahoehoe Stream. The channels enter the corridor region along an area of silty clay two miles south of Keaau and culminate, before leaving the corridor region, on the surface of a pahoehoe flow at about +180 feet. The absence of well-defined streams is a characteristic of areas of Hawaiian volcanic growth where the rate of successive flows is often high enough to cover previously eroded surfaces and where the rocks are so permeable that runoff is very slight.

GEOLOGY

GENERAL GEOLOGIC CONDITIONS

The geology of the corridor region to within 1.5 miles of Keaau is defined by lavas of the Ka'u Volcanic Series of Mauna Loa and the corridor region south of this area is defined by lavas of the Puna Volcanic Series of Kilauea. In general, the type and thickness of the overlying soil cover and vegetation can be used to determine the relative ages of the lava flows in the region. The oldest lavas are covered by volcanic ash which is typically about 1.5 feet thick. Most of the ash areas have been cultivated for sugarcane. Younger lavas have organic clayey silt less than 1 foot in thickness and are covered by dense vegetation. The most recent lavas have no soil cover. The relatively high average rainfall of 150 inches per year in this region has made it possible for the growth of ohia, ferns, and grass on lavas that flowed as recently as the year 1840.

VOLCANIC HAZARDS

The three regions of volcanic activity that could send lava flows into the corridor region are Mauna Loa, the Kilauea summit area, and the east rift zone of Kilauea. Many lava flows from the Kilauea summit have crossed the alignment corridors within the last 1500 years (Holcomb, 1980). However, it has been at least 350 years since lavas from the Kilauea summit area entered the corridor region. The last lava flow from Mauna Loa to enter any of the corridors occurred over 1500 years ago.

A future lava flow entering the corridor region will most probably come from Kilauea's east rift zone, where most of the recent flows in the region have been emitted. The most recent flow entering the corridor region was the flow of 1840 which erupted along a two-mile long fissure within the corridor area running parallel to the rift zone and crosses portions of corridor segment A. In 1955, a lava flow occurred near the Geothermal Plant terminus of the alignments. The location of the 1840 and 1955 lava flows are indicated on the Soils Map, Plate 3.

SEISMIC HAZARD

Seismic activity in the region is primarily associated with the shifting of rocks near areas of volcanic activity as the movement of magma inflates and deflates the volcanic structures. Several strike-slip faults created by the movement of magma and running parallel to the east rift zone are located within the corridor region near the site of the geothermal plant. Earthquake epicenters in the region are concentrated along the east rift zone.

SLUMPS AND LANDSLIDES

The general absence of significant soil cover over almost the entire area indicates that slumps and landslides are not significant hazards. No slump or landslide areas were observed during our field reconnaissance.

LAVA TUBES

The general geology is conducive to the formation of lava tubes. Major lava tubes in the area were mapped by Holcomb (1980) based on vegetation which tends to cluster over tubes. The Geologic Map (Plate 4) indicates the major lava tube locations mapped by Holcomb. Other smaller tubes or cavities may be encountered during construction of the transmission lines and remedial work may be required to provide lateral support to transmission pole or tower foundations where such tubes or cavities are encountered.

SOIL EROSION

Due to the lack of soil cover, the soil characteristics, and the relatively gentle slopes, the SCS has rated the entire corridor area as having slight erosion potential.

DESIGN AND CONSTRUCTION CONSIDERATIONS

Construction along the selected alignment will consist of a series of transmission poles or towers with moment (laterally loaded) foundations. Most of the foundations will be embedded into basaltic rock, which has a high lateral load bearing capacity. The primary concern in these areas will be to seek out and repair any lava tubes or other cavities immediately adjacent to the embedded foundations. It may be necessary to conduct probing operations using air-track drill or jackhammer type probes to check for such cavities

immediately adjacent to foundations. There would be little or no suitable soil for backfill in these areas, and backfill soil to be placed over the concrete foundations may need to be imported.

In the few areas with significant soil cover (Hilo silty clay loam), the foundations would need to be designed for the lower lateral load bearing capacity of these soils.

Existing wooden utility poles within the proposed corridors appear to be performing well with some tilting evident in two areas. Some poles within the Hilo silty clay loam near Keaau are tilting, probably due to the lower lateral load bearing capacity of these soils. Several poles in the vicinity of Kahakai Blvd (where segment A splits into B and C) were tilted. This tilting corresponds to the tilting of trees in the near vicinity, indicating that wind loads in this vicinity are high.

