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PLANNING/DEVELOPMENT OFFICE
DEPARTMENT OF AGRICULTURE

EXECUTIVE CHAMBERS
HONOLULU

JOHN WAIHEE
GOVERNOR

May 24, 1993

TO: The Honorable Yukio Kitagawa, Chairperson
Department of Agriculture

SUBJECT: Final Environmental Impact Statement for the Oahu Livestock Agricultural Park

I am pleased to accept the Final Environmental Impact Statement for the Oahu Livestock Agricultural Park as satisfactory fulfillment of the requirements of Chapter 343, Hawaii Revised Statutes. This environmental impact statement will be a useful tool in the process of deciding if the action described therein should be allowed to proceed. My acceptance of the statement is an affirmation of the adequacy of that statement under the applicable laws and does not constitute an endorsement of the proposed action.

When the decision is made regarding the proposed action itself, I expect the appropriate legislative bodies and governmental agencies to consider if the societal benefits justify the economic, social and environmental impacts which will likely occur. These impacts are adequately described in the statement and, together with the comments made by reviewers, provide useful analysis of the proposed action.

for JOHN WAIHEE

c: Mr. Brian J. J. Choy

FINAL ENVIRONMENTAL IMPACT STATEMENT

O'AHU LIVESTOCK AGRICULTURAL PARK

M&E Pacific, Inc.
Consulting Engineers

1993 - Oahu - FEIS - Oahu Livestock

FINAL ENVIRONMENTAL IMPACT STATEMENT

O'AHU LIVESTOCK AGRICULTURAL PARK

FILE COPY

Prepared for:

State of Hawaii
Department of Agriculture

Yukio Kitagawa
Yukio Kitagawa
Chairperson, Board of Agriculture

Prepared by:

M&E Pacific, Inc.
Engineers and Architects
Pauahi Tower, Suite 500
1001 Bishop Street
Honolulu, Hawaii 96813-3497

April 1993

Final Environmental Impact Statement

Project: O'AHU LIVESTOCK AGRICULTURAL PARK

Alternative Locations:
a. PALIKEA UPLANDS, 'EWA, O'AHU
b. KAHUKU, KO'OLAULOA, O'AHU

Proposing Agency:
STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

Accepting Authority:
GOVERNOR,
STATE OF HAWAII

Consultant:
M&E PACIFIC, INC.
PAUAHI TOWER, SUITE 500
1001 BISHOP STREET
HONOLULU, HAWAII 96813-3497
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O'AHU LIVESTOCK AGRICULTURAL PARK

FINAL ENVIRONMENTAL IMPACT STATEMENT
April 1993

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FIGURES

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PHOTOGRAPHS

FOREWORD

Subsequent to the preparation of this document, the State of Hawaii and the Estate of James Campbell will enter into an agreement for the purchase by the State under condemnation of certain lands owned by the Estate at Kahuku, Ko'olauloa, O'ahu. These lands are presently under lease by the State as the site of the existing Kahuku Agricultural Park, and will be further developed for the purpose of the Livestock Agricultural Park. Throughout this document, the lands to be acquired are the second of the two sites described in the various sections.

The primary reasons for selecting the Kahuku site for the Livestock Agricultural Park (LAP) are:

1. ***Minimal expenditure of public funds.*** **The State has already invested in infrastructure improvements for an agricultural park at Kahuku, and had planned to purchase the property in fee simple in any case to provide for perpetual agricultural use of the site. Acquisition of these lands for the LAP avoids the expense of purchase of a second site, as well as benefits from the roads, water system, and drainage improvements already constructed at the Kahuku site.**

2. ***Expedited project development.*** **During the consultation phase in preparation of this document, Campbell Estate declared its strong opposition to a livestock agricultural park being located on its lands at Kunia. In view of the need to develop this project as expeditiously as possible to provide needed relocation area for O'ahu's dairy industry, agreement was reached on State purchase of the lands at Kahuku.**

3. ***Waste utilization.*** **Farmers at and nearby the Kahuku site have expressed interest in obtaining the solid and liquid by-products from the centralized animal waste management facility, for use as soil amendment and nutrient-rich irrigation water. Having a ready market for these waste by-products increases the economic feasibility of the project.**

PREFACE

An introductory paragraph is provided for each section in the main environmental impact statement which summarizes the major points. The reader can scan these summaries for an overview; then one may continue into the sections for greater detail if additional information on a particular topic is sought.

Several agencies have already submitted comments on significant aspects of the proposed project during preliminary waste management planning. Most of the technical details are provided in the appendices. The references for the appendices are contained in the Reference Section following the main body of the environmental impact statement, as well as individual appendices.

Throughout much of the report, both the SI (metric) and English system of measurement are used. Frequently, conversions are given for values as they appear. A table of useful conversions is provided after the references for the reader. The metric system is rapidly becoming the standard in both agricultural and environmental engineering fields. Metric data commonly appears in the literature in both fields, and thus comparison of calculation results to literature and design references is facilitated by the use of the metric system.

SUMMARY

Brief Description of Proposed Action

The State of Hawaii, Department of Agriculture proposes to acquire in perpetuity between 750 to 900 acres of existing agriculturally-zoned land for a livestock agricultural park on O'ahu. In addition, the Department of Agriculture will oversee the construction of infrastructure facilities that provide a consistent standard for the waste management, water supply and irrigation, electrical power and waste recovery systems. This project is a demonstration of new technology for the dairy industry in Hawai'i.

The alternatives considered include no action, relocation of the dairy industry to a neighbor island, and alternative sites on O'ahu.

After analysis of eighteen sites on O'ahu, the potential number has been pared to two candidates —Palikea Uplands in the Kunia area and the Kahuku Agricultural Park. Environmental effects are expected at either site, and therefore it is appropriate to inform the public at this time of these alternatives, and provide an opportunity for discussion of the significance of the expected effects.

It is expected that a dairy operator might be among the first tenants of the agricultural park. Other tenants will include farms for vegetable and fruit cultivation. The ultimate development of the project provides capacity for one-fourth of the present dairy operations on O'ahu. The cost of the project construction is approximately $40 million over the project life. This includes estimates of private construction costs and cost of land acquisition. Preliminary engineering studies are expected to develop further detailed cost information, including alternative waste management plans.

Significant Beneficial and Adverse Impacts

The major benefits of the project include:

1) assurance that dairy operators can have long-term leases for land that will support investments for improved productivity and for maintaining economic viability of the industry without displacement by urbanization;

2) provide price stabilization during periods of market disruption (e.g., transportation problems) by insuring island-fresh milk supplies to consumers;

3) provide additional land not available at present individual operations, and incorporate new technology to promote recycling of waste in an environmentally sensitive and agriculturally productive manner;

4) protect the dairy segment in the diversified agricultural sector of the State's economic base, and in so doing, the approximately 300 to 400 jobs related to production, processing, and distribution of their products;

5) preserve life-style options for O'ahu's population in agriculture; and

6) preserve and maintain open space.

There may be adverse environmental impacts that must be balanced against the project benefits. It is not certain that these impacts will be significant, but it is possible that the primary effects that will accompany the project include:

1) the potential for increased soil erosion areas if pasture are overgrazed by dairy cattle,

2) the potential for higher concentrations of biological and chemical constituents in storm water originating from the project site,

3) the potential, at the Kahuku site, for effects on wetland hydrologic balance,

4) the potential for odors and insect nuisances in nearby communities, and

5) the potential for high levels of nitrate in ground water if manure management recommendations are abused.

The secondary effects that might occur as a result of these include:

1) decrease in beneficial uses of surface water such as fishing and recreation and wildlife management in downstream water bodies,

2) difficulty managing water levels in ponds for wildlife management in the James Campbell Wildlife Refuge,

3) complaints and lawsuits brought by neighboring residences against farmers and dairy operators, and

4) additional cost of water treatment or new water source development.

This document presents risk assessments of the public health aspects of these potential effects, i.e., the probability of their occurrence and the consequences of their occurrence.

Other non-health impacts, e.g., to ecosystems, cultural remains, and surface water quality are not considered significant because of proposed mitigation measures.

Proposed Mitigation Measures

There are proposed measures to reduce the significance of potential effects noted above. As the nature of the effects are better defined, additional measures will be considered in greater detail, as necessary.

Mitigation measures for reducing soil erosion, sedimentation downstream, and impacts upon beneficial uses include:

1) nonstructural measures—intensive grazing management, limited grazing pressure on steep slopes, and prohibition of land use on severe slopes; and

2) structural measures—installing a detention reservoir to confine storm runoff from dairy and waste management operations.

Mitigation measures for reducing ground water pollution and adverse effects include:

1) a manure management plan to minimize nitrogen emissions from fields during fertilization and at all times at dairy operations;

2) collection, treatment, and reclamation of manure to reduce pollutant delivery to receiving waters; and

3) development of backup potable water sources at or near the agricultural park site.

Mitigation measures for odor and insect control include:

1) requiring anaerobic (completely enclosed) primary treatment and storage of animal waste;

2) chemical, biological, and physical insect control measures; and

3) coordination by farmers of the timing and climactic conditions to promote less offensive situations when manure is used for fertilizer.

Project Alternatives Considered

Alternatives to the proposed project include:

1) no action;

2) similar action sited at alternative sites, including neighbor islands; and

3) action to increase the size of present dairies at existing farm locations.

Unresolved Issues

In accordance with the provisions of Title 11, Chapter 200, Environmental Impact Statement Administrative Rules, the Department of Agriculture has initiated early coordination with other agencies (see Section Seven). This coordination has helped to identify issues and alternatives.

The major unresolved issues and additional consultation include:

1) potential for ground water contamination and backup potable water supply—consultation with the State Department of Health and Board of Water Supply;

2) the identification of individual best management practice(s) for reduction in sediment production and nutrient loading in receiving waters—consultation with U.S. Department of Agriculture, Soil Conservation Service, and the Soil and Water Conservation District;

3) mitigation of odor and vector control—consultation with potential livestock operators, neighboring communities, the Department of Health, and the Department of Agriculture; and

4) the significance of potential effects on wetland wildlife refuges and appropriate mitigation measures—consultation with U.S. Department of Interior, Fish and Wildlife Service.

The identification of agencies above is not intended to restrict consultation; other parties may wish to become consulted parties during the environmental impact statement review process. However, the above parties at a minimum will be consulted for their expertise and interest concerning these issues.

Compatibility With Land Use Plans and Policies

The proposed action supports constitutionally-mandated agricultural policies of the State of Hawaii. In addition, the selected site is compatible with the proposed action from the standpoint of the existing State Land Use Law, county zoning, and existing adjoining agricultural land use. However, a lease covenant presently restricts livestock production at the Kahuku site; revocation of this covenant will be sought. The proposed project and adjacent agricultural operations may mutually benefit from close association.

The present State policy is promotion of agriculture on agriculturally-zoned land in windward and central O'ahu and directing urban growth to the City of Kapolei on the 'Ewa plain. The proposed project ensures that agricultural operations important to the State's economy and welfare have a chance to survive and become more productive.

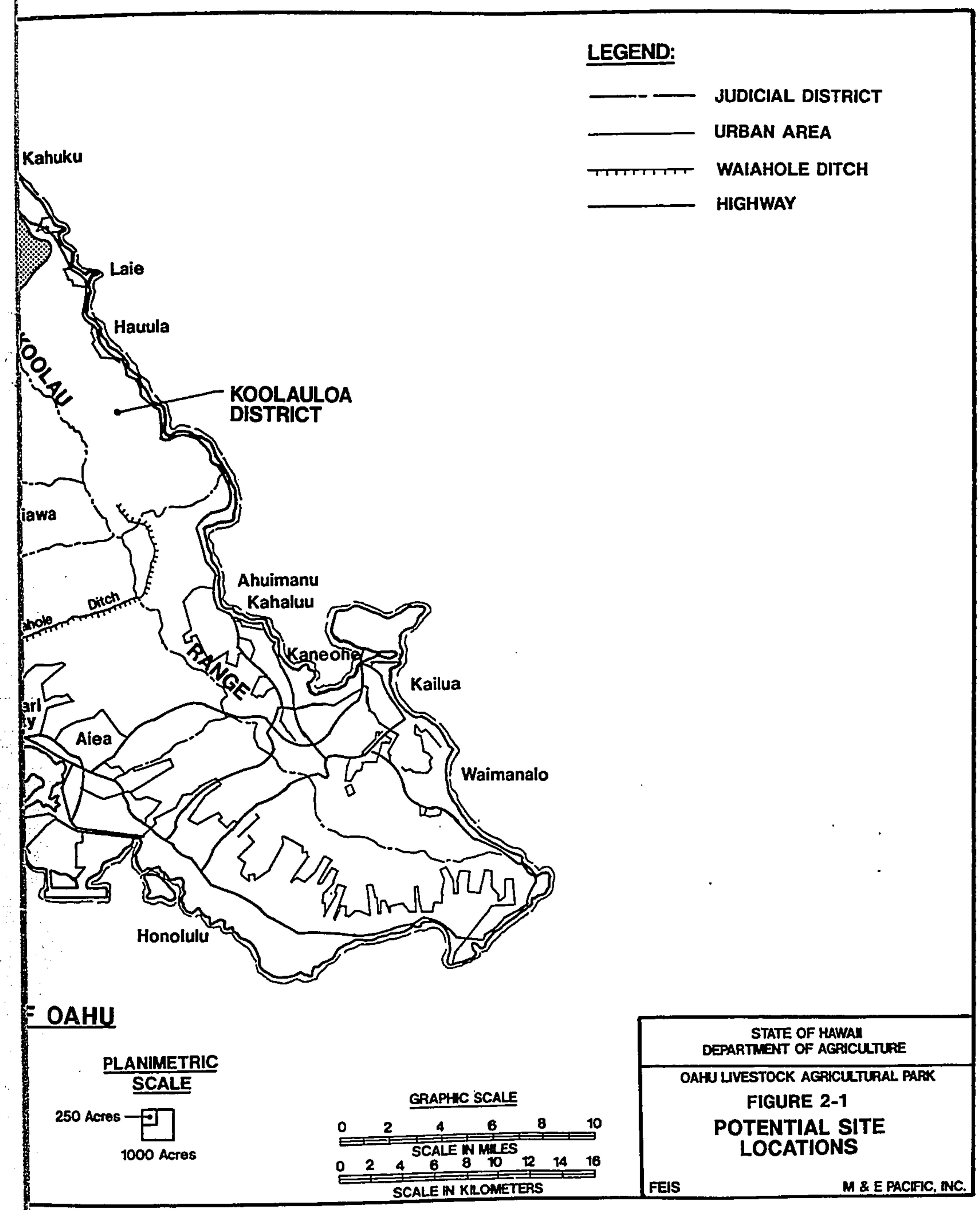
SECTION ONE — INTRODUCTION

Summary of Section One. **The State of Hawaii, Department of Agriculture proposes to acquire land and construct facilities to support a diversified livestock agricultural park at either the Palikea Uplands (the land area *mauka* of Oahu Sugar Company fields in Kunia) in the 'Ewa District, or at the Kahuku Agricultural Park in the Ko'olauloa District of O'ahu. The project is to be phased according to planning factors, tenant requirements, and demonstration of environmental compatibility. Approximately 750 to 900 acres of fallowed sugarcane land are to be included in the park, depending upon the selected site. The environmental impact statement must be accepted by the Governor. In addition, future studies, including a preliminary engineering report that will recommend the waste management system must be completed.**

I. Identification of Proposed Action

The State of Hawaii, Department of Agriculture proposes to acquire land on O'ahu to insure its long-term availability for livestock agricultural operations. Two alternative sites are under consideration. The land at both is presently owned by the Estate of James Campbell. The Palikea Uplands site is identified on Figure 2-1. It is located in the tax map First Division, Zone 9, Section 2, and includes Plat 04, portions of parcels 5 and 6. The Kahuku site is also identified on Figure 2-1. It is located in the First Division, Zone 5, Section 6, Plat 05 (parcel 9), Plat 06 (portions of parcel 19), and Plat 08 (portion of parcel 2). The Department of Agriculture intends to acquire the land by condemnation using State funds and develop a livestock agricultural park subdivision which will be offered for long-term lease to dairies which are being displaced. This document assesses the environmental effects of acquiring either site and developing it as a livestock agricultural park.

The land acquisition and project development may occur in several increments, subject to budgetary and planning factors. This environmental impact statement is intended to assess the entire project envisioned. The decision concerning which site to select will be made by the Department of Agriculture, with the concurrence of the Governor.



STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 2-1

POTENTIAL SITE LOCATIONS

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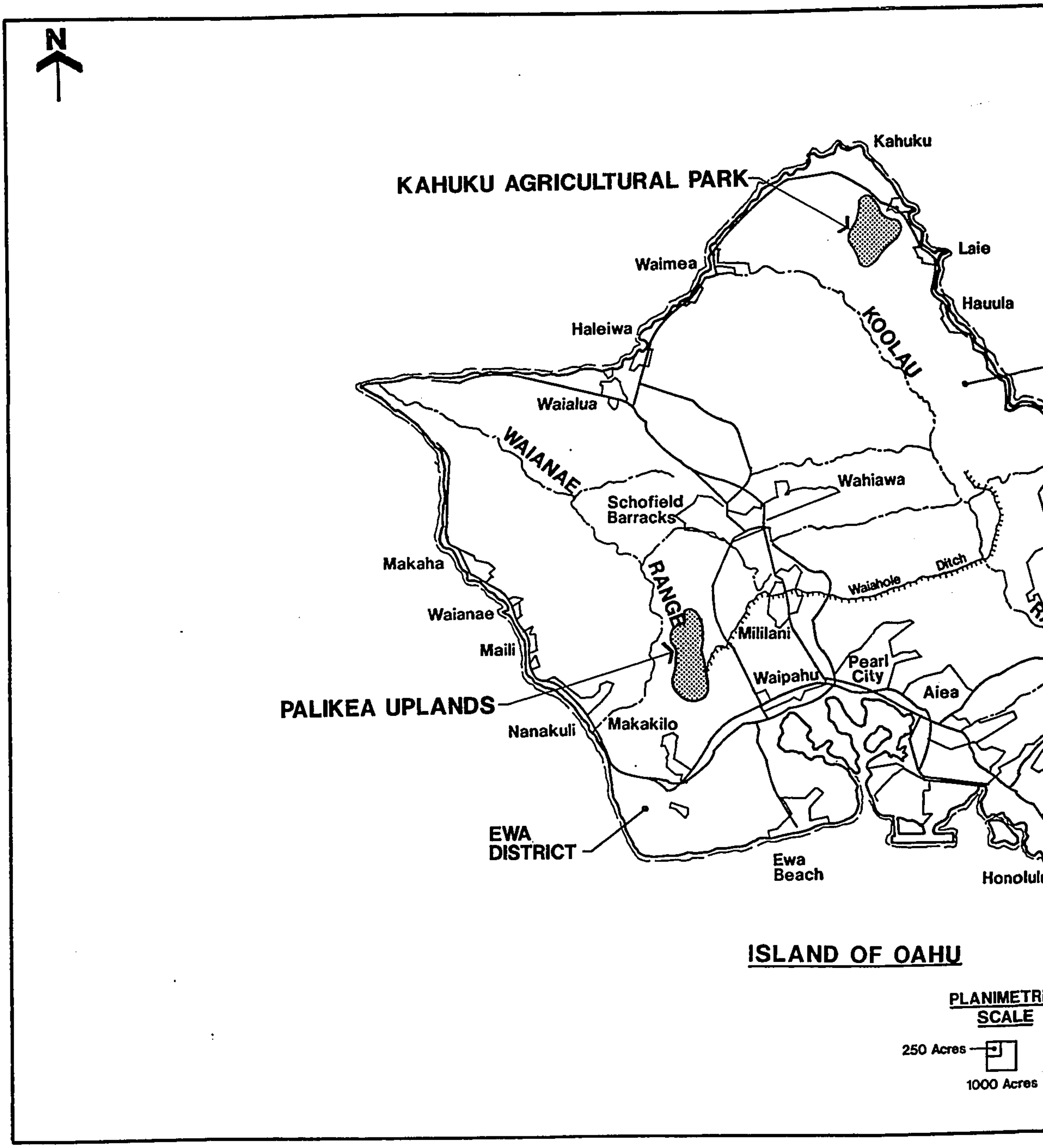
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KAHUKU AGRICULTURAL PARK
Kahuku
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Schofield Barracks
Makaha
RANGE
Waiahole Ditch
Waianae
Mililani
Maili
Pearl City
Waipahu
Aiea
PALIKEA UPLANDS
Nanakuli
Makakilo
EWA DISTRICT
Ewa Beach
Honolulu
ISLAND OF OAHU
PLANIMETRI
SCALE
250 Acres
1000 Acres

II. Identification of Proposing Agency

The proposing agency is the State of Hawaii, Department of Agriculture; the Planning and Development Office is the lead organizational element. The preparer of this environmental impact statement is M&E Pacific, Inc.

III. Identification of Funding Source

The source of funds for this project is Act 316, SLH 1989, as amended by Act 296, SLH 1991.

IV. *Identification of Accepting Agency*

The accepting authority for the environmental impact statement is the Governor, State of Hawaii, through the Office of Environmental Quality Control.

V. Timing and Phasing

The O'ahu Livestock Agricultural Park project concept was developed over a period of several years. In 1989, a "white paper" was prepared to set forth the concept to the Governor. The project has since been included in budgets of the Department of Agriculture.

In 1990, a contract (subsequently amended) was awarded by the Department of Agriculture for preparation of a waste management plan, environmental assessment, and draft environmental impact statement. In addition, a final environmental impact statement and a preliminary engineering report will be prepared.

Land acquisition and surveying work are scheduled for 1993, and it is anticipated that a portion of the project will be ready for construction in 1994.

The goal is to provide initial facilities for the first tenants to start operation in 1994 or 1995. Total development of the project is expected to require several years, depending upon the ability of tenants to obtain financing to make improvements for agricultural lots, construction of new facilities, and time for relocation.

The entire project, as presently envisioned, could ultimately accommodate approximately two to three of O'ahu's present dairy operations, with some areas to be set aside for other diversified agriculture, including poultry operations. The initial tenants are expected to be primarily dairies. The major phases in terms of land and facilities development will be developed in the preliminary engineering report and lease cost analysis and site appraisal report. Another purpose of the preliminary engineering report is to identify the details of the component processes for waste management, including a cost comparison of alternative technologies. It is possible that a demonstration project may be recommended as the first phase of project implementation.

VI. Identification of Consulted Agencies

Early coordination of the proposed action was sought with the following organizations and agencies:

State of Hawaii:

Department of Agriculture
Department of Health
Department of Land and Natural Resources
University of Hawaii Water Resources Research Center
University of Hawaii Environmental Center
University of Hawaii Cooperative Extension Service
University of Hawaii College of Tropical Agriculture and Human Resources

City and County of Honolulu:

Board of Water Supply
Department of Housing and Community Development

U.S. Government:

Department of Agriculture, Soil Conservation Service
Department of the Interior, Fish and Wildlife Service

Private:

Estate of James Campbell
Oahu Sugar Company

Hawaiian Sugar Planters Association
Mikilua Poultry Farm, Inc.
Mountain View Dairy
Kahua Beef Company
Oshiro Farm
Bank of Hawaii
INTECH of Hawaii
50th State Dairy Cooperative

Consultation has already taken place during the development of a preliminary waste management plan for the agricultural park. The focus of this consultation has been addressing public health concerns.

The State Department of Agriculture has convened an *ad hoc* advisory committee including livestock industry representatives. This committee was consulted during the process concerning overall planning for the park.

Additional consultation has taken place, including with the neighboring community in Kahuku, during preparation of the environmental impact statement.

SECTION TWO — GENERAL DESCRIPTION OF PROPOSED ACTION

I. Technical Characteristics

Summary of Subsection I. Land and water will be used for animal husbandry. The principal operations will be dairies. At both sites, moderately sloping land gives way to steeper sloping land fronting the mountains. The moderately sloping upland can be used for various agricultural operations: dairy barns, grazing, waste management facilities, and other dairy operations such as calf pens, feed, and forage storage. High elevation land can be used for extensive grazing, tree crops, and reforestation, but these are future considerations.

Waste management alternatives have been studied. The system will be planned on a closed loop concept. Wastes are to be recycled as resources; they can be bound in _the feed-to-animal-to-feed_ production cycle. The construction cost is significant. However, a closer examination of the cost-effectiveness of the health risk versus emissions trade-offs will be made concurrently with the preliminary engineering report.

A. General

The potential sites will provide land that can be developed into lots for lease to the livestock industry on O'ahu. The concept of a livestock park is new to Hawai'i; however, agricultural parks have been developed for other diversified agriculture. The size of each dairy varies. Lot sizes between 20 to 200 acres are being considered, depending upon the site. In addition, it is proposed that pasture or forage crops be grown to supplement the animals' feed ration and to manage on-site nutrient cycles from manure. The livestock park is considered a demonstration of manure management technology in Hawai'i because dairies have traditionally operated dry lot systems.

Each dairy operation will be independently constructed and managed. There are different feasible methods for waste collection and treatment, but the waste management and disposal goals will be common. Treatment operators are expected at a centralized facility.

New environmental regulations require rethinking the way dairies operate. All of the traditional activities for a modern dairy, and some new activities, such as energy recovery from waste management and materials recycling, can be contained on the site. Photo 2-1 shows the features of a modern dairy being considered as a model for the livestock project. Note that in addition to animal waste digester and energy recovery facilities, forage crops are being grown to supplement the animals' feed ration. The livestock park is considered to be a demonstration of this self-contained approach, in as far as waste management is concerned. For example, if land for forage production and pasturage are provided, some potential pollutants can be captured on-site in nutrient cycles, and the cost of importing feed will be reduced. However, the overall cost-effectiveness may or may not be increased as the amount of recycling that can be considered at a site is based upon terrain factors, micro climate, and waste management processes.

The potential sites (see Photos 2-2 and 2-3) are located on moderately sloping, fallowed sugarcane lands fronting mountain ranges. These lands are dissected by deep gulches. The terrain can be characterized into tiers or levels for planning purposes. These levels are described as "uplands" and "dissected" lands.

B. Uplands

The Palikea Uplands site is located in the physiographic province identified by the same name. The land is already buffered from non-compatible land uses by the cultivation activities of Oahu Sugar Company and Del Monte Pineapple. As long as there is land planted with sugar and pineapple, there is little need for an additional buffer zone or a land mass for buffer purposes.

The Kahuku site is in the physiographic province identified as the Kawailoa dissected upland. It also is buffered from the community by the surrounding agricultural activities: the Kahuku Agricultural Park and the site of the former Kahuku Agriculture Company/Pomai, Inc. The latter operated a guava orchard and puree factory. These lands may be leased for other diversified agricultural use in the future.

The uplands are broad slopes cut by deeply dissected gulches. They are transitional zones between broad undissected plains formed by the volcanic shields and the cliffs and valleys associated with the mountain ranges. These are the most usable areas for dairy operations.

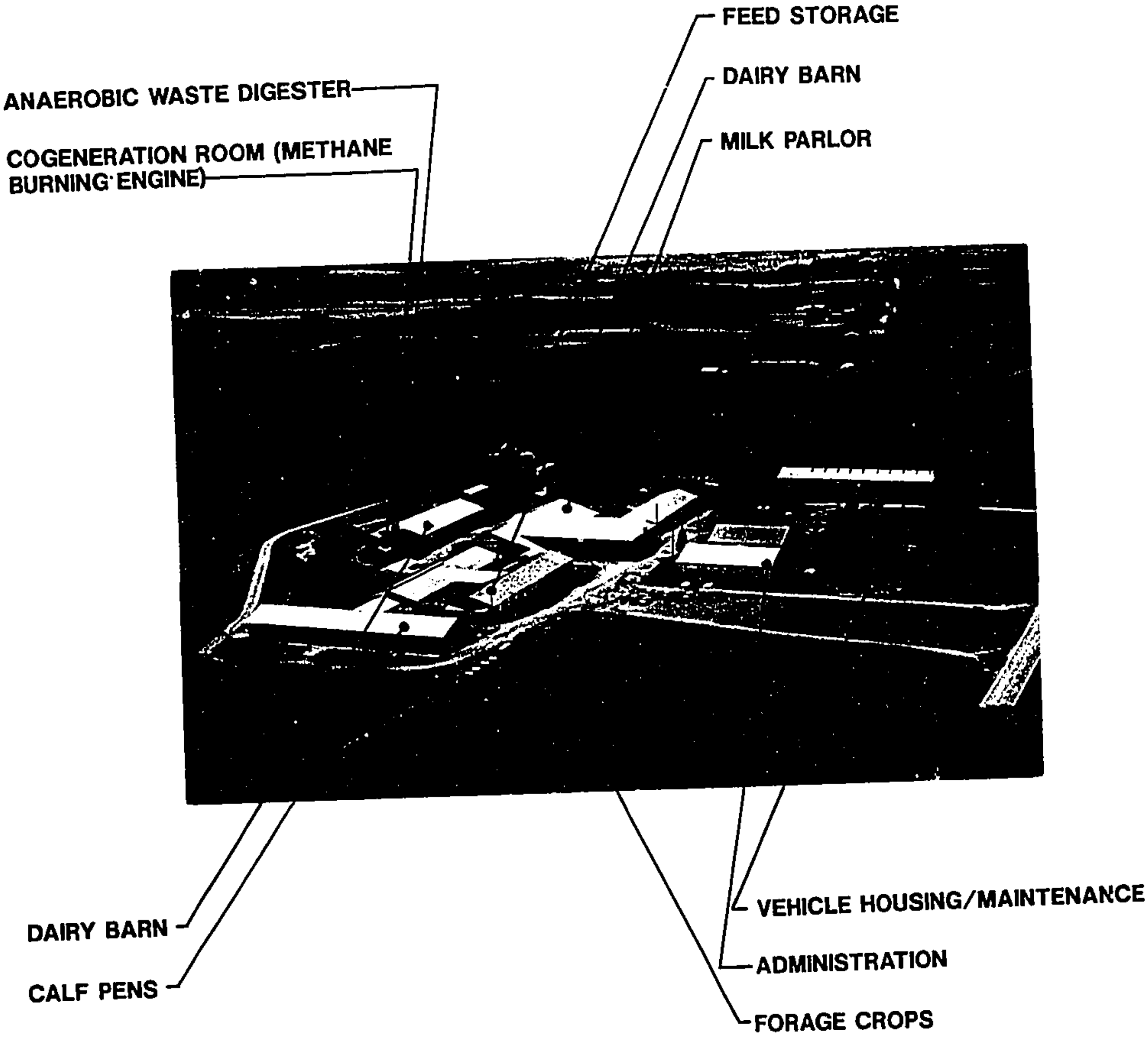

PHOTO 2-1
MODERN DAIRY FEATURES

PHOTO 2-2

PALIKEA UPLANDS SITE (VIEW LOOKING NORTH)

PHOTO 2-3
KAHUKU AGRICULTURAL PARK SITE (VIEW LOOKING SOUTH)

Hence, the upland areas are suitable for:

1) Dairy Operations — Some 15 to 40 acres per operation are needed for housing lactating and dry cows, depending on the number of animals. Space is allocated for feed and equipment storage, calf operations, milking parlors, hospital areas, office, and confinement of pregnant cows.

2) Forage Production and Pasture Areas — Forage crops grown for mechanical harvest require more level ground to allow for the use of harvesting equipment, and thus the uplands are preferable where slopes are moderate. At the Kahuku site, the existing farms near Kamehameha Highway have an opportunity for raising such crops. Grazing areas where cows can forage directly for food can be provided on moderate slopes and in gulches which can be used as buffer zones between land uses. Gulches have stands of koa-haole and guinea grass that can be used for grazing with proper management. However, lower elevations are better for younger calves since the evenings will be warmer. The more fertile soil and greater soil moisture in gulches will also allow for better quality forage throughout the year.

3) Nurseries — Two different types of nurseries are possible: i) potted foliage for export, and ii) flower nurseries, e.g., orchids. Certain areas are preferred because the wind speed will probably be slower and windbreaks (trees) easily grown. Although they are not the primary focus for this agricultural park, nurseries might also be developed on marginal lots such as steeper sloping land and near gulches.

4) Recreational Areas — It is not necessary to plan for such areas for now since the sites are buffered by other agricultural operations. In the event that this activity ceases, it would become desirable to maintain a buffer for the livestock park. The buffer could be planned to include an educational area for the public. Carefully designed, it could serve as an area where the urban O'ahu population can see and experience agricultural life by taking a simple walking/biking tour. Pasture and grazing operations mixed with vegetable growing and nurseries for ornamentals can be spaced properly to provide such an atmosphere.

5) Waste Management Facilities — Located close to the high animal concentrations, e.g., dairy barns and milk parlors, since such facilities are the major producers of waste, waste management facilities will store and treat waste. Drains

leading from pens with calves should lead directly to the waste treatment facility. Runoff from exercise lots and areas between covered facilities will be collected. Additional facilities that can be considered in the future include methane gas engine rooms for cogeneration of electricity from gas recoverable from treatment facilities, solids residual drying beds and composting rows for treatment of manure to be used as bedding in free stalls for the cows or for marketing as soil amendment and organic fertilizer. Additional discussion of waste management options follows in Section D.

C. Dissected Lands

The dissected lands are areas that are closer to the mountain foothills or gulches between the broad, sloping uplands. Use of these lands would be limited to operations that do not require extensive grading and earthwork. They could serve for the following activities:

1) Storm Water Detention — Requirements for a National Pollution Discharge Elimination System (NPDES) permit include confining storm water runoff from confined animal operations. These confinement facilities can be constructed in gulches where surface runoff concentrates. Detention facilities aid treatment of this nonpoint source of pollution.

2) Grazing Areas — Highlands are usually wetter areas. Pasture irrigation can be expensive since energy is needed to transport water. Hence, where possible, extensive grazing may be the choice for these areas where grasses may grow more rapidly. The density of grazing animals has to be carefully managed.

3) Tree Crops — In the rougher terrain, fruit crops or reforestation projects of native trees could be planted for windbreaks, boundaries and shade for animals. Fruit crops can be another form of diversified agriculture. Markets for tropical fruits like custard apple, star fruit, jack fruit, etc. can be explored.

4) Reforestation — While this activity may not appear to be a usual agricultural operation, the land offers this potential. Reforestation of the land with native trees, such as koa, is an environmentally-sound program which can add value to the site. Such programs can also provide refuge for native birds. In addition, there

CORRECTION

THE PRECEDING DOCUMENT(S) HAS
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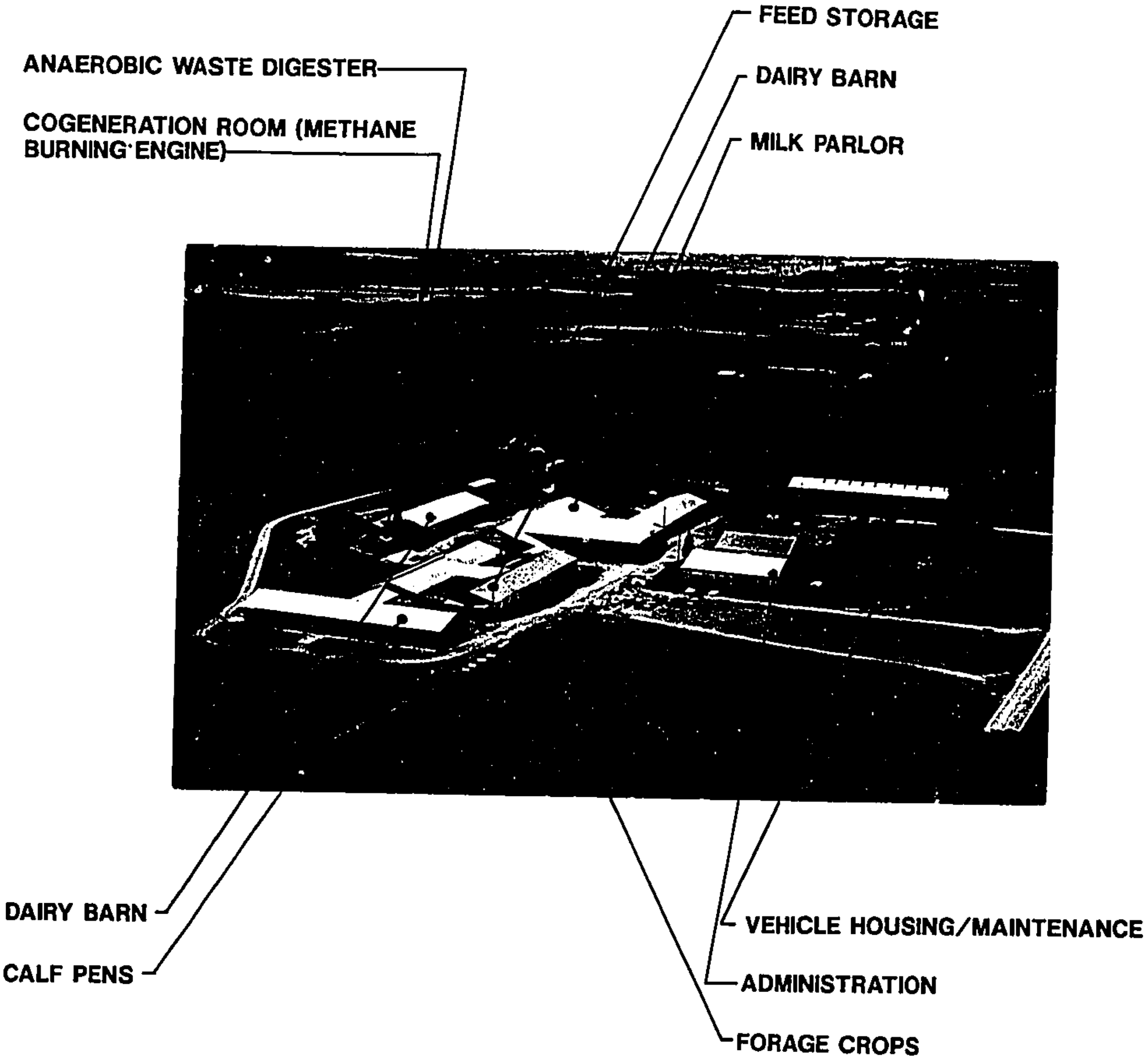

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4) Reforestation — While this activity may not appear to be a usual agricultural operation, the land offers this potential. Reforestation of the land with native trees, such as koa, is an environmentally-sound program which can add value to the site. Such programs can also provide refuge for native birds. In addition, there

probably is a market for their colorful feathers for Hawaiian arts and crafts, such as leis and hat ornaments. Dissected upland areas could serve this use.

D. Waste Management Plan Options

Recognizing that waste management is an essential component of site planning, the Department of Agriculture initiated a planning investigation to consider waste management options for the agricultural park. The scope of the planning involved 1) identifying rules, regulations and policies concerning animal waste management, 2) identifying animal husbandry factors impacting the amount and characteristics of wastes, 3) conducting a preliminary feasibility analysis to evaluate alternative treatment technologies, 4) comparing land requirements for livestock operations, including waste management, against land availability, and 5) identifying existing markets for recovered waste residuals.

In order to conduct this investigation, it was necessary to consider the livestock population that an agricultural park might be expected to confine after full development. If realized, this maximum level would take several years and phases to implement. At this time, exact forecasts of the number, type, and size of operations are not precise. Interested dairy operators are reluctant to make firm commitments until numerous factors (including waste management costs) are ascertained. Costs are related to the number of operations. It is a "chicken or the egg first" dilemma.

Each operation needs young livestock for rearing, in addition to the livestock supplying the product. For dairies, non-lactating cows must also be considered. Thus the total number of animals needed to supply the market, i.e., the standing herd, has to be considered as well. The plan provides for a maximum animal population of approximately 2,000 milking and dry cows. Replacements, i.e., young heifers, should be raised off-site, on other ranches on O'ahu or the neighbor islands. Calves up to six months of age could remain on-site until healthy enough to be moved. In terms of waste generation, the plan anticipates approximately 2,100 animal units, at the most.

The maximum animal population is useful to understand the estimated maximum amount of waste produced and limits to development. The waste management system is limited by the amount of land on which the treated waste can be applied. There are limits to the natural absorptive capacity of the surrounding agriculture which can use organic fertilizer produced from manure treatment facilities.

The animal waste collection plan is based on scraping alleys in the freestall barns and milk parlors. Scraper systems reduce odors because of frequent manure removal. A concrete reception pit can be constructed at the end of each dairy building to receive waste. The following are the reception pit capacities for different herd sizes based on one-day manure generation:

	Herd Size, no.	*Capacity, gallons*
	1,200	30,000
	600	15,000
	200	5,000
Total:	2,000	50,000

This volume includes wash water for sanitation of milk parlors and supplemental cleaning of areas not reached by mechanical scrapers. The plan is to pump the above amount into the treatment system each day.

There is an alternative collection system that uses additional water for flushing, but requires constant flushing of dairy barns to achieve gravity flow of manure to a collection point. The volume of liquid waste can be increased by an order of magnitude. The collection system is being given a lot of attention in the preliminary engineering. The tentative recommendation is to adopt mechanical scraping systems.

The preliminary waste management analysis recommended that the following alternative technologies be considered:

TABLE 2.1 - ANIMAL WASTE TREATMENT TECHNOLOGIES CONSIDERED FOR LIVESTOCK PARK

Effluent Treatment	
Primary	Covered anaerobic ponds or digesters
Secondary	Facultative ponds or aquatic vegetation ponds
Disposal	Slow rate irrigation, evaporation, or aquatic vegetation ponds
Residual Treatment & Disposal	
Dewatering & Drying	Sand drying beds or belt filter/screw press
Disposal	On-site: Use as fertilizer & soil amendment for crop production, and reuse as bedding material
	Off-site: Landfill, heat dry/pelletize & market

More complete cost comparisons will be made during the preliminary engineering design analyses between these alternative technologies.

The critical process is disposal. Between one-third to one acre of crop land is needed for each mature dairy cow to absorb the organic fertilizer constituents in the nutrient-plant cycle. Thus between 630 to 2,100 acres of surrounding crop land are desirable.

If the small diversified agricultural operations are not closer, another option is large-scale agriculture such as pineapple cultivation, the traditional receiver of most of this animal waste at the present.

The details of the waste management system will depend upon operator preference for the collection system, type of bedding material, the grower's preference for fertilizer and cropping practices, availability of water, economics of comparative treatment systems, and regulatory agency review. A general schematic of how the components might be integrated is shown in Figure 2-2. Where possible, water conserving measures will be considered in the design of this type of system, e.g., by limiting wash water in dairy barns. However, there are animal health considerations that have to be evaluated.

In the preliminary analysis of the potential technologies shown in Figure 2-2, a waste management system could be designed (theoretically) as a "closed loop" system; in other words, the emissions such as percolation into the ground, runoff into the stream, and odors into the air, will be insignificant. However, the cost of such control measures increases dramatically, depending upon how tightly the loop is configured. A closer examination of emissions and corresponding health risk is presented in Appendices A through F.

The preliminary waste management analysis also determined: 1) significant biogas production potential exists if anaerobic digestion methods are used, 2) this gas can be used to provide a significant amount of energy needed for agricultural park operations, and 3) the solids can be processed to a dry product usable as an animal bedding material or compost. One use of this energy could be to heat the digester and to heat-dry some of the solids for marketing locally as a soil amendment. But at this time, the limited O'ahu market for organic fertilizer probably makes it uneconomic for the dairy farmer to compete. A more attractive option for disposal includes reuse as fertilizer for forage or truck crop production. There will be a relatively smaller amount of sediment treated in a conventional drying bed. This material may be used as soil amendment, but may also be taken to landfills if farms are not able to use all of the material.

The site climate and soil conditions will strongly impact the design of waste treatment alternatives. Variables that are important include evapotranspiration, rainfall, temperature, and soils. These differ from site to site. It is clear that the waste application rates can be managed to avoid excessive leaching of contaminants to aquifers (Appendices A and C address this concern). The effluent's nutrient content will enhance growth of crops such as guinea or California grass that can be used as forage for the dairy animals, but the most productive application rates in terms of diversified crop yield can be best determined from small-scale field studies. Application rates for treated domestic secondary effluent have been studied at the Mililani and Honouliuli Treatment Plants, and a great deal of information has been learned from these research projects. Other crops which might use reclaimed water (which require further experimentation) include silage crops such as a hay variety that is adapted to Hawai'i, corn, and duckweed. The latter can be grown in aquatic ponds. The cost of importing forage is a large portion of dairy operating cost. Therefore, the extent to which it could be grown locally will reduce the operating

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STATE OF HAWAII
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OAHU LIVESTOCK AGRICULTURAL PARK

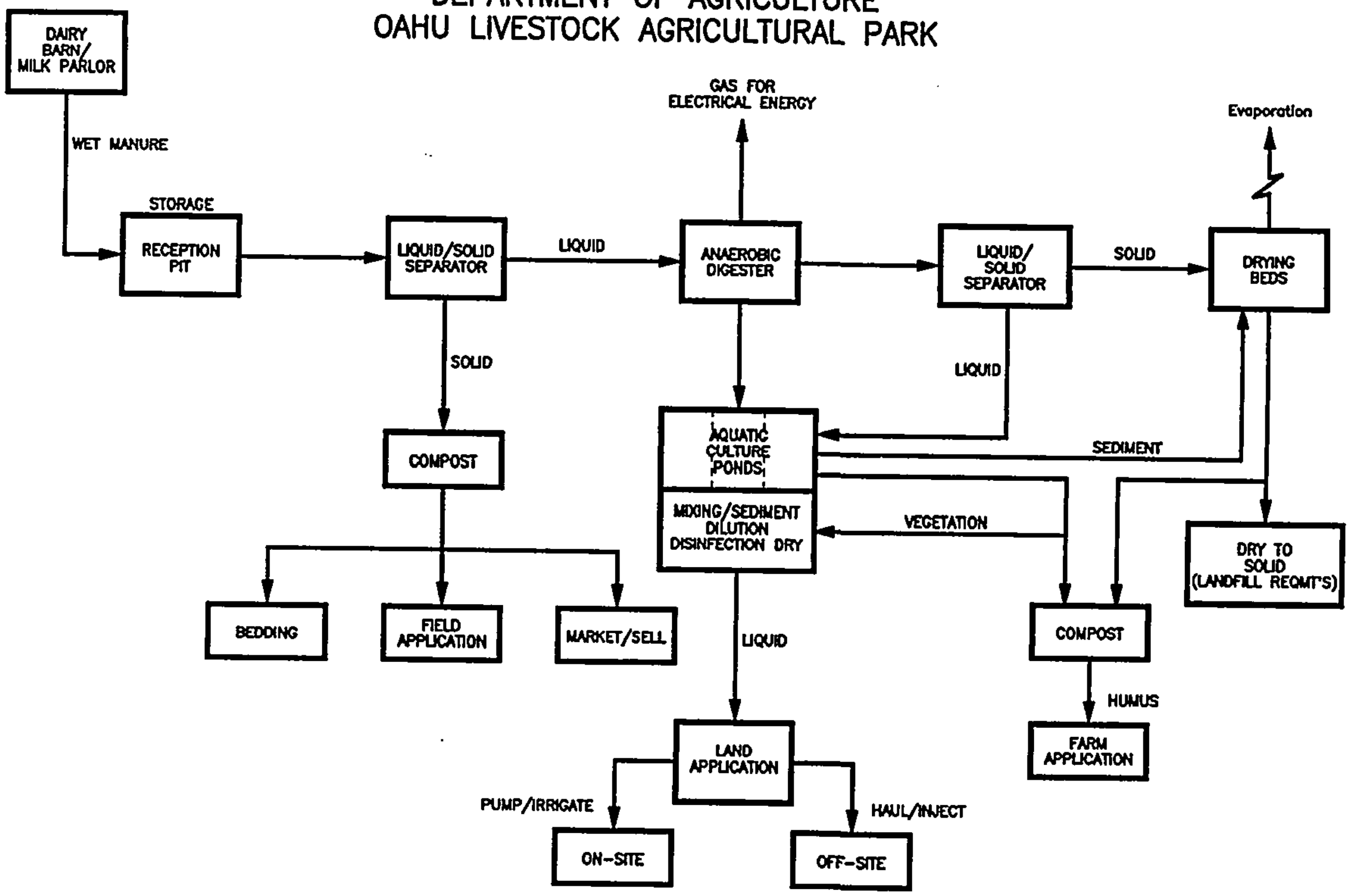


FIGURE 2-2 PROCESS FLOW DIAGRAM FOR DAIRY WASTE MANAGEMENT

costs of dairies. The opportunities may be explored in a pilot demonstration project proposed at the University of Hawaii Agricultural Experiment Station.

E. Conceptual Site Plans

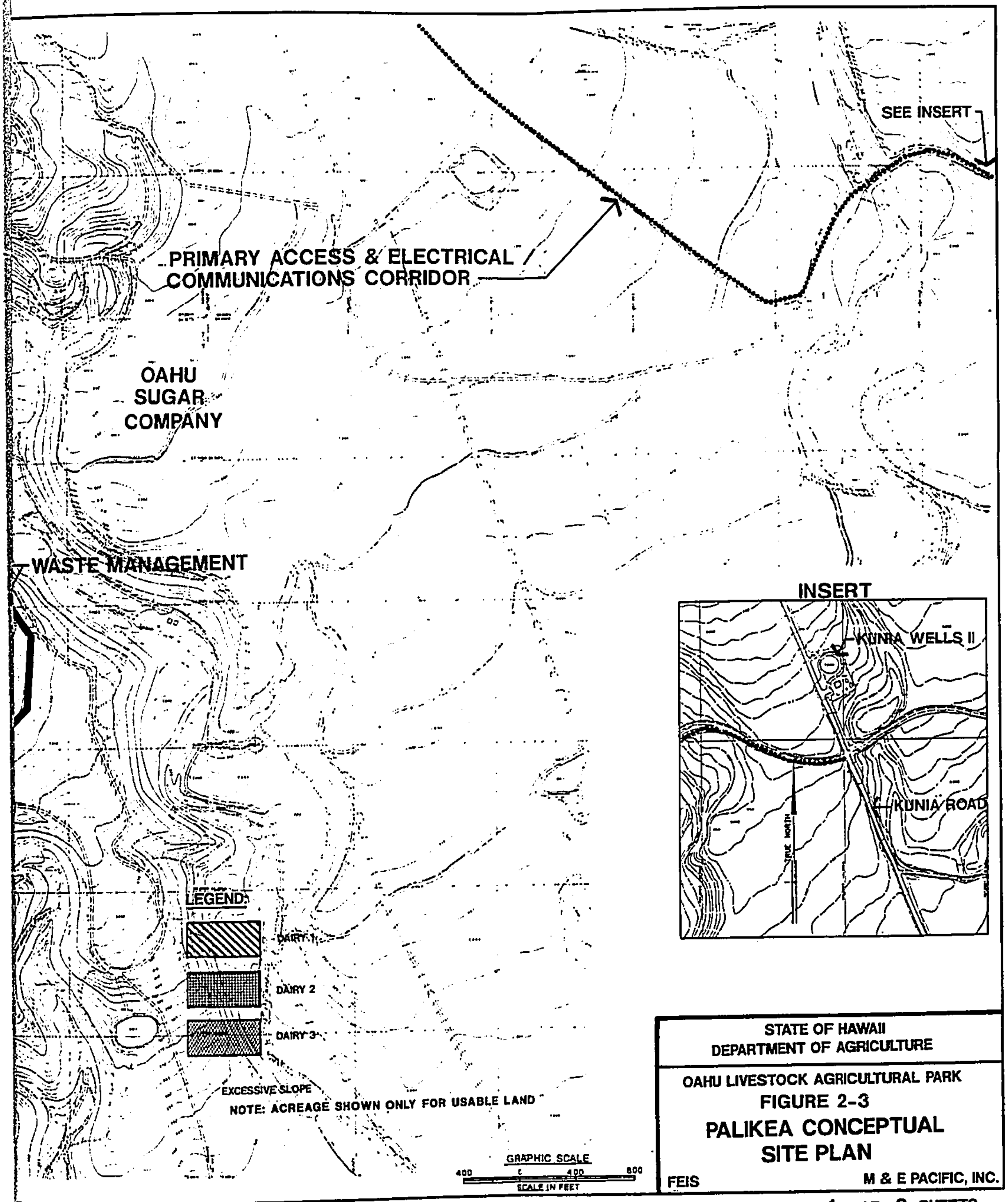
Approximately 116 acres are allocated to dairy livestock and waste management operations on the Kahuku site plan. On the Palikea site plan, approximately 187 acres are considered. The conceptual plan for Palikea is shown on Figure 2-3; for Kahuku the conceptual plan is on Figure 2-4. The conclusion of the site analysis is that sufficient land exists for freestall dairies, but non-grain feed production is limited at both sites. However, pasture may be provided to support some of the dry cows in the herd, particularly at the Palikea site.

Given the proximity of the sites to surrounding *communities*, it is recommended that the dairy operations be consolidated on a minimum area, and a centralized area be provided for waste management, pasturing dry cows, and storm runoff control. With this type of site plan, it is possible to support approximately 2,000 animal units, lactating and dry cows, under the following conditions:

1) freestall dairy management is practiced;
2) no replacement animals are raised on-site;
3) pasturage for some dry cows is provided;
4) water is supplied to irrigate pastures; and
5) surrounding agricultural operations adopt organic fertilizer as a partial substitute for commercial chemicals.

Given the above conditions, dairy operation is not significantly different between sites. In other words, the Kahuku site and Palikea site are comparable when it comes to economic feasibility. There will be management challenges—both sites are limited in terms of space and adsorptive capacity for animal waste. These limitations are not insurmountable with energy and resources, in other words, additional cost.

The major factor which allows confinement of dairy animals on the areas identified on the conceptual site plans is freestall dairy management practice. This system has become the preferred system in most modern dairy operations. In a freestall management system, each cow is provided a stall. Cows usually prefer to



STATE OF HAWAII
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OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 2-3

PALIKEA CONCEPTUAL SITE PLAN

FEIS
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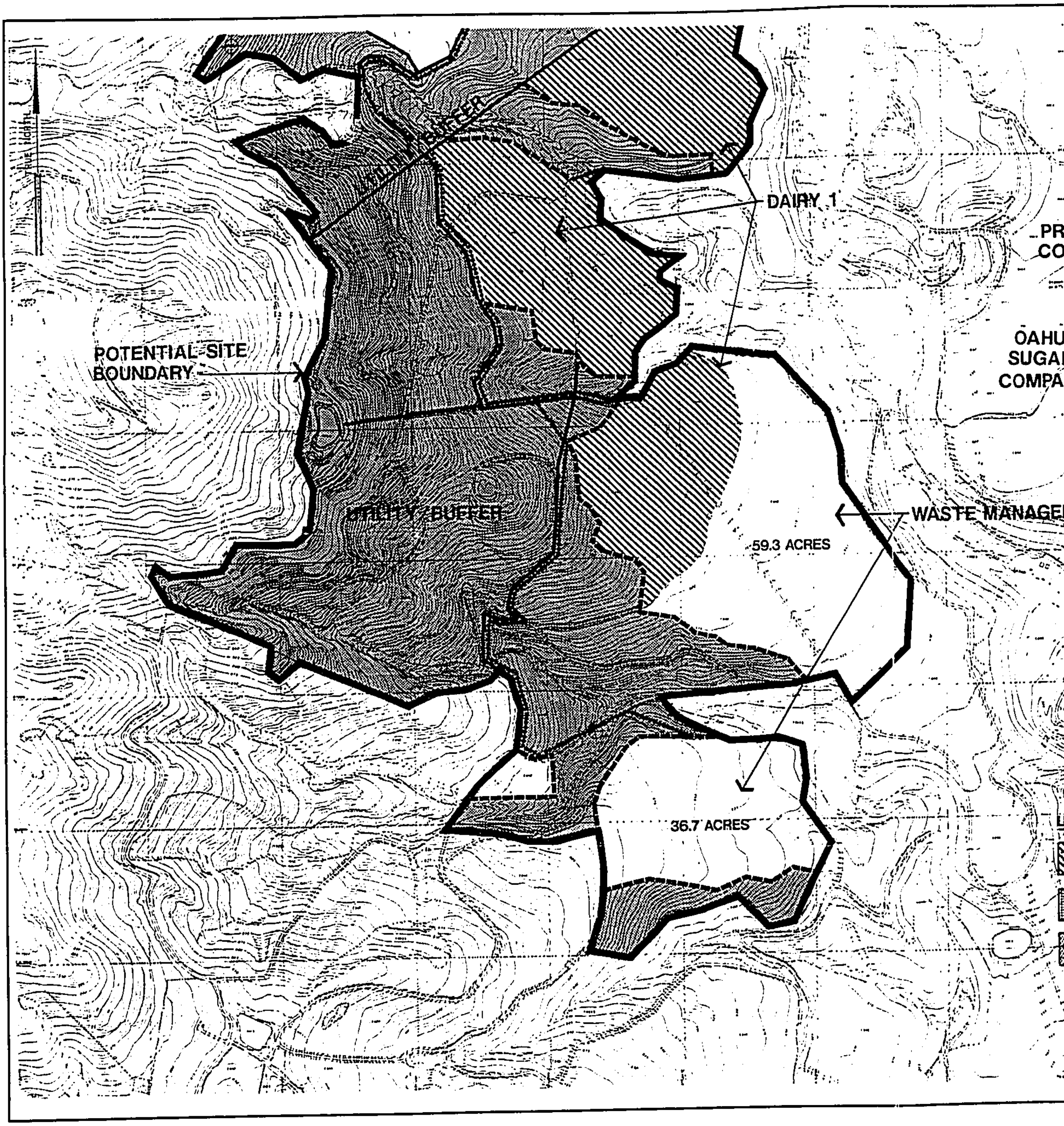
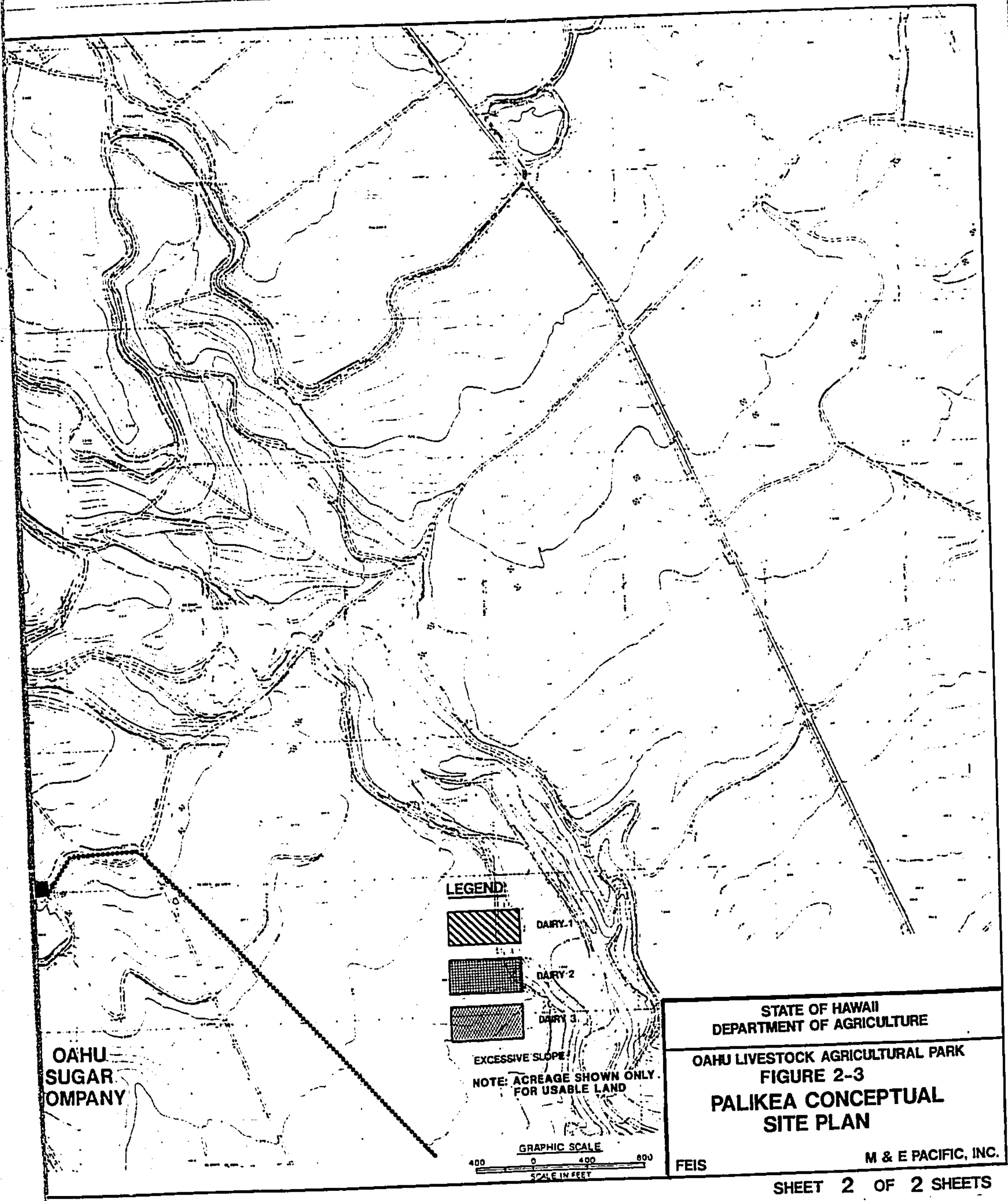
SHEET 1 OF 2 SHEETS


UTILITY BUFFER
DAIRY 1
PR
CO
POTENTIAL SITE BOUNDARY
OAHU
SUGA
COMPA
UTILITY BUFFER
WASTE MANAGE
59.3 ACRES
36.7 ACRES



STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 2-3

PALIKEA CONCEPTUAL SITE PLAN

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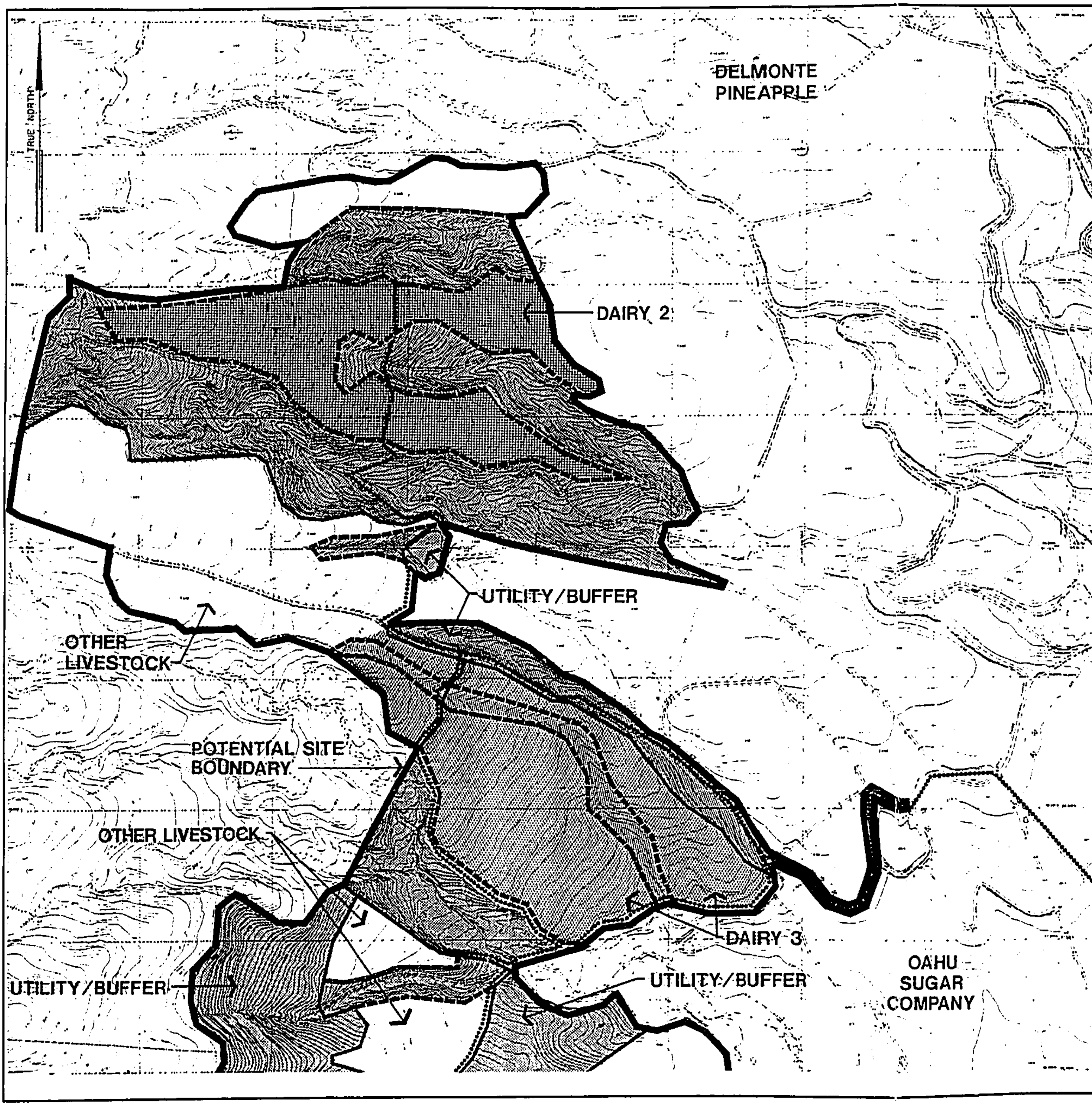
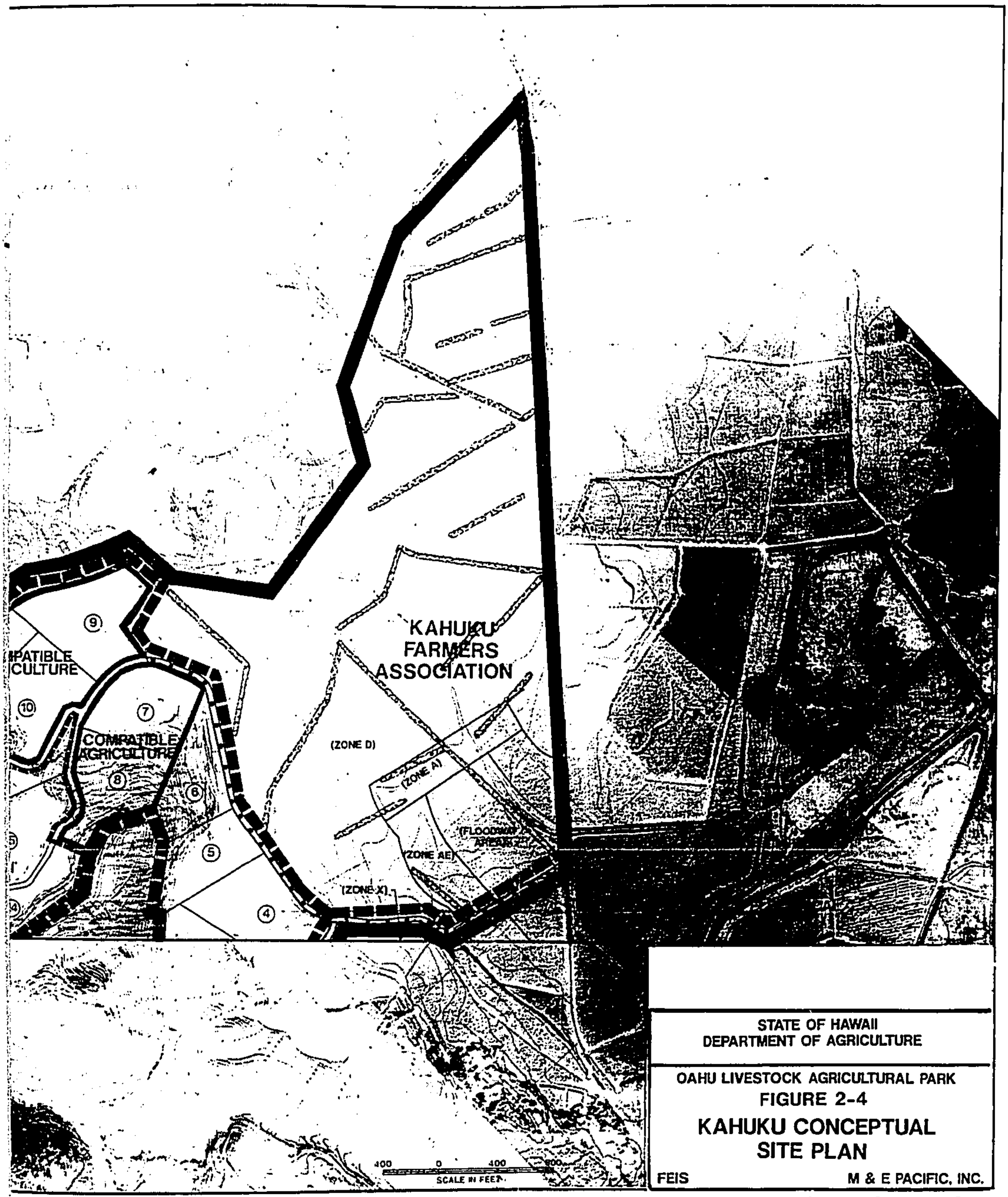
M & E PACIFIC, INC.

SHEET 2 OF 2 SHEETS


TRUE NORTH
DELMONTE
PINEAPPLE
DAIRY 2
UTILITY/BUFFER
OTHER
LIVESTOCK
POTENTIAL SITE
BOUNDARY
OTHER LIVESTOCK
DAIRY 3
UTILITY/BUFFER
UTILITY/BUFFER
OAHU
SUGAR
COMPANY



STATE OF HAWAII
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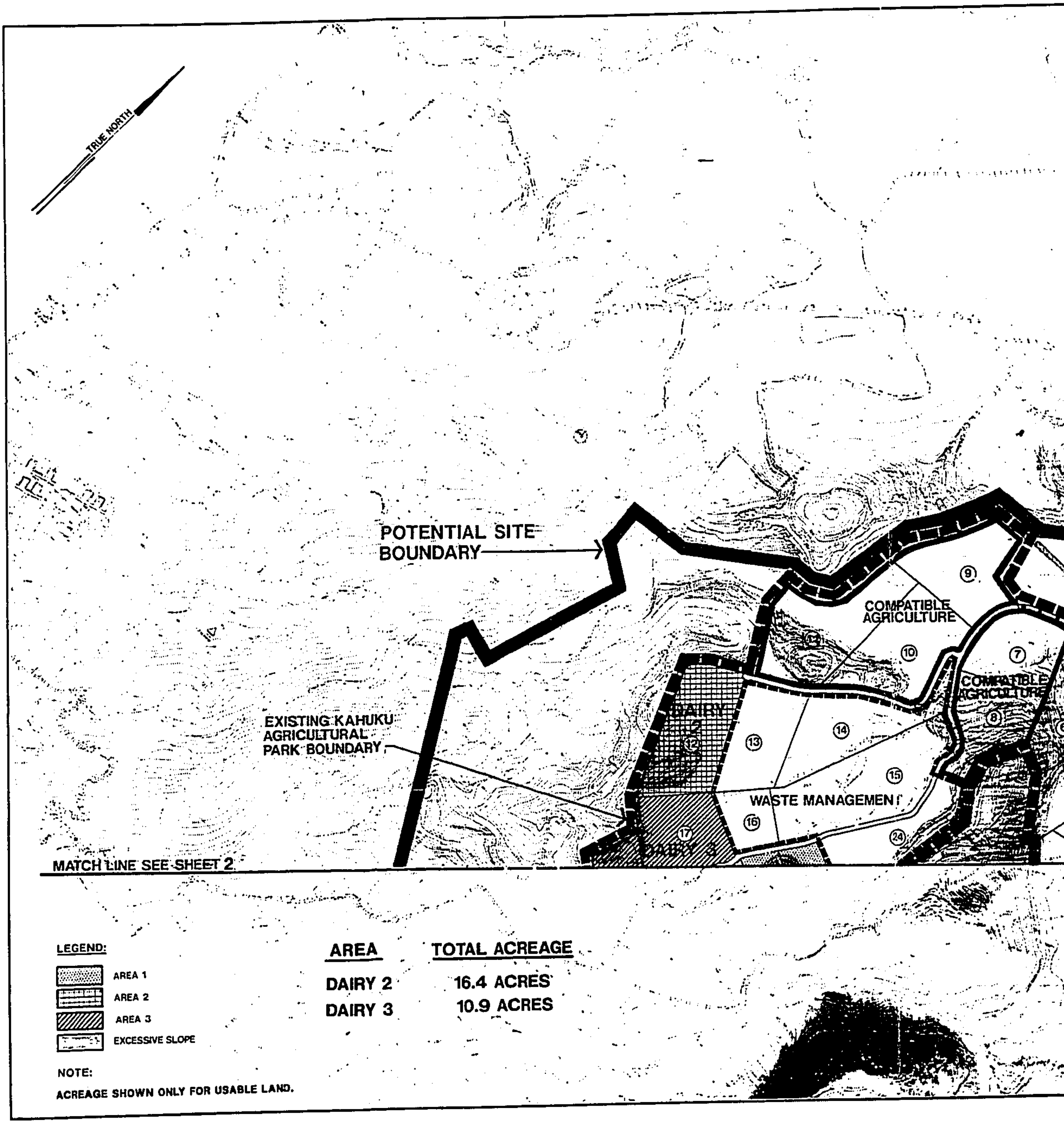
OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 2-4

KAHUKU CONCEPTUAL SITE PLAN

FEIS M & E PACIFIC, INC.

SHEET 1 OF 2 SHEETS



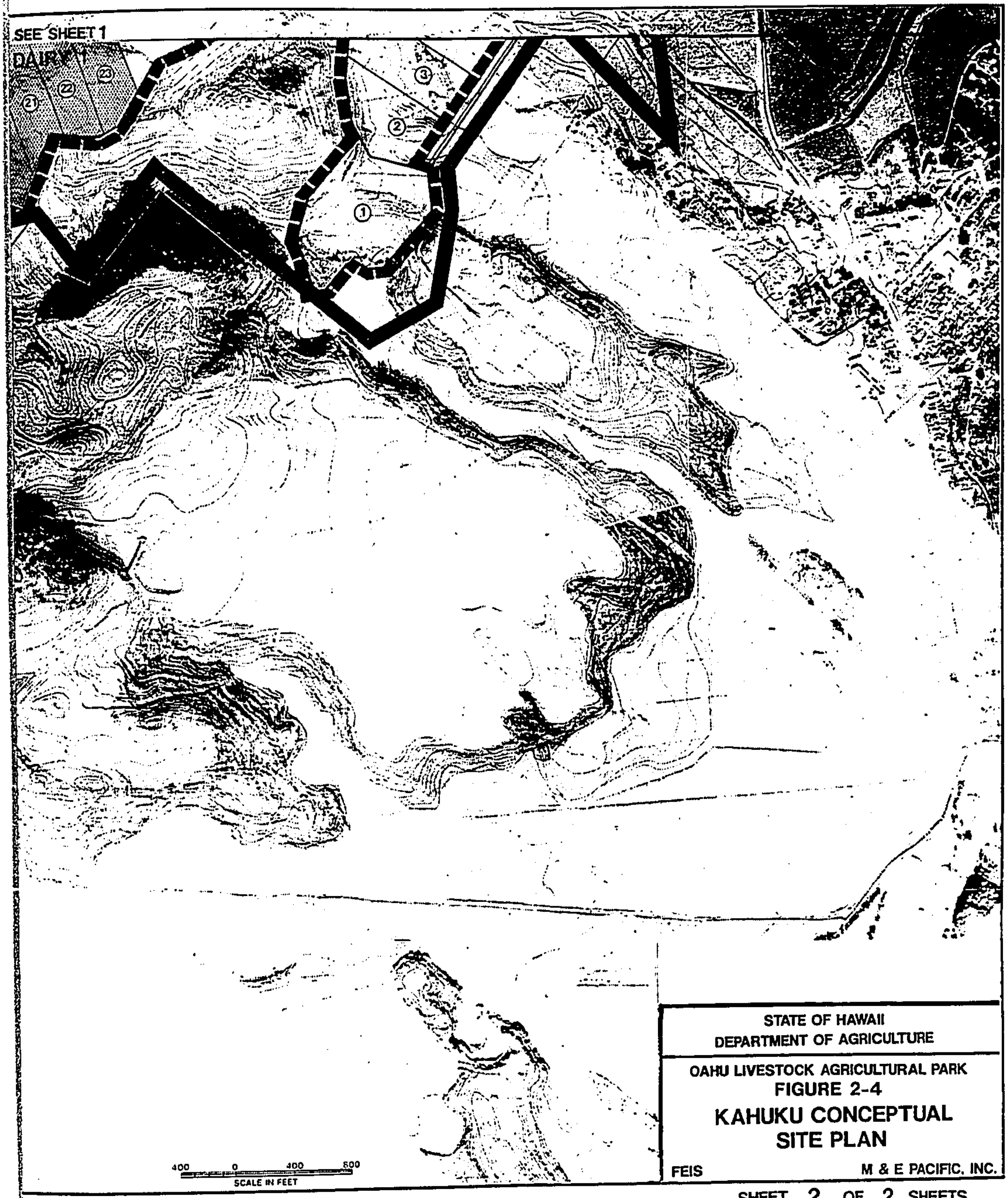
LEGEND:

- ▒ AREA 1
- ▦ AREA 2
- ▨ AREA 3
- ☐ EXCESSIVE SLOPE

AREA	TOTAL ACREAGE
DAIRY 2	16.4 ACRES
DAIRY 3	10.9 ACRES

NOTE:

ACREAGE SHOWN ONLY FOR USABLE LAND.



STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 2-4

KAHUKU CONCEPTUAL SITE PLAN

FEIS

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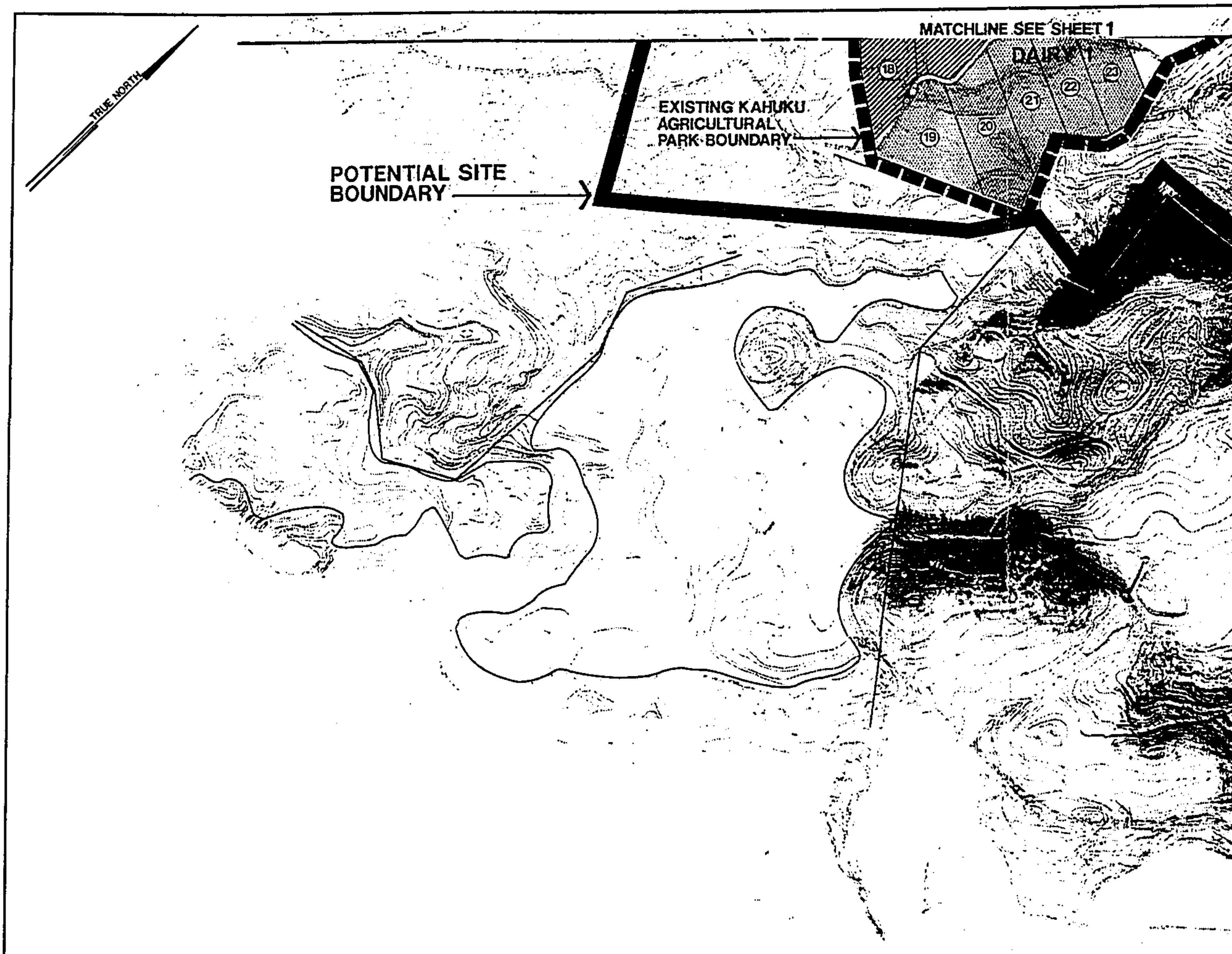
SHEET 2 OF 2 SHEETS



AREA	TOTAL ACREAGE
DAIRY 1	30.0 ACRES

LEGEND:

░	DAIRY 1
▦	DAIRY 2
▨	AREA 3
☐	EXCESSIVE SLOPE

NOTE:

ACREAGE SHOWN ONLY FOR USABLE LAND.

400

use the same one. Each stall has room for one animal to lie down. Animal comfort is important. Adequate bedding, feed, water, and ventilation are all elements of freestall barn design.

The importance of using a freestall barn cannot be overemphasized. In contrast to the "dry lot" system practiced by the majority of dairy operators in Hawai'i, it offers these advantages:

1) animals are made more comfortable and as a result milk productivity usually increases;

2) manure collection and treatment procedures are significantly improved;

3) feed wastage is reduced;

4) odor and vector control are improved.

The freestall system, however, costs considerably more to construct.

II. Socioeconomic Characteristics

Summary of Section Two, Subsection II. **Agricultural parks have been an important means of implementing the State Agriculture Functional Plan and have provided farmers the ability to acquire and maintain possession of land for agricultural use since 1973. The history of the dairy industry on O'ahu has been one of continual displacement. Because of the desire of land owners to use agricultural land for urban uses at some existing dairies, there is a need to relocate dairies to a location suitable for agricultural operations. There will always be a market on O'ahu for the products of these operations. Supporting this industry protects employment, fosters diversification of the State's economic base, promotes efficiency and self-sufficiency, thereby affecting the cost of producing dairy products, and preserves life-style and open space alternatives for future generations.**

A. Objective of Agricultural Parks — Legislative Perspective

Chapter 226, Hawaii Revised Statutes, *The Hawaii State Plan*, provides a long-range guide for Hawai'i's future and establishes a State-wide planning system. The system includes the formulation of functional plans, one of which includes agriculture.

The implementation of the *State Agriculture Functional Plan* (Department of Agriculture 1991) addresses the following problem issues:

Industry Research and Development
- Marketing
- Consumption
- Research/Development/Technology Transfer
- Finance

Agricultural Pests and the Environment
- Pest and Disease Control
- Environmental Quality

Land and Water
- Land
- Water

Services and Infrastructure
- Legislature, Information, and Public Image
- Human Resources
- Transportation
- Agricultural Infrastructure

Agricultural parks are directed to meeting portions of the land issue.

The *State Agriculture Functional Plan* proposes that in implementing water use control, priority consideration be given, where justified for the benefit of Hawai'i's people, to the maintenance of adequate water sources, supplies, and facilities for continued existing and planned beneficial agricultural uses. This measure is consistent with Hawaii State Plan priority guideline 226-103(h)(3), which encourages restriction of new urban development where water is insufficient for both agricultural and domestic uses. It may serve to limit the amount and pace of housing and tourism growth in water-scarce areas to ensure the maintenance of agricultural activities and options in such regions.

From the determination of agricultural needs and requirements, the Plan recommends the development of agricultural parks to ensure the continued availability of suitable land essential to realization of the aims established in the Hawaii State Plan, recognizing that "land is a non-replaceable fundamental resource for agricultural production."

In response to the difficulties that potential and existing farmers have in acquiring and maintaining possession of land for agricultural use, the State instituted the Agricultural Park Program in 1973. Since that time, the State and the County of Maui have developed nine parks comprising 3,915 acres and 278 lots for a variety of agricultural uses such as flowers and foliage, nursery, orchard, and truck crops.

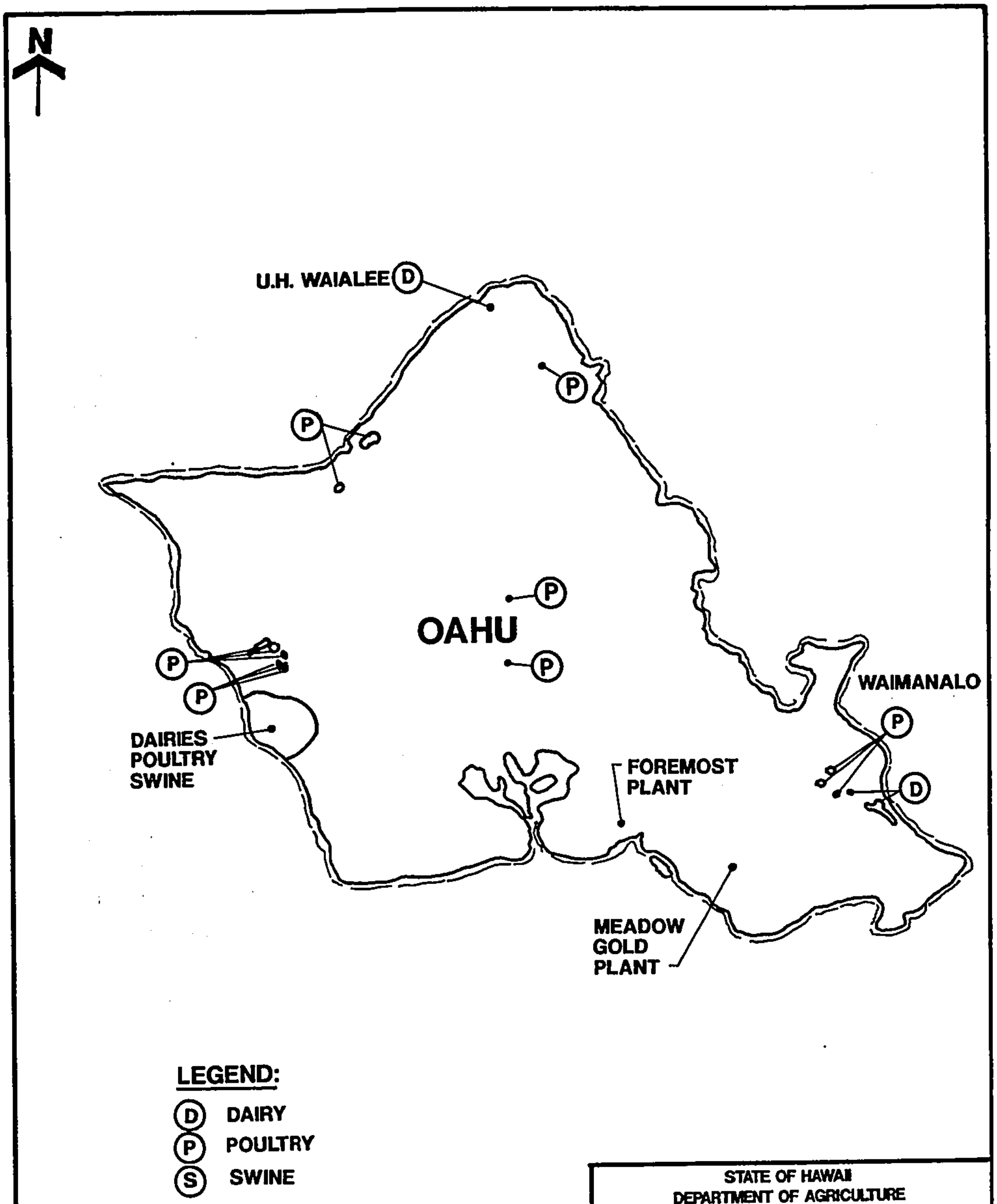
B. Livestock Industry — Historic Perspective

Cattle were introduced to the Hawaiian Islands around 1794. Milk was obtained from beef cows. Dairy cattle were introduced in the early 1800s and commercial dairies were operating by the mid-1800s. By the 1930s, Hawai'i had approximately 150 dairies. Guernseys and Holsteins replaced the beef cattle used for milking. In the 1960s, the number of dairy farms shrank to approximately 82. Cow population remained between 11,000 to 13,000 head statewide.

As land was urbanized, complaints by the general public against the dairies increased. In 1925, the City and County of Honolulu began to encourage relocating dairies from Kapahulu to Red Hill, Kāne'ohe, Kailua, and Hale'iwa. Today no dairies exist in these locations; urbanization forced the dairies to relocate repeatedly. With the exceptions of the Meadowgold Dairy in Waimānalo and the University of Hawaii dairy at Waiale'e, ten family-owned dairies are located in Wai'anae (Figure 2-5).

Much of the livestock industry on O'ahu (most notably, dairy, swine, poultry, and cattle) is facing a tenuous future as a result of lease terminations and urban encroachment. The O'ahu dairy industry is on the verge of losing one-third of its milk quota production capability, or approximately 1,000 hundredweight (11,628 gallons) per day. The O'ahu Livestock Agricultural Park has been proposed to assist the dairy, poultry and swine producers. The Department of Agriculture (1989) discussed many of the problems and needs in a white paper on which most of this discussion is based.

In 1990, there were 376 livestock operations on O'ahu with a farm value of sales of over $45 million. Statewide, the livestock industry represents about 32 percent of the total value of production of diversified agricultural activities in the State; the dairy industry is about 11 percent of the total value of production. Total livestock agricultural production value in 1990 was $181 million, approximately 1 percent of the gross State product in 1990. Sugar, pineapple, defense expenditures, and the visitor industry account for over 50 percent of the value. The farm value of sales of the O'ahu dairy industry was approximately $24 million in 1990, and represents over 78 percent of the total value of milk produced in the State. If a farm to retail value-added factor of three is applied, the annual value of this industry to the State economy is approximately $72 million. The contribution of the dairy industry to the State and O'ahu's economy, in particular, has a significant dollar value.



STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 2-5
LOCATIONS OF LIVESTOCK
OPERATIONS

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Figure 2-5 shows that dairy operations are concentrated in the Wai'anae area. Poultry operations are found on the North Shore, in Waimānalo, and in Wai'anae. What the figure does not indicate is the recent increase in urban developments in the vicinity of the livestock feedlot operations, particularly in Wai'anae.

"Gentleman farmer" subdivisions and residential developments are among the non-agricultural uses that create a deterrent to the continuation and expansion of dairies, piggeries and poultry operations. The deterrence factor often includes complaints and lawsuits about livestock odors and flies. Furthermore, the pressure for landowners to capitalize on the potentially greater returns from urban development increases as those uses encroach upon their livestock operations.

In recent years, the numbers of dairies in Hawai'i have decreased. In the 1970s, there were some 30 dairies. In the 1980s, there were 20 dairies. The 1990s began with 18 dairies. As the number of dairies decreases, their average size increases. This trend is also a reflection of what is happening throughout the United States.

Over half of the 11 dairies on O'ahu (with 10 or more cows) lease part or all of their land from the State Departments of Land and Natural Resources and Hawaiian Home Lands, or from private owners. Many of these private leases, including those held by the largest producers, will expire by 1995. Those producers that own land have little or no room to expand, are situated next to existing or planned housing developments, or have reached full capacity of their animal waste lagoons. The lagoons are filled because of the problems associated with the removal and disposal. Lack of pasture land on O'ahu has hampered the dairy industry inasmuch as heifer calves suffer severe weight loss when sent to the Big Island for growing out. Since most of the dairies are located in the arid, hot Wai'anae area, reproduction rates and milk per cow are far lower than they are on the mainland. For example, California dairies, which have recently increased their share of the milk market in Hawai'i, average 18,000 pounds per cow per year; whereas, Hawai'i dairies average 14,200 pounds per cow per year (*Statistics of Hawaiian Agriculture* 1990). This increases unit production costs and reduces the local industry's competitiveness *vis-a-vis* the California dairy industry.

In the mid-1980s, the average dairy herd had approximately 526 milking cows. The size of the farms ranged from 63 to 1,500 milk cows. In the last 12 months, the average number of milking cows per farm was estimated to be some 600 milk cows. The largest herd now milked has more than 1,600 cows. However, milk production per cow or the average daily yield as reflected by the *Statistics of Hawaiian Agriculture* (1990) records showed no major improvement in production efficiency in recent years (see Figure 2-6). While some farms have made a concerted effort to improve efficiency, many have not. The potential to have higher milk production exists if management opportunities exist. Part of the reason for the poor production is due to overcrowding. In addition, current facilities are outdated. Extensive improvement cannot be made without jeopardizing current operation since space is limited.

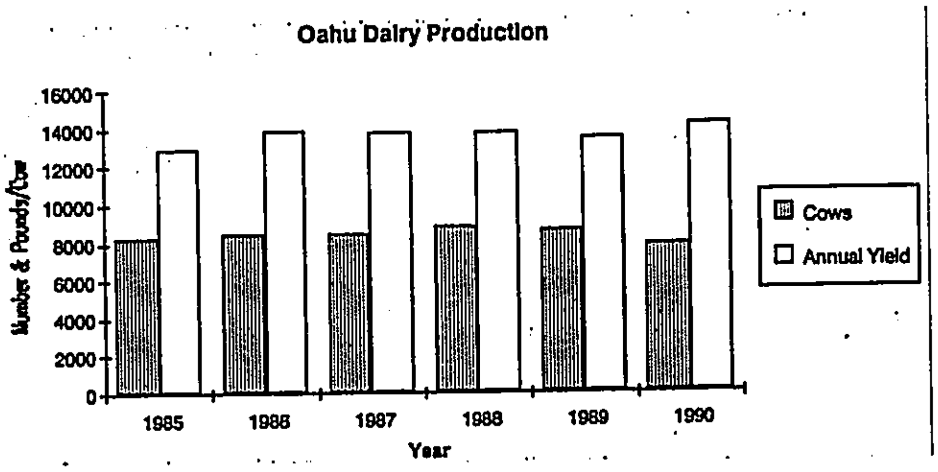
In 1989, the Department of Agriculture conducted a survey of the twelve O'ahu dairy producers then in existence, nine of whom participated. These nine supply 90 percent of the quota in O'ahu's milk shed. The survey showed that producers representing 85 percent of the total quota wanted to expand (in terms of more acreage), but only producers who made up 45 percent of the total quota were able to expand at their current sites. Producers representing 65 percent of the quota expressed an interest in relocating to a cooler, higher-elevated area, especially if they are unable to renew their leases.

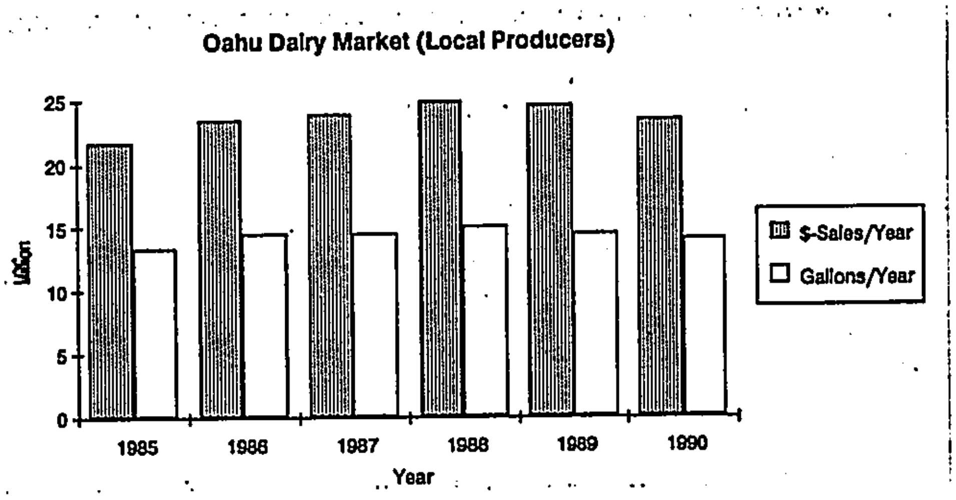
C. Future Economic Demand for Livestock Products

As population continues to grow, the demand for milk products will increase. Figure 2-6 shows that the historical trends over the past five years point to a steady demand for Hawai'i-generated dairy products in the future. Locally produced market supply has remained relatively constant, and mainland supply has been satisfying the increasing local demand.

The local dairy industry provides approximately 85 percent of O'ahu milk, and more than 95 percent of the Hawai'i, Kaua'i, and Maui milk markets. This figure is at best an estimate since no data is available on the amount of milk imported from California. Honolulu remains the major market for locally produced milk. In 1986, the local production was around 32,000 gallons per day. Surpluses occurred in the months of December, June, July, and August.

Current O'ahu population is estimated to be 850,000 people. Based on the census and on the expected growth rate in the next decade, O'ahu's population will grow approximately 6.5 percent by the year 2000. O'ahu would have (850,000 x 1.065) = 905,250 people then.


Oahu Dairy Production


Oahu Dairy Market (Local Producers)

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 2-6

OAHU DAIRY PRODUCTION AND MARKET

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At its peak, Honolulu's market needs 42,000 gallons per day. Peak season is during the school calendar year. This increase over the base period is 31 percent over a four-year period, not including the estimated 15 percent supplied by the California dairy producers via importation. There is no real data base for this estimate; just a figure generally "accepted by the industry." So the estimated per capita consumption of milk currently is calculated as follows:

42,000 gallons / 850,000 = 0.049 gallons/day or 0.42 pounds/day or 6.7 ounces/day.

By the year 2000, the market would require:

0.42 lb/day x 905,250 = 380,205 lbs/day or 44,210 gallons/day.
(1 gallon of milk = 8.6 pounds).

This would mean 2,210 gallons more milk required per day over a 10-year period (44,210 - 42,000 = 2,210 / 10) or 5.26 percent annual increase in the market.

This estimate is subject to both economic and social factors such as federal price supports for milk, and trends in consumption. As examples of the latter, the recent national trends have indicated lower per capita milk consumption. However, Hawai'i has been lower than the national average in this respect. Therefore, it is not expected to change dramatically.

D. Socioeconomic Characteristics of a Livestock Agricultural Park

1. The major benefit of land committed to agricultural operations is the assurance that producers can have long-term leases for land for supporting large investments that contribute to increased productivity. O'ahu consumers would then be assured of an alternative to mainland products, particularly milk. Assuming the retail value of the milk consumed on O'ahu is two to three times the farm value, O'ahu consumers will pay up to $92 million annually, mostly to out-of-state producers, if this industry is lost. This results in a loss in the State's economic base; that money if retained in the State could have spin-off effects on other economic sectors, e.g., assuming a multiplier ratio of three, approximately equal to $277 million annually. Approximately 300 to 400 jobs are in the dairy production and processing operations, plus those in associated input industries, although actual employment at the livestock agricultural park is expected to be much less. A typical

dairy has two to three full-time employees, in addition to the owner/operator, and several part-time employees. Large dairies, over 1,000-head, have more employees.

2. Improvements in productivity will help the competitiveness of the industry and help to keep long-term costs to the consumer lower than they might otherwise be. Despite improvements in milk production brought about by genetics, management, and nutrition, Hawai'i's per unit output has reached a plateau (see Figure 2-6) in recent years. The generally cooler climate in an elevated area will improve calf reproduction rates (O'ahu's 5 to 30 percent) in comparison to mainland (75 percent). In addition, milk production in a cooler climate could increase by 15 to 25 percent. Furthermore, existing dairies do not have the latest production technologies for improved efficiency. If producers can lower unit production costs, the savings could be passed on to consumers, and would benefit local producers by leaving them less vulnerable to periodic dumping of lower-priced, mainland imports.

3. Coordinated waste management and treatment can benefit from economies of scale not present in individual waste treatment operations. Most dairies operate dry lot systems. Manure and soil are periodically scraped for disposal in agricultural areas, historically in pineapple fields. Manure is exposed to weather, odors are created and nutrients are lost to volatization and leaching. Recycling waste into usable products such as soil amendment, organic fertilizers, methane for energy production, and irrigation water for cattle forage and other crop production are opportunities to generate new employment, new products, and income that can help to subsidize the operation, reducing environmental pollution impacts.

4. Price stabilization during periods of market supply disruption will benefit consumers. Increases in transportation rates, labor strikes in the shipping industry, and adverse weather conditions on the mainland which effect animal feed production can affect the prices paid by Hawai'i consumers for mainland dairy products. Shipping costs between neighbor islands make interisland dairy products more expensive. The impact to farmers is significant because most feed (a large operating cost factor) is imported from the mainland. All mainland shipments are transhipped from Honolulu, further adding to the cost. Locally produced supplies are added insurance that competition remains in the market place.

5. The social benefits include preserving alternative lifestyles for existing and future generations. Milk, unlike other food, is a unique need for the human

race. Milk is the major essential food item for the sustenance of infancy. As such it should be provided with some special treatment to ensure that the product is available at all times, regardless of any crisis. This is even more critical in an island economy separated by a vast ocean from its nearest alternative supply. The high cost of living in Hawai'i demands a double income family with both parents in the work force. Fluid milk, a nutritious product, allows the working parents more flexibility and choices for infant nutrition. Farming as a means of livelihood is increasingly difficult for younger generations because of scarcity of land. Agricultural parks offer a means for those with a viable proposal and need for a place to farm as a business.

An agricultural park could also serve as a training center for local students wanting to gain experience in agriculture via a rotational internship program. Similar experiences for international trainees in tropical agriculture could also be provided, thus strengthening the role Hawai'i could play in the Pacific Rim and other developing nations in Asia and Africa.

While there are important social benefits, the consumer's interest is economic—what is the impact on the cost of producing milk. The evaluation here is restricted to the cost of production to the dairy operator. This is not necessarily the same as the price of milk paid by the consumer. There are additional costs such as processing, marketing, and distribution which are not part of this analysis.

There are two considerations. The first is an estimation of the potential average unit cost of milk production. This provides an indication of the magnitude of the cost to dairy operators and whether it is worth the investment. The second consideration is whether the concept is worth it in terms of long-term economic feasibility to the dairy operator.

The capital cost of construction and land acquisition (see Section III. Resource Commitments) is estimated conservatively at $22 million. This includes the portion of land acquisition and infrastructure necessary for dairy relocation.

The value of milk is supported in Hawai'i by the Milk Control Act (Hawaii Revised Statutes, Chapter 157, SLH 1967). The present value assured the dairy producer for top grade milk is $23.10 per hundred weight (cwt). Milk weighs approximately 8.8 pounds per gallon, so this equates to roughly $2.00 per gallon. Other costs are incurred before the milk reaches the consumer's grocery basket.

In the following economic evaluations, it is assumed the increase in milk production with freestall dairy management will be approximately 15 percent on O'ahu. Average annual milk production per cow is approximately 14,200 pounds.

The projected yield is 16,775 pounds per cow per year. The cow has a lactation period of approximately 305 days, so this is an increase from 46 pounds to 55 pounds per day. A local dairy has experienced an increase from 38 pounds to 55 pounds per day after relocation and adoption of a freestall operation, so this projected increase in productivity is not unreasonable.

Table 2.2 considers only the short-term or immediate viewpoint of the dairy operator. If the amortized value of the investment is compared against the expected value of increased milk production, the ratio of value to cost is approximately 0:6, i.e., it is not a rational economic move. However, this is a very myopic viewpoint. Most dairies have not made major investments to replace their equipment and other facilities in many years; such replacements are inevitable. Furthermore, the future for waste disposal is imponderable. Recently, the amount of manure trucked to pineapple operations has been significantly reduced and the long-term future is very uncertain. At some point, investment in waste treatment and disposal facilities is inevitable.

Table 2.3 considers long-term economic profitability. All of the major factors of production are considered, including amortization of the waste treatment and freestall barn/new milk parlor facilities. The economic return per animal unit is estimated at approximately $560/cow-year. The current economic return is not available. However, the conclusion is that, on average, the new investments should be economical based on the present value received by the dairy operator for milk production.

Another conclusion of this analysis is that only the dairies that need to relocate most urgently will have an incentive to invest in the livestock agricultural park. Some dairies own their land and have better isolated themselves from surrounding urbanization pressures than others. Thus the need to provide space for all of the existing dairies is not imminent.

TABLE 2.2

	Comparison of Cost of Production and Value To Dairy Operator						
			For Livestock Park Facilities				
	Cost of Production						
	Item			$ millions			
	Land Acquisition			2			
	Infrastructure			1			
	Waste Treatment			15			
	Dairy Facilities			4			
	Total			22			
	Annual Cost		7%	$1,887,831			
	(7% & 25-year)		25				
			0.085811				
	Cost per gallon			$0.45			
	Value of Production						
	Item			value	units		
	Number of cows			2000	head		
	Present milk per cow per year			14200	lb/cow		
	Projected milk per cow per year			16775	lb/cow		
	Milk receipts @ $/cw		23.1	$6,560,400	per year		
	Milk receipts @ $/cw		23.1	$7,750,050	per year		
	Difference			$1,189,650			
	Value per gallon			$0.28			
	Comparison of Value to Cost of Production						
	Cost per gallon			$0.45			
	Value per gallon			$0.28			
	Ratio of value/cost			0.63			

DAIRY3.XLS

TABLE 2.3

				DAIRY ECONOMIC FEASIBILITY ANALYSIS								
						11/21/92						
	Evaluation of the Cost of Production On Economic Profitability Of Dairy Operations At Proposed LAP											
Assumptions	Dairy Herd Size=		550.00	Including dry cows			Tanker capacity, gallons=		5000.00	Waste Managmt $-Sharing		100%
	No on-site replacement animals raised			- purchase			Lease area , ac/cow =		0.006	Water Managmt $-Sharing		100%
	Water is available for pasture irrigation						Water use,gal/cow-day=		25.00	gpm		
	Lactation fraction=		0.75				Interest on borrowed $ =		7%			
	Milk Price= $23.10/cwt			Lease Rent, $/ac-yr=		400.00	Interest on opportunity $		5%			
Desired Calculation:		Economic profitability= Gross Receipts - (Production + Opportunity Costs)										
Item		Unit	EV $/unit	Range	Physical Amount		Units		Per Cow	Per Herd	% Receipt	Remarks
					EV	Range						
Gross Receipts												
A. 3.3 % Milk		cwt	23.1	constant	16775.00	4500.00	lb/cow/yr		$3,875	$2,131,264	96.25%	Normal Dist
B. Calf Sales		no	62.50	15 - 110	90%	constant	% cows reproducing		$42	$23,203	1.05%	Uniform Dist
C. Cull Cows		cwt	33.50	constant	25%	constant	% culled		$109	$59,881	2.70%	1300 lb cow
Total									$4,026	$2,214,348	100.00%	
Item		Unit	EV $/unit	Range	Physical Amount		Units		Per Cow	Per Herd	% Receipt	Remarks
					EV	Range						
Operating or Variable Costs												
A. Feed Requirements												
1. Forage		ton dry matter	210.00	63.00	3.83	constant	ton-DM/cow		$804	$442,365	19.98%	
2. Grain		ton	195.00	58.00	3.83	constant	ton/cow		$747	$410,768	18.55%	
3. Other		ton	10.00	3.00	0.20	constant	ton/cow		$2	$1,100	0.05%	
Subtotal of Feed Costs									$1,553	$854,233	38.58%	
B. Livestock Costs												
1. Bedding		ton	38.00	constant	1.23	constant	ton/cow		$47	$25,707	1.16%	
2. Milk hauling & marketin		trip	140.00	constant	0.41	constant	per cow		$57	$31,504	1.42%	
3. Veterinary & medical		lump sum	40.00	constant	1.00	constant	per cow		$40	$22,000	0.99%	
4. Breeding		straw	10.00	constant	2.00	constant	success rate factor		$20	$11,000	0.50%	
5. Utilities & Fuel		lump sum	50.00	constant	1.00	constant	per cow		$50	$27,500	1.24%	
6a. Water Service IA		per cow	40.00	40.00	40.00	variable	Incl cost sharing ratio		$40	$22,000	0.99%	
6b. Water Service usage		per 1000 g	0.00016	water charge	25.00	variable	per year		$1	$803	0.04%	
7a. Waste Service IA		per cow	321.79	see below	321.79	variable	Incl cost sharing ratio		$322	$176,984	7.99%	
7a. Waste Disposal		per cow	350.00	300-400	350	variable	per year		$350	$192,500	8.69%	
8. Supplies		lump sum	30.00	constant	1.00	constant	per cow		$30	$16,500	0.75%	
9. Office overhead		lump sum	25.00	constant	1.00	constant	per cow		$25	$13,750	0.62%	

DAIRY3.XLS
TABLE 2.3

Subtotal of Livestock Costs									$982	$540,248	24.40%	
Cost of Operating Capital 50 % of Feed		1267.71		5%		APR			$63	$34,862	1.57%	
	Livestock $											
Total of Operating Costs									$2,599	$1,429,343	64.55%	
Gross Margin = Gross Receipts - Total Operating Costs									$1,427	$785,005	35.45%	
▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Calculation of		Item	Percent	Investment	Salvage	Years	Average %	CRF	SPF	Remarks		
Financial Factors		Buildings	60%	3000	0.00	25.00	0.07	0.088	0.184	no salvage		0.00
		Equipment	40%	3000	480.00	10.00	0.07	0.142	0.508	% of Initial Investment=		0.40
		Livestock	100%	1712.50	428.13	4.00	0.07	0.295	0.763	% of Initial Investment=		0.25
	Waste Treatment		100%	3750.00	0.00	25.00	0.07	0.086	0.184	no salvage		
Item		Unit	EV $/unit	Range	Present Worth Salvage		Amort $	CRF	Per Cow	Per Herd	% Receipt	Remarks
Ownership or Fixed Costs												
A. Buildings		per cow	1800.00	.6(2000-4000	0.00		1800.00	0.086	$154	$84,952	3.84%	Uniform Dist
B. Equipment		per cow	1200.00	.4(1625-1800	244.01		955.99	0.142	$136	$74,861	3.38%	Uniform Dist
C. Livestock		per cow	1712.50	1625-1800	326.61		1385.89	0.295	$409	$225,034	10.16%	Uniform Dist
D. Waste Treatment		per cow	3750.00	3500-4000	0.00		3750.00	0.086	$322	$176,984	7.99%	Uniform Dist
Total Fixed Costs									$1,022	$561,832	25.37%	
Total Cost per Year									$2,449	$1,346,837	60.82%	
▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Item		Unit	EV $/unit	Range	Physical Amount		Units		Per Cow	Per Herd	% Receipt	Remarks
					EV	Range						
Summary of Economic Returns												
A. Gross Receipts									$4,026	$2,214,348	100.00%	
B. Operating/Variable Costs									$2,599	$1,429,343	64.55%	
C. Ownership/Fixed Costs									$1,022	$561,832	25.37%	
D. Return To All Capital Resources- Land, Labor, & Management									$406	$223,173	10.08%	
E. Value of Labor		hours	10.00	constant	20.00	constant	hr/cow		$200	$110,000	4.97%	
F. Return To Land & Man									$206	113173.247	5.11%	
G. Value of Management.		per cow	4026.09	constant	0.05	constant	percent of gross receipts		$201	$110,717	5.00%	
H. Return To Land									$4	2455.8405	0.11%	
I. Value of Land Lease		acre	400.00	constant	3.30	constant	area of lease		$2	$1,320	0.06%	
							Economic Profit		2	1135.8405		
									$/cow-yr	$/herd-yr		

III. Resource Commitments

Summary of Subsection III. **Land and water are required for the livestock industry. Feed is imported, though in the future the park may provide opportunities to subsidize this operation. Electrical energy is required for modern, efficient operation, although cogeneration is a future option. The cost of development, including land acquisition, over several years of construction, is estimated at approximately $40 million. This includes private costs to relocate. This is a preliminary estimate based upon development to ultimate capacity. However, as additional information becomes available on details of project phasing and construction needs, cost estimates will be refined.**

A. Water

In terms of natural resources, agricultural parks use land and water to produce products for human consumption. The majority of animal feed is presently imported from the mainland, and this is expected to prevail. However, the sites could be used to subsidize these feed imports. For example, dry cows (during non-lactating periods) and calves can be grazed on grasslands. Corn can be grown in adjoining agricultural operations for feed.