Although seismic loads are probable throughout the alignment corridors, the lateral loads due to seismic conditions would be expected to be less than that due to wind loads, and wind loads will probably be the criteria used for design.

The high elevation and geologic conditions indicate that a groundwater table would not be encountered within foundation excavations.

DISCUSSION AND RECOMMENDATIONS

ALIGNMENT CHOICE

Geologic conditions would not appear to be a significant factor in the alignment choice. Very similar geology is found along the proposed corridors and generally the same soil and geologic conditions would be encountered along each alignment.

The only significant geologic hazards appears to be lava tubes and lava flows. Lava tubes are present along all of the candidate alignment corridors.

The potential for lava flows across the transmission alignment is present for all of the corridors. The most probable source of such lava flows would the East Rift Zone, which contains the initial sections of both segments A and D. A longer section of segment D is located within the East Rift Zone (approximately 15,000 feet) than for segment A (approximately 5,000 feet). However, segment A was intercepted by a lava flow from the East Rift Zone as recently as 1840. It does not appear that either corridor is significantly less likely to be overrun by a lava flow.

MITIGATION MEASURES

Mitigation measures for lava tubes is discussed in the section on construction considerations.

Mitigation measures for lava flows does not appear to be economically feasible for this type of project.

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The following Plates and Appendix are attached and complete this report.

Plate 1	Map of Area
Plate 2	Plot Plan
Plate 3	Generalized Soils Map
Plate 4	Geologic Map
Appendix	Field and Laboratory Data

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Respectfully submitted,

DAMES & MOORE
A Professional Limited Partnership

Masanobu R. Fujioka, P.E.
Consultant

MRF/lml(3522B/1698)1269-078-11
(Three copies submitted)

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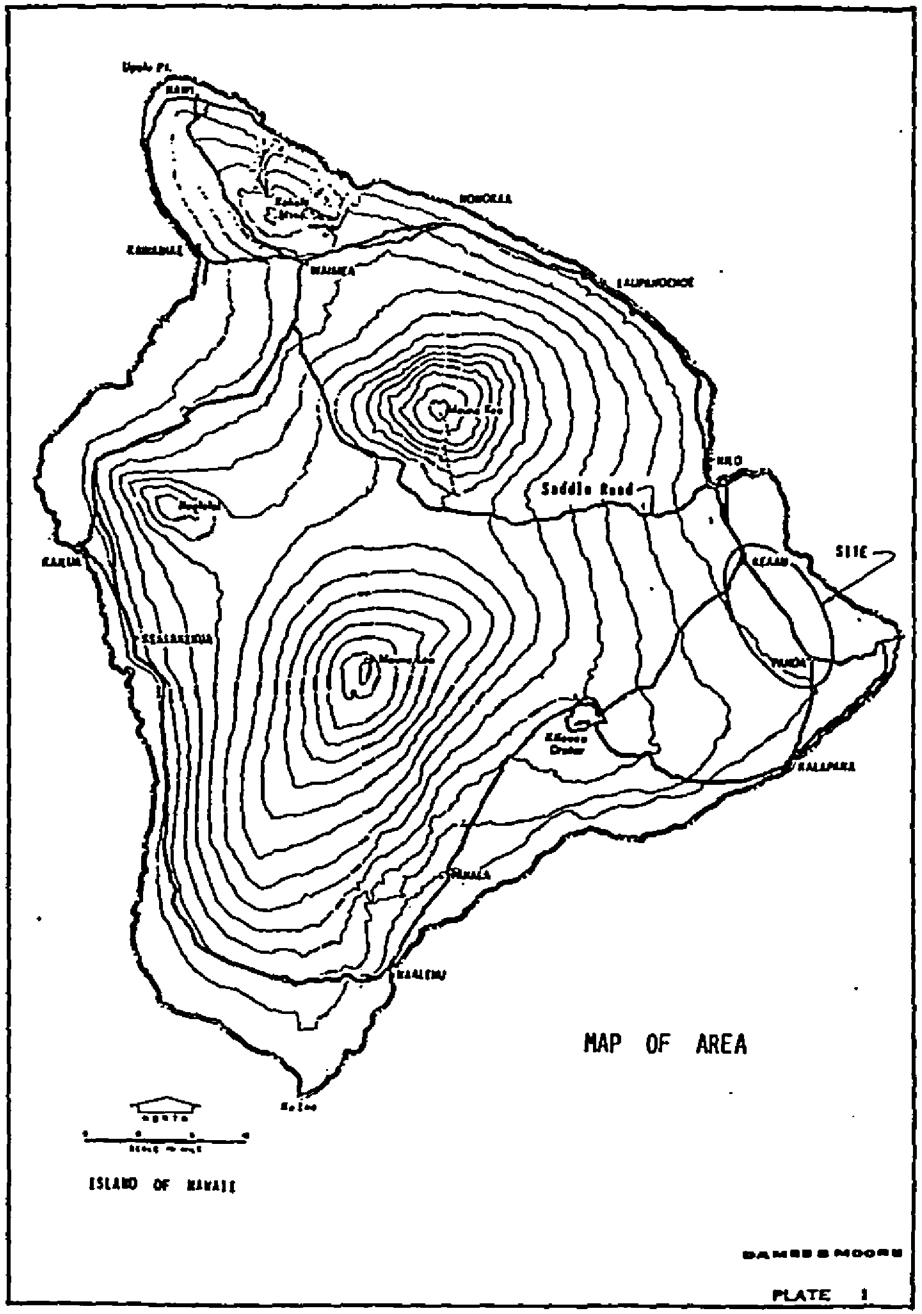