Water supply is needed for both dairy operations, and irrigated diversified agriculture. Average daily water demand for the dairies is estimated at 130,000 gallons per day. Peak daily dairy demand is estimated to be 200,000 gallons per day. Within this amount, approximately 55,000 to 82,000 gallons of potable water are needed per day for domestic and milk parlor sanitation purposes. This does not include diversified agriculture irrigation requirements. Average water demand for diversified agriculture, including lots at the Kahuku site which will be leased in the future, and Kahuku Farmers Association is estimated at 1,100,000 gallons per day. Peak water demand for diversified agriculture is estimated to be 1,400,000 gallons per day. Total peak daily demand is estimated to be 1,600,000 gallons per day. This water will be provided from existing sources.

Palikea Uplands. If this site is selected, it is proposed that the majority of the water be drawn from an existing nonpotable surface source, Waiāhole Ditch, after negotiating suitable withdrawal plans with the private owner of the system. The current average flow in the Waiāhole system is 27 mgd. The State has rights to a portion of this water. Less than 5 percent of the available flow would be needed for the livestock park development.

Kahuku. If this site is selected, it is proposed that the majority of the water supply be drawn from the source supplying the present Agricultural Park at Kahuku. This is commonly referred to as Pump Station 1, containing State Well Nos. 4057-01, -02, and -08, in present use. The declared use for this source includes one mgd for the Kahuku Farmers Association pumps and 0.98 mgd for the State Department of Agriculture pumps. The water for the livestock operations and new diversified agricultural lot leases will be credited against the 0.98 mgd declared use made by the Department of Agriculture.

With the designation of the Ko'olauloa aquifer system as a ground water management area, there will be a determination made by the Commission on Water Resource Management concerning the permissable quantity for consumptive use. A permit for water use has been filed for the amount needed for the Kahuku Agricultural Park. Determination will be most likely based, among other factors, on reasonableness and benefit of the proposed use.

B. Land

The use of the land will involve the conversion of fallowed crop land to diversified agricultural operations. The gulches within the site may be used for grazing cattle. There are additional lands adjacent to the project boundaries presently used for agriculture at both sites. These lands could be used for month-to-month leases for grazing and long-term diversified farming. The total area will be determined by future planning and land acquisition cost factors; for now, the estimated land requirements are approximately 750 to 900 acres.

C. Capital

The amount of capital expenditures to acquire the land, to construct an integrated waste management system planned as a closed loop, and to complete necessary infrastructure improvements has been preliminarily estimated at $40 million over a multi-year period. A breakdown of this expenditure is shown below:

TABLE 2.4 - COST ESTIMATE FOR PROJECT DEVELOPMENT

Item	*Cost ($ million)*
Land Acquisition	13
Animal Waste Management Systems	15
Infrastructure (roads, water, utilities, drainage)	8
New Dairy Facilities	4
TOTAL	$40 million

These costs assume total development of the agricultural park, i.e., one-fourth of O'ahu's present dairy production capacity relocated and expressed in 1992 dollars. They do not include engineering design, administration, or annual maintenance costs.

The land acquisition and a portion of the infrastructure and waste management components will be provided by State funds. These costs can be recovered through lease assessments. The lease rent charged tenants will depend upon several factors:

1) lease cost analysis aimed at recovering a fair return for the State's investment;
2) the extent that waste management practices on-site (i.e., individual collection operations) will contribute to overall reductions in the cost of operation of the waste management system;
3) the availability of entrepreneurs interested in providing joint venture capital with the State to construct and operate waste management systems, including energy and fertilizer reclamation; and

4) the cost of land acquisition.

Not all of this cost is directly related to dairy relocation. For example, at the Kahuku site, approximately 200 acres of land presently leased by Kahuku Farms is included in the $13 million land acquisition cost. Additional non-dairy diversified agricultural leases are also included in the acquisition cost. Approximately $2 million is for land allocated for dairy operation. Approximately $1 million of the infrastructure cost is estimated as directly related to dairy operations. Thus the portion of costs related to dairy relocation is approximately $22 million.

D. Energy

Livestock operations, in particular dairies, require electrical support systems to function, for example, modern milking parlors, dairy barns with ventilation equipment for cow comfort, water pumping facilities, and waste management with motors for pumps and machinery.

SECTION THREE — SUMMARY OF AFFECTED ENVIRONMENT

I. Physical Environment

Summary of Subsection I - Palikea Site. The potential site is located on the Palikea dissected upland, *mauka* of existing sugarcane cultivation. There is approximately three times more average annual evaporation than rainfall at the site. The average daily temperatures are estimated between 62 to 85 degrees Fahrenheit, depending upon the season. The prevailing winds are from northeast, east-northeast, and easterly directions. The geology and resulting soils are the result of the Wai'anae volcanic series. Soils are deep (five feet typically) and are classified as silty clay loams.

The site is within the Kunia aquifer system (a part of the Pearl Harbor Groundwater Management Area) and is believed to be hydrologically separated from the Wai'anae aquifer and weakly connected to the Waipahu system of the Pearl Harbor aquifer. Public and private wells are near the project site. A theoretical analysis of ground water movement indicates the potential exists for infiltration at the site to reach the surrounding wells. The existing ground water quality is good, although chloride concentrations are close to the standard set by the Board of Water Supply. Potable supplies are presently produced from raw water supplied by nearby Honouliuli wells. The 'Ewa Water Development Corporation plans significant withdrawals (approximately 13 million gallons per day) from this well field.

The floodplains are relatively shallow and narrow and will not be affected by potential agricultural facilities.

Existing surface water (instream) quality standards are likely exceeded because storm runoff from forested and agricultural lands contains contaminants. The stream's beneficial uses at the present are intertwined with the existing agricultural land use. A potential impact of the project is the extent that the project's agricultural activities might worsen this situation.

Summary of Subsection I - Kahuku Site. The potential site is located on the Kawailoa dissected upland, *mauka* of the Kahuku Agricultural Park. There is approximately two and one-half times more average annual evaporation than rainfall at the site. The average daily temperatures are estimated between 68 to 88 degrees Fahrenheit, depending upon the season. The prevailing winds are from east-northeast, easterly, and northeast directions. The geology and resulting soils are the result of the Ko'olau volcanic series. Soils are deep (five feet typically) and are classified as silty clays and clay loams.

The site is within the Kahuku unit of the Ko'olauloa aquifer system and is believed to be hydrologically connected to the Lā'ie unit of the same aquifer system. Public and private wells are near the project site. A theoretical analysis of ground water movement indicates the potential exists for infiltration at the site to reach the surrounding wells. The existing ground water quality is good. Potable supplies can be obtained from raw water supplied by nearby wells. The Board of Water Supply plans to provide as much as one million gallons per day from the nearby Kahuku wells.

The floodplains in the gulches are relatively shallow and narrow and will not be affected by potential agricultural facilities. However, the floodplain is relatively wide and deep where the gulches disgorge their flood flow onto the coastal plain. Dairy facilities and waste management facilities will avoid these areas. Detention of storm runoff can have a positive effect on flood reduction downstream.

Existing surface water quality standards are likely exceeded because storm runoff from forested and agricultural lands contains contaminants. This condition is a potential impact consideration because the project's agricultural activities might worsen this situation, unless strict controls on grazing, waste management, and drainage are enacted.

A. Topography

Palikea Uplands Site. The site is predominantly in the deeply-dissected Palikea upland physiographic province. The deeply-dissected Palikea upland is transitional between the Wai‘anae Range beginning at the watershed divide and ending at the Schofield saddle region where lavas impinged upon each other from the Ko‘olau and Wai‘anae Volcanoes. Figure 3-1a shows the elevation contours (mean sea level datum) at the potential site. The elevations at the more readily usable portions of the site range from approximately 500- to 800-foot elevation from the *‘ewa* direction (southern portion of the site) to the Kunia direction (northern portion of the site). Steeper portions of the site have elevations exceeding 1,000 feet.

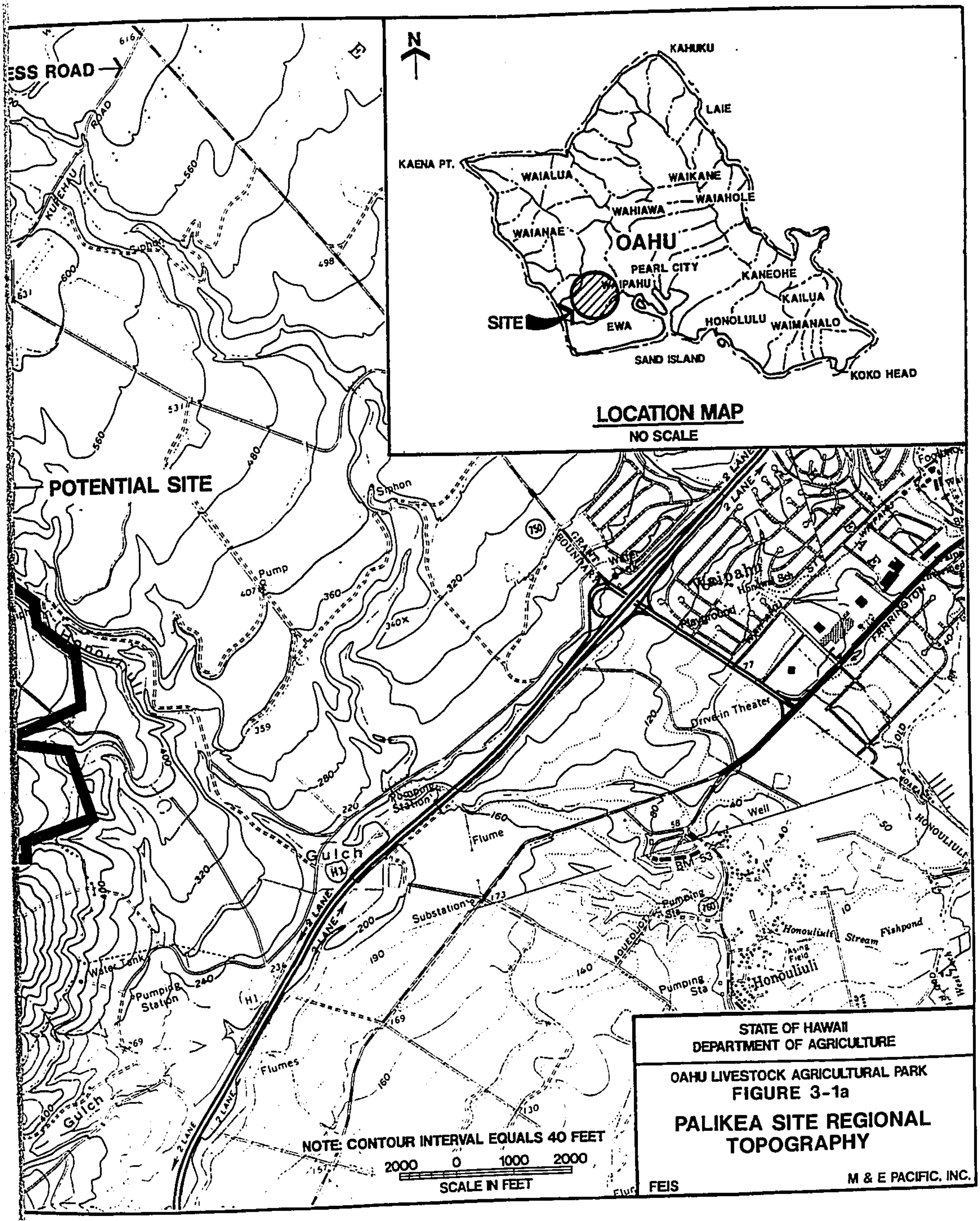
Slopes at the Palikea site vary from 20 percent or less, on fallowed sugarcane land to greater than 50 percent slope, on the upper elevations fronting the Wai‘anae Range and the gulches. The Honouliuli *Gulch forms the major boundary* on the eastern side of the site. Five minor streams that headwater in the Wai‘anae Range and traverse the site have catchment areas greater than 100 acres. These intermittent streams are not as deeply incised as Honouliuli stream, the latter having valley walls approximately 50 feet in height.

Kahuku Agricultural Park Site. The potential site is located in the Kawailoa upland which divides the Ko‘olau Range from the coastal plain. The coastal plain reaches its greatest width in this area north of Kahuku; it is approximately one and one-half miles wide. Figure 3-1b shows the elevation contours at the potential site. The elevations of the most usable portions of the site range between 50 to 300 feet. The highest portion of the site reaches the 600-foot elevation.

The relief is varied over the site. Slopes are 20 percent or less, on fallowed sugarcane lands, but can exceed 30 percent in gulches and ridges forming the *mauka* portion of the site. One principal stream traverses the site. This is the ‘Ōhi‘a Stream. On the southern (Lā‘ie) side, Kea‘aulu Gulch, a relatively smaller stream, borders the site. Kalae o Kahipa Gulch the northern (Kuilima) boundary. These are all intermittent streams at the coast.

B. Climate

Palikea Uplands Site. Median annual rainfall, i.e., equaled or exceeded 50 percent of the time, at the Palikea site is shown in Figure 3-2 to be approximately 25



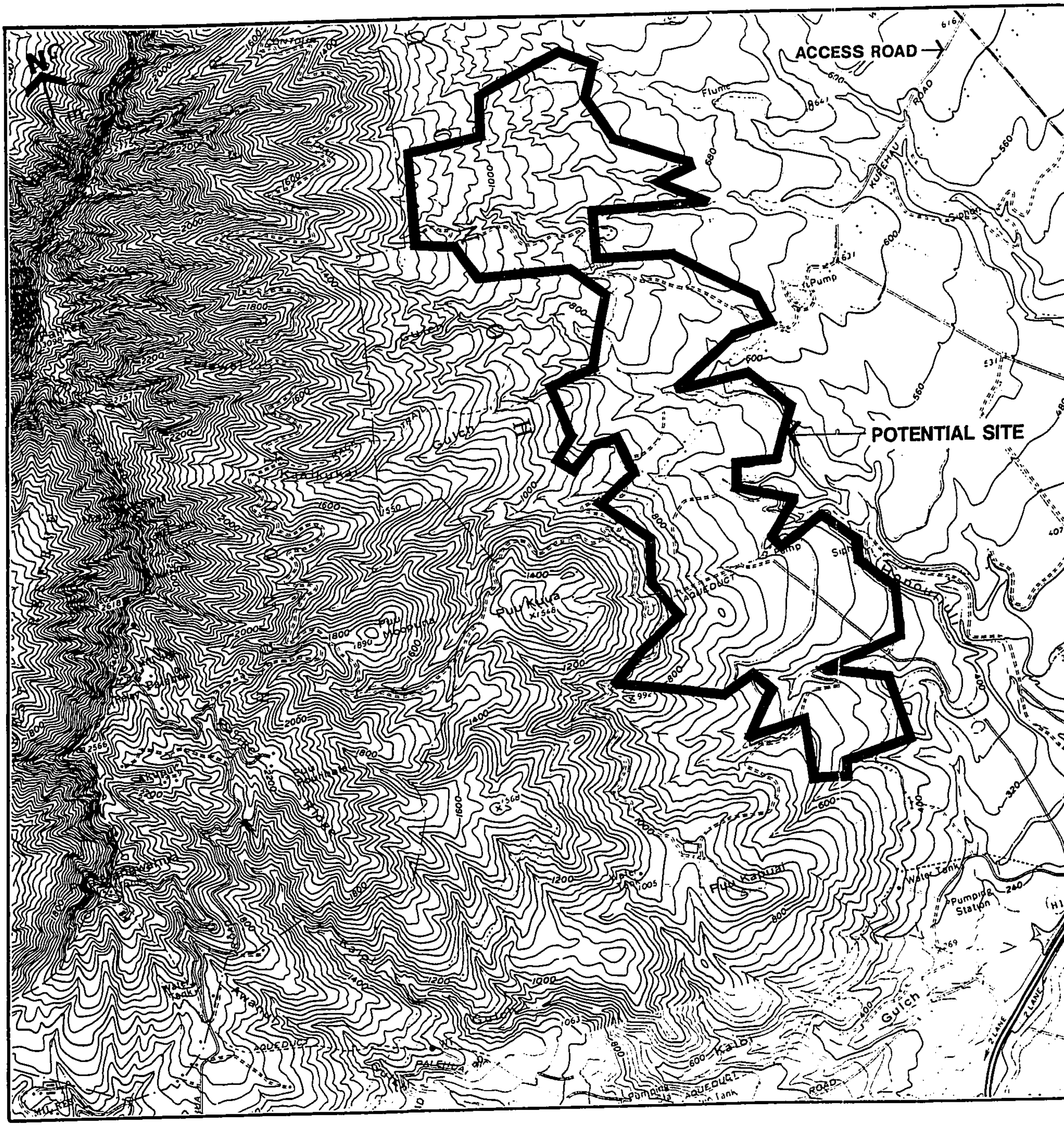
NOTE: CONTOUR INTERVAL EQUALS 40 FEET

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-1a
PALIKEA SITE REGIONAL
TOPOGRAPHY

FEIS

M & E PACIFIC, INC.


N
ACCESS ROAD
Flume
KUKEHAU ROAD
Siphon
Pump
POTENTIAL SITE
Pump
AQUEDUCT
Puu Kuua
Puu Moopuna
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Water Tank
Pumping Station
Gulch
Gulch
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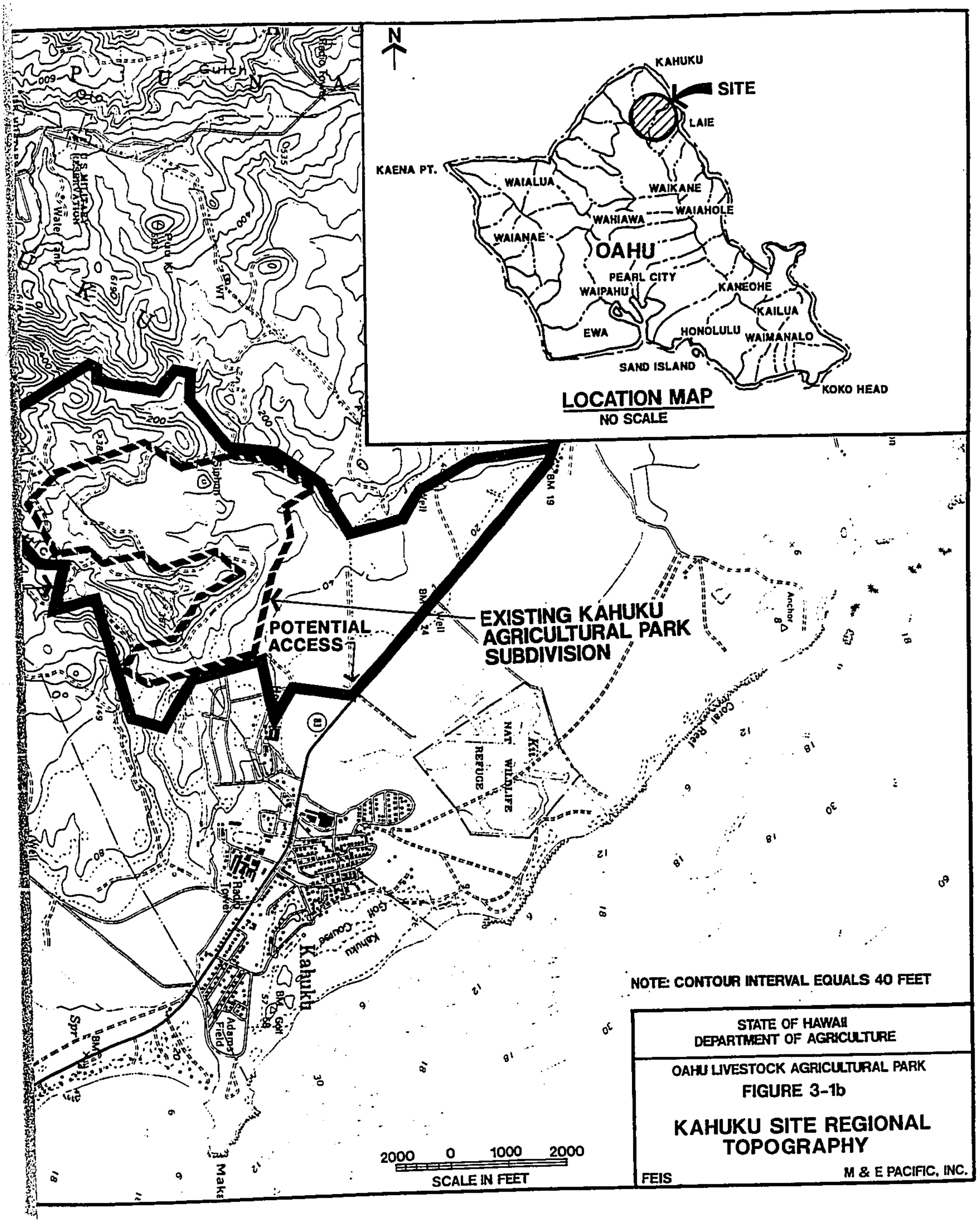
2400



NOTE: CONTOUR INTERVAL EQUALS 40 FEET

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OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-1b

KAHUKU SITE REGIONAL TOPOGRAPHY

FEIS

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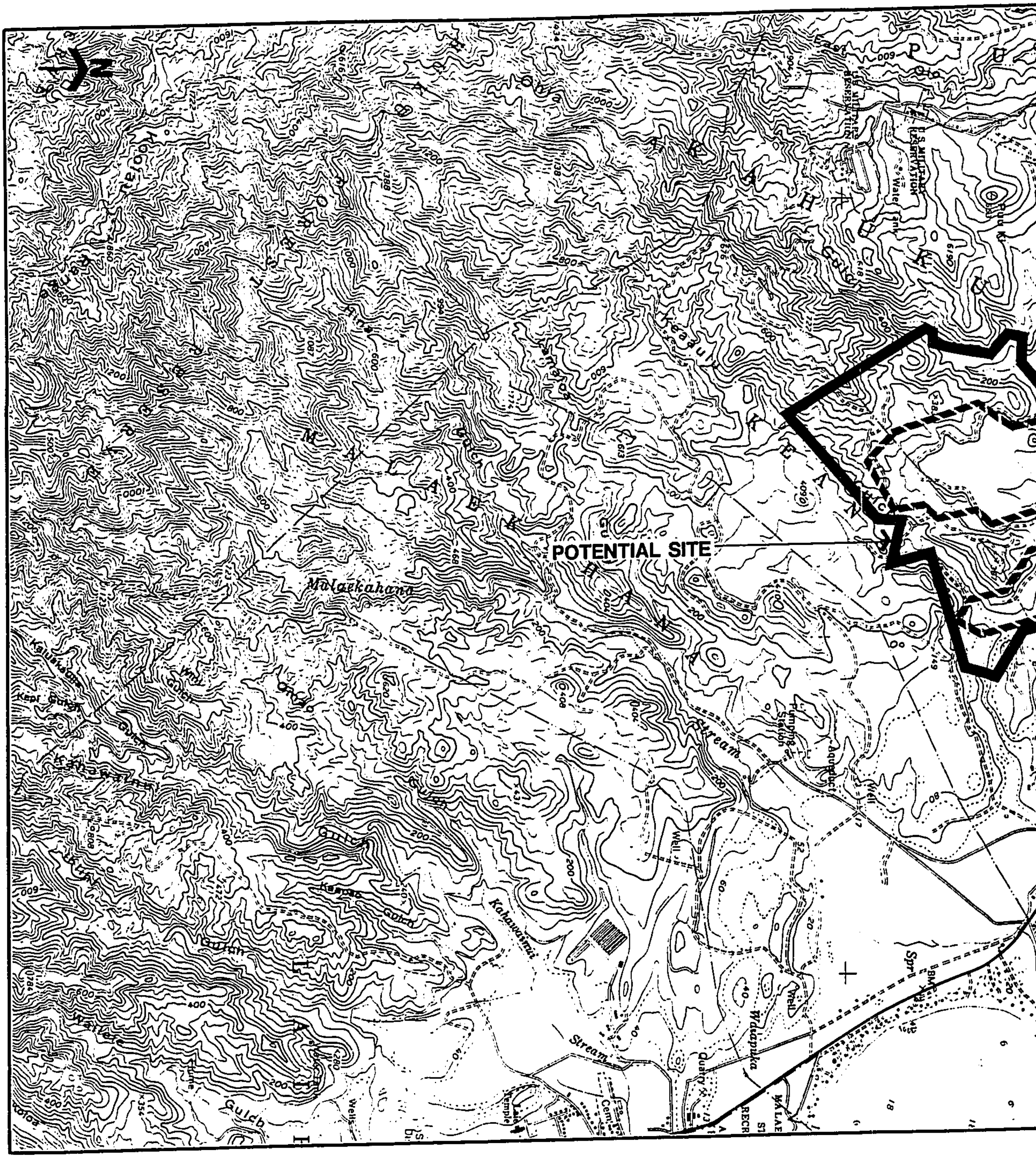
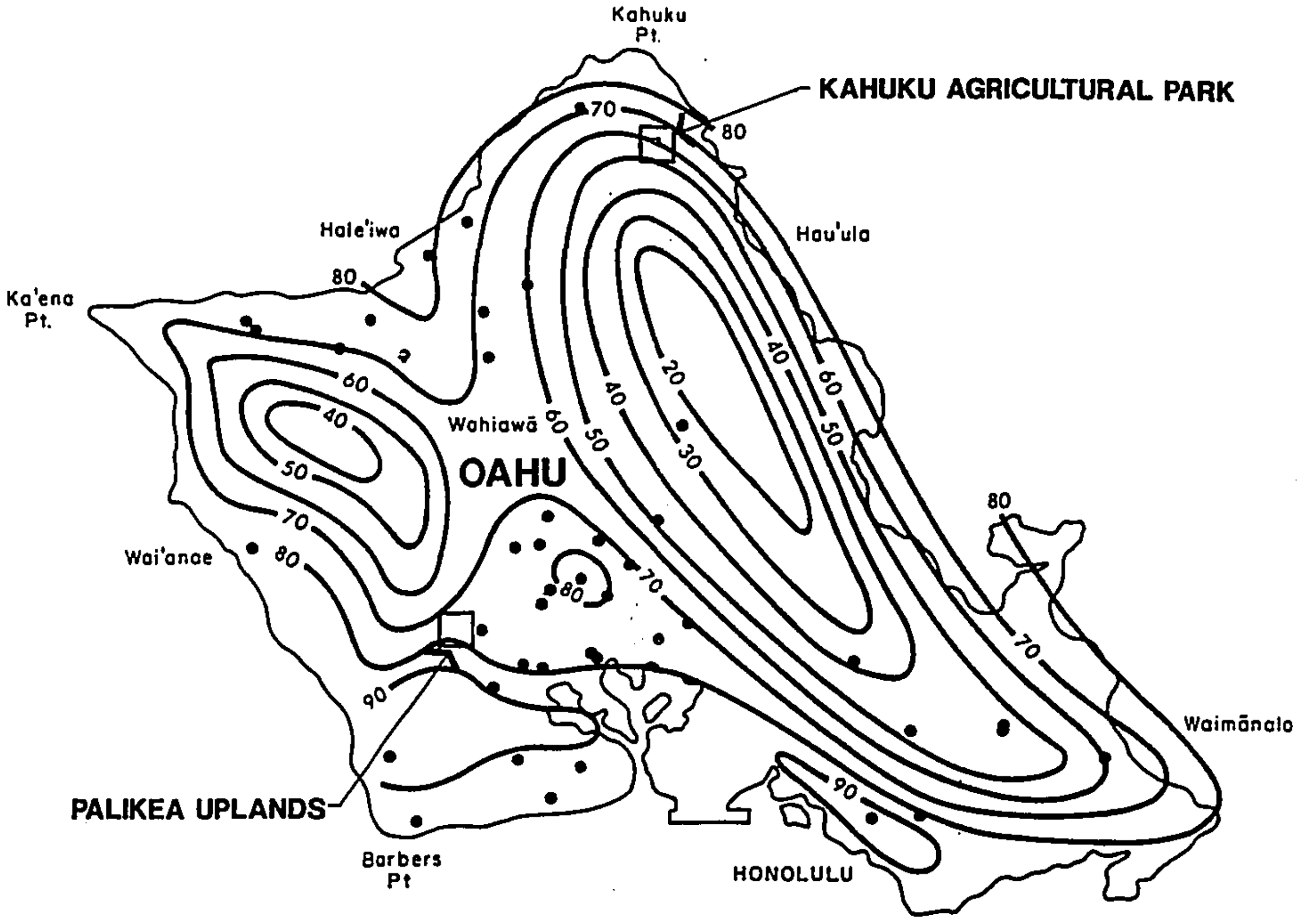
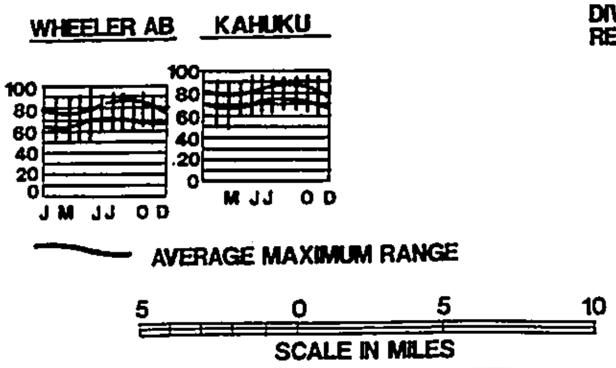

N
POTENTIAL SITE
Malaekahana
Stream
Gulch
Pumping Station
Aqueduct
Well
Kahawainui
Stream
Wailele
Gulch
U.S. MILITARY RESERVATION
Water Tank
Keaau
Temple
Quarry
Wells
Kapi Gulch
200
400
600
800
1000

MEAN ANNUAL PAN EVAPORATION (INCHES)



DAILY TEMPERATURE RANGE
(DEGREE FAHRENHEIT)



SOURCE: DEPARTMENT OF LAND AND NATURAL RESOURCES 1985
"PAN EVAPORATION. STATE OF HAWAII 1894-1983".
DIVISION OF WATER AND LAND DEVELOPMENT
REPORT R-74

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

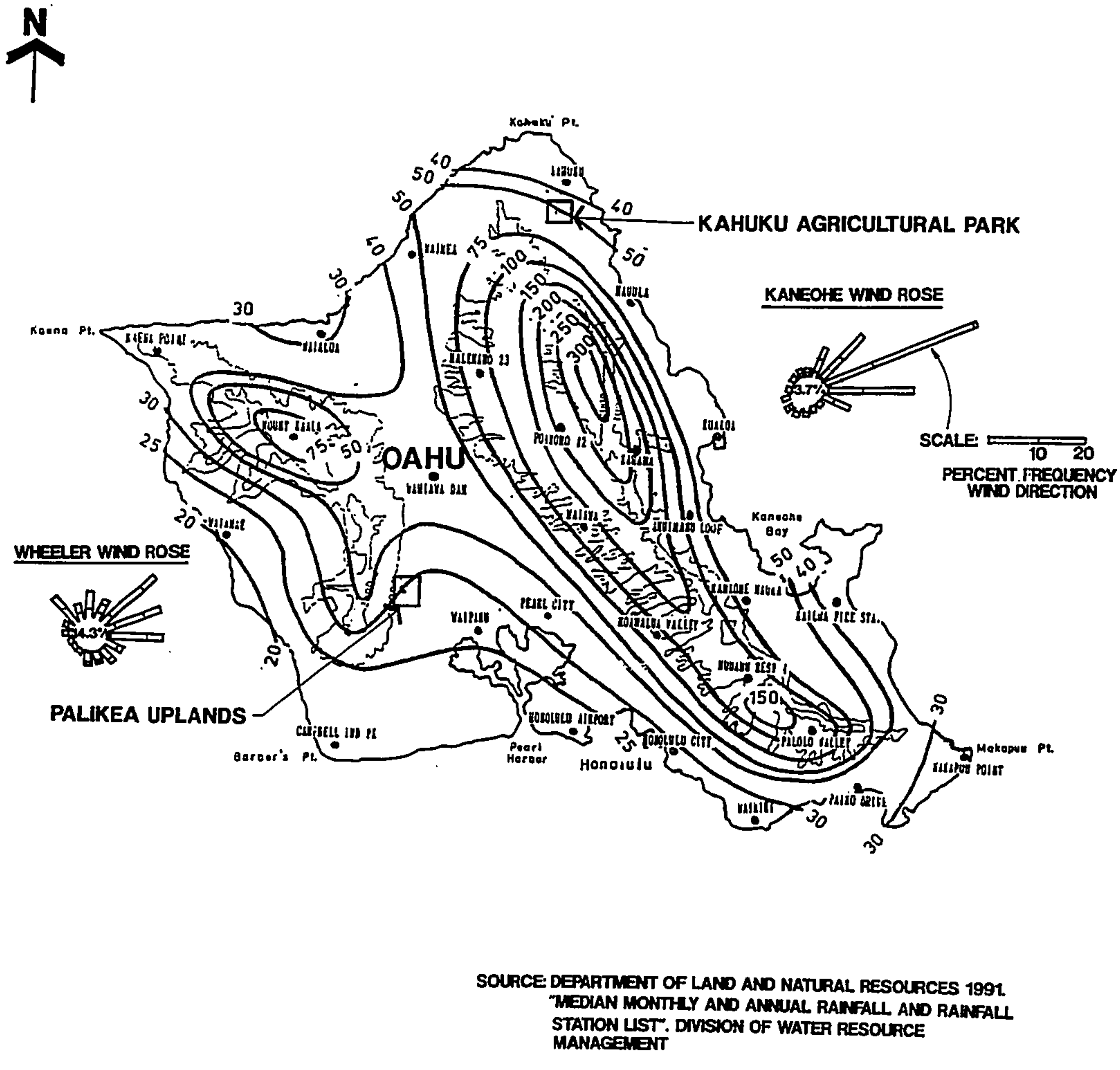
OAHU LIVESTOCK AGRICULTURAL PARK

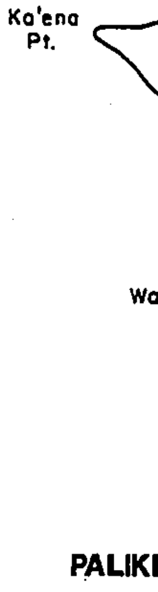
FIGURE 3-2

CLIMATE

FEIS M & E PACIFIC, INC.

MEDIAN ANNUAL RAINFALL (INCHES)





SOURCE: DEPARTMENT OF LAND AND NATURAL RESOURCES 1991. "MEDIAN MONTHLY AND ANNUAL RAINFALL AND RAINFALL STATION LIST". DIVISION OF WATER RESOURCE MANAGEMENT inches (63.5 centimeters). Using rainfall stations in proximity to the site, the average rainy season (November-April) rainfall is estimated at 3.9 inches/month (9.9 centimeters/month); dry season average rainfall is estimated at 1.5 inches/mo (3.6 centimeters/month).

Annual pan evaporation at the site is shown on Figure 3-2 to be approximately 75 inches (190.5 centimeters). Using pan evaporation stations in proximity to the site, average pan evaporation is estimated to be 5.3 inches/month (13.4 centimeters/month) in the rainy season and 7.0 inches/month (17.7 centimeters/month) in the dry season. Evapotranspiration losses at the site for the purposes of the hydrologic evaluation were assumed equal to pan evaporation. The site is covered by tall grasses and shrubs that have high potential evapotranspiration rates.

Dividing average annual rainfall by average annual pan evaporation at the Palikea site (values in centimeters) results in a ratio of 0.33 (63.5/190.5 = 0.33). This indicates it is a relatively dry site. The deficit (evaporation in excess of rainfall) is approximately 8 inches in the wet season and 33 inches in the dry season.

Temperature variation at Wheeler Air Base, which has a similar elevation to the site, is shown in Figure 3-2. Average maximum temperature during the rainy season is estimated at 27 °C (80 °F) and the average minimum is estimated at 17 °C (62 °F). During the dry season the average maximum temperature is estimated at 29 °C (85 °F) and the average minimum at 19 °C (67 °F).

The growing season is year-round, however, solar radiation is less during the winter and results in significantly less plant photosynthesis. Average solar radiation at the earth's surface is estimated at 425 langleys per day (4350 Kcal/m^2 - day).

The prevailing wind conditions are estimated based upon the Wheeler AFB instrument records shown on Figure 3-2. The most prevalent wind direction is north-east, followed by east-north-east and easterly directions. Fourteen percent of the time the surface winds are calm (less than 3 mph); approximately 40 percent of the time the wind is from the three prevalent directions noted above.

Kahuku Agricultural Park Site. Median annual rainfall at the site is shown in Figure 3-2 to be approximately 50 inches (127.0 centimeters). Using rainfall stations in proximity to the site, the average wet season (November-April) rainfall is estimated at 6.7 inches/month (16.9 centimeters/month); dry season average rainfall is estimated at 4.2 inches/mo (10.7 centimeters/month). This yields an average annual rainfall closer to 65 inches.

Annual pan evaporation at the site is shown on Figure 3-2 to be approximately 65 inches (165.1 centimeters). Using pan evaporation stations some distance from the site, average pan evaporation is estimated to be 5.3 inches/month (13.6 centimeters/month) in the wet season and 7.7 inches/month (19.6 centimeters/month) in the dry season. This yields acreage pan evaporation closer to 78 inches. Each season is considered to cover a six-month period. Evapotranspiration losses at the site for the purposes of the hydrologic evaluation were assumed equal to pan evaporation. The site is covered by tall grasses that have high potential evapotranspiration rates.

Dividing median annual rainfall by average annual pan evaporation at the Kahuku site (values in centimeters) results in a ratio of 0.77 (50/65 = 0.77). This indicates it is also a relatively dry site, but much wetter than Palikea. The surplus (rainfall in excess of evaporation) is approximately 8 inches in the wet season, but in the dry season the deficit (evaporation in excess of rainfall) is approximately 21 inches.

In comparison with the Palikea site, the Kahuku site is wetter, particularly in the wet season, where, unlike the Palikea site which has a rainfall deficit, i.e., average monthly evaporation exceeds average monthly rainfall. This is a significant factor when it comes to controlling odors and treatment of animal wastes. The rainfall and pan evaporation data (inches) by season based on climatic stations in the vicinity are summarized below:

Site	Wet Season		Dry Season		Annual	
	R	E	R	E	R	E
Palikea	23	32	9	42	32	74
Kahuku	40	32	25	46	65	78

Temperature variation at Kahuku is shown in Figure 3-2. Average maximum temperature during the wet season is estimated at 26 °C (80 °F) and the average minimum is estimated at 20 °C (68 °F). During the dry season the average maximum temperature is estimated at 31 °C (88 °F) and the average minimum at 22 °C (71 °F).

The growing season is year-round, however, solar radiation is less during the winter and results in significantly less plant photosynthesis. Average solar radiation at the earth's surface is estimated at 425 langleys per day (4350 Kcal/m^2 - day).

The prevailing wind conditions are estimated based upon the Kāne'ohe MCAS instrument records shown on Figure 3-2. The most prevalent wind direction is east-north-east, followed by easterly and north-east directions. Four percent of the time the surface winds are calm (less than three mph); approximately 70 percent of the time the wind is from the three prevalent directions noted above.

In summary, the Palikea Uplands site is drier and slightly cooler than the Kahuku Agricultural Park site. The wind conditions and solar radiation are comparable at the two sites.

C. Geology and Soils

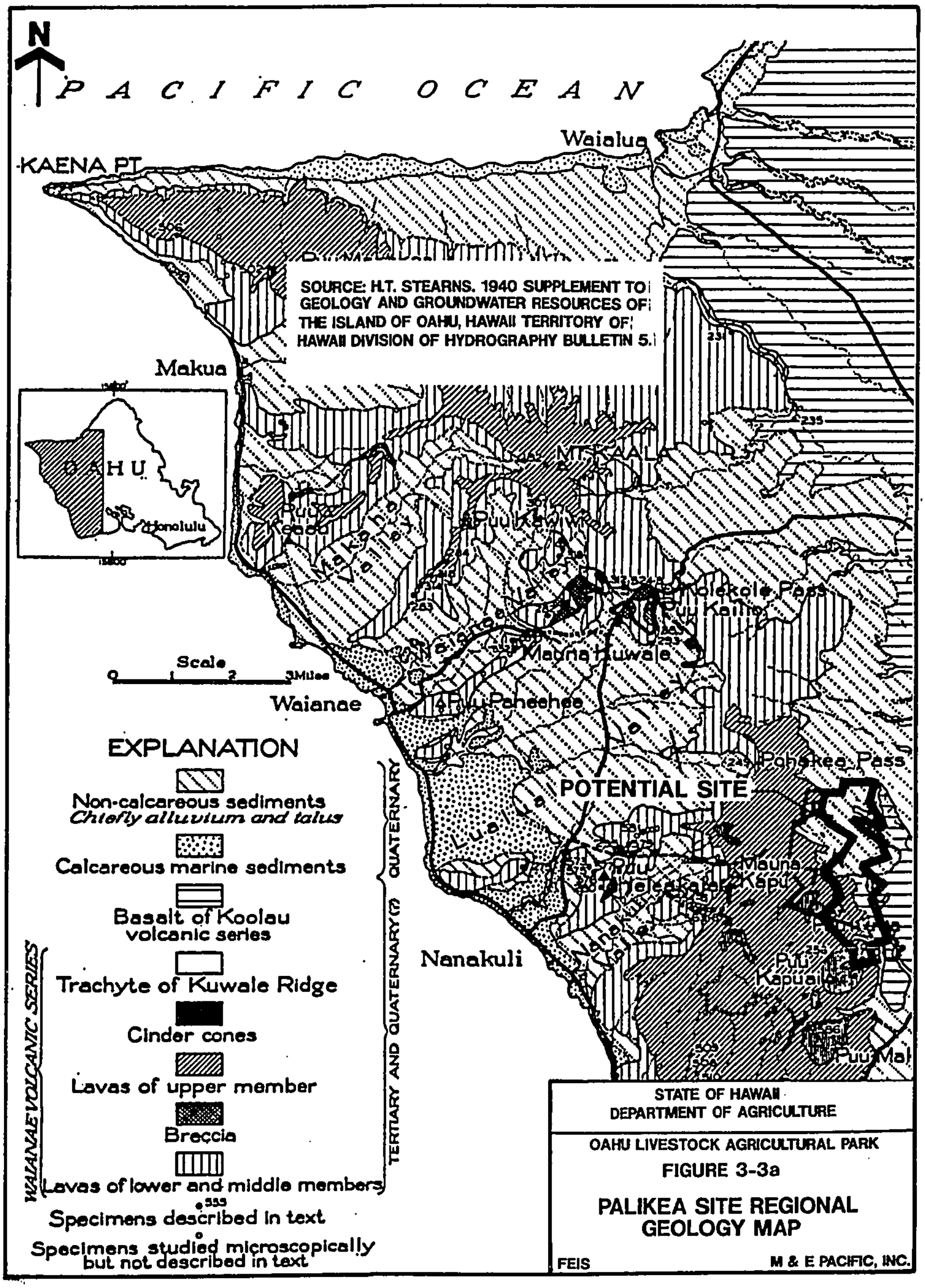
Palikea Uplands Site. Stearns (1985) estimated the age of the Wai'anae Range to be approximately 3.4 to 2.7 million years. The Wai'anae volcano is believed to have developed from both a large summit caldera near the present Kolekole Pass and a high steep fault cliff that formed a wall bounding the southwest margin of the two main rift zones. The latter feature resulted in filling of the caldera until at late stages flows spilled over onto the southern flanks and to the northwest side near Wai'anae. During the time that the caldera was filling, weathering of the flank basalts created a thin soil mantle. During the same time, the Ko'olau shield volcano building phase filled in the area between the two volcanoes. Numerous secondary cones erupted on the southern flank of the Wai'anae volcano resulting in cinder cones which left deposits of ash and cinders near the vents and thick-bedded basalt flows. Wind-blown ash added to the thin soil layer on the eastern slope. The recognizable features of this late stage eruption in the vicinity of the proposed site include Pu'u Ku'ua, and Pu'u Kapua'i (shown on Figure 3-3a). In addition, numerous andesitic basalt dikes later intruded the Upper Wai'anae Series. Though they are sparse in the poorly permeable upper member, they are more numerous in the highly permeable thin-bedded flows of the lower and middle members of the Wai'anae Volcanic Series.

Several major geologic features have resulted from the geologic history that are important in the context of the environmental impact statement. The weathering and erosional unconformity represented by alluvium and ash deposits that formed on the dormant eastern slope of the Wai'anae volcano is a poorly permeable boundary layer between the much more permeable Wai'anae volcanic series beneath and the overlying Ko'olau volcanic series. This is locally known as the Wai'anae-Ko'olau unconformity discussed later in the discussion of ground water resources. Another structural feature are the dikes. In a shield volcano, the rift zones that radiate from the central caldera are fissure zones from which lavas were extruded, but later dikes intruded into the more permeable country rock. Where the dikes are more or less parallel to the fissure they channel ground water along their trend. Where they are numerous and intersect, they form compartments reducing lateral ground water movement and impounding it at relatively high altitudes. A third structural feature which may be of some relevance are faults. Stearns (1935) believed well-cemented fault breccia was a significant impediment to ground water movement due to secondary mineralization and poor sorting.

The proposed site lies west of the boundary between late stage Wai'anae volcanics and impinging Ko'olau flows (see Figure 3-3a). This may be of considerable significance for ground water percolation as discussed in the section on ground water resources. The late stage (Upper Wai'anae Series) alkalic basalts may be expected to contain more sodium and potassium. They are interbedded with andesites. These late stage extrusives may be differentiated from more primitive tholeiitic basalts because of their lower iron content and higher alkali content. Feldspar is another mineral that may be present in significant amounts. Pyroclastic rocks such as tuff have also been identified in the upper Wai'anae member. This petrology is in part responsible for the soils found at the site.

The soil order known as Inceptisols contains the Kolekole and Kunia soil series which are among the predominant soils present on the potential site (see Figure 3-3b). These soils formed in volcanic ash and strongly weathered basic rocks. Due to the presence of humus, the soil cation exchange capacity (CEC) is moderate, less than 24 milliequivalents per 100 grams of clay. The significance of CEC is that the higher the value, the more readily the negatively-charged soil colloids can absorb cations such as metals in soil solutions.

The Kolekole soils have a surface horizon of reddish brown silty clay loam of with high bulk density. Its subsoil, however, has low bulk density and a thin pan-like layer that restricts root and water movement.



SOURCE: H.T. STEARNS. 1940 SUPPLEMENT TO GEOLOGY AND GROUNDWATER RESOURCES OF THE ISLAND OF OAHU, HAWAII TERRITORY OF HAWAII DIVISION OF HYDROGRAPHY BULLETIN 5.

STATE OF HAWAII
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OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-3a

PALIKEA SITE REGIONAL GEOLOGY MAP

FEIS

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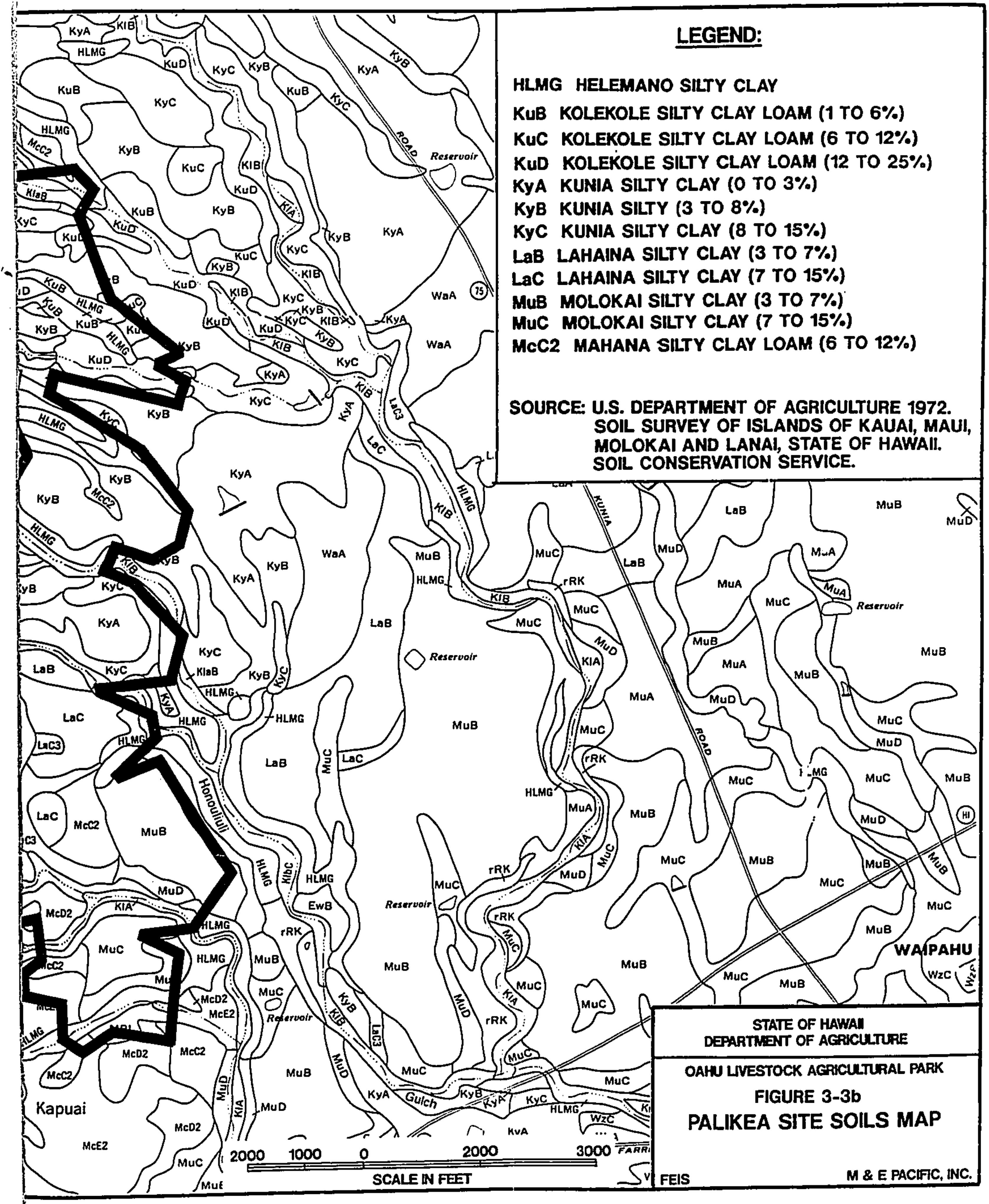

LEGEND:

HLMG HELEMANO SILTY CLAY
KuB KOLEKOLE SILTY CLAY LOAM (1 TO 6%)
KuC KOLEKOLE SILTY CLAY LOAM (6 TO 12%)
KuD KOLEKOLE SILTY CLAY LOAM (12 TO 25%)
KyA KUNIA SILTY CLAY (0 TO 3%)
KyB KUNIA SILTY (3 TO 8%)
KyC KUNIA SILTY CLAY (8 TO 15%)
LaB LAHAINA SILTY CLAY (3 TO 7%)
LaC LAHAINA SILTY CLAY (7 TO 15%)
MuB MOLOKAI SILTY CLAY (3 TO 7%)
MuC MOLOKAI SILTY CLAY (7 TO 15%)
McC2 MAHANA SILTY CLAY LOAM (6 TO 12%)

SOURCE: U.S. DEPARTMENT OF AGRICULTURE 1972.
SOIL SURVEY OF ISLANDS OF KAUAI, MAUI, MOLOKAI AND LANAI, STATE OF HAWAII.
SOIL CONSERVATION SERVICE.

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-3b

PALIKEA SITE SOILS MAP

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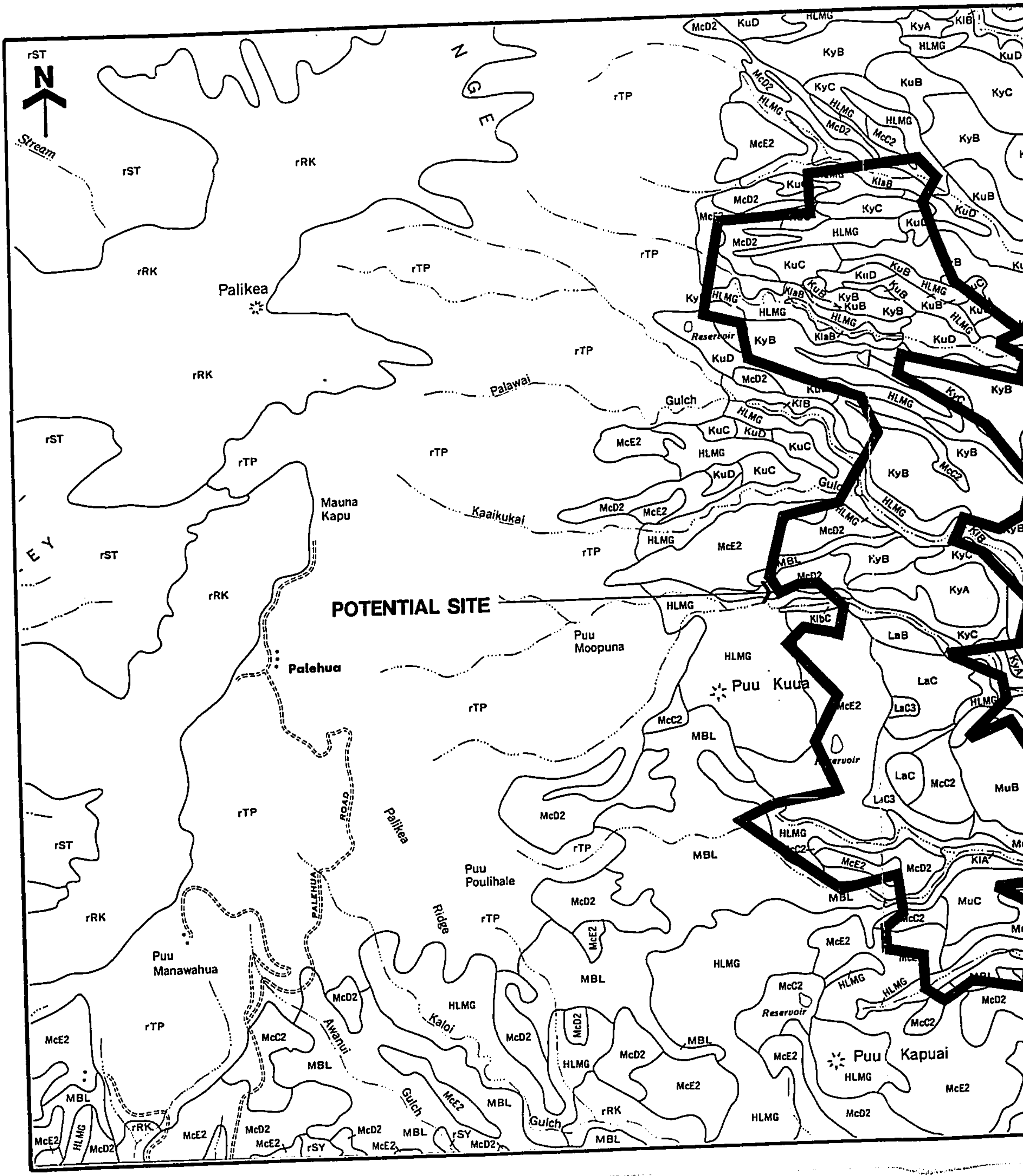


POTENTIAL SITE

The Kunia soils occur on broad, smooth slopes. They are similar to the Kolekole soil series except in mineralogy. A typical profile consists of a top surface layer of dark reddish brown clay approximately 22 inches thick with a dark reddish brown sub-soil layer of clay or silty clay loam 40 to 70 inches thick. Permeability is moderate (0.63 to 2.0 inches per hour), runoff is slow, the erosion hazard is slight, and soil is moderately to extremely acidic (pH 4.0 to 6.5).

At the southern end of the site, the predominant soils are in the soil order known as Oxisols. These are deeply weathered reddish brown soils formed on the older geomorphic surfaces on the flanks of the Wai'anae Volcano. The two soil orders represented on the site (Figure 3-3b) include the Lahaina and Moloka'i silty clays. They have a featureless profile similar to the Inceptosols but contain less humic material and have a lower cation exchange capacity. They consist of kaolin minerals and oxides of silica, iron, aluminum, and titanium.

The Moloka'i series, in particular, is found on a large, broad sloping upland at the southern end of the site. A typical profile consists of a dark reddish-brown silty clay surface layer approximately 15 inches thick underlain by silty clay loam subsoil approximately 35 to 60 inches thick. The material at depth is moderately compact. The permeability, runoff potential, and erosion hazard are similar to the Kunia series. The soil is slightly acid to neutral, except where used for pineapple cultivation. In addition to the above soils, the colluvial slopes (the sides of V-shaped gulches) consist of Helemano silty clay derived from basic igneous rock. Slopes may be from 30 to 90 percent. A typical profile consists of a 10-inch dark reddish brown silty clay over approximately 50-inch silty clay subsoil. The soil is neutral to slightly acid, permeability is moderately rapid, runoff is medium to very rapid, and the erosion hazard is very severe.

The significance of the type of soils present is that they are favorable for retention of constituents found in animal waste. Their characteristics include moderate permeability, moderate cation exchange capacity, low sodium content of the soils, and depth of soil. The important soil series that were identified on the site are summarized as follows:

TABLE 3.1 - PRINCIPAL SOIL TYPES AT PALIKEA

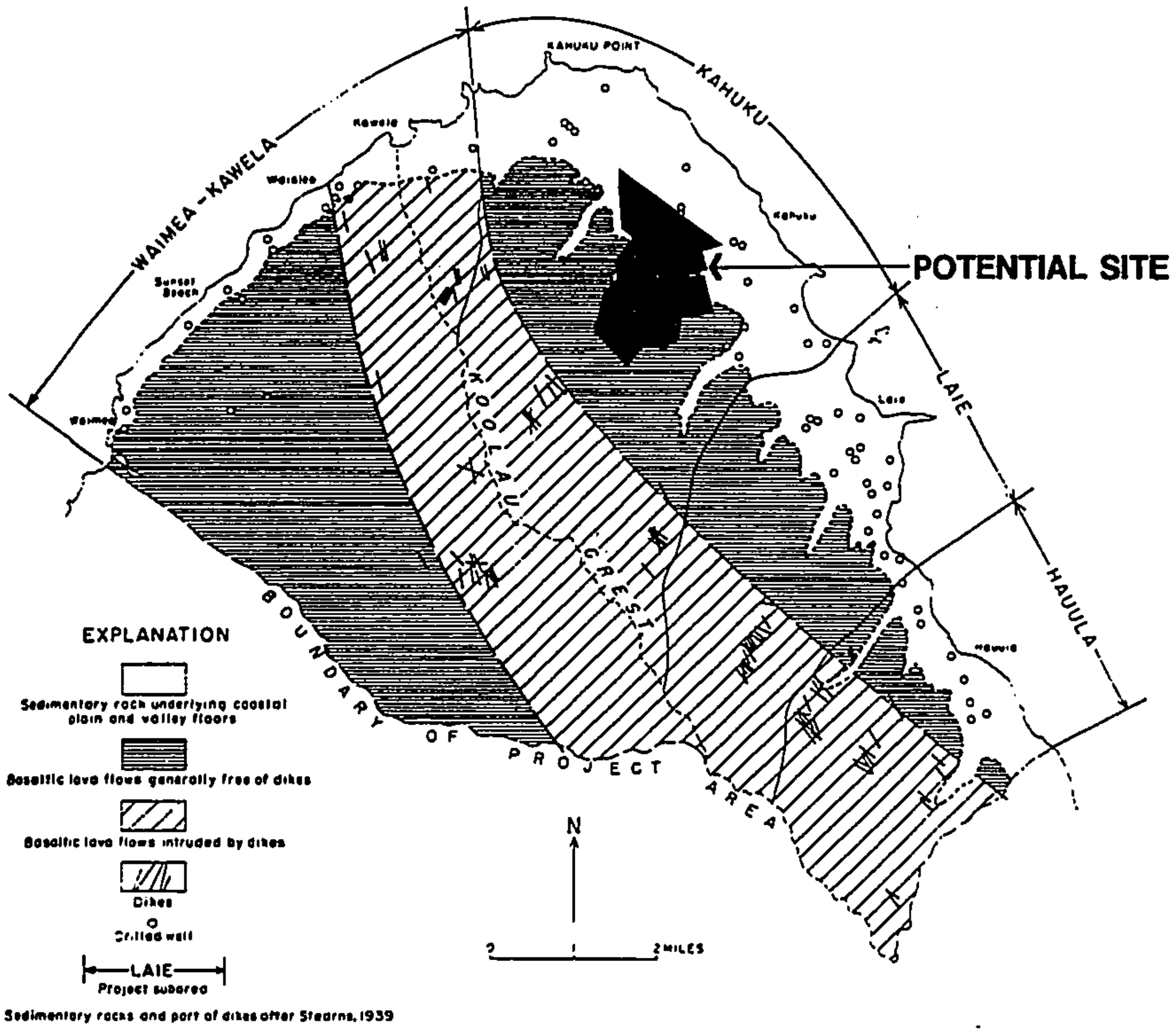
Series	Classification	Symbol	Area (acres)
Helemano	Silty Clay,ML	HLMG	136
Kolekole	Silty Clay Loam,ML	KuB,KuC,KuD	198
Kunia	Silty Clay,ML	KyA,KyB,KyC	365
Lahaina	Silty Clay,ML	LaB,LaC	63
Mahana	Silty Loam,MH	McC,McD	48
Moloka'i	Silty Clay Loam,ML	MuB,MuC	95

Note: Minor soil categories are not included.

Differences may be expected in the performance of these soils for the removal of various pollutants from effluent. For example, soils with higher CEC values would be expected to be superior for their ability to adsorb metal cations from the soil solution.

Kahuku Agricultural Park Site. The relatively younger eruption of the Ko'olau Volcano resulted in the basaltic flows and dikes in the vicinity of the Kahuku site. The principal rocks within the site are members of the Ko'olau Volcanic series. However, at the *makai* edge of the site lies the geologic contact with the sedimentary material underlying the coastal plain. The sedimentary rocks include coralline limestone and consolidated dunes; the latter composed of calcareous grains blown inland from ancient beaches and later lithified. These may be permeable as a result of dissolution action by percolating water and locally control the movement of brackish water.

The distribution of the lava flows, dikes, and sedimentary material is shown in Figure 3-4a. The basalt flows dip away from the crest of the Ko'olau Range seaward at an angle between five to ten degrees. The dikes are exposed in deeply incised valleys, but are generally restricted in occurrence to a zone approximately two miles wide centered along the crest. The sedimentary rock, interbedded alluvium, and valley fill form a poorly permeable caprock that effectively confines the ground water in the basal basalt aquifer from flowing unimpeded to the ocean. The base of the caprock is estimated (George A.L. Yuen and Associates 1990) to be



SOURCE: TAKASAKI, K.J., SANTOS VALENCIANO, AND A.M. HO, *PRELIMINARY REPORT ON THE WATER RESOURCES OF THE KAHUKU AREA, OAHU, HAWAII,* U.S. GEOLOGICAL SURVEY AND STATE OF HAWAII DEPARTMENT OF LAND AND NATURAL RESOURCES CIRCULAR C39, 1966

STATE OF HAWAII
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OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-4a

KAHUKU SITE REGIONAL GEOLOGY MAP

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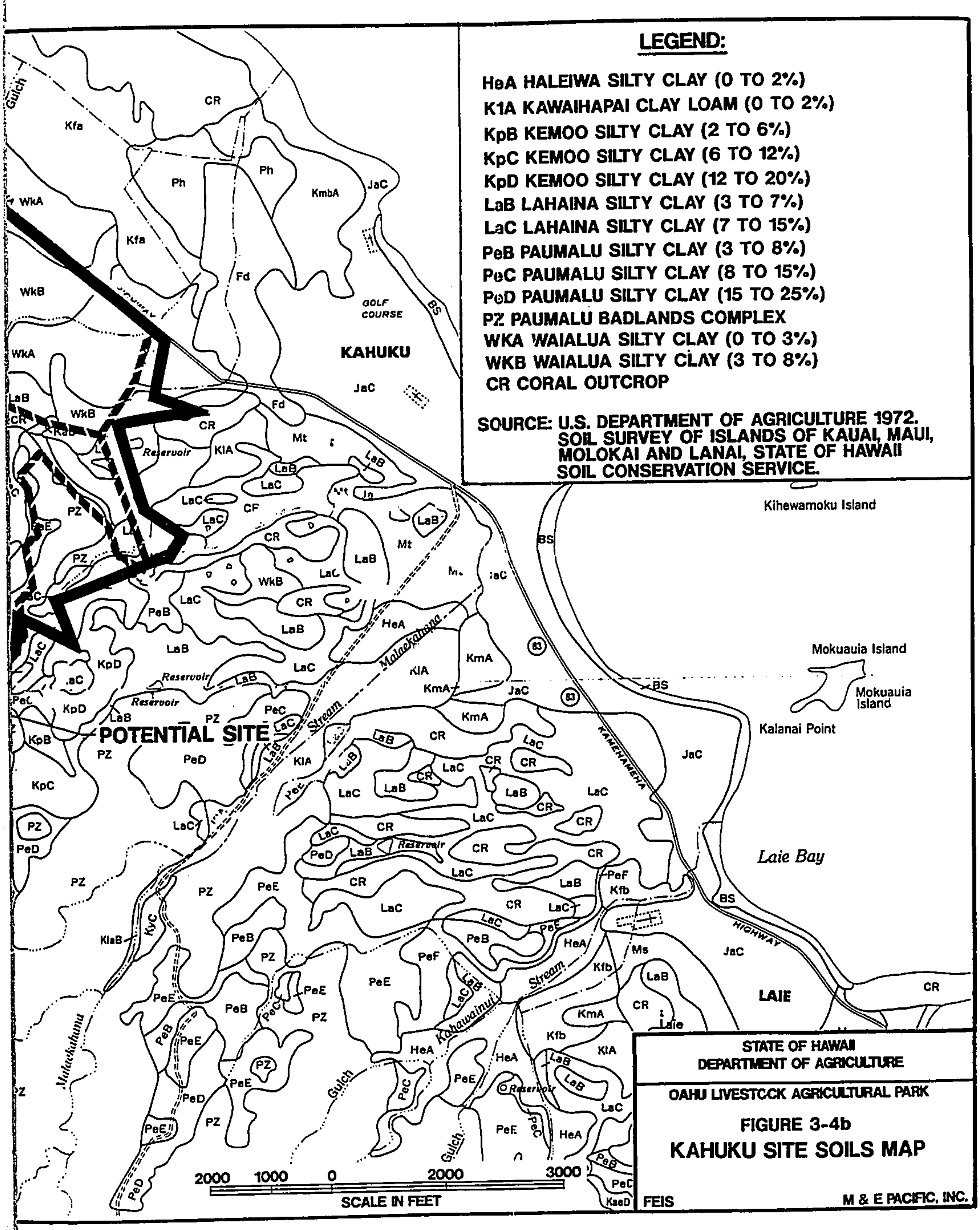

LEGEND:

HeA HALEIWA SILTY CLAY (0 TO 2%)
K1A KAWAIHAPAI CLAY LOAM (0 TO 2%)
KpB KEMOO SILTY CLAY (2 TO 6%)
KpC KEMOO SILTY CLAY (6 TO 12%)
KpD KEMOO SILTY CLAY (12 TO 20%)
LaB LAHAINA SILTY CLAY (3 TO 7%)
LaC LAHAINA SILTY CLAY (7 TO 15%)
PeB PAUMALU SILTY CLAY (3 TO 8%)
PeC PAUMALU SILTY CLAY (8 TO 15%)
PeD PAUMALU SILTY CLAY (15 TO 25%)
PZ PAUMALU BADLANDS COMPLEX
WKA WAIALUA SILTY CLAY (0 TO 3%)
WKB WAIALUA SILTY CLAY (3 TO 8%)
CR CORAL OUTCROP

SOURCE: U.S. DEPARTMENT OF AGRICULTURE 1972. SOIL SURVEY OF ISLANDS OF KAUAI, MAUI, MOLOKAI AND LANAI, STATE OF HAWAII SOIL CONSERVATION SERVICE.

STATE OF HAWAII
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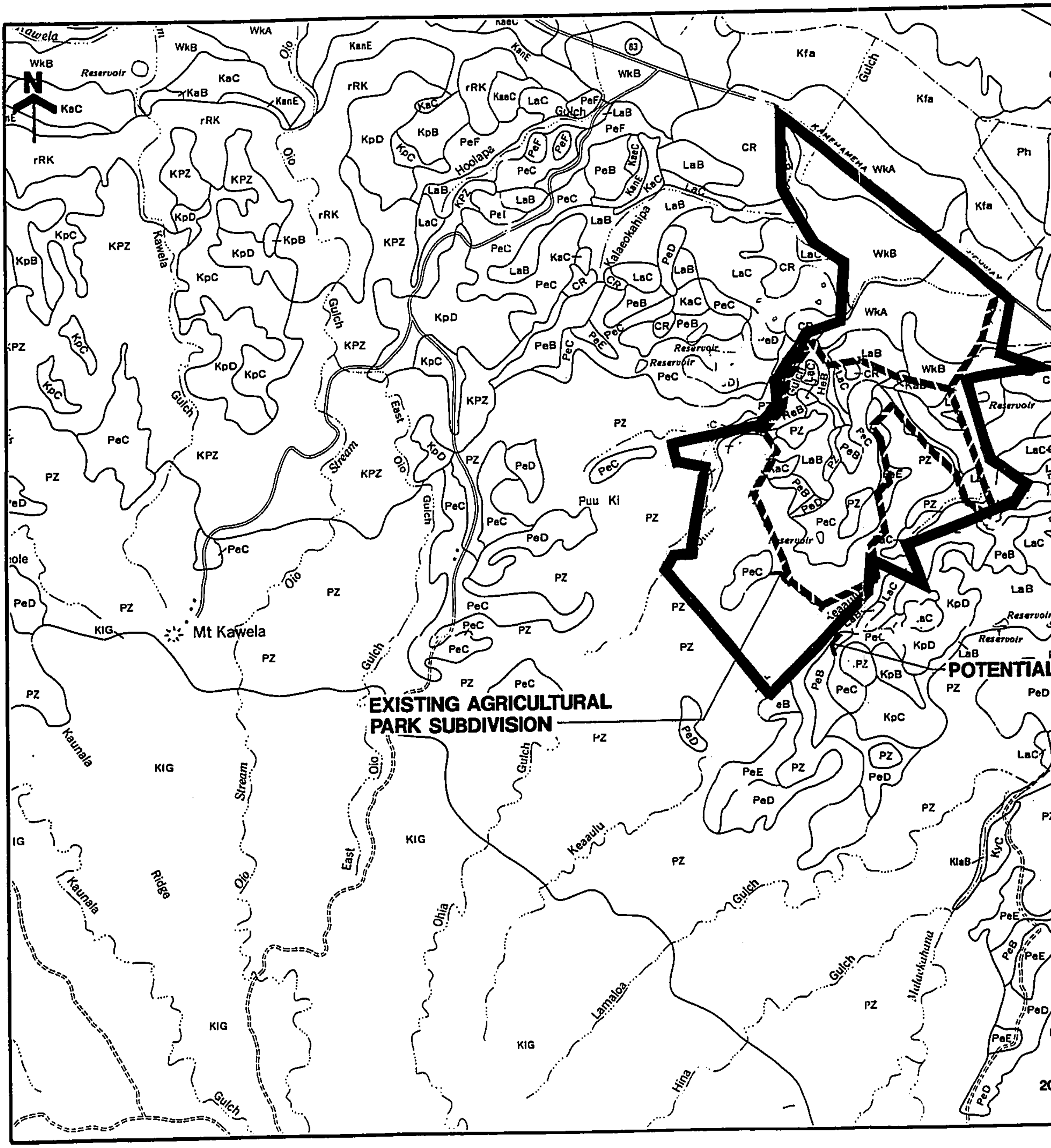
OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-4b
KAHUKU SITE SOILS MAP

FEIS M & E PACIFIC, INC.


EXISTING AGRICULTURAL PARK SUBDIVISION

POTENTIAL

between 325 feet below sea level at Kahuku to 220 feet below sea level at Mālaekahana Valley.

The Ko'olau basalts are some of the most permeable on the island of O'ahu. Stearns and Vaksvik (1935) describe the basalts as "poured out of fissures in rapid succession as short and long pahoehoe and *aa* flows ten to eighty feet thick." The pāhoehoe flows are closer to the crest where it weathers under abundant rainfall conditions into brown or black soil. In the drier, lower flanks, the basalt is covered with deep, red lateritic soil. The dikes are a few inches to several feet thick, and are generally microcrystalline structure filling the cracks in the parent basalt.

The significant aspects of the regional geology for the purposes of the environmental impact statement include the water-bearing properties of the basalt, the presence of the poorly permeable caprock, and the nature of the soils that result from intense weathering of the parent basalt. The basalts are capable of yielding copious amounts of ground water, they are extensive, and the recharge area supplying water development is considered to cover a broad region.

The soil orders that have resulted at the site include Oxisol and Ultisols. The former are reddish in color and result from intense weathering in semi-arid to humid climates, the latter under wetter conditions. There are three principal soil series represented at the site: Lahaina, Kemo'o, and Paumalū. The last two include badlands that are barren land remaining after wind and water erosion has stripped the parent soil.

The Lahaina and Paumalū series belong to the Oxisol and Ultisol orders. The Kemo'o series belongs to the Alfisols which are similar to Ultisols except that the local rainfall conditions are not sufficient to cause the leaching of exchangeable cations; thus the cation exchange capacity is higher. A typical profile of the Lahaina series consists of the following:

A Horizon	7 to 15 inches depth below surface is a dark reddish brown silty clay; fine to coarse granular structure; when dry—friable and hard; when wet—sticky and plastic; many roots and medium and fine pores and tubulars.
B Horizon	15 to 60 inches depth below surface is a dark reddish brown silty clay; medium and coarse subangular blocky structure; when dry—friable and hard; when wet—sticky and plastic; fewer roots and medium and fine pores and tubulars.

The significant site soil characteristics include the depth of the soil horizon, the abundant pores and interstitial aggregated structure that permits penetration by plant roots, and the fine pores and tubulars that hold water for plant use. The available water capacity for plant uptake is estimated to range between 0.10 to 0.12 inches per inch of soil (U.S. Soil Conservation Service 1972). The important soil series that have been identified on the potential site are summarized as follows:

TABLE 3.2 – PRINCIPAL SOIL TYPES AT KAHUKU

Series	Classification	Symbol	Area (acres)
Hale‘iwa	Silty clays and clay loams (0 to 2%)	He	30
Waialua		WkA	228
Lahaina	Silty clays (2 to 15%)	La	67
Paumalū	Silty clays (7 to 15%)	Pe	136
Paumalū and Kemo‘o	Silty clays (greater than 15%) and Badlands	KpD PeD Pz	375
Coral outcrop		Cr	15

Note: Minor soil categories are not included.

The soils that are significant for animal waste assimilation are predominantly the Waialua and Lahaina silty clays. The favorable characteristics include moderate permeability and shrink-swell potential, moderate cation exchange capacity, low sodium contents, and depth of soils. The shrink-swell potential is important because it has been demonstrated in field infiltration tests for these soils that permeability decreases several orders of magnitude as moisture content increases above field capacity. The significance is that during rainy weather, as soil moisture increases above what plants and evaporation normally remove, the decrease in permeability reduces the amount of moisture that might percolate to the ground water table.

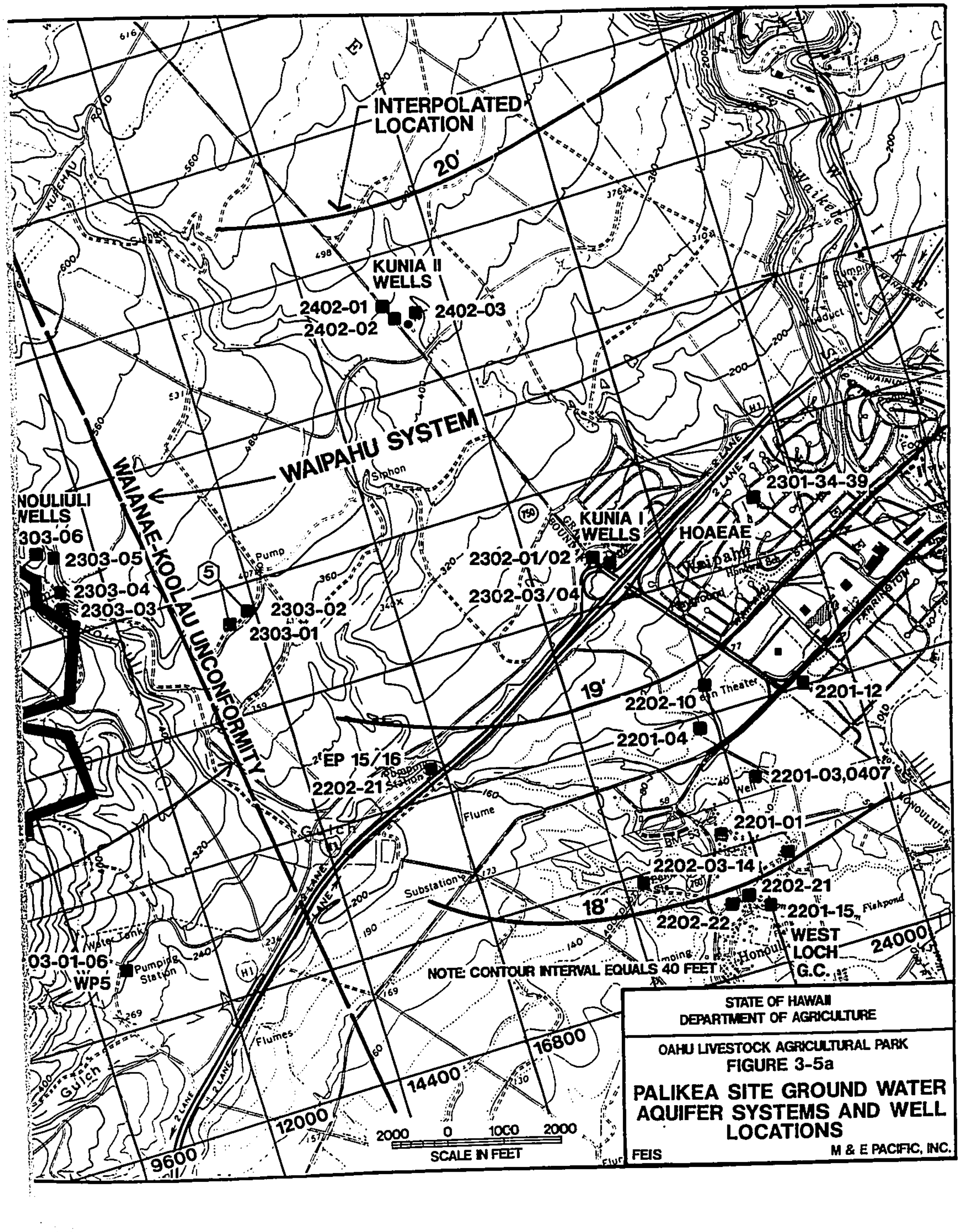
D. Water Resources

1. Hydrologic Unit

Palikea Uplands Site. This site is situated in the Kunia hydrologic unit (30205) in the Pearl Harbor aquifer sector. The Pearl Harbor aquifer is a ground water management control area within which permission for ground water withdrawal is strictly regulated by the State Commission on Water Resources Management. The boundaries between this and surrounding hydrologic units are shown on Figure 3-5a. The physical distinction between systems, however, is not exact, but does facilitate the estimation of hydrologic budgets in each sector. There is some actual hydrogeologic basis for the distinction between the Waipahu hydrologic unit and the Kunia and 'Ewa hydrologic units; it is the estimated location of the Wai'anae-Ko'olau unconformity (see Geology and Soils). However, the physical distinction between Kunia and 'Ewa hydrologic units is less distinct, but facilitates the accounting of irrigation return water transported into the Kunia unit by the Waiāhole Ditch system.

The trace of the Wai'anae-Ko'olau contact, on the basis of geological surface mapping, lies just to the east of the site (see Figure 3-5a). However, if it were superimposed on the ground surface relative to its location at sea level, the trace of the Wai'anae-Ko'olau unconformity would lie just west of Kunia Road in a north south direction. An unconformity is believed to separate the two units because the hydraulic head (potentiometric ground water surface) is different in the Ko'olau volcanics (Waipahu unit) than in the Wai'anae volcanics (Kunia unit). Seepage is assumed to take place downward through the unconformity toward the Wai'anae side although the amount has not been directly measured or estimated. This suggests that the Ko'olau side of the Pearl Harbor basal aquifer is discharging; the Wai'anae side is the recharge area.

The Pearl Harbor aquifer is one of the most studied aquifer systems in the State of Hawaii and estimates by several investigators of the sustainable yield have been made consistently ranging from 200 to 250 mgd. The estimates herein for the hydrologic areas of the proposed site are taken from the State Water Resources Protection Plan (Yuen and Associates 1990). The sustainable yield estimate for the 'Ewa-Kunia combined unit is 17 mgd assuming an equilibrium head of 18 feet, mean sea level. The water budget is discussed in greater detail in Appendix B.



STATE OF HAWAII
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OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-5a

PALIKEA SITE GROUND WATER AQUIFER SYSTEMS AND WELL LOCATIONS

FEIS

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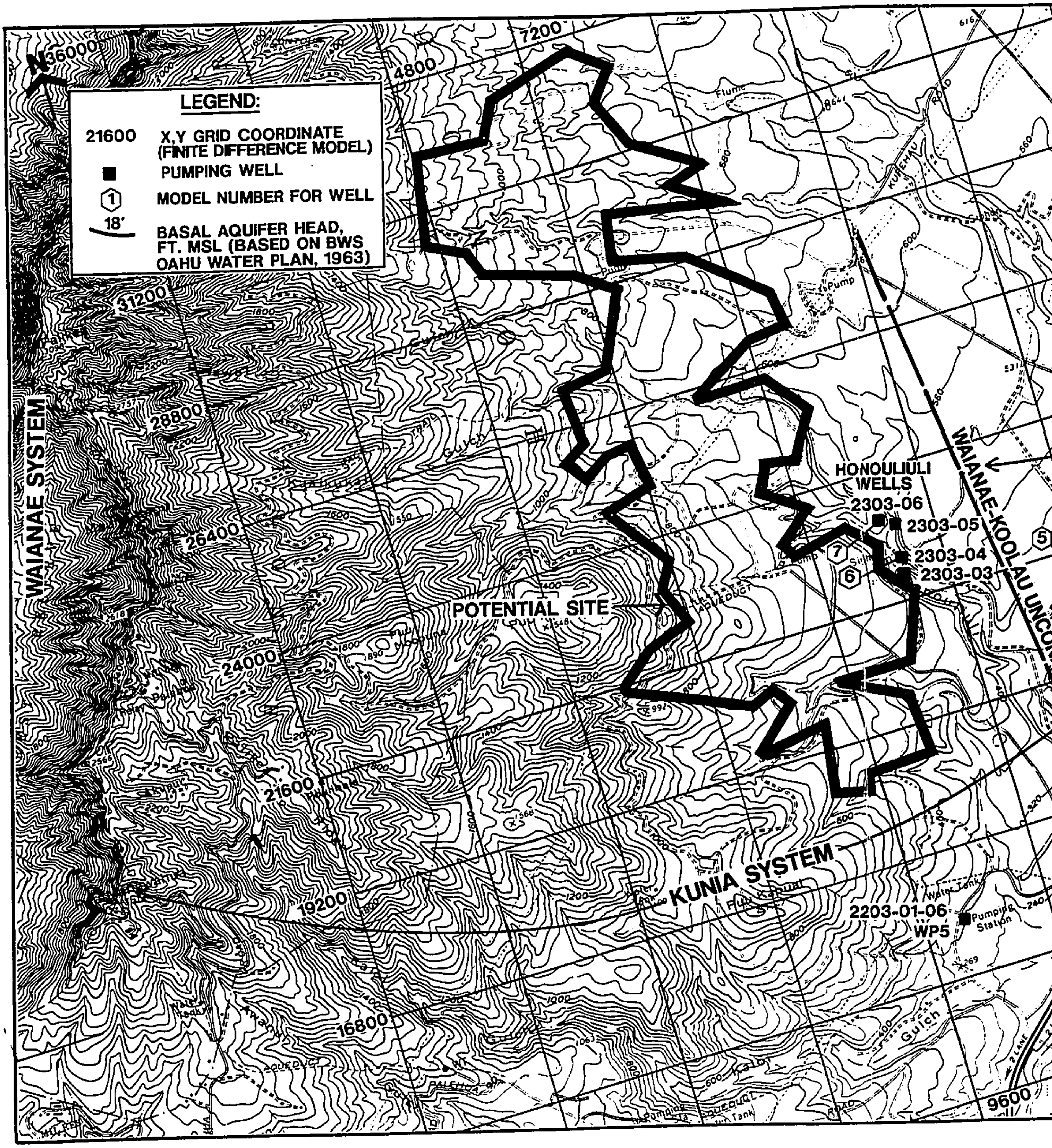

LEGEND:
21600 X,Y GRID COORDINATE (FINITE DIFFERENCE MODEL)
PUMPING WELL
1 MODEL NUMBER FOR WELL
18' BASAL AQUIFER HEAD, FT. MSL (BASED ON BWS OAHU WATER PLAN, 1963)
N
36000
31200
28800
26400
24000
21600
19200
16800
7200
4800
9600
WAIANAE SYSTEM
KUNIA SYSTEM
POTENTIAL SITE
HONOULIULI WELLS
2303-06
2303-05
2303-04
2303-03
7
6
5
2203-01-06
WP5
Pumping Station
Water Tank
WAIANAE-KOOLAU UNCO
Flume
KUNIA ROAD
AQUEDUCT
Gulch

The total ground water flux moving through these two hydrologic units is estimated at 22 mgd (Yuen and Associates 1988). The natural recharge due to deep percolation is estimated at 8 mgd, again for the combined 'Ewa-Kunia hydrologic units. The amount of recharge in the Honouliuli drainage area was estimated to be minimal in comparison to the recharge on the 'Ewa Plain (Yuen and Associates 1989). The runoff/rainfall ratio for the 12.4-square mile area was 0.136. Average runoff was 2.97 mgd based on average rainfall of 37 inches per year.

The Nānākuli hydrologic unit within the Wai'anae aquifer (from the Wai'anae Range crest to the ocean) is thought to have very little connectivity to the Kunia sector (Takasaki and Mink 1985): "The position of the rift zones relative to the crest and the valleys that cut into them makes it likely that underflow from the windward side of the crest to the lee or vice versa is small and not significant."

The Wai'anae basalt is intruded by dikes and brackish and fresh water may be found in the compartments depending upon distance from the coast. In general, the head in the Nānākuli hydrologic unit (30301) is less than five feet, mean sea level. The significance of this is that the higher head (14 feet shown on Figure 3-5a) between Pālailai wells (near Makakilo) to the Kunia wells (adjacent to Kunia Road) indicates that the topographic boundary between Wai'anae and 'Ewa corresponds to a reasonable hydrogeologic boundary as well.

Kahuku Agricultural Park Site. This site is situated within the Ko'olauloa hydrologic unit (30601). The general boundaries are considered to be the crest of the Ko'olau Range from Kahuku Point to the Punalu'u Valley, and the approximately eleven-mile circumferential caprock and Punalu'u Valley fill. The system is approximately rectangular in shape. The basal aquifer in basalt *mauka* of the caprock is unconfined, except at the margin of the dike complex. Beneath the caprock, the aquifer is confined. Early 1900-drilled wells encountered artesian water conditions.

The Commission on Water Resource Management designated the aquifer systems in the Windward O'ahu area from Makapu'u Point around Kahuku Point as ground water management areas. This includes the Ko'olauloa aquifer system. In a ground water management area, ground water use permits must be obtained (except for individual residences) for consumptive use.

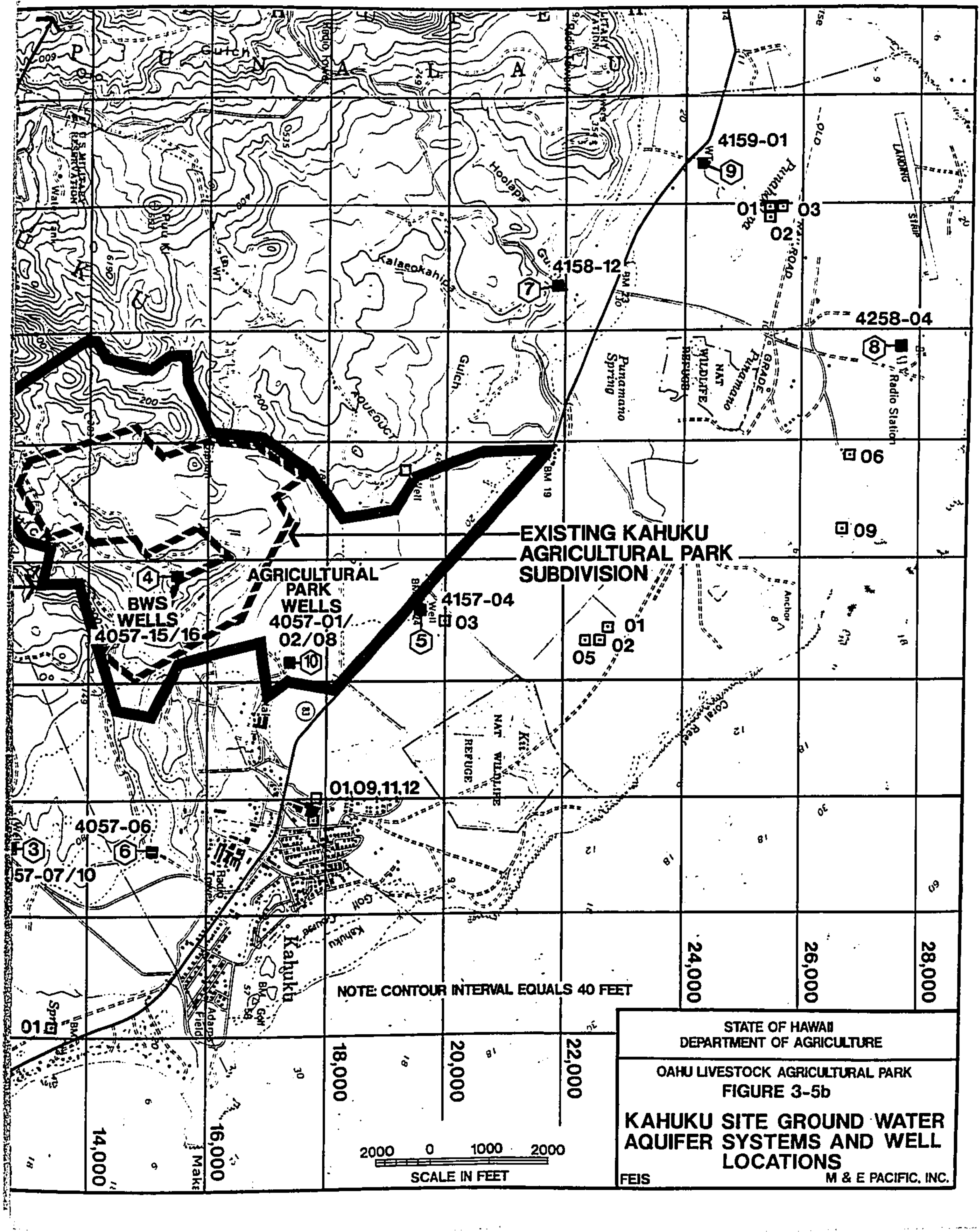
The basal aquifer is considered a fractured, hydraulically-interconnected media throughout this system, i.e., a continuum exists between the northern-most and southern-most portions. For convenience in hydrologic analysis, however, the aquifer system has been divided into units by various investigators. The most recent convention (Yuen and Associates 1990) considers four units, Kahuku being the most relevant for this discussion. This unit extends north from 'Ōma'o Gulch, south of the site. An earlier study (Takasaki et al. 1966) considered the unit boundary to be Mālaekahana Gulch, closer to the potential site (see Figure 3-5b). The uncertainties concerning the appropriate boundaries and the ground water flow direction means there is uncertainty in the estimates of sustainable yield. For example, the recharge to the basal aquifer originates in the adjacent rift zone as well as direct rainfall on the unconfined portion. Unknowns include whether the contributory portion of the zone extends beyond the crest, and how much leaks toward the coast versus following preferential flow paths parallel to the strike of the dikes. Detailed discussions of the hydrologic budget, aquifer development and behavior, water quality, and sustainable yield can be obtained in a report by George A.L. Yuen and Associates (1990), and in Appendix B.

A regional gradient in the basal aquifer of approximately one foot per mile exists from Punalu'u towards Kahuku. The significance of this is that regional ground water flow paths may be generally north to south versus east to west through the site. The marshy areas near Kahuku are thought to be the manifestations of natural leakage from the aquifer system, primarily from vertical discharge under artesian conditions. While many of the streams may be perennial near the contact with the dike zone, only Punalu'u and Kaluanui are presently perennial where they cross the caprock contact.

A summary of some hydrologic budget factors are shown below for the *Kahuku unit*:

Report	Area, sq mi	Rainfall in/yr	Rainfall mgd	Yield mgd
(1)	18	50	40	15
(2)	18	58	52	22

(1) George A.L. Yuen and Associates, 1990
(2) Takasaki, et al., 1966



STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-5b

KAHUKU SITE GROUND WATER AQUIFER SYSTEMS AND WELL LOCATIONS

FEIS
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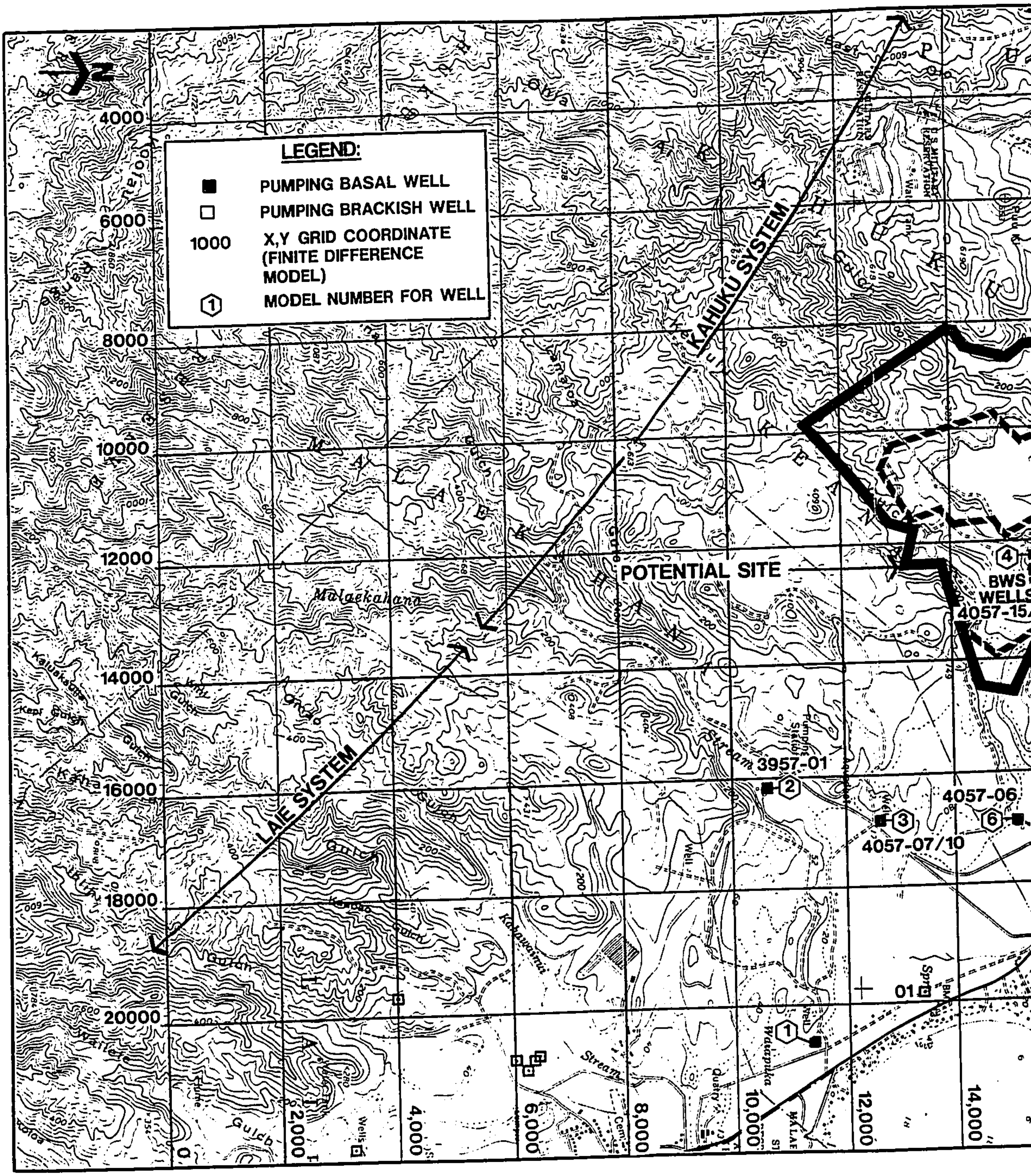

N
LEGEND:
■ PUMPING BASAL WELL
□ PUMPING BRACKISH WELL
1000 X,Y GRID COORDINATE (FINITE DIFFERENCE MODEL)
① MODEL NUMBER FOR WELL
4000
6000
8000
10000
12000
14000
16000
18000
20000
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
KAHUKU SYSTEM
LAIE SYSTEM
POTENTIAL SITE
BWS
WELLS
4057-15
④
3957-01
②
③
4057-07/10
4057-06
⑥
①
01
Malaekahana
Stream
Gulch

Report (1) above estimated the recharge for the entire 32.5 square mile *Ko'olauloa system* to be 71 mgd. These investigators estimated that a sustainable yield of 42 mgd can be achieved with an equilibrium head of 15 feet, mean sea level. However, given great uncertainties in the hydrologic budget, a more conservative value of 35 mgd was recommended.

One allocation (George A.L. Yuen and Associates 1990) of sustainable yield within the Ko'olauloa system has been proposed as shown below:

Unit	Sustainable Yield
Kahuku	15 mgd
Lā'ie	7 mgd
Hau'ula	7 mgd
Punalu'u	7 mgd

The fact that this allocation totals to 36 mgd indicates that the investigators recognized the limitations of the estimates within the artificial boundaries of each unit. However, the State Commission on Water Resource Management may need to rule on allocations or refine the estimated sustainable yield if all proposals for water development actually materialize. For example, the additional proposed uses in the Ko'olauloa system were estimated at 20 mgd by the Board of Water Supply in their 1988 regional EIS. In addition, proposed agricultural and business uses were estimated at 5 mgd. The estimated withdrawal in 1990 was 14 mgd. These proposed and current withdrawals total 39 mgd from the system.

2. Ground Water Development

Palikea Uplands Site**.** The ground water resources in the Kunia hydrologic unit have not been as extensively developed as other sectors have been within the Pearl Harbor aquifer. The major ground water development in this region is shown on Figure 3-5a. Table 3.3 lists the significant wells assumed to be within the Kunia Sector for evaluation purposes.

To the south and east of the site, there are potable and irrigation wells belonging to private owners and the Honolulu Board of Water Supply. Due south of the site is the U.S. Navy Barbers Point shaft, and the irrigation wells of Oahu Sugar Company. To the southwest are the Board of Water Supply Makakilo and Barbers Point Wells. Estimated potentiometric water levels for 1963 are also shown on

Figure 3-5a. The potentiometric surface, in an unconfined aquifer, defines the ground water surface on a regional scale. At a localized scale, e.g., a few thousand feet surrounding a well, the pattern may change. It is important to note the date of the source of this regional potentiometric map. This was one of the first comprehensive attempts to map the regional pattern based on data obtained from wells. Theoretically in an isotropic media, flow can be considered as normal to the potentiometric lines and thus a regional ground water flow pattern beneath the proposed site is inferred to be in a south-southwesterly direction; however, this may be altered by heavy pumping of the aquifer.

The potentiometric surface is significant to the environmental impact statement because it indicates the direction in which effects on ground water quality might occur. The potentiometric contours (Figure 3-5a) are not shown in the area of the proposed site because of the sparsity of wells at the time. Also note the 17-foot potentiometric contour is disjointed at the inferred Wai'anae-Ko'olau unconformity. Assuming that the potentiometric surface increases toward Wahiawā, the surface in the vicinity of the potential project site is inferred to be slightly higher on the Wai'anae side. More recent heads have been reported (State of Hawaii, Department of Land and Natural Resources, Division of Water Resource Management, *Ground Water Index and Summary* 1991) which support the same trend. For example, static water levels in Honouliuli Well Nos. 23003-03 and 2303-06 (see Figure 3-5a) were 17 to 17.4 feet, respectively in 1989, whereas approximately 2,000 feet northeast, Kunia Well No. 2402-03 was 17.0 feet. The significance is that in the vicinity of the potential project site, regional potentiometric surface trends indicate ground water discharge is probably to the south and the component expected from the east, i.e., the Waipahu unit leakage, is minor.

TABLE 3.3 – MAJOR GROUND WATER DEVELOPMENTS IN VICINITY OF PALIKEA UPLANDS SITE

No.[1]	State Well No.	Assumed[2] Pumping Rate (mgd)
1	2004-01	0.1
2	2004-04	1.3
3	2103-03	2.4
4	2006-15	1.0
5	2303-02/03	2.2
6	2303-03/04	2.0
7	2303-05/06	2.0
		11.0

[1] Model Number used in Appendix B.

[2] Based on City & County of Honolulu, Oahu Water Management Plan 1990 (Wilson Okamoto & Assocs., 1990), and personal communication with the Board of Water Supply.

The potential direction of ground water movement beneath the site is important to evaluation of possible impacts. The factors required for the evaluation of ground water movement near the site include hydrologic budget or mass balance, hydrogeologic boundary conditions, aquifer hydraulic parameters, and water well draft. There is considerable uncertainty concerning these variables. Estimates of the hydrologic budget are shown in Table 3.4.

The evaluation herein considers the aquifer in two dimensions. Longitudinal and transverse (horizontal) conductivities are assumed equal; the aquifer is assumed homogeneous and isotropic. The thickness of the aquifer is assumed constant; a sharp transition zone is assumed between fresh and salt water. These assumptions are typical of those made in other evaluations of the Pearl Harbor aquifer, but are simplifications of the actual system.

The details of the analysis are in Appendix B. A two-dimensional finite difference model (Waterloo 1990) is used to estimate the distribution of hydraulic head (potentiometric surface), ground water velocity, and zones of influence of wells (capture zones) in the Kunia/'Ewa systems of the Pearl Harbor aquifer. Essentially ground water movement within the region is estimated by this model from north to south. The result is based upon the mass balance data presented by Yuen and Associates (1988). A mass balance analysis considers the major components of the hydrologic cycle: net infiltration, inter-basin recharge, ground water draft (pumping), and irrigation return flow; comparative data are shown in Table 3.4 based upon reports by Yuen and Associates (1988) and Eyre (1987). The balance (outflow) from the sector is estimated between 13 to 28 mgd, depending upon investigation. The order of magnitude of the estimates is comparable, but the more conservative, i.e., smaller value was adopted.

The analysis also assumes the majority of ground water flux originates along the 2.5-mile Wahiawā high level boundary. The potentiometric data seem to indicate very little discharge between the Ko'olau and Wai'anae volcanics in the vicinity of the site, but more information is needed to confirm this assumption. If the boundary flux is changed (e.g., more is assumed along the Ko'olau unconformity), the amount of flow passing beneath the site to the wells decreases. The results are sensitive to estimates of boundary flux and aquifer conductivity.

TABLE 3.4 - COMPARISON OF KUNIA/‘EWA HYDROLOGIC BALANCE ESTIMATES

	Yuen & Associates, 1988	Eyre, 1987
1. Basal Flow (Wahiawā /Ko‘olau)	14.0	25.0
2. Irrigation Draft	15.0	14.0
3. Irrigation Return	6.0	9.0
4. Rainfall Recharge	8.0	8.0
5. Balance (outflow) [1 + 3 + 4 - 2]	13.0	28.0
Area (sq. mi.)	28.1	30.0
Aquifer Depth	40 x 14 + 14 = 574	550 + 15 = 565
Estimated Fluxes:		
Surface	0.0024 ft^3/ft^2 - day	0.0027 ft^3/ft^2 - day
Basal Boundary	0.247 ft^3/ft^2 - day	0.4482 ft^3/ft^2 - day

There are three conclusions from this analysis. First, a prudent conclusion is that some ground water flow originating under the site due to infiltration will be intercepted by nearby pumping wells. A second conclusion is that the majority of well water drafted is originating in the Wahiawā high level aquifer. The significance of ground water movement depends upon the constituent quality of percolating ground water and the amount of mixing. A discussion of this aspect is presented in a later section (refer to the discussion on ground water in the context of health risks, Section Four). Third, trends in water quality at Kunia Wells in the Waipahu system may not impact the wells near the Palikea Uplands site.

The water quality in the Pearl Harbor aquifer is affected by land use. However, these effects may take years before becoming discernible. Studies of residence time of O'ahu ground water by Hufer, Eyre, and McConachie (1980), and Eyre (1987), provide an indication that there is a difference of one order of magnitude for ground water transit time, i.e., the time required for meteoric water to move into the basal lens. In the first study (Hufer et al. 1980), some of the youngest samples were found in caprock regions in 'Ewa, but important differences existed between the eastern side, approximately Pearl City to Honolulu, and the western side, approximately Waipahu to 'Ewa. There has been more land use alteration in this area. As estimated on the basis of tritium and radiocarbon dating, the western portion contains older water, with a small percentage (no more than 20 percent) of younger water. Long residence time water, in excess of 200 years, may be present in the western inland region; however, young water thought to originate from overland infiltration of rain or irrigation return water was found. Young water was *considered* approximately 20 years or less in age. Perhaps some enters the aquifer at bedrock exposures and dike outcrops.

In the second study (Eyre 1987), three different methods were used to estimate the ground water travel time for irrigation return water applied near the Palikea site to reach the Barbers Point shaft. It was estimated that irrigation water from Oahu Sugar Company's western sugarcane fields might have reached Barbers Point in 11 years after application, and 21 years from the northern fields.

Additional anecdotal information is provided by Eyre (1987 and 1983) that indicates the time for infiltration (the time for displacement of soil water to the ground water table) can be even shorter. Experiences at the Schofield Barracks shaft and Waiawa shaft indicate response time may be as short as one to two years. Average pumping rate at the Schofield Barracks shaft is approximately 4 mgd. At the Palikea Uplands site, ground water springs used to water cattle diminished after irrigation cessation one year later (Santiago, personal communication).

The significance of these ground water residence time confirms that the existing ground water quality reflects land use practices. Note in Table 3.5 that the recently-developed water well (number 2303-01) in Honouliuli Gulch has nitrate as nitrogen levels well below the safe drinking water limit of 10 mg/l. These wells are adjacent to pasture grazed by cattle and receive recharge from irrigation water on adjacent sugarcane fields. These land use practices have existed for at least 30 years, and have not adversely affected water quality.

Ground water quality, in terms of chloride and temperature, in addition to nitrate concentration, in the wells near the Palikea site is shown in the following table:

TABLE 3.5 - GROUND WATER PARAMETERS IN WELLS NEAR THE PALIKEA SITE

Well No.	Temperature, °C	Cl, mg/l	NO_3 as N (mg/l)	Year Sampled
2103-03	23	240	—	1989
2603-01	22	50	—	1989
2303-01	—	160	0.87-1.06	1990

The location of these wells is shown on Figure 3-5a. There are no wells on the site *per se*. Note the temperatures 22 to 23 °C (between 72 to 73 degrees Fahrenheit) are relatively warm which indicates some mixing of the water with percolation near the wells with the Wahiawā or Wai'anae high level water.

The ground water chloride concentration increases towards 'Ewa. The caprock area *makai* of the site is underlain by brackish water. As the above table shows, chloride concentration is relatively low north of the site (Well No. 2603-01) and increases to the south (Well No. 2103-03). The chloride concentration at the latter is at the standard set by the Board of Water Supply for palatability purposes.

Nitrate as nitrogen concentrations in the new BWS Honouliuli Well (2303-01) shown in Table 3.5 indicate there is a relatively low nitrogen background level in the Kunia system of the Pearl Harbor aquifer. However, recently the Board of Water Supply has tested the nitrogen level in Kunia Wells I and II farther to the east (see Figure 3-5a) and found levels reaching 5.2 mg/l and 6.6 mg/l, respectively. In general other wells, including the Honouliuli wells have not shown evidence of elevated nitrogen levels. For example, Hō'ae'ae well field concentrations were reported between 2.4 to 3.6 mg NO_3-N. As noted previously, the U.S. EPA primary drinking water standard for nitrate nitrogen is 10 mg/l.

A study is being proposed by the Department of Agriculture and Department of Health concerning sources of the nitrogen in the Pearl Harbor aquifer. This may explain the potential role that plant fertilization has upon ground water quality, but it is unlikely that results will be available to incorporate into this environmental impact statement. An analysis of the potential impact of the livestock park upon nitrate levels of ground water is contained in Appendix A and is also discussed further in Section Four.

Bacteriological quality of ground water is considered excellent for a potable water supply. The BWS laboratory test for Well 2303-01 reported no detectable total coliform counts at the time of the sample shown in Table 3.5.

Kahuku Agricultural Park Site. Ground water has been extensively developed in the Kahuku area since the late 1800s. During the operation of the Kahuku sugar plantation, ground water withdrawals averaged 22 mgd, with maximum withdrawals of 50 mgd. With the cessation of operations, however, some of the pumping facilities fell into a state of disrepair, and others are pumped less heavily. Current pumping from the aquifer is much less. The principal water developments that are actively used are shown in Table 3.6.

TABLE 3.6 – MAJOR GROUND WATER DEVELOPMENTS IN VICINITY OF KAHUKU AGRICULTURAL PARK SITE

No.[1]	State Well No.	Assumed[2] Pumping Rate (mgd)
1	3956-01	0.5
2	3957-01	0.005
3	4057-07/10	1.9
4	4057-15/16	0.43
5	24157-04	1.8
6	4057-06	0.5
7	4158-12	0.22
8	4258-04	0.003
9	4159-01	2.5
10	4057-01/02/08	1.0
		8.858

1)Model Number used in Appendix B.
2)Based on declaration of use reported to DLNR.

Due to the location of wells in the vicinity of the site, the potential direction of ground water movement beneath the site is important to the evaluation of possible impacts. The factors required for the evaluation of ground water movement near the site include hydrologic budget or mass balance, hydrogeologic boundary conditions, aquifer hydraulic parameters, and water well draft. There is considerable uncertainty concerning these variables. The aquifer unit assumed by Takasaki, et al.

(1966), was adopted for water balance accounting purposes. Estimates of the hydrologic budget are shown in Table 3.7.

TABLE 3.7 - PRELIMINARY ANNUAL HYDROLOGIC BUDGET FOR KAHUKU AQUIFER UNIT

Parameter	Caprock	Upland	Forest
Rainfall, inches	54	76	108
Evapotranspiration, inches	82	60	40
Runoff, percent inches	10 5	13 10	16 17
Infiltration, inches	-33	6	51
Area, sq. mi.	1.7	7.7	3.5
Recharge, mgd	-2.7	2.2	8.5

Note the negative sign above indicates a net loss due to evapotranspiration and leakage to springs and streams flowing to the ocean. The caprock area shown above is assumed equivalent to the wetland area identified on the Kahuku quadrant of the U.S. Geological Survey map *makai* of Kamehameha Highway for hydrologic budget purposes. The geologic extent of the caprock is larger but is included in the upland area.

The leakage of water to the ocean and coastal wetlands in the unit is affected by the amount of water drafted, but accurate estimates of the current draft are difficult to obtain. George A.L. Yuen and Associates (1990) estimated the draft at 7 mgd. Another study, Wilson Okamoto and Associates (1990) identified an 1987 or 1988 draft of approximately 10 mgd from nine sources in the Kahuku unit. A check of the declared use (DLNR records) indicated approximately 9 mgd use in the area.

A two-dimensional finite difference model is used (see Appendix B) to evaluate the flow path direction and the potentiometric surface assuming the pumpage of the aquifer unit shown in Table 3.6. The evaluation considers the aquifer in two horizontal dimensions, i.e., vertical flow is not considered. Longitudinal and transverse (horizontal) conductivities are assumed equal; i.e., the aquifer is assumed homogeneous and isotropic. The thickness of the aquifer is assumed constant. A sharp transition zone is assumed between basal fresh and salt water. Leakage from the caprock zone is considered.

The model estimates the distribution of hydraulic head (potentiometric surface), ground water velocity, and zones of influence of wells (capture zones) in the Kahuku unit of the Ko'olauloa aquifer in terms of a steady-state solution, i.e., it is based upon the long-term values for recharge and draft. Assuming the long-term draft is approximately 10 mgd and 20 percent and is returned to the aquifer above and at the contact with the caprock, then the water balance in mgd is as follows:

Infiltration:	10.7
Pumpage:	- 10.0
Recharge:	2.0
Leakage	2.7

The leakage amount corresponds to the magnitude estimated for exfiltration from the wetland.

The results of the model (see Appendix B) indicate ground water movement within the region to be from north to south. The potentiometric data measured by Takasaki, et al., 1966 (see Figure 6 in reference report), confirm the northerly component to the ground water flow in the Kahuku unit. The potentiometric surface results are sensitive to estimates of boundary flux and aquifer hydraulic conductivity; the latter is estimated to be 200 feet/day in both horizontal directions.

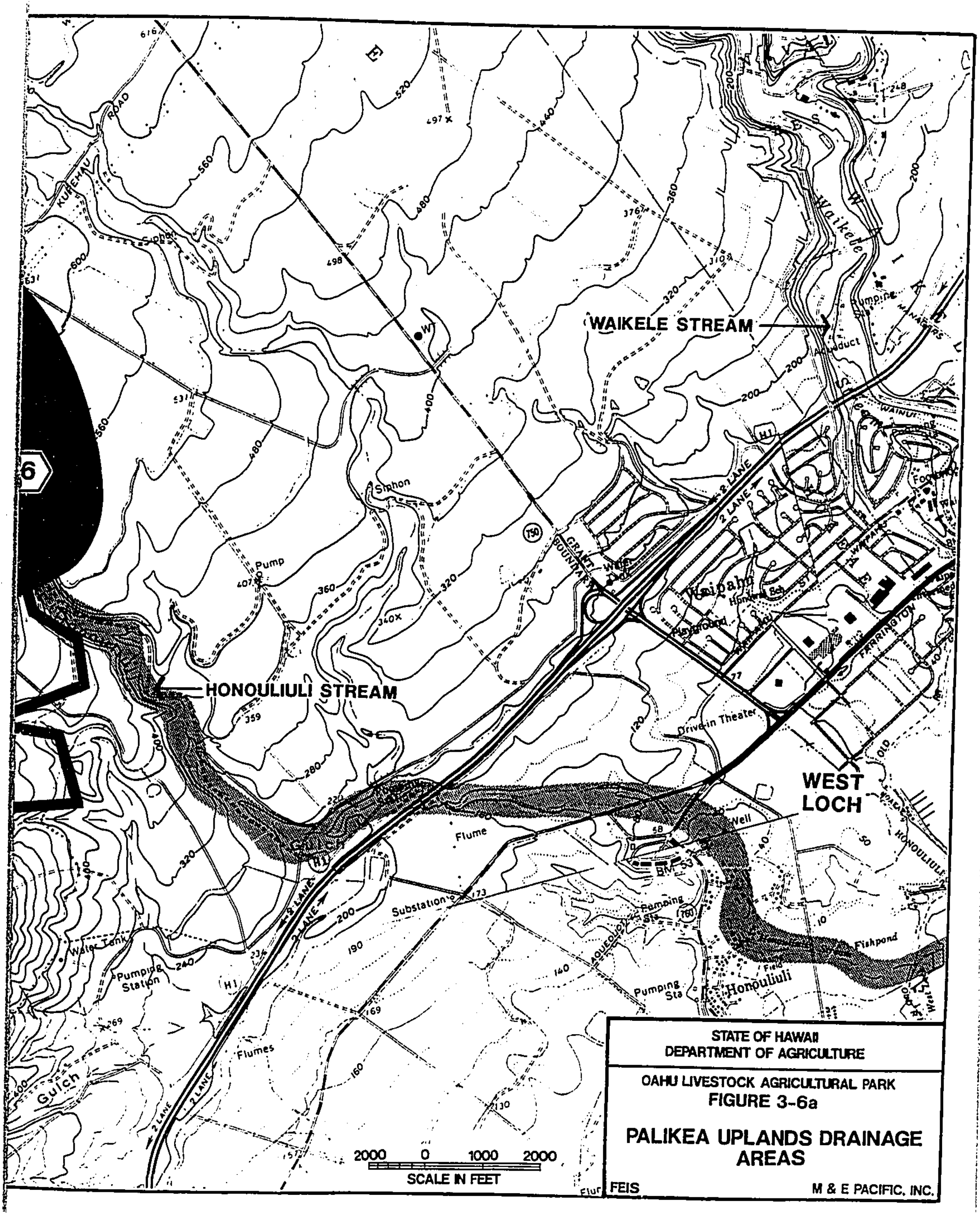
The sensitivity of the potentiometric surface to additional pumpage of the Kahuku unit is considered in Appendix B. An important consideration is the amount of hydraulic head decline in the vicinity of the wetlands as a result of increased pumpage at the agricultural park. A preliminary estimate ranges between 0.2 to 0.5 feet, assuming that Pump Station No. 1 is used for supplying additional water supply up to one mgd. The potentiometric surface in the vicinity of the wetland is estimated between 8.5 to 11.5 feet, mean sea level. Ground water is artesian where confined by the caprock at elevation below 14 feet. The average elevation in the wetland ranges between six to nine feet with lower elevations in the ponds. Thus the majority of the wetland area has the potential to receive water exfiltrating through the caprock under artesian pressure.

There are two findings of this analysis. First, a prudent assumption is that some ground water flow originating under the site due to infiltration will be intercepted by nearby pumping wells. The significance of ground water movement depends upon the constituent quality of percolating ground water and the amount of mixing with water of high-level origin. A discussion of this aspect is presented in a later section (refer to the discussion on ground water in the context of health risks, Section Four). Second, the reduction in potentiometric surface due to increased pumping of one mgd in the Kahuku unit is expected to be less than one foot. The significance is discussed in Section Four.

3. Floodplains

Palikea Uplands Site. Estimated 100-Year Discharge. The major considerations related to drainage are the location and extent of floodplains, and their significance relative to potential project effects. The areas of small catchments draining the proposed site were determined on U. S. Geological Survey 7.5-minute quadrangle maps, which show topography with a 40-foot contour interval and features at a scale of 1:24000. There are seven subareas considered: 1, 2, 2A, 3A, 3B, 4, and 5. Area 6 is the sum of all seven subareas. Figure 3-6a shows the drainage areas.

The principal regulatory floodplain which has been adopted (Department of Land Utilization, City and County of Honolulu, Land Use Ordinance No. 86-96) is based upon Flood Insurance Rate Maps. Map coverage has not been extended to the potential project site. An estimate of the potential floodplain is made using standard engineering methods. Six hydrologic/hydraulic models were used to determine the flood boundaries in the area. The peak discharge assumed (hydrologic model) was derived from the Design Curves for Peak Discharge vs. Drainage Area, on Plate 6, *Storm Drainage Standards*, City and County of Honolulu, 1988. The curve for Group C was used in the derivation. According to the hydrologic criteria in the same Standards, the recurrence interval of this flood is considered as 100 years for drainage areas greater than 100 acres. Table 3.8 summarizes the results of 100-year discharge in cubic feet per second (CFS) for each of the drainage areas.



STATE OF HAWAII
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OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-6a

PALIKEA UPLANDS DRAINAGE AREAS

FEIS

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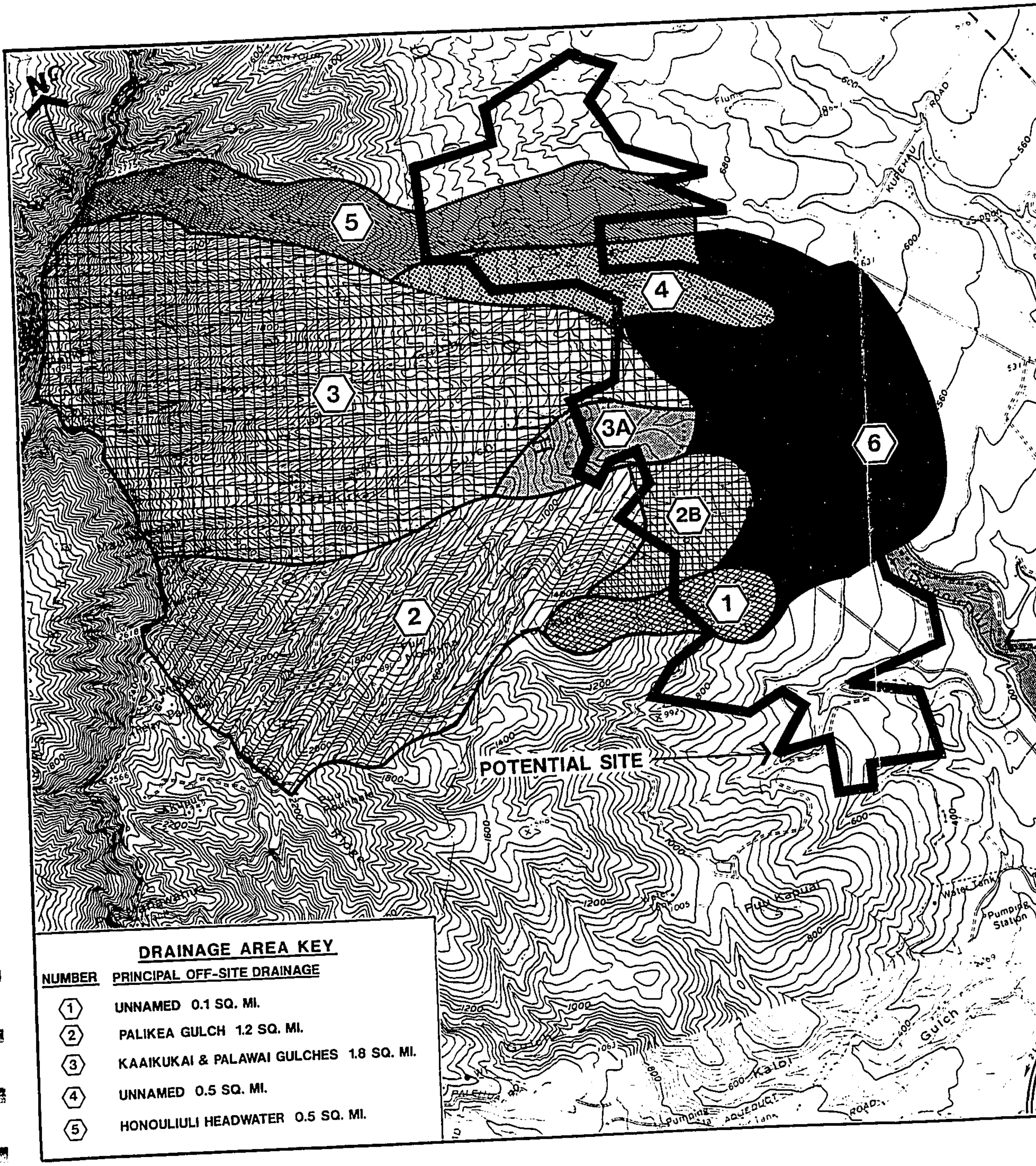

DRAINAGE AREA KEY
NUMBER PRINCIPAL OFF-SITE DRAINAGE
1 UNNAMED 0.1 SQ. MI.
2 PALIKEA GULCH 1.2 SQ. MI.
3 KAAIKUKAI & PALAWAI GULCHES 1.8 SQ. MI.
4 UNNAMED 0.5 SQ. MI.
5 HONOULIULI HEADWATER 0.5 SQ. MI.
1
2
2B
3
3A
4
5
6
POTENTIAL SITE
N
Flume
KUPEHAU ROAD
Puu Kapuai
Water Tank
Pumping Station
Kaloi
Gulch
PALEHUA
AQUEDUCT
ROAD
Pumping

TABLE 3.8 - SUMMARY OF FLOOD DISCHARGE FOR PALIKEA SITE FLOODPLAINS

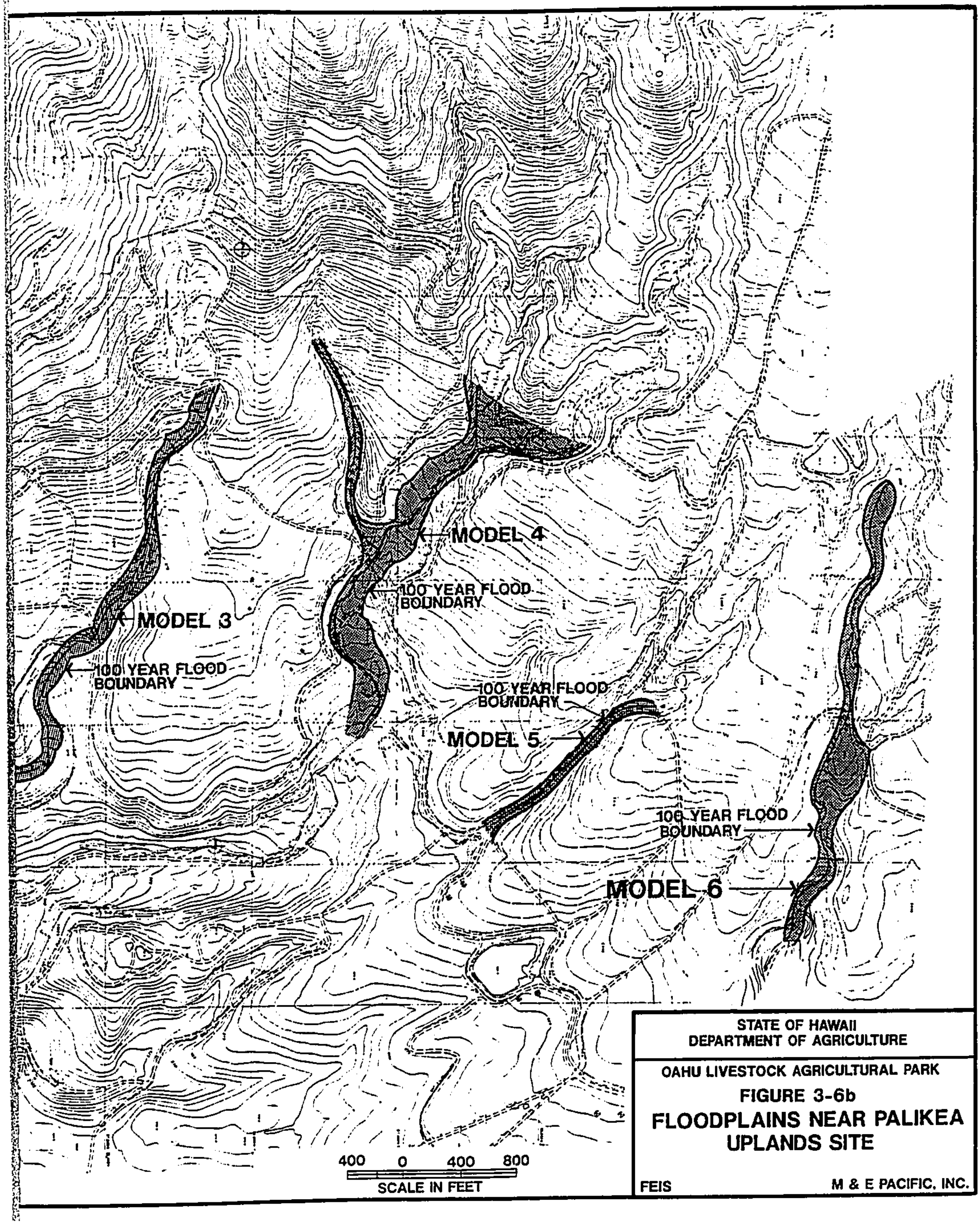
Area No.	Drainage Area (AC)	Peak Flow (CFS)	Model No.[1]
1	83	640	2
2	636	1,800	3
2A	105	680	3
3A	84	640	4
3B	1,096	2,800	4
4	307	1,250	5
5	310	1,300	6
6 [Sum(1-5)]	2,622	5,400*	1

*Note: Peak flow for Area 6 was determined directly from its drainage area which is 2,622 acres.

[1] See Figure 3.6b for model number location.

Palikea Uplands Site - Floodplain Boundary. The results of the water surface profiles used to calculate the boundaries of the 100-year floodplains are shown in Figure 3-6b. The width ranges between 22 to 330 feet; average channel velocities range between 2 to 19 feet per second.

The conclusion is there is ample room outside the boundaries shown for agricultural facilities so that floodplains will not be significantly altered by this project, nor should the risk of flooding be a significant concern. However, drainage structures to facilitate road improvements and utility line crossings should be constructed to minimize damage due to erosion.



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OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-6b

FLOODPLAINS NEAR PALIKEA UPLANDS SITE

FEIS

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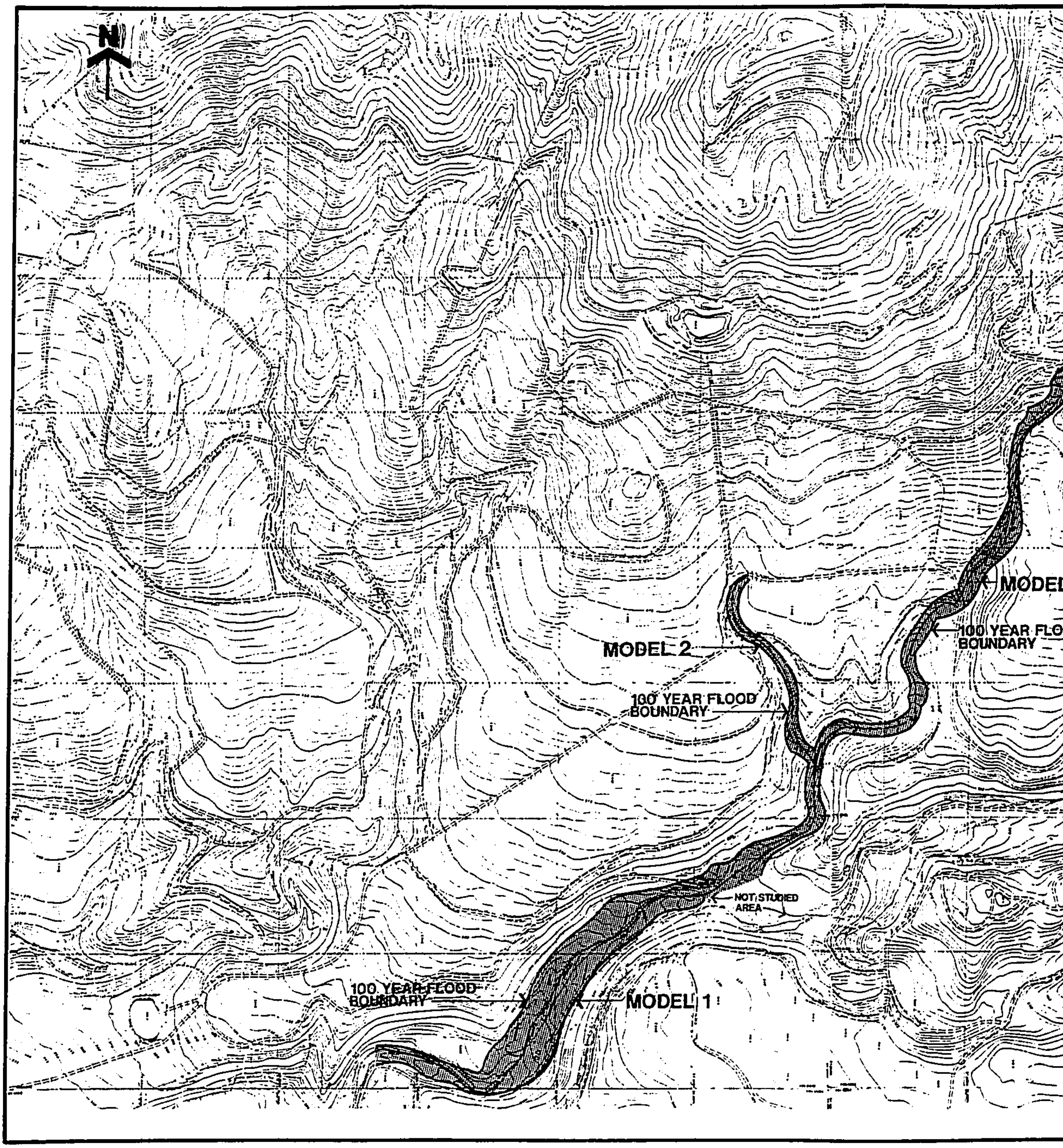

N
MODEL
100 YEAR FLO
BOUNDARY
MODEL 2
100 YEAR FLOOD
BOUNDARY
NOT STUDIED
AREA
100 YEAR FLOOD
BOUNDARY
MODEL 1

Kahuku Agricultural Park Site. Estimated 100-Year Discharge. There are three major gulches in the Kahuku area—Mālaekahana, Kea'aulu, and 'Ōhi'a. Only one, 'Ōhi'a Gulch, traverses the potential site. The drainage areas of these are shown on Figure 3-6c. The estimated areas and 100-year discharges based upon two sources are as follows:

Table 3.9 - 100-YEAR FLOODPLAIN DATA AT THE KAHUKU AGRICULTURAL PARK SITE

Area No.	Drainage Area[1] (acres)	Peak Flow By Table 1[2] (cubic feet/sec)	Peak Flow By Plate 6[3] (cubic feet/sec)
1	2,903	12,900	15,000
2	1,130	not given	6,000
3	2,098	not given	11,000
[Sum(1-3)]	6,131	—	—

[1] See Figure 3-6c for drainage number location.

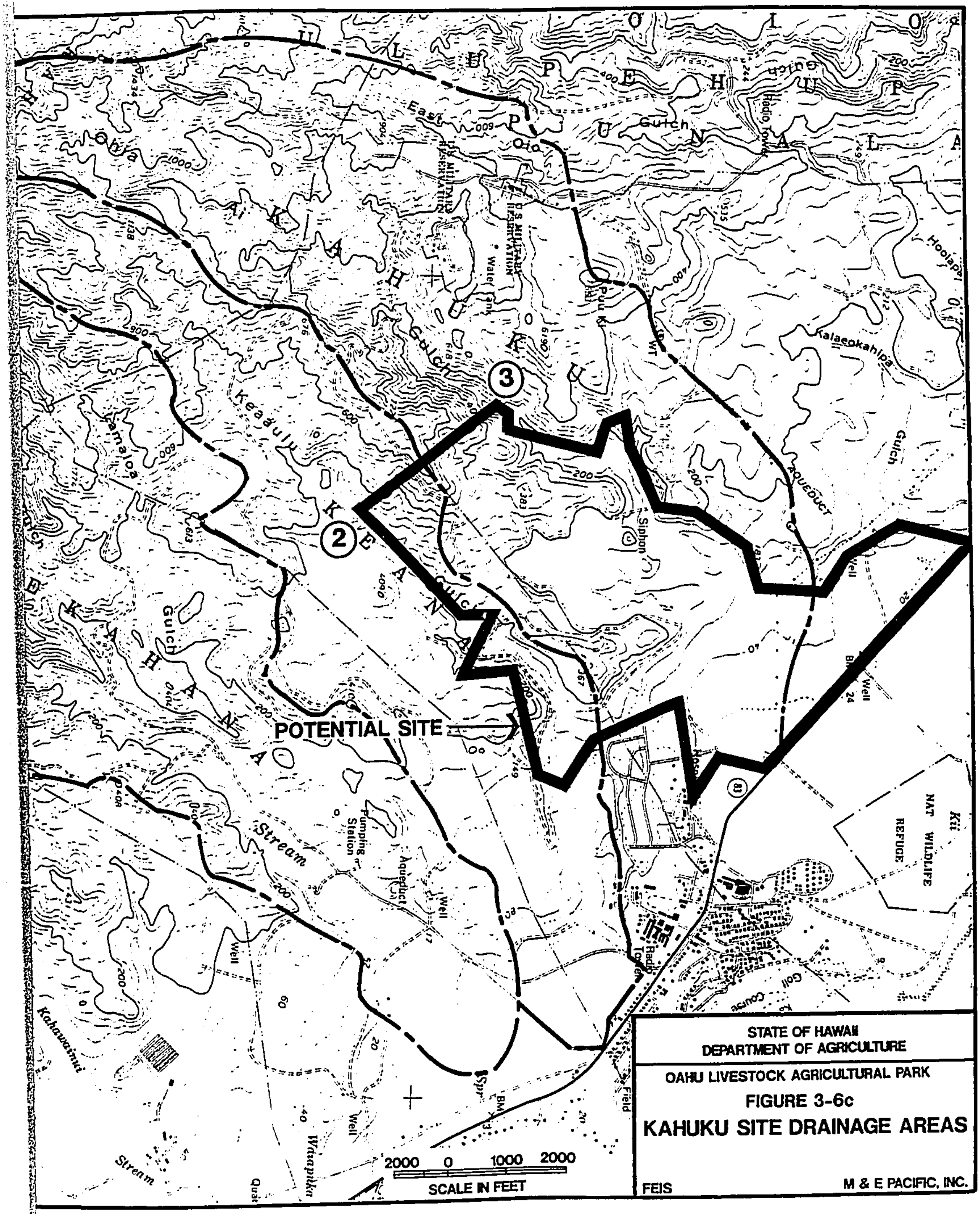
[2] Based on *City and County of Honolulu Flood Insurance Study*. September 1987. Federal Emergency Management Agency.

[3] Based on *City and County of Honolulu Storm Drainage Standards*. May 1988. Department of Public Works.

The recurrence interval given in both references is a 100-year flood, however the drainage areas are slightly different for Mālaekahana.

The conclusion is there is a significant risk of flooding on the makai portions of the potential site. The floodplain map boundary described below is based upon the flood insurance study.

Kahuku Agricultural Park Site. Floodplain Boundary. The flood insurance rate map (FIRM) is reproduced on Figure 3-6d (from reference shown in note on figure). A considerable portion of the makai portion of the site is flood prone. Flood depths above the stream channel, based upon the flood insurance study, are estimated between nine to thirteen feet just mauka of Kamehameha Highway. The FIRM boundary is extended upstream along 'Ōhi'a Stream based on an analysis conducted for this environmental impact statement. Note that the extent of the



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OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-6c

KAHUKU SITE DRAINAGE AREAS

FEIS

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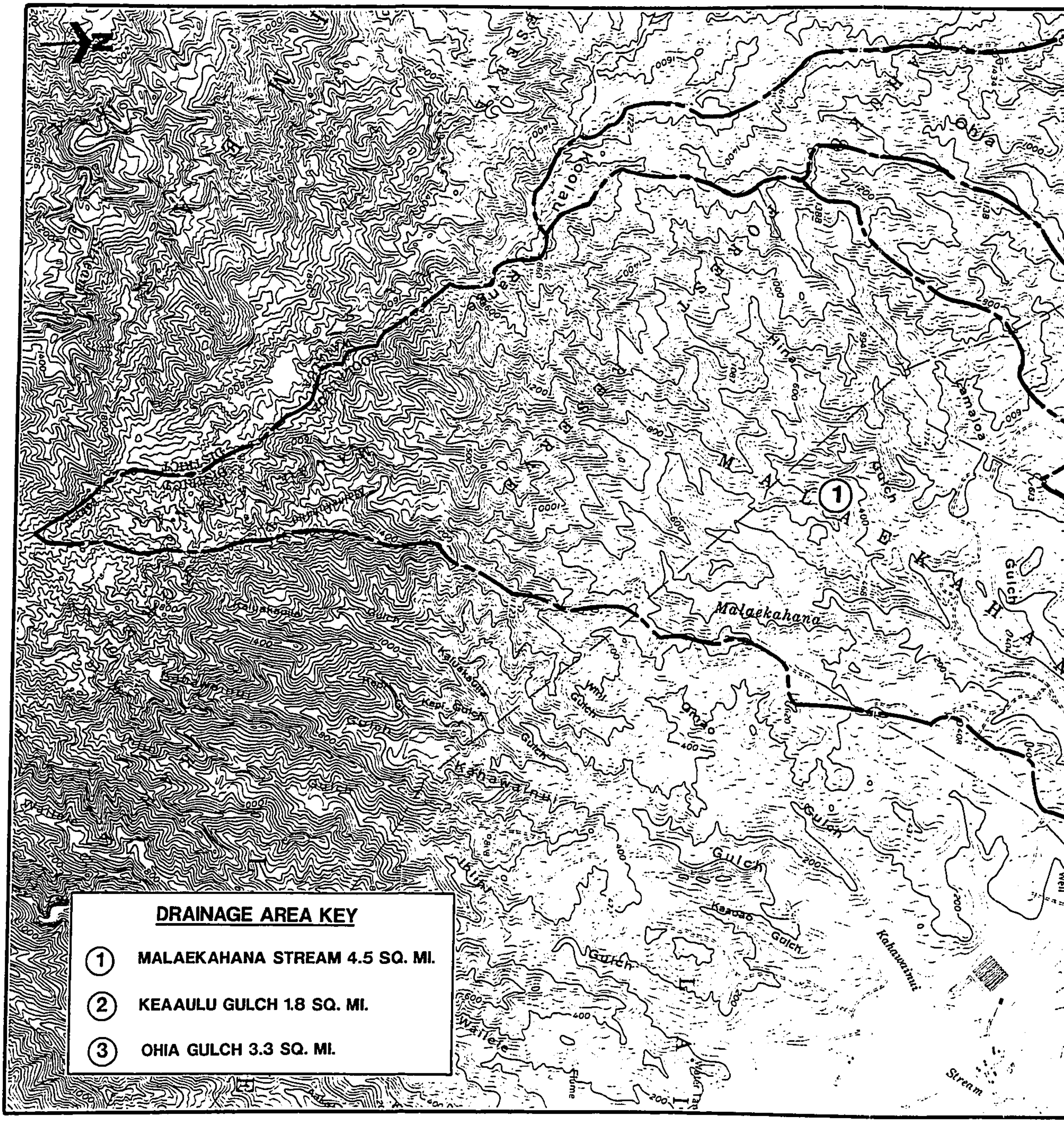
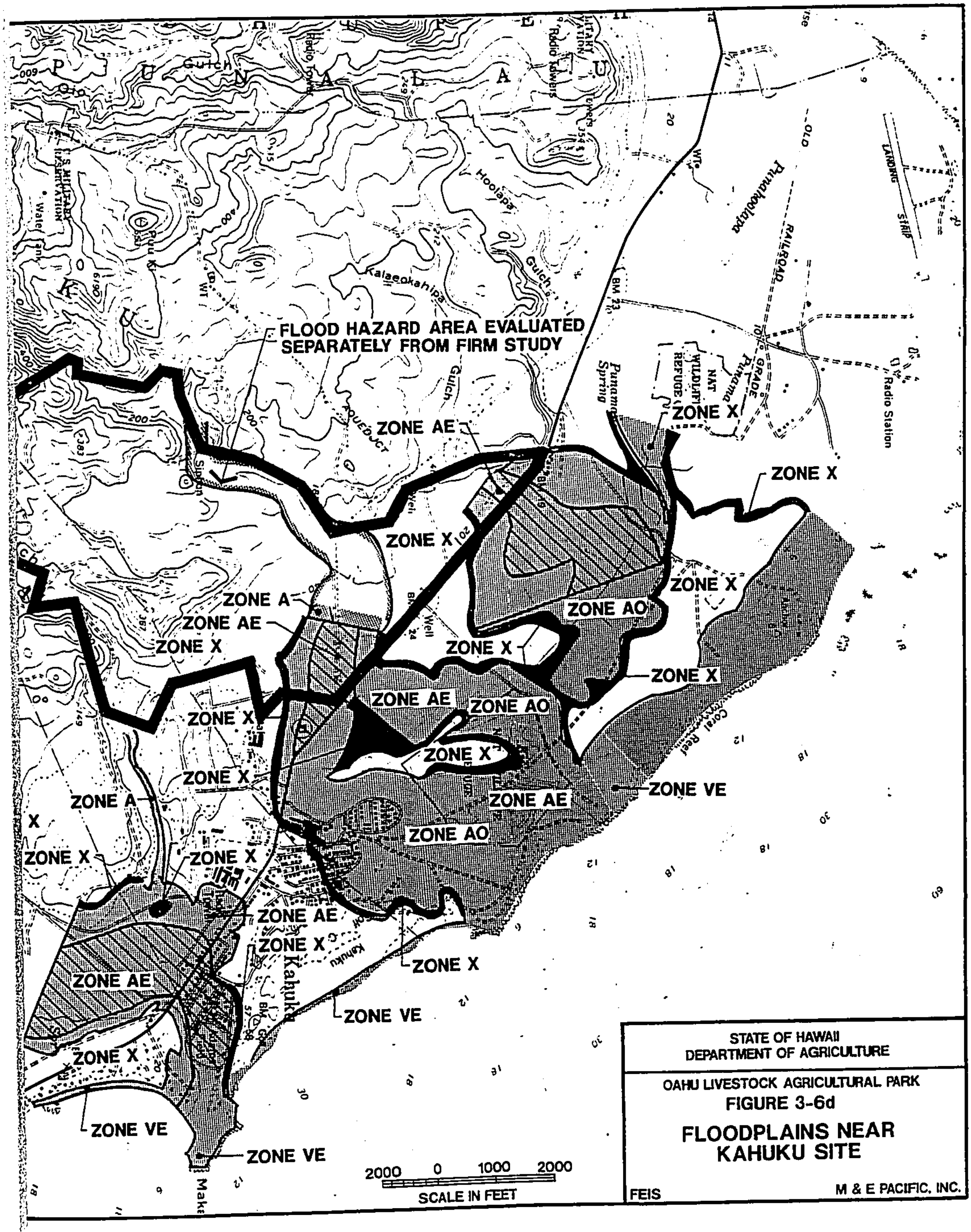


DRAINAGE AREA KEY

① MALAEKAHANA STREAM 4.5 SQ. MI.

② KEAAULU GULCH 1.8 SQ. MI.

③ OHIA GULCH 3.3 SQ. MI.



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OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-6d

FLOODPLAINS NEAR KAHUKU SITE

FEIS

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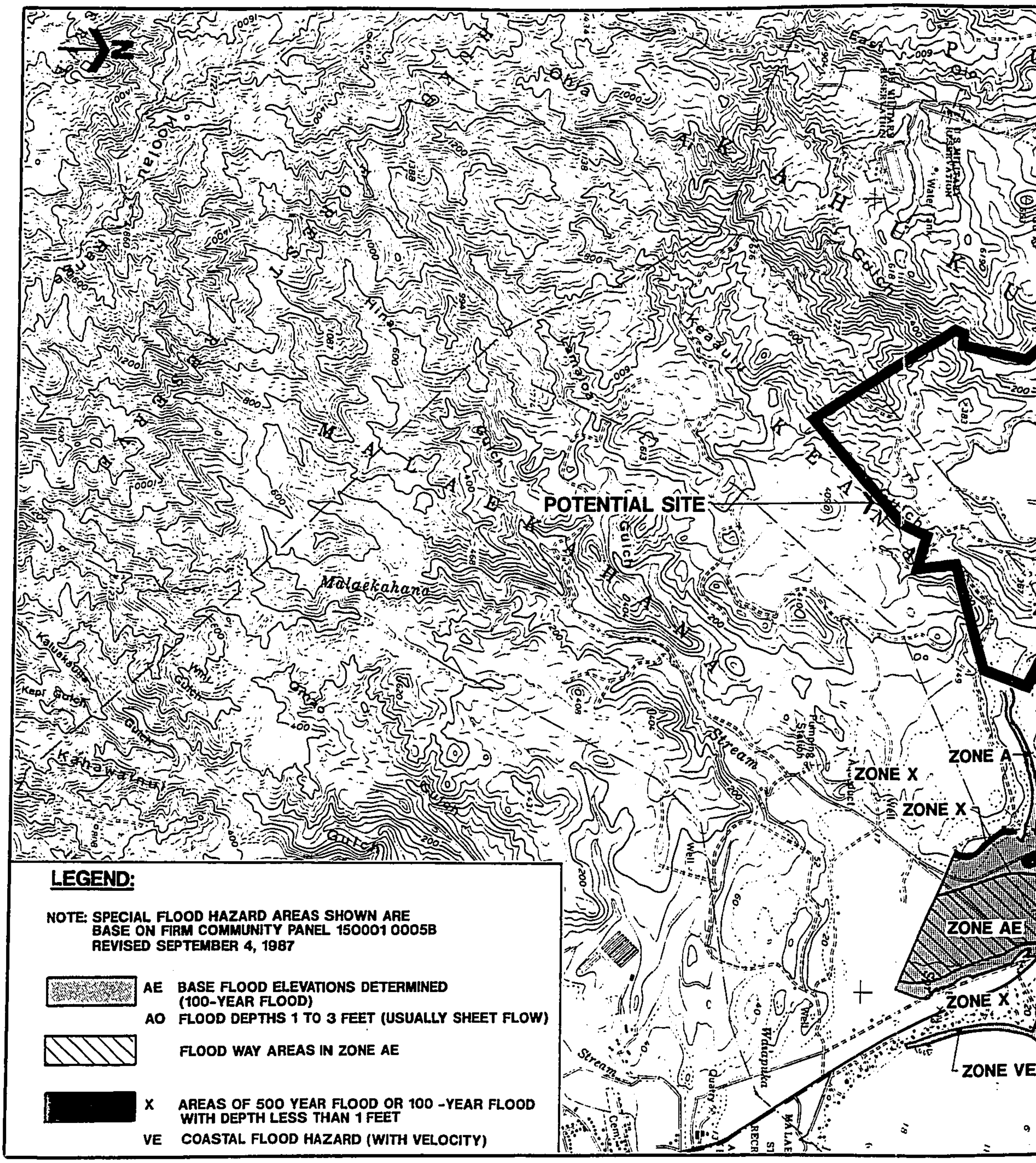


LEGEND:

NOTE: SPECIAL FLOOD HAZARD AREAS SHOWN ARE BASE ON FIRM COMMUNITY PANEL 150001 0005B REVISED SEPTEMBER 4, 1987

▒	AE	BASE FLOOD ELEVATIONS DETERMINED (100-YEAR FLOOD)
	AO	FLOOD DEPTHS 1 TO 3 FEET (USUALLY SHEET FLOW)
▧		FLOOD WAY AREAS IN ZONE AE
■	X	AREAS OF 500 YEAR FLOOD OR 100 -YEAR FLOOD WITH DEPTH LESS THAN 1 FEET
	VE	COASTAL FLOOD HAZARD (WITH VELOCITY)

floodplain is limited to a restricted area on the northern side of the agricultural park.

Zone AE shown on the figure indicates the floodway district within which permitted (City and County of Honolulu Land Use Ordinance) uses include grazing, pasture, and outdoor plant nurseries. Prohibited uses include waste management facilities. Thus the conclusion is that suitable portions of the Kahuku site have potential for use for livestock operations that are above flood-prone areas.

4. Surface Water Quality

Palikea Uplands Site. The site is dissected by five major gulches: Pu'u Ku'ua, Pālehua, Ka'aikukui/Pālāwai, Honouliuli, and Pōhākea. The largest is Honouliuli which is an intermittent stream to the ocean. A crest-stage stream gaging station (16212500) is located on Honouliuli Stream at Farrington Highway where the drainage area is 11 square miles. Although peak discharge statistics exist, average daily stream flow data is not readily available.

To the east of Honouliuli Stream, Waikele Stream, a principal watercourse in central O'ahu, has one of the U.S. Geological Survey's National Stream Quality Accounting Network Stations (16213000). Some quantitative and qualitative characteristics of the Honouliuli water course may be inferred by comparison to this station, although it should be noted that the Waikele Stream drainage area (45.7 square miles) is more than four times the size of Honouliuli watershed. The average daily discharge of Honouliuli Stream is estimated, at the downstream site boundary, to be 3.1 cubic feet per second or approximately 2 million gallons per day (mgd). Flow is intermittent and runoff is produced only after significant amounts of rainfall occur.

Honouliuli Stream is classified as a Class 2 inland water for the purposes of protecting instream uses. In addition to the basic water quality criteria set forth in Title 11, Chapter 54, paragraph 04 (Hawaii Administrative Rules), the water column criteria for this category is shown in Table 3.10 so that comparisons can be readily made to existing conditions.

Stream flow quality at the site, assuming similarity with Waikele Stream, can be characterized as containing high background amounts of suspended sediment, nitrogen, and phosphorous relative to these standards.

TABLE 3.10 – INLAND WATER COLUMN CRITERIA

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to exceed the given value more than two percent of the time
Total Nitrogen (mg N/L)	0.25 * 0.18 **	0.52 * 0.38 **	0.80 * 0.60 **
Nitrate + Nitrite Nitrogen (mg $[NO_3+NO_2]$ -N/L)	0.07 * 0.03 **	0.18 * 0.09 **	0.30 * 0.17 **
Total Phosphorus (mg P/L)	0.05 * 0.03 **	0.10 * 0.06 **	0.15 * 0.08 **
Total Nonfilterable Residue (mg/L)	20.0 * 10.0 **	50.0 * 30.0 **	80.0 * 55.0 **
Turbidity (N.T.U.)	5.0 * 2.0 **	15.0 * 5.5 **	25.0 * 10.0 **

* Wet season—November 1 through April 30.
** Dry season—May 1 through October 31.

For example, Waikele Stream water quality was reported (U.S. Geological Survey: Water Resources Data Hawaii and Other Pacific Areas) as follows during 1989:

	Range
Nitrate + Nitrite:	0.240 - 1.6 (mg/L)
Total Phosphorous:	0.120 - 1.1 (mg/L)
Turbidity:	3.100 - 9.8 (NTU)

Bacterial concentration in Honouliuli Stream is assumed be typical of other O'ahu streams. For example, during 1989, USGS water quality data on Waikele Stream exhibited a range of colonies per 100 milliliters between 2,100 to 12,000. Fujioka and Shizumura (1985) have indicated that the concentration of fecal coliform in Hawai'i streams ranged from 10^2 to 10^4 per 100 ml, including those not known to be receiving contamination from any point source. These relatively high background concentrations are due to the climate and the ability of bacteria to adapt and survive in the local soil environment, whereas they are generally considered to be indicators of fecal contamination on the mainland; their conclusion is that wastewater is not necessarily the primary source of fecal coliform.

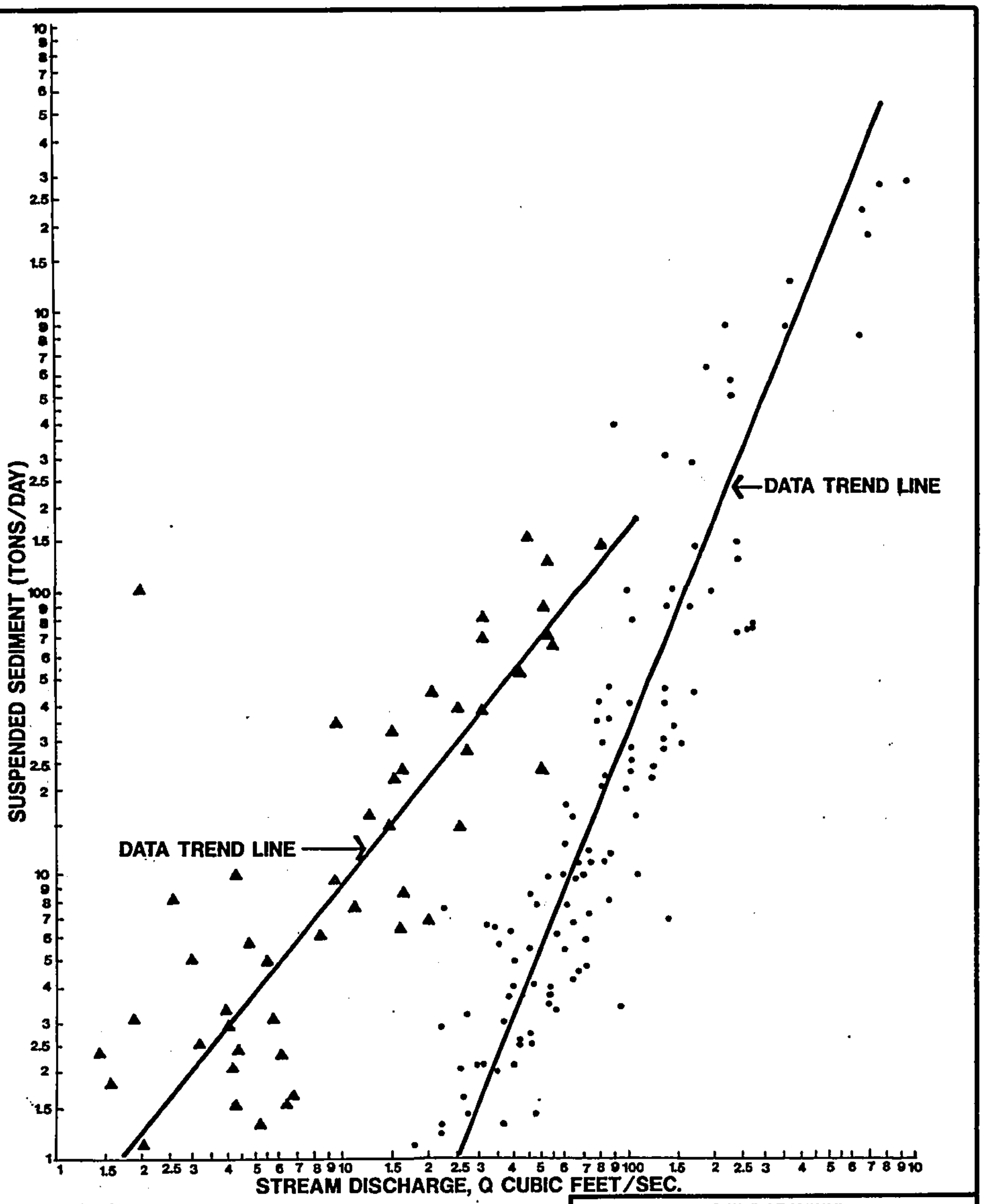
The conclusion of an islandwide water quality study for O'ahu (Sunn, Low, Tom and Hara, Inc. 1971) was that nitrate and phosphate concentrations in Waikele and Waimalu Streams are constant and independent of flow rates. This study found these nutrient mass emission rates to be linearly related to stream flow. Conversely silica and chloride were inversely proportional. The implication is that the intermittent drainage from land intervening between lowland springs and mountain catchments adds a disproportionate nutrient load relative to the contributing area.

The estimated (from this study) average concentration and mass emission rates (MER) of nitrate and phosphate are shown below:

Spring or Stream	Average Q mgd	Average mg/l-NO_3	Average, mg/l-PO_4	MER, lb/day	
				NO_3	PO_4
Honouliuli Stream	3.0	5.3	0.84	130	21
Waikele Stream	26.8	5.3	0.84	1,120	190
Kapakahi Spring	3.0	6.0	0.30	150	8
West Loch Total	32.8	16.6	1.98	1,400	219

Honouliuli Stream concentrations shown above were based on sample data for Waikele Stream.

Momentary suspended sediment discharge for Waikele Stream is shown in Figure 3-7a. Sediment production is a power function of stream discharge. As runoff increases, the amount of erosion and suspended sediment movement increases exponentially. An estimate of annual suspended sediment yield can be extrapolated from Figure 3-7a, assuming the average Honouliuli storm flow is approximately



LEGEND:

▲ RIGHT BRANCH KAMOOALII STREAM
$Y=0.5670Q^{1.2418}$ R=0.7447

● WAIKELE STREAM SUSPENDED SEDIMENT
VISUAL DATA FIT

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-7a

STREAM DISCHARGE VERSUS SUSPENDED SEDIMENT (1983-1989)

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equal to the momentary discharge shown used in the sediment-discharge relationship in Figure 3-7a, and Honouliuli Stream and Waikele Stream sediment production rates are identical. Using data developed in a study of sediment pollution loads (Sunn, Low, Tom and Hara, Inc. 1971), the relationship between drainage area and average storm runoff is

$$Q = 1.3339DA^{0.6513}$$

where: Q = average storm runoff, mgd
and DA = drainage area, square miles

The average storm runoff is estimated to be 3.3 mgd or 5.2 cfs.

Based on Figure 3-7a, the suspended sediment production from the watershed (including the Honouliuli Forest Reserve) is estimated to be approximately as 6.2 tons per day. An annual estimate is extrapolated by multiplying by 365, which would result in approximately 2,263 tons per year. This is a conservative estimate because runoff is not produced every day. If the streams in the Honouliuli watershed were gaged, it would be possible to refine this estimate. Table 3.8 gives the drainage area at the downstream boundary of the Palikea site as 2,622 acres. Thus the unit sediment production from the area which is idle land or in the forest reserve is approximately 0.86 tons/acre/year (2,263/2,622=0.86). Sediment discharge estimates may vary by one to two orders of magnitude, depending upon methodology and data. However, in comparison with an estimate using the universal soil loss equation (see Appendix F, values for idle land of in Figure F-1, item 3), this order of magnitude, namely one ton/acre/year, is reasonable for idle land.

Studies of runoff in central O'ahu (Yim and Dugan 1975) near the Palikea Uplands site indicate sediment plays a major role in stream water quality, both as a pollutant and carrier for absorbed forms of organic nitrogen, phosphorous, and heavy metals. Sediment yield (pounds/acre) was well correlated in forest watersheds to these parameters. Some results are shown in Table 3.11.

TABLE 3.11 - THE QUALITY OF RURAL RUNOFF IN THE KUNIA AREA

	Forested Area[1]		Sugarcane Field		Pineapple Field	
Parameter	Median	Range	Median	Range	Median	Range
pH	6.17	5.77-6.93	7.25	6.38-9.00	5.60	5.10-6.11
NO_2+NO_3-N (mg/l)	0.03	0.01-0.10	ND-0.86	0.06	4.04	4.00-4.08
Total N (mg/l)	2.21	0.52-10.76	0.40	0.08-1.70	6.74	6.32-7.16
Orthophosphate (mg/l)	ND	ND-0.02	0.11	0.04-0.23	ND	ND
Total P (mg/l P)	0.86	0.28-2.00	0.42	0.03-1.58	0.64	0.24-1.04
Chlorides (mg/l)	13.0	3.5-31.4	11.2	2.9-29.5	4.9	5.3-5.5
TSS (mg/l)	444	22-1416	46	6-2440	436	39-834

[1] Northwest Oahu

Note: ND = No Data

Source: Spencer K. Yim and Gordon L. Dugan, "Quality and Quantity of Nonpoint Pollution Sources in Rural Surface Water Runoff on Oahu, Hawaii," University of Hawaii Water Resources Research Center, Report No. 93, 1975.

These results of similar areas, in close proximity to the Palikea site, provide a preliminary characterization of existing background stream water quality. In general, most of the physical and chemical Class 2 standards are exceeded during storm runoff events even in more "natural" forested watersheds. For example, comparing two parameters, total nitrogen and total suspended solids, in Table 3.11 and 3.10, median concentration values may exceed standard geometric mean values by approximately an order of magnitude. The major implication is that beneficial uses may be significantly affected during major storm events. West Loch in Pearl Harbor is the receiving water for the discharge of Honouliuli Stream. Water quality is variable. Sunn, Low, Tom and Hara (1971) reported a range of total coliform/100 ml between 0 to 440,000 in West Loch, 0 to 9,000 in Middle Loch, and 0 to 1,030 in the East Loch during a period from June 1970 to February 1971.

Receiving waters downstream from the Palikea Uplands site have more stringent water quality standards to protect beneficial uses. Based upon the City and County of Honolulu *Water Quality Management Plan* (1990), water area, ecological subsystem type, and beneficial uses to be protected include:

Area	Type	Uses	Class
Honouliuli	Interrupted Stream	Agricultural water supply	2
Honouliuli Wetland	Coastal Wetland	Waterfowl habitat	*1a*
Pearl Harbor West Loch	"Dry Estuary"	Shipping, navigation, propagation of bait fish and shellfish, waterfowl habitat	2

The critical class in this inventory is 1a. In general, the basic water quality criteria apply, as opposed to the specific water quality criteria shown in Table 3.11. However, the objective of class 1 waters is to preserve them in their natural state as nearly as possible. Waste discharge is prohibited. The existing uses to be protected include the use of stream waters for the wetlands in the Honouliuli Wildlife Refuge. This provides critical habitat, especially for protection of four endangered Hawai'i waterfowl species. The U.S. Fish and Wildlife Service pumps fresh water from nearby springs into the wetland refuge when necessary to maintain essential water levels. Stream flow is not used to manage water levels. However, there is concern about the water quality as it could affect birds loafing in the stream, which led to a realignment of the Honouliuli drainage channel away from the refuge during West Loch development.

A portion of the water quality standards for Pearl Harbor are shown in Table 3.12.

TABLE 3.12 – PEARL HARBOR WATER QUALITY STANDARDS

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to exceed the given value more than two percent of the time
Total Nitrogen (mg - N/L)	0.30	0.55	0.75
Ammonia Nitrogen (mg NH_4-NL)	0.01	0.01	0.03
Nitrate-Nitrite Nitrogen (mg[NO_3+NO_2]N/L)	0.015	0.04	0.07
Total Phosphorus (mg P/L)	0.06	0.13	0.20
Turbidity (NTU)	4.00	8.00	15.00

In addition, dissolved oxygen concentrations should not fall below 60 percent of saturation. Critical uses to be protected in Pearl Harbor include shellfish propagation and compatible recreation.

These standards may be exceeded at the present time during large runoff episodes. The City and County of Honolulu Water Quality Management Plan (Department of Public Works 1990) indicates the most frequently violated water quality parameters in Pearl Harbor include nitrogen, phosphorous, turbidity, fecal coliform, and chlorophyll^{-a}. The significance for the proposed project is that storm water management plan is required to reduce potential impacts on inland stream, estuarine, and coastal waters.

Kahuku Agricultural Park Site. Much of the description of water quality conditions for the Palikea Uplands site applies to the Kahuku Agricultural Park site.

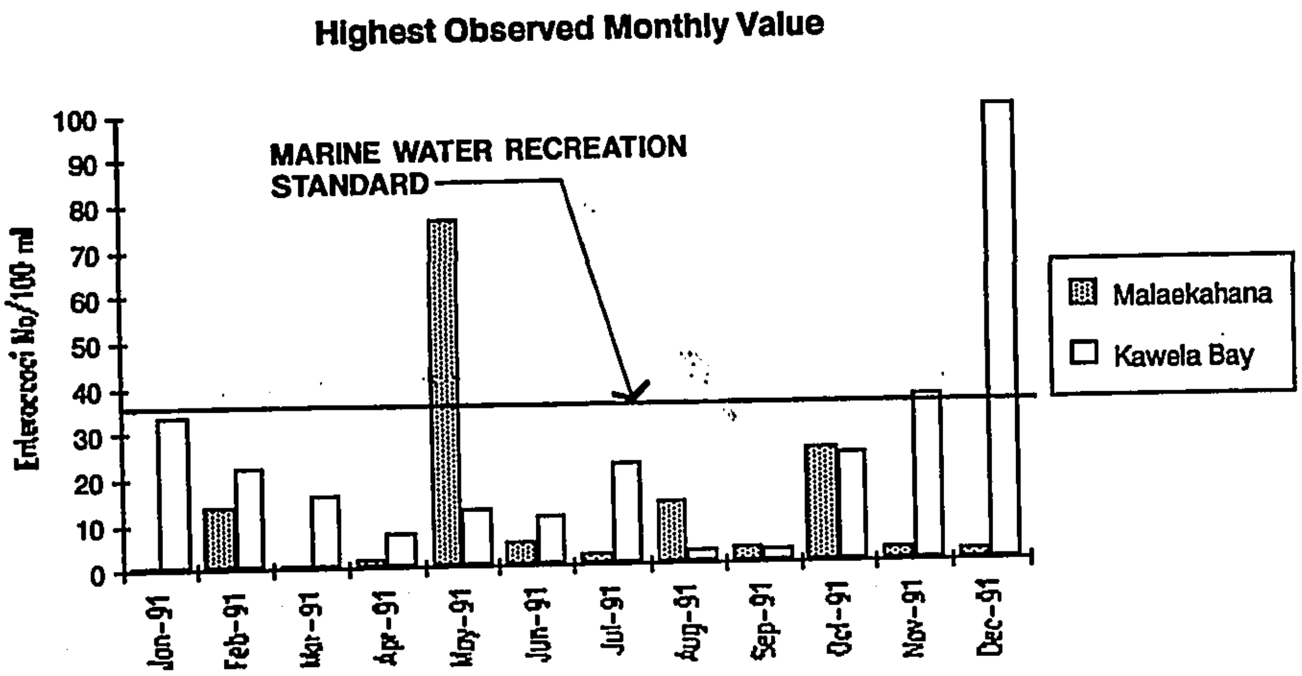
For example, both class 1 and 2 inland waters are near the site. 'Ōhi'a Stream discharges into Ki'i Ditch which in turn discharges to the open coastline. Based upon the City and County of Honolulu *Water Quality Management Plan* (1990), water area, ecological subsystem type, and beneficial uses to be protected include:

Area	Type	Uses	Class
Ki'i Pond	Low Wetland	Waterfowl habitat	*1a*
Coastline	"Dry Area"	Marine propagation, whole body & limited recreation	IIA

The critical class in this inventory is IIA. Some of the marine water quality class A (dry coastal) standards are shown in Table 3.13. In addition, other parameters include pH, temperature, and salinity. Data on marine water quality along this coastline is scarce. There are Department of Health ambient water quality stations at Mālaekahana State Recreational Area and Kawela Bay, north of Kahuku. Chemical and physical data are not available for these ambient water quality monitoring stations. Indicator organism data is shown in Figure 3-7b.

In comparison to West Loch, downstream of the Palikea site, the open coastline near the Kahuku site can be expected to disperse pathogenic agents more rapidly, and due to greater salinity, has greater toxicity. The concentrations of coliforms are generally greater in an embayment than open coastal water. Chemical and physical data are not available for the ambient water quality monitoring station at Mālaekahana.

In addition to the coastline, the existing uses to be protected include the use of stream waters to nourish the wetlands in the James Campbell Wildlife Refuge. As in the case of Honouliuli Wildlife Refuge, this provides critical habitat, especially for protection of four endangered Hawaii waterfowl species. The U.S. Fish and Wildlife Service also controls essential water levels by the use of artesian wells and occasional pumping from Ki'i Ditch. In addition to the water quality parameters identified in Table 3.10, other potential contaminants include salinity (total dissolved solids), and organic chemicals which might affect the wetland ecosystem.



Highest Observed Monthly Value

SOURCE: DEPARTMENT OF HEALTH CLEAN
WATER BRANCH

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-7b

INDICATOR ORGANISM CONCENTRATIONS

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TABLE 3.13 – MARINE WATER QUALITY STANDARDS (CLASS A)

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to exceed the given value more than two percent of the time
Total Nitrogen (mg - N/L)	0.11	0.18	0.25
Ammonia Nitrogen (mg NH_4-NL)	0.0002	0.0005	0.009
Nitrate-Nitrite Nitrogen (mg (NO_3+NO_2) - N/L)	0.0035	0.010	0.020
Total Phosphorus (mg P/L)	0.016	0.010	0.020
Light (Coefficient K units)	0.10	0.30	0.55
Chlorophyll-^{a} (mg/L)	0.00015	0.0005	0.00100
Turbidity (NTU)	0.20	0.50	1.0

There are three principal watercourses through the Kahuku site which are intermittent. Their drainage areas are estimated below:

Drainage Name	Area, Sq. Mi.	Average Storm Discharge	
		mgd	cfs
Mālaekahana	4.5	5.1	7.9
Kea'aulu Gulch	1.8	2.8	4.3
'Ōhi'a Gulch	3.3	4.2	6.5

The 'Ōhi'a Gulch drainage is the closest to the potential project site.

The annual sediment production rate estimated for 'Ōhi'a Gulch is 2,080 tons per year. This is equivalent to a unit production rate of approximately one ton/acre/year:

Discussion. The existing water quality in the vicinity of the sites and downstream receiving waters will generally exceed standards after heavy storms. The parameters that will be exceeded include bacteria, nutrients, and suspended sediment. Probably the most identifiable contaminant, and one which more is known about relative to control measures, is suspended sediment. Erosion control is the critical factor that is needed to avoid adverse affects at a potential site. Suspended sediment in runoff cannot be eliminated. There is some evidence to suggest that these background levels are endemic and not strongly related to land use activities.

A study (Sunn, Low, Tom and Hara, Inc. 1971) concluded the significant variable in suspended sediment discharge was the volume of runoff and not land use activity *per se*. For example, in a comparison of sediment load between Pearl Harbor and Kāne'ohe Bay, it was concluded there was 50 percent more runoff from the Kāne'ohe basin despite the fact that the latter is less than one-half the size of the former. The consequence can be seen by comparing the suspended sediment discharge shown in Figure 3-7a for two streams. Note that the forested and "natural" watershed, Right Branch of Kamo'oali'i Stream, has nearly an order of magnitude greater suspended sediment than the agricultural watershed, Waikele Stream, for discharges less than 10 cubic feet per second.

The *Water Quality Management Plan For the City and County of Honolulu* (1990) noted "of the few correlations between open coastal water quality and adjacent land characteristics, the most significant were between slopes greater than 10 percent and turbidity and ammonia. Rainfall also correlated with turbidity, and while conservation land (i.e., slopes greater than 10 percent) correlated with total kjeldahl nitrogen." Thus agricultural use per se does not necessarily correlate with significantly degraded water quality. In fact the above report also noted (Figures 7-7 and 12-5) that areas with severe water erosion potential do not correspond with the tributary areas to marine water that are red after severe rains, particularly in the Kahuku area. The reasons for this are not clear, but may have to do with the filtering function of the wetlands along the coast.

The conclusion is that erosion potential is a concern but agricultural activity *per se* does not necessarily correspond to increase water quality degradation; with a storm water management plan to reduce this risk, particularly when land is disturbed for cultivation, and to protect it from grazing pressure, the significance of the erosion hazard is reduced. Furthermore, the project should not worsen or exceed criteria in the absence of natural storm runoff. The relative project impacts will be greater to estuarine waters near the Palikea site which ultimately drains into the Pearl Harbor embayment with reduced circulation, than the Kahuku site which drains ultimately to the open coast. A discussion of the potential impacts is presented in Section Four.

II. Flora and Fauna Survey

Summary of Subsection II — Palikea Site. **The vegetation in this potential site is predominantly secondary because of the extensive agricultural activities in the past. Only seven common native species of plants and no native animals were found after a reconnaissance survey. The open grasslands are known to be habitats of the native pueo and the *mauka* areas above the project site are known to contain *Gardenia brighamii*. No presence of these rare and endangered species, however, was seen during the survey.**

Summary of Subsection II — Kahuku Site. **Fifteen native plant species and one native community occur in the site but all of the native species are very common in Hawaii and constitute an insignificant portion of the total vegetation. No native birds or mammals were observed in the site except plovers which were flying over a portion of the Mixed Thickets.**

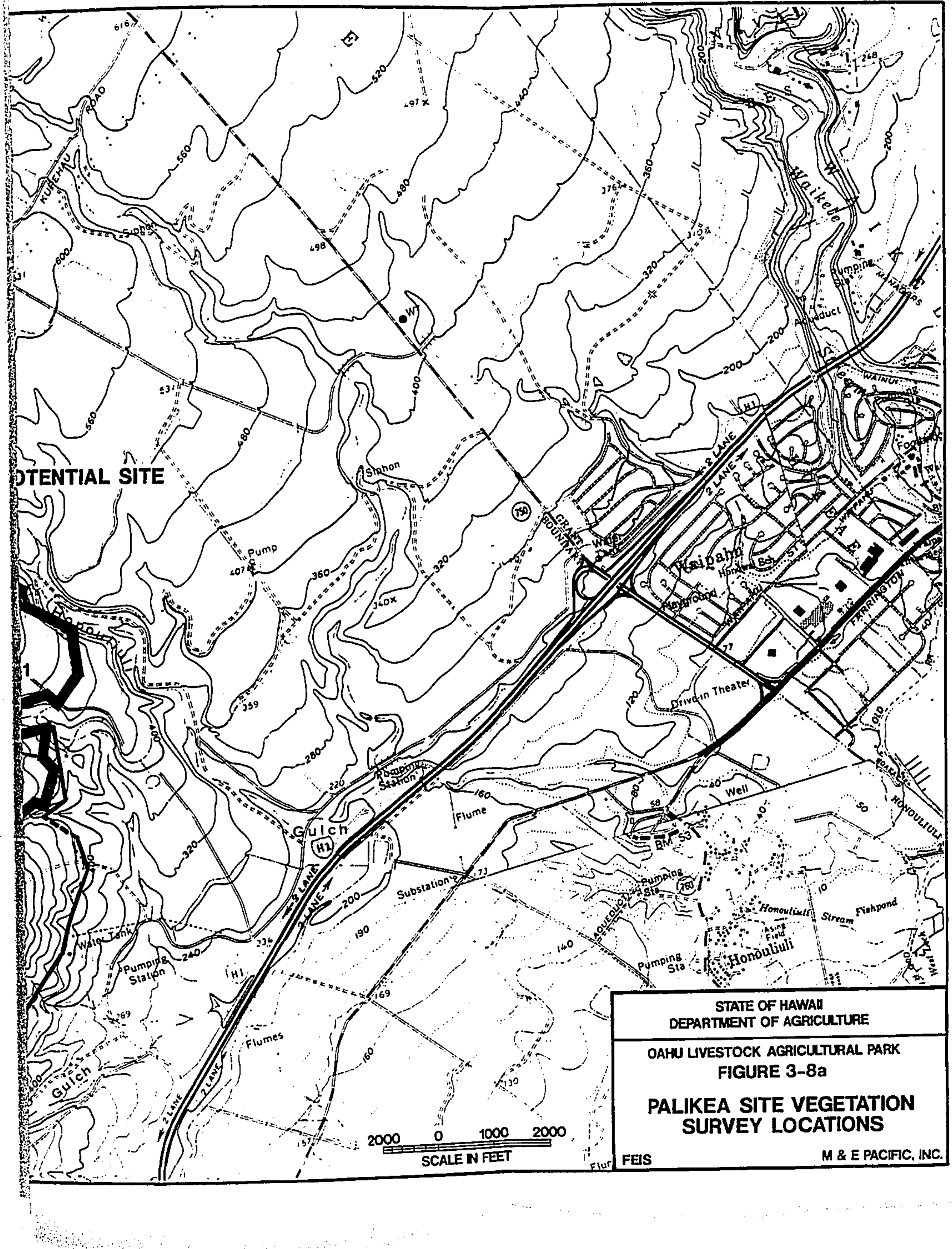
Recommendation. **Soil erosion controls must be instituted during and after construction to prevent loss of valuable topsoil and subsequent degradation of the makai ecosystems. Preservation of the native Exposed Scrub communities on the steep hillsides is recommended as a mitigating measure.**

The proposed project poses no threat to the integrity of the native biota and if responsible construction and operational techniques are employed, detrimental effects in the makai lands should be minimal.

Palikea Site

A. Introduction

The project site encompasses largely abandoned sugarcane land between Pu'u Ku'ua and Palikea in the Honouliuli region of the 'Ewa District, O'ahu. The *mauka* boundary generally approximates the 800-foot contour with a parcel extending to 1,100 feet; the *makai* boundary is generally defined by the 500- to 650-foot contours.



STATE OF HAWAII
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OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-8a

PALIKEA SITE VEGETATION SURVEY LOCATIONS

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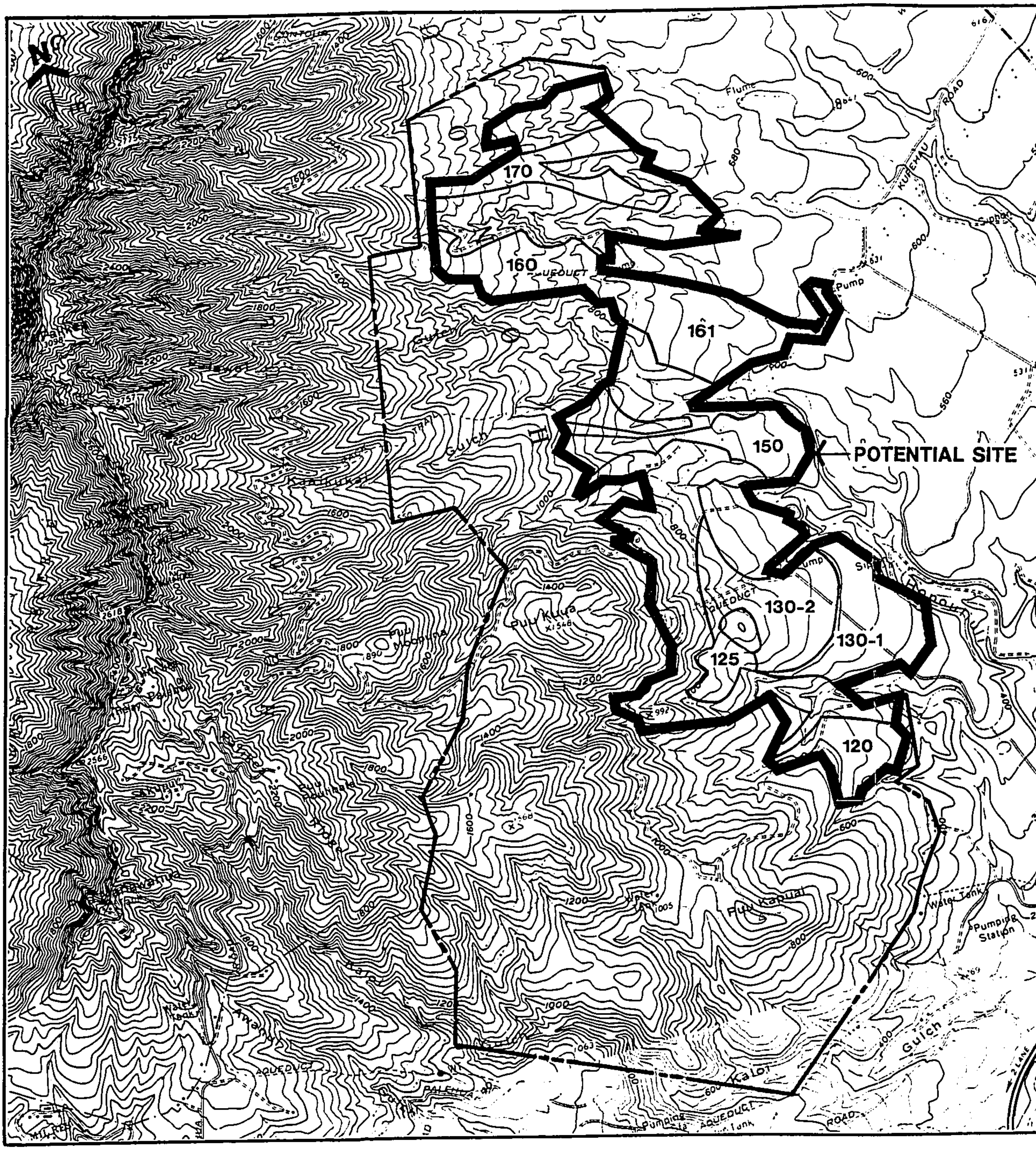

N
170
160
161
150
POTENTIAL SITE
130-2
130-1
125
120
Puu Kuua
Puu Kapuai
Kalot Gulch
Pump
Flume
Siphon
AQUEDUCT
Water Tank
Pumping Station
ROAD
KUNEHAU ROAD

The natural vegetation of the region has been described as one of xerophytic lowland shrub with some trees in the upper part (Ripperton & Hosaka 1942). Lantana (*Lantana camara*), koa-haole (*Leucaena leucocephala*), and cactus (*Opuntia ficus-indica*) are said to be the dominant shrubs in this community and often form dense stands. Smaller shrubs such as ʻuhaloa (*Waltheria indica*), ʻilima (*Sida fallax*) and Japanese tea (*Chamaecrista nictitans*) are common in open areas and short-lived perennials and annuals including Spanish needle (*Bidens pilosa*), false mallow (*Malvastrum coromandelianum*) and cocklebur (*Xanthium strumarium*) are abundant during the rainy season. Bermuda grass (*Cynodon dactylon*) and Natal redtop (*Rhynchyletrum repens*) are the dominant grasses in the *mauka* regions.

The native forest in the Wai'anae Mountains has always been known for its great diversity, and numerous rare species are found in gulches throughout the range (Nagata 1980). One Federally-listed Rare and Endangered Species, ***Gardenia brighamii***, is known from the Honouliuli area (Fed. Reg. 1985), and most of the Endangered snail genus *Achatinella* is native to the Wai'anae Mountains (Fed. Reg. 1981 a,b). More recently 26 plants from the Wai'anaes were proposed for Endangered status (Fed. Reg. 1990). The majority of these are found in native forests and well within the forest reserve boundary.

B. Methods

On May 20 and 21, 1991, a walk-through survey with 60 percent coverage was conducted to determine the floristic composition of the project site. Primary objectives of the survey also included determination of presence/absence of native plant communities and/or rare and endangered species. A cursory inventory of birds and mammals was also conducted utilizing observation and listening posts at regular intervals along vegetational transects.

Taxonomy and nomenclature for plants follow that of Wagner, et al. (1990); those for birds follow that of Berger (1981).

C. Results

Vegetation

The potential site is a considerable distance *makai* of the forest reserve boundary and well within the agricultural zone. The vegetation was found to be completely secondary in nature, consisting almost entirely of alien (i.e., non-native) species. This was predictable as virtually all of the flat or gently sloping lands were once cultivated in sugarcane and/or pineapple. Four vegetation types were recognized and are described below.

Grassland

The dominant vegetation type in the project site is the Grassland which consists of a dense layer of Guinea grass (*Panicum maximum*) 3 to 7 feet tall interspersed with koa-haole, ʻuhaloa and indigo (*Indigofera suffruticosa*) with occasional emergent Christmas berry (*Schinus terebinthifolius*) and silk oak (*Grevillea robusta*) up to 30 feet tall. In some areas koa-haole forms scrubby thickets up to 10 feet tall and in other sites these stands may be up to 20 feet in height. Vegetational cover is 100 percent. This community evolved from the abandoned sugarcane and pineapple fields and is found in all topographic sites except the deep gulches.

In shallow gullies, upper reaches of major gulches, abandoned reservoirs and irrigation canals, molasses grass (*Melinis minutiflora*) and Paragrass (*Brachiaria mutica*) often replace Guinea grass as the dominant species. Vegetation along the roadways through the Grassland consists of such typical wayside species as Bermuda grass, false mallow, swollen fingergrass (*Chloris barbata*), ʻāheahea (*Chenopodium murale*), spiny-bur (*Acanthospermum astrale*) and smooth rattlepod (*Crotalaria pallida*).

Mixed Forest

Of secondary importance in the project site is the Mixed Forest which is found only in the major gulches. Typically, it is a tall, close-canopied forest of kukui (*Aleurites moluccana*), Chinaberry (*Melia azedarach*), wiliwili (*Erythrina sandwicensis*), koa-haole, Christmas berry and silk oak. The understory is generally dominated by Guinea grass 4 to 6 feet tall. Among the few other species found in this community are ʻilieʻe (*Plumbago zeylanica*), peria (*Momordica charantia*), yellow lilikoʻi (*Passiflora edulis f. flavicarpa*) and molasses grass. Kiawe (*Prosopis pallida*) and Chinese banyan (*Ficus microcarpa*) are uncommon in the canopy. In some areas koa-haole forms dense stands 20 to 30 feet tall and in other areas Christmas berry is dominant. The herb and shrub layers are generally sparse under Christmas berry stands.

Cultivated Areas

This vegetation type designates areas presently under cultivation, cultivated plots recently abandoned and areas presently being used for ranching. Used in this sense it is more appropriately a land use designation. It is here used as a vegetation type out of convenience.

Coconuts (*Cocos nucifera*) are being grown in an approximately one-acre parcel in the lower portion of Field 161 (see Figure 3-8a) between Pump 13 and Honouliuli Gulch. Vegetation cover is less than 50 percent and the predominant weedy species include Guinea grass, Bermuda grass, goosegrass (*Eleusine indica*) and nutsedge (*Cyperus rotundus*). Adjacent to this plot is an overgrown, apparently abandoned field of plumeria cultivars (*Plumeria rubra*). Guinea grass 4 to 6 feet tall forms dense cover in this portion. 'Uhaloa, indigo, smooth rattlepod and swollen fingergrass are common. Several crown flower plants (*Calotropis gigantea*) are present in this field.

Another cultivated field is found along the *makai* boundary near Pump 13. This appears to be an experimental planting of various cultivars of three economic species—Arabian coffee (*Coffea arabica*), cocoa (*Theobroma cacao*) and tea (*Camellia sinensis*). More than 75 percent of the plantings are of coffee cultivars. Octopus tree (*Schefflera actinophylla*), hibiscus cultivars (*Hibiscus x*) and *Erythrina fusca* are used as windbreaks. Prominent weeds include nutsedge, Bermuda grass and Spanish needle. Several cherry tomato (*Lycopersicon esculentum*) and yard-long bean (*Vigna sesquipedalis*) plants are also being cultivated between the rows.

The upper portion of Honouliuli Gulch is being used for cattle ranching, resulting in a pasture of mostly Bermuda grass, Guinea grass and goosegrass with scattered kiawe, kukui, wiliwili and Christmas berry on the gulch floor. Tall stands of koa-haole dominate the steeper slopes. A single sandalwood (*Santalum freycinetianum*) was observed. Common wayside species include lion's ear (*Leonotis nepetifolia*), apple of Sodom (*Solanum sodomeum*), false mallow, indigo and currant tomato (*Lycopersicon pimpinellifolium*). The presence of "No Trespassing" signs and dogs precluded anything more than a cursory exploration of this area.

Barren Lands

At the time of the survey, Fields 171 and 172 in the northern end of the project site were being prepared for planting and were thus completely devoid of vegetation. The *mauka* portions of these fields as well as Field 170 and the intervening gulches were burned in a major brush fire earlier this year. Except for a few scorched trees, all of the vegetation was destroyed. The recovering vegetation consists entirely of re-sprouting Guinea grass. Although these burned areas are presently classified as Barren Lands they will probably revert to Grassland in the ensuing months.

Rare and Endangered Species and Native Plant Communities

Only seven native species were observed in the project site. All but two of these are considered indigenous, i.e., native to Hawaii but also native to other areas. The two endemics in the site are wiliwili which was considered "occasional" in the Mixed Forest and "uncommon" in the Grassland, and sandalwood which was found in the Cultivated Area in Honouliuli Gulch. The indigenous species include ʻuhaloa, ʻilima, huehue (*Cocculus trilobus*), koali (*Ipomoea cairica*) and ʻilieʻe. All are considered common to similar habitats throughout Hawaii. No official or unofficial rare and endangered species were observed in the site and the probability of their occurrence anywhere in the site is extremely small. The Nature Conservancy of Hawaii confirms that no rare plants have been recorded from the area (personal communication). No native plant communities were observed.

Fauna

Several common urban and field birds were heard or observed in the site. Most abundant were barred dove (*Geopelia striata*), rice bird (*Lonchura punctulata*), red-crested cardinal (*Paroaria coronata*), common mynah (*Acridotheres tristis*), and house sparrow (*Passer domesticus*). Also seen but in smaller numbers were Japanese white eye (*Zosterops japonicus*), lace neck dove (*Streptopelia chinensis*), Chinese thrush (*Gurrulax canorus*) and red-vented bulbul (*Pycnonotus cafer*). In addition, two cattle egrets (*Bubulcus ibis*) were sighted near the cattle in Honouliuli Gulch. Although none were observed it is possible that barn owls (*Tyco alba pratincola)* and/or the native pueo (*Asio flammeus sandwichensis*) are present in or near the project site.

One mongoose (*Herpestes auropunctatus*) was observed and although none were seen, one or more species of rats (*Rattus* spp.) and the field mouse (*Mus musculus*) may also be present. No native tree snails (*Achatinella* spp.) were seen.

Kahuku Agricultural Park Site

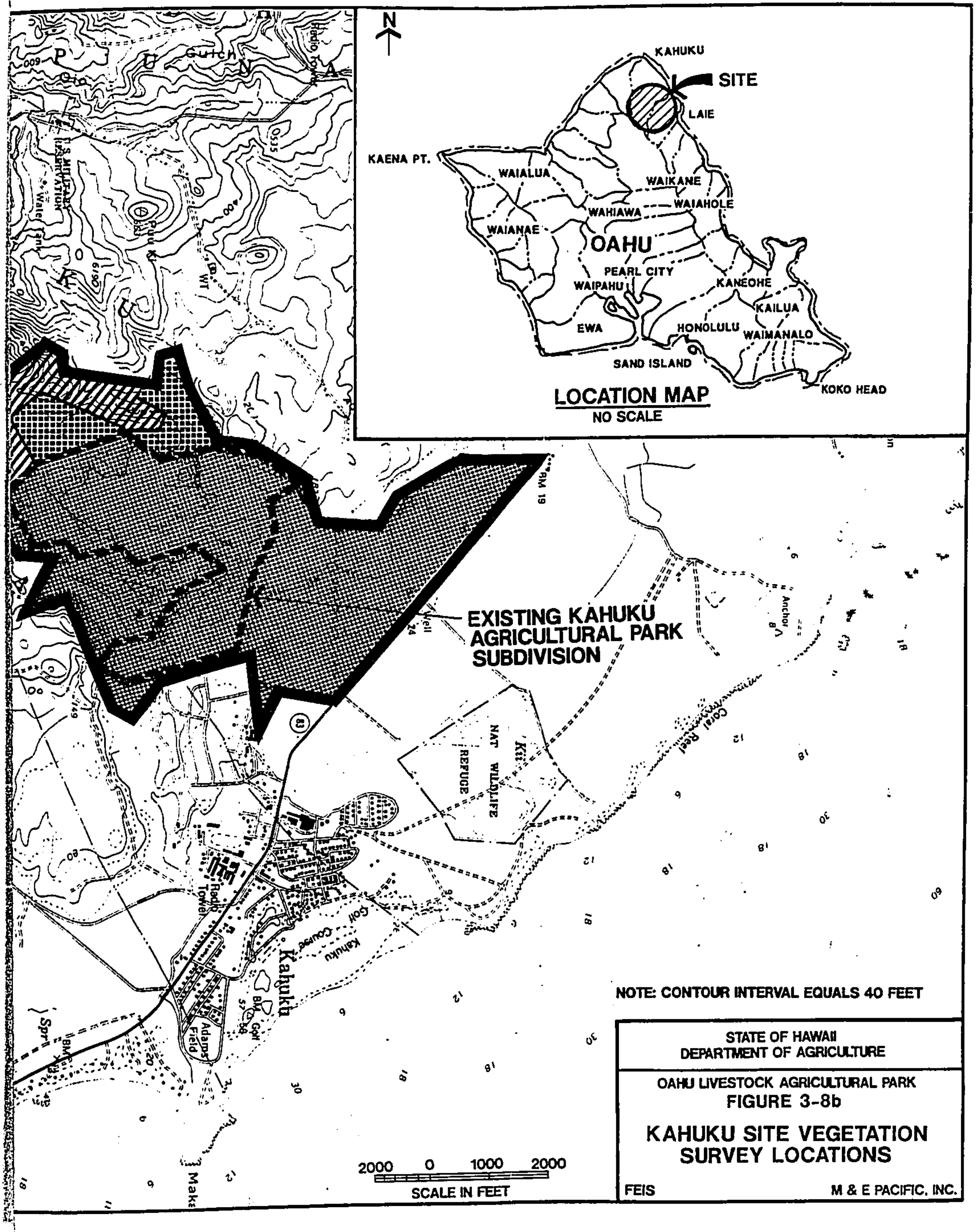
D. Introduction. The parcels within which the project site is situated comprise approximately 1,490 acres in the north end of Ko'olauloa District, Ko'olau Mountains, O'ahu. They are situated between the lands of Mālaekahana and Kahuku, *mauka* of Kamehameha Highway. Kahuku Village and Kamehameha Highway define the *makai* boundary. The *mauka* boundary fluctuates between the 200-foot and the 600-foot contours. The areas included in the survey are shown in Figure 3-8b.

Flora

Most of the site lies within Ripperton and Hosaka's vegetation Zone C, Low Phase, which consists of open shrubs and grasses (Ripperton & Hosaka 1942). Guava (*Psidium guajava*) and koa-haole (*Leucaena leucocephala*) are the predominant shrubs in this zone with the latter forming dense localized thickets. Lantana (*Lantana camara*) and also vervain (*Stachytarpheta dichotoma*) are also prominent. Widely scattered in this zone but of lesser importance are indigo (*Indigofera suffruticosa*), Japanese tea (*Chamaecrista nictitans*), 'ilima (*Sida fallax*) and 'uhaloa (*Waltheria indica*). Hilo grass (*Paspalum conjugatum*) and Natal redtop (*Rhynchyletrum repens*) are the predominant grasses and pilipili'ula (*Chrysopogon aciculatus*), ricegrass (*Paspalum scorbiculatum*) and yellow foxtail (*Setaria gracilis*) are common on eroded slopes.

The natural vegetation closer to Kamehameha Highway has been described by Ripperton and Hosaka as lowland shrub (Zone B) dominated by koa-haole. Lantana and cactus (*Opuntia ficus-indica*) are widely distributed in this zone and may form dense stands. Japanese tea, 'ilima and 'uhaloa annuals or other short-lived species such as Spanish needle (*Bidens pilosa*), false mallow (*Malvastrum coromandelianum*), cocklebur (*Xanthium strumarium*) and zinnia (*Zinnia peruviana*) are prominent especially during the rainy season.

The *mauka* most portion of the property above the 500-foot elevation extends into Ripperton and Hosaka's Zone D, Low Phase. Rainfall is high in this zone and the vegetation is one of shrubs and closed forest. Guava is dominant and forms extensive, dense stands. Prominent trees include hala (*Pandanus tectorius*), kukui (*Aleurites moluccana*) and 'ōhi'a (*Metrosideros polymorpha*). Ama'uma'u



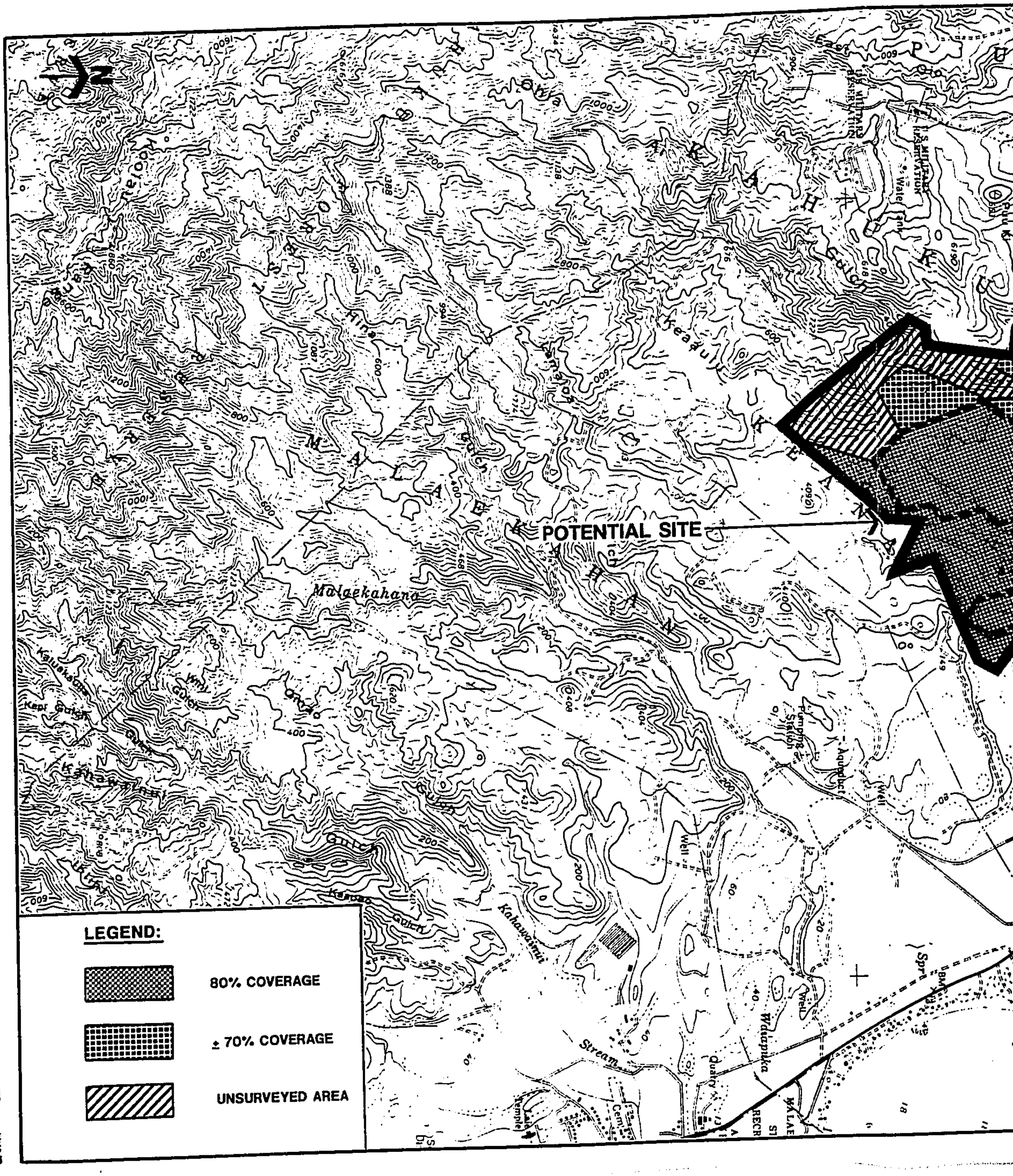
STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-8b

KAHUKU SITE VEGETATION SURVEY LOCATIONS

FEIS M & E PACIFIC, INC.

N
POTENTIAL SITE
Malaekahana
Gulch
Kahawainui
Stream
Kaluakauila
Kapi Gulch
Well
Pumping Station
Aqueduct
Quarry
Water Tank
U.S. MILITARY RESERVATION
LEGEND:
80% COVERAGE
± 70% COVERAGE
UNSURVEYED AREA

(*Sadleria spp.*), Boston fern (*Nephrolepsis exaltata*), Hilo grass, ricegrass and yellow foxtail and various sedges are common in the herb layer.

In 1984 a botanical survey was conducted through a portion of the project site (State of Hawaii 1984). The lowlands along Kamehameha Highway west of Kahuku Village were found to consist largely of cultivated fields of papaya (*Carica papaya*), corn (*Zea mays*), watermelon (*Citrullus lanatus*), green onion (*Allium fistulosum*) and eggplant (*Solanum melongena*). Cultivated fields of banana (*Musa* x *paradisiaca*), yellow liliko'i (*Passiflora edulis* f. *flavicarpa*) and guava were found in other portions of the site. Common wayside species such as buffelgrass (*Cenchrus ciliaris*), spiny amaranth (*Amaranthus spinosus*), goosegrass (*Eleusine indica*), nut sedge (*Cyperus rotundus*), and pigweed (*Portulaca oleracea*) were found throughout these farm plots. Stands of koa-haole, Christmas berry (*Schinus terebinthifolius*), Java plum (*Eugenia cuminii*) and Para grass (*Brachiaria mutica*) were also common in the lowlands. The uplands consisted largely of abandoned sugarcane fields and secondary vegetation dominated by koa-haole, Java plum, Christmas berry, Para grass, sourgrass (*Digitaria insularis*) and molasses grass (*Melinis minutiflora*). Small pockets of remnant native vegetation dominated by 'ūlei (*Osteomeles anthyllidifolia*) were found on some of the ridges which were not planted in sugarcane. Among the seven endemic species found were 'iliahialo'e (*Santalum ellipticum*, syn. *S. ellipticum* var. *littorale*) and maiapilo (*Capparis sandwichiana*).

A vegetation survey has also been executed in the land immediately northwest of the project site (Nagata 1989). The lowlands along the highway west of Tanaka Store were dominated by a mixed association of Johnson grass (*Sorghum halepense*), Guinea grass (*Panicum maximum*) and Para grass and stands of koa-haole. Most of the uplands were once planted in sugarcane but with the exception of a few remnants, these fields had been replaced by secondary growth consisting of thickets of koa-haole, Christmas berry, guava and *Macaranga tanarius* and grasslands of Para grass or Guinea grass. Scrub communities of 'ūlei, various grasses and stunted koa-haole and Christmas berry were found on slopes too steep for sugar cultivation.

E. Methods

During January 1992, walk-through surveys with 60 percent coverage were conducted throughout the project site. More attention was given to outcrops and the steep slopes and ravines in the *mauka* portion of the site as these were the most likely features to support native vegetation. Correspondingly little emphasis was given to cultivated fields and abandoned sugarcane fields as these were the least likely to support any sensitive vegetation. Plants which could not be readily identified in the field were brought back to the laboratory and pressed for later examination. Taxonomy and nomenclature are based on Wagner et al. (1990) or St. John (1973).

F. Results

The vegetation in the property was found to be very similar to that reported in the adjacent areas. It consists almost entirely of abandoned sugarcane fields and secondary forests, thickets and grasslands. Small disturbed remnants of native scrub communities are present on the hills and ridges which were not planted in sugarcane or ironwood (*Casuarina equisetifolia*). The lowlands and floodplains have been planted in fruit and vegetable crops for many years and numerous farm plots, fallowed fields and orchards are found between Kamehameha Highway and the escarpments which generally mark the *makai* boundary of the sugarcane fields. Seven vegetation types were recognized and are described below.

Abandoned Cane Fields

Almost all of the arable land in the region was once planted in sugarcane. In recent decades the lowlands were converted into truck farms and the cane fields above the ca. 200-foot contour were abandoned at various times during the past several decades. Those fields which have been abandoned the longest were invaded by various aggressive species and have evolved into other vegetation types. Sugarcane remnants can be found scattered throughout much of the upland portions of the property but generally in small disjunct patches. However, one very large field is present between Kea'aulu and Lamaloa gulches and is the dominant vegetation type in this portion of the project site.

This vegetation type is characterized by fields of sugarcane (*Saccharum officinarum*) with emergent individuals and small groves of Christmas berry, Java plum, koa-haole, ironwood, octopus tree (*Schefflera actinophylla*), Formosan koa (*Acacia confuse*) and *Macaranga*. Generally the herb layer is dense, about three feet high, and consists largely of molasses grass, Para grass, Spanish needle and Spanish clover (*Desmodium incanum*). Along the irrigation ditches, Para grass, molasses grass and Spanish needle are very well established. Numerous roadways and erosion scars are present. In such situations Vasey grass (*Paspalum urvillei*), broomsedge (*Andropogon virginicus*), Hilo grass, Japanese tea, ‘uhaloa and sensitive plant (*Mimosa pudica*) can be found.

Mixed Thickets

Most of the sugarcane fields *mauka* of the BWS water tank behind Kahuku Village have evolved into dense, closed-canopied thickets of Christmas berry, koa-haole and *Macaranga* 10 to 15 feet tall. In some areas one of these species may form pure stands but in most places they are co-dominant. Emergent ironwood, Java plum and octopus tree are scattered through the thickets. Generally these thickets are dense enough to preclude the establishment of any significant herb layer. This is especially true where Christmas berry is dominant. In other situations particularly where koa-haole is dominant, the herb layer is well developed and consists largely of Spanish clover, Spanish needle, and Para grass which is extremely dense in some sections. A few small, open sites, roadways and small patches of sugarcane may be found in the thickets. Para grass, molasses grass, sensitive plant, Spanish clover, Spanish needle, indigo and virgate mimosa (*Desmanthus virgatus*) are present in these areas.

This is the dominant vegetation type between Kea‘aulu and ‘Ai gulches *mauka* of Kahuku Village. It is found throughout the floor and slopes of ‘Ai Gulch where koa-haole is the dominant species and continues on into the former sugarcane lands where Christmas berry and *Macaranga* become more prevalent. It is also found along the slopes of Kea‘aulu Gulch, along the escarpment above the lowlands and in portions of the lowlands.

Mixed Forest

On the lower slopes and floor of the major gulches and in other areas where moisture is more readily available the densely understoried thickets grade into a more open understoried, higher canopied community. This Mixed Forest association is characterized by mixed stands of Formosan koa, Java plum, Christmas berry, *Macaranga* and koa-haole at least 20 feet tall. Typically, the forest is closed-canopied with a shrub layer of mostly tree saplings. The herb layer is often poorly developed and consists of scattered seedlings, Asiatic pennywort (*Centella asiatica*), basket grass (*Oplismenus hirtellus*), and Boston fern. In some areas basket brass and

Boston fern are well developed and in other portions of the forest Hilo grass, molasses grass and Para grass are common.

The forest canopy becomes shorter and more open along the middle and upper slopes of the gulches and the vegetation grades into Mixed Thickets. In some portions of Kea'aulu Gulch the forest is interrupted by small, open fields of Para grass, Boston fern and broomsedge and thickets of Christmas berry. The forest along Mālaekahana Stream includes extensive plantings of *Macaranga* and the "Hawaiian Giant" strain of koa-haole. The understory here is open and the herb layer consists mostly of Para grass or Chinese violet (*Asystasia gangetica*). Planted stands of "Hawaiian Giant" are also found in the cultivated fields in the lowlands.

Ironwood Forest

Numerous stands of ironwood are found throughout the *mauka* portions of the project site but in most instances these are small clusters and are included in other vegetation types. The more extensive stands, however, are designated as Ironwood Forest. Typically, this forest consists of pure, nearly closed canopied stands of ironwood 20 to 40 feet tall. Very few species are present in this community. The herb layer is generally absent and when present it consists of scattered huehue haole (*Passiflora suberosa*) and Spanish clover. On the periphery and in eroded areas such species as Java plum, pilipili'ula, lantana, Christmas berry, *Macaranga* and guava are found in very small numbers.

Grasslands

Grasslands generally occur on the hills in the *mauka*-most portion of the property, in depressions where grasses have replaced sugarcane and in certain areas of apparently constant disturbance. The Grasslands on the hills above the 400-foot elevation are dominated by broomsedge which accounts for at least 50 percent of the vegetational cover. Other grasses such as pili (*Heteropogon contortus*), feathery pennisetum (*Pennisetum polystachion*), pilipil'ula, Para grass, molasses grass and ricegrass are present in small to moderate numbers. Boston fern and 'ūlei are also locally common. Small clusters and individuals of ironwood, Christmas berry, Java plum, guava and *Macaranga* are present but aborescent species comprise less than ten percent of the vegetational cover. Erosion scars are common in the *mauka* Grasslands.

In areas where moisture is more readily available, Para grass is dominant and may form pure stands. Such communities are present in the upper portions of the left fork of Kea'aulu Gulch, in the Abandoned Cane Fields especially along the irrigation ditches and in the abandoned reservoirs *mauka* of the guava puree plant. Grasslands of Para grass and molasses grass are found all along Kea'aulu Gulch and in the northern portion of the property *mauka* of Kahuku Village but these are very small and are generally included in other vegetation types.

Exposed Scrub

This community represents the remnants of an ecosystem which probably occurred on the exposed, windswept knolls and ridges throughout the region. It is found on the hills and ridges which have remained undisturbed by sugarcane cultivation, ironwood reforestation, fires or prolonged recreational or military activity. The vegetation is typically low and windswept and usually consists of mats of 'ūlei one to two feet tall with emergent but stunted Christmas berry, Java plum, and guava and taller ironwood trees in small to very small numbers. The vegetation on the lee or protected sides of the hills is generally taller than that on the windward sections. Smaller shrubs and herbaceous species are found in moderate numbers including 'ākia (*Wikstroemia oahuensis*), Jamaica vervain (*Stachytarpheta jamaicensis*), pitted beardgrass (*Bothriochloa pertusa*), Natal redtop, pili, pilipili'ula, 'uhaloa, Spanish clover and Spanish needle.

Cultivated Fields

Most of the land below the escarpment has been devoted to diversified agriculture. Guava was the major crop in the fields east of Kahuku Village. These orchards extend from just below the escarpment in the vicinity of the abandoned reservoirs nearly to Kamehameha Highway. Generally the orchards were well maintained. The ground directly under the guava canopy was kept devoid of vegetation and low grasses such as Hilo grass were being encouraged between the rows. Common weeds include Johnson grass, Japanese tea, sensitive plant and Spanish clover. Windbreaks of ironwood or koa-haole and thickets of koa-haole are present in this section of the property. A former guava puree processing plant is located along one of the main access roads.

Fruit and vegetable farms occur west of Kahuku Village. Presently the major crops seem to be eggplant, banana and papaya although corn and watermelon are also known to be cultivated in these plots. A few of the fields are being fallowed or have been abandoned and are now overgrown with honohono (*Commelina diffusa*), castor bean (*Ricinus communis*), Guinea grass, Para grass, Johnson grass and sourgrass. Sugarcane, ironwood and koa-haole are typical windbreaks.

Native Species and Native Plant Communities

Fifteen common native species were observed in the project site—three endemics and 12 indigenous species. The most common native species was the indigenous 'uhaloa which occurs in very small to moderate numbers in all vegetation types except the Mixed Forest. Other native species may be present in one or more communities in moderate numbers but except in the Exposed Scrub these never account for more than 10 percent of the vegetational cover in any community.

The indigenous 'ūlei, the dominant species in the Exposed Scrub, is also present in two other communities but in small to very small numbers. Boston fern, another indigenous species, is a significant component in the Grasslands but is present in only three other communities in moderate to small numbers. The endemic 'ākia is an important species in the Grasslands and Exposed Scrub and is found in smaller numbers throughout the project site but is absent in the Abandoned Cane Fields and Cultivated Fields. The remaining native species are scattered in small or very small numbers in four or fewer vegetation types.

The Exposed Scrub is the one native plant community in the project site. It is dominated by the sprawling, mat-forming 'ūlei. The native pili, 'uhaloa and 'ākia are also significant components of the vegetation while two other indigenous species, huehue (*Cocculus trilobus*) and alahe'e (*Canthium odoratum*) are present in small to very small numbers. On some hills native species account for probably 90 percent of the total cover in the community but in others they provide only about 50 percent of the cover. The Exposed Scrub is one of the two smallest plant communities in the property. Most of the sites are less than half an acre in size.

Rare and Endangered Species

No official or unofficial Rare and Endangered or Threatened plant species are present in the property.

Potential Problems and Mitigating Measures

Preservation of Rare and Endangered Species or other botanically significant plants is not a factor in this particular project. Remnants of a native plant community are found on certain hills and ridges, however, and although this community is widespread in the region and no rare plants are involved, efforts should be made to exempt these hills from development.

Because of the size of this proposed project, soil erosion must also be a major consideration. Adequate precautions should be taken to prevent excessive runoff into the lowlands during construction and also during normal operations once construction is completed. Excessive siltation in the lowlands may detrimentally impact the coastal and marine ecosystems and wildlife habitats *makai* of Kamehameha Highway. Preclusion of the steep slopes and hills from development may be considered as an erosion control measure as the Exposed Scrub community which evolved on these features is well known for its soil binding capability.

Fauna

In conjunction with the vegetation survey, a cursory inventory of birds and mammals was also conducted. Observation and listening stations were established at regular intervals along the vegetation transects and all wildlife encountered during a 10-minute period was recorded. Nests were not investigated and no quantitative techniques were employed. Taxonomy of the birds is based on Berger (1981) and that of the mammals is according to Tomich (1969).

Results — Birds

Of the eleven birds encountered in the project site, nine are common urban and field birds. The most common species, the red-vented bulbul (*Pycnonotus cafer*), was present in all vegetation types. Barred dove (*Geopelia striata*) occurred in four vegetation types and lace-necked dove (*Streptopelia chinensis*), Japanese white-eye (*Zosterops japonica*), Kentucky cardinal (*Richmondena cardinalis*), ricebird (*Lonchura punctulata*) and the common mynah (*Acridotheres tristis*) were present in three plant communities. Red-crested cardinal (*Paroaria coronata*) was observed only in the Mixed Thickets and Shama thrush (*Copsychus malabaricus*) was heard in the Mixed Forest. Most birds were encountered in the Mixed Thickets than in any other community. Of all the species in the site only the ricebird and Shama thrush were not present in this community.

Two additional species were observed in the property but their status as residents in the site has not been determined. Several cattle egrets (*Bubulcus ibis*) were seen in the Mixed Thickets *mauka* of the BWS water tank and in the Cultivated Fields and two Pacific golden plovers (*Pluvialis dominica fulva*) were seen in flight over the Mixed Thickets *mauka* of the BWS water tank. Plover is the only native bird recorded in the project site but it is not known whether the vegetation types in the site offer significant feeding grounds for this migratory species. None were observed in the Grasslands.

The grasslands, scrub and thickets in the property may provide adequate feeding or nesting habitats for the native pueo (*Asio flammeus sandwichensis*) or the barn owl (*Tyco alba pratincola*). Although neither species were actually seen, several suspected owl droppings were observed in the Grasslands.