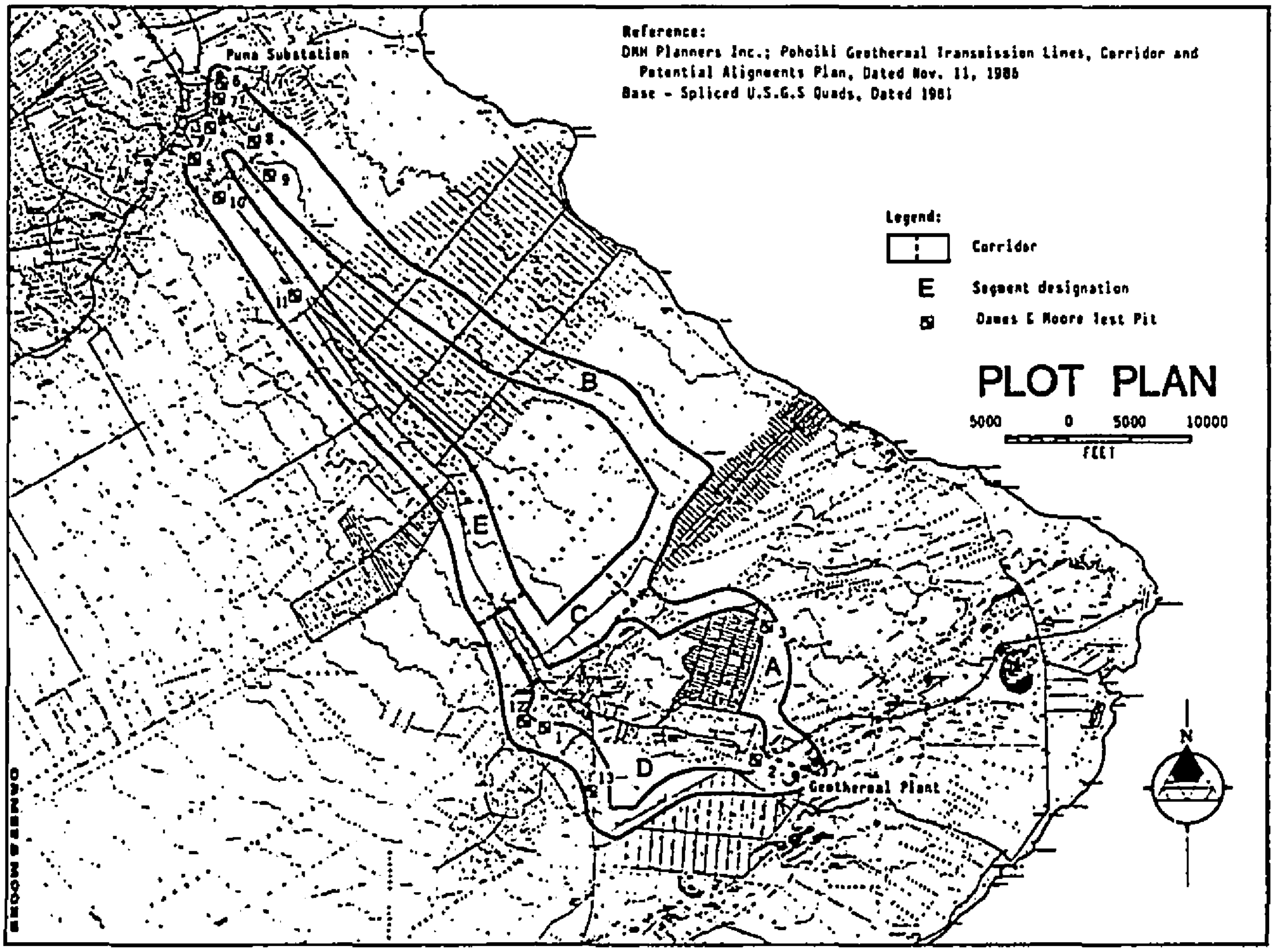