Results — Mammals

Numerous pig trails occur in the property particularly in the Mixed Forest. None were observed but it can be assumed that pigs (*Cuss scrofa*) are present as transients or residents. It is also possible that mongoose (*Herpestes auropunctatus*), field mice (*Mus musculus*) and one or more species of rats (*Rattus* spp.) are also present.

III. Socioeconomic Environment

Summary of Subsection III — Palikea Site. Knowledge of the prehistory of the Honouliuli *ahupua'a* is summarized. A reconnaissance survey resulted in the clear indication that virtually all former cultivated sugar and pineapple lands are devoid of archaeological interest. There are examples of early 20th century construction in the site. No archaeological sites are identified in the potential project area.

The present land use is fallowed sugarcane and cattle grazing. The land use district and zoning for the site are agricultural. The permitted uses include livestock production, farm dwellings, and crop production. The majority of the site is classified as prime agricultural land by the State of Hawaii ALISH system.

Average population density for the census tract in which the Palikea site is located is lower than for O'ahu as a whole and income is higher. The project can be supported by solid waste collection, police, fire, and medical services. On-site treatment of human waste within the overall waste management system is being considered. Water supply from Waiāhole Ditch is proposed, but the specific details remain an unresolved issue.

Summary of Subsection III — Kahuku Agricultural Park Site.

Observations of the Kahuku area were made by westerners around the time of initial contact with Hawaiian society and 20 or 30 years later, when declines in population and cultivation were noted. Plantation agriculture commenced in the 1880s and resulted in dramatic modification of all cultivated terrain. Currently, non-cultivated, non-altered terrain is discernible on hills and steep slopes within the project area.

Cultural Surveys Hawaii was requested by M&E Pacific, Inc., to undertake an archaeological site inventory for the approximately 785-acre proposed O'ahu Livestock Agricultural Park project (TMK 5-6-8:2) in the *ahupua'a* of Kahuku and Keana, island of O'ahu. The survey and limited subsurface testing were conducted in the months of May and June 1992. The project area includes land presently under cultivation as well as former cultivated sugarcane and pineapple fields. Only very limited portions of the project area have not been modified for commercial agriculture and contain archaeological sites. Sites include rock shelters on limestone bluffs, wall structures, and agricultural terraces. Throughout the project area is evidence of sugarcane and pineapple irrigation flumes and ditches. There are a total of 63 Land Commission Awards in the *ahupua'a* of Keana. No Land Commission Awards lie in the present project area; the majority of the Land Commission awards are *makai* of the project area.

The project area originally consisted of 1,666 acres but was later revised to 785 acres. The original project area was divided into four areas: Area 1, 1B, 2 and 3, but was later revised to Areas 2 and 3 only (Figure 3-10b). At the time of the revision the majority of the original project area had been surveyed and a total of 21 archaeological sites were located, but only seven remain in the vicinity of the revised project area (Sites 4510-4516). Limited subsurface testing was conducted at three of the archaeological sites. Site 4513 Feature B (Terrace), Site 4515 Feature B (Overhang Shelter), and Site 4516 Feature B (Overhang Shelter) were each tested with a single test trench (Trenches 1, 2, and 3). A human burial was discovered during the excavation of Trench 2, Site 4515 Feature B. The sites are concentrated on the west side of 'Ōhi'a Gulch with one site located on a limestone bluff in the *makai* portion of the project area. Charcoal samples taken from sites 4515 and 4516 were radiocarbon-dated and revealed evidence of prehistoric occupation of these sites. It is our recommendation that all sites be preserved.

A copy of this site inventory has been forwarded to the State Historic Preservation Division.

A. History and Archaeology of the Palikea Site

1. Description of Area

The Palikea site includes approximately 930 acres located on the lower slopes of the east side of the Wai'anae Range in the *ahupua'a* of Honouliuli. Much of the land was until recently cultivated in sugar and now lies covered in thick growth of volunteer grasses. On the higher slopes are former pineapple lands. Honouliuli Gulch and its tributaries have dissected the terrain through the approximate center of the project area. The tributary gullies are shallow and have gradual slopes, and the main branch of the gulch in some sections shows vertical-sided basalt cliffs and steep ravines with flat bottoms. Honouliuli Gulch flows only during flood periods.

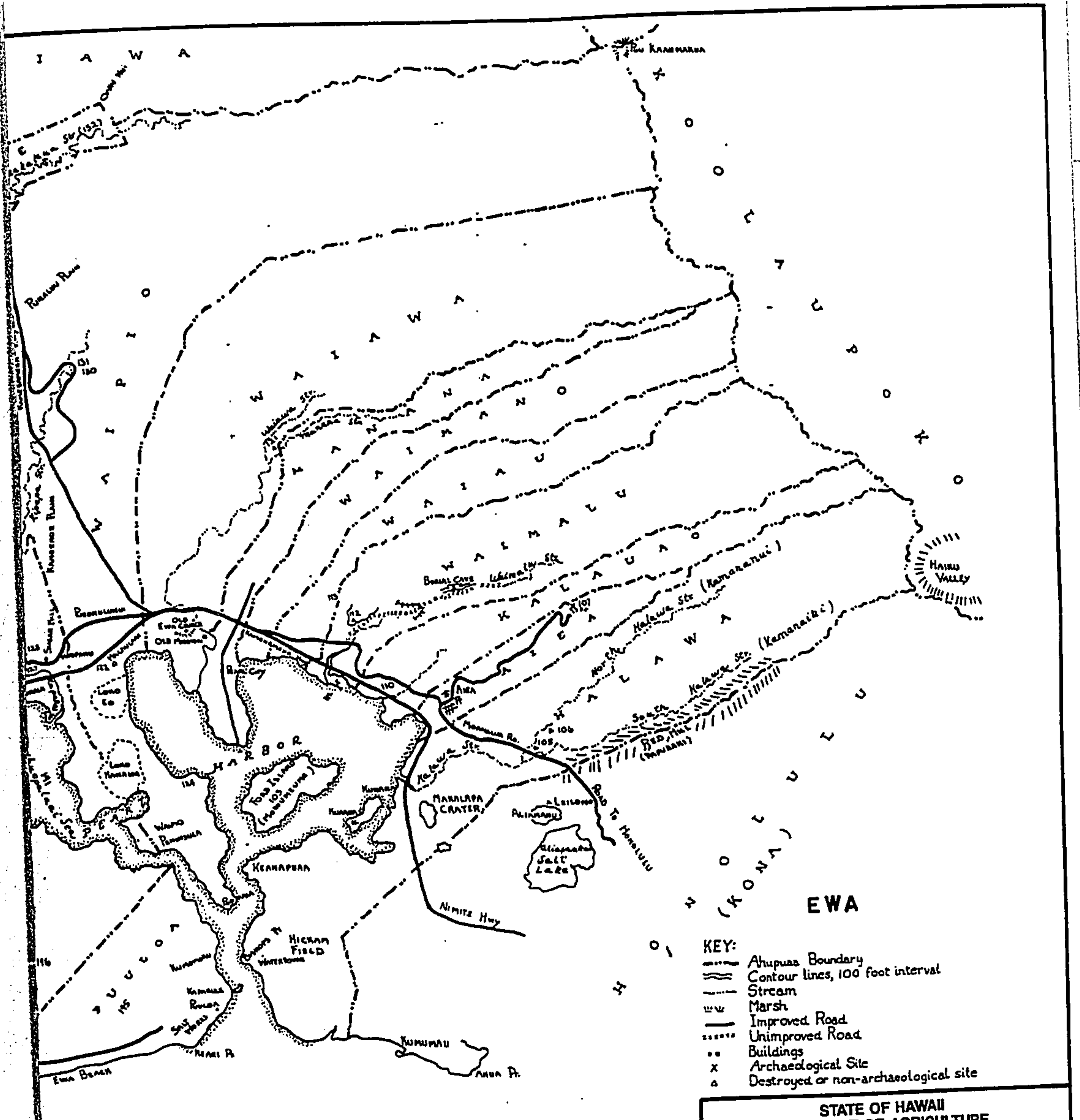
2. Honouliuli Settlement Patterns

The Physical Layout

The *ahupua'a* of Honouliuli is the largest traditional unit on the island of O'ahu. Although there has been a noteworthy history of archaeological research within this *ahupua'a,* the authors can find no *ahupua'a*-wide perspective on traditional land use and settlement. Such a comprehensive task is not attempted here. However, a broad *ahupua'a* sketch is needed to place the project area into the time and space of Hawaiian settlement.

Honouliuli (Figure 3-9) includes all the land from the western boundary of Pearl Harbor (West Loch) westward to the 'Ewa Wai'anae District Boundary with the exception of the west side of the harbor entrance which is in the *ahupua'a* of Pu'uloa (the 'Ewa Beach/Iroquois Point area). This comprises approximately 12 miles of open coastline from One'ula westward to Pili o Kahe. The *ahupua'a* extends *mauka* (almost pie-shaped) from West Loch nearly to Schofield Barracks and the western boundary is the Wai'anae Mountain crest running *makai* to the east ridge of Nānākuli Valley.

Not only is there a long coastline fronting the normally calm waters of leeward O'ahu but there are four miles of waterfront along the west side of West Loch. The land immediately *mauka* of the Pacific coast consists of a flat karstic-raised limestone reef forming a level nearly featureless "desert" plain marked in



STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

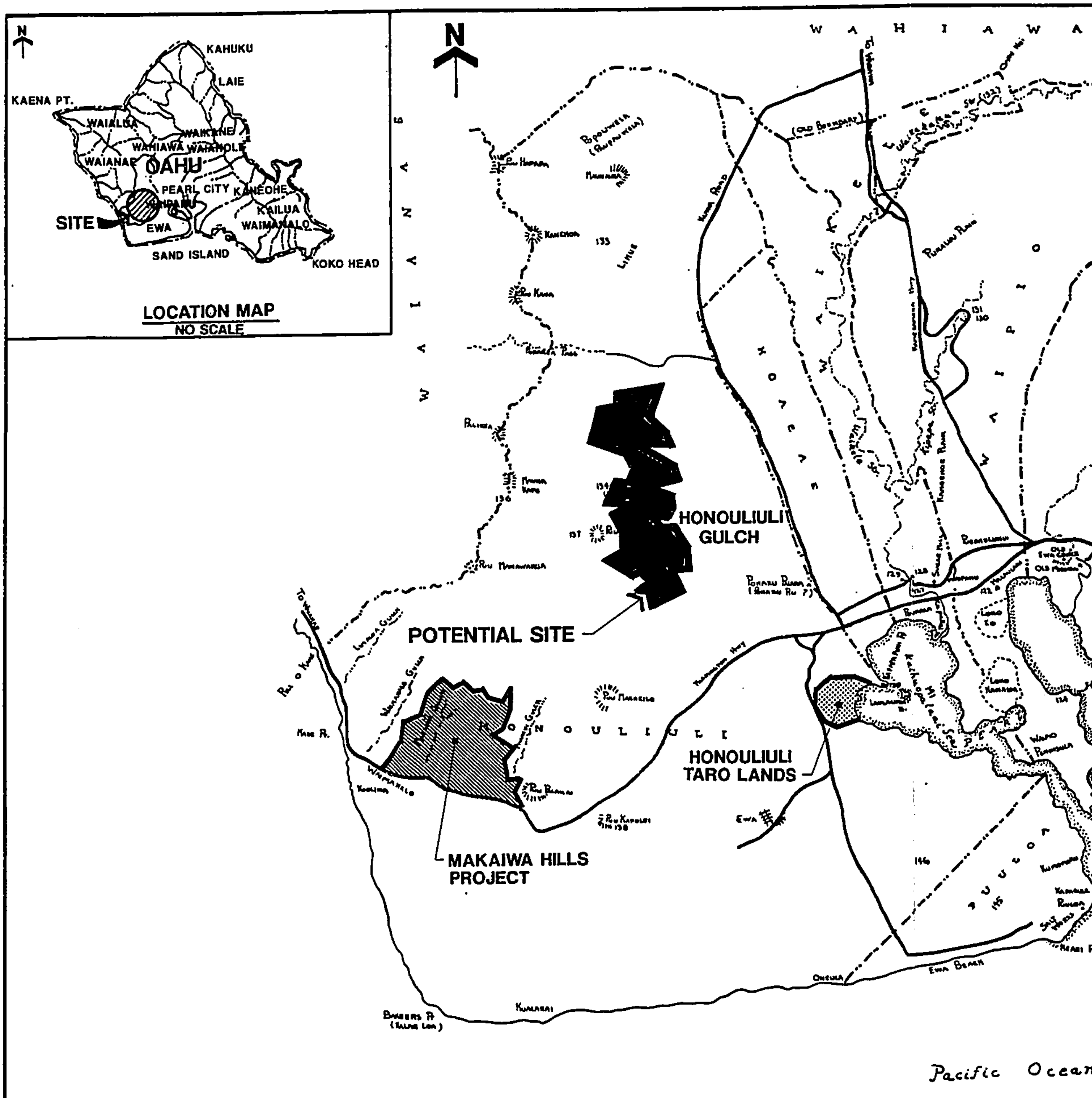
FIGURE 3-9

HONOULIULI AHUPUA'A

FEIS

M & E PACIFIC, INC.

ITES OF OAHU, COMPILED BY
LSPETH STERLING AND CATHERINE SUMMERS,
ISHOP MUSEUM PRESS, HONOLULU, 1978



ADAPTED FROM: *SITES OF OAHU,* COMPILED
ELSPETH STERLING AND CA
BISHOP MUSEUM PRESS, HO

prehistoric times (previous to illuviation caused by sugar cultivation) by thin or non-existent soil mantle. The microtopography is notable in containing countless sinkholes caused by chemical weathering (dissolution) of the limestone shelf. Proceeding *mauka* from this limestone plain, this shelf is overlain by alluvium deposited through a series of gulches draining the Wai'anae Mountains. The largest of these is Honouliuli Gulch towards the east side of the plain which drains into West Loch. To the west are fairly steep gradient gulches forming a more linear than dendritic drainage pattern. The major gulches are, from east to west: Awanui, Pālailai, Makaīwa, Waimānalo and Lumaloa. These gulches are steep-sided in the uplands and generally of a high gradient until they emerge onto the flat 'Ewa plain. The alluvium they have carried has spread out in delta fashion over the *mauka* portions of the plain, which comprises a dramatic depositional environment at the stream gradient change. These gulches are generally dry, but seasonal Kona storms carry immense quantities of runoff onto the plain and into the ocean. As typical drainages in arid slopes they are either raging uncontrollably, or are dry and as such do not form stable water sources for traditional agriculture in their upper reaches. The Honouliuli gulches, in contrast to those draining into Pearl Harbor to the east, do not have valleys suitable for extensive irrigated agriculture. However, this lack is more than compensated by the rich watered lowlands of the base of Honouliuli Gulch (the *'ili* of Honouliuli).

Honouliuli *Ahupua'a*, as a traditional land unit, had tremendous and varied resources available for exploitation by early Hawaiians. The "karstic desert" and marginal characterization of the limestone plain—which is the most readily visible terrain—does not do justice to the *ahupua'a* as a whole. The richness of this land unit is marked by the following available resources:

1. Twelve miles of coastline with continuous shallow fringing reef which offered rich marine resources.
2. Four miles of frontage on the waters of West Loch which offered extensive fisheries—including mullet, *awa*, and shellfish—as well as frontage suitable for development of fishponds (for example, Laulaunui).
3. The lower portion of Honouliuli Valley in the 'Ewa plain offered rich level alluvial soils with plentiful water for irrigation from the stream as well as abundant springs. This irrigable land would have stretched well up the valley.

4. A broad limestone plain which, because of innumerable limestone sinkholes, offered a nesting home for a large population of avifauna. This resource may have been one of the early attractions to human settlement.
5. An extensive upland forest zone extending as much as 12 miles inland from the edge of the coastal plain. As Handy and Handy (1972:469) have pointed out, the forest was much more distant from the lowlands here than on the windward coast, but it was much more extensive. Much of the upper reaches of the *ahupua'a* would have had species-diverse forest with *kukui*, *'ōhi'a*, sandalwood, *hau*, *ti*, banana, etc.

Within this natural setting archaeological and traditional sources show a general pattern of three main areas of settlement within the *ahupua'a*:

The Coastal Zone: Kalaeloa (Barbers Point)

Archaeological research at Barbers Point has focused on the areas in and around the newly-constructed Deep Draft Harbor (Barrera 1979; Davis and Griffin 1978; Hammatt and Folk 1981). Many small clustered shelters, enclosures and platforms show limited but recurrent use at the shoreline zone for marine-oriented exploitation. This settlement covers much of the shoreline with more concentrated features around small marshes and wet sinks. Immediately behind the shoreline under a linear dune deposit is a buried cultural layer believed to contain some of the earliest habitation evidence in the area.

The attraction of the area to early Hawaiians was the plentiful and easily exploited bird population. Particular evidence for taking of petrel occurs at Site 2763 (Hammatt and Folk 1981:107,213). Initial heavy exploitation of nesting seabirds and other species in conjunction with habitat destruction probably led to early extinction.

There is some indication of limited agriculture in mulched sinkholes and limited soil areas. Considering rainfall, this activity would have been limited, but probably involved tree crops and roots (sweet potatoes). The archaeological content of the sites indicates a major focus on marine resources.

Davis and Griffin (1978) distinguish functional classes of sites based on surface area size, and argue that the Barbers Point settlement consists of functionally integrated multi-household residence groups. Density contours of midden (by weight) and artifacts (by numbers) plotted for residence sites by Hammatt and Folk (1981) generally indicate narrowly defined spatial foci of discard, possibly indicating continuous use, or at least with no refurbishing or additions to the structures through time (Hammatt and Folk 1981). The focus is small habitation sites, typically lacking the full range of features found in large permanent residence complexes such as high platforms, complex enclosures and ceremonial sites. Seasonal camping on a recurrent basis is postulated. It is of interest that Berthell Davis, in his Ph.D. dissertation, in discussing the marine environment along the west coast of Oahu introduces an element of seasonality:

> "I suggest the west coast of Oahu, including the area off Barbers Point, (a) probably became a well established fishery at least by AD 1000, perhaps much earlier; (b) the initial settlement at Barbers Point also began around this time or possible earlier; and (c) the settlement initially involved task-specific groups exploiting the adjacent fishery on a seasonal round, probably during the winter months." (Davis 1990:135)

Davis also points out the seasonality of nesting of various species of birds, which is of relevance to the pattern of human habitation of the Honouliuli limestone plain (Ibid.:136).

Honouliuli Taro Lands

Centered around the west side of Pearl Harbor at Honouliuli Stream and its broad outlet into the West Loch are the rich irrigated lands of the *'ili* of Honouliuli which give the *ahupua'a* its name. The major archaeological reference to this area is Dicks, Haun and Rosendahl (1987) who documented remnants of a once-widespread wetland system (*lo'i* and fishponds) as well as dryland cultivation of the adjacent slopes.

Carol Silva has conducted "Historic Research Relative to the Land of Honouliuli" (Dicks et al. 1987) and the reader is referred to this work for an overview of the history of Honouliuli.

This area bordering West Loch was clearly a major focus of population within the Hawaiian Islands and this was a logical response to the abundance of fish and shellfish resources in close proximity to a wide expanse of well-irrigated bottom land suitable for wet land taro cultivation. The earliest detailed map (Malden 1825) shows all the roads of southwest O'ahu coalescing and descending the *pali* within the project area as they funnel into the locality which gave the district of Honouliuli its name. Dicks et al. (1987:78-79) conclude, on the basis of 19 carbon isotope dates and three volcanic glass dates, that "agricultural use of the area spans over 1,000 years." Undoubtedly, Honouliuli was a locus of habitation for thousands of Hawaiians. Prehistoric population estimates are a matter of debate but it is worth pointing out that in the earliest mission census of 1831-1832, the land (*'āina*) of Honouliuli contained 1,026 men, women, and children (Schmitt 1973:19). It is not clear whether this population relates to Honouliuli Village or district but the village probably contained the vast majority of the district's population. The nature of the reported population structure for Honouliuli (less than 20 percent children under 12 years of age) and the fact that the population decreased more than 15 percent in the next four years. Schmitt (Ibid.:22) suggests that prehistoric population of Honouliuli Village may well have been significantly greater than it was in 1831-1832. A conservative estimate would be that tens of thousands of Hawaiians lived and died at Honouliuli Village.

Pu'u Ku'ua: Inland Settlement

Documentation of inland settlement in Honouliuli *ahupua'a* is more problematic in that there are no clear archaeological sources. However, it is probable that the area around Pu'u Ku'ua, on the east side of the Wai'anae Ridge seven miles inland of the coast, was a Hawaiian place of some importance.

An 1899 Hawaiian newspaper "Ka Leo 'ea Kālai'āina" relates a story of Pu'u Ku'ua as "a place where chiefs lived in ancient times" and a "battlefield . . . thickly populated." The article summarizes:

> 1) This place was entirely deserted and left uninhabited and it seems that this happened before the coming of righteousness to Hawai'i Nei. Not an inhabitant is left.
> 2) The descendants of the people of this place were so mixed that they were all of one class. Here the gods became tired and returned to Kahiki. (Sterling and Summers 1978:33)

McAllister recorded three sites in this area—two *heiau* (134, 137)—Pu'u Kuina and Pu'u Ku'ua (both destroyed) and most interesting, a series of enclosures in Kukui'ula which he called "*kuleana* sites" (McAllister 1933). There is no direct archaeological evidence available to the authors' knowledge that Hawaiian settlement occurred here but it is considered as a place of high probability, based on the above indications. Geographically, the area is well-watered and would have had abundant locally-available forest resources.

Mr. Thomas Riley, in a letter of July 9, 1990, to Department of Land and Natural Resources, makes mention of the 'Ē Kaha Nui Complex—Site 1176 located in 'Ē Kaha Nui Gulch in upland Honouliuli.

3. Summary and Significance

Based on the above summary of areas of Honouliuli settlement, the following general considerations are made to place the project area in the context of the *ahupua'a* pattern:

1. There are three areas of Hawaiian settlement in the *ahupua'a*; two are well-documented and one is problematic:
   a. the extensive limestone plain with recurrent use habitations for fishermen and gatherers and sometime gardeners;
   b. the rich cultivated lands of Honouliuli *'ili* for extensive wetland taro and clearly the *ahupua'a* population center;
   c. the uplands around Pu'u Ku'ua for presently uncertain reasons but probably agriculture and forest resource utilization.

2. Honouliuli is designed as a unit to contain all the geographic elements of a typical Hawaiian valley *ahupua'a*, except they are arranged geomorphically in an atypical relationship. The *ahupua'a* is not organized around a single drainage network but shares the west portions of Waikele drainage in its upper reaches. A typical and highly advantageous characteristic for human subsistence is included in a vast coastline and fringing reef, an extensive limestone plain which would support only limited agriculture but would be excellent for bird catching in early times—and perhaps most importantly for the Makaīwa Hills Project—a huge expanse of sloping forest land. The richest forest land for foraging for wood, birds, feathers, etc., would have been the east slope of the Wai'anae Range. The *mauka/makai* route would have been up Honouliuli Gulch or up the Makakilo ridge, paralleling the coast from Honouliuli Gulch to Kahe. The Makaīwa slope forms a kind

of "side pocket" or dead space in both the *mauka/makai* and east/west orientation of trains in the *ahupua'a* (see Figure 3-11). For example, the most convenient route to *mauka* lands, even from the western end of the coast (Ko'olina) would have been *mauka* only to the base of the hills and then either up the Makakilo Ridge or northeast to a trail to Pu'u Ku'ua. The *makai* slope is the dry side of the ridge line. Here streams would respond to rainfall quickly but drain quickly leaving little available water for even short-term use. Bordner's survey at Waimānalo Gulch to the west of the Makaīwa project but still in Honouliuli indicated no evidence of Hawaiian occupation but the gulch has been impacted in modern times (Bordner and Silva 1983).

3. The lower western slope as evidenced by the Makaīwa Survey was not a major thoroughfare. We can see some very limited evidence of part-time agriculture in and around gulches and two foci of sparse habitation. The first is limited to *makai* portions of gulches and lava flats. This habitation is considered a *mauka* component or continuation of the Ko'olina coastal settlement rather than an independent focus. The second focus, separated from the first by a barren zone, is generally above the 800-foot elevation. This *mauka* habitation which could have been supported by seasonal dryland planting and forest foraging may be the lower portion of a thinly scattered, but widespread zone of settlement which stretches eastward and northeast along the east Wai'anae Range slopes and may increase in intensity along the more watered lands forming the *mauka* western boundary of Honouliuli.

4. There is to date no evidence of high status residence in Honouliuli. Large residential structures are not present along the Pacific shoreline where they would be expected. The late prehistoric occurrence of chiefs' houses is not apparent, perhaps because the ocean shoreline, although rich in marine resources, is uninviting for sport and unsuitable for fishponds. The chiefly focus of 'Ewa District was Waipi'o. Whatever activities of this class occurred in Honouliuli would have been in or near the rich lands fronting West Loch (the *'ili* of Honouliuli) but to date there is no direct archaeological evidence of this. Concerning status associations with Honouliuli, it is interesting to note

the connection of the Pu'u Ku'ua settlement with slaves (*kauwā*), the lowest class of Hawaiians (Sterling and Summers 1978:33).

5. The central place of the ahupua'a of Honouliuli in terms of population, as well as cultivated foods, was the *'ili* of Honouliuli. There is good reason to assume, given the lack of intensive agricultural resources in other settlement areas of the *ahupua'a* that at least by late prehistoric times, all other habitation zones were economically and socially co-dependent.

4. Reconnaissance Results

Preliminary fieldwork within the 930-acre project area gives clear indication that virtually all formerly cultivated sugar and pineapple lands are devoid of archaeological interest. The survey of Honouliuli Gulch and its tributaries shows extensive modern modification associated with commercial agriculture. Because of this modification the potential for prehistoric Hawaiian archaeological sites is nearly non-existent. However, there are historic structures associated with the sugar industry which, because they are older than 50 years, potentially are classifiable as significant historic sites. These include stone-lined ditches and flumes, stone retaining walls, house foundations, ovens and other miscellaneous structures. Virtually all of these features appear to be within Honouliuli Gulch and its tributaries. The Waiāhole Ditch is still extant here and has been in use for sugar irrigation within the project area. There are major engineering efforts evident in irrigation ditches which are cut into the sides of gullies. Some are retained by vertical walls of shaped basalt and represent fine examples of early 20th century construction techniques.

B. History and Archaeology of the Kahuku Site

1. Description of Area

The potential site is on the east side of the Ko'olau Mountains in the *ahupua'a* of Kahuku, Keana, and Mālaekahana (see Figure 3-10a). The site is located in the foothills and valleys that run from Kamehameha Highway to the Ko'olau Mountains on land that has been heavily impacted through agricultural practices in the past.

The entire project area has been planted in various commercial crops (sugar and pineapple) for over one hundred years. Kahuku Plantation, and several other companies, raised sugarcane and pineapple here well into the 20th century. Since the closing of the company former fields are now overgrown with feral sugarcane, *koa haole*, California grass, ironwood trees, and various small shrubs and weeds. Other fields have been planted in tree crops for diversified agriculture.

Limited portions of the site have not been modified for commercial agriculture and contain archaeological sites. The sites include overhang shelters, wall structures, and agricultural terraces. There are also remnants of sugarcane irrigation flumes, ditches, and a reservoir.

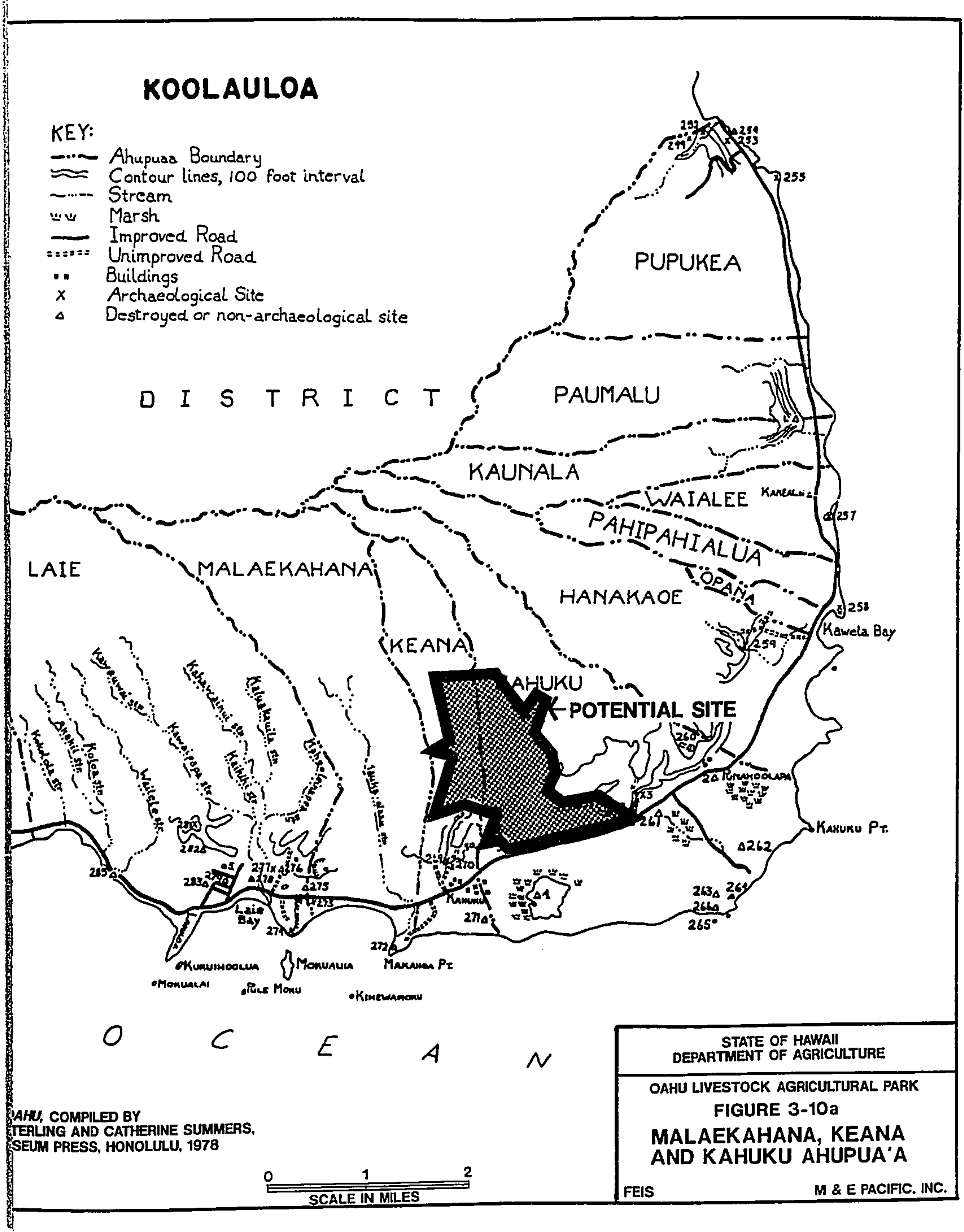
2. Reconnaissance Results

The area originally surveyed by reconnaissance techniques consisted of approximately 1,700 acres. Later, the area which was suitable for the project site was narrowed to approximately 785 acres. Of this amount, approximately 100 acres will be used for dairy operations, 110 acres for new diversified agricultural leases, and 230 acres are presently utilized for diversified agriculture by the Kahuku Farmers Association. These area estimates include area of roads, utilities, and fallowed land. At the time the site boundaries were constrained, a total of 21 archaeological sites were located. The revised estimate, with the new boundaries, is that seven sites remain (shown on Figure 3-10b). This number may be further reduced during land acquisition. However, at this time, an archaeological site inventory has been made of these seven sites. This inventory survey is contained in Appendix J.

3. Historic Background

The following earlier observations on the Kahuku area are taken from J. G. McAllister:

> "She [Mrs. John Kaleo] remembers the time when trees, now found only on the mountains, covered the Kahuku plain, now as a rather desolate, windswept area.
>
> "It hardly seems possible that this barren region could have been otherwise, yet Captain King who saw only the northern tip of O'ahu (from Kāne'ohe Bay to Waialua) says: 'It (O'ahu) is by far the finest island of the whole group. Nothing can



AHU, COMPILED BY
TERLING AND CATHERINE SUMMERS,
SEUM PRESS, HONOLULU, 1978

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-10a

MALAEKAHANA, KEANA AND KAHUKU AHUPUA'A

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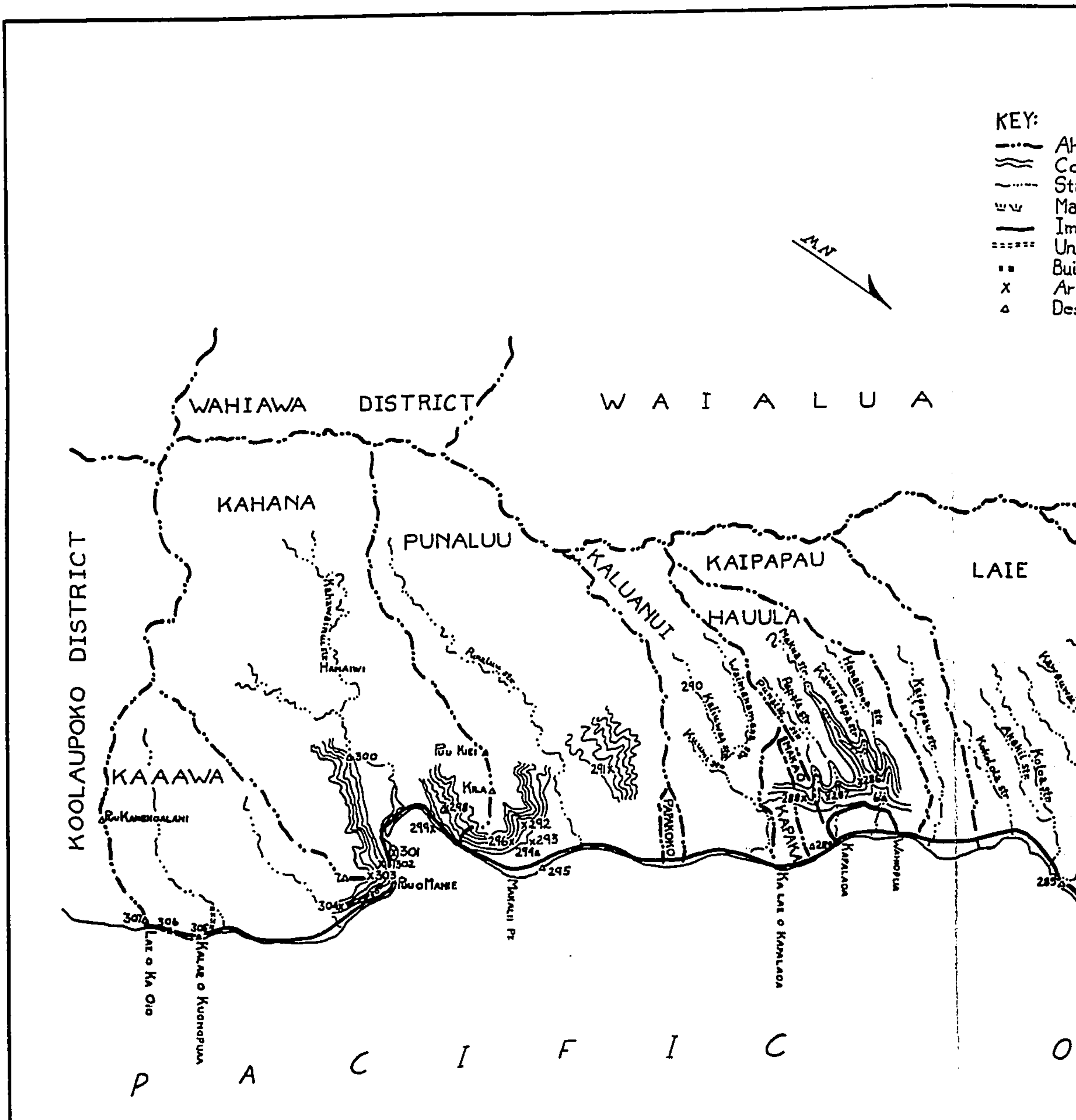

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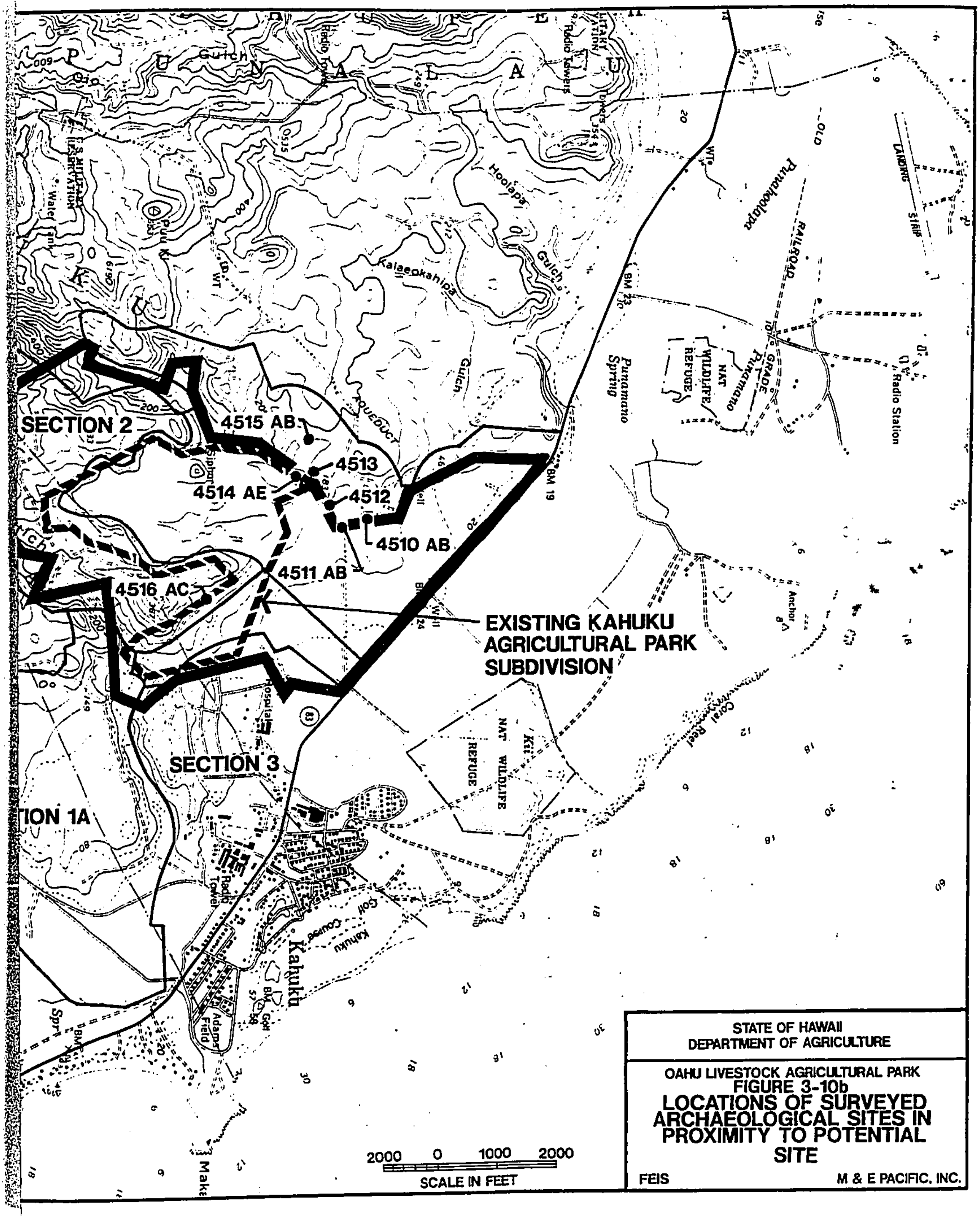

STATE OF HAWAII
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OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-10b
LOCATIONS OF SURVEYED ARCHAEOLOGICAL SITES IN PROXIMITY TO POTENTIAL SITE

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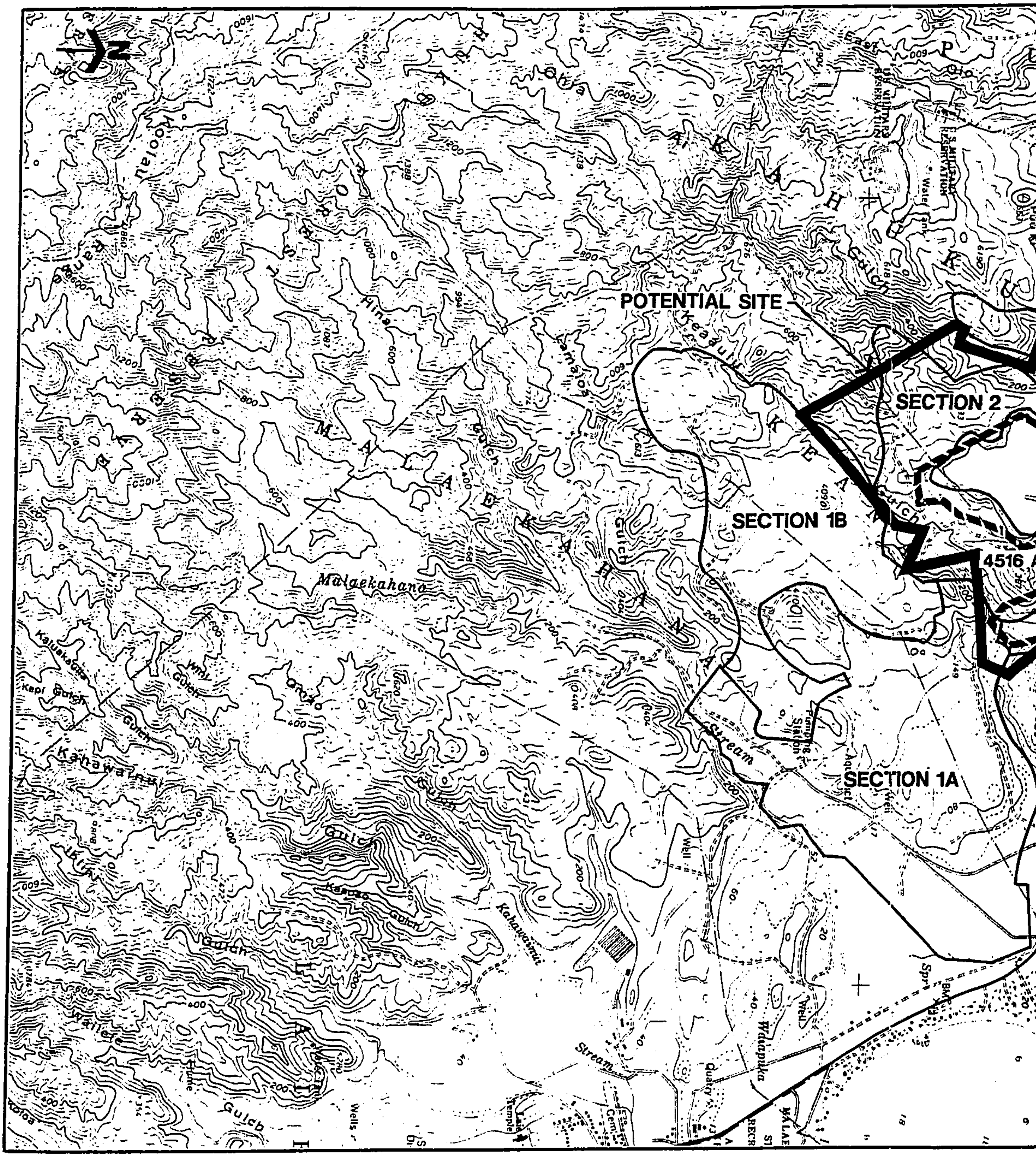

N
POTENTIAL SITE
SECTION 2
SECTION 1B
SECTION 1A
4516 A
Koolau Range
Malaekahana
Malaekahana Stream
Kahawainui Gulch
Kahawainui Stream
Keaaulu Gulch
Kamaloa Gulch
Hina Gulch
Ohia
Kaluakauila Gulch
Kapi Gulch
Wahi Gulch
Kaipapau Gulch
Waiele Gulch
Kaluanui Gulch
Kakaako
Wailapuka
Pumping Station
Aqueduct
Well
Wells
Quarry
Cem
Temple
Spr
BM
US MILITARY RESERVATION
Water Tank
Laie Point
Stream
Gulch
200
400
600
800
1000
1200
1400
1600
2000

> exceed the verdure of the hills, the variety of wood and lawn, and the rich cultivated valleys, which the whole face of the country displayed.' Thirteen years later Vancouver says of Kahuku and the surrounding territory: 'Our examination confirmed the remark of Capt. King except that in point of cultivation or fertility, the country did not appear in so flourishing a state, nor to be so numerously inhabited, as he represented it to have been at that time, occasioned most probably by the constant hostilities that had existed since that period.' In 1838 Hall makes the general statement in regard to Ko'olauloa: 'Much taro land now lies waste, because the diminished population of the district does not require its cultivation.'" (McAllister 1933, p. 153).

It is apparent that there were major changes in the population of Kahuku and in land use in the Kahuku area in the period immediately following contact with the western world. Through hostilities and population decline, the land fell into disuse. By 1838 much of the ancient taro land was abandoned.

As western contact spread through the islands, the introduction of foreign diseases, coupled with a population shift towards more urban areas, decimated the population and led to the virtual abandonment of many of the smaller rural areas of the islands. Apparently this trend began in Kahuku even before many westerners had visited Hawai'i. The introduction of a market economy and attraction of urban centers (Honolulu) combined with Kamehameha the Great's consolidation of the island under his rule were a factor in the demographic shifts.

Handy and Handy mention former irrigated terraces, presumably along Mālaekahana Stream but none in Keana. In Kahuku there were apparently no terraces along the banks of Kahuku Stream but only around Kūki'o Pond (Handy and Handy 1972, p. 462). Much of the early descriptions of verdant lands must have referred to *kula* plots probably long ago destroyed by commercial agriculture. An extensive cultural landscape in the Kahuku area is indicated by the earliest descriptions and was probably the norm throughout late prehistory. Whatever remnants of this former landscape which survived into the 19th century much would have been taken during the plantation era.

4. Previous Archaeological Research

McAllister's work in 1930 represents the first complete inventory survey of the known archaeological sites on the island of O'ahu.

He listed 21 known archaeological sites during his survey in 1930 of the Kahuku and Mālaekahana areas (Sites 257-278 in Figure 3-10a). Eight of the sites are listed as pools of water, or as fishponds that had been abandoned by the time McAllister visited the area (257, 258, 261, 262, 268, 271, 275, and 277). Most of the ponds were quite small, but several were fairly substantial in the days before McAllister surveyed the area. Other sites include a previously-destroyed heiau (site 260), caves and rockshelters (sites 267, 269, and 270) and stones that were said to be god rocks or places of worship (sites 265, 266, 272). Most of these sites are no longer in existence. The ones that survive include site 257, 258, 265, 267, 270, 275, and 277. Only site 270 appears to be close to or inside the present project area's boundaries. This is a rockshelter located near Kahuku School and would not be impacted by the development of an agricultural park.

Several more recent surveys have been completed in the Kahuku area related to development projects. Most relevant to the present project is an archaeological reconnaissance conducted by William Barrera of Chiniago (Barrera 1981). The boundaries of his study area overlap with the present project area except that the *mauka* area of the now proposed agricultural park was not surveyed and the configuration of the boundaries of his study appears to be slightly different.

Barrera found three possible sites (1-3) which include:

1. A scatter of shell, coral, and dense basalt.
2. A single cowrie shell in a plowed field.
3. A scatter of broken bottles and ceramics at the base of a limestone ledge.

Barrera provides a brief historical review and observes that although the previously cultivated lands would not contain sites, unmodified areas to have archaeological potential. Barrera does not describe the thoroughness or the extent of his field coverage.

5. Summary of Archaeological Site Inventory

Description. A total of seven archaeological sites were located and identified within the proposed Kahuku Agricultural Park project area. Sites 4510-4515 are located in the *ahupua'a* of Kahuku along the west side of 'Ōhi'a Gulch and site 4516 is located in the *ahupua'a* of Keana located on a coral limestone outcrop in the *makai* portion of the project area directly *mauka* of the Ko'olauloa Housing Project. Site types include wall sections, overhang shelters, terraces and enclosures.

These sites contain evidence of Hawaiian habitation as indicated by midden and artifacts collected during the excavation of sites 4515 and 4516. There is an absence of agricultural sites which is probably due to the modification of the land for the commercial cultivation of sugarcane. The southeast side of 'Ōhi'a Gulch probably once contained traditional Hawaiian agricultural sites which have since been obliterated.

The most significant of the sites within the project area include the overhang shelters: Site 50-80-02-4510 Features A and B; 50-80-02-4511 Features A and B; 50-80-02-4515 Features A and B, and 50-80-02-4516, Feature B. Temporary habitation or recurrent habitation is suggested by the presence of midden and the location of these sites. Both Sites 50-80-02-4511 Feature B and 50-80-02-4516 Feature B have constructed modifications on the exterior of the overhang shelters. Preservation in all of these overhang shelters appears to be fair to good. These sites are located on Figure 3-10b.

Testing. Limited subsurface testing was conducted at overhang shelters 50-80-02-4515 Feature B and 50-80-02-4516 Feature A, and Site 50-80-02-4513 Feature B terrace. No cultural material was collected during the excavation of Site 50-80-02-4513 Feature B. A fair amount of midden and artifacts were collected during the excavation of the overhang shelters. The excavation of Site 50-80-02-4516 Feature A revealed a human burial. This suggests that there is a possibility of burials in the remaining overhang shelters. Based upon the amount of midden and artifacts collected, we suggest that these shelters were utilized as a temporary and/or recurrent habitation shelters.

Dating. Three charcoal samples were sent to Beta Analytic Inc. for radiocarbon dating analyses. One sample was sent from site 4515 Feature B, Trench 2, 40-50 centimeters and two samples were taken from site 4516 Feature B, Trench

3, 10-20 cm. and 70-80 cm. The dates retrieved from these samples strongly suggest prehistoric to early historic times. The date retrieved from Trench 2 indicates that the burial post dates the time period given by the radiocarbon dating.

Site Functions. Only one site located within the project area has been designated as permanent habitation, Site 50-80-02-4513 Features A-E. This site consists of wall structures (Feature A), two cobble paved terraces (Features B and D), a U-shaped enclosure (Feature C), and an overhang shelter with rock alignments (Feature E). A single test trench was excavated at Feature B. Although no cultural material was collected during the excavation of this terrace, the size and complexity of this site itself suggests this to be a permanent habitation complex.

The remaining six sites have been designated as temporary and/or recurrent habitation sites. The locality of these sites and evidence of cultural material both collected and observed suggest that these sites were utilized while tending to once present agricultural features.

In summary, the fact that the majority of the LCAs located in the *ahupua'a* of Kahuku and Keana lie on the *makai* side of Kamehameha Highway suggests that both habitation sites and agricultural sites *(lo'i* and *kula*) were centered in these areas. Through information gathered from foreign and native testimony, we can conclude that agricultural sites, which incorporated temporary and/or recurrent habitation sites, were once present in the uplands of the *ahupua'a* of Kahuku and Keana.

The remains of the Kahuku Plantation irrigation system are visible throughout the entire project area where sugarcane was once grown. Remnants of cemented irrigation ditches and flumes which watered large fields of sugarcane and/or pineapple, many of which are impacted by erosion and/or bulldozing, are spread throughout the project area. The remains of these ditches are not considered significant archaeological sites.

Site significance evaluations are summarized in Table III in Appendix J. A total of seven sites judged to be significant are present in the project area. These sites are evaluated for significance according to the broad criteria established for the National and State Registers. The seven criteria which are listed apply to the archaeological sites in the project area as follows:

A. Site reflects major trends or events in the history of the state or nation. *This criterion does not apply to the project area.*

B. Site is associated with the lives of persons significant in our past. *There are no sites in the project area that fall into this category.*

C. Site is an excellent example of a site type. *There are no sites in the project area that fall into this category.*

D. Site may be likely to yield information of the prehistory or history. *All sites within the project area fall into this criterion.*

E. Site has cultural significance to Hawaiians or other ethnic groups. *This category includes religious sites (heiau), sites containing human burials or other sites judged to be of cultural significance. All overhang shelters have been designated with criterion E because of the possibility of burials.*

F. Not significant (NS). *No sites within the project area fall into this criterion.*

G. No Longer Significant. *No sites within the project area fall into this criterion.*

All overhang shelters have been designated with criterion D due to the fact that a human burial was revealed during the excavation of overhang shelter site 4515 Feature A. Other shelters contain deep soil deposits and are potential burial places.

6. Recommendations

It is recommended that the burial (site 4515) and all potential burials (sites 4510 Features A and B, 4511 Features A and B, 4513 Feature E, and 4516 Features A and B be preserved. All other sites significant for information content (criterion D) that cannot be avoided in the development of the agricultural park should be data-recovered. Those that will not be impacted should be preserved in place.

All further mitigation including data recovery and preservation measures should be presented in a plan to be reviewed and approved by the State Historic Preservation Division.

C. Relationship to Land Use Plans, Policies, and Controls

Palikea Site. The area under consideration for this alternative site is shown on Figure 3-11a. It includes portions of parcels 5 and 6 in TMK 9-2-04. The land is owned by the Estate of James Campbell. The land was formerly cultivated, first for pineapple, and later sugarcane; now it is used for cattle grazing. The land is classified in the Agricultural District by the State Land Use Commission, is designated Agricultural on the Central Oahu Development Plan map, and is zoned AG-1 on the City and County of Honolulu zoning map. In the *mauka* direction, above the site, the land is within the Honouliuli Forest Reserve. The Waiāhole Ditch crosses the site.

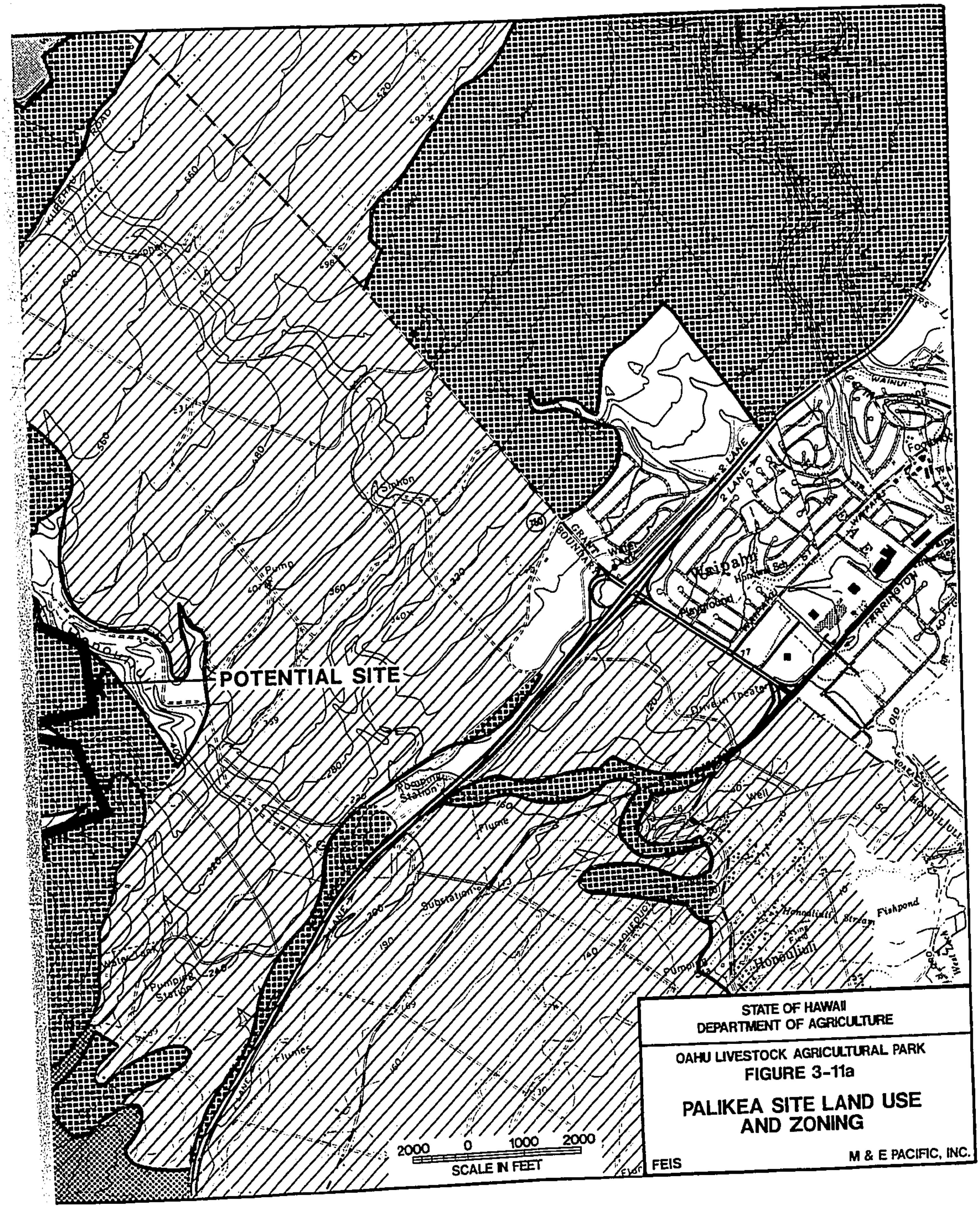
The permitted uses in AG-1 zones include the following:

Crop production
Farm dwellings
Livestock grazing
Livestock production, major
Livestock veterinary services
Utility installations, Type A

Type A utility installations include the transmission lines and structures for water supply, gas, electricity, and telecommunications. It does not include private water supplies or waste treatment systems, but these may be allowed as an accessory use.

Kahuku Agricultural Park Site. The area under consideration for this alternative site is shown on Figure 3-11b. It is located in Zone 5, Section 6, Plat 05 (portion of parcel 9), Plat 06 (portion of parcel 19), and Plat 08 (portion of parcel 2). The land is owned by the Estate of James Campbell. The *mauka* portion was formerly cultivated, first for pineapple, and later sugarcane; now it is used for military training exercises. An application to subdivide part of the site has already been approved for the portion leased from the owner by the Department of Agriculture. Roads and improvements have been made and part of the site is already leased by the owner to the Kahuku Farmers Association.

The site is classified in the Agricultural District by the State Land Use Commission, is designated Agricultural on the Ko'olauloa Development Plan map, and is zoned AG-1 and AG-2 on the City and County of Honolulu zoning map. In



STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-11a

PALIKEA SITE LAND USE AND ZONING

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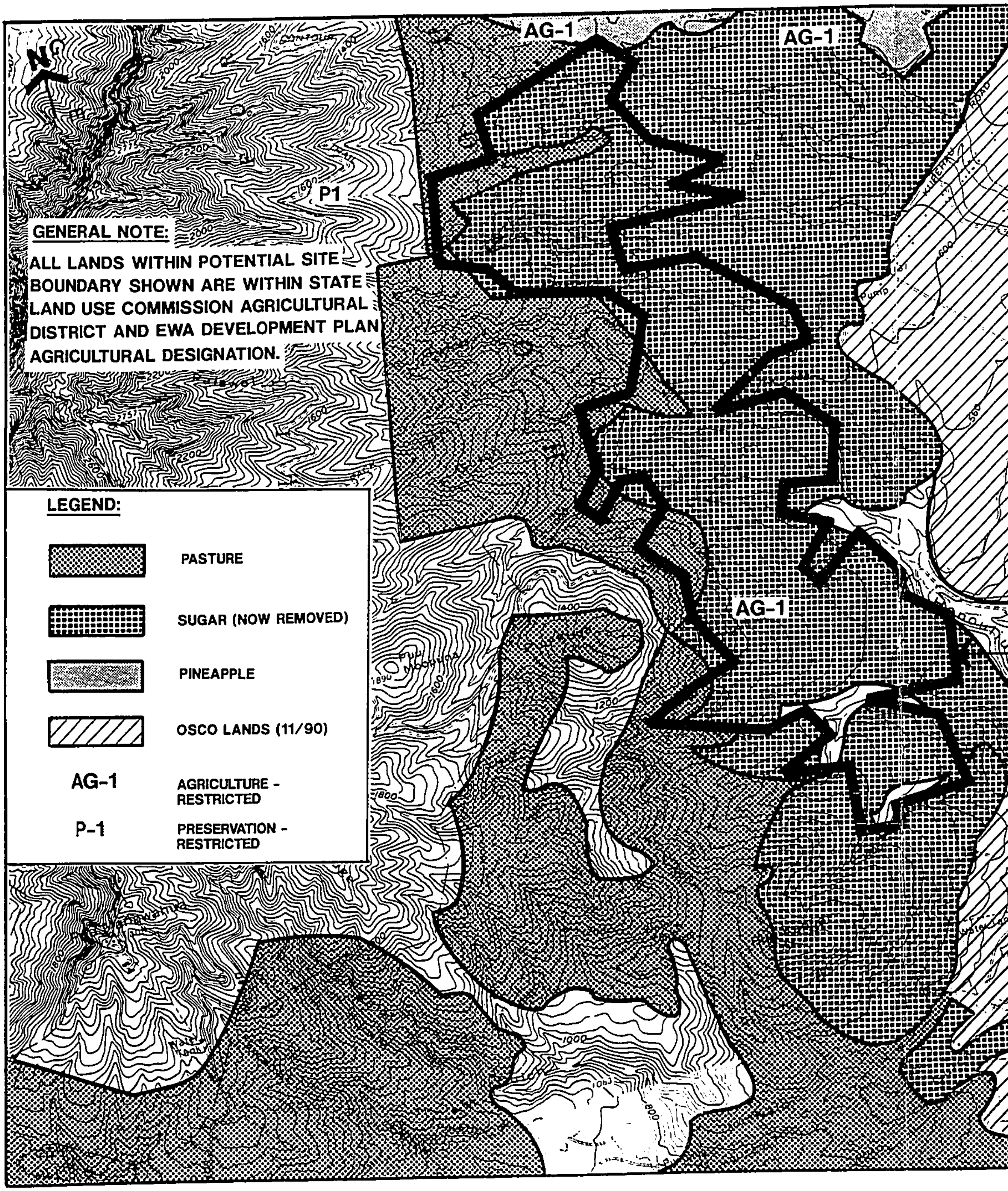
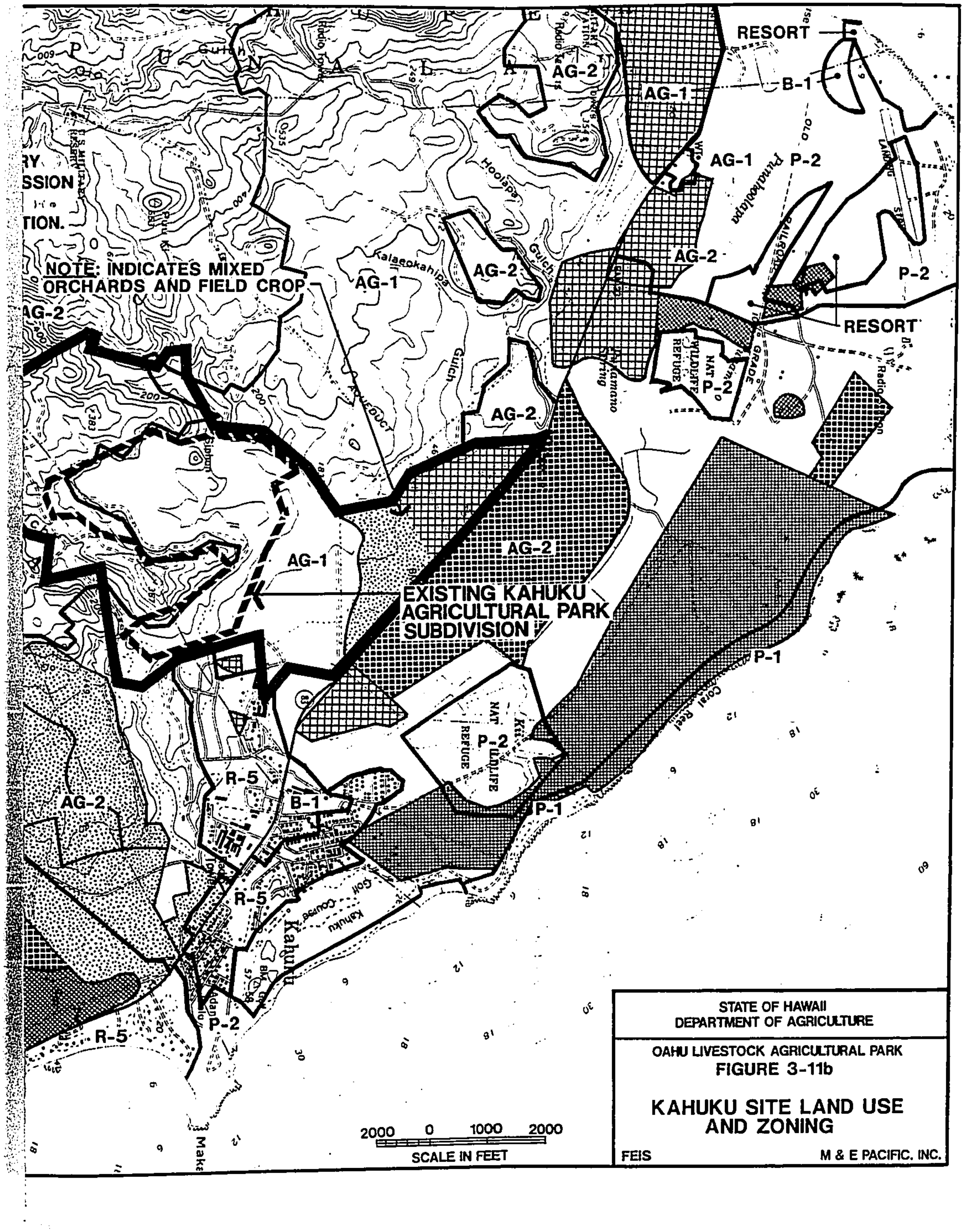


GENERAL NOTE:

ALL LANDS WITHIN POTENTIAL SITE BOUNDARY SHOWN ARE WITHIN STATE LAND USE COMMISSION AGRICULTURAL DISTRICT AND EWA DEVELOPMENT PLAN AGRICULTURAL DESIGNATION.

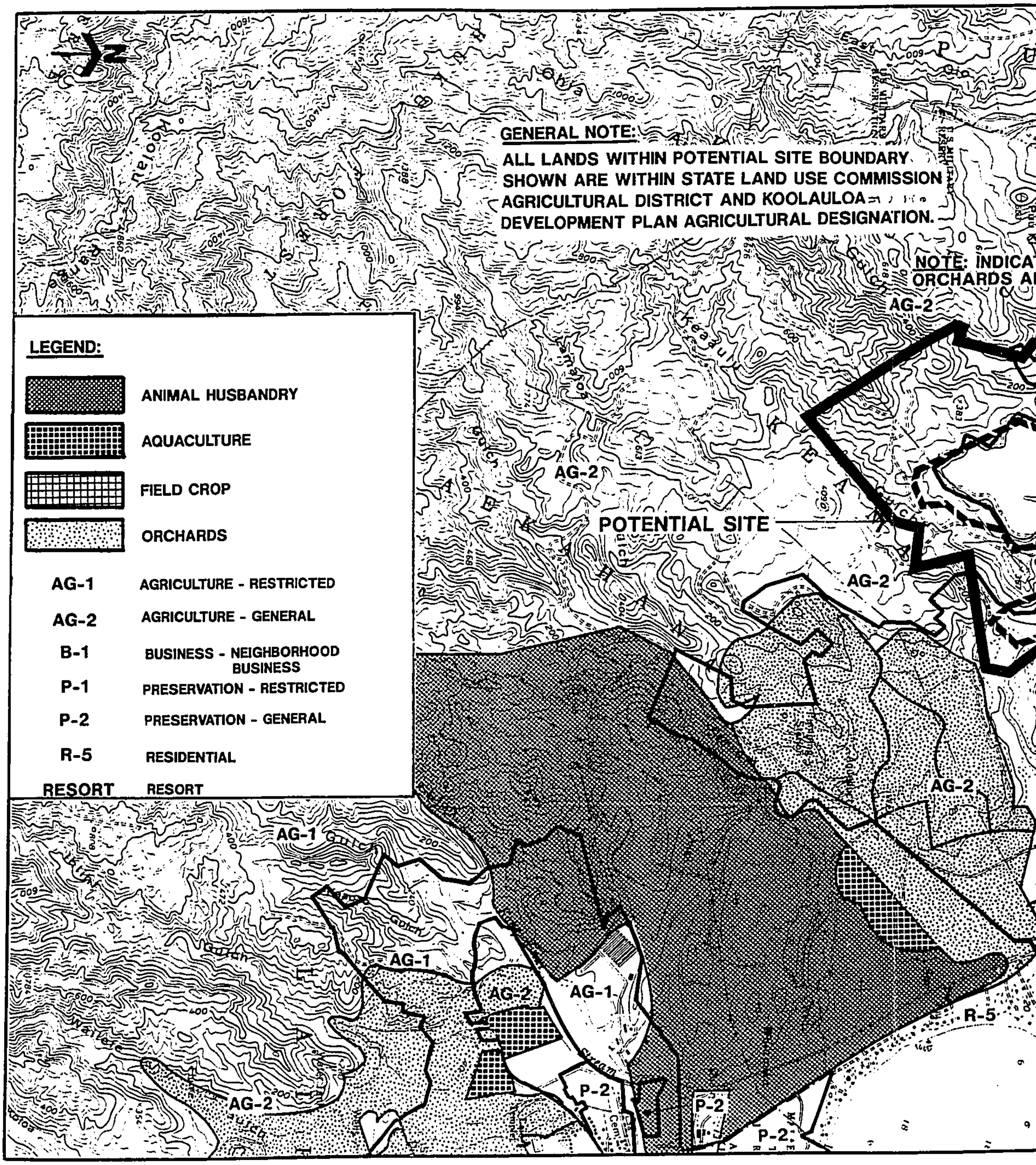


STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-11b

KAHUKU SITE LAND USE AND ZONING

FEIS M & E PACIFIC, INC.



GENERAL NOTE:

ALL LANDS WITHIN POTENTIAL SITE BOUNDARY SHOWN ARE WITHIN STATE LAND USE COMMISSION AGRICULTURAL DISTRICT AND KOOLAULOA DEVELOPMENT PLAN AGRICULTURAL DESIGNATION.

NOTE: INDICA
ORCHARDS A

LEGEND:

▓	ANIMAL HUSBANDRY
▦	AQUACULTURE
⊞	FIELD CROP
░	ORCHARDS
AG-1	AGRICULTURE - RESTRICTED
AG-2	AGRICULTURE - GENERAL
B-1	BUSINESS - NEIGHBORHOOD BUSINESS
P-1	PRESERVATION - RESTRICTED
P-2	PRESERVATION - GENERAL
R-5	RESIDENTIAL
RESORT	RESORT

the *mauka* direction, above the site, the land is within the Kahuku Forest Reserve. Permitted AG-1 uses are shown in the previous paragraph.

The permitted uses in AG-2 zones include the following:

Crop production
Farm dwellings
Game preserves
Livestock grazing
Livestock production, minor
Livestock veterinary services
Utility installations, Type A

Type A utility installations include the transmission lines and structures for water supply, gas, electricity, and telecommunications. It does not include private water supplies or waste treatment systems, but these may be permitted as an accessory use.

Permits and Approvals

The following permits and approvals are required at either potential site:

	Permit Approval	Agency
(1)	National Pollution Discharge Elimination System (NPDES)	State of Hawaii Department of Health
(2)	Grading Permit (Soil Erosion Control Plan)	City and County of Honolulu Department of Public Works
(3)	Best Management Practices (BMP) Plan	State of Hawaii Soil and Water Conservation District
(4)	Subdivision Plan	City and County of Honolulu Department of Land Utilization
(5)	Building Permit	City and County of Honolulu Department of Public Works
(6)	Individual Wastewater Treatment System	State of Hawaii Department of Health

(7)	Stream Alteration Permit	State of Hawaii Department of Land and Natural Resources
(8)	Dam Construction Permit	State of Hawaii Department of Land and Natural Resources

In addition, a wastewater reuse permit may be required from the State of Hawaii, Department of Health; a source use permit may be required for the use of well water from Pump Station No. 1 at the Kahuku Agricultural Park for potable water supply; and all wastewater plans, including handling of solids, must conform and pass review of the Department of Health under provisions of DOH Administrative Rules, Chapter 11-62, "Wastewater Systems." A covenant restricting livestock use of land leased from Campbell Estate at the Kahuku site will have to be rescinded by the City and County of Honolulu, Department of Land Utilization.

D. Land Use Suitability

The Department of Agriculture's *Agricultural Lands of Importance To The State of Hawaii (ALISH) System* classifies the lands on these potential sites as prime, unique, and other important agricultural lands (see Figures 3-12a and 3-12b).

Prime agricultural land is land best suited for the production of food, feed, forage, and fiber crops. The land has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops economically when treated and managed, including water management, according to modern farming methods.

Unique agricultural land is land other than prime agricultural land that is used for the production of specific high-value food crops. The land has the special combination of soil quality, growing season, temperature, humidity, sunlight, air drainage, elevation, aspect, moisture supply or other conditions, such as nearness to market, that favor the production of a specific crop of high quality and/or high yield when the land is treated and managed according to modern farming methods.

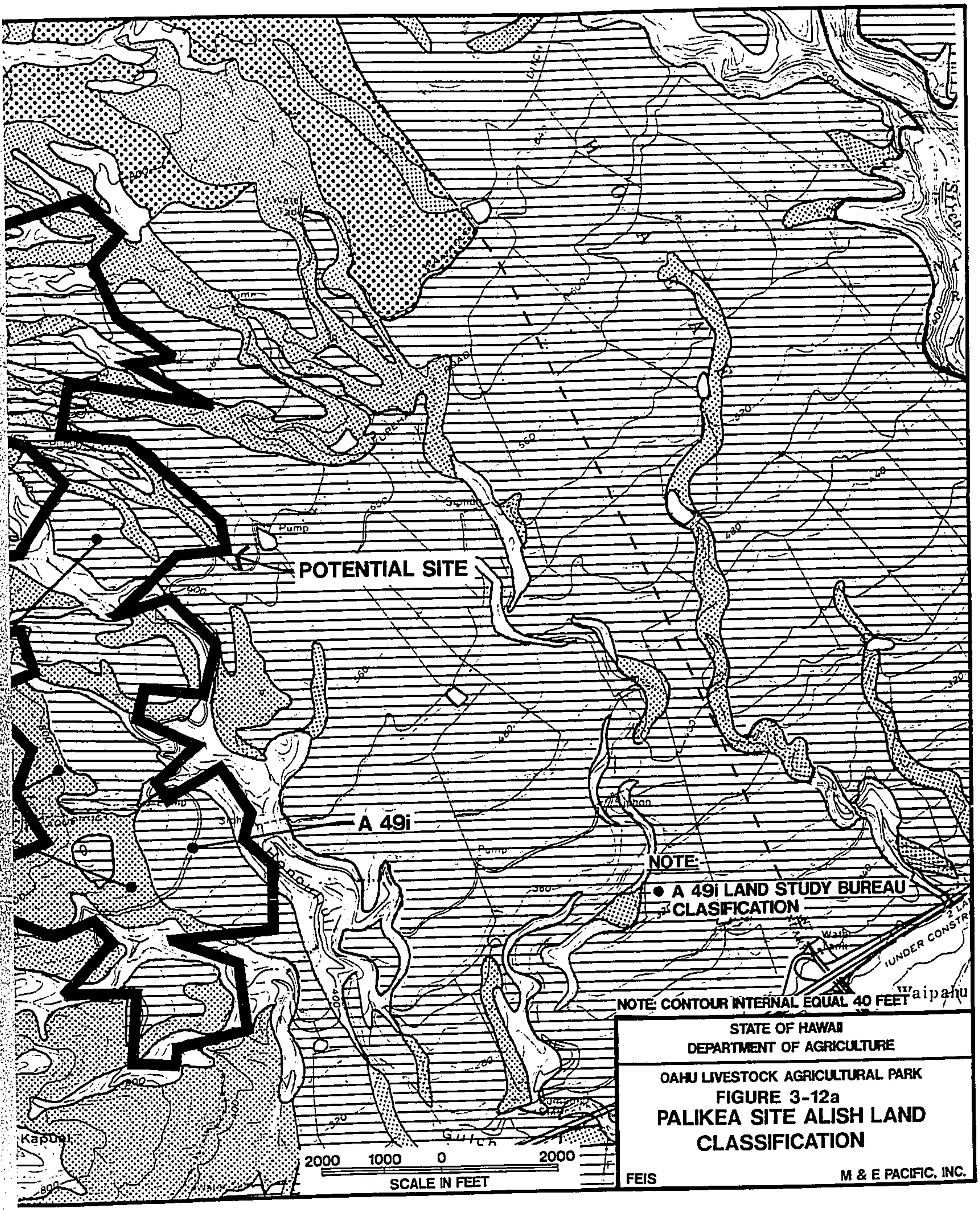
Other important agricultural land is land other than prime or unique agricultural land that is of statewide or local importance for the production of food, feed, fiber, and forage crops. The lands in this classification are important to agriculture in Hawai'i, yet they exhibit properties such as seasonal wetness, erodability, limited rooting zone, slope, flooding, or drought, that exclude them from the prime or unique agricultural land classifications. These lands can be farmed satisfactorily by applying greater inputs of fertilizer and other soil amendments, drainage improvement, erosion control practices, and flood protection, and can produce fair to good crop yields when managed properly.

The significance of the land use suitability mapping system is that it clearly identifies the value of the potential sites for agricultural uses. The majority of each potential site contains prime or unique agricultural land.

The older Land Study Bureau detailed land classification study (Land Study Bureau 1972) evaluated specific uses of agricultural lands, including forage crop and grazing use. This system classified soils into types on the basis of natural characteristics such as soil properties, surface relief, drainage, and climate; it also rates each in terms of overall productivity. Specific soil types are evaluated for selected crop productivity for pineapple, sugarcane, vegetables, forage, grazing, and timber. The specific crops are rated from "a" to "e"; their productivity being greatest for an "a" rating. For example, at the Kahuku site, a prevalent soil type near proposed livestock areas is the Waialua silty clay. It has a "c" rating for forage and grazing uses. This rating carries a pasture-carrying capacity of five to ten animal unit-years; this is without irrigation. The Lahaina silty clay at Kahuku has a "d" rating for grazing and a "c" to "d" rating for forage use.

At the Palikea site, a comparable soil is the Kunia silty clay. Depending on slope, the rating for forage production is "b" to "d"; for grazing use, the rating is "b".

The significance of the Land Study Bureau classification is that it correlates with permissible uses within State Land Use Agricultural Districts. Hawaii Revised Statutes, Chapter 205, Section 4.5, lists permissible uses for Agricultural District lands classified with overall productivity ratings of A or B, including the raising of livestock. Lands classified A and B are also subject to restrictive covenants upon subdivision. See Figures 3-12a and 3-12b for mapping of the detailed land classification for each site.

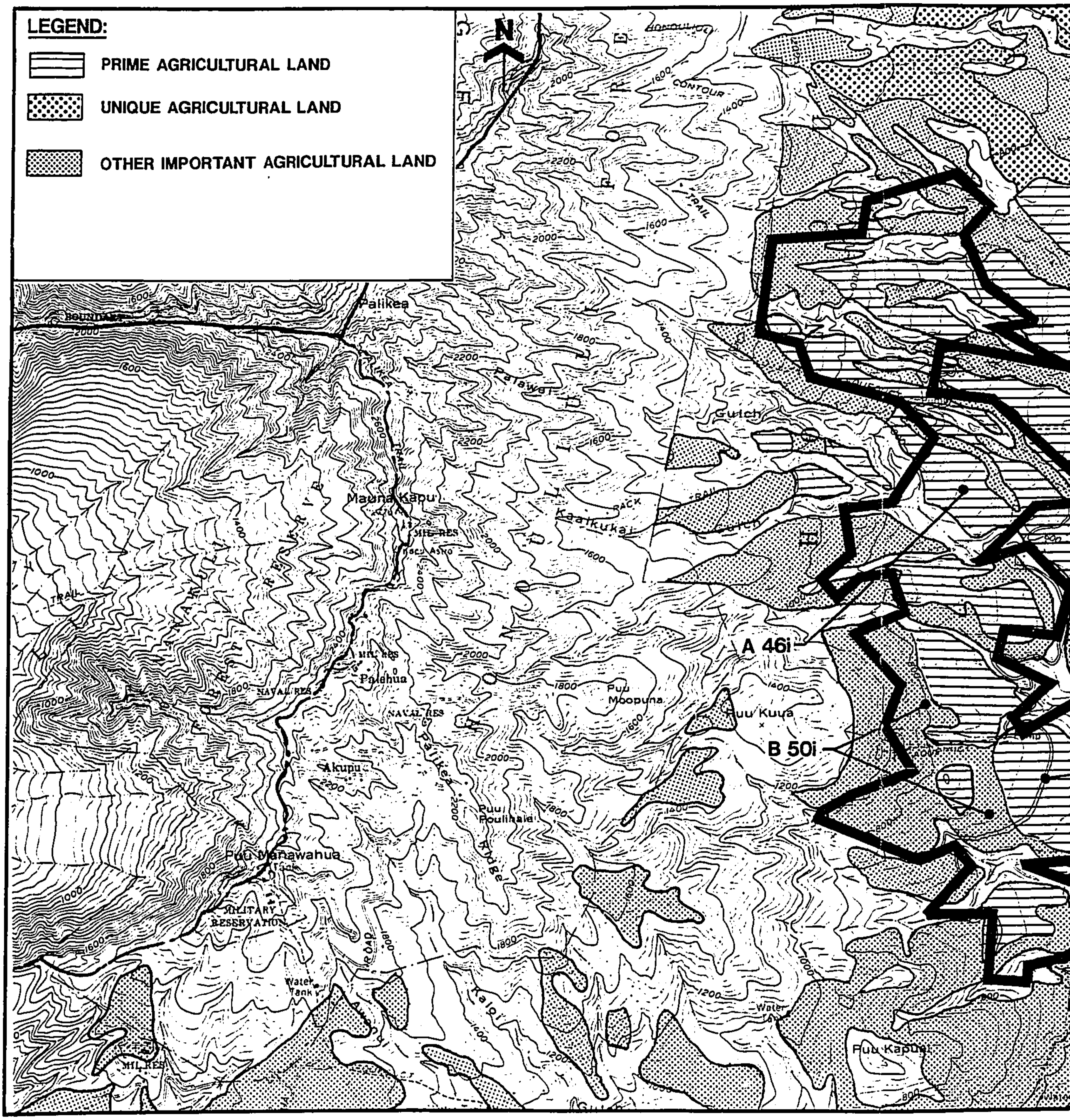


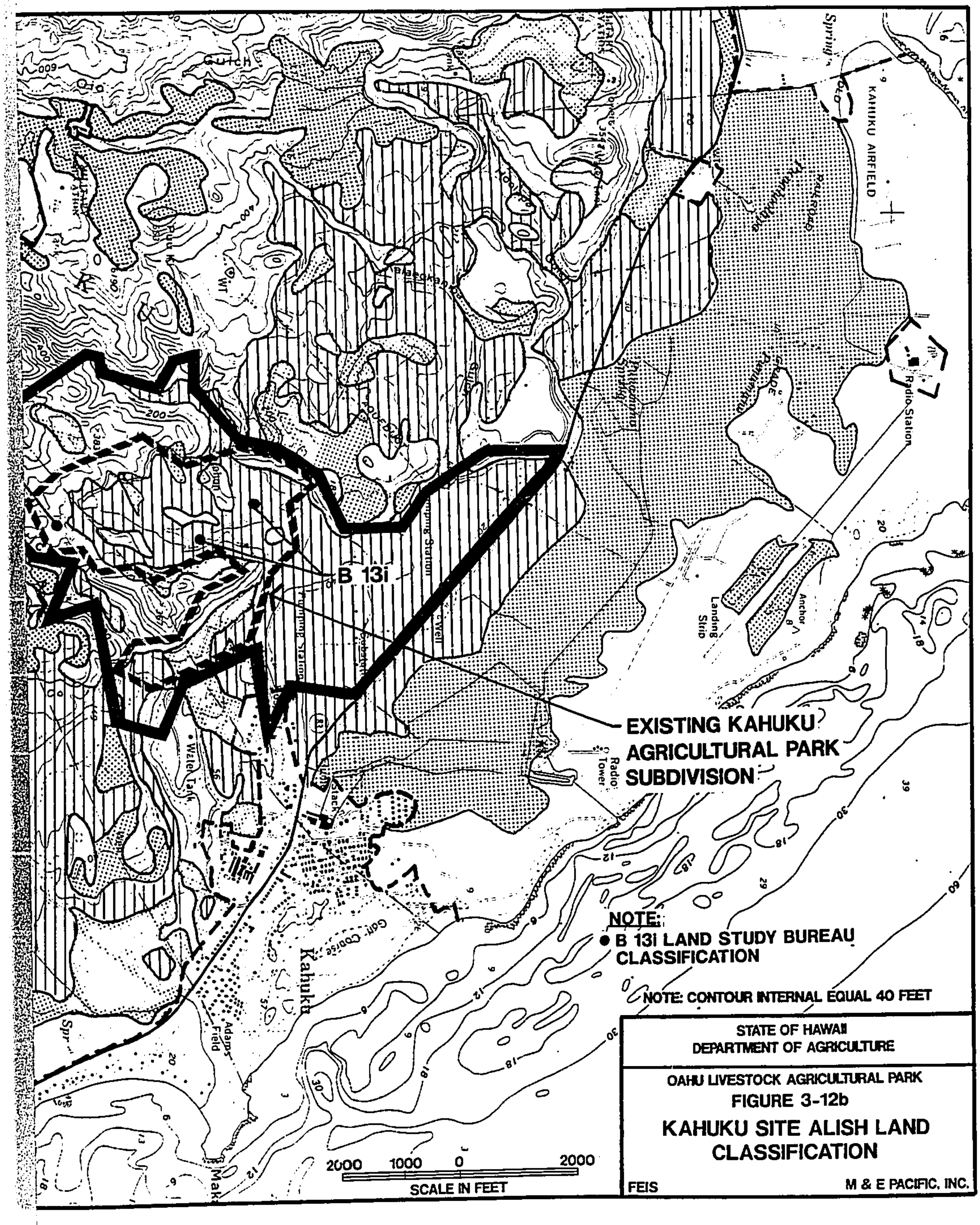
STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-12a
PALIKEA SITE ALISH LAND CLASSIFICATION

FEIS

M & E PACIFIC, INC.


LEGEND:
PRIME AGRICULTURAL LAND
UNIQUE AGRICULTURAL LAND
OTHER IMPORTANT AGRICULTURAL LAND
N
Palikea
BOUNDARY
Palawai
Gulch
Mauna Kapu
MIL RES
Kaaikukai
Gulch
A 46i
Palehua
NAVAL RES
Puu Moopuna
Puu Kuua
B 50i
Akupu
Palikea Ridge
Puu Poulihale
Puu Manawahua
Tank
MILITARY RESERVATION
Water Tank
ROAD
Kaloi
Water Tank
Puu Kapuai
MIL RES
TRAIL
CONTOUR
2200
2000
1800
1600
1400
1200
1000
800



EXISTING KAHUKU AGRICULTURAL PARK SUBDIVISION

NOTE:
● B 13i LAND STUDY BUREAU CLASSIFICATION

NOTE: CONTOUR INTERNAL EQUAL 40 FEET

2000 1000 0 2000
SCALE IN FEET

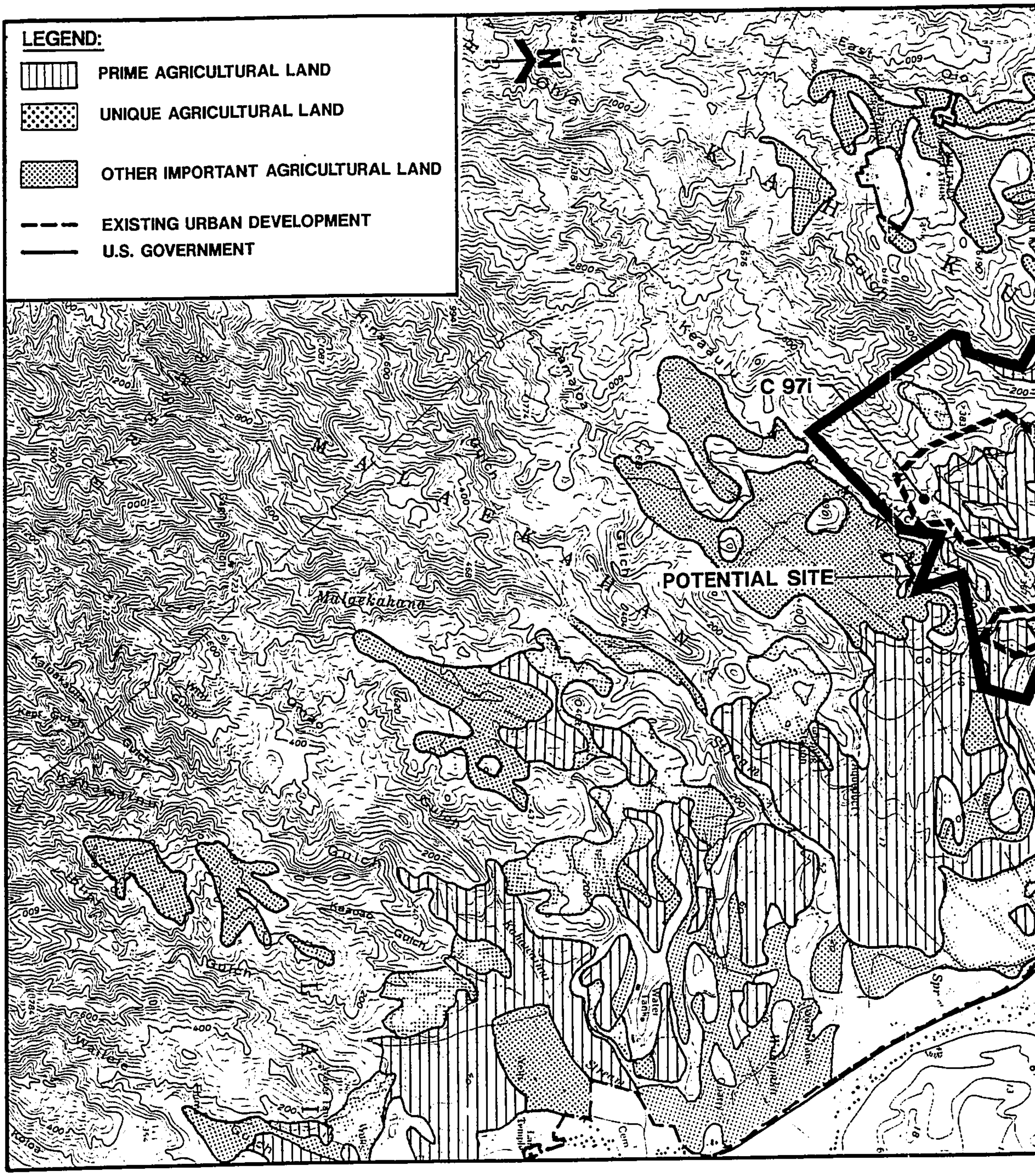
STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE 3-12b

KAHUKU SITE ALISH LAND CLASSIFICATION

FEIS

M & E PACIFIC, INC.


LEGEND:
PRIME AGRICULTURAL LAND
UNIQUE AGRICULTURAL LAND
OTHER IMPORTANT AGRICULTURAL LAND
EXISTING URBAN DEVELOPMENT
U.S. GOVERNMENT
N
C 97i
POTENTIAL SITE
Malaekahana
Keaau
Keaoae Gulch
Kaipapau
Waiele
East
Gulch
Cem

E. Population

Palikea Site. In 1980, this potential site was located in Census Tract No. 86.01. Many of the census tracts in the State were changed for the 1990 Census (see Figure 3-13). No. 86.01 was divided into Tracts 86.03 and 86.04, and the boundaries realigned. The 1990 census data are not all available at this time and it cannot be determined how the new tracts relate to Tract No. 86.01.

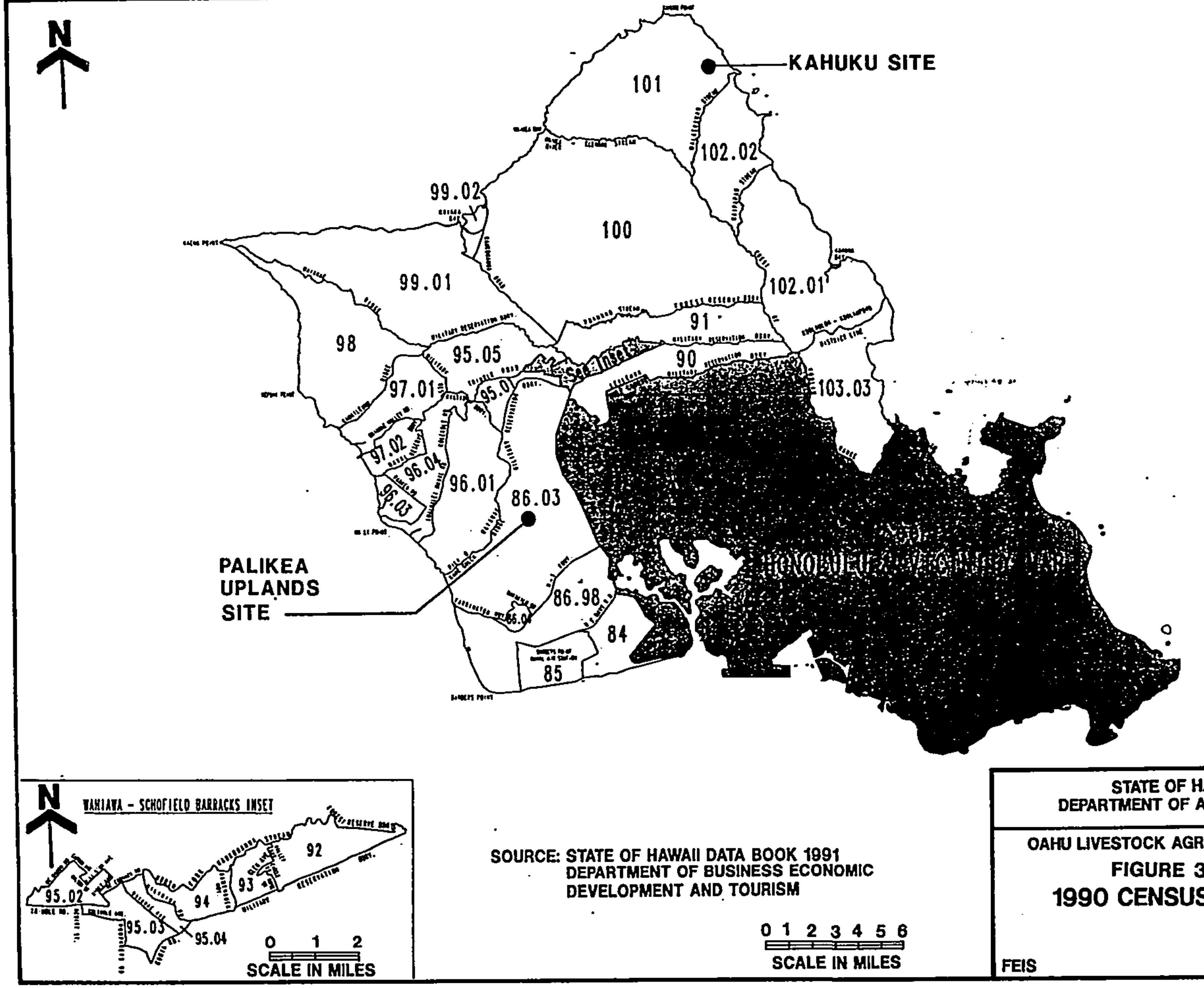
The 1990 population count for Tract No. 86.03 is 6,509; the housing unit count is 2,174. The average number of persons per housing unit is 2.99. For comparison, Tract No. 86.04, which is located adjacent to and south of Tract 86.03, has a population count of 4,015; the housing unit count is 1,042. The average number of persons per housing unit is 3.85.

The 1980 population count for Census Tract No. 86.01 was 8,559; the housing unit count was 2,340 (1,848 owner-occupied and 492 renter-occupied). The average number of persons per housing unit was 3.66.

The population density was 0.4 persons per acre. In comparison, other census tracts have higher densities; for example, the average population density on O'ahu is approximately 2.3 persons per acre. The significance to the environmental impact statement is that the low density indicates the rural nature of the area near the potential site. However, urban development is approximately one mile from the boundary of the site.

Kahuku Agricultural Park Site. The potential site is located in Census Tract No. 101 (see Figure 3-13). The 1990 population count for Tract No. 101 is 6,909; the housing unit count is 2,596. The average number of persons per housing unit is 2.66.

The population density is 0.4 persons per acre, similar to the Palikea site census tract and in comparison to other tracts on O'ahu, has lower population densities. For example, the average population density on O'ahu is approximately 2.3 persons per acre. The significance to the environmental impact statement is that the low density indicates the rural nature of the area near the potential site. The urban area is approximately one-half mile from the livestock area of the agricultural park.



SOURCE: STATE OF HAWAII DATA BOOK 1991
DEPARTMENT OF BUSINESS ECONOMIC
DEVELOPMENT AND TOURISM

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 3-13

1990 CENSUS TRACTS

FEIS M & E PACIFIC, INC.

F. Employment

Palikea Site. In 1979 the median household income was $25,322 for Census Tract 86.01, or $38,262 in 1989 dollars, based on an adjustment using the Honolulu CPI [Consumer Price Index] for all urban consumers. The median household income for O'ahu in 1979 was $21,077. Thus, the median income for Census Tract 86.01 was 20 percent higher than the islandwide median income.

Of person 16 years and over, 11.4 percent were unemployed in 1979; the islandwide rate was 6.7 percent. The percentage of families below the poverty level was 3.1 compared to the islandwide percent of 7.5. Thus, unemployment in this area may be slightly higher than for O'ahu as a whole, although income levels, on average, are higher. This data is not yet available from the 1990 census.

Kahuku Agricultural Park Site. In 1979 the median household income was $19,651 for Census Tract 101. The median household income for O'ahu in 1979 was $21,072. Thus, the median income for Census Tract 101 was lower than the islandwide median income.

G. Housing

Palikea Site. The number of households increased in the Palikea site area from 1980 to 1990 by 28 percent from 3,480 to 4,449. The household ratio (population divided by number of households) decreased from 3.8 to 3.6.

1980				*1990*			
Census Tracts	Pop.	Hseholds	No. per hsehold	Census Tracts	Pop.	Hseholds	No. per hsehold
86.01	8,559	2,337	3.6	86.03	6,509	2,086	3.1
86.02	4,653	1,143	4.1	86.04	4,015	1,026	3.9
—	—	—	—	86.98	5,521	1,337	4.1

Kahuku Agricultural Park Site. The number of households increased in the Kahuku site area from 1980 to 1990 by 42 percent from 1,496 to 2,127. The household ratio increased from 2.9 to 3.2.

1980				1990			
Census Tract	Pop.	Hseholds	No. per hsehold	Census Tract	Pop.	Hseholds	No. per hsehold
101	4,491	1,496	2.9	101	6,909	2,127	3.2

Discussion. Both potential sites are in traditionally agricultural-oriented communities. But the Palikea site is in an area rapidly changing from rural to suburban. Bedroom communities such as Village Park and Makakilo are approximately one and one-half, and one mile away, respectively, from the potential site boundaries. The density, number of households and household ratio are indicators of the present rural environment. Palikea has a greater number of households and household ratio than the Kahuku area.

The significance to the environmental impact statement is that the intended use of the land associated with the proposed project is consistent with the agricultural traditions in these communities. The number of households that are anticipated with the livestock agricultural park project, fewer than one percent of the 1990 households, will not significantly add to the housing stock in the area. Neither, however, will the increase in employment in the area place a significant burden on existing housing resources.

H. Infrastructure and Public Services

Palikea Site

Transportation

The potential site is located approximately 20 miles from Middle Street (near the Foremost Milk plant) by way of H-1. The nearest major intersection to the site is located at the juncture of H-1 and Kunia Road. The site is accessed via Kunia Road. The level of service (LOS) on H-1 from the Makakilo Interchange to the Kunia Road Interchange is B. Level of service is a measure indicating how well traffic flows on the streets and highways. Level B represents reasonably free-flow conditions, with the ability to maneuver within the traffic stream only slightly restricted. With increased residential development of Central and 'Ewa, O'ahu, LOS on this stretch of H-1 could deteriorate to LOS F. LOS F describes the condition where demand exceeds capacity, with queues forming behind stress points. Level of service on Kunia Road is D at peak morning and afternoon periods. This level is considered the minimum acceptable.

One access to the site is proposed via Kupehau Road, a cane haul road *makai* of the intersection of Kunia Road and Waiāhole Ditch. This road is shown on Figure 3-1a. There could be approximately 40 additional round trip visits per day entering the site within the proposed project. Appendix K discusses the findings of the traffic assessment study. The conclusion is that the effect of the project is insignificant in terms of changes to levels of service.

Solid Waste

Solid waste in Central and 'Ewa, O'ahu, is hauled either to H-Power at Campbell Industrial park or Waimānalo Gulch Landfill. Both are easily accessible to the potential site.

Police

The project area is serviced by District 3, Pearl City Station. The police facilities are considered adequate. As urban development in the area increases, the level of service will depend on budget increases for additional manpower an equipment.

Fire

The project site is served by Makakilo Station, with secondary protection provided by Waipahu and Wahiawā Stations. Response time from the Makakilo and Waipahu Stations is about 5 minutes; from the Wahiawā Station, about 8 minutes. Fire protection facilities are considered to be adequate.

Medical Care

Saint Francis Medical Center—West, located in 'Ewa Beach, is a full-service medical center, providing 24-hour emergency service. The Center is located approximately 5 miles from the proposed site.

Water Supply

Water sources in the area include the Board of Water Supply Kunia I and II well groups and the Honouliuli Wells in the area. Water supply in the area is very critical and assurance of the provision of public service can be provided only at the time the request is made for a hookup. Connection to the existing source/distribution system is at best, an alternative.

Another alternative is a private potable supply system. Two sources are ground water and surface supply (Waiāhole Ditch). Ground water development potential for the Kunia sector is currently being reviewed by the State Department of Land and Natural Resources; this option is considered doubtful, at best, due to source limitations. By virtue of conditions in the water leases granted to the Waiāhole Ditch Company for water extracted beneath State land, a significant proportion of the flow conveyed by the ditch system may be available for the State's use at Kunia Road. There are uncertainties relative to the amount of water reserved for State use, compensation for the water conveyance, the mode of transmission to the *potential project site, and the effect withdrawal may have upon Oahu Sugar* Company operations; but the possibility exists that surface water source may be an option, for the project at this site. Waiāhole Ditch transfers an estimated 28 million gallons per day (mgd) at the South portal of the Waiāhole Tunnel (George A.L. Yuen and Associates 1990). However, for dairy use, only a small portion of surface water will require treatment including filtration and disinfection.

The estimated water demand within the fully developed agricultural park is approximately 1.1 million gallons (MG) on an average day; peak demand is estimated at 1.6 mgd.

The conclusion is that potential water demand can be expected to be of a magnitude considerably less than the total Waiāhole Ditch capacity. If the water is to be withdrawn from Waiāhole Ditch, the plan must include consideration of long-term maintenance and operation of the supply and mitigation of effects on other agricultural operations. Water treatment for domestic purpose is also a consideration as an alternative.

Sanitary Domestic Sewage

The closest sanitary sewage service to the site is located at Village Park. Waste flows by gravity to the Kunia Pump station from where domestic sewage is pumped to the Honouliuli Wastewater Treatment Plant. An upgrade for the Kunia pump station had been proposed as part of the approval condition for the Royal Kunia Golf Course project; however, planning has not been completed.

Another alternative is on-site treatment. On-site treatment of less than 800 gallons per day is technically feasible using individual waste treatment systems.

Electrical and Telecommunication Service

The project could be serviced by Hawaiian Electric Company from their 12 kv overhead lines near the intersection of Waiāhole Ditch and Kunia Road. According to HECO, a new 12 kv transmission line would need to be built, approximately parallel to Kupehau Road, along with a new substation to service this project. From this substation, secondary distribution could be achieved by transmission lines in a generally north-south direction. Service to individual operators could be taken off this line. Telephone communication lines would follow the electrical distribution system. No problem is expected in providing these services.

Kahuku Agricultural Park Site

Transportation

The potential site is located approximately 40 miles from Middle Street (near the Foremost Milk plant) by way of H-1 and H-2. The alternative by way of Likelike and Kamehameha Highways is 32 miles. Entry to the Kahuku Agricultural Park is presently from Kamehameha Highway onto a paved private service road.

The present point of access may be unsatisfactory for reaching the *mauka* portions of the site, additional engineering studies may recommend an alternative.

Estimated maximum vehicle frequency at the Kahuku site is 40 daily trips. This includes the existing Kahuku farmers, new diversified agricultural lessees, and the dairy operations. The number of visitation is expected to be less than originally planned for the Kahuku Agricultural Park because the number of individual lots is significantly reduced to accommodate dairy sizes. Less than five percent of the daily trips are expected to be semi-trailer units. Appendix K discusses the findings of the traffic assessment study. The conclusion is that the effect of the project is insignificant in terms of changes to levels of service.

Solid Waste

At the present, due to lease conditions, the Department of Agriculture contracts for private refuse collection at the Kahuku Agricultural Park.

Police

The project area is serviced by District 4, Kahuku Substation. The Kahuku Substation is adjacent to the fire station on Kamehameha Highway in Kahuku. While no complaints have been forwarded to the Kahuku Substation, people use the site area to "hang around" during the day and night, and as a dumping ground for junked autos. A security gate has been erected to deter illegal dumping and vandalism.

Fire

The project area is served by the Kahuku Station, with secondary protection provided by the Hau'ula Station. Response time from the Kahuku Station is about four minutes; from the Hau'ula Station, about 10 minutes. Fire protection facilities are considered to be adequate. One truck at this station which holds 500 gallons of water can reach the gate to the existing Kahuku Agricultural Park within three to four minutes. Depending upon the type of alarm (for example, a burning structure) the Hau'ula Station can also be summoned with another truck as well as a tanker which holds 2,500 gallons. In the case of a brushfire, the Kahuku Station will determine if other reinforcements need to be called.

A locked gate will not deter fire-fighting efforts. A gate key may be provided to the fire station for such emergencies. Other procedures for emergency can be established. Water supply for fire protection will be included in the design of facilities for the project.

Medical Care

Kahuku Hospital--located in Kahuku, is a full service medical center, providing 24-hour emergency service. The hospital is located approximately 0.5 miles from the entrance to the potential site.

Water Supply

Potable water sources in the area include the Board of Water Supply Kahuku Wells I and II group (Wells No. 4057-15,16) and the Pump Station No. 1 facility (including Wells No. 4057-01,02,08) which is presently providing irrigation water for the agricultural park and to the Kahuku Farmers Association in the area. The provision of public service (i.e., Board of Water Supply connection) can be provided only at the time the request is made for a hookup. The Board of Water Supply has indicated that its present system capacity is limited and provision of potable water to the livestock park is unlikely. One option is to cost share the development of additional water wells on the *mauka* portions of the livestock agricultural park. Connection to a private existing source/distribution system is an alternative. Another option is to use the existing agricultural park source (Pump Station No. 1 facility) which served Kahuku until the Board of Water Supply wells were developed. Analysis of water from this source in the Kahuku Agricultural Park EIS (1984) indicated satisfactory quality.

The estimated average daily water demand within the fully-developed agricultural park is approximately 1.1 million gallons (see the discussion of Palikea site water supply). For planning purposes, a maximum day peak demand of 1.6 mgd is also assumed at the Kahuku site.

Sanitary Domestic Sewage

The closest sanitary sewage service to the site is located at Kamehameha Highway in Kahuku. Waste flows by gravity to the Kahuku Wastewater Treatment Facility from where effluent is pumped into underground injection wells near the sugar mill. An upgrade for the Kahuku Wastewater Treatment Facility has been under construction which will increase the capacity to 0.8 mgd. The average design flow for the projected 2010 population is 0.207 mgd. The 1987-1988 average flow was 0.07 mgd. Connection to this system for the purposes of domestic sewage treatment is one alternative.

Another alternative is on-site treatment. On-site treatment of less than 800 gallons per day is technically feasible using individual waste treatment systems.

Electrical and Telecommunication Service

Provisions for future electric and telephone service to the Kahuku site could be accomplished through connection and extension of the existing primary transmission lines along Kamehameha Highway. The new electric service will be routed overhead along the existing access road to the project site. It is most likely that Hawaiian Electric Company would propose to build a new substation in proximity of the project. From this substation secondary service will be provided to individual livestock operators.

Hawaiian Electric Co. and Hawaiian Telephone will jointly share service poles. Service to the site is expected to be approved by these utilities.

SECTION FOUR — IDENTIFICATION AND SUMMARY OF IMPACTS

I. Alternatives Considered

Summary of Subsection I. The alternatives considered include no action; other sites, including the neighbor islands; and enlarging existing operations. No action means the dairy industry must compete for land with urban development. As existing operations lose their land leases and their herds are consolidated with other operations, the remaining dairies will still be plagued by overcrowding, stagnation relative to productivity, and increasing urban pressure. This detracts from their ability to compete and provide a reliable supply of fresh milk for the Honolulu market. A study of 18 alternative sites on O'ahu was made to screen potential sites, two of which were then studied in greater detail. The conclusion is that a site is feasible on O'ahu. For economic, social, and logistical reasons, the dairy industry, if it is to remain viable, should remain on O'ahu into the next century and cannot be relocated to a neighbor island. The existing operations are unable to expand because of high land costs, difficulty in operating while building new facilities, adjacent land use pressures, and in some cases outright loss of land leases to other uses.