PLATE 2

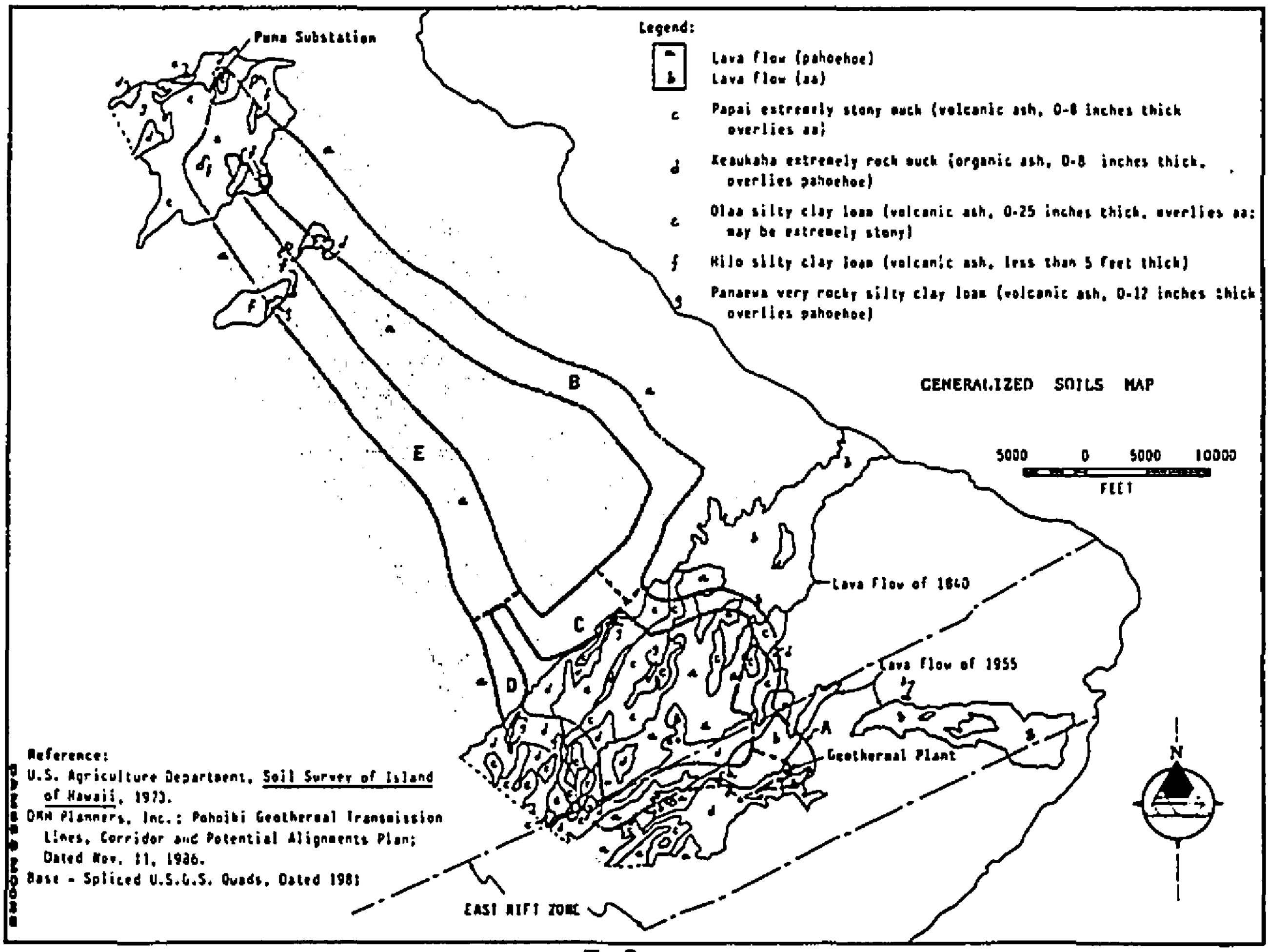