A. No Action Alternative

If this alternative is adopted, Hawai'i will act as a bystander to the events which are shaping diversified agriculture in the State, and particularly on O'ahu. No action implies no acquisition or preservation in perpetuity of land that can accommodate, and has the potential for, livestock agricultural uses. The scenario of events, of which there are several possible outcomes without government incentive to continue the dairy industry, is difficult to predict with any degree of certainty. However, the trends in this industry in recent years provide some insight into a future without action to offset the institutional constraints affecting the industry.

Without action to provide land dedicated to diversified agricultural use, the competitive economic situation for the dairy industry becomes worse, in terms of continuing operations on urban-oriented O'ahu. These trends may be expected to continue:

1) Consolidation of enterprises into fewer but larger operations as smaller operators lose leases, sell their herds to other operators and cease their business operations;
2) The fewer dairies operate at lower productivity levels due to crowded conditions and less than optimum climatic locations;
3) Limited waste management facilities, vector control problems, and odor complaints curtail remaining dairy operations making it difficult for them to operate and impossible for new ones to start;
4) The industry as a whole, including suppliers, distributors, and support sectors, becomes more vulnerable to changes in price levels and the loss of one or two major operations; catastrophic results can be the result of just one major link in the industry terminating.

Without action, the most probable future is that the industry will be unable to attract the capital necessary to develop an agricultural site reserved for operators facing the loss of their leases; cessation of business will occur for this and other reasons discussed in the previous economic description.

B. Alternative Sites

There are several important factors to consider relative to siting an agricultural park emphasizing dairy and other livestock. Without these advantages, the productivity of the potential operators will suffer and the gain to the State's consumers from government assistance will be reduced. These factors may be categorized as climate, existing and planned land use, and location (relative to potential impact on drinking water sources and odors). Considering all of these factors, a perfect location is difficult to identify.

Climate

Dairy operators prefer dry areas because high rainfall results in muddy ground conditions. Muddy environments, which are excellent breeding grounds for bacteria, increase the incidence of mastitis, an infection which affects the cow's udder. For the same reason, good soil drainage is important.

The average body temperature of a cow is 104 degrees F. The cow's rumen consists of fermentation chambers for the feed grain and forage consumed, and as such it produces a quantity of body heat. Cows have small sweat glands for cooling and thus desire cooler locations for greater comfort. Hot climates induce heat stress, which results in lower conception rates and a drop of as much as 25 percent in milk production. Poor reproduction rates mean the cow must be fed for longer (non-milk producing) periods before she begins lactating. These conditions adversely impact the cost of milk.

Favorable site conditions include unobstructed wind movement across the site to help reduce daily temperature extremes, relatively level or moderately sloping land so that cows expend less energy climbing grades, and a relatively dry climate.

Land Use and Location

The mandate of the Department of Agriculture is to promote agriculture. This extends to many forms of agriculture, including the major traditional crops such as sugarcane and pineapple which have been important sectors, historically, of the Hawai'i economy. Thus it would not be rational to purchase land with the intention of taking it from one form of agriculture to put it into another form. For this reason, an important criteria for evaluating alternative sites is the extent that the existing land that is already in intensive agricultural use can be avoided.

Land use adjacent to the site should be compatible with livestock agricultural use. Examples include other agricultural activities such as pineapple cultivation or vegetable production, conservation lands, and relatively passive open space uses such as nature preserves or low intensity forms of recreation (e.g., hiking). Open space provides room for possible expansion and reduces the chances of complaints due to odors and insects.

Buffer zones should be available on the site. Buffer zones can be used for grazing, growing feed for livestock, or other agricultural activities. Open space also helps reduce animal stress due to overcrowding and provides opportunities to build new facilities (or provide temporary space while existing ones are enlarged).

In Hawai'i, consumers in the Honolulu area use the largest quantities of milk. Milk, being highly perishable, is best preserved when the shortest possible time for transport between the dairy and the processing plant is achieved. In addition, extended transport time between the plant and dairies increases the cost of milk by limiting shelf life.

Another aspect of location is the surface and ground water resource considerations. Ground water in particular, is the major source of domestic drinking water supply on O'ahu. Other sections in this environmental impact statement describe the health considerations. However, one criterion considered for identifying a site is whether the site is "above or below" the Underground Injection Control (UIC) line on O'ahu. This line is used to regulate the disposal of waste water into ground water aquifers, and as such determines areas where special protection of the ground water quality is desired.

In summary, the criteria for preliminary screening of the sites can be enumerated as follows:

(1) agricultural land not in existing cultivation;
(2) land whose climate and relief are suitable for grazing and livestock facilities;
(3) land whose location provides some buffer between urban uses;
(4) land which is below the UIC line or separated from existing wells; and
(5) land which is accessible and allows transportation of the products to milk processors.

These criteria are not mutually consistent. For example, land whose climate is cool and dry is most likely found on leeward slopes of mountain ranges on O'ahu. On the other hand, the UIC line follows the circumferential highways, for example in the 'Ewa area, the UIC is *makai* of Farrington Highway, and in Kahuku it is *makai* of Kamehameha Highway. A site would, practically speaking, have to be very close to the ocean to be below the UIC line. Contamination of marine waters from surface runoff and potential adverse affects upon recreation uses is an issue this close to the ocean. An additional inconsistency is that the dry, warm lands close to the ocean are favored for urban and resort development; these are incompatible with livestock agricultural use. Thus there are some inevitable trade-offs in screening potential sites.

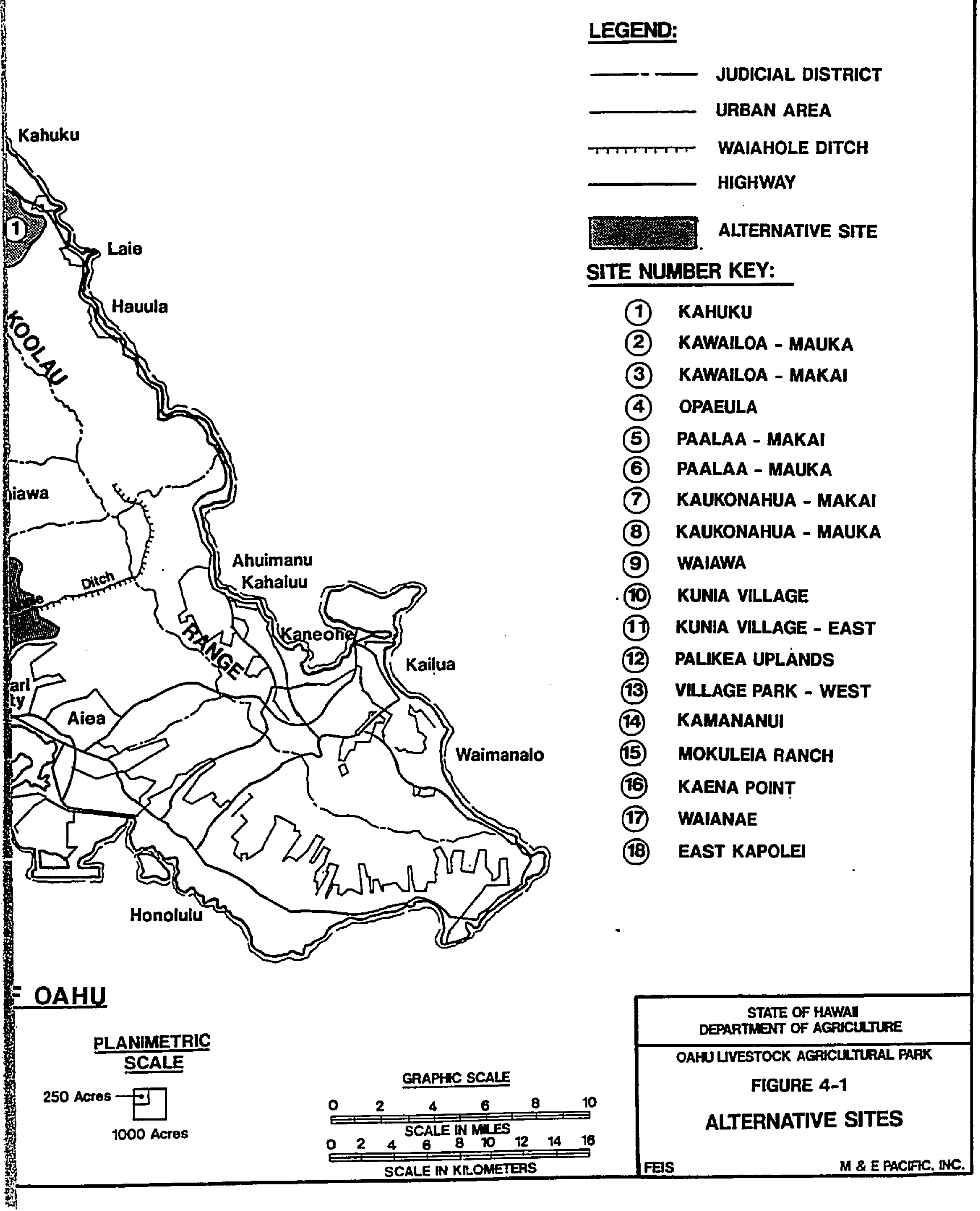
An evaluation of 18 potential sites on O'ahu (shown in Figure 4-1) capable of supporting a broad range of agricultural operations, including dairies, was made by the Department of Agriculture. Tables 4.1a and 4.1b summarize the disadvantages and advantages of each. It should be noted on Table 4.1a that only one site was identified totally below the (UIC) line. The only location on O'ahu with area below the UIC line with sufficient acreage is the East Kapolei site between H-1 Freeway and 'Ewa Village. This site is, however, being acquired by the State for housing development.

A further review of the UIC maps shows many sites in proximity to drinking water sources. Five sites had no water supply wells in close proximity; however, the potential exists that with the ever increasing demand for water on O'ahu, even the most remote areas will be sought after for water development. In fact, exploratory wells have been proposed by the Board of Water Supply near some of these sites. Thus it is impossible to not be in proximity to an existing well; what has to be determined is whether there may be any significant health effects due to proximity to the site, and what monitoring measures are adequate to verify the risk assessment.

Table 4.1b compares advantages of the sites. If all of the sites which have existing agricultural operations, planned urban development, or nearby encroachment are eliminated, four sites remain: Kahuku, Mokulē'ia Ranch, Ka'ena Point, and Palikea. However, incompatible airfield activity and temperature will make the Mokulē'ia site uncomfortable for dairy cows, and Ka'ena Point is protected to preserve natural ecological values (Ka'ena Point Natural Area Reserve).

Two sites were selected for in-depth study that (1) are not on land actively cultivated (e.g., are fallowed sugarcane land), (2) did not have drinking water sources on the site (although in proximity of them), (3) have elevations that permitted maximum milk production potential (cooler climates), and (4) were reasonably distant from existing urban encroachment. These are the Palikea and Kahuku sites. (An in-depth discussion of these alternative sites is presented in the remainder of this environmental impact statement.)

The detailed comparison of these two sites indicated they are preferred as the project site for the following reasons:



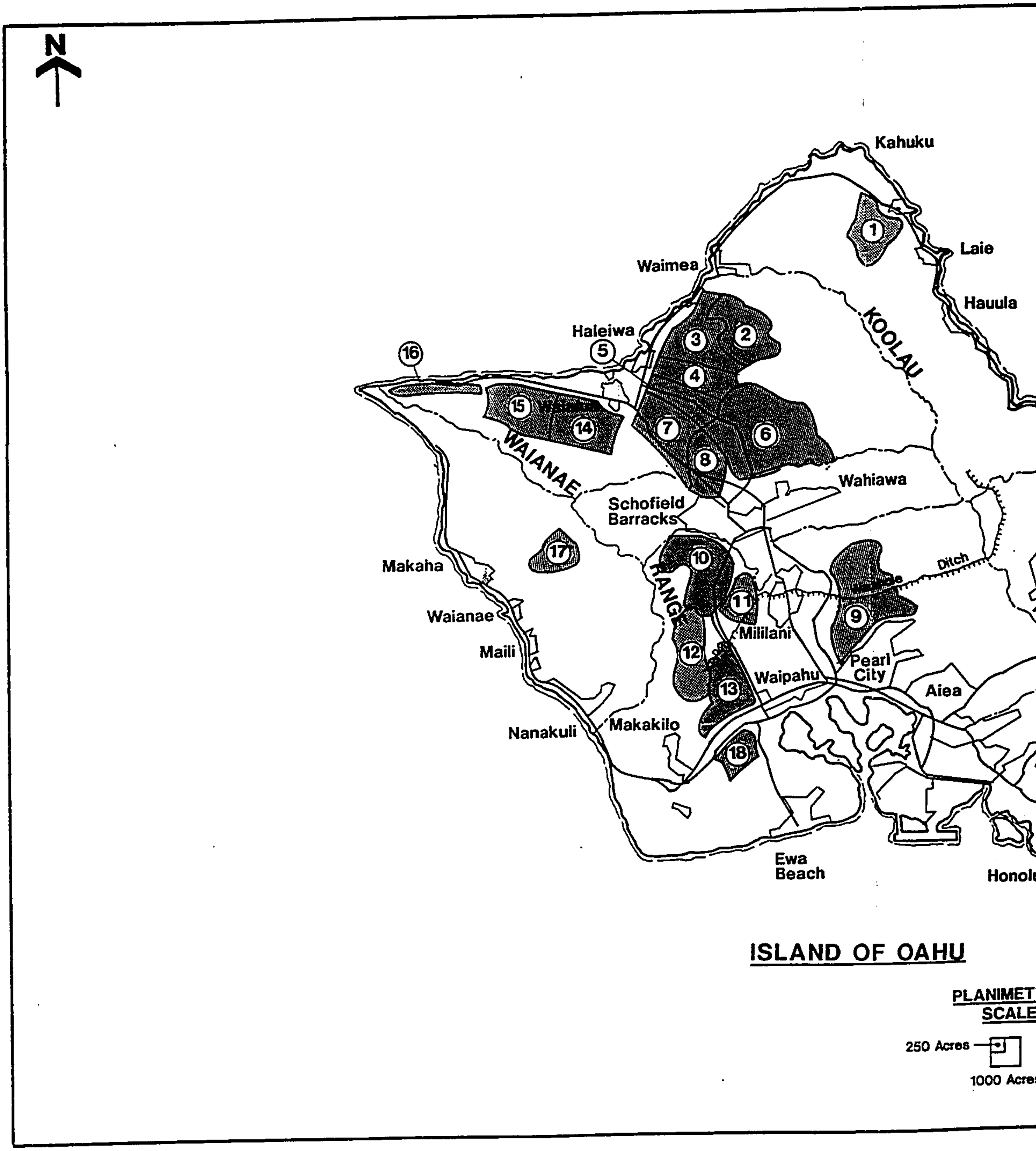
STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 4-1

ALTERNATIVE SITES

FEIS M & E PACIFIC, INC.



ISLAND OF OAHU

TABLE 4.1a – DISADVANTAGES OF ALTERNATIVE OAHU SITES CONSIDERED

	Sites	Above UIC	Existing Nearby Well	Disadvantages
1.	Kahuku	Yes	Yes	Military leases, dissected by gulches, higher temperature,higher rainfall, distance to milk processing plant
2.	Kawailoa-Mauka	Yes	No	Prime agricultural land in cultivation, dissected by gulches, poor road access, distance to milk processing plant
3.	Kawailoa-Makai	Yes	Yes	Prime agricultural land in cultivation, higher temperature, Kawailoa Camp nearby
4.	Opaeula	Yes	Yes	Many kuleana parcels along Anahulu Stream, prime agricultural land in cultivation, gulches dissect site, higher temperature
5.	Paalaa-Makai	Yes	Yes	Prime agricultural land in cultivation, higher temperature
6.	Paalaa-Mauka	Yes	Yes	Prime agricultural land in cultivation, military antennae
7.	Kaukonahua-Makai	Yes	No	Prime agricultural land in cultivation, Poamoho Stream occupies middle off-site, water supply undeveloped
8.	Kaukonahua-Mauka	Yes	No	Prime agricultural land in cultivation, Poamoho Stream occupies middle off-site, water supply undeveloped
9.	Walawa	Yes	Yes	Planned urban encroachment (Walawa Gentry), U.S. Navy Walawa Shaft downgradient, higher rainfall
10.	Kunia Village	Yes	Yes	Kunia Camp nearby site, prime agricultural land in cultivation
11.	Kunia Village East	Yes	Yes	Prime agricultural land in cultivation
12.	Palikea	Yes	Yes	Dissected by gulches
13.	Village Park	Yes	Yes	Prime agricultural land in cultivation, planned urban encroachment (Hale Ole, Royal Kunia)
14.	Kamananui	Yes	Yes	Some prime agricultural land in cultivation, dissected by gulches, planned urban encroachment, higher temperature, poor road access, distance to milk processing plant
15.	Mokuleia Ranch	Yes	Yes	Steep mauka area limits site to coast, higher temperature, active airfield, poor road access, distance to milk processing plant
16.	Kaena Point	Yes	No	Steep mauka area limits site to coast, higher temperature, active airfield, poor road access, distance to milk processing plant, sensitive ecology
17.	Waianae	Yes	Yes	Higher temperature, limited area in ranching use, steep mauka area
18.	East Kapolei	Yes	No	Prime agricultural land in cultivation, land bank proposed for future urban use, planned urban encroachment (Ewa)

TABLE 4.1b – ADVANTAGES OF ALTERNATIVE OAHU SITES CONSIDERED

	Sites	Median Rainfall < 50 in.	Existing Grazing Use	Advantages
1.	Kahuku	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture, existing agricultural park
2.	Kawailoa-Mauka	No	No	Previously contoured uplands w/ suitable land for existing or improved pasture
3.	Kawailoa-Makai	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture
4.	Opaeula	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture
5.	Paalaa-Makai	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture
6.	Paalaa-Mauka	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture
7.	Kaukonahua-Makai	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture
8.	Kaukonahua-Mauka	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture
9.	Walawa	No	Yes	Previously contoured uplands w/ suitable land for existing or improved pasture
10.	Kunia Village	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture
11.	Kunia Village East	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture, State land
12.	Palikea	Yes	Yes	Previously contoured uplands w/ suitable land for existing or improved pasture
13.	Village Park	Yes	No	Previously contoured uplands w/ suitable land for existing or improved pasture
14.	Kamananui	Yes	Yes	Previously contoured uplands w/ suitable land for existing or improved pasture
15.	Mokuleia Ranch	Yes	Yes	Previously contoured uplands w/ suitable land for existing or improved pasture
16.	Kaena Point	Yes	No	Distance from urban center
17.	Waianae	Yes	Yes	Existing agricultural park, State land
18.	East Kapolei	Yes	No	Below BWS "No-Pass" line, State land

1) climatic conditions (cooler temperatures, more evaporation, less rainfall) more favorable for animal husbandry and waste management;
2) less potential for conflict with developments that are being considered in the immediate future;
3) less potential for contamination of ground water recharge of drinking water sources because of silty clay soils;
4) potential for animal waste reuse on surrounding agricultural operations;
5) potential water supply at each site;
6) sufficient land area to provide for long-term stability for the dairy industry;
7) sufficient land with suitable slope conditions for construction of facilities;
8) compatible agriculture use surrounding site that will provide a buffer between livestock and other land uses;
9) proximity to feed supply facilities (Palikea site only); and
10) lower transportation cost between dairies and processing plants (Palikea site only).

Some potential examples considered relative to item (4) include potential use of treated wastewater for crop irrigation, use of solid waste as organic fertilizer for crop production, and use of bagasse waste for dairy stall bedding material.

C. Expansion of Existing Dairies

Section 2, Subsection II describes the history of agricultural parks program, and in particular the livestock industry. The program originated because the diversified agriculture industry was having difficulty expanding its operations. Historically, as dairy operators ceased operations, their herds were consolidated with other dairies. However, now these dairies lack the land to provide for further expansion. The operation buildings were expanded to by tacking on additions. This resulted in inefficient labor usage and overcrowding of animals.

To be an economical alternative, several factors need to be overcome at existing dairies:

1) climatic conditions (cooler temperatures, more evaporation, less rainfall) more favorable for animal husbandry and waste management;
2) less potential for conflict with developments that are being considered in the immediate future;
3) less potential for contamination of ground water recharge of drinking water sources because of silty clay soils;
4) potential for animal waste reuse on surrounding agricultural operations;
5) potential water supply at each site;
6) sufficient land area to provide for long-term stability for the dairy industry;
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To be an economical alternative, several factors need to be overcome at existing dairies:

1. Additional space must be available for housing, feeding, exercise, and foraging, including grazing of animals.
2. Additional capacity for waste management must be available (or the potential to construct it must exist).
3. The operation must be a sufficient distance from the surrounding community.

The probability of achieving these objectives at existing locations is zero.

A good example of what relocation can mean to this industry can be seen at the Meadowgold Anahola Dairy on Kaua'i. This dairy was relocated from Kawailoa on O'ahu where climate and conditions were less favorable for milk production. Modern dairy barns, milk parlors, calf rearing pens, and a semiautomatic waste collection and treatment system were installed. Cooler temperatures prevail because of higher elevations. Productivity of this herd increased from approximately 35 to 50 pounds of milk per day per cow.

D. Relocation of Dairies from O'ahu to a Neighbor Island

There are several issues that must be considered to make relocation to a neighbor island a viable alternative. Three of them include: 1) whether it will be profitable for relocated dairies on the neighbor islands to compete with those remaining on O'ahu, 2) whether the relocation is physically feasible from the standpoint of protecting the quality of the shipment of milk to O'ahu, and 3) whether it is economical, from the public viewpoint to do so.

There are two scenarios to consider with these issues: 1) the milk processing plants do not relocate, and 2) at least one of the two milk processing plants on O'ahu phases down and relocates to a neighbor island. These scenarios are considered in the context of the first three issues.

A possible site for a livestock agricultural park on neighbor islands is considered to be either the Big Island or Moloka'i. Agricultural land is relatively abundant on these islands, however, the choices can be rapidly narrowed to a few locations on each. On the Big Island, the preferable locations will be the South Point region, Waimea, and the Kohala Coast. Other locations are too wet, too rocky, or too expensive. Even in the Waimea area, some land costs may be as high as $25,000 per acre. Land prices are less on Moloka'i, but water is a controversial issue. Water from Hawaiian Homes lands may be unavailable. The entire island has recently been designated a water management control area by the State Commission on Water Resources.

Remaining Competition. Not all of the producers on O'ahu will need to relocate. Some own their land and are in less danger of being evicted due to encroachment or loss of their lease. Thus the relevant question is to what extent the dairies that do possess milk quota for O'ahu, and choose to relocate to an agricultural park on a neighbor island will be in a competitive position after doing so.

Milk movement and pricing are managed by the State Department of Agriculture under Hawaii Revised Statutes, Chapter 157. The minimum price provided to producers under this regulation can be adjusted by the Board of Agriculture based on an annual cost of production study. Each producer in two counties, O'ahu and the Big Island, are allocated a portion of the total production or "quota" under this system. From 1982 to 1991, the O'ahu minimum price was $21.09 per hundredweight (cwt) for Class 1 milk. One hundred weight is 100 pounds. Milk is graded (or classed) according to fat content. The minimum price has recently been raised to $23.20 and $21.09 per cwt for the O'ahu and Big Island producers, respectively. However, the 1991 cost of production study for the Big Island showed the price, if based on current costs of production, could be raised as high as $23.51 per cwt. Thus the cost of production is indicated to be more on a neighbor island.

There are two implications of this information. First a producer would have to be irrational to move to a location where their cost of production was higher, and ship their produce back to a location where the minimum price was lower. This assumes that the dairy quota for O'ahu is ruled valid regardless of where the milk is produced. Unless the cost of transportation is lower than at the present, it is not profitable for the producer to relocate.

The commercial cost for shipping a refrigerated container with 3,000 gallons of raw milk from Hilo is approximately $414 (including July 1992 increase). This equates to an additional cost of $1.72 per cwt {$414 / (3,000 gal x 8 lb/gal x 1/100 per cwt)}. The shipping cost from Moloka'i is slightly higher.

The transportation factor is a major reason why the agricultural park (for the dairies serving the O'ahu market) would not be economically feasible if sited on a neighbor island. There is approximately a one-dollar difference between O'ahu and the neighbor islands in the farm-gate price per 100 pounds of milk. The higher price for raw milk on O'ahu is not enough to offset the shipping cost. Furthermore, most of the needed feed (grain and forage) is imported from the mainland or Asian countries. Transshipment costs for feed from O'ahu and milk to O'ahu (assuming that milk processing plants would relocate to the neighbor islands) would increase the cost to the consumer. It would also require extra care (and cost) in handling the product by the shipper because milk spoils rapidly with minute changes in refrigeration temperatures.

The conclusion is that profitability will be less for a producer to compete against the remaining dairies from a neighbor island location.

Reliability of Shipping Raw Milk. In the past, the shipments of milk between islands have been pasteurized (processed) milk. Because of the perishability of raw milk, it raises significant questions concerning the ability to transport milk between the dairy on the neighbor island and the processing plant on O'ahu. Recall that the bulk of the market is on O'ahu (34,000 gallons per day not including peak season) and therefore the neighbor island plants do not presently have the capacity. For example, the Hilo plant capacity is about 5,800 gallons per day.

There can be a doubling of microbial population in the milk every 20-40 minutes when the temperature increases about 45 °F. At the temperatures above this, the milk plant will reject the milk. The Department of Health regulations limit for the standard plate count (test for microbial population) is 50,000; it is not uncommon for raw milk from the cow to have a plate count of 20,000. Thus milk is extremely sensitive to temperature changes and delays in transportation.

The shipping schedule between either Hilo or Moloka'i to Honolulu is such that the producer will be required to have extremely sound planning in terms of transportation arrangements. There are only two shipping days from Hilo to Honolulu and three from Kaunakakai to Honolulu, and none for the latter between Thursday to Monday. This leaves gaps of three days in shipping. It is common practice that milk does not remain on the farm for more than two days to reduce the risk of spoilage.

The conclusion is that the present shipping schedule and arrangements for a highly perishable product such as raw milk makes it very risky for the producers to transport their product from a neighbor island to an O'ahu processing plant. Spoiled milk has to be rejected and disposed in the sanitary sewer system. On O'ahu, the Sand Island treatment plant flow rate is about 80 mgd, so the wasted milk which might be 5,000 gallons at most, is diluted. The effect on the treatment plant is insignificant. But in a neighbor island location, this will have a shock effect on the treatment plant receiving the discharge.

Economics of Processing Plant Relocation. Conventional wisdom concerning the public economic analysis of public investment decisions generally disregards sunk costs, i.e., investments already made and over which no control can be exerted. However, when there are in reality a limited number of suppliers (in this case milk plant processors), their investment considerations have to be recognized because the reality is that decisions have to be economically rational to create change.

The existing milk plants on O'ahu have in recent years invested millions of dollars to expand their current facilities. A loss in throughput capacity on O'ahu would equate to a loss of return on their investment. Meadowgold Dairies Hawaii has expanded their refrigeration capabilities in recent years. They operate their own dairy farm, have no immediate need to relocate, and therefore they have the least reason to relocate their plant to "follow" the dairy farms.

Foremost has spent more than $10 million on plant improvements since 1987. The cost of building a new plant which could handle approximately 30,000 gallons of milk per day is estimated to be approximately $10 million in today's prices. Assuming that a plant has a 20-year, straight-line depreciation rate, there is $7.5 million to amortize on the existing plant plus $10 million investment for a new plant; hence a total of $17.5 million cost to be absorbed by the consumer if Foremost were to decide to rebuild its facility on a neighbor island. These costs do not include the cost of the building, the land, the infrastructure to support the new plant, the engineering, and relocation of personnel and their families. This could be easily double or triple the cost of the plant. The two milk processors together employ several hundred people. **Thus overall costs to the economy could be several times the value shown above to relocate a plant to a neighbor island, and is unlikely to be seen as a rational economic move by processors.**

Conclusion. The conclusion is that it will be less profitable and therefore less likely that dairy operators will relocate to a neighbor island in order to continue supply the O'ahu market at this time. There is a very high risk that shipment of raw milk from the neighbor islands will result in some spoilage and therefore economic losses to producers and higher unit production cost for the consuming public. The likelihood that existing processors will want to relocate entirely, or down scale their O'ahu operations and rebuild on a neighbor island is considered very remote.

II. Identification and Discussion of Potential Effect Categories

Summary of Subsection II. The environmental effects are reviewed and analyzed in terms of: 1) irrevocable commitments of natural resources, 2) adverse effects on the economic or social welfare of the community, 3) commitments for larger actions, 4) degradation of environmental quality, 5) curtailment of beneficial long-term uses, 6) significant health effects, and 7) effects in environmentally sensitive areas. In terms of the first four categories, no significant adverse effects are anticipated. The health risk associated with emissions from the site is quantified both for ground water and surface water. Downstream sensitive areas include wildlife refuges. The magnitude of the effect, in terms of hydrologic budget, is assessed; the Kahuku site is potentially more significant. Other sensitive areas are coastal recreation locations; West Loch is considered potentially of greater significance. Water quality standards in streams receiving storm water are presently exceeded after heavy rainfall events, and it is necessary to prevent the situation from worsening. This requires storm water runoff control. The potential for impact on environmentally sensitive areas is an unresolved issue that requires further consultation.

A. General

An action is deemed to have a significant effect on the environment if:

> "the sum of effects on the quality of the environment, including actions that irrevocably commit a natural resource, curtail the range of beneficial uses of the environment, are contrary to the State's environmental policies or long-term environmental goals and guidelines as established by law, or adversely affect the economic or social welfare, or are otherwise enumerated in section 11-200-9."
>
> (Title 11, Department of Health, Chapter 200, Environmental Impact Statement Rules)

The potential for significant effects of the project is reviewed in this section relative to this statement.

The evaluation is considered to be generic to the project, unless specific differences are attributed to one or the other potential site (Palikea or Kahuku). The details of several evaluations are presented in the appendices.

B. Irretrievable and Irreversible Commitment of Resources

Land acquisition of agriculturally-zoned land and its dedication for agricultural uses preserves the resource for future generations. The ALISH designation described in the previous section (Section Three — III. Socioeconomic Environment, Subsection C. Land Use Suitability) provides a technical basis to establish that from the resource management perspective, the lands at the potential sites are suitable for these agricultural uses. The fact that these lands are no longer in active production means that the proposed action does not result in a loss of existing agricultural productivity. Moreover, because the proposed action is another agricultural activity, it does not involve a commitment of these lands to other uses.

The Department of Agriculture takes the perspective that agriculturally-suitable land is a resource in its own right. Agriculturally-suitable lands once developed for other land use are no longer available for agricultural use, and the resource management and long-term social and economic options become fewer. Experience shows that once the land passes into new use, the resource is forever removed from agricultural production. The history of the continual relocation of the dairy industry on O'ahu is one example. Maintaining the agricultural use preserves the option for the future, but does not foreclose other options forever.

C. Adverse Effects on the Economic or Social Welfare of the Community

The potential sites will improve the possibility for continuing a viable dairy industry on O'ahu. Improved productivity will help stabilize milk prices. Productivity improvements as high as 30 percent have occurred to dairies that adopted free-stall dairy management and relocated to a more favorable location.

Existing economic activities are not expected to be adversely affected. At the Palikea site, the land to be acquired is fallowed sugarcane land and Oahu Sugar Company has not indicated an intent (personal communication, 1991) to return to cultivating the majority of the area being considered for acquisition. Thus the project will not displace economic activity, including the existing grazing operation, and will return agricultural land to productive use. The existing grazing operation on these lands can be returned within portions of the site not used for dairy operations.

At the Kahuku site, the acquisition will not displace existing agricultural users, who may remain under lease agreements with the State of Hawaii, Department of Agriculture. The Kahuku sugar plantation ceased operation in the early 1970s, and is therefore not a factor. Additional diversified agricultural leases will be offered on a portion of the project site not dedicated to dairy operations. Housing for owner/operators of the dairies will be permitted on-site. This will not increase the demand on limited local housing which is in short supply. Workers will be required to commute. The number of employees at each dairy will not create new congestion on highways. The impact upon social services is considered insignificant.

There may be employment opportunities at the selected site, but these gains are offset by losses at the present location of the dairies. A typical dairy employs two to three persons in addition to the owner operator as milkers and herdsmen. Wages in the livestock industry are lower than the State average in general, and the sugar and pineapple industries in particular. For example, the 1989 average State wage was $21,641; the sugar and pineapple average wage was $22,924 and $20,800, respectively. Based on an average hourly rate of $7.70, a livestock worker's average annual earnings are $16,016. It is too early to know which workers will give up their jobs or decide to commute.

There are social considerations that can be considered positive effects; however, they benefit a relatively small number of individuals rather than the communities as a whole. These include the proximity of employment opportunities which reduces commute time, preservation of agricultural lifestyle in traditional agricultural communities, and opportunities for young generations to pursue agricultural careers.

Another consideration is the possible impact upon economic development in the area, particularly Kahuku, where the visitor industry is part of the community's economy. There is much potential for tourism and farming sectors to work together. For example, Vermont's dairy industry has tapped into people's longing to get away from fast-paced urban areas and spend some time in peaceful farming communities. In that state, Ben and Jerry's Homemade Ice Cream, Inc., conducts educational tours that feature family dairy farmers. Trip routes for interested cyclists include a chance to see a morning milking. It brings people together on common ground and broadens their perspective of agriculture. The company's motives are not purely financial—they believe "a healthy rural community is absolutely essential to a healthy society."

The majority of adverse social affects will be related to nuisances created by agricultural activities. Dust and noise are generated on the site during planting, harvesting, and at times during construction of facilities. The extent of these is restricted to the sites and will not be detectable, with the exception of houses abutting the agricultural park in Kahuku. There are steps that can be taken to reduce the frequency of nuisances. The siting of facilities considers the prevailing wind direction. This is discussed in Subsection G.

Livestock waste management will generate odors. The critical times are when treatment facilities such as anaerobic digesters are cleaned and when manure is spread for fertilizer. These affects can be *minimized, but not eliminated.* By taking operational precautions such as avoiding application on days with adverse wind conditions, composting manure before application, and tilling manure immediately into the soil (if used for crop production), odors can be minimized.

Another issue is one of vector control, particularly dung flies, which have plagued dairy operations. Flies can be minimized when manure management is practiced. The frequent washing or scraping of dairy barns and covered anaerobic treatment are two components of a plan. Fly traps and natural predator control means are a third component.

Wasps have been used effectively for fly control. Local experiments have been limited to releasing wasps to feed on fly pupae in pastures in Kohala on the Big Island. In controlled tests in New York state, wasps reduced fly population by one-half during the peak of the fly season. It was found in that research that each wasp will kill about 300 fly pupae.

The key to good fly control, however, is management of manure in calf-rearing areas. Locating the calf-rearing areas close to the dairy barns facilitates the disposal; collected manure can be flushed to reception pits in the barns.

A fourth option is altering the dairy ration. Local research has shown that reducing the amount of corn in the animal ration reduces the attractiveness of the manure to flies. Since maggots develop only in rich organic areas with 40 to 70 percent moisture, a combination of management measures described above has the capability to reduce the nuisance due to flies.

Other minor affects include aesthetic and recreational factors. New power lines will be needed at the site, but will be insignificant aesthetic effects and unobservable from principal viewpoints near each site. Existing recreational uses occur, albeit unauthorized, by enthusiasts riding all-terrain vehicles and dirt bikes. These uses will be curtailed by the additional security gates and cattle fences that will be constructed.

Another vector problem in agricultural operations is rodents. In Kahuku, rat and mongoose sightings by farmers are common at this site, and likely at any rural site to be considered for an agricultural park. What will be critical is methods employed by individual operators to control nearby rodent populations, particularly near feed storage areas. The existing dairy operations have not experienced problems with rats, as most dairies host a cat population.

D. Commitment for Larger Actions

Land acquisition for the project is individually limited to a commitment of resources to acquire one of the two potential sites for agricultural use. The potential sites are already used for agricultural purposes, for example, cattle grazing at the Palikea site and farms at the Kahuku site. Not all of the land shown as part of the potential site will be used for agriculture. For example, at the Kahuku site, the *mauka* area of the site below the conservation district provides watershed area that can be used for future wells and surface water that can be useful for irrigation of grazing areas on the site.

The acquisition of the site commits the proposing agency to expenditure of funds for the development of common infrastructure facilities to serve multiple lots. The commitment includes assurance that waste management facilities will be constructed and operated in compliance with the Department of Health regulations. Lease agreements are necessary to develop individual responsibilities, for example, freestall dairy management.

The administration of the agricultural park leases will be made by the Agricultural Resource Management Division of the Department of Agriculture which presently administers similar State agricultural park leases. Operating expenses will be, in part, paid for by lease rentals and/or special assessments.

E. Health Risks

Overview

It is an unavoidable fact that living in a modern industrial society results (voluntarily or involuntarily) in some health risks. Some of the risks (in terms of the U.S. population as a whole) we may face are shown in Table 4.2.

TABLE 4.2 - COMPARATIVE LIFETIME RISKS OF DEATH OR FATAL DISEASE

Risk (Lifetime)	Approximate Risk
All Causes	1
Smoking (one pack per day, 40 years)	3×10^{-2}
Automobile accidents	1×10^{-2}
Alcohol (light drinker)	2×10^{-3}
Breathing indoor air	2×10^{-3} to 3×10^{-4}
RCRA hazardous waste1)	1×10^{-4} to 1×10^{-5}
Eating 4 tablespoons of peanut butter per day (contains natural carcinogen)	8×10^{-6}

Source: William J. Walsh, "The Use of Risk Assessment In Ground Water Cleanups," *Risk Assessment For Groundwater Pollution Control,* edited by William F. McTernan and Edward Kaplan, American Society of Civil Engineers, 1990.

Note: 1)Resource Conservation and Recovery Act definition of hazardous waste site.

These estimates are presented to introduce the reader to the concept of risk. Risks are stated in probability terms; a number whose value can range between zero and one.

The ways in which risk assessments are determined by the public and technical experts differ. Lay persons primarily perceive risks on the basis of social, cultural, and psychological factors. For example, choice and control strongly influence risk perceptions (Glicker 1992). People often perceive involuntary risks, whose source they cannot control, as less dangerous. Also if one group is to bear an activity's potential risks while another reaps its benefits, the activity appears more dangerous. It is important to note that these factors are not part of the risk assessment formulation here; while they may be valid concerns, it is less confusing to incorporate public concerns into public decision-making and keep the technical risk assessment separate.

The technical considerations in this subsection are: 1) making a risk estimate, expressed as a probability, that an activity at the livestock park may affect health, and 2) estimating the magnitude of the effect. The determination that the activity is a significant or unacceptable risk, after considering the magnitude in the overall context of the environmental impact statement, must be made by the Department of Health (Chapter 342, Hawaii Revised Statutes, Section 342-6(c)). Among the considerations for determination of the public interest is "promoting the optimum balance between economic development and environmental quality," where the certainty of an outcome is unclear.

The balancing of the benefit of the proposed action versus the cost or the risk is a public health determination. Where the outcome of an activity is quite clear, the determination of what is hazardous to public health is facilitated by standards. The determination of what constitutes a hazardous dose, e.g., is based upon numerical drinking water standards or other health standards, and varies according to contaminant.

Risk is defined as the probability of contracting a disease or injury under a specific set of circumstances. The Council on Environmental Quality guidelines (Cohrssen and Covello 1989) for risk assessment of drinking water due to potential contamination provided the framework for this analysis. There are four potential components that are evaluated: 1) hazard identification, 2) human exposure assessment, 3) dose-response assessment, and 4) risk characterization. The amount of a substance in the air or water is the exposure concentration. The amount that is received by the person at risk is the dose; this may be a different amount than the exposure amount. The dose, its duration and timing, and the size of the receiving population are critical factors for dose-response assessment; but this requires considerable epidemiological data. This discussion emphasizes hazard identification and exposure assessment; these alone, it is argued in the forthcoming subsections, are sufficient to estimate the level of risk as very small.

Given sufficient data to identify a hazard, the second and third components above can be assessed so that the risk can be quantitatively assessed as a probability. This is calculated to be the joint frequency or the joint probability of a particular exposure level of a pathogenic agent occurring at a defined site and the probability of infection from that exposure, or:

RISK = P(E) x P(I)
P(E) = probability of exposure concentration in water or air

P(I) = probability of an infective dose-response at exposure level E.

There are two types of contaminants considered: chemicals which are chronic and life-shortening; and pathogens which are acute and have a wide range of affect depending upon the organism, the dosage consumed, and the immune response of the individual.

Chronic effects can be lifelong and relatively irreversible. Acute effects refer to short durations. Drinking water standards for chemicals, particularly carcinogens, are for chronic effects. They are also based on what technically and economically can be achieved. These standards may try to achieve a target protection level of between 10^{-4} and 10^{-6} incremental lifetime risk. However, comparable target levels for all contaminants, such as pathogens, have not been set, although some organisms have received recent attention, such as *giardia*.

There are two major pathways considered here as a means of potential transmission of potentially hazardous agents or substances: waterborne transmission via ground and surface water, and aerosol transmission via prevailing winds. The potential for physical contact with animals is considered restricted to farm workers who may take special precautions, and not the general public who may be unaware of risks.

Waterborne Transmission

At either site for the livestock agricultural park, the potential sources of contamination include surface runoff, with which the public may come in contact, and ground water percolating to aquifers tapped for drinking water. Issues concerned with the degradation of environmental quality and beneficial uses, including the aesthetic quality impacts of sediment are considered in a subsequent subsection. In this subsection, we first consider two situations: the risks related to ground water consumption and the risks due to accidental ingestion of stream runoff. Drinking water contaminants of concern include nitrogen and pathogens; total dissolved solids is also a secondary concern because it affects palatability.

Nitrogen Contamination Risk Considerations. The potentially hazardous agents or substances considered in ground water (drinking water source) are conservative parameters, namely nitrogen, and nonconservative parameters including bacteria and viruses. Nitrogen is a chemical found in all living organisms and essential to life; it is a plant nutrient that occurs naturally in ground water at all locations in Hawai'i. At high concentrations, it has been linked to methemoglobin (excessive nitrite level in the bloodstream), particularly in infants. At the topsoil horizon, nitrogen is removed by a combination of crop uptake, denitrification, ammonia volatilization, and soil storage. Below the water table, however, dissolved forms of nitrogen (as nitrate-nitrite) remain relatively stable in concentration. On O'ahu, background concentrations of nitrogen are typically on the order of one milligram per liter (mg/l), and some nitrogen is found even in the ground waters of relatively pristine areas such as the Ko'olau Forest Reserve. The safe drinking water standard for this parameter permits concentrations up to 10 mg/l.

Phosphorus, another chemical associated with agricultural activities, is generally not a health consideration in Hawaii's ground water. Phosphorus removal, particularly in kaolinitic and montmorillanitic clays at either site, is very high. Tasato and Dugan (1980) note the mechanisms of absorption and precipitation, microbial action, and crop uptake removed 93 percent of phosphorus from wastewater applied to Wahiawā soil. Lau, et al. (1974, 1975) reported 95 percent applied phosphorus removal from secondary effluent application. Phosphate contamination in ground water is not considered a significant issue. Phosphorus is more important to beneficial uses of surface water as excessive amounts can promote eutrophication.

The potential health risk at either site is the result of three common agricultural practices: 1) substituting animal waste as a fertilizer on land used to grow crops or pasture areas, 2) the potential affect of percolate through compacted earth in unpaved areas between dairy barns and milk parlors, and 3) infiltration of nitrogen from manure on pasture land.

The dairy management concept proposed for the livestock park needs some additional explanation at this point. The future dairy operators will be required to construct freestall barns to house their animals. So-called "dry-lot" operations will not be permitted. Freestall barns have two significant affects on manure management. First, they keep rainfall from mixing with the majority of manure generated, therefore reducing percolation of concentrated amounts of nitrogen. Secondly, the paved floors facilitate better collection and treatment. After anaerobic digestion (treatment) there are two types of products that can be used in crop cultivation—a liquid slurry and a solid residual. Both have fertilizer value, but the second is also a valuable soil amendment. It takes between one-third to one acre of crop land to safety absorb the nutrients in one mature dairy cow's waste per year.

Because of this, the potentially larger effect of manure relates to its substitution for chemical fertilizer on surrounding agricultural land. In Kahuku, this includes land used for vegetable and fruit crops. At Palikea, this includes land used for pineapple production. The number of dairy cows is expected to be between 200 and 2,000 cows (dry and lactating) at the site chosen. The land area necessary for absorbing these nutrients could range from 60 to 200 acres at the smallest utilization of the park to 600 to 2,000 acres at full capacity. This makes manure fertilization the more significant consideration.

Dairy barns and milk parlors are typically separated by two to three acres of bare earth. Cows will travel between buildings at least twice a day for a few hours. Manure from the animals is trampled and packed into the soil which itself is compacted by the hoofs of the animals. The trampling is an important part of breaking up the dung pats to promote microbial decay, and in intensive grazing operations it promotes the natural treatment process and reduces the fly population. These areas can be scraped to collect the manure for disposal, but percolation into the deep soil horizon must be considered.

Manure distribution in the earth areas will be uneven or "patchy." Cows tend to congregate—around water troughs or under shade trees. Manure incorporated into soil continues the process of organic degradation. Under aerobic conditions the majority of the nitrogen is in organic form in fresh manure and decomposes by the process called mineralization. The microbial conversion of organic to inorganic nitrogen forms is affected by soil factors including moisture, temperature, aeration, and pH.

Finally another area of consideration is the manure that falls in pastures. Manure in these areas will tend to be less uniform and mixing occurs more readily, with the existing pasture grasses which helps hold material in place and promote rapid uptake. The same factors apply, however, as with crop uptake, and pasture grasses are an important mechanism that determines ultimate the emission quantity that may reach the ground water table.

An analysis of manure nitrogen migration in these types of locations—pastures, earth lots, and crop areas—is presented in Appendix A. The analysis consists of five submodels that consider:

1) the amount of nitrogen and fertilizer value for various crops,
2) the transformation of organic and mineralized nitrogen in the top layer of the soil into nitrate form,
3) the infiltration of water and uptake of nitrate by plants,
4) the dispersion and percolation of soluble nitrate below the soil surface, and
5) the mixing of nitrate (as a conservative parameter) into the aquifer ground water system beneath the site.

The critical submodels are 2) and 4); they result in a reduction in dissolved nitrogen concentrations by approximately two orders of magnitude. Two different calculation methods are used for each submodel to compare the results. In addition, data is presented from manure application experiments at the University of Hawaii Agricultural Experiment Station at Waiale'e.

Consideration is given in Appendix A to the extent water percolating into the aquifer mixes with other water before reaching water wells tapping the aquifer. Again, as with dairy operations, there are two scales to consider: 1) the entire aquifer unit considering the scale of crop fertilization practices, and 2) the local scale of water reaching a single source because of short-circuiting (no mixing) between a dairy and a selected well.

In summary, the results of these calculations *expressed as nitrogen* are:

	Typical Area,acres	Soil Water (before percolation) mg-N/l	Ground Water (aquifer mixing) mg-N/l
Dairy Lot	100	25.6	1.4
Field Application	400	1.3	1.1

The deep percolation values are estimates below the root zone, i.e., before the water reaches the water table. The mixing model assumes complete mixing. See Appendix A for more details on this evaluation, including sensitivity analyses concerning the mixing assumptions.

The above analysis indicates the ground water in the aquifer beneath a site is comparable considering both agricultural practices. These estimates are the expected values; the probability of a deep percolation concentration reaching the safe drinking water standard of 10 mg/l is less than one percent, considering that the dairy earth lot. It excludes mixing within the aquifer. To arrive at the probability of a health risk, this exposure assessment should be multiplied by the probability of dose-exposure response. This will lower the risk. But the conditions required to obtain this result are just not reasonable to expect, as discussed next.

Numerous assumptions concerning the processes and parameters were made to arrive at this estimate. The range of variables is identified in Appendix A. The variability of parameters such as soil characteristics, rainfall, plant assimilation of nitrogen, and evaporation are considered. Where simplifications are in order, conservative values were adopted. For example, the analysis:

1) neglects denitrification losses of nitrogen to the atmosphere;
2) neglects the reduction in hydraulic conductivity during drying cycles;
3) neglects the immobilization of nitrate by deep saprolitic zones beneath the upper soil horizons and above the basalt aquifer.

The conditions were considered in Appendix A that could make aquifer water nitrogen concentrations approach 10 mg/l. First, farm application would have to greatly exceed recommended fertilizer application rates. The results would become evident to farmers whose yields will decline; this will trigger a reduction in fertilizer use.

The identification of agricultural irrigation return water in ground water supplies has been known for decades. The concentrations predicted are comparable to the experience resulting from years of sugarcane and pineapple use of fertilizer. The magnitude of this impact has been predictable and within acceptable health limits. The impact of other sources such as urbanization, golf courses, and military land use has not been as well documented. These sources of nitrogen may also have a pronounced affect upon the ground water quality.

In conclusion, with substitution of manure for chemical fertilizer, the nitrogen loading may be comparable to the experience with sugarcane cultivation. However, it is more probable that the nitrogen concentration will be much less. The evaluation does not include potential increases due to other land use activities over the aquifer systems. Other nonagricultural land use activities may have a significant effect, but the scope of this investigation is not to assess these and all potential future sources.

Pathogen Risk Considerations. Research on potential health risks due to pathogens in reused wastewater in Hawaii has been directed toward domestic wastewater reclamation practices. Nationally, the health risk from bacterial contamination of discharges on land application areas from properly engineered slow-rate natural waste treatment systems is now confidently known to be insignificant. Several sites which support this statement are Santee, California; Windhoek, South Africa; and Muskegon, Michigan, to name a few (Water Pollution Control Federation 1990). Treatment of animal waste represents an increase in scale and land area required due to mass loading considerations and bacteriological concentrations, but biological and chemical treatment mechanisms are similar to those for domestic sewage. In medium- to fine-textured soils normally used for slow-rate systems, complete removal of bacteria can be achieved within five feet of the surface.

Species of pathogenic organisms carried in wastes vary greatly in their ability to survive away from the host. Bacteria and protozoa are known to be transmitted from animal to man, as well as to other animals, although viruses tend to be host specific, i.e., infecting similar organisms. Counterparts of major groups of viruses known to infect man are also found in domestic animals. There are more than 100 bacteria affecting animals and more than 500 viruses, but there are fewer diseases (approximately 100) that can be transmitted from animals to man (Reddy et al. 1981). The pathogenic organisms that can be considered significant and their half-life characteristics are shown in Table 4.3. Half-lives are the times for one-half of the population of microorganisms to die. Thus, for example, if one considers bacteria with a half-life of 1.5 days, the concentration is reduced exponentially so that in seven days it is .003 percent of the original amount. Viruses are the critical pathogens in ground water because of the size and their persistence, although it

TABLE 4.3 – PATHOGEN TRANSMISSION ASSESSMENT DATA

Exposure	Mode of Transmission	Portal of Entry	Pathogenic Microorganism	Type	Disease	Die-Off Rate Day^{-1}	Half-Life	Remarks
							Hours:	
Animal-to-man	Waterborne	Gastrointestinal	Salmonella typa	Bacteria	Typhoid	0.77	21.6	Sewage
			Vibrio cholerae	Bacteria	Cholera	2.31	7.2	
			Shigella dysenteriae	Bacteria	Bacterial Dysentery	0.74	22.5	Soil/Water
			Salmonella SPP	Bacteria	Gastroenteritis	1.33	16.0	
			Campylobacter SPP	Bacteria	Gastroenteritis			
			Rotavirus	Virus	Gastroenteritis	1.45		
			Hepatitis A Virus	Virus	Hepatitis			
			Entomoeba histalytica	Protozoa	Amoebic Dysentery			
			Cryptosporidia	Protozoa	Amoebic Dysentery			
			Escherichia Coli	Bacteria	Diarrhea	0.92		Soil/Water
			Giardia lamblia	Protozoa	Diarrhea			
Animal-to-animal	Waterborne	Gastrointestinal	Salmonella SPP	Bacteria	Salmonellosis		Weeks	
			Campylobacter SPP	Bacteria	Leptospirosis		Weeks	
			Leptospira	Bacteria	Brucellosis		Days	
	Airborne	Respiratory	Mycobacterium tuberculosis	Bacteria	Tuberculosis		Weeks	
	Direct Contact	Abrasions	Bacillus anthracis	Bacteria	Anthrax			

Sources:
1) R.M. Sterritt and J.N. Lester, *Microbiology for Environmental and Public Health Engineers*, E. & F.N. Spon, 1988.
2) K.R. Reddy, R. Khaleel, and M.R. Overcash, Behavior and Transport of Microbial Pathogens and Indicator Organisms in Soils Treated with Organic Wastes, *Journal of Environmental Quality*, vol. 10, no. 3, 1981.

should be noted they cannot reproduce outside of the host. The effects of ultraviolet light and high temperature are reduced in ground water which translates into longer survival times than in surface waters. Bacteria and protozoa survival in surface water has been found to range from several weeks to months. The significance of Table 4.3 is that when travel time between the point of origin and the point of ingestion is considered, the risk of infection is significantly reduced or eliminated.

Surface water contamination is examined for the case of an extreme runoff event, for example, runoff from grazing areas during a 25-year, 24-hour storm. Pathogens that are suspended in the water may be transported downstream to surface water bodies. The consideration is accidental ingestion of harmful pathogens in estuarine and nearshore coastal areas immediately after major storms.

Ground Water. Among pathogenic organisms, viruses are the greater concern rather than bacteria and protozoa because of size. The size and shape of protozoa vary greatly, from one to 2,000 microns (one micron equals 0.001 millimeter). Protozoa are typically the largest pathogens and most readily filtered from water by soil particles. *Cryptosporidium* (a protozoa), which is a potential concern from animal waste, vary from four to six micrometers (0.004 to 0.006 mm). Bacteria are intermediate in size with spherical organisms ranging from 0.2 to 1.5 microns (0.0002 to 0.0015 mm) in diameter. Viruses typically range in size from five to 10 nanometers (5×10^{-6} to 10×10^{-6} mm).

Evaluation of the occurrence of *Giardia* and *cryptosporidia* in surface and ground waters on O'ahu is only at the research stage. Recent sampling and testing of surface water in selected streams on O'ahu by researchers at the University of Hawaii Water Resources Research Center have identified the occurrence of *cryptosporidia* in some streams. Three Board of Water Supply wells have also been tested but the identification of *cryptosporidia*, while present, was at low levels which are not a health concern (Fujioka, personal communication 1991).

Testing of tunnel waters in Windward O'ahu demonstrated under low rainfall conditions *E. coli* (bacteria) are filtered from the above soil horizon; no detectable levels were observed in water collected from tunnels, although densities (number/gram) of 10^5 were estimated in the top three centimeters of soil and 10^2 in the top 36 centimeters of soil at the ground surface.

A detailed assessment of pathogen risks due to migration to drinking water drawn from wells is contained in Appendix C. The conclusions of the analysis are:

1) the risk of bacterial contamination is near zero,
2) the risk of viral contamination is on the order of 10^{-3}.

These risk assessments are based upon the average lifetime of 70 years, and assume an individual will consume two liters (approximately 1/2 gallons) each day of ground water drawn from wells. The risk increases the more water one consumes, but one-half gallon per day is a reasonable upper limit to the amount of tap water people consume. For example, one-half gallon is 64 fluid ounces which is equal to 5.3 cans equal in size to a 12-ounce beverage.

Total Dissolved Solids. The total concentration of dissolved minerals in a water is a general indication of its suitability for any use. There are two considerations that are important: 1) the palatability of water for drinking, and 2) the potential for accumulation of salt in agricultural soils.

The discussion focuses on the first issue, i.e., drinking water. This is the more limiting condition; water can be used safely on crops that is too salty for human consumption. A secondary standard for drinking water recommended by the U.S. Environmental Protection Agency for chloride ions, one of the more predominant constituents of total dissolved solid concentration, is 250 mg/l. Chloride concentration in water extracted from Pump Station No. 1 at the Kahuku Agricultural Park has a level of about 60 mg/l; the total dissolved solids concentration is approximately 215 mg/l.

Animal manure has a relatively higher concentration of total dissolved solids. For example, a sample of animal manure taken from a local dairy had a total dissolved solids concentration of approximately 12,000 mg/l. However, this concentration is significantly reduced by the amount of rainfall and irrigation water that mixes with the manure at the surface, and later in the aquifer with basal water. For example, at Kahuku, the average annual rainfall is approximately 65 inches, and evaporation is approximately 78 inches; but average crop irrigation is about 73 inches, annually. Thus the surplus dilution water per unit area is about 60 inches (65 - 78 + 73 = 60), or 5 feet, annually.

Consider an area the size of one acre in order to estimate total dissolved solid concentration. Five acre-feet of water is approximately 1.6 million gallons. This is 6 million liters of water. Assume that the manure application is high-equivalent to three animal units per acre per year. Annually, a mature dairy cow produces about

20 tons of manure containing about 480 pounds of dissolved solids (20 tons x 2,000 pounds/ton = 0.012), based on a concentration of 1.2 percent, or 12,000 mg/l. This is 217 million milligrams. Dividing the number of milligrams of salt by the volume of water yields a concentration of 36 mg/l ($217 \times 10^6 / 6 \times 10^6 = 36$ mg/l).

Not all of the total dissolved solids applied in manure for fertilization purposes migrates to the ground water. Some is immobilized in the soil horizon. But the evidence indicates that even heavy applications of manure do not result in a significant accumulation in soils where rainfall and irrigation are high. For example, soil sampled at the University of Hawaii Agricultural Experiment Station at Waiale'e evidenced low salinity (total dissolved solids). Soil was sampled in a pasture that has been manured for almost 20 years. The soil salinity was measured in units of millimhos per centimeter. One millimhos per centimeter is approximately 640 mg/l concentration. The soil samples were tested at between 1 to 2 millimhos per centimeter (640 to 1,280 mg/l). Soils with salinity less than 2 millimhos/cm are not limited in terms of most crops that can be grown. Some crops such as banana and papaya may be sensitive at levels approaching 2 millimhos/cm.

The conclusion is that the risk is insignificant for ground water contamination with excessive dissolved minerals from manure applied in amounts recommended for nutrient fertilization. This assessment assumes that supplemental irrigation is applied, which would be a necessity for crop production in the areas considered for the agricultural park.

Surface Water

Under surface water regulations (Hawaii Administrative Rules, Title 11, Chapter 55, Water Pollution Control), an NPDES permit will be required before operating a concentrated animal feeding operation such as a dairy. One of the requirements for permits is complying with State water quality standards. To meet these standards and comply with federal requirements, on-site storm water detention is proposed. The storm water detention facility is to confine the surface runoff generated on or near dairy facilities, pastures, and central waste treatment facilities. The detention provides time for sedimentation and disinfection of the water which is to be released at a low flow rate.

The design storm for this facility is (by regulation) a 25-year, 24-hour event. The consideration in terms of surface water pathogens is for events exceeding this magnitude.

The details of a probability analysis of the risk of ingestion of contaminated surface water are presented in Appendix D. The risk assessment concludes the order of magnitude is approximately 0.04 (4×10^{-2}). Several factors such as the chance of exposure in surface streams immediately after a flood, and the chance of ingesting a mouthful of contaminated water, are likely to reduce this risk to a smaller level, but the data is not available to evaluate them. In comparison, the risk is comparable to the estimated risk of death from an automobile accident at 1×10^{-2} (see Table 4.2), based on national statistics. The analysis does not consider other sources of viruses, e.g., in urban runoff (domestic pets) and forested watersheds (feral animals) pathogens that may contaminate surface water runoff. However, the analysis concludes the risk is small given storm runoff control measures. Storm water runoff will be disinfected before being used for irrigation.

Airborne Transmission

Some bacteria are transmitted by an airborne pathway, e.g., *Mycobacterium tuberculosis*. However, research (Lam and Young 1982) indicates that at sewage treatment plants, bacteria downwind of the plant are limited to close proximity to the facility. For example, measured concentrations of total bacteria and total coliform bacteria were rapidly eliminated. Approximately 80 to 90 percent of the microorganisms were removed from the air at a 45-meter (150 feet) downwind location. At the Wahiawā Sewage Treatment Plant (STP), total bacteria colonies counts were only 85 colonies/cubic meter above the background control level of bacteria in the air (from other sources).

A preliminary assessment of the potential magnitude of microorganisms at critical distances from population concentrations is made in Appendix E. By analogy with the concentration of microorganisms at sewage treatment plants where aeration facilities induce airborne transmission potential, it is shown that it is unlikely that pathogenic concentrations in aerosol form required to survive the critical distances from a livestock agricultural park to population areas will be produced. Microorganism concentrations are typically reported in aerosol form in coliphase (CFU) or plaque-forming units (PFU). Aerosol densities at the Wahiawā STP were the highest at the aeration basin (1.6×10^3 PFU/m^3) and at the Pearl City STP preparation unit (1.6×10^3 PFU/m^3). It is estimated in Appendix E that an initial concentration 62 times that observed at treatment plants would be required to transport 1 CFU/m^3 downwind. This transported concentration would be far less than existing exposure to background bacteria, and much less than an infectious dose.

Infectious doses of bacteria and protozoa in healthy humans vary. Dose count for *E. coli* or *V. cholerae* was 10^8; for *salmonella*, 10^4 to 10^9; and *Shigella*, 10^1 to 10^2. For viruses, 1 to 10^2 or more may be required for infection. The conclusion is that the risk of contact with infectious diseases due to airborne transmission off-site is insignificant.

Discussion of Risk Assessment

The considerations are waterborne and aerosol transmission of bacteria and viruses, total dissolved solids, and nitrogen in drinking water. The risk is assessed quantitatively for waterborne transmission, and by analogy for aerosols. The conclusion is that the risk to population groups outside the boundaries of the agricultural park will be insignificant. Experience, however, shows that public perception to the presence of a livestock park or waste management facility in the region will be negative.

Waterborne risks are estimated for nitrogen contamination and viruses in ground water; and for bacteria in surface water that may be accidentally ingested. The risks are low; however, as with the case of aerosols, public perception and confidence is crucial. It can be concluded that the design, strict monitoring by the lead agency, and potential corrective measures must lead to compliance.

F. Potential for Curtailing Long-Term Beneficial Uses of the Environment

Consideration of the potential affect upon ground water quality and water supply has already been assessed in the context of public health in the previous subsection. Other considerations are degradation of surface water quality and soil loss, which might affect on-site and downstream beneficial uses.

Soil erosion produces suspended sediment which may depress dissolved oxygen due to the biochemical oxygen demand (BOD) of organic material in the suspended sediment, increases turbidity, and may have associated organic chemicals such as pesticides adsorbed to sediment particles. A more complete discussion of the erosion risk is presented in Appendix F; this discussion is a summary.

Erosion Potential

Palikea Uplands Site. Table 4.4 shows estimates of annual sediment production developed using the universal soil loss equation. Procedures for estimating the erosion hazard rating were based on the Soil Erosion Standards and Guidelines (Department of Public Works, City and County of Honolulu 1975). Additional data for developing the estimates with conservation measures were based on Soil Conservation Service (1981) guidelines for erosion and sediment control. Three predominant soil types at the Palikea site were considered: Kunia silty clays (five and nine percent slopes) and Mahana silty clay loam. A representative location on the potential site, where dairy cattle grazing could be expected, was selected for analysis. It should be noted that soil losses calculated are sheet and rill erosion (not gully and stream bank), and are averages based on experiments, but not predictions of actual events. Details of the calculations are in Appendix F.

TABLE 4.4 – RESULTS OF REPRESENTATIVE SOIL EROSION POTENTIAL ANALYSIS AT PALIKEA (WITHOUT MANAGEMENT MEASURES)

Area	Soil Type	Slope %	Erosion, tons/acre Idle	Erosion, tons/acre Pasture
A	Kunia (KyC)	5	1	4
B	Kunia (KyB)	9	2	9
C	Mahana (McD)	15	8	32

The primary difference between idle and pasture conditions is the height of grass assumed. For the pasture condition, no appreciable canopy was assumed. For the idle condition, an appreciable canopy height of two meters was assumed, based upon the existing grass condition. The height of the canopy is important because it reduces the impact energy of rainfall. The erosion potential between existing and heavily grazed conditions could be increased by a factor of approximately four.

The significance of these values is evaluated using the City and County of Honolulu Soil Erosion Standards and Guidelines (1975). A severity rating system is assigned based upon the following formula:

H = (2FT + 3D) AE

where: H = severity rating number

F = a unit factor for potential damage to areas downslope and downstream from the site, to be selected from Table 1, Exhibit 1 (in erosion standard)

T = time duration of the project in years, from clearing or first disturbance to completion of all construction and protective measures

D = a unit factor for potential sediment damage to coastal waters, to be selected from Table 2, *Exhibit 1 (in erosion standard)*

A = area of disturbance, in acres; if the project includes areas of natural vegetation which will not be disturbed in any way, and the natural vegetation provides effective erosion control, such areas need not be included in A

E = soil erosion rate, tons/acre/year

The evaluation of these parameters is somewhat subjective. The values assigned are:

F = 1, damage area more than 1 mile downstream, i.e., *makai* of H-1

T = 25, duration of project in years, assumed project life

D = 4, special conservation concern is U.S. Fish and Wildlife refuge downstream near West Loch, Pearl Harbor

A = 100, area of disturbance in acres, assuming a grazing density of 1.5 cows/acre

E = as shown in Table 4.4.

A discussion of the development of these parameters is provided in Appendix F. The results of this rating procedure are shown below:

Soil Type	Erosion Hazard Rating[1]	
	Idle	Pasture
Kunia (KyC)	12,200	51,300
Kunia (KyB)	5,400	22,600
Mahana (McD)	41,800	175,400

[1]Rounded to nearest thousand.

According to the standard, the maximum amount of environmental damage considered acceptable is represented by an H value of 50,000. No project with a severity rating above 50,000 will be approved until measures have been taken to reduce the number to meet the standard. The severity of erosion will probably exceed standards for some soils (and slope) conditions if mitigative (management) measures are not taken. A discussion of potential measures, an effect assessment, and recommendations are contained in Appendix F and summarized in Section Five.

Kahuku Agricultural Park Site. Table 4.5 shows estimates of annual sediment production developed with the universal soil loss equation for the Kahuku site. Procedures for estimating the erosion hazard rating were based on the Soil Erosion Standards and Guidelines (Department of Public Works, City and County of Honolulu 1975). Additional data and methods are similar to the Palikea discussion and are described in Appendix F. Three predominant soil types at the Kahuku site (on 12 and 15 percent slopes) were considered: Lahaina silty clay and Paumalū silty clay loam. A representative location on the proposed site, where dairy cattle grazing could be expected, was selected for analysis. The increase in erosion potential between idle and heavily grazed conditions is a factor of between three to five.

TABLE 4.5 – RESULTS OF REPRESENTATIVE SOIL EROSION POTENTIAL ANALYSIS AT KAHUKU (WITHOUT MANAGEMENT MEASURES)

		Erosion, tons/acre	
Soil Type	Slope %	Idle	Pasture
Lahaina (LaB)	5	1	3
Paumalū (PeC)	12	1	5
Paumalū (PZ)	15	8	32

An analysis of the hazard rating was performed; as was the case for Palikea, several soil conditions represent a severe hazard:

	Erosion Hazard Rating[1]	
Soil Type	Idle	Pasture
Lahaina (LaB)	6,800	28,700
Paumalū (PeC)	12,900	54,000
Paumalū (PZ)	84,300	354,100

[1] Rounded to nearest thousand.

Discussion of Erosion Potential. The reduction in potential soil erosion from grazing land is identified as a requirement to avoid significant environmental deterioration and impaired use of water downstream. Two options include intensive grazing land management and sediment control structures. The former includes controlling the density of animals per acre or intensively rotating of animals in fenced paddocks. Additional operation effort is required of the dairy management. The net effect is to reduce the amount of grazing pressure on a given area and allow the grass to grow to the point where maximum nutritional content can be harvested without destroying the ability for rapid regrowth. Control structures include intercepting ditches, terracing improved pastures, and sedimentation basins to collect erosion material before it discharges downstream. These latter are considered additional safeguards for achieving desired environmental pollution control; however, they do not prevent erosion and will require maintenance. The structural measures require more capital input and energy to construct. The most effective means is to reduce erosion at the point of precipitation impact. The grazing management measures require more labor to accomplish the objective, but are recommended.

Discussion of Other Water Quality Considerations

Reduction of erosion also correlates with reducing water quality impacts, because evidence suggests a number of water contaminants: nutrients, pathogens, metals and organic material adsorbed to soil particles. The principal pollutants associated with livestock agriculture operations at the potential sites, in addition to sediment, include biochemical oxygen demand (BOD), pathogens and nutrients. This analysis focuses upon possible affects due to grazing land runoff; concentrated animal operations such as exercise lots will require waste collection and treatment. Under existing regulatory requirements, dairies are considered a concentrated feedlot operation and no discharge is permitted; they will be regulated under the NPDES system. A best management practices (BMP) plan will be required for dairy nonpoint source runoff.

The situation with respect to nonpoint pollution related to dairy operations in general was reviewed by Sunn, Low, Tom and Hara (1971) in a study of pollutant loads on O'ahu. Their statement described the situation then as follows:

> "[1] Volumes of wastewaters, according to water consumption data, are small relative to the watershed hydrologic elements;
>
> [2] the effect of dairy wastewaters on Pearl Harbor and Kā-ne'ohe Bay is not discernible;
>
> [3] this does not mean the animal operations are pollution free; their effect is pronounced in localized areas in the immediate vicinity;
>
> [4] under conditions of intermittent runoff, the pollutant loads are not the same as the waste generated because some nutrients in the manure are taken up by plants and organic matter degraded by microorganisms or remain relatively inert in the soil;
>
> [5] nutrient levels in runoff from grazing land can be high but long-term monitoring is not precise enough to sort out this

> component from the integrated effect of other possible sources in the watershed."

Monitoring and predicting the potential impact upon water quality of receiving water by grazing operations is problematic in light of the above considerations, and information presented in Section III.1.D. Water Resources that suggests high background levels of water contaminants, particularly nutrients, already exist.

The amount of biochemical oxygen demand (BOD) from grazing land will vary with grazing density. Background levels of BOD (in addition to other contaminants) will be present from runoff, with and without the proposed action. Using the Waikele Stream water quality monitoring station data (Table 4.6) for a benchmark to establish background water quality conditions, the relative impact on dissolved oxygen downstream of the site can be considered. The background dissolved oxygen conditions, assuming similar runoff quality between Honouliuli and Waikele Streams, can be considered represented by data in Table 4.6:

TABLE 4.6 – WAIKELE STREAM DISSOLVED OXYGEN CONDITIONS (1987-1989)

Discharge cubic feet/sec	Dissolved Oxygen (mg/l)	% Saturation	Temperature 0 Centigrade
11	5.9	71	25.0
36	8.2	92	21.0
36	7.8	88	21.0
48	8.0	92	22.5
28	7.3	85	23.0
161	7.7	91	24.0
22	6.8	82	24.5
98	8.3	94	21.5
12	7.0	82	23.5
37	7.6	87	22.5
29	7.8	89	22.0
18	6.6	78	23.5
12	6.2	71	22.0
22	6.9	81	23.5
41	7.4	82	21.0
18	7.2	82	22.0
66	7.0	80	22.0
Average: 100	7.8	92	23.5

Source: U.S. Geological Survey, Water Resources Data – Hawaii and Other Pacific Areas.

The experience in Table 4.6 shows that shallow, turbulent streams have not been found to be problems relative to dissolved oxygen levels. The limitations of the data base make definitive calculations difficult for the actual conditions encountered. Extensive water quality monitoring is required to evaluate:

1) the kinetic BOD degradation rate and reaeration rate which may be significantly different for a shallow, intermittent streams from storm to storm;

2) the unknown BOD load imposed by other nonpoint sources, including intervening urban areas between the site and coastal water is unquantified; and

3) the actual amount of BOD runoff from the potential site may differ from assumed values, depending upon erosion control measures.

The primary consideration is therefore development of a "best management plan" with the potential for protecting the water quality, particularly the coastal waters. The source of water quality constituents is considered to be the storm runoff from grazing land. The technical characteristics (see previous section) of the proposed project include provisions for the containment of storm runoff generated from pastures and around dairy barns on-site. The elements of this plan are identified in Section Five.

Microorganisms

Transmission of pathogenic organisms in surface waters and potential effects, other than on human health (previously discussed), is a consideration for inland and marine waters. One consideration for the sites would be bacteria and protozoa that might come into contact with waterfowl in the wildlife refuge. Disease transmission between warm-blooded mammals, such as cows to birds, has not been a documented threat.

Another consideration is waterborne pathogens that may enter the coastal waters and become a potential problem if they infect the benthic population. Most (90 percent) of the coliform bacteria are destroyed within one hour in the marine waters off Sand Island surrounding the sewage outfall (Loh, Lau, and Fujioka 1980). However, less is known about the survival of viruses in sediment and uptake by shellfish organisms.

The strategy to reduce microbial transport off-site is based on reducing soil erosion because:

1) Viruses readily adsorb to soil;

2) Virus survival is greatly reduced in soil if soil is dried and exposed to sunlight, because sunlight is believed to be a major factor in killing viruses;
3) Virus survival on crops is shorter than in soil because of greater exposure to deleterious environmental effects; and
4) Viruses cannot reproduce in the soil and ultimately die off.

These factors point to the importance of keeping vegetative cover on soil at the site, minimizing erosion, and trapping erosion that does occur on-site as much as possible to reduce the risk at downstream receiving waters and spreading this soil back on pastures to expose pathogens to sunlight and absorb nutrients in plant growth cycles.

G. Involves a Degradation of Environmental Quality

A major concern in terms of degrading the surrounding environment is agricultural odors. The degree of significance is related to the proximity between the potential site and existing/proposed (including uncertain) developments and prevailing wind direction. The degree of significance is also inversely related to the surrounding compatible conservation or agricultural land use and rural nature of the surrounding community.

Technical criteria are not readily available for siting livestock operations, although personal communications with agricultural extension agents in Hawai'i and the mainland indicate one mile is generally sufficient to minimize complaints concerning odors. The American Society of Agricultural Engineers Standards recommends a one-mile separation from developments and one-quarter to one-half mile from residences. The proposed sites meet this standard in terms of dairy barns and other concentrated annual operations.

The most critical condition will occur when wind blows from the dairies toward the community. Kahuku is considered here because the proximity to the area where dairy operations could be located is less than at Palikea. Figures 4-2a and 4-2b show these relative locations. The Kahuku community is separated from the dairies by a hill approximately 200 feet higher than the community.

The critical wind direction will be from west south west blowing to the east north east. Wind direction and wind speed information were collected at the Kahuku Agricultural Park. The results are shown for the months of September to

October, 1992. Each data point on the wind rose represents the average wind direction and speed (as noted by the scale) over a 30-minute interval. During this one-month period, the wind was from this direction less than two percent of the time, and never exceeded 20 mph.

Long-term wind direction statistics available at the Kāne'ohe Marine Corps Air Station indicate that 2 percent of the time at that location, wind is from west south west, and 4 to 12 knots (1 knot = 1.15 mph). Using these statistics to put the potential problem into perspective, on an annual basis, two percent of the time is 175 hours or about one week—and this is not all at once.

The conclusion is that odors cannot be completely eliminated, but the amount of time the potential for problems will occur will be relatively small. Thus some type of mitigation is necessary to reduce the intensity of odors and reduce their noticeability at nearby residences. There are two recommendations for odor control:

1) use freestall dairy barns to reduce the amount of manure exposed to the elements—wind and rain; and
2) use an anaerobic (airtight) manure treatment system to confine the manure until putrescent material is degraded; it is this material which releases gases causing odors.

Experience shows that where this type of manure management is used, odors can be minimized at the distances involved at the site.

Another approach is to consider the waste treatment facilities siting standards. For example, City and County of Honolulu, Division of Wastewater Management Design Standards recommends that treatment plants be located at least 1/4 mile (1,320 feet) from inhabited areas, and effluent disposal at least 1,000 feet from a drinking source. Other guidelines (Metcalf & Eddy 1991) for odor control considerations include 500 feet separation for advanced treatment lagoons and land disposal areas, and 1,000 feet from aerated lagoons.

Other sources of odors and dust are the nearby farms that use manure to cultivate crops. These odors can be minimized by applying composted manure products during dry periods, and avoiding days with unfavorable wind conditions.

Although existing agricultural use at these sites will be protected by the *Hawaii Right To Farm Act* (Chapter 165, Hawaii Revised Statutes), which protects farming operations from nuisance complaints when nonagricultural uses extend into agricultural areas, the problem will require farms and the communities to cooperate in order to maintain agriculture as a major sector of the Hawai'i economy.

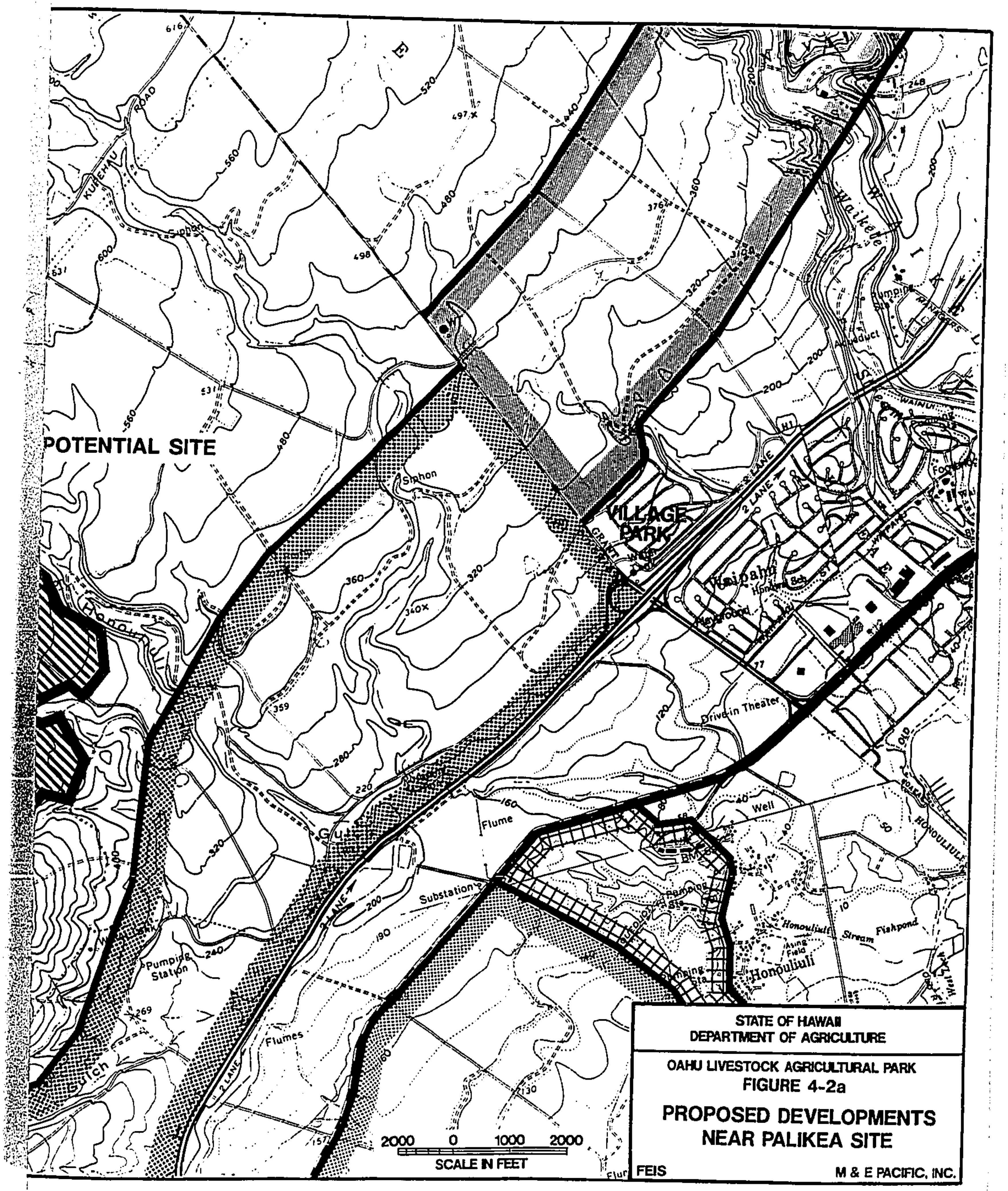
H. Effects On Environmentally Sensitive Areas

Floodplains

Palikea Uplands Site. As discussed earlier (Floodplains, Section III1.D.4), the floodplains in the site are narrow, depths are shallow, and these areas can be avoided in the location of agricultural activities. Existing farm roads crossing the floodplains can be used to the maximum extent possible to avoid exposing new construction to flood hazard. Any utilities crossing these floodplains can either be buried or elevated according to prevailing design standards to reduce the exposure to damage. No adverse impact on either the height or extent of flooding is expected due to the proposed agricultural activities.

Kahuku Agricultural Park Site. Floodplains in the *mauka* portions of the site are narrow and do not restrict use of the majority of the site. However, floodplains in the *makai* portion are extensive and restrict uses of that portion of the site for livestock agriculture. Uses in the flood zone include forage or crop production, drainage improvements and sediment control structures, and buffers between the livestock park and other uses.

The conceptual site plan for the use of the site identifies the area to be reserved for waste management and storm water control structures. To mitigate potential adverse effects of storm runoff due to the project, a detention reservoir will be constructed. This will confine runoff from dairies and waste treatment areas during a 25-year, 24-hour storm. The impact of increased impervious areas, e.g., dairy barns, roads, and other paved areas is considered. For storms exceeding the design, the reservoir will still reduce storm water discharge magnitude below levels without the project, but it will not eliminate all storm water discharge. Furthermore, the tributary area of the project is relatively small in comparison to the total tributary area that drains into Mālaekahana, 'Ōhi'a, and Kea'aulu gulches. Therefore existing flood hazards will continue, and this project will not supplant the need for other flood control measures that have been proposed for Kahuku.



STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

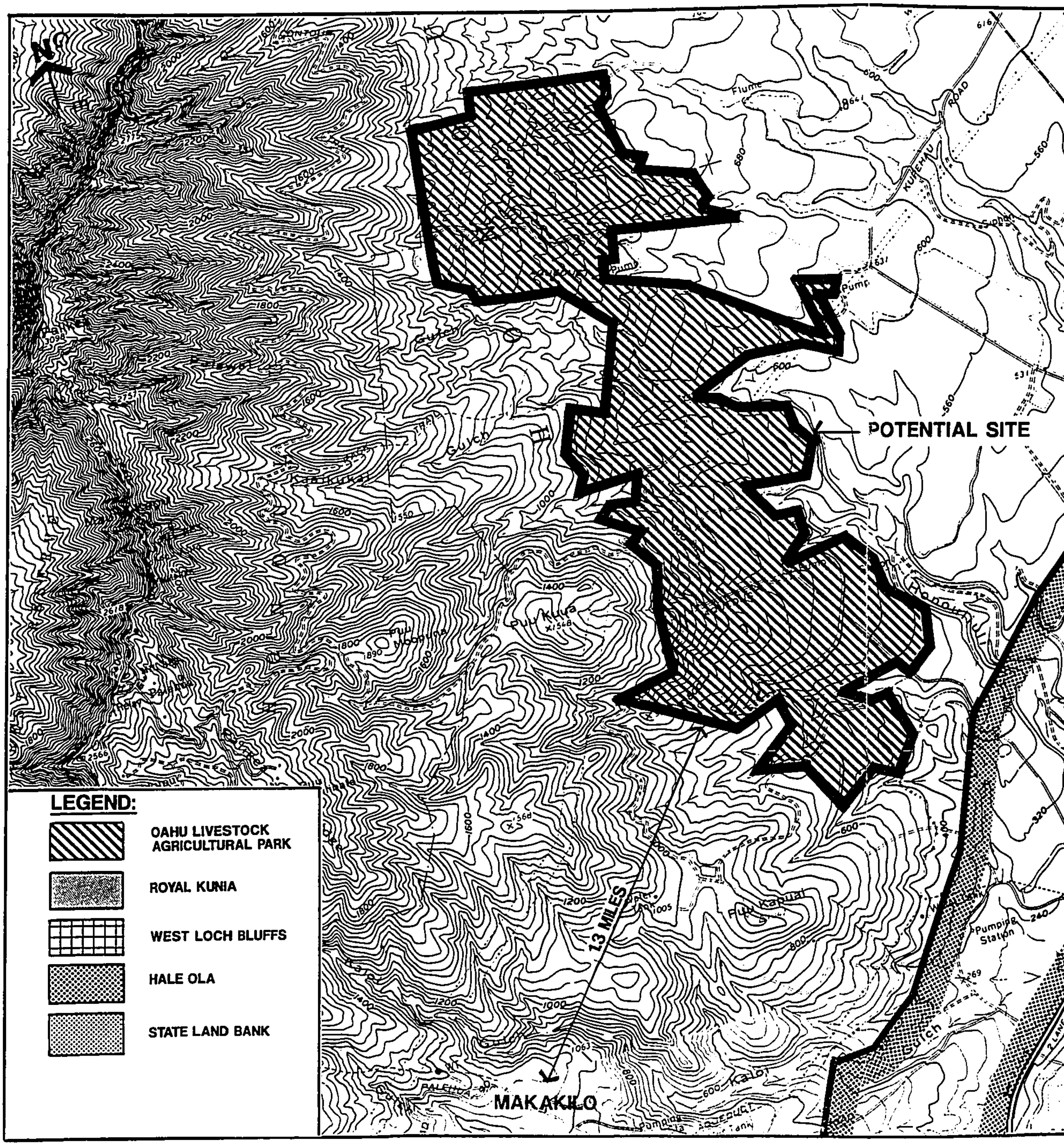
OAHU LIVESTOCK AGRICULTURAL PARK

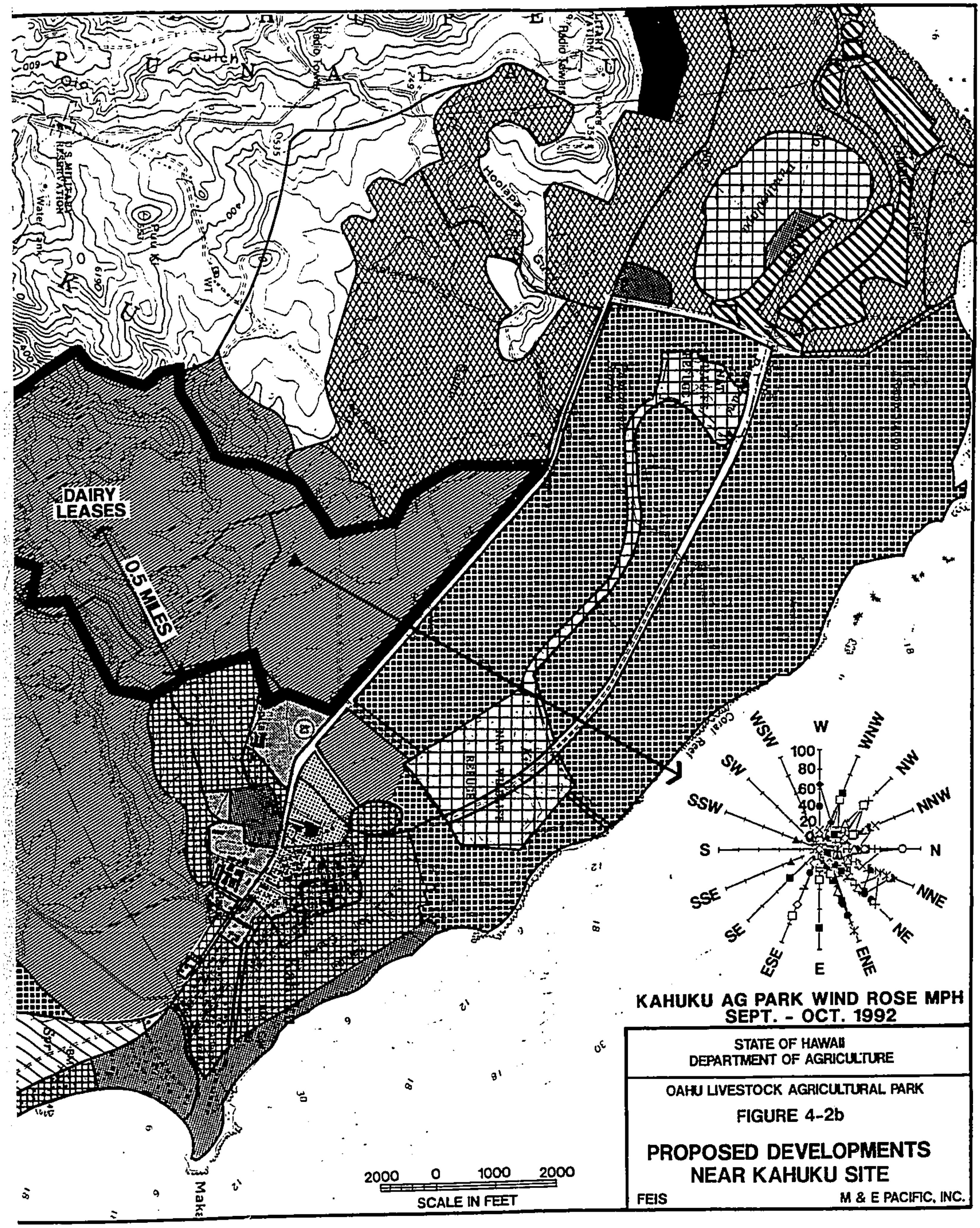
FIGURE 4-2a

PROPOSED DEVELOPMENTS NEAR PALIKEA SITE

FEIS

M & E PACIFIC, INC.


N
POTENTIAL SITE
13 MILES
MAKAKILO
Puu Kuua
Puu Kapuai
Pumping Station
KUNIA ROAD
Flume
Pump
Gulch
LEGEND:
OAHU LIVESTOCK AGRICULTURAL PARK
ROYAL KUNIA
WEST LOCH BLUFFS
HALE OLA
STATE LAND BANK



KAHUKU AG PARK WIND ROSE MPH
SEPT. - OCT. 1992

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

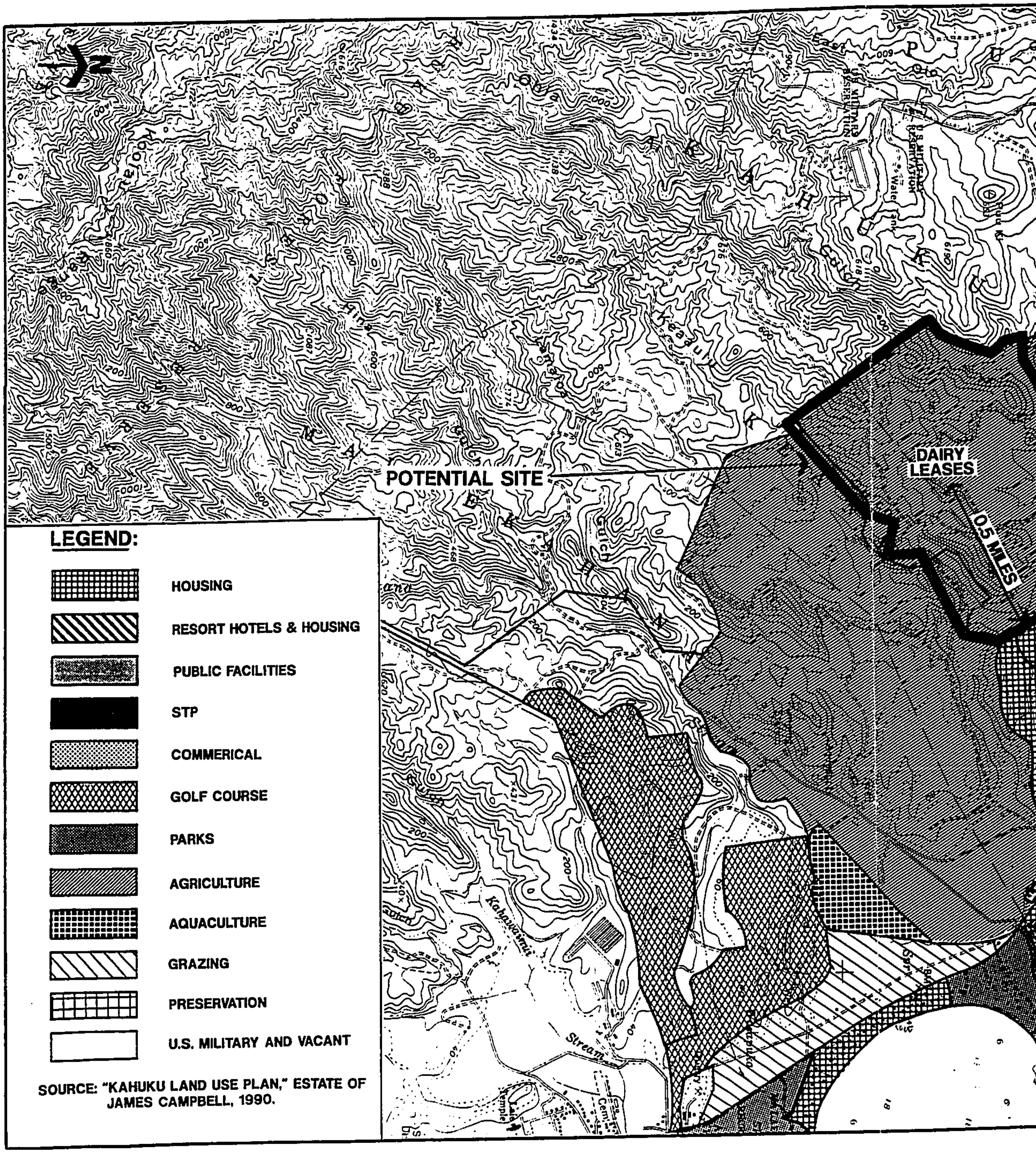
OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE 4-2b

PROPOSED DEVELOPMENTS NEAR KAHUKU SITE

FEIS

M & E PACIFIC, INC.



SOURCE: "KAHUKU LAND USE PLAN," ESTATE OF JAMES CAMPBELL, 1990.

Aquifers

The health considerations in terms of contamination of ground water quality have already been discussed and will not be repeated except for the quantitative consideration of whether the proposed activities will significantly reduce recharge of the aquifer.

The amount of natural recharge for the total area represented by each potential site is minor compared to recharge from high level aquifer sectors. Annual effective infiltration at the potential sites is negative if one subtracts annual evapotranspiration from annual rainfall indicating the low recharge potential. Of course, heavy rains will saturate the soil, and therefore, some percolation will always occur. However, except for relatively impermeable surfaces (roofs of dairy barns and unpaved exercise lots), the changes to net recharge are insignificant. Most of the site will remain unpaved, and in vegetative cover.

Wetlands

The runoff from the site may reach coastal wetland areas. The federally-managed Honouliuli National Wildlife Refuge near Palikea and James Campbell National Wildlife Refuge near Kahuku are sustained by artesian wells and springs to maintain water levels. In addition, other wetlands not within the refuges receive water from the aquifer and surface streams. The considerations for these wetlands are sediment transport, nutrients, dissolved oxygen, and pathogens previously discussed in various sections of this assessment.

The keys to minimizing negative effect on these wetlands are collection and treatment of concentrated animal waste, management of grazing areas to prevent soil erosion from becoming a hazard, and the reduction of soil transport by constructing structures to trap sediment that does materialize. Erosion control management can reduce adverse water quality impacts.

Organic chemicals, such as insecticides, are not used for pasture cultivation, and therefore are not significant constituents in runoff from the dairy operations. Insecticides and herbicides are used by Kahuku Farmers Association and it is incumbent upon the existing lessees to use these chemicals in accordance with the manufacturer's instructions and best management practice.

Disinfectants are used to sterilize milk tanks in the milk parlors. Milk parlor wash water and animal wastes will be collected by the waste treatment system. These chemicals will degrade in the treatment process.

Water supply at the Kahuku site from existing wells will require additional pumping from the aquifer. While this additional withdrawal will not exceed the average one mgd indicated in the environmental impact statement of the Kahuku Agricultural Park (1984), it will be different than the existing condition in which no withdrawal is currently made by State-owned pumps. Artesian water conditions supply water to the wetlands, and in particular, the Ki'i Unit of the James Campbell National Wildlife Refuge. Additional withdrawal (above presently experienced) will lower potential water surface elevations, i.e., hydraulic head, in the aquifer. The extent that the lower head results in less flow to the wetland is estimated in Appendix G. The conclusion of this appendix is that additional pumpage, approximately one million gallons per day (mgd) declared use for the State agricultural park, in addition to existing use of up to one mgd by the Kahuku Farmers Association (total, 1.98 mgd), will increase the time required to fill the ponds in the Ki'i Unit. The significance of the effect is an unresolved issue.

Endangered Species

Endangered flora or fauna have not been identified at either potential site. Downstream of the sites, at the wildlife refuges, four endangered Hawaiian water birds nest. These are the Common Moorhen, *Gallinula chloropus sandvicensis*; American Coot or Hawaiian Coot, *Fulica americana alai*; Black-Necked Stilt, *Himantopus mexicanus knudseni*; and Koloa Duck, *Anas wyvilliana*. In addition, numerous other avian wildlife are supported at these refuges.

The possibility exists, but cannot be accurately quantified at this time, that some birds may migrate to constructed wetlands (such as waste treatment lagoons) that may be developed at the site. The possibility is speculation at present, but as a precaution, the U.S. Fish and Wildlife Service will be consulted during the planning and design of waste management facilities to mitigate potential adverse effects.

III. SUMMARY OF PROBABLE ADVERSE ENVIRONMENTAL EFFECTS

Summary of Subsection III. **This section, being relatively short and important, is left in its entirety for the reader.**

The previous subsection reviewed and discussed major impact categories. It is concluded that the major adverse environmental affects are expected to be related to storm runoff impact on beneficial uses of surface water downstream of the potential sites. The principal receiving water body at greatest risk of exceeding standards for protecting beneficial uses are the marine waters. The primary considerations are suspended sediment due to soil erosion, pathogens, and nutrient concentrations added from storm runoff. Beneficial uses, recreation, waterbird habitat management, and fishing will continue to be debilitated after major storms. Storm water control is identified to reduce the potential for major adverse effects.

Additional withdrawal of water for the agricultural park from the wells in Pump Station No. 1 drilled in the basal aquifer will probably affect the discharge of artesian well water in the Ki'i Unit of the James Campbell National Wildlife Refuge. These sources are separated by a distance of 2,700 feet. What is critical is that the wetland wells are not pumped; natural artesian pressure creates the discharge. The reduction in this pressure, by virtue of additional pumpage, means larger lead times will be needed to manage pond levels. The significance of this effect is an unresolved issue. It could require as yet unidentified additional mitigation measures.

The acquisition and development of the site will result in continued agricultural use which will continue to have these effects, some of which will be intermittent and relatively short in duration, and others which will be continuous and with greater longevity, including:

a) dust and erosion by agricultural activities;
b) agricultural odors and flies generated by livestock operations;
c) construction of overhead electrical transmission lines, or replacement of abandoned lines along existing rights-of-way;
d) construction of drainage culverts in streams crossed by farm roads;

e) erection of fences to protect sensitive conservation areas from grazing cattle, promote intensive grazing land management, and restrict unauthorized access; and

f) vehicular traffic into and exiting the project (these effects are considered in greater detail in Appendix K, "Traffic Assessment").

The significance of the potential odor problem is an unresolved issue. However, it is recommended that measures be instituted now during planning and design of the facility to reduce this problem to negligible levels. There are two significant (and costly) steps:

1) require all dairy operators to construct freestall barns and adopt manure management practices; and
2) provide for centralized anaerobic treatment of manure to stabilize wastes and reduce the amount and intensity of odor generation.

The application of treated manure to agricultural areas in the vicinity of the dairy operations has been evaluated relative to risks inherent to ground water resources. The conclusion is that the substitution of manure for chemical fertilizer, when applied at recommended rates, does not pose a significant risk to drinking water. The existing quality of water at the Kahuku Agricultural Park meets the safe drinking water standards. The potential to degrade this quality if highly contaminated water percolates directly into the recharge zone of water sources is remote, but cannot be guaranteed with 100-percent certainty. Knowledge about preferential movement of soil and ground water between the site and nearby wells is unavailable. Thus as a precaution it is recommended that a backup source of drinking water for community use be provided.

SECTION FIVE - POTENTIAL MITIGATION MEASURES AND MONITORING

Summary of Section Five. **Potential mitigation measures are categorized as being on-site or off-site. On-site measures are to reduce impacts on surface water quality and ground water resource utility. Off-site measures include monitoring of fertilizer use and effects on wetland habitat management. These unresolved issues and mitigation measures, if any, are to be determined.**

I. On-site Mitigation Measures

Surface Water Quality. On-site mitigation will be used to reduce erosion hazards, particularly from sloping areas used for grazing. The recommended measures include:

a) intensive grazing land management;
b) structural measures;
c) land use controls; and
d) conservation practices and land treatment.

The first measure consists of supervised rotation of a portion of the dairy herds by grazing managers in paddocks where density can be closely supervised. The second measure includes sediment-detention basins, contouring improved pastures, and interception of storm runoff above site development. The U.S. Soil Conservation Service and the University of Hawaii, Cooperative Extension Service, will be consulted concerning the reduction in soil erosion and implementation of best management practices. The third measure is discussed next.

The conclusion of the erosion risk assessment in Appendix F is that grazing management is acceptable on moderate slopes; however, grazing pressure should be controlled and grazing in severely sloping areas should be avoided. There are three considerations for these controls:

1) a covenant in the lease agreement to enforce compliance by operators with respect to on-site herd replacement and allowable grazing density;

2) restrictions concerning grazing other than in permitted areas; and

3) hiring a resource manager to monitor compliance with the best management practices plan.

The site plan shows the central waste management area where rotational grazing will be permitted on the project so that runoff and erosion control can be managed.

The fourth measure will require dairies to become co-operators with the Windward Soil and Water Conservation District. This assures that a conservation plan will be prepared under direction of the SCS. Such a plan will inventory the soil and other factors for erosion control and provide an organized, detailed plan to prevent erosion, sedimentation and flooding from polluting surface water. Some land treatment measures, i.e., mulching, pasture revegetation with suitable cover crops, grassed waterways and hillside ditch terracing can be included in the lease as restrictive covenants and would be enforceable under threat of lease cancellation.

Areas subject to grading as a result of construction activities related to dairy operations and waste treatment operations will be evaluated according to the Soil and Erosion Control Standards by the City and County of Honolulu Department of Public Works to determine specific practices concerning soil erosion control. Specific details will be contained in construction documents submitted for review by City and County of Honolulu Department of Public Works to obtain grading permits.

As part of the best management practices plan, a central storm runoff confinement facility will be constructed. This will consist of an embankment for impounding runoff, a reservoir for sedimentation, a plan to reuse the water for supplemental irrigation, and an emergency spillway to pass extreme floods around the embankment.

The design storm for the reservoir confinement volume is to be a 25-year, 24-hour event. The amount to be collected and stored will be reduced by diverting *mauka* watersheds away from animal confinement areas and pastures. The on-site drainage system at each dairy will be constructed to collect rainfall coming in contact with manure on any dairy and milk parlor facility that is not part of the waste management system. Contaminated runoff will receive treatment. Some of the treated storm water may be used for irrigation.

Ground Water Resource Protection. A manure management program will be established by the Department of Agriculture. The program will consist of the following elements:

(1) soil fertility sampling of farms at the agricultural park receiving waste products for fertilizer use;

(2) monitoring the number of animals, water used, and liquid waste generated by each dairy;

(3) monitoring the acres fertilized, date, and amount applied; and

(4) existing well water sampling and testing for nitrogen, total dissolved solids, and fecal coliforms.

II. Off-site Mitigation Measures

Ground water contamination is not expected, based upon the risk assessment herein. The proposed monitoring plan to verify compliance with recommended fertilizer practice is noted above for on-site locations. The soil fertility monitoring will be expanded to off-site locations as needed, i.e., if farmers in adjacent areas adopt manure management as part of their fertilizer practice. In addition, it is proposed that monitoring of water wells near these areas be considered.

Impacts, if any, will require years to manifest. However, given the time necessary for planning, exploration, testing, and construction of new water sources, the State of Hawaii proposes to develop new ground water sources on lands acquired for this project, if located in Kahuku, or surface water sources if located in Kunia, to replace the existing sources used for potable water supply.

For Kahuku, the alternative water sources will be carried by the State as a monitor well until such time that it is clearly proven that contamination is occurring in the existing well from our project. Such certification must be presented either by the Board of Water Supply or Department of Health, or both, before the new well will be connected and dedicated to the Board of Water Supply.

For Kunia, surface water source treatment to meet drinking water standards will be constructed by the State to replace an equivalent quantity of polluted well water. Again, there must be clear indication the pollution has occurred from our project and shall be certified by either the Board of Water Supply or Department of Health, or both, before dedication will occur.

The existing sources will continue in use as irrigation sources for agricultural purposes. The new source development will be coordinated with the State of Hawaii Department of Land and Natural Resources, Department of Health, and the City and County of Honolulu Board of Water Supply.

Consultation will be continued with the U.S. Fish and Wildlife Service to determine the significance of effects upon wetlands managed for waterfowl habitat. Mitigation measures may be needed as a result of this consultation. This remains an unresolved issue.

III. Summary of Environmental Monitoring and Protection

A. Land Resources

1. Soil Conservation

a. Facility Construction. An Erosion Control Plan will be submitted with the construction drawings. This plan will reflect the project construction phasing (to be determined) and will be based on the City and County of Honolulu Erosion Control Standard.

b. Agricultural Practices. Best management practices to reduce erosion and control sedimentation during agricultural activities will be developed by each operator, with technical assistance from the Soil Conservation Service.

2. Grazing Management

The density will depend on rotational techniques, irrigation efficiency, infestations by noxious weeds and insects, and local weather patterns. Thus adjustment of the grazing density will be required from time to time. At a maximum, grazing density will be based on 1.5 acres per animal unit.

B. Water Resources

1. Ground Water

a. Manure Management. Protection of ground water resources from excessive concentration of nitrogen requires manure management practices. These practices can also improve farm productivity. The elements of the manure management plan are:

1) soil fertility testing;
2) manure fertility testing;
3) liquid injection systems for manure application or treatment, sedimentation, disinfection, and effluent irrigation.

Soil fertility testing can be done with technical assistance from county extension agents and the U.S. Soil Conservation Service. The critical parameters to test are macronutrients—nitrogen, phosphorus, and potassium. However, other micronutrients and soil salinity can be requested. Laboratory analysis can be obtained from the Agricultural Diagnostic Service Center at the University of Hawaii College of Tropical Agriculture and Human Services for a nominal fee. The results of the soil fertility tests can be used to match manure fertilizer application to crop requirements.

The fertilizer value of the manure from the waste treatment process can be updated by testing similar to soil. The fertilizer value will vary depending whether the material is liquid or solid, the age after treatment, whether it is incorporated immediately into the soil, and the animal ration to a smaller degree. Assistance with fertility testing can be obtained from University of Hawaii extension personnel.

Liquid injection systems are recommended if liquid manure slurry application is used because:

1) incorporation into the soil immediately after application reduces nitrogen loss due to ammonium volatilization;
2) there is a reduction in nuisances associated with manure on the soil, such as odors and flies; and
3) there is a reduction in risk of surface runoff stripping the manure and fertilizer from the field before planting.

b. ***Monitoring***. The following table identifies the monitoring and reporting recommended for the manure management plan.

TABLE 5.1 — RECOMMENDED MONITORING PLAN FOR GROUND WATER PROTECTION

Factor	Frequency	Agent
Soil Fertility	Annually	U.S. SCS
Animal Head Count	Monthly	Dairy Operator
Water Consumption	Monthly	Dept. of Agriculture
Manure Generation	Monthly	Dept. of Agriculture
Acres Fertilized	Monthly	Dept. of Agriculture
Existing Well Water	Quarterly	Dept. of Agriculture

2. Surface Water

a. ***Storm Water Management.*** The concept for storm water management is to confine (collect) the runoff of a design storm in order to store water for later treatment and irrigation of agricultural areas. Runoff exceeding the storage capacity of the collection works will be discharged. The magnitude of the design storm is selected to be the 25-year, 24-hour storm event. The development of this storm runoff and plans for control will be developed during design.

b. ***Soil Conservation.*** On-site mitigation will be used to reduce erosion hazards, particularly from sloping areas used for grazing. The recommended measures include:

1) intensive grazing land management;
2) land use controls.

The first measure consists of supervised rotation of a portion of the dairy herds by grazing managers in paddocks where density can be closely supervised. The U.S. Soil Conservation Service and the University of Hawaii, Cooperative Extension Service, should be consulted concerning the reduction in soil erosion and implementation of best management practices. The second measure is discussed next.

The conclusion of the erosion risk assessment in Appendix F is that grazing management is acceptable on moderate slopes; however, grazing pressure should be controlled and grazing in severely sloping areas should be avoided. There are two considerations for these controls:

1) a covenant in the lease agreement to enforce compliance by operators with respect to on-site herd replacement and allowable grazing density; and

2) restrictions concerning grazing other than in permitted areas.

SECTION SIX — DETERMINATION

***Summary of Section Six*. This section, being relatively short and very important, is left in its entirety for the reader.**

I. Discussion

The environmental affects of developing an agricultural park for livestock are reviewed in terms of the following categories:

a. irrevocable commitments of natural resources;
b. adverse effects on the economic or social welfare of the community;
c. commitments for larger actions;
d. health effects;
e. degradation of environmental quality;
f. curtailment of beneficial uses;
g. effects upon environmentally sensitive areas.

No significant effects of the proposed land acquisition and project development are anticipated relative to categories a through c and e, above. The magnitude of the risks relative to public health considerations are quantified in Appendices A, C, D, and E, relative to waterborne transmission of contaminants to ground water drinking sources, or airborne transmission to inhabited areas downwind. The risk estimated for accidental ingestion of pathogens discharged during storms to inland waters is comparable to other voluntary and involuntary risks taken by society. The approach taken to reduce these risks is to construct storm runoff confinement. The principal treatment mechanisms are sedimentation, microbial decay, and disinfection. Mitigation measures are proposed to address concerns related to health risks (ground water and surface runoff), degradation of environmental quality (odor), and will be taken depending upon the significance of effects on environmental quality.

The surface water control measures will reduce the potential impact on surface water quality which may affect downstream beneficial uses, but these will not eliminate flooding. It is impossible to provide storm water control at the site during catastrophic flooding in Kahuku. Other measures may be warranted; these should be determined in a separate study. There may also be an impact on refuge management in the Ki'i Unit of the James Campbell National Wildlife Refuge. However, long-term flood control planning for the Kahuku area may also provide options that reduce these impacts.

The best management practice to reduce the impact of surface runoff from grazing and crop land will be determined by lessees of agricultural lots. Their plans will be reviewed by the Soil Conservation Service and must be approved by the Windward Soil and Water Conservation District. Between the present time and when the project is reviewed for specific permits, additional nonpoint pollution control guidelines and criteria, as part of a coastal zone management program, may be developed by the State Department of Health.

II. Unresolved Issues

Of seven archaeological sites identified within the vicinity of the agricultural park site in Kahuku, only one remains within the area proposed for acquisition. This site (4516 AC) is at the periphery of the area proposed for diversified agricultural leases on the existing agricultural park lease. It will not be impacted by dairy operations and will be preserved in place. This is not expected to be an issue.

The mainland experience shows that properly sited and designed modern waste management systems for dairies can be operated in proximity to urban areas, even when minimal buffer space is provided. However, public perception will continue to be based upon past experiences which did not include modern management practices such as frequent collection, anaerobic covered digesters, methane collection and energy generation, composting and incorporation of treated waste immediately into crop acreage. Thus this is expected to remain an issue until a demonstration of these systems proves otherwise, and a public information program reports on the results to all concerned parties.

The potential health risk from nitrogen and viral percolation into ground water was assessed with pathway models and a ground water flow path model. The expected effects are insignificant. Ground water quality monitoring is proposed as part of this project. The development of a backup source of potable water that is agreeable to all parties remains to be resolved.

In addition, the significance of potential effects on waterfowl habitat because of effects related to artesian well discharge on the hydrologic balance and appropriate mitigation measures requires additional consultation with the U.S. Department of Interior, Fish and Wildlife Service.

In spite of the environmental assessment herein, several other topics (than those noted above) may be the subject of future discussion and reviewer's comments. In the interest of completeness, the following itemizes the other topics and the location in the environmental impact statement where the topic discussion begins:

1) attraction of endangered species to constructed wetlands—Section Four, II.H., page 206;

2) waterborne and airborne transmission of bacteria and viruses, and ground water contamination by other pollutants—Section Four, II.E., page 191; and

3) conflicts between agricultural operations perceived as nuisances by the public—Section Four, II.G., pages 200 to 202.

SECTION SEVEN — CONSULTATION PROCESS

I. Agencies and Individuals Consulted During Preparation of the Environmental Assessment

Federal

U.S. Department of Interior, Fish and Wildlife Service:
- George Fisher
- Jerry Leinecke
- Michael Silbernagel
- Andrew Yuen

U.S. Department of Agriculture, Soil Conservation Service:
- Michael Bajinting
- John Bedish
- George Love
- James Lum
- Lawrence Yamamoto

State of Hawaii

Department of Agriculture:
- Yukio Kitagawa, Chairperson, Board of Agriculture
- Robert Tsuyemura, Administrative Assistant
- Letitia Uyehara, Communications Officer
- Mitsuo Uechi, Special Assistant

Planning Development Office:
- Dr. Paul J. Schwind
- Michael Baker
- Earl Yamamoto
- Dr. Fen Hunt

Division of Animal Industry:
- Dr. Calvin Lum

Division of Agricultural Resource Management:
- Paul Matsuo

Marketing Division
- Masao Hanaoka

Plant Industry Division
  Dr. Lyle Wong

Department of Land and Natural Resources:
  Division of Water and Land Development:
    Manabu Tagomori
    Edward Sakoda
    Roy Hardy

Department of Health:
  Bruce Anderson, Deputy Director for Environmental Health

  Vector Control Branch:
    James Ikeda
    Jerry Haruno

  Wastewater Branch:
    Dennis Tulang
    Chauncey Hew
    Terry Kearney
    Kevin Wood

  Drinking Water Branch:
    Thomas Arizumi
    William Wong

  Environmental Planning:
    Mary Rose Teves
    Kelvin Sunoda
    Arthur Bauckham

  NPDES Permits:
    Denis Lau
    Alec Wong

University of Hawaii:
  Department of Animal Sciences:
    Dr. C. N. Lee

  Department of Agricultural Engineering:
    Dr. P. Y. Yang

  Department of Agronomy and Soil Sciences:
    Dr. Richard Green

Water Resources Research Center:
Dr. Roger Fujioka

City and County of Honolulu

Board of Water Supply:
Ryan Adachi
Bert Kuioka
Chester Lao

Department of Housing and Community Development:
Randy Wong, Project Manger

Organizations and Individuals

Oahu Sugar Company:
William Balfour

Hawaiian Sugar Planters Association:
Dr. Robert Osgood

Mikilua Poultry Farm, Inc.:
Phyllis Shimabukuro

Bank of Hawaii:
Robert Ota (retired)

INTECH of Hawaii:
James McElvaney

Kahua Beef:
Alan Gottlieb

Mountain View Dairy:
David Wong, Jr.

Oshiro Farm:
David Oshiro

50th State Dairy Cooperative:
Gale Young

Kahuku Community Association:
Claudia de la Cruz

Kahuku Farmers' Association:
Norwood Conner

Ko'olauloa Neighborhood Board:
Harry Brown

Amorient Aqua Farm, Inc.:
Jeffrey Wallace

II. Agencies, Organizations, and Individuals Consulted During Preparation of the Environmental Impact Statement

Federal

- Department of Interior
  - Fish and Wildlife Service
  - Geological Survey

- Department of Agriculture
  - Soil Conservation Service

- Department of Defense
  - Army Corps of Engineers

- U.S. Environmental Protection Agency

State of Hawaii

- Office of the Governor
  - Office of State Planning
- Department of Accounting and General Services
- Department of Agriculture
- Department of Business, Economic Development and Tourism
  - Land Use Commission
- Department of Defense
- Department of Health
- Department of Hawaiian Home Lands
- Department of Land and Natural Resources
  - Commission on Water Resource Management
  - State Historic Preservation Office
- Department of Transportation
- Office of Environmental Quality Control
- Office of Hawaiian Affairs

- University of Hawaii
  - Environmental Center
  - Water Resources Research Center
  - College of Tropical Agriculture and Human Resources

City and County of Honolulu

Office of the Mayor
Board of Water Supply
Building Department
Department of General Planning
Department of Housing and Community Development
Department of Land Utilization
Department of Parks and Recreation
Department of Public Works
Department of Transportation Services
Police Department

Organizations

American Lung Association of Hawaii
Amorient Aqua Farm, Inc.
Ewa Plain Water Development Corporation
50th State Dairy Farmers Cooperative
Greenpeace
Hawaii Audubon Society
Hawaii Farm Bureau Federation
Hawaii's Thousand Friends
Hawaiian Electric Company
Hawaiian Sugar Planters Association
Kahuku Community Association
Kahuku Farmers Association
Ko'olauloa Neighborhood Board
Life of the Land
Oahu Sugar Company
Sierra Club, Hawaii Chapter
Sierra Club Legal Defense Fund
The Estate of James Campbell
The Hawai'i—Lā'ieikawai Association, Inc.
The Nature Conservancy of Hawaii

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Ramona Maddox
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USEFUL CONVERSIONS AND ABBREVIATIONS

Quantity	*From:* Inch-Pound Unit	*To:* SI Unit	Multiply By:
Area	square foot (ft^2) acre (ac) square mile (mi^2)	square meter (m^2) hectare (ha) square kilometer (km^2)	0.092903 0.0404687 2.589998
Density of heat flow	British Thermal Unit/square feet - hour (BTU/h times ft^2)	joule (w/m^2)	3.154591
Flow rate	gallons per minute (gpm) cubic feet per second (cfs)	liters per minute (L/m) liters per second (L/sec)	3.785412 28.317
Mass	ounce (oz)	kilogram (kg)	28.3495
Mass density	ounces per ton	milligrams/kilograms (mg/kg)	32.25
Length	inch (in) foot (ft) mile (mi)	centimeter (cm) meter (m) kilometer (km)	2.54 0.3048 1.609344
Pressure	pounds per square inch (psi)	kilograms per square centimeter	0.070307
Temperature	Degree Fahrenheit (°F)	Degree Centigrade (°c)	$t_c = (t_F - 32)/1.8$
Volume	cubic foot (ft^3) cubic yard (yd^3)	cubic meter (m^3) cubic meter (m^3)	0.028316 0.764554

Other useful conversions:

1 ac ft day x 0.3258 = million gallons per day (mgd)

pounds per square inch (psi) x 2.308 = feet of water

pounds per acre (lb/ac) x 1.12 = kilogram per hectare (kg/ha)

microns x 0.001 = millimeters (mm)

APPENDICES

APPENDIX A
NITROGEN PATHWAY ANALYSIS AND RISK ASSESSMENT

CONTENTS

FIGURES

APPENDIX A
NITROGEN PATHWAY ANALYSIS AND RISK ASSESSMENT

Humans ingest varying amounts of nitrate into their bodies every day. The amount varies with food type and exposure to water high in nitrate. In a "normal" diet, Bouchard, et al. (1992) indicate the total dietary intake is on the order of 75 milligrams nitrate per day, of which 86.4 percent is from vegetables and 2.6 percent from water. If a person were to drink water with the maximum contaminant level (MCL) of 10 mg nitrate-N/liter, their intake would increase to 250 mg nitrate per day and 70 percent of their dietary intake would be due to water consumption.

The magnitude of health risks due to high levels of nitrate in water are undecided, but the U.S. Environmental Protection Agency MCL of 10 mg-N/l in drinking water appears to greatly reduce the risk of infant methemoglobinemia. No known cases have been reported where nitrate-N concentrations were below the MCL. It is rarely seen in adults, but non-fatal cases have been reported internationally.

Protecting ground water from nitrate contamination is a complex management challenge because there are many potential sources, agricultural activities being the most usually considered as a major contributor, although nitrate is found naturally in relatively pristine ground water of the Ko'olau forest reserve.

From a national perspective, most dairy operations opt to recycle animal manure on the farm because its fertilizer value offsets their commercial fertilizer cost. Either forage or grain crops such as corn are grown, generally for silage when land is available. With management, a potential pollutant can instead be an organic fertilizer substitute for chemicals and subsidize the dairy by reducing operation costs. The nitrogen pathway analysis considers the transformation and fate of nitrogen from the animal to the environment. Mainland experience (Bouchard et al. 1992) indicates that successful manure management involves making fertilizer recommendations to growers based on site specific soils information. Mainland soils and geology, however, are different from Hawai'i. The local experience in Hawai'i relative to manure management is fundamentally different, because most dairy operations lack adequate land for crop production. Historically dairy operators have imported their forage and grain feed, and exported manure to large-scale agricultural operations for use as fertilizer. Thus if dairy operations could operate in close proximity to small-scale farms which could use organic fertilizer, **the significant health aspects related to ground water would include:**

1) the risk of ground water contamination associated with the amount of manure that is applied as fertilizer, at a regional scale of hundreds of acres; and
2) the risk that is associated with percolation of water through compacted earth dairy lots, at a site local scale of tens of acres.

Note that in the first circumstance, organic fertilizer is being substituted for chemical fertilizer.

The purpose of this appendix is to address issues as they relate to potential contamination of ground water aquifers by excessive nitrogen. The analysis is shown first for the larger-scale consideration, namely, the fertilizer application. Subsequently, the problem at the dairy lot scale is considered in the sensitivity analysis.

This risk assessment uses idealized conceptual models of the processes by which nitrogen may escape the project site and enter the environment. More robust models require significantly more data than is presently available. At this stage of the project, the focus is identifying the order of magnitude of potential affect upon ground water drinking sources. There are a number of processes involved with nitrogen transformations in the soil and migration to aquifers. Some information for this evaluation is known or can be reliably estimated based on research studies, but some of it is only qualitatively known. The possible ranges of the parameters in these processes are considered in the analysis to determine the amount by which the results may vary. Probability distributions of variables are used in a simulation procedure that varies the values it selects for a computation using the assumed distribution. A large number of calculations, generally 500, is performed for each spreadsheet in the subsequent analysis to determine the distribution of possible outcomes. The results are expressed as percentages or probabilities that concentrations of nitrogen reach calculated levels.

Conceptual Models

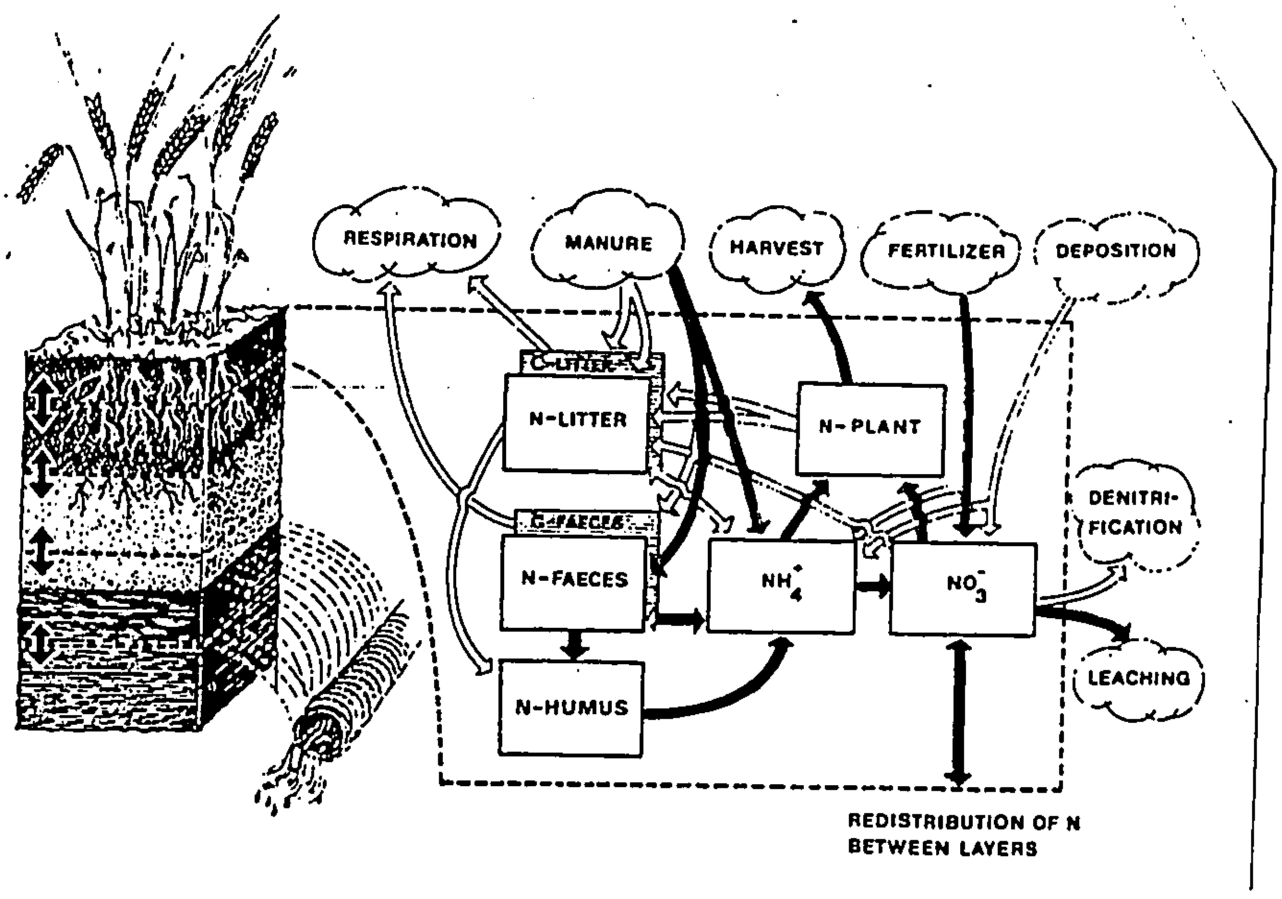
The nitrogen cycle is conceptually depicted in Figure A-1. There are numerous pathways and transformations that may occur. The major pathways that affect ground water quality are included in this analysis. Gains and losses as a result of atmospheric exchanges are not considered. Agricultural management and crop studies can provide data concerning the inputs and outputs of nitrogen relative to manure and crops (harvest and fertilizer). Denitrification and respiration (by microbes) losses are relatively minor, are between the soil and the atmosphere, and therefore can be neglected here.

The analysis consists of five submodels that consider:

1) the calculation of fertilizer values of manure,
2) the transformation of organic and mineralized nitrogen in the top layer of the soil shown in Figure A-1,
3) the infiltration of water and uptake of nutrients by plants,
4) the percolation of soluble nitrate below the root zone, and
5) the mixing of nitrate (as a conservative parameter) into the aquifer ground water body beneath the project site.

Each submodel is introduced in subsequent paragraphs along with the assumptions and conditions that are considered. Treatment and storage effects on manure are neglected. Nitrogen losses during treatment and storage depend upon whether the manure is in an aerobic state; the main consideration is the ammonium fraction that may be lost during storage. During aerobic storage the nitrogen loss can be significant—as much as 20 percent. The transformations of nitrogen in the root zone of the soil are based upon empirical model data found in the literature. Percolation beyond the root zone into the subsoil is based upon an infiltration model that considers the hydrologic budget. The nitrogen concentration in the soil that reaches the aquifer is estimated using two equations. The equations are empirical. The distributions of the equations' parameters are included in a sensitivity analysis. The equations consider the time required for transport of nitrate through the soil. One equation is based upon hydraulic dispersion terms; its parameters are estimated from laboratory studies developed for Hawaiian-aggregated soils. The other equation is taken from the U.S. Department of Agriculture model known as "CREAMS" to evaluate nonpoint pollution.

Nitrate Leaching from Arable Soils



LEGEND:

⬅ MAJOR PATHWAYS CONSIDERED IN ANALYSIS

SOURCE: JANSSON, ANTIL, BORG, "SIMULATION OF NITRATE LEACHING FROM ARABLE SOILS TREATED WITH MANURE," *NITROGEN IN ORGANIC WASTES APPLIED TO SOIL*, ACADEMIC PRESS, 1989

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE A-1

NITROGEN CYCLE

FEIS
M & E PACIFIC, INC.

The results of these empirical models are compared to field data collected at the University of Hawaii Agricultural Experiment Station at Waiale'e. Soils are similar to the Kahuku site. Sampling results are shown from an experiment in which cow manure was applied to a one-acre paddock of California grass. Infiltration was measured in the field. Residual nitrate concentrations in soil samples were analyzed. The results, when combined with other field measurements of the mechanisms for nitrate transformation and migration, provide an independent comparison of the empirical submodels.

The soil submodel is coupled with an aquifer mixing model to estimate the resulting concentrations in spring outflow. The mixing model has been used in a previous study (Sunn. Low, Tom, and Hara 1971) to evaluate the affect of waste water application to agricultural land in the O'ahu central plain.

Dairy Manure Fertilizer Submodel

The goal of manure management as it pertains to the livestock park is recycling the nitrogen and other nutrients in manure within the site. Practical experience indicates some emissions are unavoidable; their magnitude is identified in this risk assessment. The manure must be stored during the period when it cannot be applied to agricultural land to promote crop growth. During the treatment/storage phase, it will undergo transformations, i.e., there will be biological, physical, and chemical reactions; those that affect the nitrogen content in the soil after it is applied are of interest here.

The assumptions for this submodel include:

1) the nitrogen content of the dairy animals is based on American Society of Agricultural Engineers standards;
2) the transformations of nitrogen are equal to those observed by Besson, et al. (1986) in studies of farm operations; and
3) the nitrogen uptake is based on studies on grasses in Hawai'i,
4) manure application is made at a rate to satisfy fertilizer recommendations on initial planting, but subsequent fertilizer application (at recommended rate) is assumed to be a chemical product. These rates are shown in Figure A-2.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1							FIGURE A-2										
2						Dairy Manure Fertilizer Submodel											
3					Concentrations of Fertilizer Values Applied To Fields												
4							10/20/92										
5	1. Fertilizer equivalency factors:					TKN	P2O5	K2O						Remarks			
6		Based on as produced lb/ au:			Percent	0.45%	0.20%	0.35%									
7		86	1300	111.80	lb/day/au	0.503	0.224	0.391									
8		Raw manure DM prct:		13%													
9		Based on portion retained after separation:															
10						TKN	P2O5	K2O	Lb/cuFt								
11		Note: These percentages are			lb/cf Liq	0.229	0.13	0.28	62								
12		based on Agway lab data			lb/cf Solid	0.105	0.26	0.11	45								
13																	
14						TKN	P2O5	K2O		Triple 16				TKN for Agway sample tested at 3800 ppm			
15		Assume perct solid in separated			lb/lb liquid	0.37%	0.21%	0.42%						after liquid/solid sep; after 3 mos storage- 3000 ppm			
16		Liquid manure:		6%	lb/lb solid	0.23%	0.58%	0.24%		16.00%				Equivalent to 0.38% & 0.3% respectively			
17		Solid manure:		30%													
18																	
19	2. Target Fertilizer Application Rates																
20			Months till				lb/ac							Based on Hawaii Coop. Extension Ser.			
21	Crop	Season (mo)	2nd Appl	Mo/ Yield	Initial N	2nd N	Initial P2O5	2nd P2O5	Initial K2O	2nd K2O	Fert cycle/yr			Home Garden Vegetables Series			
22	Banana	60.0	4.0	12.0	96	96	48	48	192	192	1.0			Commodity Fact Sheet BA-3(A)			
23	Eggplant	6.0	1.0	6.0	65	65	196	130	65	65	2.0			Home Garden Vegetable Series No.13			
24	Watermelon	3.0	1.0	3.0	100	100	225	225	100	100	4.0			Commodity Fact Sheet WA-3(A)			
25	Papaya	24.0	3.0	9.0	44	28	44	28	44	28	1.3			Commodity Fact Sheet PA-3(A)			
26	Corn	2.5	1.0	2.5	98	98	98	98	98	98	4.8			Home Garden Vegetable Series No.4			
27	Cucumber	2.5	1.0	2.5	100	100	225	225	100	100	4.8						
28	Snap beans	3.0	1.0	3.0	100	100	225	225	100	100	4.0						
29	Avg	14.4	1.7	5.4	86	84	152	140	100	98	2.2						
30	St Deviation	21.5	1.3	3.8	22	28	85	86	46	50	2			Application of fertilizer normal distribution			
31														with mean as shown & std dev equal to 1/3 mean			
32	3. Total Fertilizer Applied For Initial Plant Nitrogen Requirements																
33		As Liquid	As Solid	As T-16										Amount of N divided by N as percent total fertilizer			
34																	
35	(lb/ac)	23323	36918	538										Cell E29/F15,F16 or J16			
36	(gal/ac)	2915															
37	(cuft/ac)	389	615	9													
38	(ac-in)	0.11	0.17	0.00													

The biological degradation of organically-combined nitrogen in stored manure may lead to several pathways by which nitrogen content may be reduced. These depend upon the type of application. Besson, et al. (1986) have studied these transformations at a field-operation scale. They sampled manures stored under different conditions at dairies to obtain their data. Their data provides the basis for the first empirical approach here. Some nitrogen may be lost by assimilation by microbes during the production of methane. The reduction of the nitrogen to ammonia results in some loss because of the volatility of the ammonia fraction. The amount of reduction during storage is shown in the remarks in Figure A-3. The calculated result is an estimated plant available nitrogen value of 113 lb/ac.

A key parameter in this analysis is the fertilizer value of manure (expressed in terms of weight per area) used for fertilization. An animal unit is defined as the animal equivalent, based on body weight of a 1,300-pound dairy cow. Comparison of manure total kjeldahl nitrogen from different sources indicates that as a percent by weight, the nitrogen in manure is fairly constant. For example, dairy manure from several animals at the University of Hawaii Experiment Station were tested. Total nitrogen ranged generally between 3,000 to 5,000 mg/kg or 0.3 to 0.5 percent by weight. The American Society of Agricultural Engineers Standards (1991) estimate total nitrogen at 0.45 percent on a wet weight basis. In another set of samples taken from a mainland dairy that separates solids and treats the liquid by anaerobic process proposed for this project, the total nitrogen ranged between 3,000 to 3,800 mg/kg or 0.3 to 0.38 percent.

Thus the equivalent fertilizer value (to commercial chemical products) in a given quantity of manure can be predicted. The fertilizer application is based on Hawaii Cooperative Extension Service recommendations for truck crops as shown in Figure A-2.

Numerous nitrogen transformations take place in the uppermost layer of the soil profile as shown in Figure A-1. For the purposes here, the soil layer is assumed to be the plow layer, approximately 45 cm (18 inches) deep. There are several pools of nitrogen that may be mineralized—litter, faeces, and humus. Litter includes crop residue, other plant roots, and microbial mass, and is readily decomposable; humus is the more resistant decomposition product. The transformation between the pools is considered to be a first order rate process dependent upon empirical constants that are soil and climate specific. These are shown in Figure A-3. The first approach

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
39																	
40																	
41							Figure A-3										
42						Unsaturated Soil Zone Submodel											
43						Changes In Concentrations After Application											
44	1. a. Chemical Transformation of Nitrogen In Soil Surface Based On "Simplified Model"																
45						Total Nitrogen Applied As Manure								Remarks			
46							86	lb/ac						Average N Requirement For First Application			
47																	
48						After Incorporation With Soil											
49							52	lb/ac						Loss varies between 20 to 60 percent			
50														Uniform distribution assumed			
51				Organic N				Mobile N									
52				23	lb/ac			28	lb/ac					Between 50 to 60 % as NH4-N			
53														Uniform distribution assumed			
54			Mineralized N		Residual N		Volatized N		Ammon N								
55		First Year	5	20%	19	80%	7	25%	21	75%				Fraction assumed constant			
56		After 1 year	2	12%	14												
57		After 2 years	1	5%	12									Mineralized % times residual after			
58		After 3 years	0	2%	11									first year			
59		Cumulative	8														
60						Plant Available N											
61							113	lb/ac						Plant available N= Cell I55+C59+F29			
62	1. b.. Nitrogen Uptake By Plants				Conversion:	kg/sqm/mo x 0.2048 x 43560 sqft/ac = lb/ac/mo								Applied ammon. N+mineralized N+2nd chemical N			
63	Item													Assumes 100% commercial fertilizer in 2nd applica.			
64	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec				
65	Daylight,hr	10.8	11.3	11.8	12.3	12.8	13.3	13.3	12.8	12.3	11.8	11.3	10.8				
66	Days/mo	31	28	31	30	31	30	31	31	30	31	30	31				
67	N uptake	69	80	91	101	112	122	122	112	101	91	80	69	N uptake=(-0.0177+(0.00236*daylight))*0.205*43560			
68	Residual	44	33	23	12	2	-9	-9	2	12	23	33	44	plant avail N - uptake of N			
69														Cell G61-Row 67			
70	1.c. Potential Percolation N									Average Annual N Uptake, lb/ac/mo			96	Average of Row 67			
71	Avg Ann	18	lb-N/ac			20	kg-N/ha	<--- Average Monthly Residual (kg/ha) Used For Percolation Model									
72	St Dev	19	lb-N/ac			21	kg-N/ha							NO3-N=N/0.226			
73														kg N/ha=lb N/ac/0.889			
74	References:	Henry K. Gee, Edwin T. Murabayashi, & Reginald H.F. Young.															
75		Wastewater Irrigation For Alfalfa, Guinea Grass,and Papaya. 1985															
76		University of Hawaii Water Resources Research Center															
77		Technical Report No. 170.															

is a simple model (Beauchamp and Paul 1989) that considers ammonia volatilization, organic nitrogen mineralization in terms of percent of total nitrogen. The conversion coefficients are based upon reported research. The principal **assumption in the unsaturated soil zone submodel is that the fate of part of the manure nitrogen within the surface zone after transformation into nitrate species is removed by plant uptake and volatilization.** The simplified model considers: 1) removal, due to volatization, and 2) long-term mineralization. After manure is applied, nitrogen, some of which has already been mineralized (degraded from organic nitrogen) during storage, is available for assimilation by plants. The remaining organic portion may be mineralized over several years. The fate over three years is shown. Plant available nitrogen (for assimilation) including residual nitrogen mineralized in previous years is shown in Figure A-3.

The potential project sites are covered by a dense growth of grasses, guinea grass and California grass being the most predominant. The grasses are also an excellent forage plant in the early growth stage before maturation. It is assumed that these will be planted on portions of the site for pasture crop. In addition, at the Kahuku site, adjacent farms grow a variety of truck crops shown in Figure A-2. Estimates of its nitrogen uptake capacity are based on a study by Gee, et al. (1985) of wastewater irrigation at the Mililani Wastewater Treatment Facility. This study considered alfalfa, guinea grass, and papaya. A subsequent sensitivity analysis considers the effect if it is assumed no plant uptake occurs.

Another approach to calculating the nitrogen transformation and migration is to use a mechanistic approach, i.e., based on the fundamental biological and physical relationships. These can be grouped as: 1) the first order kinetic rate at which microorganisms convert hydrolyzed urea to ammonium, and then into soluble mineral nitrate, and 2) the rate at which infiltration transports the solute through the soil horizon. In this approach, the transformations are assumed to follow the theoretical equations shown in Figure A-4.

The biodegradation constants, K_1 and K_2, are determined locally from experiments. The K_1 factor is the rate constant for urea to ammonium conversion, and the K_2 factor is the rate constant from ammonium to nitrate conversion. The range of these values are shown below for soils comparable to those at the potential sites:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
78																	
79							Figure A-4										
80						Unsaturated Soil Zone Submodel											
81						Changes in Concentrations After Application								Remarks			
82	2.a. Biotransformation Model of Nitrogen in Soil Surface																
83		U= Uoexp(-K1T)															
84		NH4=(K1/(K2-K1))Uoexp(-K1T)+(((K1Uo)/(K1-K2))+NH4o)exp(-K2T)+((Uo)+(NH4o))+(NO3o))															
85		NO3=(K2/(K1-K2))(Uo)exp(-K1T)+(((K1(Uo))/(K2-K1))-(NH4o))exp(-K2T)+((Uo)+(NH4o)+(NO															
86		Where:							% TKN								
87			Uo=	Initial urea concentration, lb/ac				43	50%								
88			NO3o=	Initial nitrate concentration, lb/ac				2	5%								
89			NH4o=	Initial ammonium concentration, lb/ac				19	45%								
90			K1=	rate constant for urea, per day				1									
91			K2=	rate constant for ammonium to nitrate, per day				0.065									
92			T=	Time, days													
93																	
94		1	5	10	15	20	25	30	45	90	180	360	720				
95	U	43	0	0	0	0	0	0	0	0	0	0	0				
96	NH4	2	99	90	83	78	74	71	67	65	65	65	65				
97	NO3	19	30	39	48	51	55	58	62	64	65	65	65				
98																	
99	2.b. Plant Utilization			3.2	lb/ac-day									Based on annual average, lb/ac/mo/avg days/mo			
100														Cell M70/30.4			
101																	
102		1	5	10	15	20	25	30	45	90	180	360	720				
103	N,lb/ac	3	13	16	16	16	16	16	47	142	284	567	1134				
104	Resid,lb/ac	16	33	57	88	123	163	205	220	142	-77	-579	-1649				
105																	
106																	
107																	
108					Average Monthly Residual (kg/ha) During 90 day Period --->					(lb/ac)	121						
109										kg/ha	137						
110							Standard Deviation During 90 day Period			kg/ha	45						
111																	
112																	
113																	
114																	
115																	
116																	

The label "Time in Days" is printed in column G, above the time values in rows 94 and 102.

Soil	K_1, per day	K_2, per day	Reference
Wahiawā silty clay	0.5 to 1.5	0.03 to 1.0	Khan et al. 1986
Honouliuli silty clay		0.03 to 0.1	Abouna 1981

The range in constants varies with initial concentration of urea and lag time, i.e., the time delay observed until the nitrifying bacteria population is large enough such that a first order kinetic reaction results. A lag time of between seven to ten days occurred in the experiments in Wahiawā silty clays.

The residual concentrations predicted by the equations in Figure A-4 are higher than those in Figure A-3 (simplified model). The higher values were adopted for additional analyses because they have an empirical basis from local soils.

Infiltration Submodel

The greater the retention time of the nitrogen in the surface zone, the greater the opportunity for recycling. The driving force for percolation is the downward movement of infiltrating water. This can be rainfall or irrigation; both are considered. The major assumptions include:

1) the distribution of mean monthly rainfall at the potential project sites, can be described by a lognormal distribution such that the expected value of rainfall is equal to the mean, and standard deviation based on rainfall records;

2) the potential infiltration at the project site is based on the Talsma-Parlange equation shown on Figure A-4 (Green et al. 1982);

3) the potential pan evaporation at the project site is lognormally distributed with mean and standard deviation based on pan evaporation stations;

4) the crop coefficient for converting pan evaporation to potential evapotranspiration is assumed to be 0.8;

5) the rainfall probability on any day during the month is taken from a study of O'ahu rainfall probability (Hull and Pitko 1972).

6) the saturated hydraulic conductivity of soils at the project site is assumed to be lognormally distributed, with a mean and standard deviation based on field infiltrometer tests at the site.

Climatic data at two potential project sites are compared below:

Potential Project Site	Average Rainfall inch/year	Average Evaporation inch/year	Rainfall/ Evaporation Station Nos.
Palikea	30.3	77.3	738.1/738.4
Kahuku	64.9	78.8	899.4/908.0

At the Palikea site, rainfall station 738.1 (Oahu Sugar - Field 160) is at an elevation of 800 feet. Pan evaporation station 738.4 (Oahu Sugar - Field 155) is at an elevation of 600 feet. The potential project site lies approximately between 525 to 900 feet.

At the Kahuku site, rainfall station 899.4 is at an elevation of approximately 300 feet. Pan evaporation station 908 is at an elevation of approximately 40 feet. The potential project site lies between elevation 40 to 300 feet. The Kahuku site is considered the more critical of the two sites because of the relatively greater amount of rainfall. Therefore, the Kahuku site is considered in the infiltration and aquifer submodels.

Comparative soil data taken from the U.S. Soil Conservation Service soil survey maps is shown below:

Potential Project Site	Predominant Soil Series	Secondary Soil Series	Minor Soil Series
Palikea	Kunia Silty Clay	Lahaina/Moloka'i Silty Clays	Kolekole/Helemano Silty Clays
Kahuku	Waialua Silty Clay	Lahaina Silty Clay	Kaumalu Silty Clay/Badland

Field infiltration rates in the silty clays of the sites vary considerably depending upon moisture content. For example in the Waialua silty clays, values were observed between 1.2 and 0.03 cm/min based on ring infiltrometer tests. A wide range is considered in the evaluation. The mean value is assumed to be 0.6 cm/min and the standard deviation of possible values is assumed to be 0.5 cm/min. The distribution of possible values is assumed to be lognormal to preclude zero values.

Probability distributions for daily rainfall at the potential agricultural park sites on O'ahu are generally unavailable, but other locations (leeward and windward) are used in this analysis to obtain a distribution of daily rainfall depth. The probability of daily rainfall and the number of hours of rainfall per storm have been estimated for O'ahu (Hull and Pitko 1972). The daily rainfall may be estimated assuming the depth is proportional to the monthly rainfall depth distribution. A simulation procedure used in the analysis (see Figure A-5) samples the monthly rainfall distribution and estimates a total rainfall depth that is converted to an average hourly intensity determined by the number of hours in a particular month. The number of hours per day of rainfall, given rainfall occurs, is multiplied times this intensity to determine the daily rainfall depth. The total net rainfall percolating into the soil in each monthly period is simulated using a Monte Carlos procedure in a program named ***@RISK*** (Palisade Corporation 1991). A daily simulation is made by estimating the daily probability of rainfall assuming a binomial distribution where the probability of success (i.e., rainfall) is based on the Hull and Pitko (1972) study.

The potential infiltration is determined based on the Talsma-Parlange equation. The principal parameters are sorptivity and saturated hydraulic conductivity. Estimates of these parameters are based on ring infiltrometer studies at the Kahuku site and the Waiale'e experiment station. Similar soils occur at both potential project sites. A comparison of potential infiltration to rainfall depth is made to determine effective infiltration; ponded rainfall is assumed to become runoff. In addition, irrigation water is added to storm-generated the effective infiltration. This total depth must exceed plant requirements and evaporation to result in excess water that may percolate to deeper zones. Crop uptake requirements are accounted for by subtracting the potential evapotranspiration. Plant evapotranspiration is estimated at 0.8 times the monthly pan evaporation.

The result of the infiltration simulation is accumulated daily net infiltration which, after deducting crop requirements, is assumed to result in wetting front displacement in the saturated surface soil zone. Upward movement by evapotranspiration will offset downward, by reducing the hydraulic conductivity, but this is neglected. Consideration of this result, relative to the concentration of nitrogen at the saturated zone, means that neglecting the drying interval overestimates the travel time of the percolate and concentration of the solute because there is less time for nitrogen uptake.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
117							FIGURE A-5										
118					Surface Soil Horizon Infiltration Submodel - Kahuku Site												
119					Concentrations That Result From Infiltration Through Soil												
120							10/2/92										
121	1. Rainfall & Evaporation Data																
122	Rainfall Station = 911 Elev = 45 feet				Pan Evap Station = 908.0			Crop pan coefficient =		0.8							
123	Item													Remarks			
124	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec				
125	Days w/ rain	55%	65%	70%	65%	60%	65%	70%	75%	65%	70%	68%	70%	Taken from Hull & Pitko, 1972			
126	Rain,In/mo	6.64	4.43	5.19	3.47	2.43	1.56	2.12	2.37	1.89	3.21	4.92	5.05	Based on records at Station 911.0			
127	Std Dev	2.85	2.26	2.11	2.48	1.21	1.21	1.17	1.56	1.09	2.15	1.95	1.56	Based on records at Station 911.0			
128	Exp.Val,In	6.64	4.43	5.19	3.47	2.43	1.56	2.12	2.37	1.89	3.21	4.92	5.05	Assume lognormal distri. based on mean & std dev			
129	R Dur.hr/mo	100	78	110	88	87	50	88	81	58	80	118	119	Taken from Figure 16, Hull & Pitko, 1972			
130	I, In/hr	0.07	0.06	0.05	0.04	0.03	0.03	0.02	0.03	0.03	0.04	0.04	0.04	Average Intensity = Expect val/hours rainfall/ mo			
131	Hr/day	4.1	5.6	4.7	5.3	5.1	9.4	5.9	6.9	8.1	6.5	4.1	4.4	Equals hrs/mo x % chance daily rain / hrs/ mo - rain			
132	Evap,In/mo	4.75	5.31	6.06	5.93	8.32	8.07	8.08	8.58	7.20	5.60	5.59	4.06	Data input taken from DLNR R74			
133	St dev,In/mo	0.59	0.29	0.89	1.65	1.49	0.82	1.06	0.69	0.85	0.32	0.40	0.50	Data input taken from DLNR R74			
134	Evap,In/mo	4.75	5.31	6.06	5.93	8.32	8.07	8.08	8.58	7.20	5.60	5.59	4.06	Assigned lognormal distrib w/ mean & std dev			
135	ET,In/day	0.12	0.15	0.16	0.16	0.21	0.22	0.21	0.22	0.19	0.14	0.15	0.10	Potential ET x Crop pan coefficient / no. days/mo			
136	2. Monte Carlo simulation																
137		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec				
138	Storm P	0.55	0.65	0.7	0.65	0.6	0.65	0.7	0.75	0.65	0.7	0.68	0.7	From % chance daily rain, above			
139	Storm Model	1	1	1	1	1	1	1	1	1	1	1	1	Binomial distrib, n=1, p=probability of daily rain			
140	Ant Time,hr	19.9	18.4	19.3	18.7	18.9	14.6	18.1	17.1	15.9	17.5	19.9	19.6	Ant Time=24 hours(if no rain)+(24-hours rain/day)			
141	AT, min	1194	1104	1156	1121	1132	878	1085	1027	956	1049	1191	1177	AT,Ant time in hours x 60			
142	Ant Moist	0.40	0.41	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.40	0.40	Ant Moisture, gr/gr dry soil = 0.64*AT^-0.065			
143	Ks,cm/min	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	Hydraulic conduct., lognorm(0.6,0.5)			
144	S,cm/s^1/2	47.78	47.78	47.78	47.78	47.78	47.77	47.78	47.78	47.78	47.78	47.78	47.78	Sorptivity S=48.217-1.074*AM, based on measures			
145	P Infiltr,cm	52.15	69.81	59.65	66.49	64.30	114.34	73.55	85.02	99.00	80.54	52.82	55.47	I= S*(T)^-0.5 + 1/3*Ks*(T) + 1/9*Ks^2/(S*(T)^1.5)			
146	P Infiltr,In	20.34	27.22	23.26	25.93	25.08	44.59	28.69	33.16	38.61	31.41	20.60	21.63	Potential Infiltration (see note)			
147	Event R,In	0.27	0.32	0.22	0.21	0.14	0.29	0.14	0.20	0.26	0.26	0.17	0.19	Rainfall, In/hr * no hours/day			
148	Effective I,In	0.27	0.32	0.22	0.21	0.14	0.29	0.14	0.20	0.26	0.26	0.17	0.19	Effective Infiltration: Amount </= to potential Infilt			
149	Ponded, In	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Rainfall - Effective Infiltr			
150	Net Infiltr.,In	0.15	0.17	0.07	0.05	-0.07	0.08	-0.07	-0.02	0.07	0.12	0.02	0.08	Effective I - Pot ET			
151	Month NI,In	2.54	3.03	1.45	1.00	-1.33	1.50	-1.43	-0.46	1.38	2.53	0.49	1.76	Probability x net infilt x days per month			
152	Month R,In	4.63	6.41	4.85	4.23	2.67	5.88	3.09	4.69	5.30	5.67	3.65	4.03	Probability x rain per event x days per month			
153											Average Annual Net Infiltr., In		12.5	Note: Potential Infiltration (Row 145&146) is based on			
154												Average Annual Rainfall,In	55.1	Talsma-Parlange Eq. from Green et al 1982			
155										Ratio of Effective Infiltration To Rainfall			0.23				

Therefore if it is neglected, the calculation shows higher nitrogen concentrations in percolation water.

The available nitrogen and percolating water mix to form a concentration whose magnitude is estimated is shown in Figure A-6, part 1. This concentration decreases with more percolated water and increases with less water, assuming the applied rate of application is not changed.

Transmission Zone Submodel

The amount of water and soluble species of nitrogen (nitrate form) that may percolate is estimated in Figure A-6, parts 2 and 3. The transport of this solute through the surface horizon is attenuated by convection and dispersion phenomena. Only the uppermost soil zone is considered, the top 40 cm (16 inches) where manure mixed in the soil undergoes mineralization and losses (volatilization, assimilation, and immobilization) occur and the deeper soil and saprolite zone wherein available nitrogen is neglected. The surface root zone is assumed to be the location where potential for mass retention exists. The weathered saprolite zone which may be more than one hundred feet thick, for example in the vicinity of the Palikea site (Eyre 1987), and several hundred feet of marine sediments at Kahuku, may also have an immobilizing affect on nitrate-nitrogen migration; however, due to the possibility of larger interstitial spaces (voids, fissures, and bedding planes) in the matrix, it is assumed to have relatively less retardation. Therefore, nitrogen loss in this zone is neglected in the analysis, and therefore the analysis overstates this aspect of contaminant migration.

The advancement of the nitrate through aggregated soils, such as at the potential sites, has been found (Balasubramanian et al. 1973) to be retarded relative to the movement of water. For example, in a Moloka'i silty clay, it was found that the ratio of nitrate peak concentration movement to average pore water movement ranged from 0.33 to 0.28 depending whether the nitrate application was given time to equilibrate in the soil before irrigation (resulting in the lower ratio). Balasubramanian (et al. 1973) used a form of the dispersion equation to predict the nitrate profile in the field in comparison to laboratory measurements.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
156																	
157																	
158																	
159							FIGURE A-6										
160						Transmission Submodel - Kahuku Site											
161						Concentration of Nitrate in Percolation Water											
162							10/2/92										
163																	
164	1. Available water and nitrate for percolation (from previous spreadsheets)																
165		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Remarks			
166	Day Irr,in	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
167	Mo. Tot Irr	6.2	5.6	6.2	6.0	6.2	6.0	6.2	6.2	6.0	6.2	6.0	6.2				
168	Net Infiltr. In	2.5	3.0	1.5	1.0	-1.3	1.5	-1.4	-0.5	1.4	2.5	0.5	1.8	From Figure A-4, Row 151			
169	Tot Infil,In	8.7	8.6	7.7	7.0	4.9	7.5	4.8	5.7	7.4	8.7	6.5	8.0				
170	Tot.Infiltr,cm	22.2	21.9	19.4	17.8	12.4	19.1	12.1	14.6	18.7	22.2	16.5	20.2	(Total Net Infilt + Irrigation) x 2.54			
171	N,kg/ha	137	137	137	137	137	137	137	137	137	137	137	137	Lognorm. distr. ,mean:Cell K107,SD:CellK108			
172	Initial,mg/l	62	62	70	77	110	72	113	94	73	62	83	68	kg/ha x (1ha/10000 sqm) x (1/(0.01 x Tot Infilt, cm))			
173														x 1000 = mg/l			
174																	
175	2. Dispersion Equation Model : Cmax=CoXo(2x3.14xBxXm)^-0.5																
176		Constant parameters:		Xo, cm=	1	k,cm/min=	0.33	where k is dispersion coefficient			Soil porosity	0.4					
177		Variable parameters:		V=depth/time x soil porosity		B,cm= empirical constant=			15								
178														B is assumed lognormal dist; mean 15, st dev 10			
179		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Avg			
180	V,cm/min	1.24E-03	1.23E-03	1.09E-03	9.96E-04	6.93E-04	1.07E-03	6.78E-04	8.16E-04	1.05E-03	1.24E-03	9.23E-04	1.13E-03	1.01E-03			
181	B, cm	15	15	15	15	15	15	15	15	15	15	15	15	15			
182	Xm,cm	56	55	49	44	31	48	30	36	47	55	41	51	45			
183	Cmax,mg/l	0.9	0.9	1.0	1.2	2.0	1.1	2.1	1.6	1.1	0.9	1.3	1.0	1.3			
184																	
185	3. CREAMS Equation Model: Cmax = {((Co-Cr)/K1F)(1-exp(-K1F))+Cr}																
186		Constant parameters:		Cr, mg/l=	1	K1=	0.25	ExKn=	0.01	IA=Initial Abstraction= 10mm*porosity			4				
187		Variable Parameters:		F= Total Infiltration,mm													
188		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Avg			
189	Co, mg/l	62	62	70	77	110	72	113	94	73	62	83	68	79			
190	F,mm	222	219	194	178	124	191	121	146	187	222	165	202	181			
191	Cmax,mg/l	2.1	2.1	2.4	2.7	4.5	2.5	4.7	3.5	2.5	2.1	3.0	2.3	2.9			
192												Selected N For Aquifer Mixing,mg/l			1.3		
193												Based on Local Experience (part 2 , above)					

The maximum concentration at a selected depth x_m is estimated by the equation:

$$C_{max} = C_o x_o (2PI\, Bx_m)^{-1/2} \qquad (1)$$

where $B = 2\,k/v$

$PI = 3.14$

C_o = initial concentration

x_o = depth at which there is no nitrate

x = depth at concentration of nitrate, C, in profile

v = water velocity for a given porosity

k = dispersion coefficient

The critical parameter is B. This value is an empirical value that can vary widely; values between 5 cm and 24 cm were obtained (Balasubramanian et al. 1973) in experiments on Moloka'i silty clay treated with 100 kg-N/ha (89 lbs - N/ac).

A comparison of the estimate made with Equation (1) was made by assuming a different model of contaminant transport in Equation (2). This model is used by the U.S. Soil Conservation Service (Knisel 1980) to evaluate best management practices for manure management. The average concentration, C, during infiltration is:

$$\bar{C}_1 = ((C_o - C_R) / K_1F)(1 - \exp(-K_1F)) + C_R \qquad (2)$$

C_o = Initial concentration

C_R = Rainfall concentration

K_1 = Rate constant for downward movement
$= \frac{ExKN_1}{dPOR} = 0.25$

$ExKN_1$ = Extraction coefficient assumed to vary between 0.1 and 0.5

F = Total infiltration, cm

d = 10 mm

POR = porosity = 0.4

Figure A-6 estimates the annual average of nitrogen in downward percolating water as between 1.3 to 2.9 mg-N/l. The initial concentration as a result of the field application of manure is between 62 to 113 mg N/l assuming uptake by plants. The result of equation (2) compares within an order of magnitude of the expected value obtained by equation (1). The result based on local experiments is selected; higher values are obtained with equation (2), but these are not significantly different, and the constants require calibration, according to the author (Knisel 1980). These two methods do indicate the order of magnitude obtained from the transmission zone submodel conforms to observed experience in Hawaii, as will be discussed in the next section.

Observation of Nitrogen Under Field Conditions

In addition to numerical model estimates of nitrogen migration, an evaluation was conducted under field conditions. The intent of this evaluation is to demonstrate the order of magnitude of nitrogen concentrations that will be observed under similar conditions. The results verify that the concentration of soil nitrogen in silty clay soils with similar plant uptake will be on the order of 1 to 3 mg-N/l.

Estimates of the uptake capacity of mineralized nitrogen were made at the UH Agricultural Experiment Station at Waiale'e. The nitrogen was applied in organic form of cow manure. A one-acre pasture of California grass is considered upon which 1,350 cubic feet of cow manure was applied. The manure weighs approximately 42 tons wet. The manure had been stacked and some aerobic decomposition initiated before application. Assuming that after storage, approximately 80 percent of the original nitrogen content remains, the total nitrogen applied is approximately 350 pounds per acre. Manure was sampled and tested for nitrogen content. the total nitrogen contained in the manure varied between 3,120 to 5,120 mg/kg or 0.3 to 0.5 percent by weight. The soils at all three locations are identified (Soil Conservation Service 1972) as Waialua silty clays (WkB). Similar soils, including Waialua silty clays occur at the Kahuku site.

Only a portion of the applied nitrogen reaches the plant. Greenhouse experiments with sudan grass (Stanford, Legg, and Smith 1973) in thirty-nine soils indicated an average recovery of 85 percent of mineral nitrogen formed before and during the cropping period. However, the utilization for other crops, under field conditions is reported (India Agricultural Research Institute 1980) to be much lower. For example, utilization of applied nitrogen fertilizer is on the order of 35 to 55 percent for wheat, and in maize (corn) approximately 20 to 25 percent. The crop system and root development are factors in plant utilization rates. Thus it is of interest to see the extent what changes in the soil nitrogen occur after manuring and irrigation.

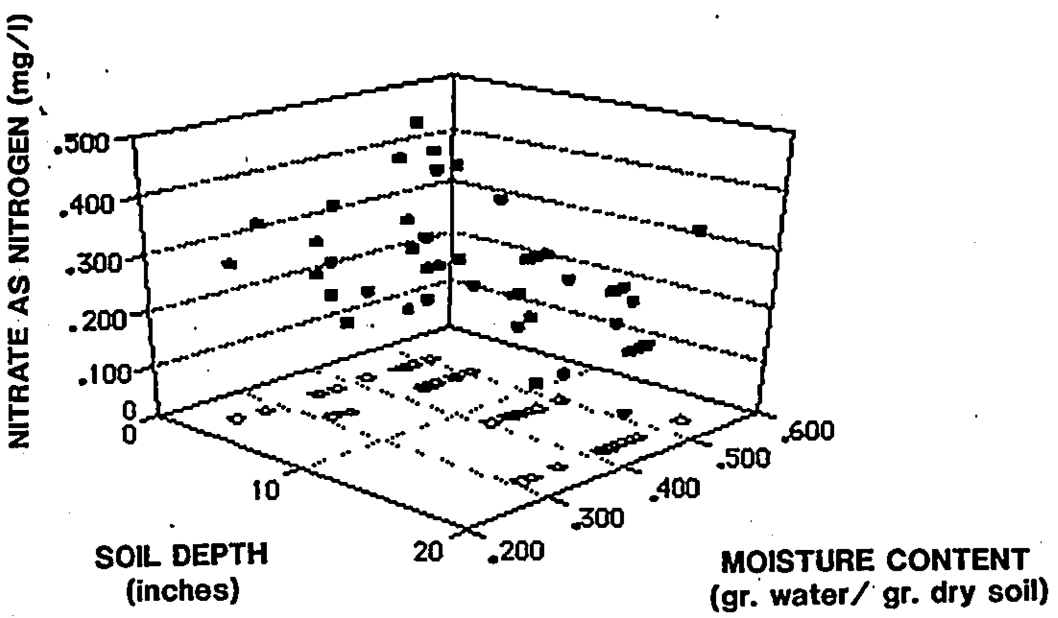
Soil cores were extracted at approximately weekly intervals beginning with initial application of manure and following a period of sprinkler irrigation. Precipitation and irrigation was measured in a rain gage on the pasture. Four samples were collected at each location: 1) at 3 inches (7.6 cm), 2) at 6 inches (15.2 cm), at 12 inches (30.5 cm), and 4) 18 inches (45.7 cm). Samples were sealed in brass containers and later analyzed for moisture content, ammonium, and nitrate. A combination of field soil fertility kit and laboratory analytical techniques was used to analyze the chemical concentrations and pH of each sample. There was no statistical difference between independent environmental laboratory and field kit analyses during each round of sampling. Moisture content was calculated after oven drying at 105 degrees centigrade for 24 hours.

The soil nitrate (as nitrogen) concentrations are shown in Figure A-7. Concentration levels are expressed in mg-N/l. The conclusion from the sample analyses is that soil nitrogen remained below 1 mg-N/l during this period. There is a slight decrease in concentration with soil depth. Approximately 12 inches of water were applied (measured) as irrigation or rainfall during this period. If the total amount of applied water (12 inches) and the fraction of nitrogen are estimated at 0.45 percent by weight, the theoretical concentration of a surface water/manure mixture is approximately 130 mg-N/l. However, not all of the nitrogen (or water) is immediately available, but this indicates the order of an upper limit on the initial nitrogen concentration.

Based on the pasture observations at Waiale'e, the amount of available nitrogen did not change significantly even with 390 kg/ha (350 lb/acre) application. Note this application is considerably greater (a factor of four times) than that assumed in Figure A-2 for manure application to crops. In experiments (Ekern and Handley 1981), California grass has been observed to linearly assimilate nitrogen up to 2,700 lb/acre (3,027 kg/ha). Optimum uptake rates for California grass and guinea grass production are estimated to be between 110 to 70 kg/ha/month (98 to 62 lb/ac/month). A typical growing season is 45 to 60 days. In comparison, total crop of corn and alfalfa removal is estimated to be 50 to 90 kg/ha.

FIGURE A-7

SOIL NITRATE (AS NITROGEN)
UNIVERSITY OF HAWAII AGRICULTURAL EXPERIMENT STATION-WAIALEE



BASED ON 48 SAMPLES TAKEN BETWEEN APRIL 1 AND APRIL 30, 1992.

In summary, soil nitrogen concentrations are on the same order of magnitude (or a little less) than those estimated in Figure A-6.

Ground Water Aquifer Mixing Submodel

A risk assessment of the possibility of ingestion of high concentrations of nitrogen in water supplied by wells must consider the mixing effect of the aquifer as water which has percolated to the basal lens migrates toward wells. A mixing model is used to quantify the potential range of concentrations that might be expected, with available data concerning the hydrologic mass balance of these aquifer systems. The Kahuku site is considered in this analysis because the larger quantity of flow through the Kunia aquifer subsystem makes the Kahuku subsystem the more critical of the two sites, and the estimated percolate concentrations are on the same order of magnitude at each site.

In terms of critical assumptions, the mixing model is the most difficult to verify in comparison to the other analyses thus far in this appendix. There are two extremes: 1) the surface percolate concentrations are assumed to be completely mixed in the basal aquifer, and 2) no mixing and no other ground water flux reaches wells. In the latter, the water's circulation through basal basalts might not completely mix the percolate migrating down from the project site with the underlying ground water flowing through the aquifer. The data to better characterize migration routes in the aquifer is presently unavailable.

As noted previously, only the surface soil horizon is assumed to retard nitrate movement in approximately 60 cm (23 inches). The sorbing of nitrogen in the fractured zone is not considered in the further development of the nitrogen pathway analysis. Fractures and bedding planes provide relatively macroscopic pore space which reduces contact between nitrate ions and the minerals ions.

The pathway of nitrogen from manure used as fertilizer, once it reaches the aquifer, is relatively unknown. It is assumed in this analysis that nitrogen acts as a conservative (nonreactive) parameter which is completely mixed by advection within the basal lens with other basal flow containing natural nitrogen input, as well as irrigation return water carrying nitrogen from other agricultural operations and urban applications that have different nitrogen concentrations.

The mixing model concept utilized here was first used for a mass balance of the agricultural application of nitrogen by sugarcane operations considered by Sunn, Low, Tom and Hara (1971). The conclusions of that study relative to the pathway analysis include:

1) based on agronomy studies, the uptake by sugarcane ranges from 25% to 35% with 80% to 90% of the amount applied remaining in the top 3 feet of the soil layer;
2) this retention is verified by the nitrate concentration in springs discharging into Pearl Harbor using the mass balance approach—a 91% retention is achieved;
3) the 91% retention includes a 14% reduction for retention from recycled irrigation water—the fraction passing through the soil layer is 23% after the first pass.

In comparison, the nitrogen amount to pass the soil layer is 16 percent, estimated by the simplified model in the pathway analysis. The amount of applied nitrogen is estimated (Figure A-3) at 86 lb/ac; the amount available after plant assimilation is estimated at 18 lb/ac (18/113 = 0.16). Note this is less than the above study, but consistent because organic fertilizer is not as readily mobile in soil water as chemical fertilizer. Return water in the 1971 study was estimated to constitute 50% of total draft, however, this amount has been probably been reduced by the conversion to drip irrigation from furrow irrigation.

The mixing model in Figure A-8 is based on the following parameters:

1) Basal ground water flow passing through the aquifer sectors is 13.4 mgd with a background nitrogen concentration of one mg/l;
2) Surface water use in the Kahuku sector is minor and can be neglected;
3) Irrigation draft in the sector is 10 mgd with a nitrogen concentration of 1.5 mg/l;
4) Irrigation return flow is based on an average fraction of 0.23 making the return approximately 2.3 mgd with a nitrogen concentration of 0.3 mg/l due to the fraction of chemical fertilizer;
5) The assumed withdrawal of the agricultural park is 2 mgd with a return of 0.5 mgd and a nitrogen concentration mean of 1.3 mg N/l; and

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
194																	
195																	
196																	
197																	
198																	
199																	
200							FIGURE A-8										
201						Aquifer Mixing Zone Submodel											
202					Concentrations Within Uniformly Mixed Aquifer												
203							10/20/92							Remarks			
204																	
205		Total Influx To Basal Aquifer=			13.4	mgd	Based on Appendix B		Qag=	2							
206		Nitrogen concentration =			1.3	mg/l	from Figure A-6 (Model 1)		r= return flow ratio		0.23			r From Cell M155			
207		Mixing Model Schematic:							k= fraction of applied nitrate percolatin			0.27		k assumed constant			
208			Qw	Qr	Qagpr	Qdr	Qd							Explanation of Mixing Model Terms			
209			0	2.2	0.5	2.3	10							Qagp= Draft from ag park wells			
210		Qb	A= QbCb +kQwCw + kQrCr + kQdrCdr + QagpCagp					Qs	Qs=Total Influx-Qag-Qd					Qb=Ground water inflow into basal level			
211		8.5		F= (1-r)Qd + Qs				1.4	Total Influx= Qb+Qw+Qr+Qagpr+Qdr					Qw= surface water recharge to aquifer			
212														Qr= Rainfall on Aquifer recharge areas			
213														Qd=Irrigation draft			
214				Term	Without Livestock Park		With Livestock Park							Qdr= Return part of irrigation draft to aquifer			
215	Concentration values in mg/l			Cb=	1		1							Cb= Concentration of ground water inflow to basal			
216				Cw=	0		0							Cw=Concentration of surface water input for irrigatio			
217				Cr=	1		1							Cr= Concentration of rain water fall on aquifer areas			
218				Cd=	1.5		1.5							Cr= Concentration in water in irrigation draft			
219				Cdr=Cdxk=	0.4		0.4							Cdr= Concentration in return water to aquifer			
220				Cagp=	0		1.3							Cagp= Concentration in percolate over ag park			
221				Cs=A/F=	1.0		1.1							Cs= Concentration in spring or artesian outflow			

6) By calculating a simple water budget, the spring outflow is on the order of 1.4 mgd.

The irrigation return flow is based upon a return flow fraction of 23 percent, based on the ratio of effective infiltration to rainfall in Figure A-5. The simulation result (Figure A-8) shows the comparison of aquifer nitrogen concentrations with and without the agricultural park input that is expected to occur in spring discharge.

The maximum contaminant level established by the U.S. EPA for nitrogen is 10 mg/l. In comparison, the expected value of the nitrogen concentration using the aquifer mixing model is shown on Figure A-9. The expected value of nitrogen with the agricultural park is 1.1 mg/l; without the project, it is 1.0 mg/l. The maximum value predicted by the model is 1.6 mg/l with the project.

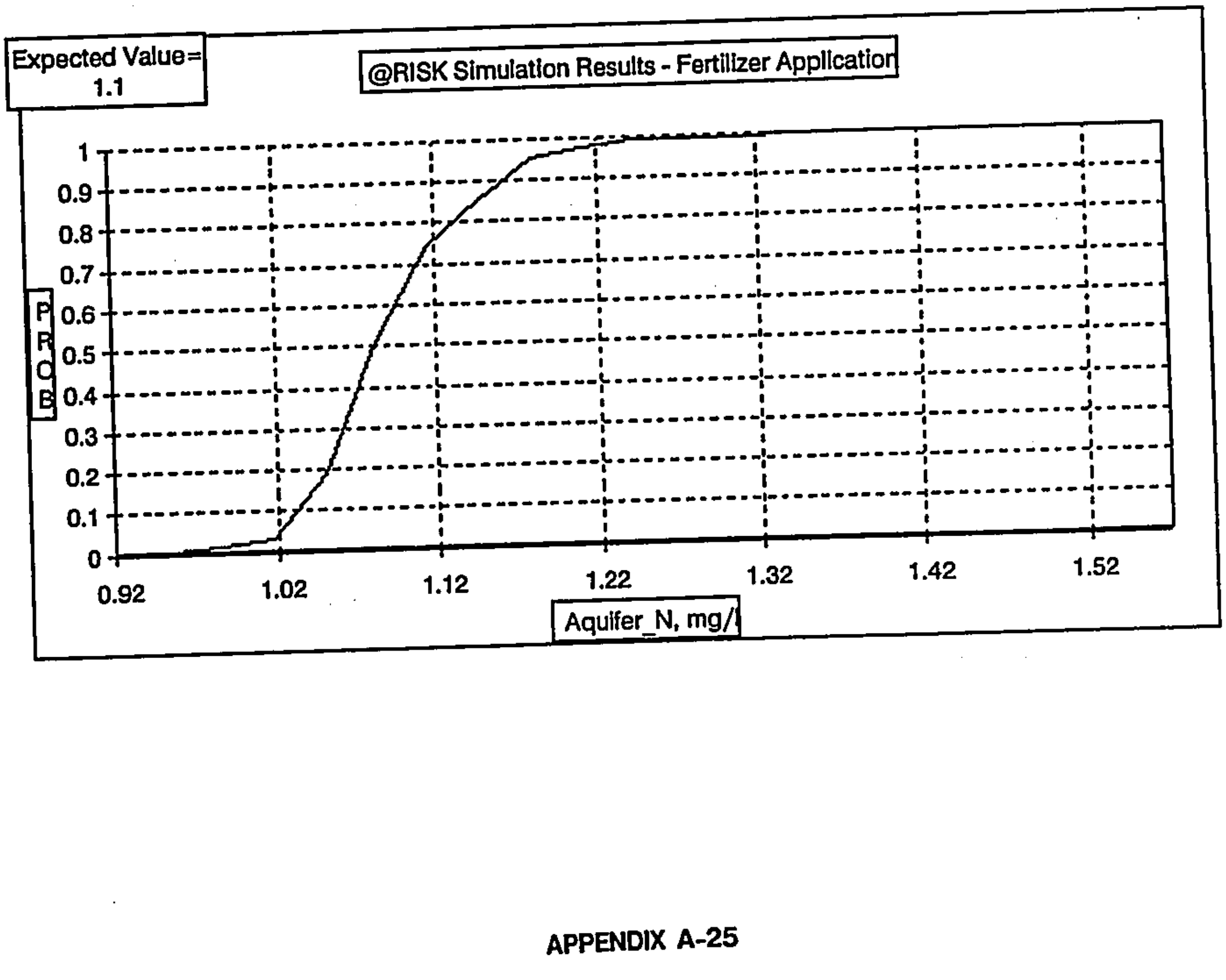
Sensitivity Analysis

There are two considerations to factor into these results. One is the sensitivity of the analysis to the uptake of nitrogen by plants (or the lack of plants where bare soil could exist). The other is the amount of mixing (or lack thereof) that could exist in the aquifer. First to be considered here is the earth lots between milk parlors and barns for dairy cows while waiting their turn for milking. The size of these areas will vary; typically less than one acre would be required depending upon the size of the herd. The consideration is what nitrate-nitrogen concentration values in the ground water might result from such concentrated operations.

Assuming a typical lot between a milk parlor and dairy barn is approximately one-fourth acre, the average density is then assumed to be 400 animals per acre. The average time an animal spends in this unsheltered area is used to estimate the manure that would not be collected in the dairy barn or milk parlor. The initial soil nitrate concentration is recomputed using the spreadsheets in Figures A-2 and A-3, neglecting any plant assimilation, and again the models in Figure A-6 are employed. The average soil surface loading is equivalent to 738 lb/ac. The percolate concentrations are estimated to range between 25 to 40 mg-N/l using equations in Part 2 and Part 3 of Figure A-6, respectively. However, the amount of water percolating at the barnyards where these animals will be standing is limited by the physical size of each dairy lot and the net infiltration. This is estimated to be 0.1 mgd.

FIGURE A-9

PROBABILITY VERSUS PREDICTED AQUIFER NITROGEN CONCENTRATION



The results of the calculations do not significantly change the outcome, the range of nitrate-nitrogen concentrations in the aquifer. It is estimated to be between 1 to 1.5 mg-N/l, based on the range of results determined by the ***@RISK*** simulation procedure, and incorporating the assumption of complete aquifer mixing.

Aquifer mixing is an uncertainty. The most critical condition conceivable is that water percolating onto the earth areas between dairy buildings flows directly into the water table and then is mixed with a small amount of basal water that constituted the entire well recharge for the BWS well near the site. The Kahuku site is considered in this analysis as the more limiting situation because of its smaller hydrologic aquifer system.

The question to be addressed now is what is the risk that the worst situation described in the preceding paragraph results in water reaching a potable well that exceeds the safe drinking water standard for nitrogen. The conditions in the spreadsheet shown in Figure A-8 are adjusted as follows:

1) the amount of percolating water above 100 acres of dairy lots is estimated to be 0.1 mgd;
2) the concentration of this water percolating from above is estimated to vary according to the random variables in the spreadsheet calculation, e.g., the average value is 25 mg-N/l, but could be as high as 100 mg-N/l and low as 10 mg-N/l;
3) the quantity of water flowing into the basal aquifer from mauka areas is assumed to be 0.5 mgd; and
4) plant uptake is neglected.

A comparison of the sensitivity analysis of water quality reaching the BWS well is shown below with the complete mixing result:

	Concentration, mg-N/l, Due to Dairy Lot Contamination	
Range	with Complete Mixing	without Mixing
Lowest Value	1.0	1
Average Value	1.4	4
Maximum Value	2.2	12

The percent of possible outcomes that are less than 10 mg-N/l is approximately 99.2 percent. In other words there is less than 1 percent chance of exceeding the MCL given what is an arguably impossible condition. The reason this is deemed impossible is because the aquifer system would have to be grossly overdrafted before the only source of recharge to the Kahuku BWS well becomes percolating surface water at the agricultural park. Consider, e.g., the present usage in wells in the vicinity:

Well No.	mgd	Remark
4057-05/16	0.4	BWS
4157-04	1.8	Amorient
4057-1/2/8	1.0	KFA
Ki'i Unit	0.5	US F&WS
Total	3.7	

The total amount of recharge to these wells which are all within one mile of each other certainly exceeds the local percolation; otherwise quality would have deteriorated in terms of chloride concentration in each well. These wells all penetrate the basal aquifer well below sea level.

In summary, expected value estimates of soil and ground water concentrations, nitrate as nitrogen in mg/l are:

	Typical Area, acres	Soil Water (before percolation)	Ground Water (aquifer mixing)
Dairy Lot	100	25.6	1.4
Field Application	400	1.3	1.1

Risk Assessment

The results of considering the range of variables and possible outcomes leads to these conclusions:

1) For regional application, manure when substituted for chemical fertilizer and applied at recommended rates poses no significant risk in terms of increasing nitrogen concentration in basal ground water resources being used for drinking water; and

2) Under the most severe well recharge conditions imaginable, the risk of contamination due to localized short-circuiting of percolating water below earth dairy lots, exceeds the safe drinking water standard is less than one percent.

There are natural factors which will alert water well users in advance of the onset of any potential contamination. Growers will experience declines in their productivity if optimum fertilizer application rates are greatly exceeded. For example, cornstalks will produce prolific numbers of ears, but each will be short and not well developed. Overdraft of the aquifer will lead to increases in chloride concentrations and similar adverse crop effects, and noticeable change in the palatability of water. The next section discusses the need for monitoring to provide feedback to resource management, to prevent abuse of the natural resource system.

Conclusions

The above analysis concludes the risk of ground water contamination due to excessive nitrogen reaching the aquifer at the project site is insignificant. Numerous assumptions concerning the processes and parameters were made to arrive at this conclusion. The range of variables was identified. The variability of parameters such as soil characteristics, rainfall, plant assimilation of nitrogen, and evaporation was considered. Where simplifications are in order, conservative values were adopted. For example, the analysis:

1) neglects denitrification losses of nitrogen to the atmosphere;
2) neglects the reduction in hydraulic conductivity during drying cycles;
3) neglects the immobilization of nitrate by deep saprolitic zones beneath the upper soil horizons and above the basalt aquifer; and
4) considers relatively large amounts of nitrogen applications.

However, the analysis does not include estimates of the effect of decomposition by plant residues, and assumes the basal aquifer is completely mixed. The latter is the more critical assumption, but determining the possibility of preferential flow in the aquifer near the site would require significant exploration and monitoring; these will be expensive. The hydraulic connectivity of the aquifer, e.g., at the Kahuku site, is an uncertainty. This study examined the worst case. There is a small chance of short-circuiting the natural treatment system.

It is inevitable that as additional information becomes available, this risk assessment may need revision. Considering the risk in terms of future trends in ground water quality, requires some additional information not presently available. These include the effects of reduction in agricultural water return flow, the increase in area converted to urban uses, particularly those where fertilizers are applied, especially golf courses, and changes in the fertilizer practices by agricultural users. For example, assuming that drip irrigation uses 75 percent of the water that furrow irrigation used, the conversion to drip has the concentrating effect of 1.33 (1/0.75=1.33). If nitrate-N concentrations ranged between 1.6 and 4 mg/l prior to the conversion in the Waipahu aquifer system, then concentrations between 2.1 and 5.3 mg-N/l could be expected considering only the reduction in applied water. There may be several explanations may be due to various factors and not a single one. A study of the source of nitrate concentrations in the Pearl Harbor aquifer is being considered by the Department of Health and the Department of Agriculture; the results of these should be followed closely.

Perhaps the most significant variable is future management practice. The application rate of manure in this analysis was considered both as fertilizer over a broad area (400 acres), and concentrated buildup in lots over a small area (100 acres). The percolate nitrogen concentration becomes critical for the latter if there is no aquifer mixing. This is not anticipated; however, the most prudent mitigation measure is to plan for the worst case and hope for the best case. The mitigation measures should therefore consider providing reserve potable water well capacity to the surrounding potable suppliers.

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APPENDIX B
GROUND WATER FLOWPATH ANALYSIS

CONTENTS

FIGURES

APPENDIX B
GROUND WATER FLOWPATH ANALYSIS

Objective

Considerations relative to ground water contamination include the potential concentration of substances reaching the ground water table, the transmission of these through the aquifer, and the risk that these substances may be consumed in drinking water. The question of the concentration of potentially harmful substances is considered in other appendices. This appendix considers the transmission phenomena, i.e., the flowpaths that are possible for ground water near the potential sites. The aspects include the capture zone of nearby wells, and the time it takes for particles to reach them. Another consideration is the potential effect of additional water withdrawal from the aquifer near the Ki'i Unit of the James Campbell Wildlife Refuge in Kahuku. Artesian wells are used to supply fresh water, and these wells' discharges are related to the artesian pressure, or potentiometric water level.

Methodology

The first step to evaluate flow direction is to determine the hydrologic budget—factors including precipitation, evapotranspiration, agricultural recharge, inter-basin flow, leakage, and withdrawals (consumption). After determining the magnitude of these factors, a two-dimensional model is used to simulate regional ground water movement. Then the potential flow paths for percolating water can be considered.

The models for estimating regional ground-water movement are based on mass balances developed for 1988 and 1990 conditions, depending upon the site. The mass balance equation is:

$$L = I - D \qquad (1)$$

where: L = leakage potential (flow to the ocean)
D = draft (pumping)
I = infiltration into aquifer = P - RO - ET + RET
P = precipitation

RO = runoff lost to the ocean
ET = evapotranspiration
RET = return irrigation water

Convenient units for these terms are million gallons per day (mgd) or inches per year.

This analysis assumes a steady state condition, i.e., it estimates long-term average potentiometric (ground water surface) levels in the aquifer, ground water flow directions, and velocities. The numerical solution for the analysis is a computerized program, FLOWPATH, which uses a finite difference calculation scheme developed to simulate two-dimensional ground water movement (Waterloo Hydrogeologic Software 1990). This model does not consider the vertical movement of water in the saturated aquifer nor the unsaturated zone above it. However, at this phase a relatively simple steady state model of continuity conditions is valuable to establish regional trends in terms of particle movement near existing wells.

The governing equation used in the FLOWPATH model for two-dimensional steady-state flow in homogeneous, saturated, anisotropic, porous media is:

$$\frac{d}{dx}\left(Tx\frac{dh}{dx}\right) + \frac{d}{dy}\left(Ty\frac{dh}{dy}\right) +/- Q(x,y) = 0 \qquad (2)$$

where:

T_x, T_y = principal components of transmissivity in x and y directions
x,y = Cartesian coordinate (grid) system
h = hydraulic head

The model, as applied to the two potential project sites, assumes an unconfined aquifer condition, and therefore the terms potentiometric surface, hydraulic head, and water table are synonymous. The sensitivity of the estimated potentiometric surface to this assumption is considered later, for a confined aquifer condition at the Kahuku site. The water balance data is used to estimate:

Q(x,y) = volumetric fluxes of sinks (-) and sources (+) per unit surface area of the aquifer.

Examples of this term include pumping wells, evapotranspiration, and infiltration.

Transmissivity is defined:

$$T_x = bK_x \qquad (3)$$

where:

K_x = hydraulic conductivity in the x direction
b = saturated aquifer thickness for unconfined aquifers

The saturated thickness is assumed to constant throughout the aquifer and equal to the 40 times the aquifer head. The aquifer head is assumed to be equal to the lowest head observed at the downstream boundary of the model during the period for which the aquifer withdrawal (pumping data) is valid. Thus the aquifer is assumed to be homogeneous in terms of thickness.

Hydraulic conductivity in equation (3) may be varied in the model to consider a different hydraulic conductivity in the y direction. Relatively little is known about the differences in horizontal conductivity (x and y directions) in these aquifer systems, although the difference in vertical hydraulic conductivity is considerably smaller, perhaps one-tenth to one-hundredth the horizontal value. However, the conductivity is assumed equal in both horizontal directions, i.e., the aquifer is assumed to be isotropic, for this analysis.

The relationship between the properties of the porous medium and ground water velocity is:

$$V_x = q_x/\theta \qquad (4)$$

where:

V_x = velocity
q_x = flow rate per unit area the x direction
θ = effective porosity

A similar equation may be written for the y direction. The effective porosity of basalts is considered to be in the range of 0.05 to 0.10 based upon other investigations. This value is also assumed constant throughout the aquifer.

Flowpath lines provide a visual representation of the ground water flow direction. The path line is equivalent with the concept of open (surface) channel stream lines, i.e., the trace of the path of individual particles, if they could be observed by a stationary observer. These flow paths are normal (perpendicular) to the potentiometric contours (lines of equal hydraulic head).

The two-dimensional characteristic equation of a path line is given by:

$$P(x,y) = p(x_o,y_o) + \text{Integral } Vdt \qquad (5)$$

where:

P = vector containing the x, y coordinates of the pathlines
$p(x_o,y_o)$ = the starting point of the pathline
V = the average linear ground water velocity
t = time

The model calculates travel time as a by-product of the path line integration of equation (5).

Limitations of Model Due to Assumptions

In summary, the assumptions that limit the results include the following:

Methodological

a. The system is assumed in a steady state equilibrium, i.e., temporal phenomena, such as short-term droughts and pumping variations, are not considered. The time increment used for calculating the budget, namely, an annual period does not describe the entire distribution of climatological variables. Infiltration occurs everywhere, even within the coastal plain, especially during prolonged monthly rainfall episodes, however annual statistical averages used to develop the data mask this fact. Steady state conditions require years to stabilize, and thus the model is an approximation of the aquifer hydraulic distribution that keeps changing depending upon climate and ground water withdrawal.

b. The model boundaries are not known with irrefutable certainty, but must be inferred based on geology, hydrologic factors, and the response of the aquifer to withdrawal conditions.

c. The fractured basal basalt rock is assumed to be isotropic, however, preferential permeability is commonly observed when conducting pumping tests in drilled wells.

d. The aquifer is considered unconfined and homogeneous, i.e., the thickness is constant. Near the caprock zone, the aquifer can be expected to thin considerably due to leakage; however, the region of interest is the unconfined basalt aquifers, and the assumption is a reasonable limitation at this time.

Data

e. The aquifer systems represented by these models are hydraulically interconnected to other systems, but the data is not available to accurately define the boundaries; thus confining the models to only those areas of immediate interest makes it necessary to approximate values such as interflow through boundaries. One implication is that the area which replenishes each pumping well may be different than portrayed by the models.

f. The time period used for the well pumping data is different from the time period used to corroborate the model hydraulic head distribution at both sites. This is because the data was collected by different investigators at different times; however, obtaining updated data is difficult because not all of the information is accessible and available to the public. The results obtained in terms of hydraulic head patterns are, nonetheless, similar in terms of other investigations (Liu et al. 1983 and Takasaki et al. 1966).

Two potential sites, Kahuku and Palikea, were evaluated in terms of ground water path line direction. A lattice of grid lines were superimposed over the region (see Figures 3-5a and b in the main text) to geometrically locate the wells, aquifer boundaries, aquifer characteristics, and the distribution of infiltration. Each site was modeled independently. The total surface area represented by the Palikea model is 18.6 square miles; for the Kahuku site, the model represents 23.7 square miles. Ground water boundaries were selected to correspond with aquifer systems or units in previous studies to facilitate the hydrologic budget analysis and comparison with previous estimates. For the Palikea site, the Kunia system boundaries were proposed by George A.L. Yuen and Associates (1988) and Takasaki, et al. (1966) proposed the Kahuku unit boundaries; thus hydrologic budget estimates can be compared.

The validity of the model was based on the degree to which previous results from other studies were reproduced in terms of the calculated steady state hydraulic head pattern. These studies were broader in geographic scope and data collection and thus were able to estimate the hydraulic head levels within a larger aquifer context. The previous ground water modeling work considered for the Pearl Harbor system (Liu, Lau, and Mink 1983) provided most of the basis for the comparison for the Palikea site, and the regional hydraulic head pattern shown by Takasaki, et al. (1966) was compared to results for the Kahuku site.

Hydrologic Budget

Hydrologic budget estimates of the Pearl Harbor sector have been prepared by Giambelluca (1983), ground water conditions and sustainable yields of the basal aquifer have been reviewed by George A.L. Yuen and Associates (1988), and the ground water resources and sustainable yield of the 'Ewa plain caprock aquifer estimated by George A.L. Yuen and Associates (1989). George A.L. Yuen and Associates (1990) reviewed the ground water and surface water resources of Windward O'ahu, and Takasaki, et al. (1966) reviewed the ground water resources of the Kahuku area. These are more exhaustive studies of the entire ground water regime than undertaken here and the reader is referred to the reference section for citations of these reports.

Palikea Site

Precipitation. Precipitation data were developed from the *Rainfall Atlas of Hawaii* (Department of Land and Natural Resources, 1986). Potential infiltration in four zones within the Palehua grid network was estimated assuming an infiltration coefficient of 0.8 multiplied times rainfall for each zone. In other words, 20 percent of total precipitation was assumed to be disposed as surface runoff. In comparison, Yuen and Associates (1989) used runoff/rainfall ratios of between 0.11 and 0.14 and 0.25 for the 'Ewa Plain and Honouliuli sectors, respectively.

Evapotranspiration. Evapotranspiration data were based on the *Pan Evaporation of the State of Hawaii* (Department of Land and Natural Resources, R74, 1985). Evapotranspiration distribution for four zones within the Palikea grid network was estimated assuming a coefficient of 0.8 multiplied by pan evaporation values for each zone. Evapotranspiration is considered approximately equal to open lake evaporation which is approximately 80 percent of pan evaporation values. Drip-irrigated sugarcane uses about 80 percent of surface pan evaporation (Department of Land and Natural Resources, R74, 1985).

Return Flow. Agricultural recharge was based on George A.L. Yuen and Associates (1988) study of the Wai'anae sector of the Pearl Harbor aquifer. The Wai'anae sector includes the 'Ewa and Kunia aquifer systems. This study estimated the return water in the Kunia/'Ewa sectors at six mgd due to the agricultural irrigation water that infiltrates into the aquifer.

Infiltration. The net recharge, or deep infiltration to the basal aquifer was estimated as the balance of the precipitation minus runoff minus evapotranspiration plus agricultural return flow. For the Palikea model, one can assume the surface recharge is negligible, because the model mass balance accounts for only for percolation deep into the aquifer water table and not vertical movement of soil moisture in the vadose zone. The values obtained from other studies indicate surface flux (flow per unit area) is on the order of 0.000 to 0.0005 cubic feet/square feet-day. Thus for the Palikea site, it can be concluded that infiltration is insignificant.

Inter-Aquifer System Flow. Flow from the Wahiawā high level aquifer sector into the Kunia/'Ewa plain sectors was estimated at 14 mgd based on George A.L. Yuen and Associates (1988) study.

Draft. Pumping well average annual 1987-1988 consumption was obtained from the Oahu Water Management Plan, Technical Reference Document (Wilson Okamoto & Associates 1990). Total daily consumption of the pumping wells included in the Kunia/'Ewa aquifer systems is estimated at approximately 15 million gallons per day (mgd). The downgradient wells, i.e., outside the boundary between Kunia and 'Ewa systems are not represented, however, in the Palikea model. Thus the total pumpage in the model is approximately 11 mgd.

Two references were used to compare the magnitude of surface recharge and interflow from hydraulically connected aquifer systems. Each reference used a different area but the surface flux, i.e., the flow rate per unit area overlying the aquifer is comparable. The hydrologic budget is summarized as follows:

PALIKEA MODEL HYDROLOGIC BUDGET

Factor	Ref (1)	Ref (2)
Rain-ET-RO	8	8
Draft	15	14
Return	6	9
Infiltration	-1	3
Interflow	14	25
Sum	13	28
Area (sq.mi.)	28.1	30.0
Aquifer Depth	40 x 14 + 14 = 574	550 + 15 = 565
Estimated Fluxes:	ft^3/ft^2 - day	ft^3/ft^2 - day
Surface[1]	0.000	0.0005
Boundary[2]	0.226	0.4110

Notes: [1] Based upon infiltration divided by area shown
[2] Based upon 14,400 feet northern boundary of Kunia system divided by depth shown

Reference (1) Yuen, George A.L., and Associates. 1988. *Review and Re-Evaluation of Groundwater Conditions in the Pearl Harbor Groundwater Control Area, Oahu, Hawaii.* Prepared for the State of Hawaii Commission on Water Resource Management, Report R-78.

Reference (2) Eyre, Paul. 1987. *Sources of Salts in the Waianae Part of the Pearl Harbor Aquifer Near Barbers Point Water Tunnel, Oahu, Hawaii.* U.S. Geological Survey Report 87-4247.

Kahuku Site

The Kahuku unit suggested by Takasaki, et al. (1966) is considered to contain areas overlain by caprock, unconfined basal basalt, and a dike-confined aquifer zone. The total area represented by the model is 23.67 square miles. The wetland area within the caprock region is considered to be the principal discharge zone. The freshwater wetlands are sustained in part by springflow and artesian wells. The hydrologic budget (not considering draft and return flow) is estimated as follows:

KAHUKU MODEL HYDROLOGIC BUDGET

Factor	Wetland	Basal basalt	Dike - confined	Unit
Rain	54	76	108	in/yr
ET	82	60	40	in/yr
Runoff	5	10	17	in/yr
Area	1.7	7.7	3.5	sq mi
Balance	-2.7	2.2	8.5	mgd
Flux	-0.008	0.0014	—	ft/ft^2 - day
	—	—	0.109	ft^3/ft^2 - day

The wetland area considered is less than the total caprock area. The remainder is considered to be poorly permeable and neither gaining nor losing recharge and considered only as it relates to well water withdrawal. The negative sign for the wetland indicates exfiltration, i.e., leakage from the aquifer. Dividing these hydrologic balances by the areas gives the surface flux for each zone in the FLOWPATH model. The boundary flux representing the dike-confined zone is based upon a length of 17,000 feet determined by the shape of the assumed boundary.

Aquifer Characteristics

Palikea Site

Hydraulic Characteristics. Hydraulic conductivity may range from less than 50 feet per day in poorly permeable caprocks sediment to over 1,000 feet per day in very permeable basalt. Variations within basalt can range one or two orders of magnitude, depending upon the type. The uncertainty of this parameter is considered to be greater in magnitude than the flux estimates. Thus the hydraulic conductivity is selected within a reasonable range that produces a likely hydraulic head pattern in the model. The hydraulic conductivity is assumed to be 400 feet per day in the Palikea model.

The thickness of the aquifer is based on the Ghyben-Herzberg relation which is a result of the relative density of fresh and sea water. Fresh water heads were multiplied by 40 and added to the fresh water head (above sea level) to estimate the fresh water lens thickness. The fresh water head at the boundary is estimated to be approximately 14 feet, and therefore, the aquifer thickness is assumed to be 574 feet (40x14+14=574).

Boundary Conditions. Flow per unit area of aquifer at the upgradient boundary is assumed on the basis of the boundary flow values determined in the hydrologic budget evaluation. After some initial simulations, the results indicated either boundary flux values shown in the previous table produced results comparable to those in previous investigations. The lower boundary flux (based upon 14 mgd from Wahiawā system) is assumed.

The model is based on a geometric grid established so that the primary flow field would be from top to bottom of the grid. Flow out of the model grid to the right or left were neglected. A constant head boundary condition was assumed at the top of the model grid to simulate the freshwater head created by the near the boundary with the Schofield high level aquifer. The Palikea model assumes a constant head at the upgradient boundary of 22 feet, mean sea level (msl).

Kahuku Site

Hydraulic Characteristics. Hydraulic conductivity in the unconfined Ko'olau windward basalts in this region appears lower than in the Wai'anae basalts. The hydraulic gradient in this unit shown by Takasaki, et al. is approximately 3 to 4 feet per mile. This is significantly greater than the gradient of 1.3 feet per mile in the Kunia/'Ewa systems (Board of Water Supply 1963). The hydraulic conductivity is selected such that the model produces a hydraulic potentiometric surface similar to that shown by Takasaki, et al. (1966) for the regional potentiometric surface in 1962. The pumpage at that time was approximately 22 mgd, but a larger proportion of irrigation draft was likely returned to the aquifer. The hydraulic conductivity for the model is assumed to be 300 feet per day in the Kahuku model. A check on this conductivity estimate was estimated from a short duration recovery test performed at the AMORIENT well. The estimated transmissivity is 396,000 gallons per day per foot which when divided by the well penetration depth and units converted, yields 265 feet per day for hydraulic conductivity.

Boundary Conditions. The dike-confined boundary flux is estimated by dividing the infiltration recharge by the length of the boundary, assumed to be 17,000 feet based on the model geometry. The dike-confined potentiometric head is assumed to be 14 feet, msl. This estimated head was made by Takasaki, et al. (1966) in their regional potentiometric surface map based upon heads reported in 1962. At that time, regional pumping draft in the Kahuku unit was approximately 22 mgd. The fresh water head at the *mauka* boundary is estimated to be approximately 615 feet, and therefore, the average aquifer thickness is assumed to be approximately 600 feet (40x15+15=615).

Potentiometric Head Gradients and Flow Velocity Fields

Palikea Site

Figure B-1 shows the FLOWPATH potentiometric (hydraulic head) surface results assuming draft is similar to 1988 data and a constant head condition at the upgradient boundary of 22 feet, msl. The location of wells and system boundaries are also shown. Note the contours "dip" on the west side of the model, just as the measured hydraulic head did in the 1963 survey of wells by the Board of Water Supply.

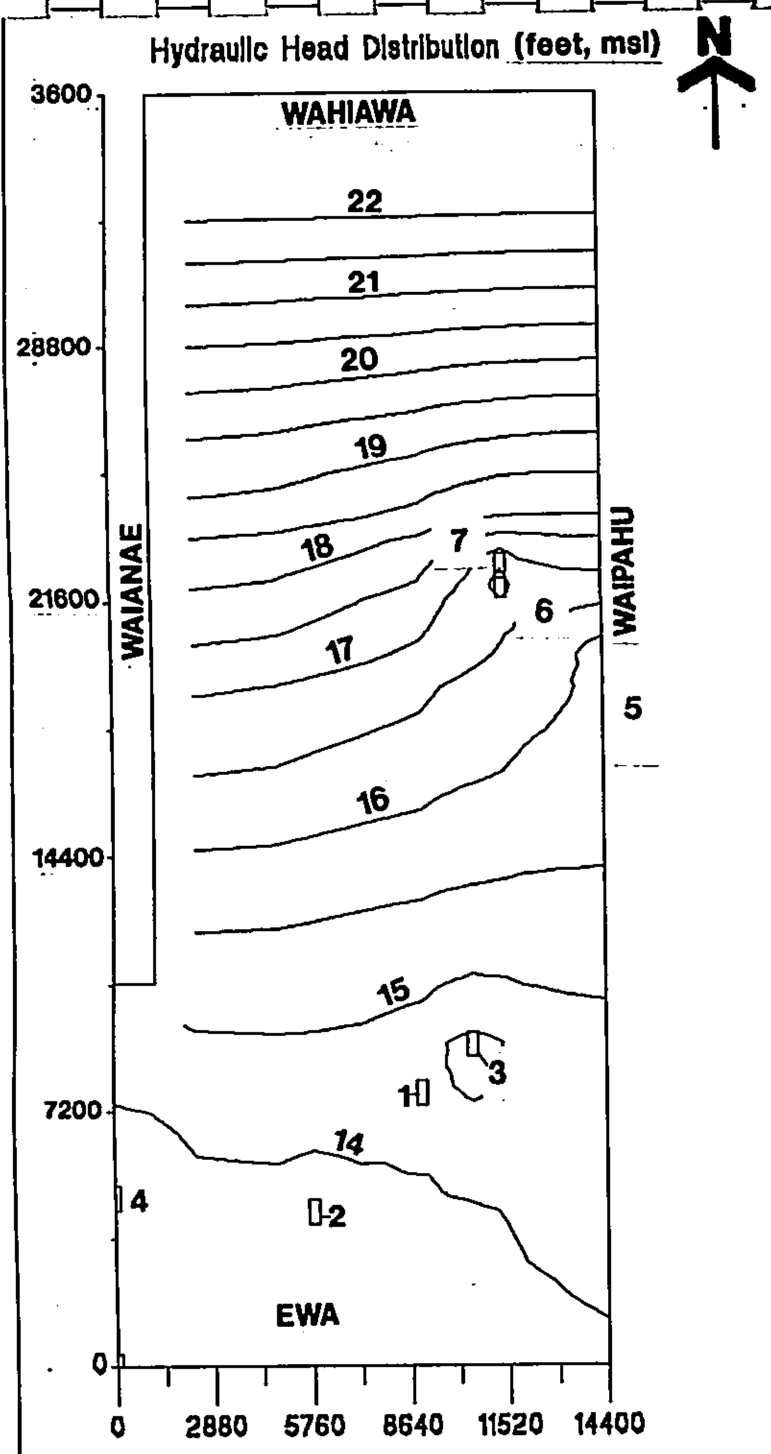
The velocity vectors through the system are shown on Figure B-2. Velocity is measured in feet per day. The average velocity is approximately 0.9 feet per day. At this rate, it takes a water particle entering the model at the north end, approximately 110 years (36,000 feet/ 0.9 ft/day/ 365 day/year = 110 years) to exit at the model, at the south end. Recall that the model does not consider local surface recharge and assumes the aquifer is isotropic and homogeneous, so the flow lines are very smooth.

Figure B-3 shows the path lines of hypothetical particle movements. Particle movement for selected wells in close proximity to the LAP site were determined by calculating the velocity and time of travel in reverse from a hypothetical circle around each well. In this manner, the "capture zone" of each of the well can be estimated. It indicates the path lines of ground water movement is from north to south in general and some water transmission beneath the Palikea site may be intercepted by the Honouliuli wells and the U.S. Navy Barbers Point well.

Kahuku Site

Figure B-4 shows the potentiometric surface results for the Kahuku site. Note the hydraulic head distribution indicates a northerly ground water to gradient. Other investigations (Takasaki et al. 1966) have shown similar trends. The influence of pumping wells is relatively modest; one-half foot drawdowns near the wells are indicated.

Figure B-5 shows the velocity vectors. Flow is from the southwest (dike-confined zone) to the north (the wetland spring discharge zone). The average water particle velocity is approximately 0.6 feet per day. Ground water velocity in the vicinity of wells is greater. For example, near wells close to the Kahuku site, velocity vectors (Figure B-5) are about 2 feet/day. Travel time beneath the site, assuming a 4,000-foot distance and 2 feet/day, is on the order of 5.5 years. Figure B-6 shows the hypothetical particle capture zones for selected wells in the Kahuku model. A portion of the ground water flow beneath the potential site may be intercepted by the wells in the vicinity.



NO.	STATE WELLS NO.	PUMPING RATE (mgd)
1	2004-01	0.1
2	2004-04	1.3
3	2103-03	2.4
4	2006-15	1.0
5	2303-02/03	2.2
6	2303-03/04	2.0
7	2303-05/06	2.0
		11.0

FIGURE B-1

PALIKEA POTENTIOMETRIC SURFACE

FLOWPATH

Copyright
1989,1990
by WHS

Steady
State
Flow

Min :
1.40E+01
Max :
2.20E+01
Inc :
5.00E-01

Units :
[ft]

File :
PALIKEA

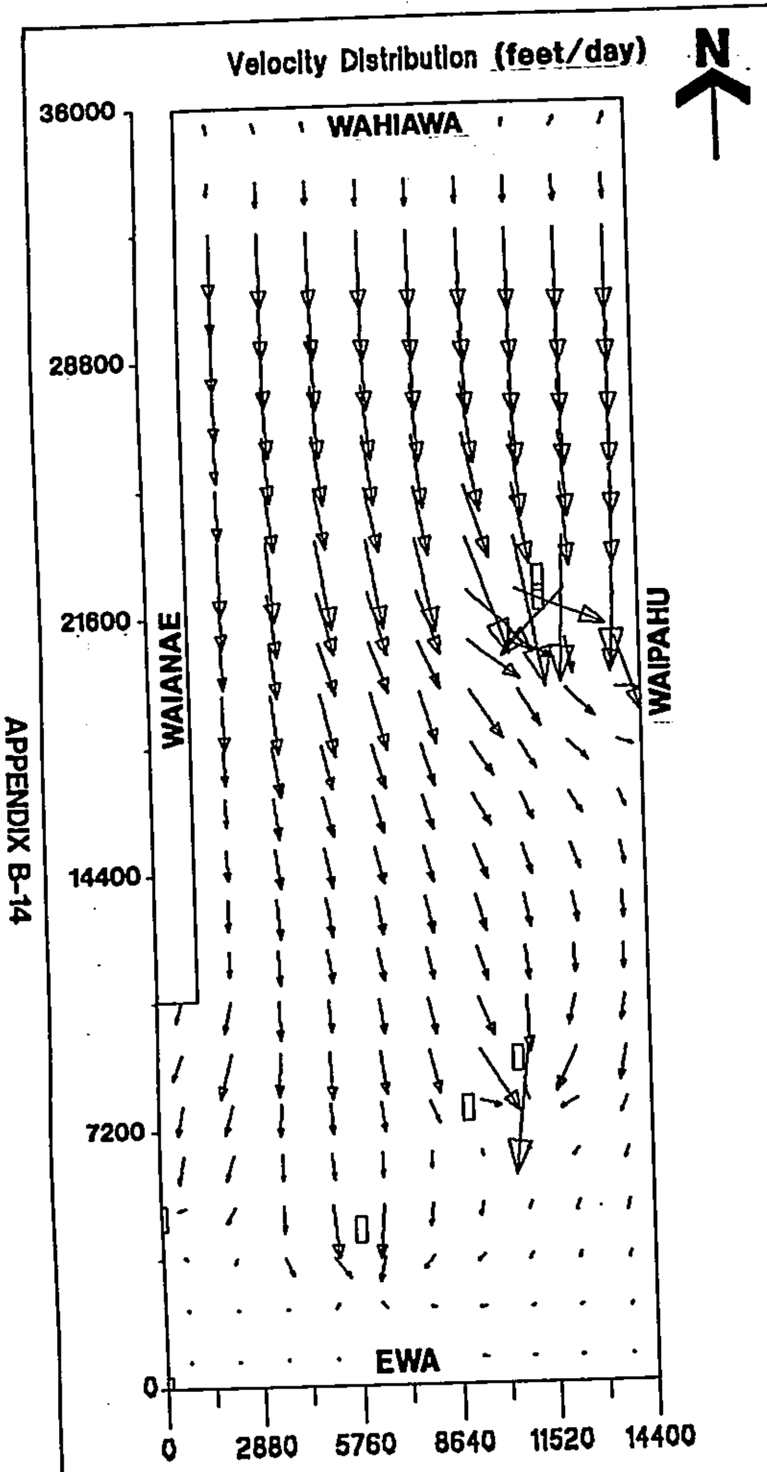


FIGURE B-2
PALIKEA VELOCITY VECTORS

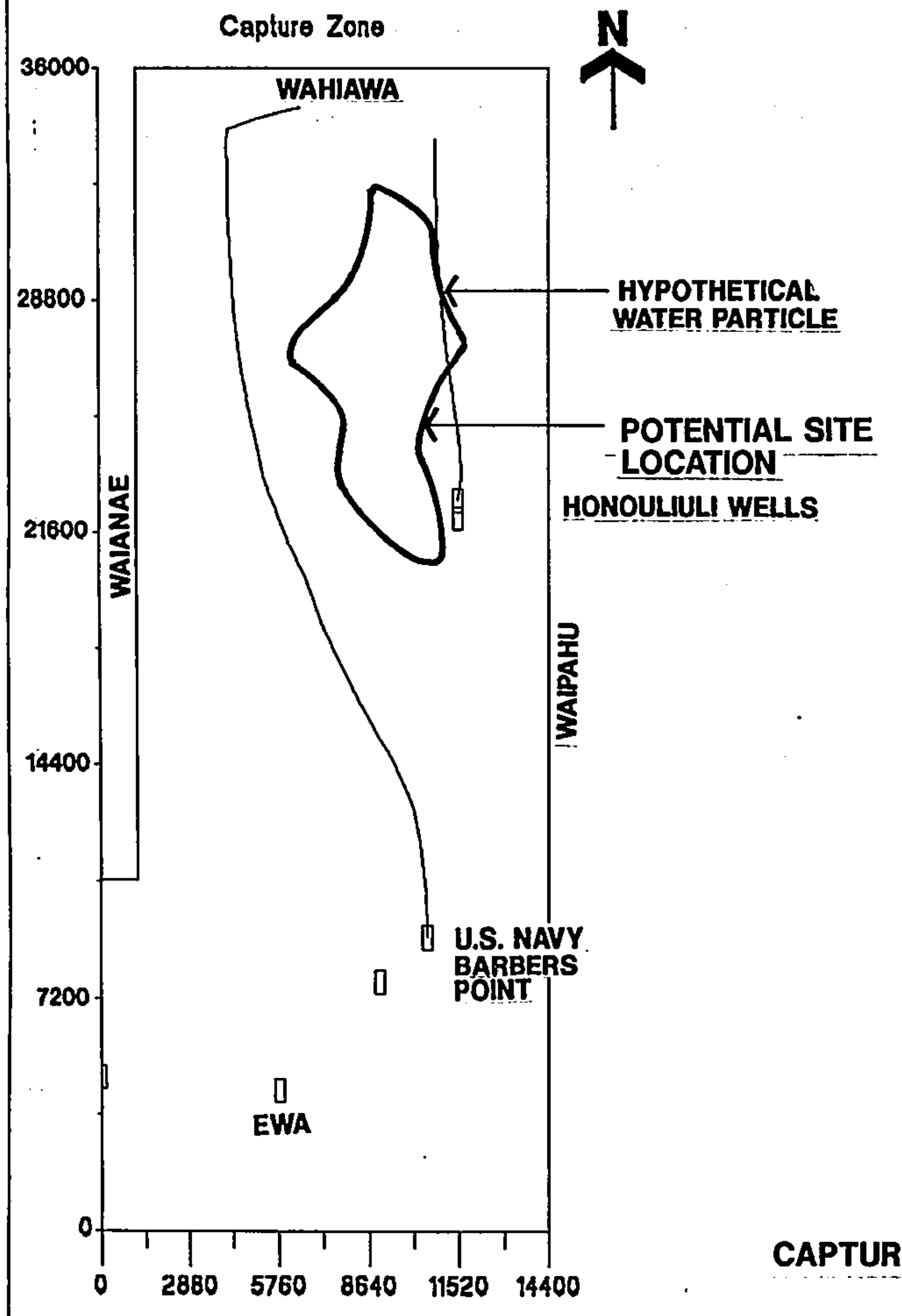
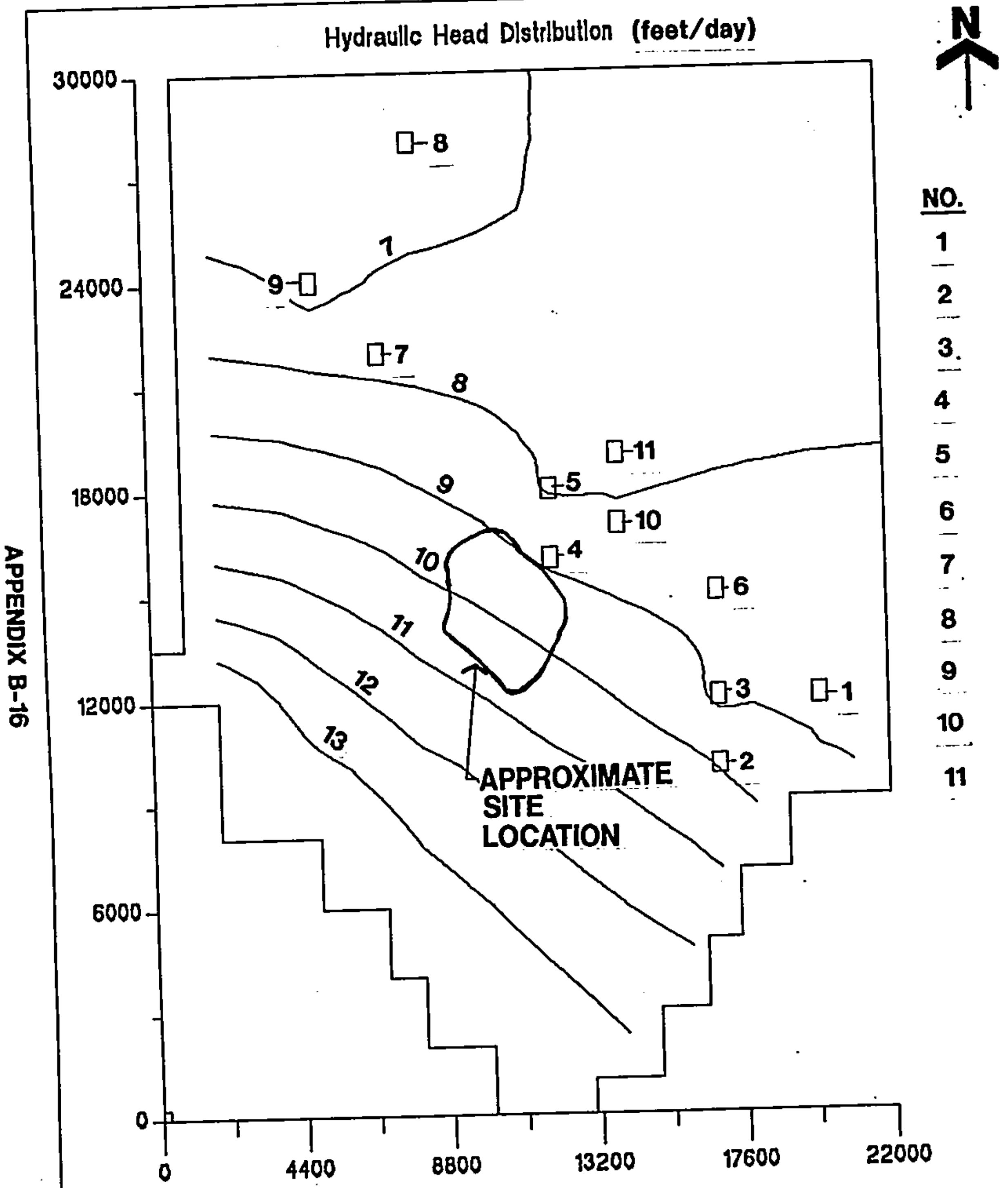


FIGURE B-3

CAPTURE ZONE FOR SELECTED WELLS



NO.	STATE WELL NO.	PUMPING RATE (mgd)
1	3956-01	0.5
2	3957-01	0.005
3.	4057-07/10	1.9
4	4057-15/16	0.43
5	4157-04	1.8
6	4057-06	0.5
7	4158-12	0.22
8	4258-04	0.003
9	4159-01	2.5
10	4057-01/02/08	1.0
11		0.5
		9.358

FIGURE B-4

KAHUKU POTENTIOMETRIC SURFACE

FLOWPATH

Copyright
1989,1990
by WHS

Steady
State
Flow

Min :
7.00E+00
Max :
1.80E+01
Inc :
1.00E+00

Units :
[ft]

File :
KAHUKU4

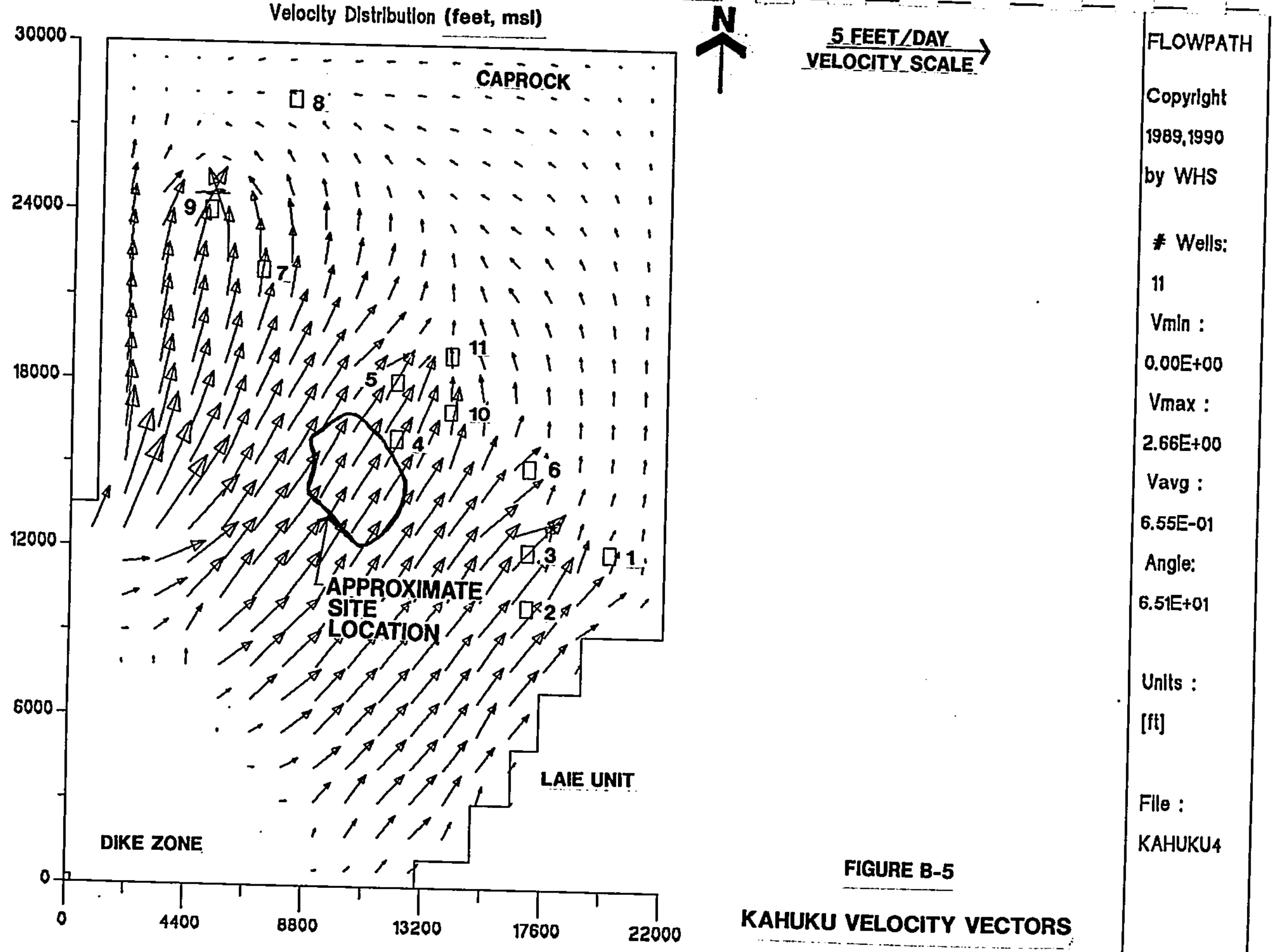


FIGURE B-5

KAHUKU VELOCITY VECTORS

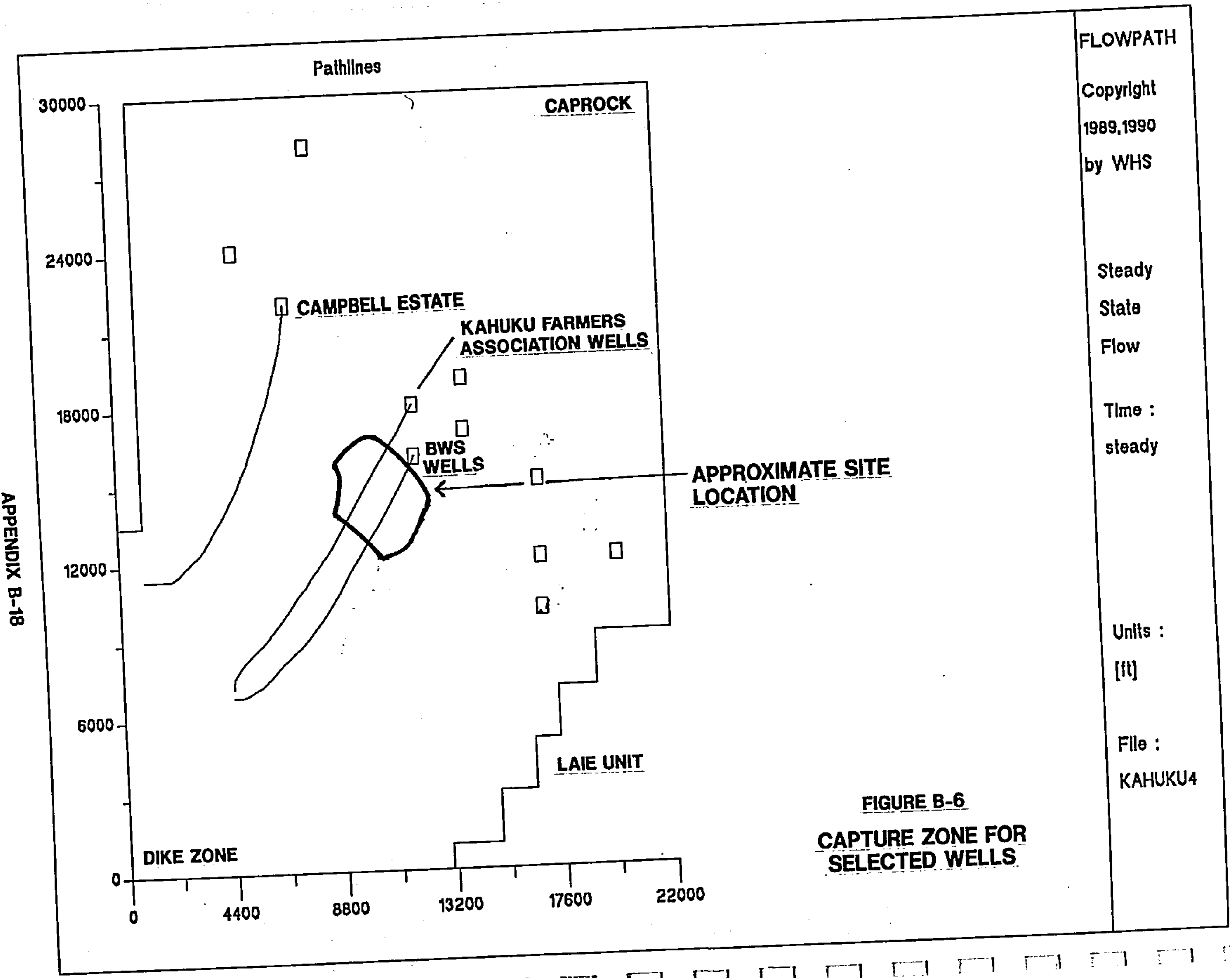


FIGURE B-6

CAPTURE ZONE FOR SELECTED WELLS

Implications For Ground Water Monitoring

In the Palikea model, the direction of ground water movement is estimated to be toward wells to the south and east of the site. The majority ground water flowing under the site may be captured by the wells to the south of the Kunia system supplying irrigation water for sugarcane in 'Ewa plain operated by Oahu Sugar Company.