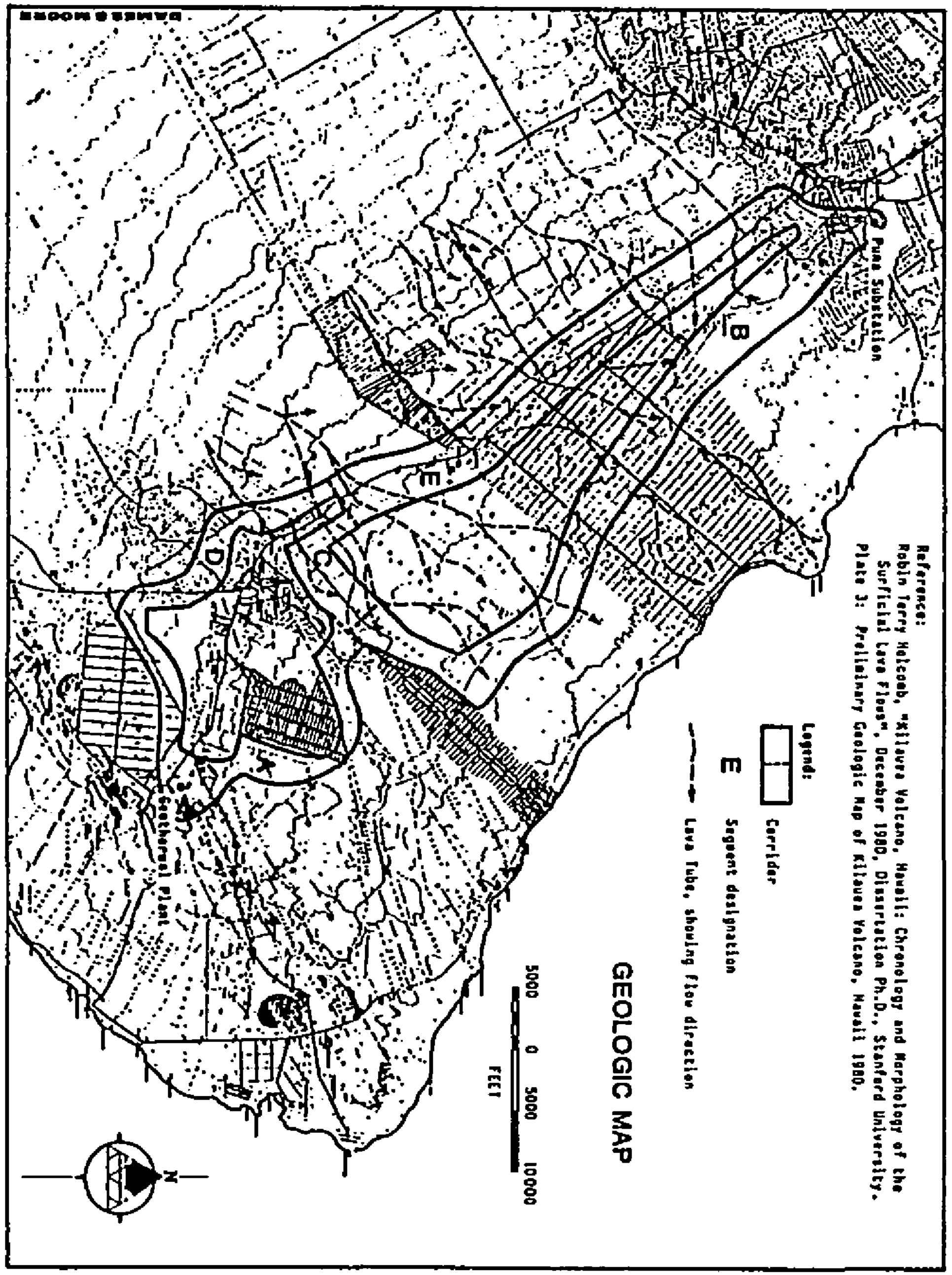