In the Kahuku model, the existing agricultural users may capture most of the flow. The ground water movement is estimated to be generally from south to north. The leakage due to spring discharge near the coast may be responsible for drawing some of the ground water from southeast to northwest.

The order of magnitude of ground water travel, exclusive of percolation through the upper soil layers, is estimated to be years. The implications for monitoring are that if adverse effects can occur, they will take a long time to manifest themselves in nearby wells. The critical period is the longest duration required for ground water to pass beneath the site which maximizes the exposure to percolation water from the surface. Considering the Palikea site, the travel time across the site to the Honouliuli wells may be approximately 15 years (10,800 feet/ 2ft/day/ 365 day/year = 15 years). At the Kahuku site, the travel time across the site may be on the order of 5.5 years. The conclusion is that monitoring ground water quality trends solely on the basis of sampling from deep wells is too slow. Information has to be obtained faster to confirm predictions that public health will be unaffected.

Another consideration is that deep well monitoring does not identify a source of contamination. In reality, the capture zone particle paths exhibit greater irregularity; and it may prove impossible to trace particle movement several hundred feet underground along an irregular route thousands of feet long with confidence as to the source of the results. Other factors will affect aquifer quality. These include chemicals used by homeowners, golf courses, and other agricultural operations, leakage from small individual waste treatment locations, and injection wells. Identifying the sources at any site versus the potential from extraneous sources of off-site origin is a significant problem.

Thus the use of deep wells for monitoring ground water quality near the downstream boundary of the potential site is problematic. Figures B-2 and B-5 show most water flow lines passing beneath the site might bypass a single pumping well.

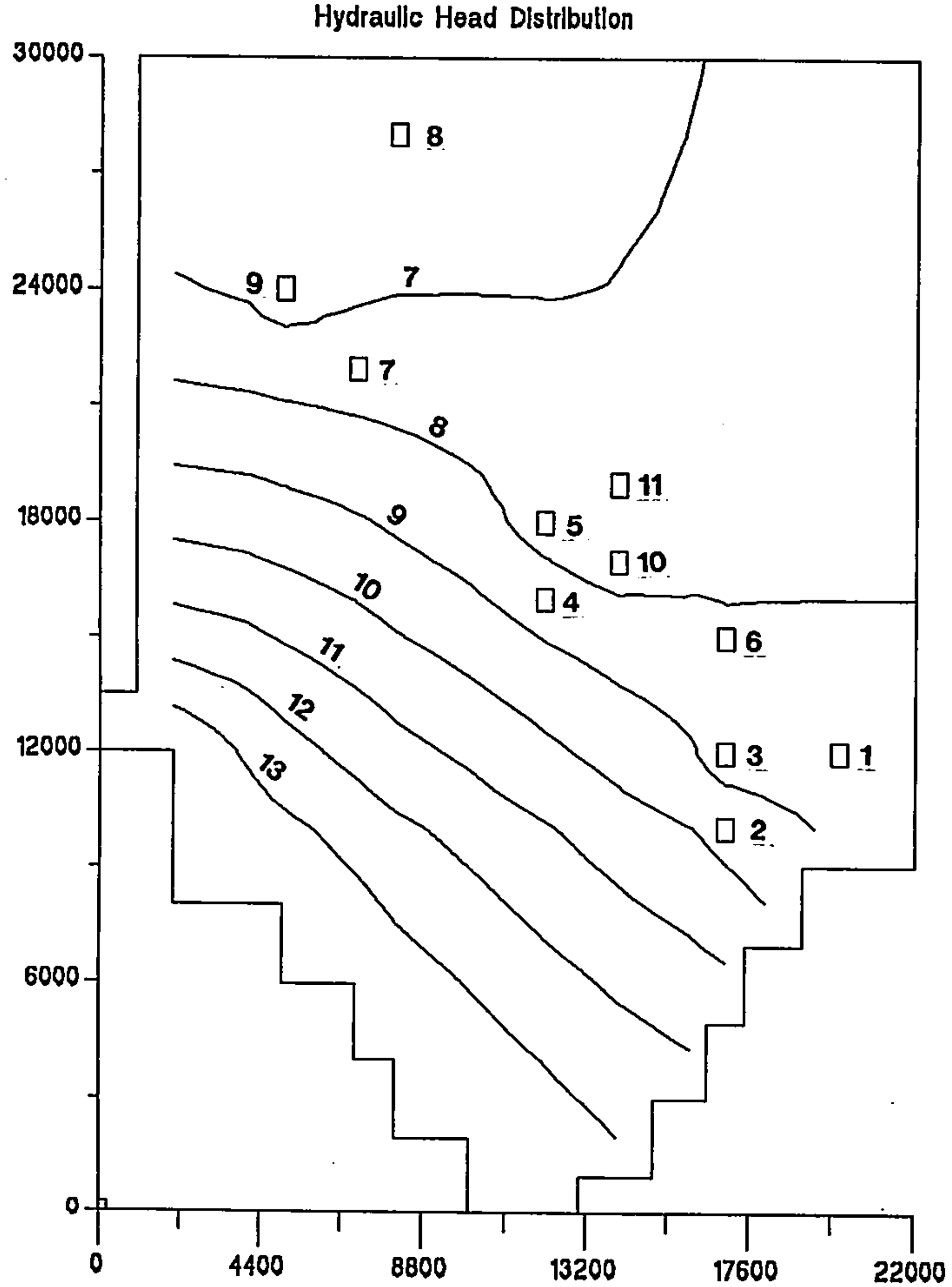
The models used here assume isotropic aquifer conditions and thus the particle tracks are straight and regular. Given the very permeable nature of the basalts, great quantities of water will have to be purged from wells to create a capture zone that will conceivably intercept all water flowing beneath the site, which would waste a great deal of water. Numerous wells in close proximity to the site would be required to be capable of capturing ground water moving under the site which could receive deep percolation of water in order to monitor for the presence of pathogens, organic and inorganic constituents passing through upper soil layers. There may be a better way, if vadose (unsaturated soil zone) monitoring can be relied upon for the bulk of the first line of monitoring, with sampling of existing and future wells as a redundant means of monitoring.

Implications For Wetland Management

A comparison of the Kahuku regional groundwater model for two pumping conditions is used to estimate the affect of additional withdrawal at the agricultural park on aquifer potentiometric surface and (in Appendix G) the implications for wetlands water management at the Ki'i Unit of the James Campbell National Wildlife Refuge. The model (see Figure B-4) was modified such that pumpage from Source No. 10 (State Well Nos. 4057-01/02/08) is increased from 1.0 mgd to 2.0 mgd (see Figure B-7). The Kahuku Farmers Association presently use three pumps to withdraw up to 1 mgd. The State Department of Agriculture has filed a declaration with the State Water Resources Commission of its intention to use up to an additional 1 mgd from the same sources (using a different set of three pumps) for the agricultural park which is contiguous with the proposed livestock park. Thus the total expected increase in withdrawal at this source is 1 mgd.

The model shows that at the location in the finite difference grid where the artesian wells are located, the potentiometric surface declines by approximately 0.4 feet with the increase in pumping from Well No. 4057-01/02/08. However, the model assumes the aquifer is unconfined when in fact there are strong indications that it is partially confined, which results in the artesian flow at the Ki'i Unit wells. For example the drilled wells at the Ki'i Unit penetrate the caprock and reach the basal basalt. The water in these wells will rise to an estimated elevation of more than 7 feet mean sea level, which is approximately two feet above the ground surface at the wells, yet the water surface in the ponds is a few feet below this elevation.

Hydraulic Head Distribution



NO.	STATE WELL NO.	PUMPING RATE (mgd)
1	3956-01	0.5
2	3957-01	0.005
3	4057-07/10	1.9
4	4057-15/16	0.43
5	4157-04	1.8
6	4057-06	0.5
7	4158-12	0.22
8	4258-04	0.003
9	4159-01	2.5
10	5047-1/2/8	2.0
11	KII UNIT	0.5
		10.358

FIGURE B-7

KAHUKU POTENTIOMETRIC SURFACE

FLOWPATH

Copyright
1989,1990
by WHS

Steady
State
Flow

Min :
7.00E+00
Max :
1.80E+01
Inc :
1.00E+00

Units :
[ft]

File :
KAHUKU3

The significance of a confined aquifer condition is the decrease in the potentiometric surface will be less for a confined aquifer than an unconfined one. Figure B-8 shows a theoretical comparison of the change in head for two conditions: confined with one mgd, and two mgd withdrawal from a well assumed to be fully penetrating the aquifer. For the confined condition, the theoretical change in head is estimated to be on the order of 0.16 foot (0.31 - 0.15 = 0.16) versus the 0.4 foot obtained by the finite difference (FLOWPATH) model. Thus the expected effect of the livestock park, assuming the water withdrawal is increased on the order of one mgd is estimated between 0.2 to 0.4 foot decline in the potentiometric surface near the refuge wells. The decline is noteworthy because the wetlands rely on artesian flow; there are no provisions for pumping water from these wells at the present. For other sources drawing from the basal lens, the decline in head is not considered significant because these wells rely on pumps to draw and transport water to the intended point of use.

FIGURE B-8a

Theoretical Reduction in Aquifer Potentiometric Elevation
As A Result of Additional Water Well Pumping
Based on Existing Confined Conditions

Ho-Hw= (Q/2PIKb)ln(Ro/Rw)
Ho= Head above top of confined layer at boundary
H1 = Head at artesian wells
Q= Discharge from pumping well
K= Hydraulic conductivity
b= Confined thickness
Ro= Radial distance from pumping well to boundary
Rw= Radial distance from pumping well to artesian wells

Ho-Hw=	0.15	ft			
Q=	133700	cuft/day	(mgd x1.337xE5=c	1	mgd
K=	300	ft/day	(K=T/b)	1238	gpd/ft
b=	320	ft			
Ro=	6000	ft			
Rw=	3000	ft			

FIGURE B-8b

Theoretical Reduction in Aquifer Potentiometric Elevation
As A Result of Additional Water Well Pumping
Based on Project Confined Conditions

Ho-Hw= (Q/2PIKb)ln(Ro/Rw)
Ho= Head above top of confined layer at boundary
H1 = Head at artesian wells
Q= Discharge from pumping well
K= Hydraulic conductivity
b= Confined thickness
Ro= Radial distance from pumping well to boundary
Rw= Radial distance from pumping well to artesian wells

Ho-Hw=	0.31	ft			
Q=	267400	cuft/day	(mgd x1.337xE5=c	2	mgd
K=	300	ft/day	(K=T/b)	1238	gpd/ft
b=	320	ft			
Ro=	6000	ft			
Rw=	3000	ft			

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APPENDIX C
GROUND WATER PATHOGENIC PATHWAY ANALYSIS AND RISK ASSESSMENT

FIGURES

APPENDIX C

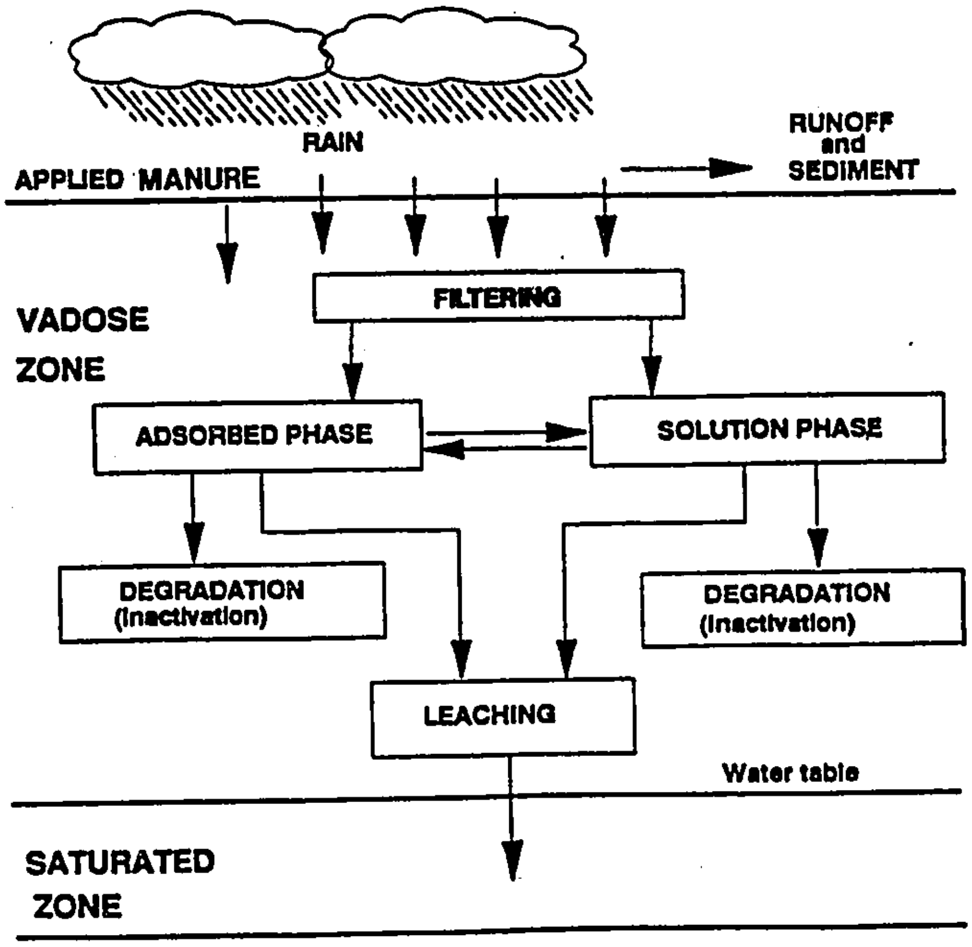
GROUND WATER PATHOGENIC PATHWAY ANALYSIS AND RISK ASSESSMENT

A conceptual model for the pathways of pathogenic material migration is shown in Figure C-1. The pathogens considered in this analysis are protozoans, bacteria, and viruses. The first two classes are capable of reproducing outside of the host, but because of their size relative to soil particles, are more readily filtered from percolating water in the top layers of the soil. Viruses are considerably smaller and conceivably can pass through even silty clay soils, although a portion is still retained in the soil column. However, viruses do not reproduce outside of their host, and tend to be host specific, i.e., the number of viruses that are transmitted from animals to man is fewer than the number from man to man (Diesch 1970). Thus the consideration for protozoa and bacteria is the retention capacity of the surficial soils, provided the pore size is limiting. The consideration for viruses is the travel time to the water table, provided it is significantly greater than the die-off rate.

The optimum situation for the provision of natural physical and biological treatment mechanisms will be achieved by identifying a location where soil types effectively filter larger pathogens, and distance to water sources significantly reduces the chance that smaller pathogens might enter water supply systems before their inactivation.

The situations that are critical are pastures where grazing animals are confined. Dairy manure in barns and milk parlors is to be collected on concrete floors reducing concern about percolation of pathogens into the soil. However, pastures are a different consideration because animal waste is not collected.

The dairy animals allowed to use pasture will be restricted to dry cows and calves (newborn to six months of age). Another option is to confine the dry cows in the barn, letting only a few feed on forage. The maximum number of mature cows is assumed based on the carrying capacity of a pasture. The maximum amount of land for pasture considered available is 100 acres.



SOURCE: TIM, UDOYARA S. AND SAIED MOSTAGHIMI. 1991. MODEL FOR PREDICTING VIRUS MOVEMENT THROUGH SOILS. GROUND WATER VOL. 29 NO. 2

STATE O HAWAII
DEPARTMENT OF AGRICULTURE

OAHU LIVESTOCK AGRICULTURE PARK
FIGURE C-1
CONCEPTUAL MODEL OF PATHOGEN MIGRATION PATHWAYS

FEIS
M & E PACIFIC, INC.

Approximately 1.5 acres is required per animal for grazing sustenance. The maximum carrying capacity is estimated to be approximately 70 animals. This population is used to estimate the pathogenic load at the soil horizon.

The removal of bacteria (and larger) microbes is predominantly due to filtering and adsorption mechanisms. Filtering, or straining, is attributed to the contact of microbe particles to the sides of adjacent soil particles due to the limitation of the pore space. Corapcioglu and Haridas (1984) suggest straining is significant when the ratio of the microbe particle size to the soil grain diameter is greater than 0.05. Adsorption results when the molecule is affixed to the surface as a result of van der Waals forces. These forces are generated as a result of electrical charge differences between ends of molecules that cause the molecules to interact. They are significant for particle diameters greater than 0.1 micron, or in other words, for most bacteria and some viruses.

Corapcioglu and Haridas (1984) presented the following expression for the filtered volume of deposited particles with uniform shape per unit volume of total porous medium based on purely geometric considerations:

$$S = 1/2\,(1-n_o)\,\mathrm{PIz}\ (d/dg)^2[(1+d/dg)^2-1]^{1/2} \qquad (1)$$

Where:

S = the retained fraction of microbes

n_o = initial porosity, assumed to vary between 0.30 to 0.40 locally

d = diameter of suspended microbe particle

dg = diameter of soil grain,

z = coordination number indicating interconnectedness of individual grains, a value of 7 is typical

PI = 3.14

Microbial survival in the soil is also one of the factors controlling the number of organisms available for migration. The bacterial die-off and growth rates are assumed to be first order kinetic reactions. The number of organisms remaining in the soil at the end of any period can be estimated (Reddy et al. 1981):

$$M_t = M_o \exp\{(k_G - k_D)\,t\} \qquad (2)$$

Where:

M_t = microbial concentration at time t

M_o = initial microbial concentration

k_G = rate coefficient for growth of microorganisms, per day

k_D = rate coefficient for die-off of microorganisms, per day

Half-lives of fecal coliform range from 2 to 150 hours; for *Salmonella*, 2 to 185 hours; and polio virus, 7 to 416 hours. For *E. coli* bacteria, the die-off rate (per day) has been estimated at between 0.15 to 1.39, corresponding to half-lives of 12 to 110 hours. Calculations using equation (2) assume a lognormal distribution to estimate net (growth minus die-off) rate constant. A mean net die-off rate of 0.5 per day and standard deviation of 0.25 per day are used for bacteria analysis. For viruses, a mean of 0.05 per day and standard deviation of 0.025 per day is used; in other words an order of magnitude lower die-off rate is assumed for the latter pathogenic group, based on Reddy, et al., 1981, who summarize results of several studies on the rate constants for various pathogens.

The average contribution of fecal bacteria per animal (assumed to be a 1,300-lb. cow) per day is 36 billion, i.e., 36×10^9 (Reddy et al. 1981). They estimate approximately 1.5 million bacteria per gram of feces. Using this estimate as the mean parameter, assuming a normal distribution with a standard deviation of one-half this amount, the initial contribution of microorganisms is estimated on the basis of a mean of 70 animal units, and a standard deviation of 30 animal units. This represents the number of animals expected in pastures where animal waste will contain pathogens which may migrate into the soil. The number of virus organisms is assumed comparable to bacteria. Sensitivity of the bacteria count to the results is indicated later in this discussion.

For purposes of evaluating the transit time of meteoric water to the basal lens, the lowest order of magnitude considered relevant is 1 year; the highest is assumed to be about 10 years. The elevations where pastures are considered appropriate at each potential site range from a minimum of 300 feet at Kahuku to 600 feet at the Palikea site. The travel time is estimated by considering annual soil pore water displacement at the site:

Factor	*Palikea*	*Kahuku*
Annual rainfall, inches	32	60
Depth to water table, feet	600	300
Effective porosity	0.05	0.05
Transit time, years	11.25	3.0

The travel time estimate for Palikea is made as follows: (600 ft x 0.05)/(32 in./yr / 12 in/ft) = 11.25 yr. A similar calculation is used for Kahuku. For the purposes of estimating results considering the variability, the range of travel time is assumed to vary one order of magnitude, namely 1 to 10 years, and is uniformly distributed, i.e., equally likely to occur.

Combining the straining, adsorption, and kinetic equations with transit time yields estimates of the number of bacteria and viruses reaching the ground water table. The results in Figure C-2 are for bacteria, or micron sized particles. The results in Figure C-3 are for viruses, or sub-micron sized particles. The expected value of bacteria is zero; for viruses it is insignificant, i.e., less than one unit.

The retention of bacteria in the soil is expected to be significant. The results in Figure C-2 indicate the expected value of the fraction of bacteria retained due to straining and adsorption is 0.18 or 18 percent. Most of this effect may be the result of straining. The significant effect, however, is the die-off time. As a result of this, the expected value of bacteria is effectively zero, considering the net die-off effect and given the assumptions and conditions used in Figure C-2.

Viral contamination risk assessment differs in that the die-off rate is significantly lower, assumed here an order of magnitude lower, and the particle diameter is also considered to be two orders of magnitude smaller than bacteria. Figure C-3 shows simulation results for viruses assuming the initial concentration in animal waste is comparable to bacteria. The expected number reaching the water table is zero.

The concentration of animals in a dairy lot is a different consideration. Although manure is collected in the barns and milk parlors, there is the potential for animal waste to accumulate in the soil during the time animals pass between the barn and the milk parlor, are led to pasture, or are isolated in a maternity pen. The most critical will be the line of cows waiting to enter the milk parlor.

The quantity of manure can be estimated based on the physical size for each cow and the typical amount of space between the two buildings. Milk parlors in new facilities are as close to the dairy barn as possible so that the animal does not expend considerable energy. A conservative estimate of animal density is 400 cows/acre; in other words each cow occupies a space approximately 10 by 11 feet. The largest dairy anticipated at the livestock park is 1,200 cows. These might be housed in three 400-cow barns, but only half would be milked at a time. Thus the largest concentration in the open, considering the head size and physical limits between buildings is considered to be 200 cows. While the actual time each animal spends in the open is limited, milking operations could be continuous, thus the daily manure generation for 200 cows is considered.

The additional considerations necessary for risk assessment include the amount of aquifer mixing, the die-off during travel time toward the source of ground water supply, the dosage a person is likely to ingest, and the dose-response characteristics (the likelihood of becoming ill after ingestion). Aquifer mixing between the source of supply and the site is considered for this analysis. Figure C-4 shows a probability plot of 1,000 possible outcomes. The key part of the analysis is the probability distribution of extreme numbers of viruses reaching the water table. The results (Figure C-4) of the ***@RISK*** analysis show the extreme values and the expected value of the viruses at the source, considered to be adjacent to a well site, is estimated on the order of 0.5 units; the critical number is one virus unit.

The dose response model adopted is based upon recent (Regli et al. 1991) assessment of the experimental data on human response. A conservative model is:

$$P_i = - \exp(-r\, u\, V) \qquad (3)$$

Where: P_i = probability of an infection
r = fraction of ingested microorganisms that survive to initiate infections
u = average number of organisms per unit volume
V = volume of liquid ingested

Considering the total quantity of water a person may drink in a day, the estimated daily risk is on the order of 10^{-8}. Considering a lifetime, 70 years, drinking two liters (approximately one-half gallon) per day, every day, the lifetime risk is on the order of $2x10^{-3}$.

The results of these estimates conform to other experience (Hori et al. 1970) and can be summarized as follows:

(1) the risk due to bacterial infection is insignificant;
(2) the risk due to viral infection is on the order of 10^{-3}.

FIGURE C-2

APPENDIX C

PATHWAY ANALYSIS & RISK ASSESSMENT - PASTURE LOCATION

10/21/92

Bacteria (Micron Size) Analysis

Estimated Contribution of Microorganisms							Remarks	
		1	Avg Weight	590	Animal unit weight in kilograms		Weight in pounds	1300.00
		2	Per capita	2E+06	Number bacteria per gram feces per animal per day		Lognormally distributed;m-1.5,sd0.5e6	
		3	No. animals	70	Number of pastured cattle (dry cows & heifers)		Normally distributed;m-775,sd-250	
		4	Avg Weight	51	Average weight of feces per day per capita, gram		Reference (2), Table 1	
		5	Contribution	5E+09			5=2x3x4	
Ref (1) Formula For Retention:			S=1/ 2*(1-No)*3.14*z*(d/dg)^2.0*((1+(d/dg))^2.0-1)^0.5 = volume retained per volume soil				Reference (1) eq. 2	
	Where:	No=	0.40	Soil porosity				
		z=	7.00	Interconnectedness factor				
		d=	0.001	Assume lognormally distrib- mean 0.0001 & sd 0.0005 mm bacteria particle size			Bacteria 0.5 to 1 micron size	
Silt-Clay	Where	dg=	0.005	Assume lognormally distrib- mean 0.005 & sd 0.002 mm soil grain size			Silt & clay size particles	
Soils								
	Ratio , S=	0.1750	Retained/Contributed Microorganisms					
Expected Value		4E+09					Equals S x Contribution (4, above)	
	In Soil Pores							
Ref (2) Formula For Adsorption:			MORT=K*MOSOL = Organisms retained on soil, no. per gram of soil				Reference (2), eq 11	
		Where:	MOSOL=	3E+06	Organisms present in soil solution		contribution per gram/soil porosity	
			K=2.445*(SS) - 72.7=		491.05	Retention coefficient		
			SS=	230.57	Specific surface = 3.786*(%clay)-9.94;for soil > 18% clay		Reference 2, eq. 16	
			Perc clay=	63.50	Percent of clay fraction;		Based on Molokai & Wahiawa clays	
			Density	1.20	gram per cm of soil		Bulk density, based on SCS data	
			Unit Volume	91.44	centimeters in soil column		Assumes soil has normal distribution	
							mean 36 inches deep, sd 16 inches	
	MORT=	2E+09	Total Retention In Soil Column=			2E+11		
Expected Value		0E+00	Percent Retained In Soil=			100%	(Amount retained by adsorp. + strain.)/	
	In Solution		After Straining & Adsorption				Contribution (5, above)	

Ref (2) Formula For Microbial Growth & Die-Off:				Mt= Moexp((Kg-Kd)T)		
						Reference (2) , eq. 2
		Where:	Mt=	concentration at time t		
			Mo=	expected value in solution	0E+00	
			Kg=	see below	microbial growth rate	Lognormal m-0.5, sd 0.25 per day
			Kd=	see below	microbial die-off rate	Based on Ref (2), Table 2
			Kn=	0.50	net microbial die-off rate	Based on min 1, max 10 year, see text
			t=	5.50	time for migration to water table, year	Uniform distribution
				2008	days	
	Expected Value	0E+00				
	In Ground Water					
References:						
	(1) Corapcioglu, Yavuz, and A. Haridas. 1984. Transport and Fate of Microorganisms in Porous Media: A Theoretical Investigation.					
	Journal of Hydrology, 72:149-169					
	(2) Reddy, K.R., R. Khaleel, and M.R. Overcash. 1981. Behavior & Transport of Microbial Pathogens & Indicator Organisms in Soils Treated With Organic Wastes					
	Journal of Environmental Quality. Vol. 10, no. 3: 255- 266.					

					FIGURE C-3			
						APPENDIX C		
				PATHWAY ANALYSIS & RISK ASSESSMENT- PASTURE LOCATION				
						10/21/92		
					Virus (Sub-Micron Size) Analysis			
								Remarks
Estimated Contribution of Microorganisms								
		1	Per capita	2E+06	Number per gram feces per animal per day			Lognormally distributed;m-1.5,sd0.5e6
		2	No. animals	70	Number of pastured cattle (dry cows & calves)			Normally distributed;m-775,sd-250
		3	Avg Wt	51	Average weight of feces per day per capita, gram			Reference (2), Table 1
		4	Contribution	5E+09				4=1x2x3
Ref (1) Formula For Retention:			S=1/ 2*(1-No)*3.14*z*(d/dg)^2.0*((1+(d/dg))^2.0-1)^0.5 = volume retained per volume soil					Reference (1) eq. 2
	Where:	No=	0.40	Soil porosity				
		z=	7.00	Interconnectedness factor				
		d=	0.00001	Assume lognormally distrib- mean 0.00001 & sd 0.000005 mm virus particle size				Bacteria 0.5 to 1 micron size
Silt-Clay	Where	dg=	0.0050	Assume lognormally distrib- mean 0.005 & sd 0.002 mm soil grain size				Silt & clay size particles
Soils								
	Ratio , S=	0.0000	Retained/Contributed Microorganisms					
								Equals S x Contribution (4, above)
	Expected Value	5E+09						
	In Soil Pores							
Ref (2) Formula For Adsorption:			MORT=K*MOSOL = Organisms retained on soil, no. per gram of soil					Reference (2), eq 11
		Where:	MOSOL=	4E+06	Organisms present in soil solution			Contribution per gram/soil porosity
			K=2.445*(SS) - 72.7=		491.05	Retention coefficient		
			SS=	230.57	Specific surface = 3.786*(%clay)-9.94;for soil > 18% clay			Reference 2, eq. 16
			Perc clay=	63.50	Percent of clay fraction;			Based on Molokai & Wahiawa clays
			Density	1.20	gram per cm of soil			Bulk density, based on SCS data
			Unit Volume	121.92	centimeters in soil column			Assumes soil has normal distribution
								mean 36 inches deep, sd 16 inches
	MORT=	2E+09	Total Retention In Soil Column=			3E+11		
								(Amount retained by adsorp.+ strain)/
	Expected Value	0E+00	Percent Retained In Soil=			100%		Contribution (4, above)
	In Solution		After Straining & Adsorption					

Ref (2) Formula For Microbial Growth & Die-Off:				Mt= Moexp((Kg-Kd)T)			
		Where:	Mt=	concentration at time t			Reference (2) , eq. 2
			Mo=	expected value in solution		0E+00	
			Kg=	see below	microbial growth rate		
			Kd=	see below	microbial die-off rate		Lognormal m-0.05, sd 0.025 per day
			Kn=	0.05	net microbial die-off rate		Based on Ref (2), Table 2
			t=	5.50	time for migration to water table, year		Based on min 1, max 10 year, see text
				2008	days		Uniform distribution
	Expected Value	0E+00					
	In Ground Water						
References:							
	(1) Corapcioglu, Yavuz, and A. Haridas. 1984. Transport and Fate of Microorganisms in Porous Media: A Theoretical Investigation.						
	Journal of Hydrology, 72:149-169						
	(2) Reddy, K.R., R. Khaleel, and M.R. Overcash. 1981. Behavior & Transport of Microbial Pathogens & Indicator Organisms in Soils Treated With Organic Wastes						
	Journal of Environmental Quality. Vol. 10, no. 3: 255- 266.						

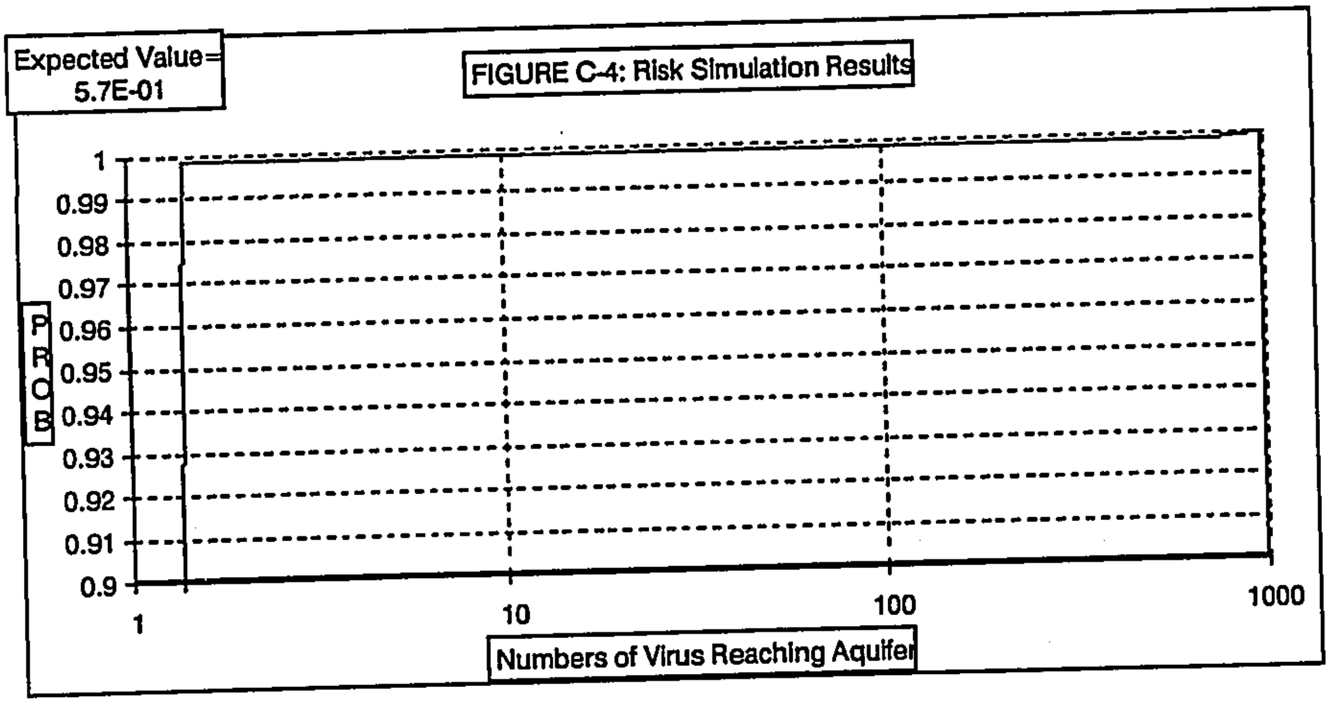


FIGURE C-4: Risk Simulation Results

FIGURE C-5

APPENDIX C

PATHWAY ANALYSIS & RISK ASSESSMENT

10/21/92

Source Distribution & Dose Response Estimation

Ground Water Recharge			Remark
Surface Flux	0.0014	ft/sq ft-day	Determined in Appendix B for Kahuku site, Assume Lognormal Distribution- mean =0.0014, std dev =0.0004
Surface Area	0.50	acres	Based on 100 ac in dairy operation Assume Normal Distribution - mean = 100, std dev = 50
Ground Water Recharge	3E+01	cu ft/day	Surface flux x Surface Area
	9E+02	liters/day	
Viral Density in Percolation Water To Aquifer	5E-01	number	Based on virus pathway migartion analsyis, Assume lognormal distribution - mean=0.5, std dev=18
Inflow Aquifer Volume	1E+06	cubic feet	Based on 600 feet thick aquifer, porosity = 0.1, underlying surface area
	1E+01	million gal	
	4E+07	liters	
Inflow Aquifer Contam.	1E+00	number	Assume background contamination level of 1 unit
Total Water Volume	4E+07	liters	Ground Water Recharge + Aquifer Volume
Virus Concentration	6E-04	number/liter	Percolation water
Source Density Distribution			Remark
Expected Value of Viral Density After Aquifer Mixing	4E-08	number	Based on relative concentrations in percolate and flux into aquifer
Daily Dose Response Probability			Remark
Dose Volume,V	2.00	liter	Based on average personal consumtpion 2 liters/day, per EPA
Rate of Survival,rs	1.00	fraction	Fraction amount of virus which survives in host, depends on receptivity Assume all survive
Probability of Infection	8E-08	fraction	Assume Exponential Distribution with P=1-exp(-rsUV) U= viral density number per volume of liquid, V
Lifetime Dose Response Probability			
Lifetime Probability of Infection	2E-03		Based on 70 years for 365 days per year

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APPENDIX D
SURFACE WATER PATHOGENIC PATHWAY ANALYSIS AND RISK ASSESSMENT

CONTENTS

APPENDIX D

SURFACE WATER PATHOGENIC PATHWAY ANALYSIS AND RISK ASSESSMENT

The consideration here is the risk of transmission of enteric viruses in nonpoint runoff that will be generated from the site. The critical storm is considered to be a storm with an intensity of a 25-year, 24-hour (0.04 annual exceedance probability) rainfall depth, because less intense storm runoff is to be contained on-site.

The more immediate consideration is enteric virus ingestion in estuarine and marine waters because viruses are more resistant to the toxic affect of marine water than bacteria. Another consideration is the transmission of infectious hepatitis through consumption of shellfish. Although most infections occur from ingestion of raw shellfish, one study (Hetrick 1978) indicates 5 to 10 percent of viral infectivity may remain after normal cooking of contaminated oysters.

Estimates of viral concentrations in pasture runoff in Hawai'i are not well documented. Viral concentration is measured in plaque forming units (PFU). Great variability can be expected. In one study (Stephenson and Street 1978) total coliform bacteria in runoff from rangeland grazed at between 1.6 to 2 animal units per acre varied between 5×10^2 to 5×10^3 per ml or 5×10^5 to 5×10^6 per liter. Based on another mainland study (Moore, Sagik, and Sorber 1981), the concentration of enteric viruses in pastured area runoff was estimated between 6×10^2 to 9.0×10^2 PFU/ liter daily. The viral concentration in surface runoff may be less than bacteria because of the toxic effect of ultraviolet light; however, lacking more accurate data, the assumption here is that the viral concentration can vary on the order of between 10^3 to 10^6 PFU per liter. One PFU is assumed to be the infective dose.

The die-off rate of viruses in surface water will be greater than in ground water because of the exposure to ultraviolet light and temperature. Microbial decay (die-off) is assumed to follow a first order kinetic relationship. Die-off constants are assumed to vary between 1.5 to 0.15 per day (Reddy, Khaleel, and Overcash 1981). Viruses do not reproduce outside of their host; new growth is not a factor. The decay may be estimated by:

M_t = M_O (exp $^{-kt}$) (1)

Where: M_t = microbial concentration at time t

M_t = initial microbial concentration

k = the decay constant per day

t = time, days

The significant parameters are the microbial decay constant and the order of magnitude of the initial concentrations. The results are shown for two potential sites—Palikea and Kahuku.

Palikea Site

Based upon 10.25 inches of rainfall and assuming a runoff coefficient of 0.7, the 25-year, 24-hour event can generate approximately 0.2 mgd of runoff per acre at the Palikea site. Assuming a total grazing area of 100 acres is under active grazing at the time of the storm, the total runoff is estimated as 20.0 mgd, or 75 x E6 liters.

At West Loch, the total tributary area of Honouliuli Stream is approximately 7,610 acres. On the basis of drainage areas, the contribution of a 100-acre pasture area would be 100/7,610 = 0.013 fraction of total inflow. Assuming the expected value (mean) of the viral concentration from the site to be between 10^3 to 10^5 PFU per liter, then the mixed concentration at West Loch, neglecting other viral inputs from the intervening urban and agricultural tributary area, the total number can be estimated as:

$$10^3 \text{ PFU/L} \times 0.013 = 13 \text{ PFU/L}$$

to

$$10^5 \text{ PFU/L} \times 0.013 = 130 \text{ PFU/L}$$

The decline in microbial population after one day travel time is estimated to range as follows:

Initial Concentration	13 PFU/L	130 PFU/L
Die-off @ 1.5/day	2.9 PFU/L	29 PFU/L
Die-off @ .15/day	11.1 PFU/L	112 PFU/L

This survival rate ignores that viruses are not tolerant of saline and brackish water found in estuaries. Thus the actual survival concentration would be less.

The standard dose assumed for an average adult for drinking water risk assessment is ingestion of two (2) liters (0.5 gallon) of water every day over a 70-year lifetime. This standard is arguably too stringent in the case of recreational water, and especially, water not usually used for whole body contact such as in West Loch. The amount of water a person might ingest accidently by swallowing a mouthful (about one-tenth of a cup) of water, or 10 ml, would be a more realistic dose.

The range in the amount received as a dose in milliliters is estimated as follows:

Initial Concentration	13 PFU/L	130 PFU/L
Die-off @ 1.5/day		
Dosage, PFU number/ml	2.9×10^{-3}	2.9×10^{-2}
Die-off @ .15/day		
Dosage, PFU number/ml	0.01	0.01

Assuming that viral concentrations are "patchy" in occurrence and follow the Poisson distribution, then the probability of a dosage of 1 PFU/10 ml in the surface water can be based upon the following distribution, using the above dosage to estimate the mean concentration of organisms:

$$P(N) = \frac{(uV^N)e^{-UV}}{N!} \quad (2)$$

Where:
P(N) = probability of a patch of water containing exactly one PFU
u = mean concentration of microorganisms, PFU/ml
V = volume of sample, 10 ml

Thus the range of probability for the dosage range in surface waters that can be obtained is:

Range in Dosage, PFU/10 ml	2.9×10^{-3}	0.11
P(N)	2.8×10^{-2}	0.37

The probability of exposure (P_e) can be estimated as the chance that a person will experience a 25-year storm event or greater during a 25-year average lifetime for this project. The probability that one or more events will exceed a given storm magnitude in a specified period can be estimated from the binomial distribution:

$$P_I = \frac{N!}{I!\,(N-I)!} P^I (1-P)^{N-I}$$

where P_e is the probability of obtaining in N years exactly I number of storm events with annual exceedance probability P.

From this expression,

$$P_e \text{ (1 or more)} = 1 - (I-P)^N$$

so that P_e (1 or more 25-year storms in 25 years) $= 1 - (1 - 0.04)^{70} = 0.64$.

The probability of exposure could be multiplied by the chance that a person would be exposed to surface water one day after a serious flood times the chance that he or she would actually ingest water accidentally; these statistics are unknown and were neglected. The exposure probability will therefore be lower than this estimate.

Thus, the overall risk from exposure to surface water with potential viral contamination is estimated based on:

$$\text{Risk} = \text{Probability of Dose} \times \text{Probability of Exposure}$$

$$= 2.8 \times 10^{-2} \times 0.64 = 1.8 \times 10^{-2}$$

to

$$= 3.7 \times 10^{-1} \times 0.64 = 0.24 \times 10^{-1}$$

Kahuku Site

The factors that need be adjusted for the Kahuku site are only the initial concentrations due to different quantities of runoff and size of the drainage basins. Although Kahuku is on the windward side of O'ahu which has greater annual rainfall depths, the peak 24-hour rainfall depths are not significantly different.

Based upon 10.75 inches of rainfall for the 25-year, 24-hour event, the Kahuku site can be expected to generate approximately 5 percent more runoff, all other factors assumed equal. Thus the runoff is approximately 0.21 mgd of runoff per acre at the Kahuku site. Assuming a total grazing area of 100 acres is under active grazing at the time of the storm, the total runoff is estimated as 21 mgd.

At the entrance of Ki'i Ditch to the wildlife refuge, 'Ōhi'a Gulch, the total tributary area is approximately 3.3 square miles (2,112 acres). On the basis of drainage areas, the contribution of a 100-acre pasture area would be 100/2,112 = 0.047 fraction of total inflow. Assuming the expected value (mean) of the viral concentration from the site to be between 10^3 to 10^5 PFU per liter, then the mixed concentration at Mālaekahana, neglecting other viral inputs from the intervening tributary area can be estimated as:

$$1 \times 10^3 \times 0.047 = 47 \text{ PFU/L}$$

to

$$1 \times 10^5 \times 0.047 = 470 \text{ PFU/L}$$

The risk can be estimated on the basis of a similar calculation procedure for West Loch. The result (not shown) of overall range in risk, all other factors assumed to be equal is:

$$4.5 \times 10^{-2}$$

to

$$0.24$$

The conclusion is that the risk of exposure of pathogens by accidental ingestion of surface water is less than between 2 to 24 percent over the lifetime of the project. A number of significant factors are ignored especially in this type of risk calculation— the risk of an accidental ingestion of stream water.

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APPENDIX E
PATHOGENIC AEROSOL PATHWAY ANALYSIS

APPENDIX E
PATHOGENIC AEROSOL PATHWAY ANALYSIS

A conceptual model (McBean, Rovers, and Schmidtke 1990) is used to make a preliminary assessment of the potential effect airborne transmission of pathogens. In very simple terms, measuring the concentration along the centerline of the plume of air and assuming level ground, the concentration is calculated as:

$$C(x,o,o,H) \quad = \quad \frac{Q}{PI\, S_y S_z u} \exp[-1/2(\frac{H}{S_z})^2]$$

Where:

Q is initial concentration, microorganisms/cubic meter,

S_y, S_z are dispersion coefficients in the transverse and vertical directions,

H is the height above ground level, assumed to be 5 feet, 1.5 meters

u is the average wind velocity assumed to vary 3 meters/second (6.7 mph) and 5 meters/second (11.2 mph)

The critical distance is between the site and location of inhabited areas. This varies according to site; at Palikea it is approximately 1.5 miles (approximately 2.5 km) downwind, and at Kahuku, 0.5 mile upwind.

Dispersion is a function of distance and air stability. Incoming solar radiation during the day creates greater advection of air, increasing turbulence and reducing downwind concentration. More favorable conditions for airborne transmission will occur in the evening when surface wind speeds are moderate. Based upon relationships shown in (McBean, Rovers, and Schmidtke 1990), S_y and S_z were estimated at 170 and 60 meters, respectively, for windspeed range of 3-5 meter/sec (6.7 to 11.2 mph) under stable (evening) atmospheric condition. Using the above equation, the initial concentration of microorganisms required to yield one organism, C(1,0,0,1.5), downwind is:

$$Q = \frac{1}{\exp[-1/2(\frac{H}{S_z})^2]} (PI\, S_y\, S_z\, u)$$

$$= \frac{1}{\exp[-1/2(\frac{1.5}{60})^2]} (3.14x170x60x3) = 9.6 \text{ x } 10^{4,} \text{ say, } 1x10^5$$ microorganisms/cubic meter

to

$$= \frac{1}{\exp[-1/2(\frac{1.5}{60})^2]} (3.14x170x60x5) = 1.6 \text{ x } 10^{4,} \text{ say, } 1x10^4$$ microorganisms/cubic meter

Densities of pathogens in the atmosphere are typically much lower than this at domestic waste treatment facilities. For example (Lam and Young 1982) at one O'ahu wastewater treatment plant, the viral density was measured on the order of 2 plaque-forming units/cubic meter at aeration basins. It concluded the probability of animal wastewater lagoons generating the above-computed density (1 x 10^4 to 1 x 10^5 microorganisms/cubic meter) must be very low. The conclusion is that the risk of aerosol migration of virus downwind of each site is insignificant, based on the wind speeds used herein.

References

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APPENDIX F
SOIL EROSION RISK ASSESSMENT AND BEST MANAGEMENT PRACTICES EVALUATION

CONTENTS

FIGURES

APPENDIX F

SOIL EROSION RISK ASSESSMENT AND BEST MANAGEMENT PRACTICES EVALUATION

Overview

In addition to the need to reduce the potential adverse effects on stream and marine water quality, soil conservation of agricultural land is desirable to conserve resources, especially nutrients that would have to be replaced to grow crops. This appendix assesses the potential for adverse effects at each agricultural park site and options for conserving soil resources. The effects are compared to the erosion control standard's hazard rating definition of an acceptable risk. This standard is based on the potential downstream effects of sediment produced at a site. The concept of acceptable risk is, however, a moving target. What is acceptable today, may not be tomorrow. New regulations, as a result of the Coastal Zone Act Reauthorization Amendments of 1990, will be forthcoming. The U.S. Environmental Protection Agency has issued proposed guidance specifying management measures for sources of nonpoint pollution in coastal waters (EPA 1991). The State of Hawaii will be promulgating administrative rules in the future to implement this program.

The institutional process for identifying an acceptable set of agricultural activities is known as preparing the best management practice (BMP) plan. BMP means a combination of measures that are determined after problem assessment, examination of alternatives, and appropriate public participation to be the most effective and practical means of reducing pollution generated by agricultural operations to levels compatible with water quality goals. These goals are set forth in Title 11, Chapter 54, Water Quality Standards (Hawaii Administrative Rules, Department of Health).

Each potential livestock park site has three general types of land: arable land, grazing land, and unusable land. Arable, or land that can support cultivation, can be used to produce crops, provide intensive grazing area, livestock-rearing facilities such as dairy barns, and waste management facilities. Land with slopes in excess of 12 percent, but generally less than 15 percent, can be used for extensive grazing. "Extensive" infers that the density of animals or grazing pressure is relatively low. Operation of equipment at steeper slopes is difficult, and the potential for erosion is greater. It is recommended that land use on slopes exceeding 15 percent be restricted.

Arable land may be used for a variety of uses that are consistent with zoning regulations, other local ordinances, and lease covenants which might apply. Soil conservation planning for these lands will depend upon the particular uses adopted by each operator. Thus the best management practice for these areas has to be developed at the time of the initial start-up of operations. For example, risks associated with construction will be identified during the design stage of the project when locations of buildings are accurately known. An erosion control plan will be prepared to accompanying construction drawings at that time. This is identified as a future permit/approval requirement.

In this appendix, therefore, the focus is on the risk associated with long-term grazing on land that is considered non-arable. The approach examines alternatives and evaluates the effectiveness of a tentative BMP plan for each site. Further development of specific BMP recommendations are to be based on consultation between operators and soil conservationists.

Methodology of Soil Erosion Risk Assessment

The universal soil loss equation (USLE) is widely used as a prediction method in evaluation of soil erosion and conservation practices. It is incorporated into the City and County of Honolulu's *Soil Erosion Standards and Guidelines* (1975), the Soil Conservation Service's *Soil Conservation Erosion and Sediment Control Guide for Hawaii* (1981), and *Technical Guide for Nutrient Management* (1991). These guidelines are the references used to estimate the effect of best management practices.

The equation expresses an "average" response between factors that cause soil loss and those that help reduce such loss, based on long-term site and climatic conditions. The relationships are generally developed in hydrologic field laboratories. Uncertainty exists over the variability that might exist transferring the results from location to location, season to season, and even storm to storm. Erosion control effectiveness will be variable because of timing, management measures, and storm intensity. The assessment of management measures is subjective, and therefore adds another component of variability. The results of the equation might appropriately be called an index of effectiveness, rather than a specific result.

The methodology used here incorporates variability into the predictions. The spreadsheets used for the calculations show (see remarks in accompanying figures) assumptions used for the distribution of these variables. A simulation that incorporates randomly varied estimates of parameters is used to obtain the range of possible outcomes of the erosion hazard rating. A large number of trials is drawn from the distributions to estimate this range. The results can be viewed as a sensitivity analysis which is preferable to expressing the results as a single valued estimate. The hazard rating is used to indicate the probability of meeting the erosion control objectives.

The language in EPA guidance (1991) does not require the demonstration of causal relationships between management measures and the reduction in nonpoint pollution. The guiding philosophy for the program is "Congress' rationale is that, with few exceptions, neither States nor EPA have the money or the time to create the complex monitoring programs that would be required to document a causal link between specific land use activities and specific water quality measures." (EPA, 1991, pp. 1-7). What this means in effect is that a set of practical technology will be established, as, for example, was the case of the point source pollution control program which implemented the secondary treatment standards.

Soil Erosion Risk Assessment

The soil loss equation is shown in Figure F-1, along with definitions of the parameters needed for calculation of annual soil loss. Two potential sites are evaluated—Palikea and Kahuku. The soils prevalent at these sites are listed in the figure. Typical areas are evaluated at each site. Note that the equation includes a length-slope parameter. Slopes differ between various sections, as do their lengths. Therefore isolated areas are evaluated, and conclusions drawn from these for the entire site; the equation is not able to develop erosion estimates for the entire site simultaneously. The important result of the USLE is the soil erosion potential, in tons per acre per year (see item 3, Figure F-1) which is used for hazard assessment.

The significance of the soil erosion potential is evaluated using the City and County of Honolulu Soil Erosion Standards and Guidelines (1975). A hazard severity rating system is assigned based upon the following formula:

H = (2FT + 3D) AE

where: H = hazard severity rating number

F = a unit factor for potential damage to areas downslope and downstream from the site, to be selected from Table 1, Exhibit 1, in reference (1975)

T = time duration of the project in years, from clearing or first disturbance to completion of all construction and protective measures

D = a unit factor for potential sediment damage to coastal waters, to be selected from Table 2, Exhibit 1, in reference (1975)

A = area of disturbance, in acres; if the project includes areas of natural vegetation which will not be disturbed in any way, and the natural vegetation provides effective erosion control, such areas need not be included in A

E = soil erosion rate, tons/acre/year, computed by the USLE

The evaluation of certain parameters is somewhat subjective. For example, the following values are assigned:

F= 1 to 2, depending on whether damage area is more than 1 mile downstream; in the case of Palikea, i.e., *makai* of H-1, but less than 1 mile in the case of Kahuku

T= 25, duration of project in years, assumed project life, however, there is no guarantee individual operators will continue this long

D= 4, special conservation consideration is U.S. Fish and Wildlife refuges downstream near West Loch, Pearl Harbor, and Ki'i Unit near Kahuku

A = 100, area of disturbance in acres, assuming a grazing density of 1.5 animal units/acre

E = annual soil loss as calculated in item 3, Figure F-1

The number of animal units (one unit = 1,300-pound dairy cow) assumes the grazing herd consists of dry cows. It does not include calves because they are generally kept in separate pens until mature enough to pasture with dry cows. Due to land limitations, particularly at Kahuku, heifers will be raised off-site, e.g., on neighbor islands until they can be brought back for milk production.

A hazard rating of 50,000 or more indicates a condition of unacceptable environmental damage, as defined by the soil erosion and sediment control standard. This potential is identified at both the Palikea and Kahuku sites under certain soil conditions. At the Palikea site, the potential for severe erosion under idle conditions occurs where Mahana (McD) soils on 15 percent slopes occur. The severity is even greater assuming unrestricted grazing conditions. In addition, the risk is significant that excessive erosion may occur on Kunia (KyC) soils having 9 percent slopes or greater. At the Kahuku site, the Paumalū (PZ) badland soils represent an unacceptable erosion risk under both idle and grazed conditions. In addition, the erosion hazard is significant for Paumalū soils (PeC) with slopes exceeding 12 percent, assuming unrestricted grazing.

FIGURE F-1
APPENDIX F
SOIL EROSION RISK ASSESSMENT
10/5/92

Universal Soil Loss Eq.: A= RKLSCP

WHERE:

A= Computed soil loss in tons per acre per year

R= Rainfall factor

K= Soil erodability factor

LS= Length-Slope factor= (Slope length/72.6)^m x ((430x^2+30x+0.43)/6.57415)

C= Cover and management factor

P= Erosion control practice factor

m=0.5, s>5	0.5
m=0.4, s=4	0.4
m=0.3,s<3	0.3

Existing Condition — Existing Condition

1. Characteristic Soil Types & Areas

		Palikea					Kahuku		
Type	Kunia	Kunia	Mahana	Type	Lahaina	Paumalu	Paumalu	Remark
Symbol	KyC	KyB	McD	Symbol	LaB	PeC	PZ	See See Soils Map Section 3
Slope, %	9	5	15	Slope, %	5	12	15	Based on soil classification map (SCS, 1972)
Area, ac	14.2	16.9	8.7	Area, ac	15.3	29.1	42.8	Planimetry
Typical L, ft	1500	1400	1550	Typical L, ft	500	450	400	Based on soil classification map (SCS, 1972)

2. Soil Erodability Factors

		Palikea				Kahuku		
Type	KyC	KyB	McD	Type	LaB	PeC	PZ	Remark
Rain factor,R	200	200	200	Rain factor,R	300	300	300	Average Annual Values of Rainfall R (SCS, Oct 1982)
Erodability,K	0.24	0.24	0.37	Erodability,K	0.17	0.1	0.49	Table 14, Soil Properties (SCS, 1981)
C,Idle	0.01	0.01	0.01	C,Idle	0.01	0.01	0.01	Table 5, (SCS, 1986)
C, grazing	0.042	0.042	0.042	C, grazing	0.042	0.042	0.042	Table 5, (SCS, 1986)
LS factor	4.55	2.00	10.08	LS factor	1.20	3.83	5.12	Exhibit 6, (SCS, 1981)
Managmt,P	1	1	1	Managmt,P	1	1	1	

Notes:

C values for idle land assume 95-100 % cover at surface is weeds and/or undecayed vegetation

C values fro grazing land assume 60% cover which is grasslike plants and litter with no appreciable canopy

P value assumes no management practices

3. Soil Erosion - A, tons/acre/year

		Palikea					Kahuku		
Type	KyC	KyB	McD		Type	LaB	PeC	PZ	Remark
A-idle	2.2	1.0	7.5		A-idle	0.6	1.1	7.5	Soil Loss Eq
A-grazing	9.2	4.0	31.3		A-grazing	2.6	4.8	31.6	Soil Loss Eq

4. Hazard Assessment

H=(2FT + 3D)AE, City & County Honolulu Soil Erosion Standards & Guidelines, 1975

Standard: H=50,000- represents "maximum amount of environmental damage considered tolerable"

WHERE:

F= unit factor for potential damage downstream, depends upon distance

T= time duration of project in years

D= unit factor for potential damage to coastal waters

A= area of disturbance in acres, does not include areas that will not be distrubed by project

E= soil erosion rate, same as A, above, in tons/acre/year

		Palikea					Kahuku		
Type	KyC	KyB	McD		Type	LaB	PeC	PZ	Remark
F,dam. pot.	1	1	1		F,dam. pot.	2	2	2	Exhibit , (C&C-HNL,1975)
T,yr	25	25	25		T,yr	25	25	25	Project Life
D,conserv.	2	2	2		D,conserv.	4	4	4	Exhibit 1, (C&C-HNL,1975)
A,acres	100	100	100		A,acres	100	100	100	100 acres/1.5animals/ac, assume normal dist
E,Erosion A	2.2	1.0	7.5		E,Erosion A	0.6	1.1	7.5	Idle land erosion rate
	9.2	4.0	31.3			2.6	4.8	31.6	Grazing land erosion rate
H	12218	5387	41773		H	6842	12862	84310	Idle land erosion rate
	51316	22627	175447			28734	54022	354100	Grazing land erosion rate

5. References

(1) Soil Conservation Service. 1972. "Soil Survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii". U.S. Department of Agriculture.
(2) Soil Conservation Service. 1981. "Erosion and Sediment Control Guide for Hawaii". U.S. Department of Agriculture.
(3) Department of Public Works. 1975. "Soil Erosion Standards & Guidelines". City and County of Honolulu
(4) Goldman, Steven; Katherine Jackson; & Taras Bursztynsky. 1986. "Erosion & Sediment Control Handbook". McGraw Hill

Options for Best Management Practice Planning

Soil Conservation

Soil conservation options considered in this analysis include 1) reforestation of steeply sloping land, 2) intensive grazing management, and 3) sedimentation basins. The principal effect of the first two options is to increase the cover and therefore dissipate the erosive energy of raindrop impact. Sedimentation basins do not reduce erosion, but may limit the transport downstream. However, to be effective, they need to be sized large enough to provide adequate detention time so that fine-grained sand and silt particles will settle. In addition, they must be periodically excavated to maintain their efficiency. The surface area requirements recommended by one reference (Goldman et al. 1986) are shown below:

Particle (size, mm)	Settling Velocity (ft/sec)	Surface Area (ft^2/ft^3sec) Discharge
Fine sand (0.1)	0.02300	52.2
Medium silt (0.02)	0.00096	1,250
Clay (0.005)	0.00006	20,000

The range of sediment basin size varies from approximately one acre for a 15-acre plot to three acres for a 43-acre plot, depending upon slope, as shown in item 4, Figure F-2, part 4, for trapping silt-size particles; the sizes are more than an order of magnitude greater to trap clay size particles.

The magnitude of the surface area required makes sediment basins less attractive than other management measures if the erosion hazard is severe. For example, for a 14-acre plot of Kunia soil (KyC), 14 acres are estimated as needed to settle clay-size particles. For the short term, such as during construction where area exposed is relatively small, these (basins) can be considered as temporary measures.

The best practical management strategy for the most severe hazard soil groups is to prevent their disturbance. This entails prohibiting use of these areas—for any activity that might have the potential to expose the soil horizon. This can be accomplished by:

						FIGURE F-2			
					BEST MANAGEMENT PRACTICES ASSESSMENT				
		Potential Condition					Potential Condition		
1. Options Assessment- C or P factor									
		Palikea					Kahuku		
Type	KyC	KyB	McD		Type	LaB	PeC	PZ	Remark
) Plant Tree	0.013	0.013	0.013		Plant Trees	0.013	0.013	0.013	Improve cover to 80 % with tree canopy of 25 %
b) Increase	0.0075	0.0075	0.0075		Increase	0.0075	0.0075	0.0075	Improve grass cover to 80% to 95% with 1.5 ft high
Cover					Cover				C varies uniformly between 0.012 to 0.003
c) Sediment	0.8	0.8	1		Sediment	0.7	0.8	1	Assumed contour irrigation furrows
Basins					Basins				
2. Revised Soil Erosion									
		Palikea					Kahuku		
Type	KyC	KyB	McD		Type	LaB	PeC	PZ	Remark
A-Opt a)	2.8	1.3	9.7		A-Opt a)	0.8	1.5	9.8	Soil loss eq using revised C value
A- Opt b)	1.6	0.7	5.6		A- Opt b)	0.5	0.9	5.6	Soil loss eq using revised C value
A- Opt c)	7.3	3.2	31.3		A- Opt c)	1.8	3.9	31.6	Soil loss eq using revised P value
3. Revised Erosion Hazard									
		Palikea					Kahuku		
Type	KyC	KyB	McD		Type	LaB	PeC	PZ	Remark
A-Opt a)	15884	7003	54305		A-Opt a)	8894	16721	109602	Revised erosion hazard eq using revised soil loss
A- Opt b)	9164	4040	31330		A- Opt b)	5131	9647	63232	Revised erosion hazard eq using revised soil loss
A- Opt c)	41053	18101	175447		A- Opt c)	20114	43218	354100	Revised erosion hazard eq using revised soil loss

4. Peak Discharge & Sediment Basin Size

Type	Kunia	Kunia	Mahana		Type	Lahaina	Paumalu	Paumalu	Remark
Symbol	KyC	KyB	McD		Symbol	LaB	PeC	PZ	See See Soils Map Section 3
Slope, %	9	5	15		Slope, %	5	12	15	Based on soil classification map (SCS, 1972)
Area, ac	14.2	16.9	8.7		Area, ac	15.3	29.1	42.8	Planimetry
Typical L, ft	1500	1400	1550		Typical L, ft	500	450	400	Based on soil classification map (SCS, 1972)
Curve Num	85	85	85		Curve Num	85	85	85	Assume Group D, based on Table 25 ref (2)
24Hr-Rainfall	5	5	5		24Hr-Rainfall	6	6	6	Based on 2-yr,24-hr rain, ref (5); see note (1)
Runoff	3.35	3.35	3.35		Runoff	4.32	4.32	4.32	Based on Table 24, ref (2);see note (2)
Mod S cfs/l	-	11	-		Mod S cfs/l	9	-	-	Based on p.90, ref (2)
St S cfs/l	10	-	6		St S cfs/l	-	20	26	Based on p. 91, ref (2)
S Adj	0.94	1.05	0.94		S Adj	1.05	0.95	0.99	Based on Table 28, ref (2)
Peak Q,cfs	31	39	19		Peak Q,cfs	41	82	111	Based on runoff x cfs/in runoff x S adj factor
Basin Size,ac					Basin Size,ac				Based on Table 8.1 ref (4)
Silt	0.9	1.1	0.5		Silt	1.2	2.4	3.2	Assume settling velocity = 0.00096 ft/sec
Clay	14	18	9		Clay	19	38	51	Assume settling velocity = 0.00006 ft/sec

Notes:
(1) Assume lognormal distribution of 2-yr 24 hour rainfall; std dev = 50%; approximately reproduces rainfall frequency in Tp No. 43
(2) Ratio of runoff to rainfall depth: assume 0.67 @ Palikea & 0.72 @ Kahuku

5. References

(1) Soil Conservation Service. 1972. "Soil Survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii". U.S. Department of Agriculture.
(2) Soil Conservation Service. 1981. "Erosion and Sediment Control Guide for Hawaii". U.S. Department of Agriculture.
(3) Department of Public Works. 1975. "Soil Erosion Standards & Guidelines". City and County of Honolulu
(4) Goldman, Steven; Katherine Jackson; & Taras Bursztynsky. 1986. "Erosion & Sediment Control Handbook". McGraw Hill
(5) U.S. Dept. of Commerce. 1962. "Rainfall-Frequency Atlas of the Hawaiian Islands." U.S. Weather Bureau Tech Paper No.43

(1) judicious subdivision planning to eliminate land with slopes exceeding 15 percent in lot plans,
(2) convenants in the leaseholder's agreement that restrict grazing density in the land areas having between 9 and 15 percent slope,
(3) identification of erosion hazard areas on the subdivision plan to be restricted from use, and
(4) the use of sedimentation basins during construction activities and reduction in sediment load for trapping silt.

The amount of forage that a mature dairy cow consumes and the rate of growth are considered, theoretically, to establish a preliminary density limit for grazing on steep slopes (12 to 15 percent). A mature cow, assumed to weigh 1,300 pounds, must consume 1.5 to 2 percent of her weight in dry matter per day for maintenance energy. This equates to 4,305 kg per year:

$$1{,}300\text{ lb} \times 0.4536\,\frac{\text{kg}}{\text{lb}} \times 0.02 \times 365\text{ days/yr} = 4{,}305\text{ kg/yr}$$

A stand of guinea grass, assuming sufficient soil moisture, can produce 21 tons per acre of growth a year. Assuming 80 percent moisture content, this equates to 1,905 kg/year dry matter:

$$21\text{ tons/yr/ac} \times 2{,}000\,\frac{\text{lb}}{\text{ton}} \times 0.4536\,\frac{\text{kg}}{\text{lb}} \times 0.1 = 3{,}810\text{ kg/yr/ac of dry matter}$$

Guinea grass can be grazed on a two-month cycle in the summer months and a three-month cycle in cooler winter months. It should not be grazed closer than 10 inches. Assuming a mature height of 4 feet (96 inches) and a remaining cover of one foot (12 inches) after grazing for erosion control purposes, approximately 75 percent of the growth can be grazed. Thus the acreage limitation for good cover on steep grazing land is:

$$4{,}305 / 3{,}810 / 0.75 = 1.51\text{ acres per animal unit, say 1.5 acres/animal unit}$$

This is equivalent to approximately two-thirds animal unit per acre. A 300-pound calf could be considered 0.23 animal units, on a weight basis. If the average animal unit is considered to be a calf, then one-third acre/animal unit is required on the basis of forage production. These factors are for optional conditions, i.e., sufficient moisture, good grazing management, etc. They should be reevaluated as the situation warrants.

A comparison of the hazard rating with three management options is shown in Figures F-3 through F-5 for the Palikea site and Figures F-6 through F-8 for the Kahuku site. These charts show the effect that Option A (reforestation), Option B (intensive grazing management), and Option C (sediment basins) are estimated to have on hazard ratings. There is uncertainty, as the confidence bands indicate, is shown by the top line which indicates the limit of 90 percent of the estimates, and the bottom line indicates the lower 10 percent of the estimated results. The results are shown for three soil types at each site. These are labeled at the bottom of each figure.

Two conclusions can be drawn: 1) intensive grazing management is potentially more effective than reforestation, and 2) grazing on the first two soil types considered at each site, with grazing management, is an acceptable risk. However, the critical soil at each site has slopes exceeding 15 percent and will not be useable with an acceptable hazard rating number. In fact, these limiting soils, the Mahana (McD) and Paumalū (PZ) soils are on slopes generally considered too steep for satisfactory roads and the operation of farm equipment. The use of these areas should be restricted.

The conclusions have several implications. First, intensive rotational grazing requires good herd management. Paddocks must be fenced and a herdsman selected to rotate the livestock. The details and techniques for this type of operation are covered elsewhere (Smith, Leung, Love 1986). But a centralized commitment to institute this management technique is essential. If one dairy operation provides good stewardship of grazing area, but another does not, the system breaks down. Thus the grazing management should be centralized. In addition, it is recommended that a backup system be provided. A centralized runoff control reservoir can function as a sediment basin for this purpose. Another implication concerns reforestation. Although not practical in the short term, this might be a way to expand grazing areas in the long term. Development of suitable tree-covered pastures on steep slopes, however, requires time. Cattle must be excluded intially to prevent trampling young growth, and the work is labor intensive.

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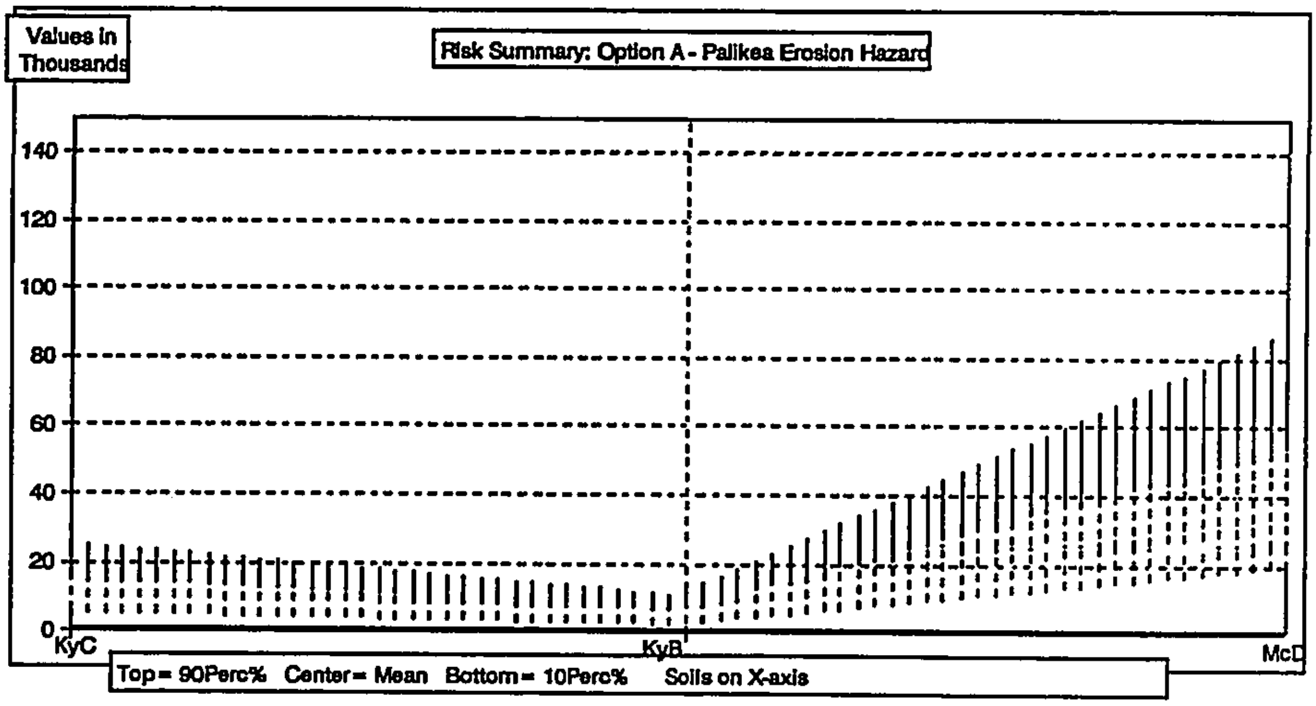


FIGURE F-3

RISK SUMMARY
OPTION A - PALIKEA

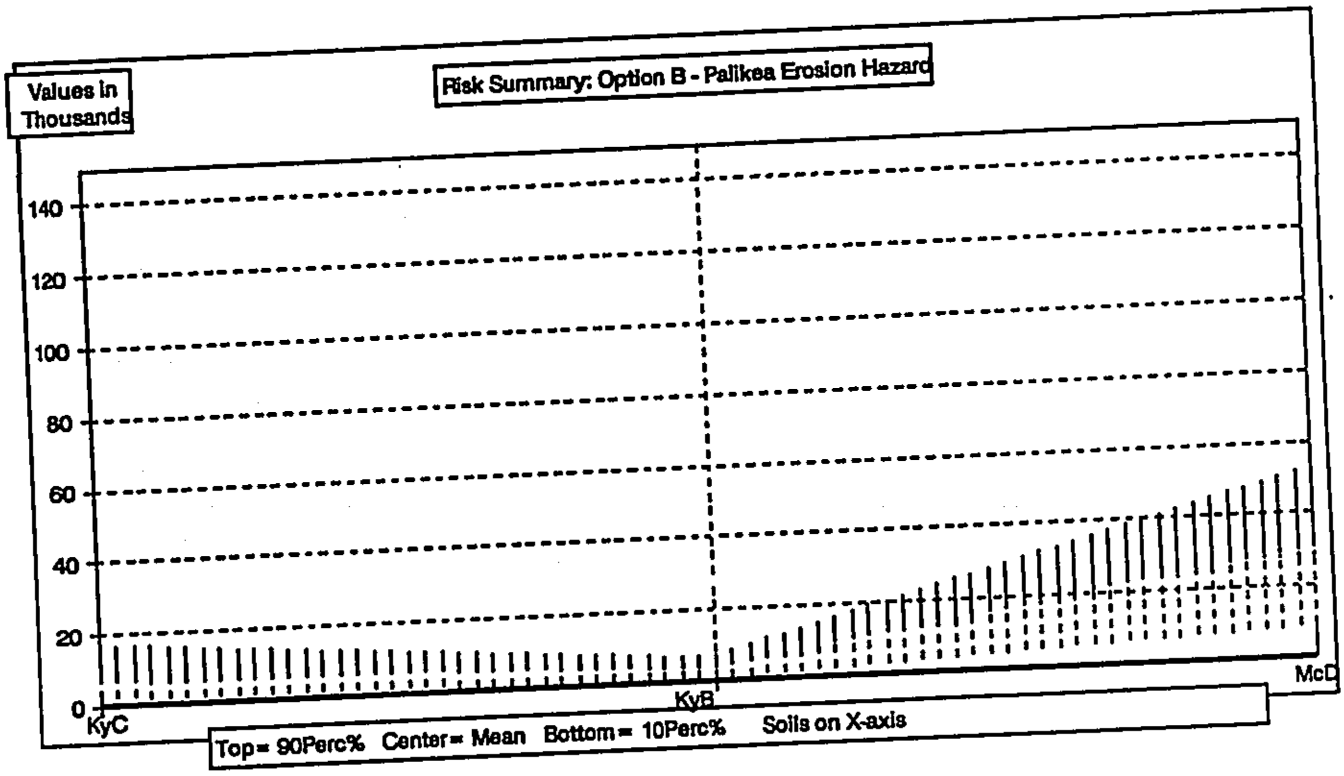


FIGURE F-4

RISK SUMMARY
OPTION B - PALIKEA

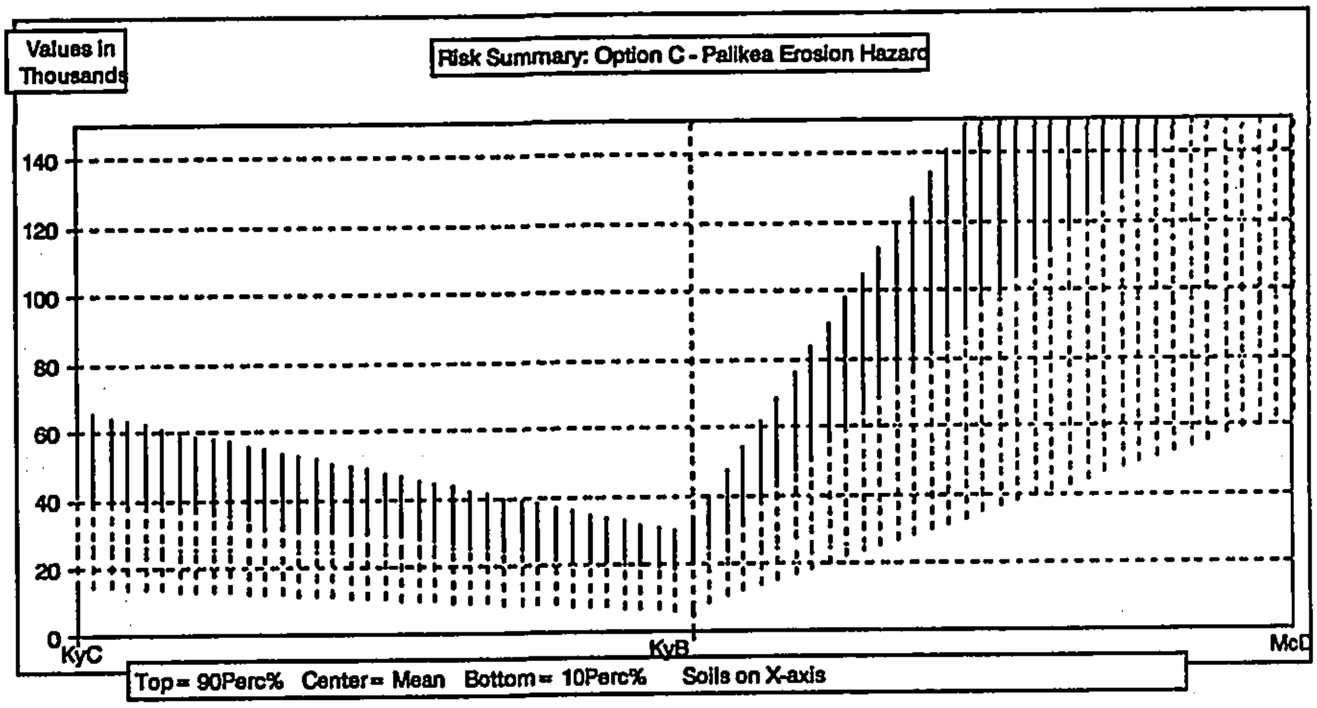


FIGURE F-5

RISK SUMMARY
OPTION C - PALIKEA

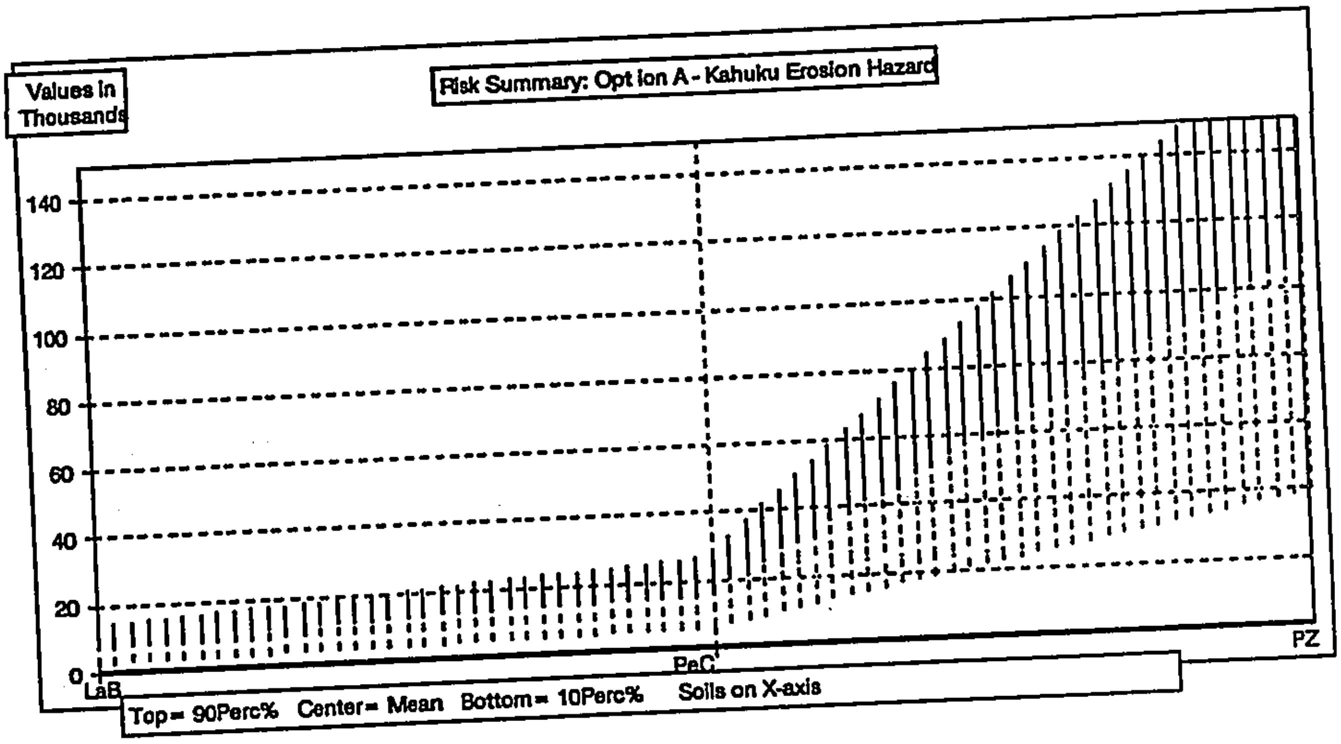


FIGURE F-6

RISK SUMMARY
OPTION A - KAHUKU

Chart5

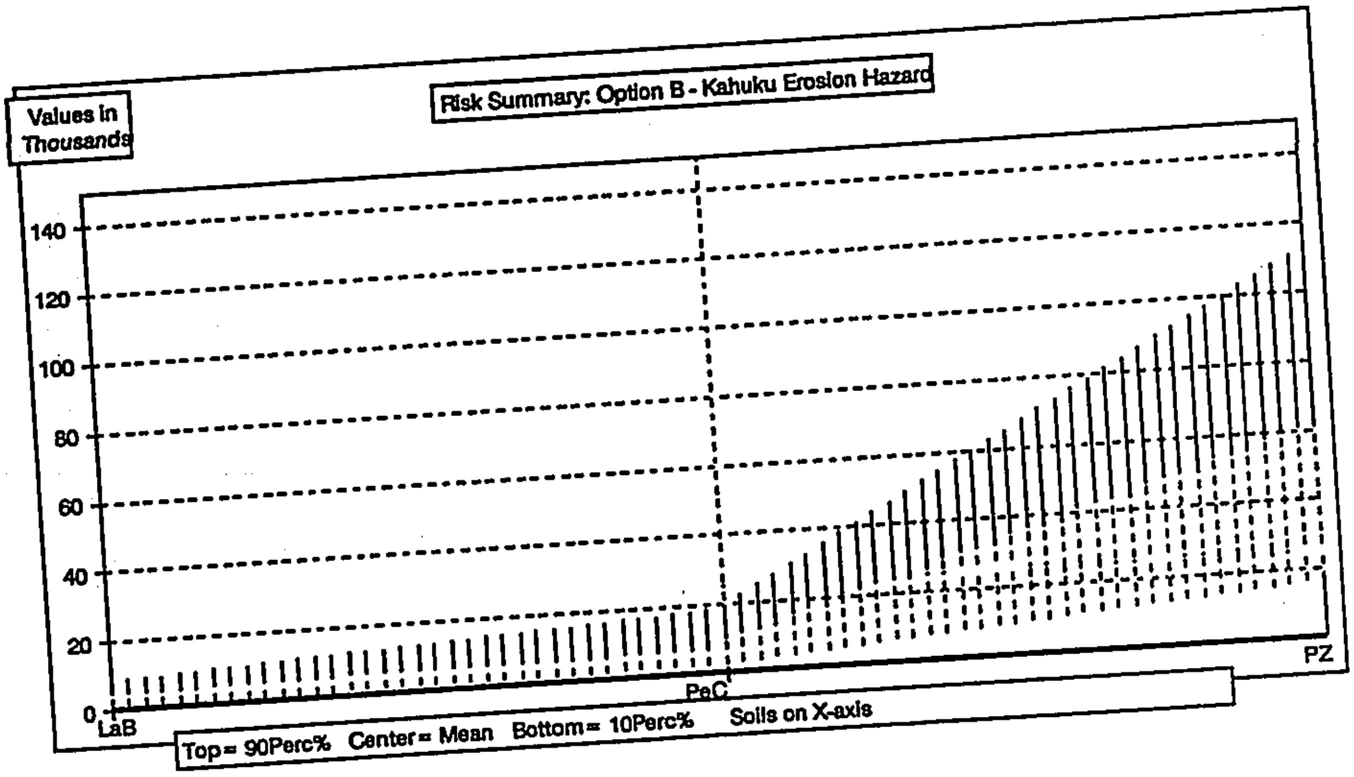


FIGURE F-7

RISK SUMMARY
OPTION B - KAHUKU

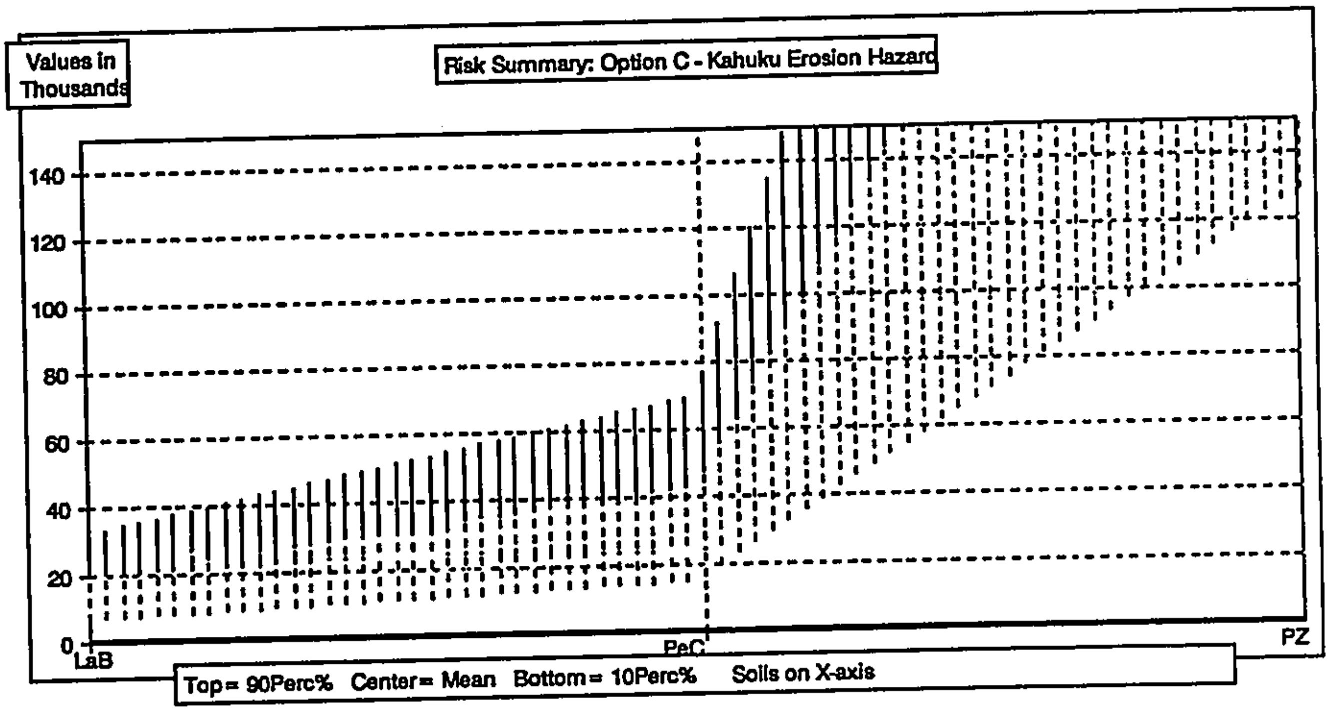


FIGURE F-8

RISK SUMMARY
OPTION C - KAHUKU

APPENDIX G
KI'I WETLANDS HYDROLOGIC BUDGET ANALYSIS

CONTENTS

FIGURES AND SPREADSHEET

APPENDIX G

KI'I WETLANDS HYDROLOGIC BUDGET ANALYSIS (James Campbell National Wildlife Refuge)

Objective

Ground water ushering from three wells in the Ki'i Unit of the James Campbell National Wildlife Refuge is a major supply of water in the wetland ecosystem. The wells tap the confined basal aquifer, as do other wells in the vicinity, including the wells at Pump Station No. 1, on the Kahuku Agricultural Park site. Withdrawals from other wells in the system have effects on each other. A decline on the order of tenths of feet is predicted as a result of increased pumping of Pump Station No. 1. This is discussed in Appendix B. The objective of this appendix is to estimate the potential this effect has upon the hydrologic budget in the wetland.

The principal components of the hydrologic budget are shown in the following water balance equation:

$$\text{Inflow - Outflow} = \text{Change in Storage} \qquad (1)$$

Where Inflow = Rainfall + Inlet Stream Flow + Artesian Well Flow
Outflow = Evapotranspiration + Outlet Stream Flow + Leakage

The methodology to develop the estimates of these parameters is described below.

The hydrologic considerations include: 1) estimation of the flow into the wetlands from the artesian wells as a function of hydraulic head, 2) estimation of the contribution of stream flow to the overall water balance (with some idea of its temporal variation), and 3) use of the water balance equation to assess the potential affect resulting from decline in aquifer head.

The Ki'i wetlands are a brackish water ecosystem. "Brackish" water is defined by the Hawaii Administrative Rules Title 11, Chapter 54, Water Quality Standards, as waters with dissolved inorganic ion concentrations (salinity) of between 500 to 38,000 parts per million (ppm). Fresh water is mixed with sea water in the ditches and ponds creating an ecosystem sensitive to changes in the hydrologic balance.

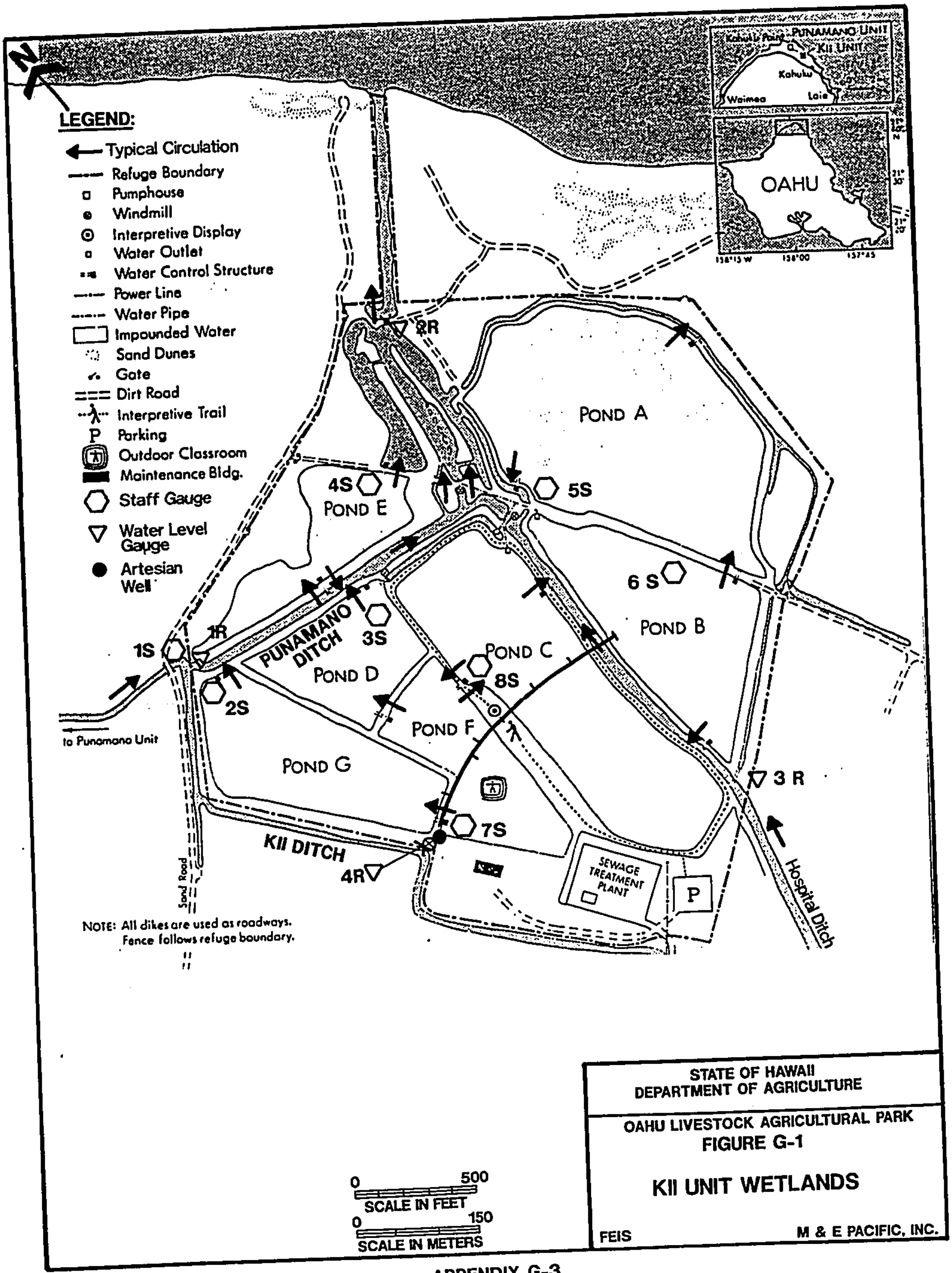
Overview of the Hydrologic System

The Ki'i Unit is a series of manmade wetlands (see Figure G-1) that in their present form are shallow ponds constructed initially by the Kahuku Plantation, and later modified by the U.S. Fish and Wildlife Service. However, wetlands existed before this, as shown in the *Sites of Oahu* (Elspeth Sterling and Catherine Summers, Bishop Museum Press 1978). It is possible that these wetlands were the result of spring discharge, but heavy pumping during the plantation era lowered the aquifer potentiometric water surface. The potentiometric surface of a confined aquifer is an imaginary surface coinciding with the hydrostatic pressure level in the aquifer.

There are two principal surface water inlets, one on the west known as the Punamanō ditch, and one on the east, known as the hospital ditch. The *Ki'i Ditch* confluences with the Punamanō Ditch at the latter's entrance into the Ki'i Unit. In addition, there are three wells near the southern boundary of the unit that were drilled in the 1980s to provide fresh water for the system. This water is distributed by a 12-inch diameter pipe from a wet well that receives the artesian discharges to Ponds F, G, C, and B. Valves at the discharge points in each of these ponds provides control of the discharge. In addition, there are a series of culverts between each pond that link them together and eventually to the two principal ditches that cross through the refuge and meet near its center.

At times, when it is desirable to rapidly increase the pond water levels, a tractor driven pump is used to draw water from the Ki'i ditch and discharge it into the wet well serving the artesian wells. This water reaches the ponds through the 12-inch pipe distribution system. Generally, the flow from one of the wells is sufficient to maintain low levels in the ponds during nesting season.

The system discharges through several culverts (see Figure G-1) beneath an interior road way into a manmade ditch to the ocean. The culverts have flap gates to reduce tidal exchange, but water level recordings indicate all of the ditches are tidal. A pump station has been constructed where the culverts cross under an interior roadway, which is activated during flood stages to provide additional discharge capacity. The outlet is excavated in consolidated marine sediments and coral near the ocean. The high spot in this outlet channel bottom, approximately 0.9 feet elevation, msl, is the hydraulic control point.



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OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE G-1

KII UNIT WETLANDS

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Water flows generally from south to north through the system. Although the surface ditches provide flow, particularly for Pond E, the pond hydraulics are dominated by the discharge of the artesian wells which provides fresh water at greater potential elevation. The total dissolved solids concentration of the artesian water is approximately 200 mg/l, and the temperature is approximately 23 degrees centigrade (72 degrees F). In comparison, the total dissolved solids concentration of the ditch water is estimated to be on the order of 3,500 to more than 5,000 mg/l and 30 degrees centigrade (86 degrees F). Although some of the brackish water originates from discharges of the salt-water aquaculture ponds along Punamanō ditch, both ditches are tidal throughout the wetland, and thus mixed with ocean water during tidal exchanges.

Methodology

Rainfall, inlet and outlet stream flow, and artesian well flow can be measured. Rainfall is collected in a rain gauge by AMORIENT, the aquaculture farm near the southwestern boundary of the unit. Discharges at each inlet, outlet, and the artesian well outlet (in the wet well) were monitored by installing electronic water level sensors. Velocity and channel geometry measurements were made at each discharge point. An elevation-discharge relationship was developed at each location. Discharge values are developed for an approximately two-month period from February 20 to April 15, 1992, except for the artesian wet well for which approximately one month (March 13 through April 15, 1992) of data is available.

Historical pan evaporation data is used to estimate evapotranspiration. Kahuku Plantation maintained evaporation station 908 (1960-1965) near the refuge for approximately five years. The monthly data were converted to daily totals based upon the number of days in each month. A shallow water / pan evaporation coefficient of 0.8 was used to estimate pond evaporation. The change in water levels in each pond are monitored by the US Fish and Wildlife Service, thus providing an estimate of change in storage. Equation (1) can be solved using these measured and estimated data; the change in storage can be compared to the measured change in storage. The unknown in equation (1) is the amount of leakage through the bottom of the ponds into the subsurface.

The water budget is shown in the accompanying spreadsheet, BUDGET3.XLS. A time interval of six hours is chosen in order to capture the tidal effects. Velocity measurements made at the outlet indicate the discharge is sensitive to the tide condition. Figure G-2 shows the variation in the discharge at the outlet ditch. Depending upon the tide, outlet discharge may vary approximately an order of magnitude. At high stages, e.g., flood tide, the discharge is reduced by approximately fifty percent. The discharge curve is based on a limited set of observations. At flood flows, there will be a shift in the curve to the right on the graph, but the tidal effect is probably still significant.

Results

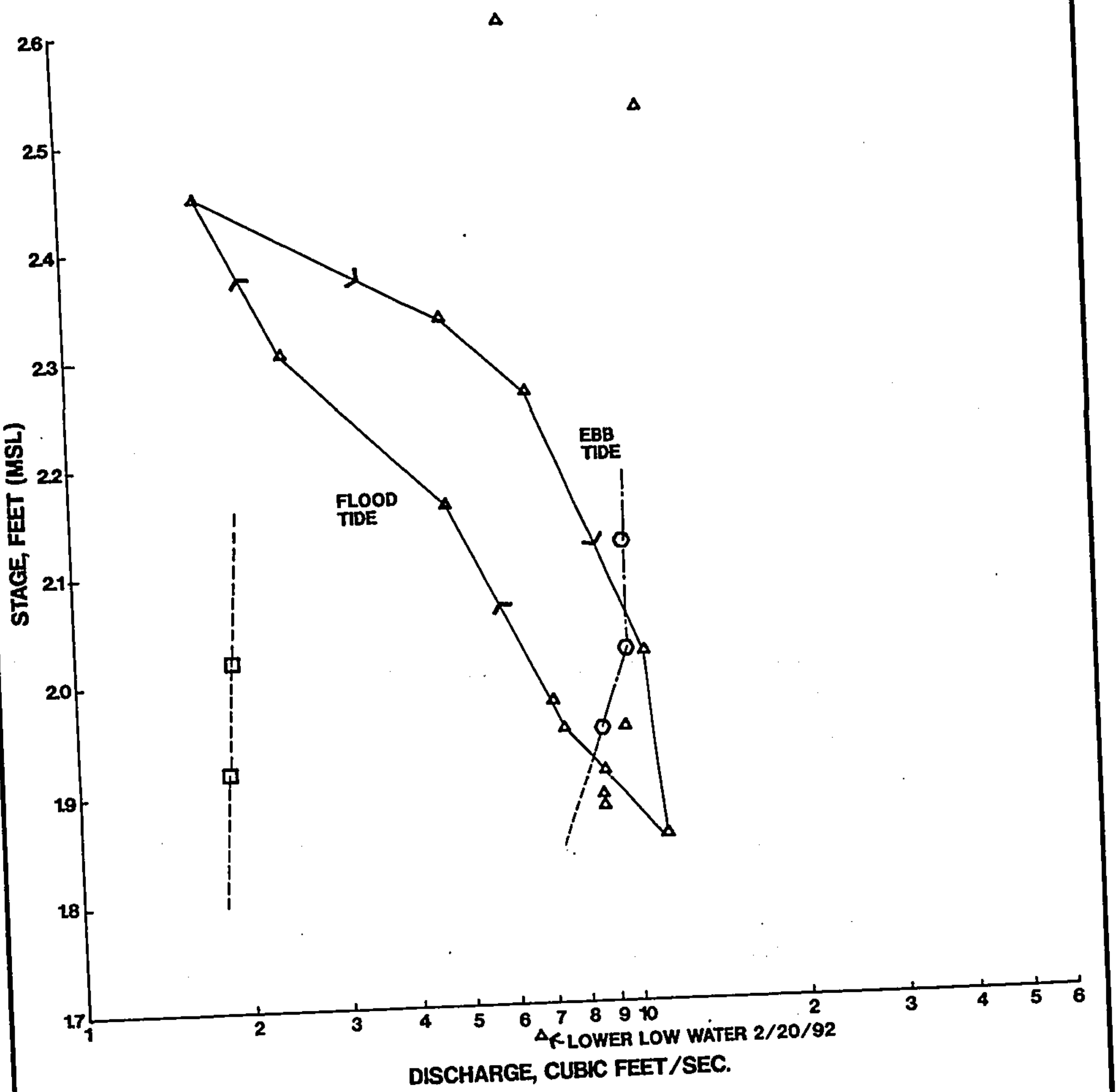
The spreadsheet analysis at the end of the appendix (BUDGET3.XLS) summarizes the hydrologic budget for the period between March 13 to April 15, 1992. The unknown variable is leakage; and also the one variable for which physical measurements are not available because the ponds are covered by water. The average condition over this period is summarized below:

TABLE G-1. HYDROLOGIC WATER BALANCE

Values in million gallons per day and percent of total					
Inflow			*Outflow*		
Stream Inflow	Artesian Well Flow	Rainfall	Outflow to Ocean	Evapora -tion	Leakage
4.63 96.7 %	0.15 3.1 %	0.01 0.2 %	3.03 60.5 %	0.05 1.0 %	1.93 38.5 %

The total water flux through the system is on the order of approximately 4 to 5 million gallons per day, of which the artesian component is a relatively small, but critical component. Artesian flow more than offsets estimated evaporation and thus moderates the salinity conditions which undoubtedly would be more harsh if the fresh water is not provided. Note that the artesian well flow is not the maximum possible, but the average during this period when from one to three wells were in operation. The flow can be shut off at the well head by closing valves.

The cumulative change in the pond storage is used to evaluate the leakage estimate. Cumulative change means the sum of the fluctuation over all ponds, measured in inches since the beginning of the period of the water budget.



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OAHU LIVESTOCK AGRICULTURAL PARK

FIGURE G-2

KII NWR OUTLET DITCH DISCHARGE RATING

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Figure G-3a shows the observed changes (accumulated for each pond) along with that predicted by the water budget spreadsheet (Figure G-3b). The general downward trend of the ponds is reproduced by the model, but the magnitude of individual pond fluctuations is not faithfully reproduced. The complex circulation pattern within the ponds has to be considered in order to model individual pond dynamics.

Leakage is a significant component, approximately one-third of the outflow. The wetlands act as a sink, in resource terms, for water, sediment, and nutrients. Although water quality characterizations were not performed, it can be hypothesized that an important affect of this system is the reduction of sediment and nutrient discharges to marine waters that might otherwise have an impact on their beneficial uses. The saturated hydraulic conductivity is estimated to be 0.3 feet per day which is equivalent to $1xE^{-4}$ cm per second. This rate is typical of silts, fine sands, and stratified clays.