PLATE 3

PLATE 4



APPENDIX

FIELD INVESTIGATION AND LABORATORY TESTING

FIELD INVESTIGATION

The field investigation was conducted in two parts. The first part consisted of a helicopter fly-over of the selected corridors with the project team. This fly-over was performed on September 26, 1987. During the fly-over, we used a video camera to record the aerial view of the selected corridors. Later review of the video tape assisted us in identifying significant topographic features and access constraints, such as dense vegetation and rugged terrain.

The second part of the field investigation consisted of a field reconnaissance of the corridors during which we examined in more detail the general site conditions identified during our preliminary studies and helicopter fly-over. We examined topographic features, geologic features, and conditions, soil and rock types, and natural hazards during the week of January 26, 1987.

Access through the corridors was provided by a network of paved and non-paved roads. The large size of the corridor region and the often rugged and densely vegetated terrain restricted most of the field reconnaissance to areas accessible by roads.

Thirteen shallow test pits, 0.3 to 1.5 feet in depth, were excavated with hand auger equipment at selected locations. Disturbed soil samples were retained for further examination and laboratory testing. Soil types were classified in accordance with the Unified Soil Classification System shown on Plate A-1.

In general, test probing with the hand auger advanced until rock was encountered. Logs of the test pits are summarized on Table A-1.

LABORATORY TESTING

Selected samples of the near surface soils obtained in the field investigation were subjected to laboratory testing to aid in evaluating their engineering properties. The testing consisted of moisture determinations, grain size analyses, Atterberg limits tests, and an expansion test.

Moisture Determinations - Moisture content determinations were performed on each soil sample. The test results are presented in the Summary of Test Pits, Table A-1.

Atterberg Limits Tests - Four Atterberg limits tests were performed on selected soil samples to aid in the classification of these materials. The tests were performed in accordance with ASTM Test Method D 4318-84. The test results are presented on Plate A-2 and in the Summary of Test Pits, Table A-1.

Grain Size Analysis - Three grain-size analyses were performed on representative soil samples to aid in the classification of these materials. The tests were performed in accordance with ASTM Test Method D 422-84. The test results are presented as gradation curves on Plate A-3.

Percent Expansion Test - One expansion test was performed on a selected sample of organic silty clay obtained from Test Pit 6 to determine its shrink-swell characteristics. The expansion test was performed by placing a one-inch thick remolded sample of soil into a consolidometer and applying a surcharge load of 100 pounds per square foot to the sample. The sample was then immersed in water and the linear volumetric expansion recorded. The results of this test are listed below.

		Initial		Final		
Test Pit Number	Depth (ft)	Moisture (%)	Dry Density (%)	Moisture (%)	Dry Density (%)	Percent Expansion
6	0-1.0	31.5	86.5	33.5	86.4	0.5

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The following Table and Plates are attached and complete this Appendix:

Table A-1 - Summary of Test Pits

Plate A-1 - Unified Soil Classification System
Plate A-2 - Atterberg Limits
Plate A-3 - Gradation Curves (Grain Size Analyses)

TABLE A-1

SUMMARY OF TEST PITS

Test Pit No.	Depth (ft)	Unified Soil Class.	Soil Description	Moisture Content	Atterberg Limits (%) PL	LL	PI	Test Reported Elsewhere
1	0-0.3	OH	Dark brown sandy clayey silt with some gravel, roots, and some organics, moist	30	87	139	52	
	0.3		Gray basalt					
2	0-0.3	GP-GM	Dark brown silty sandy gravel with roots and decomposed vegetation, moist	13				G
	0.3		Gray basalt					
3	0-0.5	GP	Dark brown to black silty sandy gravel with trace of organics, moist	5				G
	0.5		Gray basalt					
4	0-1.0	ML	Dark brown sandy clayey silt with some basaltic gravel, lots of roots, and organics, moist	17				
	1.0		Gray basalt					
5	0-1.5	ML	Dark brown clayey silt with some sand and gravel and some roots, moist	130				
	1.5		Gray Basalt					
6	0-1.0	OH	Dark brown to black organic clayey silt with some sand, gravel, roots, and some decomposed vegetation, moist	63	67	85	18	Exp.
	1.0		Gray basalt					
7	0-0.5	GP-GM	Dark brown silty sandy gravel with some roots, moist	11				G
	0.5		Gray basalt					
8	0-1.5	ML	Dark brown clayey silt with some sand and gravel, and some roots, moist	24				
	1.5		Gray basalt					

Continuation ...

TABLE A-1
Page 2

SUMMARY OF TEST PITS

Test Pit No.	Depth (ft)	Unified Soil Class.	Soil Description	Moisture Content	Atterberg Limits (%) PL	LL	PI	Test Reported Elsewhere
9	0-1.5	ML	Brown clayey silt with some sand and gravel and some roots, moist	76				
10	0-0.5	OH?	Dark brown sandy clayey silt with some gravel and lots of decomposed vegetation, moist	33				
	0.5		Gray basalt					
11	0-1.5	OH	Reddish brown clayey silt with some roots, moist	239	191	256	65	
12	0-1.0	MH	Dark brown sandy clayey silt with some gravel and some roots, moist	47	112	171	59	
	1.0		Gray basalt					
13	0-1.0	ML	Dark brown sandy clayey silt with basaltic gravel and some roots, moist	55				
	1.0		Gray basalt					

Note: G - Designates grain size analysis performed, Refer to Plate A-3.

SOIL CLASSIFICATION CHART

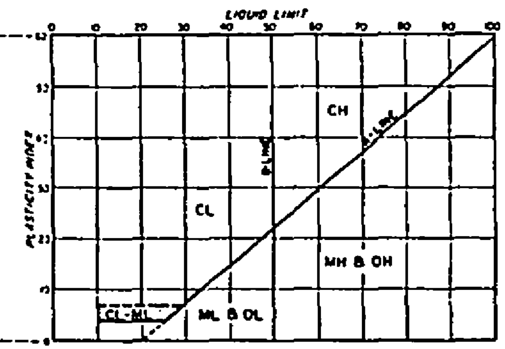
Major Divisions			Graphic Symbol	Letter Symbol	Typical Descriptions
[illegible]	[illegible]	[illegible]		GW	[illegible]
				GP	[illegible]
	[illegible]	[illegible]		GM	[illegible]
				GC	[illegible]
[illegible]	[illegible]	[illegible]		SW	[illegible]
				SP	[illegible]
	[illegible]	[illegible]		SM	[illegible]
				SC	[illegible]
[illegible]	[illegible]	[illegible]		ML	[illegible]
				CL	[illegible]
				OL	[illegible]
[illegible]	[illegible]	[illegible]		MH	[illegible]
				CH	[illegible]
				OH	[illegible]
[illegible]				PT	[illegible]

GRADATION CHART

Material Size	Particle Size			
	Lower Limit		Upper Limit	
	Millimeters	Sieve Size	Millimeters	Sieve Size
Sand				
Fine	[illegible]	[illegible]	[illegible]	[illegible]
Medium	[illegible]	[illegible]	[illegible]	[illegible]
Coarse	2.00	[illegible]	[illegible]	[illegible]
Gravel				
Fine	[illegible]	[illegible]	[illegible]	[illegible]
Coarse	[illegible]	[illegible]	[illegible]	[illegible]
Cobbles	[illegible]	[illegible]	[illegible]	[illegible]
Boulders	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

PLASTICITY CHART



NOTES

[illegible]

SAMPLES

[illegible]

UNIFIED SOIL CLASSIFICATION SYSTEM

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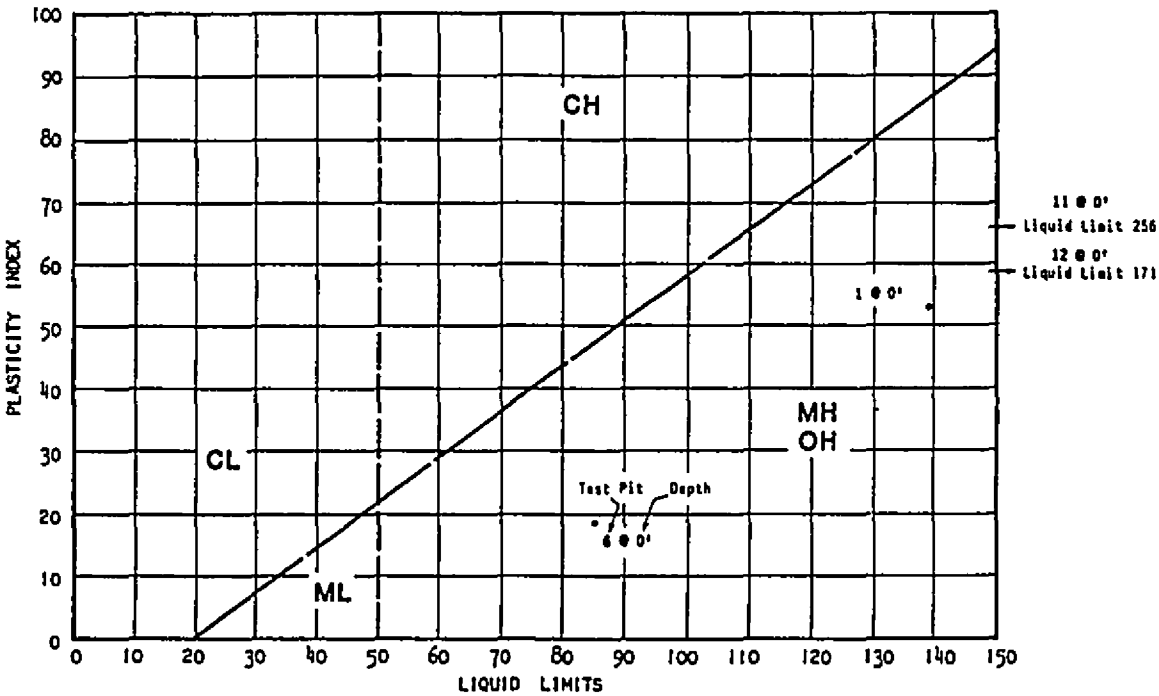
PLATE A-1



ATTERBERG LIMITS

PLATE A-2

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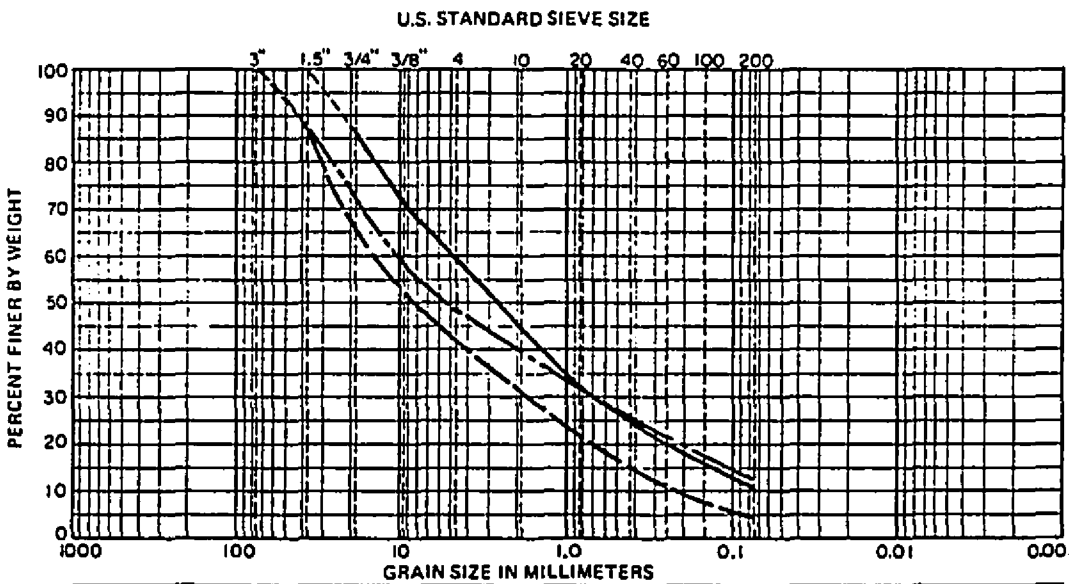

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

TEST PIT	DEPTH	CLASSIFICATION		NAT. W C	LL	PL	PI	
2	Surface	GP-GM	Dark brown sandy clayey silt with some gravel, roots and organics, moist					———————
3	Surface	GP	Dark brown to black silty sandy gravel with trace organics, moist					—— ————
7	Surface	GP-GM	Dark brown silty sandy gravel with some roots, moist					——— - ———

GRADATION CURVE

PLATE A-3

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