FIGURE G-3a

Kil Ponds - Cumulative Observed Fluctuation

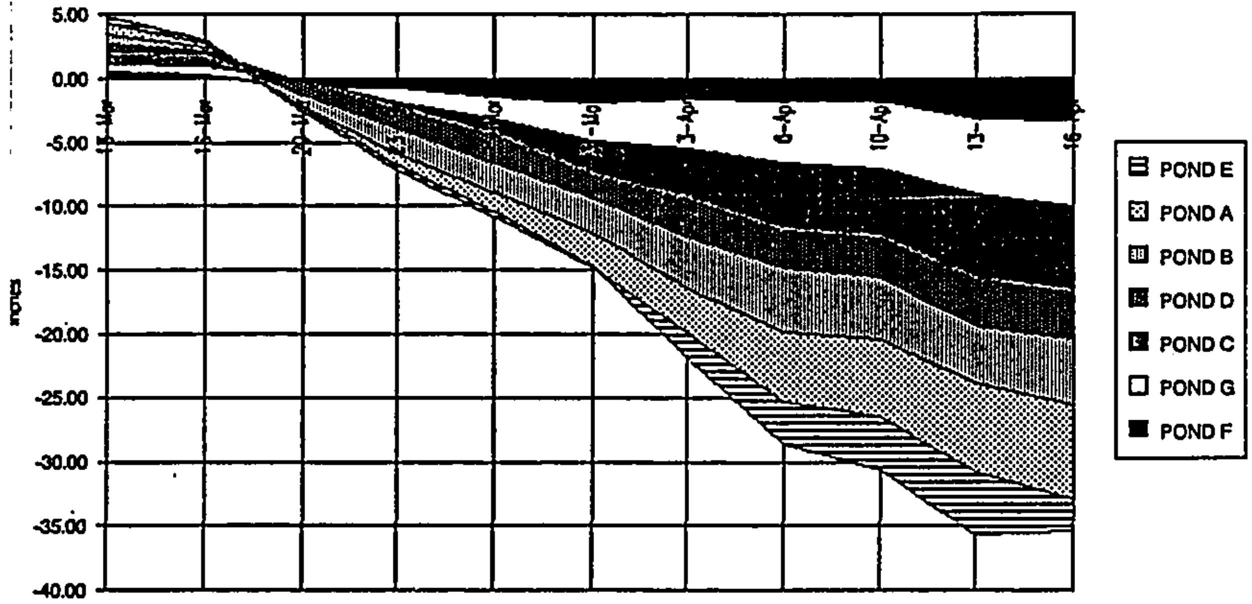
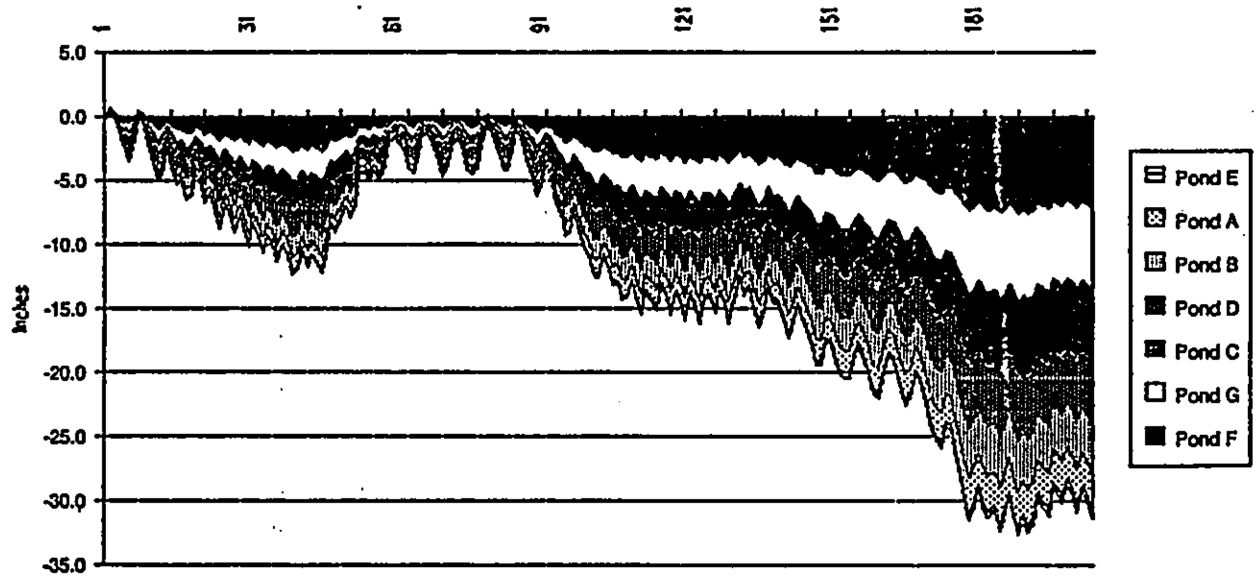


FIGURE G-3b

Kil Ponds - Predicted Cumulative Fluctuation - k=0.78 ft/day



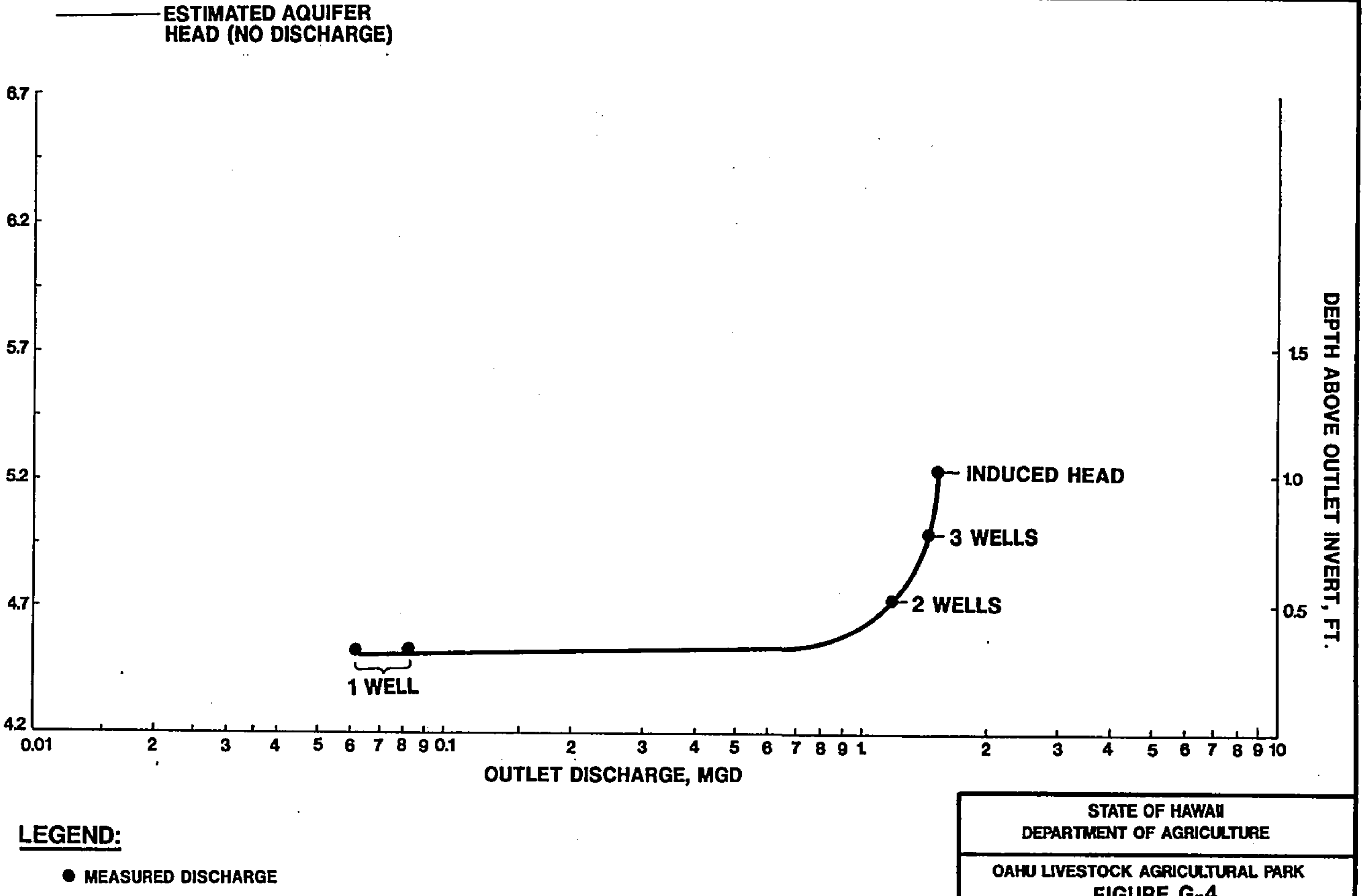
Potential Effects

The potential magnitude of decrease in aquifer potentiometric elevation at the artesian source is considered to be between 0.25 to 0.5 feet, assuming the increase in ground water withdrawal at the agricultural park is one million gallons per day, including the existing Kahuku Farmers' Association withdrawal. The reduction in potential energy, according to conservation of energy considerations, will manifest itself in a reduction in the discharge elevation in the wet well.

Figure G-4 shows measured elevations in the wet well and computed discharges in the outlet pipe based on velocity measurements made at the entrance to the pipe. From the figure, it can be seen that the discharge from all three wells is estimated to be approximately 1.4 million gallons per day (mgd). One well produces approximately 60,000 to 80,000 gallons per day. Note that not all of the wells are producing equally since the total number of wells multiplied by the single well observation does not equal the observed output of three wells, i.e., 3 x 80,000 = 1.8 mgd, not 1.4 mgd. As more wells are used, flow into the wet well increases. However, the head loss can be expected to be greater as the water tries to enter the outlet pipe resulting in less proportional discharge, other factors being equal. Furthermore, it would be unusual for each well to produce equal amounts due to differences in drilling and geological factors. Note that pumping additional water into the wet well may significantly increase the head (or water surface elevation above the outlet pipe), but the rate of increase in discharge diminishes because of increased energy losses.

An analysis of the decrease in potential energy elevation (hydraulic head) at the wet well is based on Figure G-4. Using the average water budget data obtained from the shaded results on the spreadsheet, the increase (or decrease) in average pond elevation is estimated for three conditions: 1) existing potential energy conditions in the aquifer, 2) assuming a 0.25 feet decrease, and 3) assuming a 0.5 feet decrease. The artesian flow for these conditions are estimated to be 1.45, 1.2, and 0.7 mgd, respectively. Figure G-4 indicates the change in discharge with depth or head above the outlet invert.

The critical condition is assumed to be when the pond levels are increased in the fall in preparation of the arrival of migratory waterfowl during the winter. A four-month (120-day) interval is considered. Note that the results are based on the



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OAHU LIVESTOCK AGRICULTURAL PARK
FIGURE G-4

KII ARTESIAN WELL
OUTLET DISCHARGE

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water budget during the period of observation. The rainfall is below normal for this period, however, the rainfall as a percentage of total flux is relatively insignificant.

The results are shown in Figure G-5. Assuming all three wells operate with the existing head condition, the projected rise in 120 days is estimated to be approximately 20 inches. However, if the potential energy elevation (hydraulic head) in the wet well is reduced by 0.25 feet, the increase in the same period is less than five inches. With a 0.5 feet decrease in wet well hydraulic head, there is estimated to be a decline during the period of 120 days over 25 inches.

The management of the pond levels is based on the following criteria:

Condition	*Stage, ft*
Flooding	4.5
Full	4.0
Stilt Nesting	3.5

These criteria vary somewhat for Ponds C and F which operate at higher levels due to the artesian well discharge. However, the limiting criteria is assumed to be the ability to bring the ponds from the 3.5 to 4.5 feet stage. Thus the existing condition results indicate the achievement of the filling process may be accomplished in less than 120 days, approximately 75 days. **If the potential hydraulic head decreases by 0.25 feet at the wells, the estimate is that the desired pond levels cannot be reached in 120 days.**

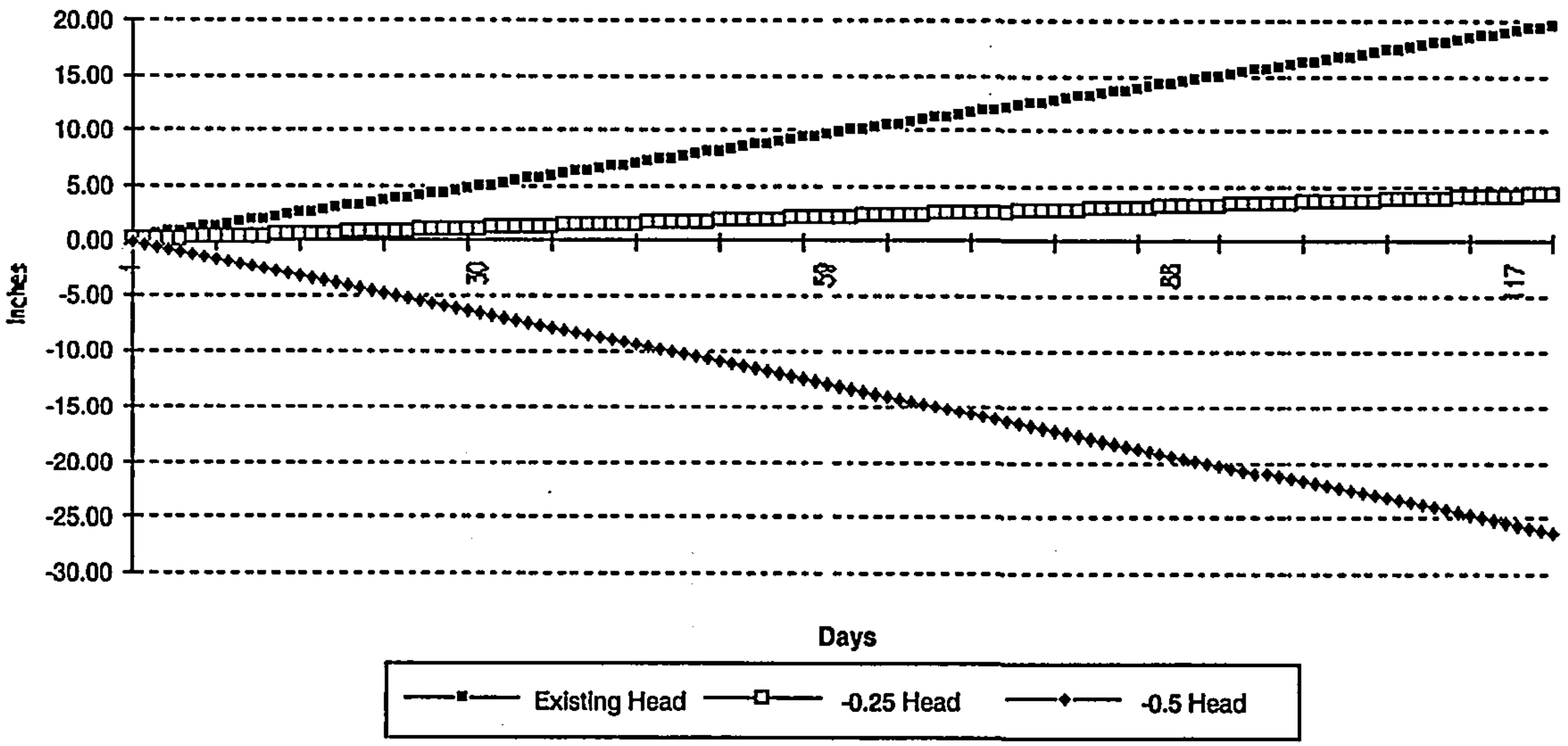
The conclusion is that if the hydraulic grade line decreases 0.5 feet, the present well operation may not meet wildlife management requirements. There are several mitigation options that could be pursued. These require detailed consultation with the U.S. Fish and Wildlife Service.

Limitations of Analysis

The analysis is a hypothetical evaluation that ignores tidal hydraulics, which will have the effect of maintaining water levels at least equal to the tidal levels. In addition, the role that streamflow through the wetlands has on maintaining water surface elevations is poorly understood. It is known that there are periods when water is exchanged between the ponds and the ditches and vice versa. The model would have to be considerably more complex to understand these hydraulic relationships.

FIGURE G-5

Estimated Average Pond Fluctuation



If the decrease in potential head at the wells is on the order of 0.5 feet, the results indicate there is significant potential for more tidal exchange and this will result in increased salinity in the ponds which could affect the ecosystem. In addition, there will be greater exposure of bottom areas if the decrease in pond levels predicted materialize, with the attendant loss of water surface area.

The evaluation here considers only the effect of a single source, Pump Station No. 1, on the aquifer potentiometric surface. However, there are other wells in the vicinity of the artesian wells that can affect the outflow rate. For example, Figure G-6 shows the theoretical reduction that could result from pumping a well 10,000 feet distant from the artesian wells at two rates—2.5 and 4 mgd. The calculations are based on an assumed ideal condition:

1) the water-bearing aquifer material has uniform hydraulic conductivity;
2) the aquifer is not stratified;
3) the pumping well penetrates the entire aquifer; and
4) the regional potentiometric surface is horizontal, i.e., there is no slope of this surface toward the ocean.

Additional considerations are the hydraulic conductivity, assumed to be 300 ft/day, and the boundary of the system, estimated to be 12,000 feet to the forest reserve, assumed as the start of dike-confined water.

Figure G-6 shows an increase of 1.5 mgd increases the head difference, or decreases the artesian head 0.05 feet. Overall, the magnitude of the head loss due to a well pumping 4 mgd at a 10,000-foot distance is about the same order of magnitude as a well pumping 1 mgd at a 3,000-foot distance, all other factors assumed the same. If the hydraulic conductivity is assumed to be 150 feet/day (50 percent less), the head decrease doubles. The conclusion is that other wells in the vicinity will also have an effect depending upon their distance and pumping rate.

Another limitation of this analysis is that it assumes a steady state condition. In other words, temporal changes in aquifer pumping, hydrologic parameters such as rainfall extremes, and different well operation schedules are not considered. These abberations may explain some of the variability in fresh water flow into the wetlands from the artesian wells. For example, Figure G-7 shows the average four-hour

FIGURE G-6a

Theoretical Reduction in Aquifer Potentiometric Elevation

As A Result of Additional Water Well Pumping

Based on Existing Pumping In Confined Conditions

Ho-Hw=	(Q/2PIKb)ln(Ro/Rw)					
Ho=	Head above top of confined layer at boundary					
H1=	Head at artesian wells					
Q=	Discharge from pumping well					
K=	Hydraulic conductivity					
b=	Confined thickness					
Ro=	Radial distance from pumping well to boundary					
Rw=	Radial distance from pumping well to artesian wells					
Ho-Hw=	0.10	ft				
Q=	334250	cuft/day	(mgd x1.337xE5=c		2.5	mgd
K=	300	ft/day	(K=T/b)	1238	gpd/ft	
b=	320	ft				
Ro=	12000	ft				
Rw=	10000	ft				

FIGURE G-6b

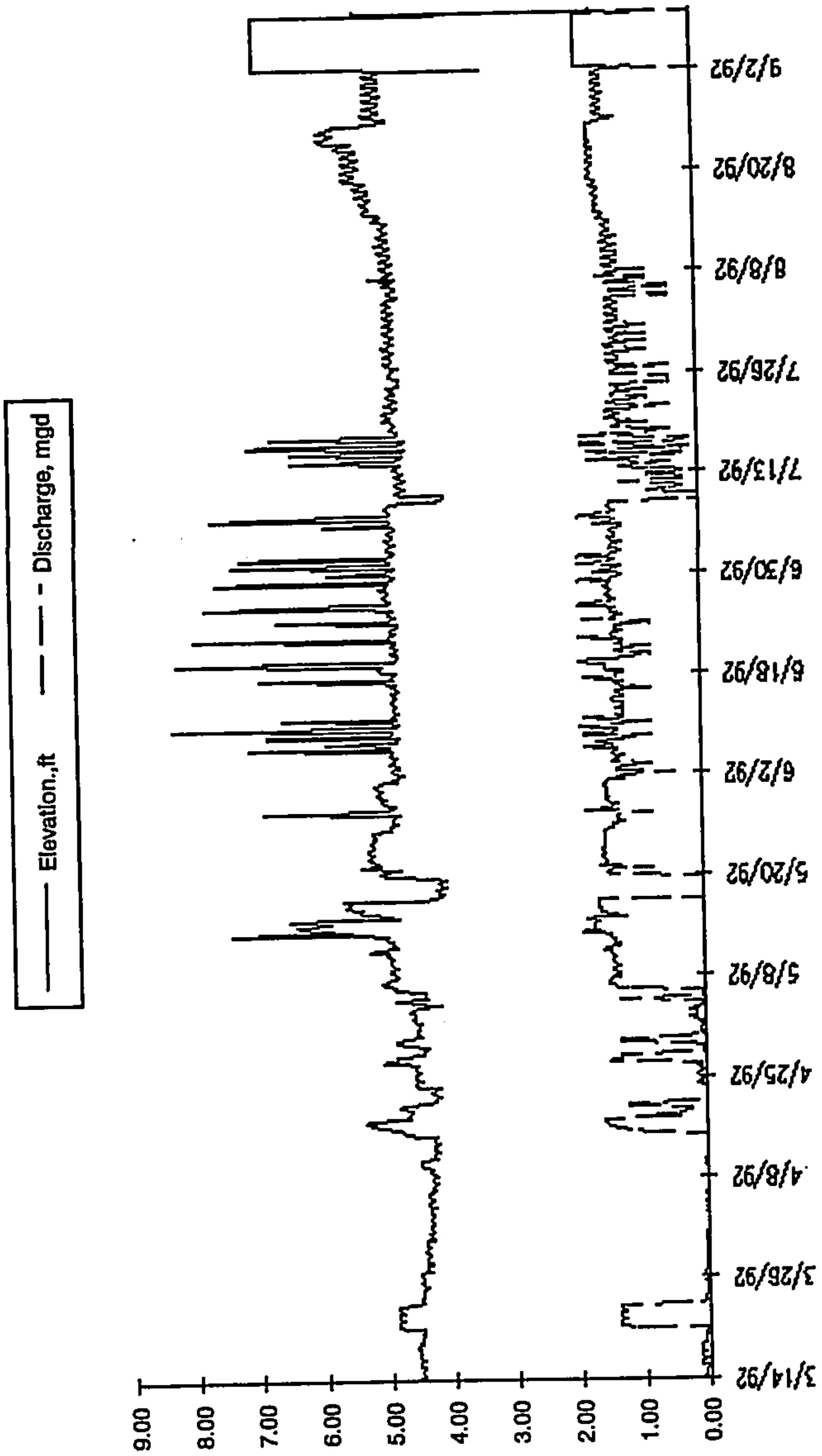
Theoretical Reduction in Aquifer Potentiometric Elevation

As A Result of Additional Water Well Pumping

Based on Increased Pumping In Confined Conditions

Ho-Hw=	(Q/2PIKb)ln(Ro/Rw)					
Ho=	Head above top of confined layer at boundary					
H1=	Head at artesian wells					
Q=	Discharge from pumping well					
K=	Hydraulic conductivity					
b=	Confined thickness					
Ro=	Radial distance from pumping well to boundary					
Rw=	Radial distance from pumping well to artesian wells					
Ho-Hw=	0.16	ft				
Q=	534800	cuft/day	(mgd x1.337xE5=c		4	mgd
K=	300	ft/day	(K=T/b)	1238	gpd/ft	
b=	320	ft				
Ro=	12000	ft				
Rw=	10000	ft				

FIGURE G-7 Wet Well Elevation & Discharge



elevation and outflow estimates for the wet well that receives artesian well flow and surface water pumped from Ki'i Ditch. The large "spikes" of water elevation are in part due to pumping ditch water into the wet well for distribution. However, there are times when no operational changes occur, yet changes in water level and outflow are observed. For example, during low flow periods in late March and early April 1992, minor fluctuations in wet well elevation occurred.

The ground water analysis in Appendix B for the Kahuku site suggests some of the variability may be due to ground water use activities that take years to propagate through the system. For example, the average velocity in the aquifer region between the Ki'i artesian wells and Pump Station No. 1 is approximately two (2) feet per day. Average effective velocity should not be confused with average hydraulic conductivity which can be measured in feet per day per foot of hydraulic head. At that flow rate, and with 2,700 feet horizontal separation between the two sources, the time it takes for a water particle to pass between the sources is on the order of years (2,700 feet / 2 feet/day / 365 days/year = 3.7 years). Thus the propagation of increased pumpage effects will not be instantaneous as assumed in the hydrologic budget analysis, but will take months, perhaps years to manifest. It is possible that the "small scale" differences in water levels are due to previous perturbations in pumping schedules. Other factors include tides, barometric pressure changes, and the outlet hydraulic controls of the pond/ditch system.

Kii Wetland Unit - James Campbell NWR

Water Budget For Period February 20 - April 15, 1992 (Leakage Assumed)

Apr-92

General Equation: Inflow - Outflow = Change in Storage

Where: Inflow = Inlet ditch discharges + Rainfall + Artesian Well Inflow

Outflow Outlet ditch discharge + Evaporation + Leakage

Notes: Inlet & Outlet ditch discharges are based on water levels records

Rainfall is based upon AMORIENT daily rainfall gauge readings

Evaporation is based upon monthly pan evaporation records at Station 908

Artesian well discharge is based upon water level records

Ditch Section @ Water Level Recorder Kii 1R:			Ditch Section @ Water Level Recorder Kii 3R:			Ditch Section @ Water Level Recorder Kii 4R:		
Elev	Flow	Punamano Ditch	Elev	Flow	Hospital Ditch	Elev	Flow	Artesian Wells Outlet Pipe
1.85	7.40		1.80	1.80		4.20	0.001	
1.88	7.70		1.85	1.84		4.30	0.010	
1.90	8.00		1.90	1.86		4.35	0.015	
1.93	8.35		1.92	1.87		4.40	0.03	
1.95	8.70		1.95	1.880		4.45	0.06	
1.96	8.85		1.96	1.890		4.50	0.10	
1.97	9.00		1.97	1.895		4.55	0.20	
1.98	9.10		1.98	1.900		4.60	0.35	
1.99	9.25		1.99	1.905		4.65	0.65	
2.00	9.40		2.00	1.910		4.70	1.20	
2.01	9.55		2.01	1.915		4.75	1.85	
2.02	9.70		2.02	1.920		4.80	2.05	
2.03	9.72		2.03	1.925		4.85	2.15	
2.04	9.74		2.04	1.930		4.90	2.22	
2.05	9.75		2.05	1.935		4.95	2.27	
2.06	9.76		2.06	1.940		5.00	2.30	
2.07	9.77		2.07	1.945		5.05	2.32	
2.08	9.78		2.08	1.950		5.10	2.36	
2.09	9.79		2.09	1.955		5.15	2.38	
2.10	9.80		2.10	1.960		5.20	2.40	
2.11	9.81		2.11	1.965		5.25	2.43	
2.12	9.82		2.12	1.970		5.30	2.45	
2.13	9.85		2.13	1.975		5.35	2.48	
2.14	9.87		2.14	1.980		5.40	2.50	
2.15	9.89		2.15	1.985				

Ditch Section @ Water Level Recorder Kii 2R:			
Elev	Flow	Outlet Ditch (Flood Tide)	
1.70	11.20	2.16	4.70
1.73	11.20	2.17	4.50
1.75	11.20	2.18	4.30
1.78	11.20	2.19	4.10
1.80	11.20	2.20	3.90
1.83	11.20	2.21	3.70
1.85	11.20	2.22	3.55
1.86	10.50	2.23	3.40
1.87	10.25	2.24	3.25
1.88	9.80	2.25	3.10
1.89	9.50	2.26	2.95
1.90	9.10	2.27	2.80
1.91	8.80	2.28	2.70
1.92	8.40	2.29	2.60
1.93	8.10	2.30	2.50
1.94	7.80	2.31	2.40
1.95	7.50	2.32	2.35
1.96	7.30	2.33	2.30
1.97	7.20	2.34	2.25
1.98	7.00	2.35	2.20
1.99	6.90	2.36	2.15
2.00	6.70	2.37	2.10
2.01	6.60	2.38	2.05
2.02	6.40	2.39	2.00
2.03	6.30	2.40	1.95
2.04	6.15	2.41	1.92
2.05	6.00	2.42	1.87
2.06	5.90	2.43	1.84
2.07	5.75	2.44	1.80
2.08	5.65	2.45	1.75
2.09	5.50	2.6	1.5
2.10	5.40		

Ditch Section @ Water Level Recorder Kii 2R:			
Elev	Flow	Outlet Ditch (Ebb Tide)	
1.70	11.20	2.16	8.00
1.73	11.20	2.17	7.90
1.75	11.20	2.18	7.70
1.78	11.20	2.19	7.60
1.80	11.20	2.20	7.40
1.83	11.20	2.21	7.30
1.85	11.20	2.22	7.15
1.86	11.15	2.23	7.00
1.87	11.10	2.24	6.90
1.88	11.05	2.25	6.80
1.89	11.00	2.26	6.65
1.90	10.95	2.27	6.30
1.91	10.90	2.28	6.00
1.92	10.85	2.29	5.75
1.93	10.80	2.30	5.50
1.94	10.75	2.31	5.20
1.95	10.70	2.32	4.90
1.96	10.68	2.33	4.70
1.97	10.63	2.34	4.30
1.98	10.60	2.35	4.00
1.99	10.58	2.36	3.70
2.00	10.55	2.37	3.40
2.01	10.53	2.38	3.10
2.02	10.50	2.39	2.90
2.03	10.25	2.40	2.70
2.04	10.00	2.41	2.50
2.05	9.90	2.42	2.30
2.06	9.70	2.43	2.10
2.07	9.50	2.44	1.90
2.08	9.30	2.45	1.75
2.09	9.20	2.6	1.5
2.10	9.00		

Inflow/Outflow Area Conversions:				Pond			
	A	B	C	D	E	F	G
Area	20.40	10.40	15.50	5.40	5.10	6.60	8.90
(acres)							
Sum	20.40	30.80	46.30	51.70	56.80	63.40	72.30
(Inflow = daily rainfall, ft x sum, acres x 0.5042 = cfs)							
Conversion Factor=1/12*U39*0.5042=				3.04			
		For 4 equal daily periods		0.76			
		For 6 equal daily periods		0.51			
Leakage:		Assume hydraulic conductivity=			0.780	ft/day	
	A	B	C	D	E	F	G
cf/period	115521	58893	87773	30579	28880	37374	50399
Evaporation (inches)							
Jan	Feb	Mar	Apr	May	Jun		
4.80	5.36	6.12	5.99	8.40	8.18		
Jul	Aug	Sep	Oct	Nov	Dec		
8.68	8.66	7.27	5.65	5.64	4.10		
Evaporation (cfs/day)							
Jan	Feb	Mar	Apr	May	Jun		
0.47	0.69	0.71	0.71	0.97	0.98		
Jul	Aug	Sep	Oct	Nov	Dec		
1.00	1.00	0.87	0.65	0.67	0.47		
(Outflow = daily evap, ft x sum, acres x 0.5042 = cfs)							
Conversion Factor: monthly cfs/day/# pe					Feb	Mar	Apr
		For 4 equal daily periods			0.17	0.18	0.18
		For 6 equal daily periods			0.11	0.12	0.12

	2.11	5.30					2.11	8.80					Inflow/Outflow Allocation:				Pond			
	2.12	5.15					2.12	8.65						A	B	C	D	E	F	G
	2.13	5.05					2.13	8.50					Area	20.40	10.40	15.50	5.40	5.10	6.60	8.90
	2.14	4.95					2.14	8.35					Sum	20.40	30.80	46.30	51.70	56.80	63.40	72.30
	2.15	4.80					2.15	8.20					% Total	0.28	0.14	0.21	0.07	0.07	0.09	0.12
													Factor(cfs/day to inches)							
													4 Per	0.292	0.572	0.384	1.102	1.167	0.902	0.669
													6 Per	0.195	0.382	0.256	0.735	0.778	0.601	0.446
			INFLOWS						OUTFLOWS						CHANGE in STORAGE (inches)					
Date	Kil1R	Kil1R	Kil3R	Kil3R	Kil4R	Kil4R	Rainfall	Kil2R	Kil2R	Kil2R	Evap	Leaks	Sum	Pond F	Pond G	Pond C	Pond D	Pond B	Pond A	Pond E
M-D-YR	Elev	Flow	Elev	Flow	Elev	Flow		Elev	Stage	Flow			%Remain	1.00	0.91	0.79	0.57	0.50	0.35	0.07
3-13-92	1.96	8.85	2.08	1.95	4.60	0.35	0.08	1.95	F	7.50	0.17	4.74	-1.18	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0
3-13-92	2.16	9.89	2.06	1.94	4.43	0.03	0.29	2.68	F	1.75	0.12	4.74	5.55	0.4	0.3	-0.1	-0.1	0.0	0.0	0.0
3-13-92	2.13	9.85	2.04	1.93	4.43	0.03	0.29	2.11	E	8.80	0.12	4.74	-1.55	0.2	0.2	-0.2	-0.1	-0.1	-0.1	0.0
3-13-92	2.11	9.81	2	1.91	4.6	0.35	0.29	2	E	10.55	0.12	4.74	-3.04	0.0	0.0	-0.4	-0.3	-0.2	-0.2	0.0
3-13-92	2.06	9.76	1.99	1.91	4.67	0.65	0.29	1.91	E	10.90	0.12	4.74	-3.15	-0.3	-0.3	-0.6	-0.4	-0.4	-0.3	-0.1
3-13-92	2.11	9.81	1.96	1.89	4.6	0.35	0.29	1.88	E	11.05	0.12	4.74	-3.56	-0.6	-0.5	-0.8	-0.6	-0.5	-0.4	-0.1
3-13-92	2.15	9.89	2	1.91	4.51	0.10	0.29	2.26	F	2.95	0.12	4.74	4.39	-0.2	-0.2	-0.5	-0.4	-0.3	-0.2	0.0
3-14-92	2.11	9.81	2.04	1.93	4.57	0.20	0.03	2.64	F	1.75	0.12	4.74	5.36	0.2	0.2	-0.2	-0.1	-0.1	-0.1	0.0
3-14-92	2.12	9.82	2	1.91	4.54	0.10	0.03	2.08	E	9.30	0.12	4.74	-2.30	0.0	0.0	-0.3	-0.2	-0.2	-0.1	0.0
3-14-92	2.11	9.81	1.99	1.91	4.5	0.10	0.03	1.92	E	10.85	0.12	4.74	-3.87	-0.3	-0.3	-0.6	-0.4	-0.4	-0.3	-0.1
3-14-92	2.07	9.77	1.99	1.91	4.5	0.10	0.03	1.92	E	10.85	0.12	4.74	-3.91	-0.6	-0.5	-0.8	-0.6	-0.5	-0.4	-0.1
3-14-92	2.05	9.75	1.96	1.89	4.51	0.10	0.03	1.88	E	11.05	0.12	4.74	-4.14	-0.9	-0.9	-1.1	-0.8	-0.7	-0.5	-0.1
3-14-92	2.13	9.85	1.97	1.90	4.51	0.10	0.03	2.08	F	5.65	0.12	4.74	1.36	-0.8	-0.8	-1.0	-0.7	-0.6	-0.5	-0.1
3-15-92	2.11	9.81	2.04	1.93	4.52	0.10	0.01	2.59	F	1.75	0.12	4.74	5.24	-0.4	-0.4	-0.7	-0.5	-0.4	-0.3	-0.1
3-15-92	2.06	9.76	2.03	1.93	4.52	0.10	0.01	2	E	10.55	0.12	4.74	-3.62	-0.7	-0.6	-0.9	-0.7	-0.6	-0.4	-0.1
3-15-92	2.09	9.79	1.96	1.89	4.48	0.06	0.01	1.91	E	10.90	0.12	4.74	-4.02	-1.0	-0.9	-1.2	-0.8	-0.7	-0.5	-0.1
3-15-92	2.05	9.75	1.98	1.90	4.49	0.06	0.01	2.06	F	5.90	0.12	4.74	0.95	-0.9	-0.9	-1.1	-0.8	-0.7	-0.5	-0.1
3-15-92	2.02	9.70	1.96	1.89	4.55	0.20	0.01	1.91	E	10.90	0.12	4.74	-3.96	-1.3	-1.2	-1.4	-1.0	-0.9	-0.6	-0.1
3-15-92	2.14	9.87	1.96	1.89	4.56	0.20	0.01	2.01	F	6.60	0.12	4.74	0.51	-1.2	-1.1	-1.3	-1.0	-0.8	-0.6	-0.1
3-16-92	2.12	9.82	2.05	1.94	4.55	0.20	0.00	2.65	F	1.75	0.12	4.74	5.35	-0.8	-0.7	-1.0	-0.7	-0.6	-0.4	-0.1
3-16-92	2.06	9.76	2.04	1.93	4.55	0.20	0.00	2.04	E	10.00	0.12	4.74	-2.97	-1.0	-0.9	-1.2	-0.9	-0.7	-0.5	-0.1
3-16-92	2.08	9.78	1.97	1.90	4.49	0.06	0.00	1.91	E	10.90	0.12	4.74	-4.03	-1.4	-1.2	-1.4	-1.0	-0.9	-0.6	-0.1
3-16-92	2.07	9.77	1.99	1.91	4.52	0.10	0.00	2.12	F	5.15	0.12	4.74	1.77	-1.2	-1.1	-1.3	-1.0	-0.8	-0.6	-0.1
3-16-92	2.02	9.70	2	1.91	4.56	0.20	0.00	1.95	E	10.70	0.12	4.74	-3.75	-1.5	-1.4	-1.6	-1.1	-1.0	-0.7	-0.1
3-16-92	2.11	9.81	1.95	1.88	4.55	0.20	0.00	1.95	E	10.70	0.12	4.74	-3.67	-1.8	-1.7	-1.8	-1.3	-1.1	-0.8	-0.2
3-17-92	2.17	9.89	2.05	1.94	4.57	0.20	0.00	2.5	F	1.75	0.12	4.74	5.42	-1.4	-1.3	-1.4	-1.1	-0.9	-0.6	-0.1
3-17-92	2.07	9.77	2.07	1.95	4.56	0.20	0.00	2.08	E	9.30	0.12	4.74	-2.24	-1.6	-1.4	-1.6	-1.2	-1.0	-0.7	-0.1

3-17-92	2.11	9.81	1.98	1.90	4.54	0.10	0.00	1.91	E	10.90	0.12	4.74	-3.95	-1.9	-1.7	-1.8	-1.3	-1.2	-0.8	-0.2
3-17-92	2.13	9.85	2.02	1.92	4.55	0.20	0.00	2.21	F	3.70	0.12	4.74	3.41	-1.6	-1.5	-1.6	-1.2	-1.0	-0.7	-0.1
3-17-92	2.05	9.75	2.04	1.93	4.57	0.20	0.00	2.03	E	10.25	0.12	4.74	-3.23	-1.9	-1.7	-1.8	-1.3	-1.2	-0.8	-0.2
3-17-92	2.1	9.80	1.96	1.89	4.58	0.20	0.00	1.93	E	10.80	0.12	4.74	-3.77	-2.2	-2.0	-2.1	-1.5	-1.3	-0.9	-0.2
3-18-92	2.13	9.85	2.02	1.92	4.59	0.20	0.00	2.38	F	2.05	0.12	4.74	5.06	-1.8	-1.6	-1.8	-1.3	-1.1	-0.8	-0.2
3-18-92	2.07	9.77	2.05	1.94	4.58	0.20	0.00	2.08	E	9.30	0.12	4.74	-2.25	-2.0	-1.8	-1.9	-1.4	-1.2	-0.9	-0.2
3-18-92	2.1	9.80	1.96	1.89	4.53	0.10	0.00	1.92	E	10.85	0.12	4.74	-3.92	-2.3	-2.1	-2.1	-1.6	-1.4	-1.0	-0.2
3-18-92	2.2	9.89	2.01	1.92	4.52	0.10	0.00	2.21	F	3.70	0.12	4.74	3.35	-2.0	-1.8	-1.9	-1.4	-1.2	-0.9	-0.2
3-18-92	2.08	9.78	2.11	1.97	4.54	0.10	0.00	2.13	E	8.50	0.12	4.74	-1.51	-2.1	-1.9	-2.0	-1.5	-1.3	-0.9	-0.2
3-18-92	2.08	9.78	1.99	1.91	4.53	0.10	0.00	1.92	E	10.85	0.12	4.74	-3.92	-2.5	-2.2	-2.3	-1.7	-1.4	-1.0	-0.2
3-19-92	2.18	9.89	2.01	1.92	4.53	0.10	0.00	2.21	F	3.70	0.12	4.74	3.35	-2.2	-2.0	-2.1	-1.5	-1.3	-0.9	-0.2
3-19-92	2.05	9.75	2.07	1.95	4.53	0.10	0.00	2.08	E	9.30	0.12	4.74	-2.36	-2.4	-2.2	-2.2	-1.6	-1.4	-1.0	-0.2
3-19-92	2.05	9.75	1.96	1.89	4.5	0.10	0.00	1.91	E	10.90	0.12	4.74	-4.02	-2.7	-2.5	-2.5	-1.8	-1.6	-1.1	-0.2
3-19-92	2.19	9.89	1.95	1.88	4.49	0.06	0.00	2.1	F	5.40	0.12	4.74	1.57	-2.6	-2.3	-2.4	-1.7	-1.5	-1.1	-0.2
3-19-92	2.1	9.80	2.09	1.96	4.52	0.10	0.00	2.24	F	3.25	0.12	4.74	3.75	-2.3	-2.1	-2.1	-1.6	-1.4	-1.0	-0.2
3-19-92	2.07	9.77	2.01	1.92	4.5	0.10	0.00	1.99	E	10.58	0.12	4.74	-3.65	-2.6	-2.3	-2.4	-1.7	-1.5	-1.1	-0.2
3-20-92	2.15	9.89	1.99	1.91	4.48	0.06	0.03	2.17	F	4.50	0.12	4.74	2.52	-2.4	-2.1	-2.2	-1.6	-1.4	-1.0	-0.2
3-20-92	2.08	9.78	2.07	1.95	4.48	0.06	0.03	2.13	E	8.50	0.12	4.74	-1.55	-2.5	-2.3	-2.3	-1.7	-1.5	-1.0	-0.2
3-20-92	2.05	9.75	1.98	1.90	4.78	1.85	0.03	1.94	E	10.75	0.12	4.74	-2.08	-2.7	-2.4	-2.4	-1.8	-1.5	-1.1	-0.2
3-20-92	2.18	9.89	1.97	1.90	4.84	2.05	0.03	2.09	F	5.50	0.12	4.74	3.50	-2.4	-2.2	-2.2	-1.6	-1.4	-1.0	-0.2
3-20-92	2.11	9.81	2.07	1.95	4.87	2.15	0.03	2.43	F	1.84	0.12	4.74	7.23	-1.8	-1.6	-1.7	-1.3	-1.1	-0.8	-0.2
3-20-92	2.04	9.74	2.01	1.92	4.87	2.15	0.03	1.98	E	10.60	0.12	4.74	-1.63	-1.9	-1.7	-1.9	-1.3	-1.2	-0.8	-0.2
3-21-92	2.09	9.79	1.94	1.87	4.86	2.15	0.03	2.04	F	6.15	0.12	4.74	2.83	-1.7	-1.5	-1.7	-1.2	-1.1	-0.8	-0.2
3-21-92	2.05	9.75	1.98	1.90	4.86	2.15	0.03	2.04	F	6.15	0.12	4.74	2.82	-1.4	-1.3	-1.5	-1.1	-0.9	-0.7	-0.1
3-21-92	2.05	9.75	1.94	1.87	4.81	2.05	0.03	1.88	E	11.05	0.12	4.74	-2.21	-1.6	-1.5	-1.6	-1.2	-1.0	-0.7	-0.1
3-21-92	2.18	9.89	1.94	1.87	4.82	2.05	0.03	2.03	F	6.30	0.12	4.74	2.68	-1.4	-1.3	-1.5	-1.1	-0.9	-0.7	-0.1
3-21-92	2.11	9.81	2.07	1.95	4.86	2.15	0.03	2.47	F	1.75	0.12	4.74	7.32	-0.8	-0.7	-1.0	-0.7	-0.6	-0.4	-0.1
3-21-92	2.09	9.79	2.01	1.92	4.87	2.15	0.03	2.09	E	9.20	0.12	4.74	-0.18	-0.8	-0.7	-1.0	-0.7	-0.6	-0.4	-0.1
3-22-92	2.09	9.79	1.99	1.91	4.87	2.15	0.00	1.99	E	10.58	0.12	4.74	-1.59	-0.9	-0.9	-1.1	-0.8	-0.7	-0.5	-0.1
3-22-92	2.09	9.79	2	1.91	4.87	2.15	0.00	2	F	6.70	0.12	4.74	2.29	-0.8	-0.7	-1.0	-0.7	-0.6	-0.4	-0.1
3-22-92	2.1	9.80	2.01	1.92	4.82	2.05	0.00	1.91	E	10.90	0.12	4.74	-1.99	-0.9	-0.8	-1.1	-0.8	-0.7	-0.5	-0.1
3-22-92	2.16	9.89	2.01	1.92	4.83	2.05	0.00	1.95	F	7.50	0.12	4.74	1.50	-0.8	-0.7	-1.0	-0.7	-0.6	-0.4	-0.1
3-22-92	2.18	9.89	2.08	1.95	4.86	2.15	0.00	2.34	F	2.25	0.12	4.74	6.88	-0.2	-0.2	-0.5	-0.4	-0.3	-0.2	0.0
3-22-92	2.13	9.85	2.09	1.96	4.87	2.15	0.00	2.15	E	8.20	0.12	4.74	0.90	-0.2	-0.1	-0.5	-0.3	-0.3	-0.2	0.0
3-23-92	2.12	9.82	2.05	1.94	4.88	2.15	0.00	2.01	E	10.53	0.12	4.74	-1.48	-0.3	-0.3	-0.6	-0.4	-0.4	-0.3	-0.1
3-23-92	2.1	9.80	2.02	1.92	4.87	2.15	0.00	2.01	E	10.53	0.12	4.74	-1.51	-0.4	-0.4	-0.7	-0.5	-0.4	-0.3	-0.1
3-23-92	2.08	9.78	2	1.91	4.59	0.20	0.00	1.91	E	10.90	0.12	4.74	-3.87	-0.7	-0.7	-0.9	-0.7	-0.6	-0.4	-0.1
3-23-92	2.11	9.81	1.98	1.90	4.48	0.06	0.00	1.93	F	8.10	0.12	4.74	-1.19	-0.8	-0.7	-1.0	-0.7	-0.6	-0.4	-0.1
3-23-92	2.17	9.89	2.03	1.93	4.53	0.10	0.00	2.26	F	2.95	0.12	4.74	4.11	-0.5	-0.4	-0.7	-0.5	-0.5	-0.3	-0.1
3-23-92	2.15	9.89	2.08	1.95	4.53	0.10	0.00	2.37	F	2.10	0.12	4.74	4.98	-0.1	-0.1	-0.4	-0.3	-0.3	-0.2	0.0

3-24-92	2.12	9.82	2.07	1.95	4.52	0.10	0.00	2.17	E	7.90	0.12	4.74	-0.89	-0.1	-0.1	-0.5	-0.3	-0.3	-0.2	0.0
3-24-92	2.09	9.79	2.04	1.93	4.5	0.10	0.00	2.13	E	8.50	0.12	4.74	-1.54	-0.3	-0.2	-0.6	-0.4	-0.4	-0.3	-0.1
3-24-92	2.09	9.79	1.99	1.91	4.48	0.06	0.00	1.96	E	10.68	0.12	4.74	-3.78	-0.6	-0.5	-0.8	-0.6	-0.5	-0.4	-0.1
3-24-92	2.11	9.81	1.99	1.91	4.48	0.06	0.00	1.96	E	10.68	0.12	4.74	-3.76	-0.9	-0.8	-1.1	-0.8	-0.7	-0.5	-0.1
3-24-92	2.18	9.89	2.01	1.92	4.48	0.06	0.00	2.19	F	4.10	0.12	4.74	2.90	-0.6	-0.6	-0.9	-0.6	-0.5	-0.4	-0.1
3-24-92	2.21	9.89	2.07	1.95	4.48	0.06	0.00	2.43	F	1.84	0.12	4.74	5.19	-0.2	-0.2	-0.5	-0.4	-0.3	-0.2	0.0
3-25-92	2.14	9.87	2.13	1.98	4.48	0.06	0.00	2.26	E	6.65	0.12	4.74	0.39	-0.2	-0.2	-0.5	-0.4	-0.3	-0.2	0.0
3-25-92	2.09	9.79	2.07	1.95	4.49	0.06	0.00	2.07	E	9.50	0.12	4.74	-2.57	-0.4	-0.4	-0.7	-0.5	-0.4	-0.3	-0.1
3-25-92	2.06	9.76	1.99	1.91	4.44	0.03	0.00	1.93	E	10.80	0.12	4.74	-3.96	-0.7	-0.7	-0.9	-0.7	-0.6	-0.4	-0.1
3-25-92	2.05	9.75	1.94	1.87	4.43	0.03	0.00	1.93	F	8.10	0.12	4.74	-1.31	-0.8	-0.8	-1.0	-0.7	-0.6	-0.5	-0.1
3-25-92	2.17	9.89	1.94	1.87	4.48	0.06	0.00	2.1	F	5.40	0.12	4.74	1.56	-0.7	-0.6	-0.9	-0.7	-0.6	-0.4	-0.1
3-25-92	2.17	9.89	2.07	1.95	4.48	0.06	0.00	2.43	F	1.84	0.12	4.74	5.19	-0.3	-0.3	-0.6	-0.4	-0.4	-0.3	-0.1
3-26-92	2.15	9.89	2.07	1.95	4.49	0.06	0.00	2.38	E	3.10	0.12	4.74	3.93	0.0	0.0	-0.3	-0.2	-0.2	-0.1	0.0
3-26-92	2.11	9.81	2.06	1.94	4.52	0.10	0.00	2.11	E	8.80	0.12	4.74	-1.81	-0.1	-0.1	-0.4	-0.3	-0.3	-0.2	0.0
3-26-92	2.07	9.77	2.01	1.92	4.48	0.06	0.00	1.98	E	10.60	0.12	4.74	-3.72	-0.4	-0.4	-0.7	-0.5	-0.4	-0.3	-0.1
3-26-92	2.01	9.55	1.97	1.90	4.48	0.06	0.00	1.95	E	10.70	0.12	4.74	-4.06	-0.7	-0.7	-0.9	-0.7	-0.6	-0.4	-0.1
3-26-92	2.05	9.75	1.92	1.87	4.5	0.10	0.00	1.98	F	7.00	0.12	4.74	-0.14	-0.8	-0.7	-1.0	-0.7	-0.6	-0.4	-0.1
3-26-92	2.19	9.89	1.98	1.90	4.52	0.10	0.00	2.28	F	2.70	0.12	4.74	4.33	-0.4	-0.4	-0.7	-0.5	-0.4	-0.3	-0.1
3-27-92	2.11	9.81	2.12	1.97	4.52	0.10	0.00	2.37	F	2.10	0.12	4.74	4.92	0.0	0.0	-0.4	-0.3	-0.2	-0.2	0.0
3-27-92	2.01	9.55	2.02	1.92	4.52	0.10	0.00	2.04	E	10.00	0.12	4.74	-3.29	-0.3	-0.2	-0.6	-0.4	-0.4	-0.3	-0.1
3-27-92	1.98	9.10	1.94	1.87	4.4	0.03	0.00	1.91	E	10.90	0.12	4.74	-4.76	-0.7	-0.6	-0.9	-0.6	-0.6	-0.4	-0.1
3-27-92	1.95	8.70	1.89	1.84	4.35	0.02	0.00	1.94	F	7.80	0.12	4.74	-2.10	-0.8	-0.8	-1.0	-0.7	-0.6	-0.5	-0.1
3-27-92	1.97	9.00	1.87	1.84	4.4	0.03	0.00	1.91	E	10.90	0.12	4.74	-4.89	-1.2	-1.1	-1.3	-1.0	-0.8	-0.6	-0.1
3-27-92	2.15	9.89	1.91	1.86	4.41	0.03	0.00	2.14	F	4.95	0.12	4.74	1.97	-1.1	-1.0	-1.2	-0.9	-0.8	-0.5	-0.1
3-28-92	2.08	9.78	2.08	1.95	4.41	0.03	0.00	2.33	F	2.30	0.12	4.74	4.60	-0.7	-0.6	-0.9	-0.7	-0.6	-0.4	-0.1
3-28-92	2.02	9.70	2.01	1.92	4.4	0.03	0.00	1.97	E	10.63	0.12	4.74	-3.84	-1.0	-0.9	-1.1	-0.8	-0.7	-0.5	-0.1
3-28-92	1.99	9.25	1.92	1.87	4.34	0.01	0.00	1.91	E	10.90	0.12	4.74	-4.63	-1.4	-1.3	-1.4	-1.1	-0.9	-0.6	-0.1
3-28-92	1.98	9.10	1.89	1.84	4.35	0.02	0.00	1.93	F	8.10	0.12	4.74	-2.00	-1.6	-1.4	-1.6	-1.1	-1.0	-0.7	-0.1
3-28-92	1.96	8.85	1.88	1.84	4.4	0.03	0.00	1.91	E	10.90	0.12	4.74	-5.04	-2.0	-1.8	-1.9	-1.4	-1.2	-0.9	-0.2
3-28-92	2.1	9.80	1.89	1.84	4.41	0.03	0.00	2.04	F	6.15	0.12	4.74	0.66	-1.9	-1.7	-1.9	-1.4	-1.2	-0.8	-0.2
3-29-92	2.05	9.75	2.02	1.92	4.43	0.03	0.00	2.27	F	2.80	0.12	4.74	4.04	-1.6	-1.4	-1.6	-1.2	-1.0	-0.7	-0.1
3-29-92	2.02	9.70	1.97	1.90	4.41	0.03	0.00	2.01	E	10.53	0.12	4.74	-3.76	-1.9	-1.7	-1.8	-1.3	-1.2	-0.8	-0.2
3-29-92	2.01	9.55	1.9	1.86	4.37	0.02	0.00	1.91	E	10.90	0.12	4.74	-4.33	-2.2	-2.0	-2.1	-1.5	-1.3	-1.0	-0.2
3-29-92	1.98	9.10	1.88	1.84	4.38	0.02	0.00	1.96	F	7.30	0.12	4.74	-1.20	-2.3	-2.1	-2.2	-1.6	-1.4	-1.0	-0.2
3-29-92	1.98	9.10	1.88	1.84	4.41	0.03	0.00	1.91	E	10.90	0.12	4.74	-4.79	-2.7	-2.5	-2.5	-1.8	-1.6	-1.1	-0.2
3-29-92	2.13	9.85	1.89	1.84	4.41	0.03	0.00	1.99	F	6.90	0.12	4.74	-0.04	-2.7	-2.5	-2.5	-1.8	-1.6	-1.1	-0.2
3-30-92	2.16	9.89	2.08	1.95	4.45	0.06	0.32	2.24	F	3.25	0.12	4.74	4.11	-2.4	-2.2	-2.2	-1.6	-1.4	-1.0	-0.2
3-30-92	2.12	9.82	2.11	1.97	4.42	0.03	0.32	2.04	E	10.00	0.12	4.74	-2.72	-2.6	-2.4	-2.4	-1.8	-1.5	-1.1	-0.2
3-30-92	2.1	9.80	2.04	1.93	4.37	0.02	0.32	1.98	E	10.60	0.12	4.74	-3.39	-2.9	-2.6	-2.6	-1.9	-1.7	-1.2	-0.2
3-30-92	2.05	9.75	2.02	1.92	4.41	0.03	0.32	2	F	6.70	0.12	4.74	0.46	-2.9	-2.6	-2.6	-1.9	-1.7	-1.2	-0.2

3-30-92	2.02	9.70	2	1.91	4.42	0.03	0.32	1.97	E	10.63	0.12	4.74	-3.52	-3.2	-2.9	-2.8	-2.1	-1.8	-1.3	-0.3
3-30-92	2.09	9.79	1.98	1.90	4.43	0.03	0.32	1.98	F	7.00	0.12	4.74	0.18	-3.1	-2.9	-2.8	-2.1	-1.8	-1.3	-0.3
3-31-92	2.1	9.80	2.05	1.94	4.41	0.03	0.02	2.24	F	3.25	0.12	4.74	3.67	-2.8	-2.6	-2.6	-1.9	-1.6	-1.2	-0.2
3-31-92	2.04	9.74	2.03	1.93	4.4	0.03	0.02	2.01	E	10.53	0.12	4.74	-3.67	-3.1	-2.9	-2.8	-2.1	-1.8	-1.3	-0.3
3-31-92	2.15	9.89	1.99	1.91	4.3	0.01	0.02	1.97	E	10.63	0.12	4.74	-3.66	-3.4	-3.1	-3.1	-2.2	-1.9	-1.4	-0.3
3-31-92	2.13	9.85	2.09	1.96	4.32	0.01	0.02	2.32	F	2.35	0.12	4.74	4.62	-3.1	-2.8	-2.8	-2.0	-1.7	-1.2	-0.2
3-31-92	2.11	9.81	2.07	1.95	4.36	0.02	0.02	2.13	E	8.50	0.12	4.74	-1.57	-3.2	-2.9	-2.9	-2.1	-1.8	-1.3	-0.3
3-31-92	2.14	9.87	2.04	1.93	4.35	0.02	0.02	2.1	E	9.00	0.12	4.74	-2.03	-3.4	-3.1	-3.0	-2.2	-1.9	-1.3	-0.3
4-1-92	2.17	9.89	2.07	1.95	4.36	0.02	0.00	2.51	F	1.75	0.12	4.74	5.24	-2.9	-2.7	-2.7	-1.9	-1.7	-1.2	-0.2
4-1-92	2.09	9.79	2.1	1.96	4.34	0.01	0.00	2.09	E	9.20	0.12	4.74	-2.30	-3.1	-2.8	-2.8	-2.0	-1.8	-1.3	-0.3
4-1-92	2.13	9.85	1.99	1.91	4.3	0.01	0.00	1.95	E	10.70	0.12	4.74	-3.79	-3.4	-3.1	-3.1	-2.2	-1.9	-1.4	-0.3
4-1-92	2.11	9.81	2.05	1.94	4.32	0.01	0.00	2.33	F	2.30	0.12	4.74	4.60	-3.0	-2.8	-2.8	-2.0	-1.7	-1.2	-0.2
4-1-92	2.04	9.74	2.02	1.92	4.34	0.01	0.00	2.11	E	8.80	0.12	4.74	-1.99	-3.2	-2.9	-2.9	-2.1	-1.8	-1.3	-0.3
4-1-92	2.11	9.81	1.93	1.87	4.34	0.01	0.00	1.99	E	10.58	0.12	4.74	-3.74	-3.5	-3.2	-3.1	-2.3	-2.0	-1.4	-0.3
4-2-92	2.18	9.89	2.04	1.93	4.34	0.01	0.05	2.43	F	1.84	0.12	4.74	5.18	-3.1	-2.8	-2.8	-2.0	-1.8	-1.3	-0.3
4-2-92	2.06	9.76	2.07	1.95	4.34	0.01	0.05	2.1	E	9.00	0.12	4.74	-2.09	-3.3	-3.0	-2.9	-2.1	-1.8	-1.3	-0.3
4-2-92	2.11	9.81	1.94	1.87	4.33	0.01	0.05	1.93	E	10.80	0.12	4.74	-3.92	-3.6	-3.3	-3.2	-2.3	-2.0	-1.4	-0.3
4-2-92	2.16	9.89	2.01	1.92	4.33	0.01	0.05	2.42	F	1.87	0.12	4.74	5.14	-3.2	-2.9	-2.8	-2.1	-1.8	-1.3	-0.3
4-2-92	2.08	9.78	2.06	1.94	4.34	0.01	0.05	2.27	E	6.30	0.12	4.74	0.62	-3.1	-2.8	-2.8	-2.0	-1.8	-1.3	-0.3
4-2-92	2.14	9.87	1.96	1.89	4.34	0.01	0.05	1.99	E	10.58	0.12	4.74	-3.61	-3.4	-3.1	-3.0	-2.2	-1.9	-1.4	-0.3
4-3-92	2.18	9.89	2.05	1.94	4.34	0.01	0.03	2.3	F	2.50	0.12	4.74	4.50	-3.0	-2.8	-2.7	-2.0	-1.7	-1.2	-0.2
4-3-92	2.05	9.75	2.07	1.95	4.34	0.01	0.03	2.06	E	9.70	0.12	4.74	-2.83	-3.3	-3.0	-2.9	-2.1	-1.9	-1.3	-0.3
4-3-92	2.1	9.80	1.94	1.87	4.3	0.01	0.03	1.9	E	10.95	0.12	4.74	-4.10	-3.6	-3.3	-3.2	-2.3	-2.0	-1.4	-0.3
4-3-92	2.18	9.89	1.99	1.91	4.32	0.01	0.03	2.42	F	1.87	0.12	4.74	5.10	-3.2	-2.9	-2.9	-2.1	-1.8	-1.3	-0.3
4-3-92	2.07	9.77	2.08	1.95	4.35	0.02	0.03	2.43	F	1.84	0.12	4.74	5.06	-2.8	-2.5	-2.5	-1.8	-1.6	-1.1	-0.2
4-3-92	2.02	9.70	1.98	1.90	4.34	0.01	0.03	1.96	E	10.68	0.12	4.74	-3.90	-3.1	-2.8	-2.8	-2.0	-1.8	-1.3	-0.3
4-4-92	2.05	9.75	1.97	1.90	4.35	0.02	0.00	2.13	F	5.05	0.12	4.74	1.75	-3.0	-2.7	-2.7	-1.9	-1.7	-1.2	-0.2
4-4-92	1.98	9.10	1.98	1.90	4.35	0.02	0.00	2	E	10.55	0.12	4.74	-4.39	-3.3	-3.0	-3.0	-2.2	-1.9	-1.3	-0.3
4-4-92	2.04	9.74	1.9	1.86	4.28	0.00	0.00	1.89	E	11.00	0.12	4.74	-4.26	-3.7	-3.3	-3.2	-2.4	-2.0	-1.5	-0.3
4-4-92	2.14	9.87	1.96	1.89	4.31	0.01	0.00	2.24	F	3.25	0.12	4.74	3.66	-3.4	-3.1	-3.0	-2.2	-1.9	-1.3	-0.3
4-4-92	2.07	9.77	2.06	1.94	4.36	0.02	0.00	2.53	F	1.75	0.12	4.74	5.12	-2.9	-2.7	-2.7	-1.9	-1.7	-1.2	-0.2
4-4-92	2.01	9.55	2.01	1.92	4.35	0.02	0.00	1.98	E	10.60	0.12	4.74	-3.98	-3.3	-3.0	-2.9	-2.1	-1.8	-1.3	-0.3
4-5-92	2.02	9.70	1.96	1.89	4.36	0.02	0.00	2.04	F	6.15	0.12	4.74	0.60	-3.2	-2.9	-2.9	-2.1	-1.8	-1.3	-0.3
4-5-92	2.02	9.70	1.99	1.91	4.34	0.01	0.00	2	E	10.55	0.12	4.74	-3.79	-3.5	-3.2	-3.1	-2.3	-2.0	-1.4	-0.3
4-5-92	2.05	9.75	1.95	1.88	4.29	0.00	0.00	1.91	E	10.90	0.12	4.74	-4.13	-3.9	-3.5	-3.4	-2.5	-2.1	-1.5	-0.3
4-5-92	2.16	9.89	1.99	1.91	4.32	0.01	0.00	2.12	F	5.15	0.12	4.74	1.80	-3.7	-3.4	-3.3	-2.4	-2.1	-1.5	-0.3
4-5-92	2.17	9.89	2.08	1.95	4.36	0.02	0.00	2.57	F	1.75	0.12	4.74	5.25	-3.3	-3.0	-2.9	-2.1	-1.9	-1.3	-0.3
4-5-92	2.09	9.79	2.11	1.97	4.37	0.02	0.00	2.08	E	9.30	0.12	4.74	-2.39	-3.5	-3.2	-3.1	-2.3	-2.0	-1.4	-0.3
4-6-92	2.08	9.78	2.03	1.93	4.35	0.02	0.00	2.04	E	10.00	0.12	4.74	-3.14	-3.7	-3.4	-3.3	-2.4	-2.1	-1.5	-0.3
4-6-92	2.03	9.72	2.01	1.92	4.36	0.02	0.00	2	E	10.55	0.12	4.74	-3.76	-4.1	-3.7	-3.5	-2.6	-2.2	-1.6	-0.3

4-6-92	2.03	9.72	1.97	1.90	4.29	0.00	0.00	1.9	E	10.95	0.12	4.74	-4.19	-4.4	-4.0	-3.8	-2.8	-2.4	-1.7	-0.3
4-6-92	2.13	9.85	1.96	1.89	4.32	0.01	0.00	2	F	6.70	0.12	4.74	0.19	-4.4	-4.0	-3.8	-2.8	-2.4	-1.7	-0.3
4-6-92	2.18	9.89	2.07	1.95	4.28	0.00	0.00	2.5	F	1.75	0.12	4.74	5.23	-4.0	-3.6	-3.5	-2.5	-2.2	-1.6	-0.3
4-6-92	2.14	9.87	2.13	1.98	4.29	0.00	0.00	2.17	E	7.90	0.12	4.74	-0.91	-4.0	-3.7	-3.5	-2.6	-2.2	-1.6	-0.3
4-7-92	2.11	9.81	2.08	1.95	4.29	0.00	0.00	2.03	E	10.25	0.12	4.74	-3.35	-4.3	-3.9	-3.7	-2.7	-2.4	-1.7	-0.3
4-7-92	2.11	9.81	2.05	1.94	4.26	0.00	0.00	1.99	E	10.58	0.12	4.74	-3.69	-4.6	-4.2	-4.0	-2.9	-2.5	-1.8	-0.4
4-7-92	2.15	9.89	2.07	1.95	4.25	0.00	0.00	1.97	F	7.20	0.12	4.74	-0.22	-4.6	-4.2	-4.0	-2.9	-2.5	-1.8	-0.4
4-7-92	2.14	9.87	2.09	1.96	4.25	0.00	0.00	1.99	F	6.90	0.12	4.74	0.07	-4.6	-4.2	-4.0	-2.9	-2.5	-1.8	-0.4
4-7-92	2.16	9.89	2.1	1.96	4.31	0.01	0.00	2.44	F	1.80	0.12	4.74	5.20	-4.2	-3.8	-3.7	-2.7	-2.3	-1.6	-0.3
4-7-92	2.16	9.89	2.11	1.97	4.32	0.01	0.00	2.3	E	5.50	0.12	4.74	1.51	-4.1	-3.7	-3.6	-2.6	-2.2	-1.6	-0.3
4-8-92	2.11	9.81	2.11	1.97	4.3	0.01	0.19	2.04	E	10.00	0.12	4.74	-2.89	-4.3	-3.9	-3.7	-2.7	-2.4	-1.7	-0.3
4-8-92	2.05	9.75	2.05	1.94	4.26	0.00	0.19	2.01	E	10.53	0.12	4.74	-3.51	-4.6	-4.2	-4.0	-2.9	-2.5	-1.8	-0.4
4-8-92	2.05	9.75	2	1.91	4.22	0.00	0.19	1.91	E	10.90	0.12	4.74	-3.91	-4.9	-4.5	-4.2	-3.1	-2.7	-1.9	-0.4
4-8-92	2.11	9.81	1.99	1.91	4.28	0.00	0.19	1.93	F	8.10	0.12	4.74	-1.05	-5.0	-4.5	-4.3	-3.1	-2.7	-1.9	-0.4
4-8-92	2.12	9.82	2.04	1.93	4.3	0.01	0.19	2.25	F	3.10	0.12	4.74	3.99	-4.7	-4.2	-4.0	-2.9	-2.5	-1.8	-0.4
4-8-92	2.12	9.82	2.11	1.97	4.34	0.01	0.19	2.49	F	1.75	0.12	4.74	5.37	-4.2	-3.8	-3.7	-2.7	-2.3	-1.7	-0.3
4-9-92	2.1	9.80	2.07	1.95	4.34	0.01	0.02	2.16	E	8.00	0.12	4.74	-1.08	-4.3	-3.9	-3.8	-2.7	-2.4	-1.7	-0.3
4-9-92	2.06	9.76	2.04	1.93	4.31	0.01	0.02	1.97	E	10.63	0.12	4.74	-3.76	-4.6	-4.2	-4.0	-2.9	-2.5	-1.8	-0.4
4-9-92	2.05	9.75	2.01	1.92	4.37	0.02	0.02	1.89	E	11.00	0.12	4.74	-4.16	-5.0	-4.5	-4.3	-3.1	-2.7	-1.9	-0.4
4-9-92	2.06	9.76	2.02	1.92	4.46	0.06	0.02	1.91	F	8.80	0.12	4.74	-1.90	-5.1	-4.7	-4.4	-3.2	-2.8	-2.0	-0.4
4-9-92	2.13	9.85	2.01	1.92	4.49	0.06	0.02	2.1	F	5.40	0.12	4.74	1.58	-5.0	-4.5	-4.3	-3.1	-2.7	-1.9	-0.4
4-9-92	2.12	9.82	2.08	1.95	4.49	0.06	0.02	2.55	F	1.75	0.12	4.74	5.24	-4.6	-4.2	-3.9	-2.9	-2.5	-1.8	-0.4
4-10-92	2.06	9.76	2.07	1.95	4.49	0.06	0.02	2.12	E	8.65	0.12	4.74	-1.73	-4.7	-4.3	-4.1	-3.0	-2.6	-1.8	-0.4
4-10-92	2.01	9.55	2.01	1.92	4.48	0.06	0.02	1.89	E	11.00	0.12	4.74	-4.32	-5.1	-4.6	-4.3	-3.2	-2.7	-1.9	-0.4
4-10-92	1.98	9.10	1.94	1.87	4.25	0.00	0.02	1.87	E	11.10	0.12	4.74	-4.97	-5.5	-5.0	-4.7	-3.4	-2.9	-2.1	-0.4
4-10-92	1.96	8.85	1.92	1.87	4.25	0.00	0.02	1.88	F	9.80	0.12	4.74	-3.92	-5.8	-5.3	-4.9	-3.6	-3.1	-2.2	-0.4
4-10-92	2.09	9.79	1.89	1.84	4.28	0.00	0.02	1.92	F	8.40	0.12	4.74	-1.61	-5.9	-5.4	-5.0	-3.7	-3.2	-2.3	-0.5
4-10-92	2.13	9.85	2.03	1.93	4.27	0.00	0.04	2.37	F	2.10	0.12	4.74	4.86	-5.5	-5.0	-4.7	-3.4	-3.0	-2.1	-0.4
4-11-92	2.05	9.75	2.07	1.95	4.26	0.00	0.04	2.19	E	7.60	0.12	4.74	-0.72	-5.6	-5.1	-4.8	-3.5	-3.0	-2.1	-0.4
4-11-92	1.97	9.00	1.99	1.91	4.25	0.00	0.04	1.88	E	11.05	0.12	4.74	-4.96	-6.0	-5.5	-5.1	-3.7	-3.2	-2.3	-0.5
4-11-92	1.94	8.35	1.9	1.86	4.21	0.00	0.04	1.85	E	11.20	0.12	4.74	-5.81	-6.5	-5.9	-5.4	-4.0	-3.4	-2.4	-0.5
4-11-92	1.92	8.00	1.86	1.84	4.24	0.00	0.04	1.88	F	9.80	0.12	4.74	-4.78	-6.9	-6.2	-5.8	-4.2	-3.6	-2.6	-0.5
4-11-92	2.02	9.70	1.85	1.84	4.27	0.00	0.04	1.85	E	11.20	0.12	4.74	-4.48	-7.2	-6.6	-6.0	-4.4	-3.8	-2.7	-0.5
4-11-92	2.14	9.87	1.97	1.90	4.27	0.00	0.04	2.18	F	4.30	0.12	4.74	2.65	-7.0	-6.4	-5.9	-4.3	-3.7	-2.6	-0.5
4-12-92	2.07	9.77	2.07	1.95	4.27	0.00	0.00	2.22	F	3.55	0.12	4.74	3.31	-6.8	-6.1	-5.7	-4.1	-3.6	-2.5	-0.5
4-12-92	2.04	9.74	2	1.91	4.24	0.00	0.00	1.86	E	11.15	0.12	4.74	-4.36	-7.1	-6.5	-5.9	-4.3	-3.8	-2.7	-0.5
4-12-92	2.11	9.81	1.96	1.89	4.21	0.00	0.00	1.93	F	8.10	0.12	4.74	-1.26	-7.2	-6.6	-6.0	-4.4	-3.8	-2.7	-0.5
4-12-92	2.09	9.79	2.01	1.92	4.23	0.00	0.00	2.07	F	5.75	0.12	4.74	1.10	-7.1	-6.5	-6.0	-4.3	-3.8	-2.7	-0.5
4-12-92	2.1	9.80	2	1.91	4.27	0.00	0.00	1.91	E	10.90	0.12	4.74	-4.05	-7.5	-6.8	-6.2	-4.5	-3.9	-2.8	-0.6
4-12-92	2.14	9.87	2.02	1.92	4.26	0.00	0.00	2.17	F	4.50	0.12	4.74	2.43	-7.3	-6.6	-6.1	-4.4	-3.8	-2.7	-0.5

4-13-92	2.11	9.81	2.07	1.95	4.27	0.00	0.00	2.37	F	2.10	0.12	4.74	4.80	-6.9	-6.2	-5.7	-4.2	-3.6	-2.6	-0.5
4-13-92	2.04	9.74	2.06	1.94	4.24	0.00	0.00	1.9	E	10.95	0.12	4.74	-4.13	-7.2	-6.5	-6.0	-4.4	-3.8	-2.7	-0.5
4-13-92	2.08	9.78	1.97	1.90	4.44	0.03	0.00	1.89	E	11.00	0.12	4.74	-4.15	-7.5	-6.9	-6.3	-4.6	-4.0	-2.8	-0.6
4-13-92	2.07	9.77	2.01	1.92	4.73	1.20	0.00	2.11	F	5.30	0.12	4.74	2.73	-7.3	-6.6	-6.1	-4.4	-3.9	-2.7	-0.5
4-13-92	2.03	9.72	1.99	1.91	4.77	1.85	0.00	1.91	E	10.90	0.12	4.74	-2.28	-7.5	-6.8	-6.3	-4.5	-4.0	-2.8	-0.6
4-13-92	2.18	9.89	1.96	1.89	4.77	1.85	0.00	1.99	F	6.90	0.12	4.74	1.87	-7.4	-6.7	-6.1	-4.5	-3.9	-2.8	-0.6
4-14-92	2.11	9.81	2.13	1.98	4.82	2.05	0.00	2.23	F	3.40	0.12	4.74	5.58	-6.9	-6.3	-5.8	-4.2	-3.6	-2.6	-0.5
4-14-92	2.06	9.76	2.07	1.95	4.81	2.05	0.00	1.93	E	10.80	0.12	4.74	-1.90	-7.0	-6.4	-5.9	-4.3	-3.7	-2.6	-0.5
4-14-92	2.14	9.87	2	1.91	5.12	2.36	0.00	1.89	E	11.00	0.12	4.74	-1.72	-7.2	-6.5	-6.0	-4.4	-3.8	-2.7	-0.5
4-14-92	2.15	9.89	2.07	1.95	5.22	2.40	0.00	2.24	F	3.25	0.12	4.74	6.13	-6.7	-6.1	-5.6	-4.1	-3.5	-2.5	-0.5
4-14-92	2.05	9.75	2.06	1.94	5.27	2.43	0.00	1.98	E	10.60	0.12	4.74	-1.34	-6.8	-6.2	-5.7	-4.1	-3.6	-2.6	-0.5
4-14-92	2.08	9.78	1.97	1.90	5.25	2.43	0.00	1.88	E	11.05	0.12	4.74	-1.81	-6.9	-6.3	-5.8	-4.2	-3.7	-2.6	-0.5
4-15-92	2.05	9.75	2.03	1.93	5.34	2.45	0.01	2.09	F	5.50	0.12	4.74	3.77	-6.6	-6.0	-5.6	-4.1	-3.5	-2.5	-0.5
4-15-92	1.98	9.10	1.99	1.91	5.3	2.45	0.01	1.87	E	11.10	0.12	4.74	-2.50	-6.8	-6.2	-5.7	-4.2	-3.6	-2.6	-0.5
4-15-92	2.08	9.78	1.92	1.87	4.73	1.20	0.01	1.84	E	11.20	0.12	4.74	-3.20	-7.1	-6.5	-5.9	-4.3	-3.8	-2.7	-0.5
4-15-92	2.17	9.89	2.01	1.92	4.65	0.65	0.01	2.24	F	3.25	0.12	4.74	4.35	-6.7	-6.1	-5.7	-4.1	-3.6	-2.5	-0.5
4-15-92	2.03	9.72	2.07	1.95	4.71	1.20	0.01	2.04	E	10.00	0.12	4.74	-1.99	-6.9	-6.3	-5.8	-4.2	-3.7	-2.6	-0.5
4-15-92	2.04	9.74	1.96	1.89	4.68	0.65	0.01	1.85	E	11.20	0.12	4.74	-3.77	-7.2	-6.6	-6.0	-4.4	-3.8	-2.7	-0.5
Units	ft	cfs	ft	cfs	ft	cfs	cfs	ft	E- ebb	cfs	cfs	cfs	cfs	inches	inches	inches	inches	inches	inches	inches
	INFLOWS							OUTFLOWS							CHANGE in STORAGE (inches)					
Date	Kii1R	Kii1R	Kii3R	Kii3R	Kii4R	Kii4R	Rainfall	Kii2R	Kii2R	Kii2R	Evap	Leaks	Sum	Pond F	Pond G	Pond C	Pond D	Pond B	Pond A	Pond E
M-D-YR	Elev	Flow	Elev	Flow	Elev	Flow		Elev	Stage	Flow			%Remain	1.00	0.91	0.79	0.57	0.50	0.35	0.07
Ave	1.29	5.99	1.24	1.18	2.76	0.23	0.02	1.28		4.69	0.07	2.92	-0.26							
Sum		1994.7		392		75	6			1560.5	24	971	-88	-600	-545	-544	-396	-344	-244	-49
Units	ft	cfs	ft	cfs	ft	cfs	cfs	ft	E- ebb	cfs	cfs	cfs	cfs							
		cfs-6hr		cfs-6hr		cfs-6hr	cfs-6hr		F-flood	cfs-6hr	cfs-6hr	cfs-6hr	cfs-6hr							
Mass Balance,MGD		3.87		0.76		0.15	0.01			3.03	0.05	1.89	-0.17	<- Error						

APPENDIX H
FLORA AND FAUNA SPECIES LISTS
PALIKEA AND KAHUKU

CHECK LIST OF PLANTS

Palikea Uplands

SCIENTIFIC NAME	COMMON NAME	STATUS	N·	FH*	RELATIVE ABUNDANCE									
PTERIDOPHYTES					G	CA	MF							
DAVALLIACEAE														
Nephrolepis exaltata (L.) Schott	Boston.fern	I			R	–	U							
GYMNOSPERMS														
ARAUCARIACEAE														
Araucaria columnaris (Forst. f.) Hook.	Cook pine	X			–	X	–							
ANGIOSPERMS – MONOCOTYLEDONES														
AGAVACEAE														
Cordyline fruticosa (L.) A. Chev.	Ti	P			–	X	–							
Furcraea foetida (L.) Haw.	Mauritius hemp	X			–	X	–							
ARECACEAE														
Cocos nucifera L.	Coconut	P			–	X	–							
CYPERACEAE														
Cyperus rotundus L.	Nut grass	X			U	X	–							
MUSACEAE														
Musa x paradisiaca L. (cultivar)	Banana	X			–	X	–							
POACEAE														
Brachiaria mutica (Forssk.) Stapf	Para grass	X			O	X	–							
Chloris barbata (L.) Sw.	Swollen fingergrass	X			U	–	–							
C. divaricata R. Br.	Star grass	X			U	–	–							
C. gayana Kunth	Rhodes grass	X			R	–	–							
C. radiata (L.) Sw.	Radiate fingergrass	X			R	X	–							
Cynodon dactylon (L.) Pers.	Bermuda grass	X			U	X	–							
Digitaria ciliaris (Retz.) Koeler	Henry's crabgrass	X			–	X	–							
D. insularis (L.) Mez ex Ekman	Sourgrass	X			U	X	–							
Eleusine indica (L.) Gaertn.	Goosegrass	X			U	X	–							
Melinis minutiflora P. Beauv.	Molasses grass	X			O	X	U							
Panicum maximum Jacq.	Guinea grass	X			A	X	A							
Pennisetum clandestinum Chiov.	Kikuyu grass	X			U	X	–							
Rhynchelytrum repens (Willd.) Hubb.	Natal redtop	X			U	X	–							
Saccharum officinarum L.	Sugar cane	X			R	X	–							
Sorghum bicolor (L.) Moench	Sorghum	X			–	X	–							
Sporobolus africanus (Poir.) Robyns & Tournay	Smutgrass	X			R	X	–							
ANGIOSPERMS – DICOTYLEDONES														
ACANTHACEAE														
Asystasia gangetica (L.) T. Anderson	Chinese violet	X			R	–	R							
AMARANTHACEAE														
Alternanthera caracasana Kunth	Mat chaff flower	X			R	X	–							
A. sessilis (L.) DC	Sessile joyweed	X			–	X	–							
Amaranthus spinosus L.	Spiny amaranth	X			U	X	–							

* Category not applicable

APPENDIX H-1

CHECK LIST OF PLANTS

Paikea Uplands

SCIENTIFIC NAME	COMMON NAME	STATUS	N	FH *	RELATIVE ABUNDANCE									
					G	CA	MF							
ANACARDIACEAE														
Schinus terebinthifolius Raddi	Christmas berry	X			O	X	C							
APOCYNACEAE														
Plumeria x	Plumeria	X			–	X	–							
ARALIACEAE														
Schefflera actinophylla (Endl.) Harms	Octopus tree	X			–	X	–							
ASCLEPIADACEAE														
Calotropis gigantea (L.) R. Br. ex Ait. f.	Crown flower	X			–	X	–							
ASTERACEAE														
Acanthospermum australe (Loefl.) Kuntze	Spiny-bur	X			U	X	–							
Ambrosia artemisifolia L.	Common ragweed	X			U	–	–							
Bidens pilosa L.	Spanish needle	X			R	X	–							
Conyza bonariensis (L.) Cronq.	Hairy horseweed	X			U	X	–							
Emilia fosbergii Nicolson	Pualele	X			R	X	–							
Pluchea symphytifolia (Mill.) Gillis	Sourbush	X			U	X	–							
Sonchus oleraceus L.	Sow thistle	X			–	X	–							
Tridax procumbens L.	Coat buttons	X			–	X	–							
Verbesina encelioides (Cav.) Benth. & Hook.	Golden crown-beard	X			U	–	–							
Xanthium strumarium L.	Cocklebur	X			U	–	–							
BRASSICACEAE														
Lepidium virginicum L.		X			U	–	–							
CACTACEAE														
Opuntia ficus-indica (L.) Mill.	Pānini	X			O	–	–							
CHENOPODIACEAE														
Chenopodium carinatum R. Br.		X			R	X	–							
C. murale L.	'Aheahea	X			U	–	–							
C. sp.		X			R	–	–							
CONVOLVULACEAE														
Ipomoea alba L.	Moon flower	X			U	–	U							
I. indica (J. Burm.) Merr.	Koali 'awahia	I			O	–	–							
I. obscura (L.) Ker-Gawl.		X			R	–	–							
I. triloba L.	Little bell	X			U	X	–							
CUCURBITACEAE														
Momordica charantia L.	Peria	X			U	X	U							
EUPHORBIACEAE														
Aleurites moluccana (L.) Willd.	Kukui	P			R	X	U							
Chamaesyce hirta (L.) Millsp.	Hairy spurge	X			U	X	–							
C. hypericifolia (L.) Millsp.	Graceful spurge	X			R	–	–							
C. hyssopifolia (L.) Small		X			U	–	–							
Ricinus communis L.	Castor	X			U	–	–							

* Category not applicable

C H E C K L I S T O F P L A N T S

Palikea Uplands

SCIENTIFIC NAME	COMMON NAME	STATUS	H·	FH*	RELATIVE ABUNDANCE		
					G	CA	MF
FABACEAE							
Acacia confusa Merr.	Formosa koa	X			R	–	–
A. farnesiana (L.) Willd.	Klu	X			O	–	–
Canavalia cathartica Thouars	Maunaloa	X			R	–	–
Chamaecrista nictitans (L.) Moench	Partridge pea	X			O	X	–
Crotalaria incana L.	Fuzzy rattlepod	X			U	X	R
C. pallida Aiton	Smooth rattlepod	X			U	X	–
Desmanthus virgatus (L.) Willd.	Virgate mimosa	X			U	–	–
Erythrina fusca Lour.		X			–	X	–
E. sandvicensis Degener	Wiliwili	E			U	X	–
Glycine wightii (Wight & Arnott) Verdc.		X			R	X	–
Indigofera suffruticosa Mill.	Indigo	X			O	X	–
Leucaena leucocephala (Lam.) de Wit	Koa-haole	X			C	X	C
Macroptilium lathyroides (L.) Urb.	Cow pea	X			U	–	–
Medicago sativa L.	Alfalfa	X			R	–	–
Melilotus alba Medik	White sweet clover	X			R	–	–
Paraserianthes falcataria (L.) I. Nielsen		X			R	–	R
Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth	Kiawe	X			R	X	U
Senna occidentalis (L.) Link	Coffee senna	X			R	X	U
Vigna sesquipedalis (L.) Fruw.	Yard long bean	X			–	X	–
LAURACEAE							
Persea americana Mill	Avocado	X			–	X	–
LAMIACEAE							
Leonotis nepetifolia (L.) R. Br.	Lion's ear	X			–	X	–
Stachys arvensis L.	Staggerweed	X			U	–	–
MALVACEAE							
Abutilon grandifolium (Willd.) Sweet	Hairy abutilon	X			U	–	O
Hibiscus x	Hibiscus	X			–	X	–
Malachra alceifolia Jacq.		X			R	–	–
Malvastrum coromandelianum (L.) Garcke	False mallow	X			U	X	R
Sida fallax Walp.	'Ilima	I			R	–	–
S. rhombifolia L.		X?			U	X	–
S. spinosa L.	Prickly sida	X			U	X	–
MELIACEAE							
Melia azedarach L.	Chinaberry	X			U	–	O
MENISPERMACEAE							
Cocculus trilobus (Thunb.) DC	Huehue	I			R	–	–
MORACEAE							
Ficus microcarpa L. fl.	Chinese banyan	X			–	X	R
MYRTACEAE							
Psidium guajava L.	Guava	X			U	–	R
Syzygium cumini (L.) Skeels	Java plum	X			U	–	R

* Category not applicable

C H E C K L I S T O F P L A N T S

Paikea Uplands

SCIENTIFIC NAME	COMMON NAME	STATUS	N.	PH *	RELATIVE ABUNDANCE G	CA	MP
OXALIDACEAE							
Oxalis corniculata L.	Yellow wood sorrel	P?			–	X	–
PASSIFLORACEAE							
Passiflora edulis f. flavicarpa Degener	Yellow liliko'i	X			R	–	O
PLUMBAGINACEAE							
Plumbago zeylanica L.	'Ilie'e	I			–	–	O
PORTULACACEAE							
Portulaca oleracea L.	Pigweed	X			–	X	–
PROTEACEAE							
Grevillea robusta A. Cunn. ex R. Br.	Silk oak	X			U	–	U
RUBIACEAE							
Coffea arabica L.	Arabian coffee	X			–	X	–
SANTALACEAE							
Santalum freycinetianum Gaud.	Sandalwood	E			–	X	R
SOLANACEAE							
Lycopersicon esculentum Mill.	Cherry tomato	X			–	X	–
L. pimpinellifolium (Jusl.) Mill.	Currant tomato	X			–	X	–
Nicandra physalodes (L.) Gaertn.	Apple of Peru	X			R	–	–
Solanum linneanum Hepper & P. Jaeger	Apple of Sodom	X			–	X	–
STERCULIACEAE							
Theobroma cacao L.	Cacao	X			–	X	–
Waltheria indica L.	'Uhaloa	I?			C	X	–
THEACEAE							
Camellia sinensis (L.) Kuntze	Tea	X			–	X	–
TILIACEAE							
Triumfetta semitriloba Jacq.	Sacramento bur	X			R	–	R
ULMACEAE							
Trema orientalis (L.) Blume	Gunpowder tree	X			–	X	R
VERBENACEAE							
Lantana camara L.	Lantana	X			U	–	R

* Category not applicable

CHECK LIST OF ANIMALS

Paikea Uplands

SCIENTIFIC NAME	COMMON NAME	STATUS	H·	PH*	RELATIVE ABUNDANCE									
					G	CA	MF							
BIRDS														
ARDEIDAE														
Bubulcus ibis	Cattle egret	X			–	X	–							
COLUMBIDAE														
Geopelia striata	Barred dove	X			X	X	–							
Streptopelia chinensis	Lace-neck dove	X			X	X	–							
PHASIANIDAE														
Phasianus colchicus torquatus	Ringneck pheasant	X			X	–	–							
PLOCEIDAE														
Lonchura punctulata	Ricebird	X			X	X	–							
Paroaria coronata	Red-crested cardinal	X			X	X	X							
Passer domesticus	House sparrow	X			X	–	–							
PYCNONOTIDAE														
Pycnonotus cafer	Red-vented bulbul	X			X	–	X							
STURNIDAE														
Acridotheres tristis	Common mynah	X			X	X	–							
TIMALIIDAE														
Gurrulax canorus	Chinese thrush	X			X	–	–							
ZOSTEROPIDAE														
Zosterops japonica	Japanese white-eye	X			X	–	X							
MAMMALS														
VIVERRIDAE														
Herpestes auropunctatus	Small Indian mongoose	X			X	–	–							

* Category not applicable

CHECK LIST OF PLANTS

Kahuku Agricultural Park

SCIENTIFIC NAME	COMMON NAME	STATUS	RELATIVE ABUNDANCE						
			ACF	MT	MF	IF	G	ES	C
PTERIDOPHYTES									
ADIANTACEAE									
Pityrogramma calomelanos (L.) Link	Silver fern	X	-	-	U	-	R	-	-
DAVALLIACEAE									
Nephrolepis exaltata (L.) Schott	Boston fern	I	O	U	O	-	C	-	-
DENNSTAEDTIACEAE									
Pteridium aquilinum var. decompositum (Gaud.) R. Tryon	Bracken fern	I	-	-	-	-	R	-	-
LINDSAEACEAE									
Sphenomeris chusana (L.) Copel.	Pala'a	I	-	-	U	-	R	-	-
POLYPODIACEAE									
Microsorium scolopendrium (Burm.) Copel.	Laua'e	P	U	U	U	-	-	U	-
PSILOTACEAE									
Psilotum nudum (L.) Beauv.	Moa	I	-	-	R	-	-	-	-
WOODSIACEAE									
Christella parasitica (L.) Leveille		X	-	-	U	-	-	-	-
GYMNOSPERMS									
ARAUCARIACEAE									
Araucaria columnaris (Forst. f.) Hook.	Cook pine	X	-	-	R	-	-	-	-
ANGIOSPERMS - MONOCOTYLEDONES									
AGAVACEAE									
Cordyline fruticosa (L.) A. Chev.	Ti	P	-	R	R	-	-	-	-
Furcraea foetida (L.) Haw.	Mauritius hemp	X	-	R	R	-	-	R	-
ARECACEAE									
Cocos nucifera L.	Coconut	P	-	-	R	-	-	-	-
Phoenix sp.	Date.	X	-	-	R	-	-	-	-
COMMELINACEAE									
Commelina diffusa N.L. Burm.	Honohono	X	-	-	R	-	-	-	X
MUSACEAE									
Musa x paradisiaca L. (cultivar)	Banana	X	-	-	R	-	-	-	X
ORCHIDACEAE									
Arundina graminifolia (D. Don) Hochr.	Bamboo orchid	X	-	-	-	-	R	-	-
Spathoglottis plicata Blume	Malayan ground orchid	X	-	-	U	R	U	U	-
PANDANACEAE									
Pandanus tectorius S. Parkinson ex Z.	Hala	I?	-	-	R	-	-	-	-

CHECK LIST OF PLANTS

Kahuku Agricultural Park

SCIENTIFIC NAME	COMMON NAME	STATUS			RELATIVE ABUNDANCE									
					ACE	MT	MF	IF	G	ES	C			
POACEAE														
Andropogon virginicus L.	Broomsedge	X			U	U	U	R	A	U	-			
Axonopus fissifolius (Raddi) Kuhlm	Narrow-leaved carpetgrass	X			-	-	U	R	U	R	-			
Bothriochloa pertusa (L.) A. Camus	Pitted beardgrass	X			-	U	-	-	-	O	X			
Brachiaria mutica (Forssk.) Stapf	Para grass	X			O	O	O	-	O	U	X			
Chloris barbata (L.) Sw.	Swollen fingergrass	X			-	-	-	-	-	-	X			
C. divaricata R. Br.	Star grass	X			-	-	-	-	-	-	X			
Chrysopogon aciculatus (Retz.) Trin.	Golden beardgrass	X			-	U	U	U	O	O	-			
Cynodon dactylon (L.) Pers.	Bermuda grass	X			U	-	-	-	-	-	X			
Dichanthium annulatum (Forssk.) Stapf	Angleton grass	X			U	R	-	-	-	-	X			
Digitaria ciliaris (Retz.) Koeler	Henry's crabgrass	X			-	-	-	-	-	U	X			
D. insularis (L.) Mez ex Ekman	Sourgrass	X			-	-	-	-	-	-	X			
Ehrharta stipoides Labill.	Meadow ricegrass	X			-	R	U	-	-	-	-			
Eleusine indica (L.) Gaertn.	Goosegrass	X			-	U	U	-	-	-	X			
Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult.	Pili	I?			-	-	-	-	U	U	-			
Hyparrhenia rufa (Nees) Stapf	Thatching grass	X			-	-	R	-	O	-	X			
Melinis minutiflora P. Beauv.	Molasses grass	X			C	-	O	R	U	U	X			
Oplismenus hirtellus (L.) P. Beauv.	Basket grass	X			-	-	C	-	-	-	-			
Panicum maximum Jacq.	Guinea grass	X			U	U	U	-	R	-	X			
Paspalum conjugatum Bergius	Hilo grass	X			O	U	U	-	-	-	X			
P. dilatatum Poir.	Dallis grass	X			U	-	-	-	U	-	X			
P. scorbiculatum L.	Ricegrass	X			O	U	U	-	U	U	X			
P. urvillei Steud.	Vasey grass	X			U	-	-	-	-	-	-			
Pennisetum polystachion (L.) Schult.	Feathery pennisetum	X			U	U	U	R	O	U	-			
P. purpureum Schumach.	Napier grass	X			-	U	U	-	R	R	X			
Phyllostachys nigra (Lodd.) Munro	Black bamboo	X			-	-	R	-	-	-	-			
Rhynchelytrum repens (Willd.) Hubb.	Natal redtop	X			-	O	R	-	-	O	X			
Saccharum officinarum L.	Sugar cane	X			-	O	U	-	-	-	X			
Sacciolepis indica (L.) Chase	Glenwood grass	X			-	U	-	-	-	-	X			
Setaria gracilis Kunth	Yellow foxtail	X			-	U	U	-	-	U	-			
S. verticillata (L.) P. Beauv.	Bristly foxtail	X			-	-	-	-	-	-	X			
Sorghum halepense (L.) Pers.	Johnson grass	X			-	U	-	-	-	-	U			
Sporobolus africanus (Poir.) Robyns & Tournay	Smutgrass	X			-	U	R	-	-	-	X			
ANGIOSPERMS - DICOTYLEDONES														
ACANTHACEAE														
Asystasia gangetica (L.) T. Anderson	Chinese violet	X			-	U	U	-	-	-	X			
AMARANTHACEAE														
Amaranthus spinosus L.	Spiny amaranth	X			-	U	R	-	-	-	X			
ANACARDIACEAE														
Mangifera indica L.	Mango	X			O	-	U	-	-	-	X			
Schinus terebinthifolius Raddi	Christmas berry	X			-	C	C	-	O	O	X			
APIACEAE														
Centella asiatica (L.) Urb.	Asiatic pennywort	X			U	-	O	-	-	U	X			
Ciclospermum leptophyllum (Pers.) Sprague	Fir-leaved celery	X			-	-	-	-	-	-	X			

CHECK LIST OF PLANTS

Kahuku Agricultural Park

SCIENTIFIC NAME	COMMON NAME	STATUS	RELATIVE ABUNDANCE ACF	MT	MF	IF	G	ES	C
ARALIACEAE									
Schefflera actinophylla (Endl.) Harms	Octopus tree	X	U	U	C	-	-	-	-
ASTERACEAE									
Acanthospermum australe (Loefl.) Kuntze	Spiny-bur	X	U	-	-	-	R	-	-
Ageratum conyzoides L.	Maile honohono	X	-	-	U	-	-	-	X
Bidens pilosa L.	Spanish needle	X	C	U	U	R	U	U	X
Conyza bonariensis (L.) Cronq.	Hairy horseweed	X	-	U	-	-	U	U	-
Crassocephalum crepidioides (Benth.) S. Moore		X	-	-	-	-	-	-	X
Emilia fosbergii Nicolson	Pualele	X	-	-	-	-	U	-	-
E. sonchifolia (L.) DC.	Flora's paintbrush	X	U	U	U	-	U	U	X
Pluchea symphytifolia (Mill.) Gillis	Sourbush	X	-	U	U	-	-	-	X
Sonchus oleraceus L.	Sow thistle	X	-	-	-	-	-	-	X
Synedrella nodiflora (L.) Gaertn.	Nodeweed	X	-	-	U	-	-	-	X
Vernonia cinerea (L.) Less.	Little ironweed	X	U	R	-	-	-	-	X
CARICACEAE									
Carica papaya L.	Papaya	X	-	-	-	-	-	-	X
CASUARINACEAE									
Casuarina equisetifolia L.	Common ironwood	X	U	U	C	A	U	U	X
CONVOLVULACEAE									
Ipomoea alba L.	Moon flower	X	-	U	-	-	-	-	-
I. indica (J. Burm.) Merr.	Koali 'awahia	I	-	U	-	-	-	-	-
I. obscura (L.) Ker-Gawl.		X	-	U	R	-	-	-	X
Merremia tuberosa (L.) Rendle	Wood rose	X	-	U	-	-	-	-	-
CURCUBITACEAE									
Momordica charantia L.	Peria	X	-	-	R	-	-	-	X
EBENACEAE									
Diospyros sandwicensis (A. DC.) Fosb.	Lama	E	-	-	-	-	-	R	-
EPACRIDACEAE									
Styphelia tameiameiae (Cham. & Schlechtend.) F.v. Muell.	Pukiawe	I	-	-	-	-	R	-	-
EUPHORBIACEAE									
Aleurites moluccana (L.) Willd.	Kukui	P	-	-	U	-	-	-	-
Chamaesyce hirta (L.) Millsp.	Hairy spurge	X	-	-	U	-	-	-	X
C. hypericifolia (L.) Millsp.	Graceful spurge	X	-	R	-	-	-	-	-
Macaranga tanarius (L.) Mull. Arg.		X	C	C	C	U	U	-	X
Phyllanthus debilis Klein ex Willd.	Niruri	X	U	U	-	R	-	U	X
Ricinus communis L.	Castor	X	-	-	-	-	-	-	X
FABACEAE									
Acacia confusa Merr.	Formosa koa	X	U	U	C	R	U	-	-
Chamaecrista nictitans (L.) Moench	Partridge pea	X	U	U	U	R	-	U	X
Crotalaria incana L.	Fuzzy rattlepod	X	-	-	-	-	-	-	X

CHECK LIST OF PLANTS

Kahuku Agricultural Park

SCIENTIFIC NAME	COMMON NAME	STATUS	RELATIVE ABUNDANCE						
			ACF	MT	MF	IF	G	ES	C
Crotalaria pallida Aiton	Smooth rattlepod	X	U	R	-	R	-	R	-
Desmanthus virgatus (L.) Willd.	Virgate mimosa	X	-	U	-	-	-	-	X
Desmodium incanum DC.	Spanish clover	X	C	O	O	U	O	O	X
D. sandwicense E. Mey.	Spanish clover	X	-	-	-	-	-	-	X
D. triflorum (L.) DC.		X	R	U	-	-	-	-	X
Glycine wightii (Wight & Arnott) Verdc.		X	-	U	-	-	-	-	-
Indigofera suffruticosa Mill.	Indigo	X	-	U	R	-	-	-	X
Leucaena leucocephala (Lam.) de Wit	Koa-haole	X	-	O	O	-	-	R	X
Mimosa pudica var. unijuga (Duchass. & Walp.) Griseb.	Sensitive plant	X	U	U	U	-	-	U	X
Paraserianthes falcataria (L.) I. Nielsen		X	-	U	R	-	-	-	-
LAMIACEAE									
Leonotis nepetifolia (L.) R. Br.	Lion's ear	X	-	U	R	-	-	-	X
MALVACEAE									
Abutilon grandifolium (Willd.) Sweet	Hairy abutilon	X	-	-	-	-	-	-	X
Hibiscus tiliaceus L.	Hau	I?	-	-	R	-	-	-	-
Malvastrum coromandelianum (L.) Garcke	False mallow	X	-	-	U	-	-	-	X
MELASTOMATACEAE									
Clidemia hirta (L.) D. Don	Koster's curse	X	-	-	O	R	R	-	-
MENISPERMACEAE									
Cocculus trilobus (Thunb.) DC.	Huehue	I	-	R	-	-	R	-	-
MORACEAE									
Ficus microcarpa L. fil.	Chinese banyan	X	-	R	R	-	-	-	-
MYRTACEAE									
Metrosideros polymorpha Gaud.	Ohia	E	-	-	R	-	-	-	-
Psidium cattleianum Sabine	Strawberry guava	X	-	U	O	U	R	R	-
P. guajava L.	Guava	X	-	O	C	-	U	U	X
Syzygium cumini (L.) Skeels	Java plum	X	U	O	C	U	O	U	X
NYCTAGINACEAE									
Bougainvillea sp.		X	-	-	R	-	-	-	-
OXALIDACEAE									
Oxalis corniculata L.	Yellow wood sorrel	P?	-	-	-	-	-	-	X
O. corymbosa DC.	Pink wood sorrel	X	-	R	R	-	-	-	X
PASSIFLORACEAE									
Passiflora edulis f. flavicarpa Degener	Yellow liliko'i	X	-	-	U	-	-	-	-
P. foetida L.	Love-in-a-mist	X	-	-	U	R	U	O	-
P. suberosa L.	Huehue haole	X	-	U	U	U	-	U	X
PHYTOLACCACEAE									
Rivina humilis L.	Coral berry	X	-	R	-	-	-	-	-

CHECK LIST OF PLANTS

Kahuku Agricultural Park

SCIENTIFIC NAME	COMMON NAME	STATUS	RELATIVE ABUNDANCE ACE	MT	HF	IF	G	FS	C
PLANTAGINACEAE									
Plantago major L.	Common plantain	Y	-	-	-	-	-	-	X
PORTULACACEAE									
Portulaca oleracea L.	Pigweed	X	-	-	-	-	-	-	X
PROTEACEAE									
Grevillea robusta A. Cunn. ex R. Br.	Silk oak	X	-	-	R	-	-	-	-
ROSACEAE									
Osteomeles anthyllidifolia (Sm.) Lindl.	'Ōlei	I	-	-	-	R	U	A	-
RUBIACEAE									
Canthium odoratum (G. Forster) Seem.	Alahe'e	I	-	R	R	-	R	R	-
Morinda citrifolia L.	Noni	P	-	-	U	-	-	R	-
Spermacoce assurgens Ruiz & Pav.	Buttonwood	X	-	-	U	-	-	-	X
SOLANACEAE									
Capsicum annuum L.	Red pepper	X	-	-	-	-	-	-	X
Lycopersicon pimpinellifolium (Jusl.) Mill.	Currant tomato	X	-	R	-	-	-	-	-
Solanum americanum Mill.	Pōpolo	I?	-	U	-	-	-	-	-
S. melongena L.	Egg plant	X	-	-	-	-	-	-	X
STERCULIACEAE									
Waltheria indica L.	'Uhaloa	I?	U	U	-	R	R	O	X
THYMELAEACEAE									
Wikstroemia oahuensis (A. Gray) Rock	'Ākia	E	-	U	U	R	O	O	-
VERBENACEAE									
Lantana camara L.	Lantana	X	O	U	U	U	U	R	-
Stachytarpheta jamaicensis (L.) Vahl	Jamaica vervain	X	U	U	U	-	-	-	-
S. urticifolia (Salisb.) Sims		X	-	U	U	-	-	O	X

CHECK LIST OF ANIMALS

Kahuku Agricultural Park

SCIENTIFIC NAME	COMMON NAME	STATUS	RELATIVE ABUNDANCE						
			ACF	MT	MF	IF	G	ES	C
BIRDS									
ARDEIDAE									
Bubulcus ibis	Cattle egret	X	-	-	-	-	-	-	X
COLUMBIDAE									
Geopelia striata	Barred dove	X	X	X	X	-	-	-	X
Streptopelia chinensis	Lace-necked dove	X	-	X	X	-	-	-	X
FRINGILLIDAE									
Richmondena cardinalis	Kentucky cardinal	X	-	X	X	X	-	-	X
MUSCICAPIDAE									
Copsychus malabaricus	Shama thrush	X	-	-	X	-	-	-	X
PLOCEIDAE									
Lonchura punctulata	Ricebird	X	-	-	-	X	X	X	-
Paroaria coronata	Red-crested cardinal	X	-	X	-	-	-	-	-
Passer domesticus	House sparrow	X	-	-	-	-	-	-	X
PYCNONOTIDAE									
Pycnonotus cafer	Red-vented bulbul	X	X	X	X	X	X	X	X
STURNIDAE									
Acridotheres tristis	Common mynah	X	X	X	-	-	-	X	X
ZOSTEROPIDAE									
Zosterops japonica	Japanese white-eye	X	-	X	-	X	-	-	X
MAMMALS									
SUIDAE									
Sus scrofa	Pig	X	X	X	X	-	-	-	-

APPENDIX I

COMMENTS AND RESPONSES ON DRAFT ENVIRONMENTAL IMPACT STATEMENT

The following agencies submitted 'no comment' responses:

Federal

- Department of the Interior
  - Geological Survey, Water Resources Division
- Department of the Navy
  - Commander, Naval Base Pearl Harbor

State of Hawaii

- Department of Accounting and General Services
- Department of Budget and Finance
  - Housing Finance and Development Corporation

City and County of Honolulu

- Department of General Planning
- Department of Housing and Community Development
- Department of Parks and Recreation
- Department of Public Works
- Fire Department

Responses from the Department of Agriculture to these parties follow:

Federal

- Department of the Army
  - U.S. Army Engineer District, Honolulu
  - Headquarters, U.S. Army Support Command, Hawaii

State of Hawaii

- Department of Business, Economic Development & Tourism
  - Land Use Commission

State of Hawaii (cont.)

- Department of Defense
- Department of Health
- Department of Land and Natural Resources (September 4, 1992)
  - Commission on Water Resource Management
  - Division of Aquatic Resources
  - Division of Land Management
  - Division of Forestry & Wildlife
  - State Historic Preservation Division
- Department of Land and Natural Resources (February 3, 1993)
  - Division of Aquatic Resources
  - State Historic Preservation Division
- Department of Transportation
- University of Hawaii at Manoa
  - Environmental Center

City and County of Honolulu

- Board of Water Supply
- Department of Transportation Services
- Police Department

Organizations and Individuals

- Hawaiian Electric Company, Inc.
- The Hawai‘i — Lā‘ieikawai Association, Inc.
- The Nature Conservancy of Hawaii
- Dr. William Harris
- Ruth E. Heidrich
- Eliot Jay Rosen
- Cynthia Smith

SEND COPIES TO
APPROPRIATE PARTIES

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, HONOLULU
BUILDING 230
FT. SHAFTER, HAWAII 96858-5440

REPLY TO
ATTENTION OF:

January 15, 1993

POSTED
JAN 15 1993

Planning Division

RECEIVED JAN 20 1993

'93 JAN 19 A10:20
OFC. OF ENVIRONMENTAL
QUALITY CONT.

Mr. Brian Choy, Director
Office of Environmental Quality Control
220 South King Street, Fourth Floor
Honolulu, Hawaii 96813

Dear Mr. Choy:

Thank you for the opportunity to review and comment on the Draft Environmental Impact Statement for the Proposed Oahu Livestock Agricultural Park, Hawaii. We have no additional comments to offer from those presented in our previous letter dated August 12, 1992.

Sincerely,

Adrian Au, P.E.
Acting Director
of Engineering

c: Dr. Paul J. Schwind, Dept. of Agriculture
Dr. James Dexter, M&E Pacific, Inc.

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Mr. Kisuk Cheung, P.E.
Director of Engineering
Department of the Army
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858-5440

Dear Mr. Cheung:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

We are responding to your department's letter dated January 15, 1993, signed by Adrian Au, Acting Director, concerning the Oahu Livestock Agricultural Park. The letter stated there were no additional comments other than those in a previous letter dated August 12, 1992.

Our reply to that letter (dated November 30, 1992) addresses those comments.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

Attachment

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

November 30, 1992

Kisuk Cheung, P.E.
Director of Engineering
Planning Division
Department of the Army
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858-5440

Dear Mr. Cheung:

Subject: Response to Comments on Environmental Assessment (EA) and Notice of Preparation of Environmental Impact Statement (EIS) for Oahu Livestock Agricultural Park

Thank you for your response dated August 12, 1992.

Your letter expressed particular interest in farmed wetlands and potential DA permits; FIRM boundaries; and extent of flood hazards.

Our consultants have inquired about the delineation of wetland areas that might affect the project or be affected by it. To their knowledge, there are no farmed wetland areas mauka of Kamehameha Highway. Please inform the present lessees and Campbell Estate, as well as this Department, if such is being undertaken by a federal agency and when this information will be available.

Section Three–I.D., Water Resources, in the Draft EIS describes the extent of floodplains. Section Two–I.E., Conceptual Site Plan, identifies the location for livestock operations. These facilities will not be located in floodplains; described measures will be taken to confine runoff.

Please refer to these sections in the Draft EIS for further discussion of the topics.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

YK:lt

Island Fresh

DEPARTMENT OF THE ARMY
HEADQUARTERS, UNITED STATES ARMY SUPPORT COMMAND, HAWAII
FORT SHAFTER, HAWAII 96858-5000

[illegible] FEB 1993

REPLY TO
ATTENTION OF

Directorate of Public Works

RECEIVED FEB 8 1993

Honorable John Waihee
Governor, State of Hawaii
c/o Office of Environmental Quality Control
220 South King Street, 4th Floor
Honolulu, Hawaii 96813

Dear Governor Waihee:

Attached for your review are comments pertaining to the Draft Environmental Impact Statement, Oahu Livestock Agricultural Park. The comments are provided by the Director of Plans, Training, Mobilization & Security. They are the major user of the land adjacent to the project area.

The information on the enclosed site map was provided by our Real Estate office and is the basis for our concern. Military training may adversely affect dairy operations, especially production, if cows are influenced by noise created by helicopters and fixed winged aircraft.

Should you require additional information, please contact Mr. Mark Salley, Environmental Office, phone 656-2878.

Sincerely,

Charles R. Wilson
Colonel, U.S. Army
Director of Public Works

Enclosure

Copies Furnished:
State of Hawaii:
  Office of Environmental Quality Control
  Department of Agriculture
✓M&E Pacific Inc.

APVG-GT (350)

27 January 1993

MEMORANDUM FOR DPW

SUBJECT: Proposed Oahu Livestock Agricultural Park, Kahuku

1. Reference, Draft Environmental Impact Statement, Oahu Livestock Agricultural Park, M&E Pacific, Inc., December 1992.

2. The following information is provided concerning above subject matter.

a. Enclosed site map (figure 3-1b) reflects superimposed boundaries. The area bounded in orange represents the Pomai Lease Agreement. We have worked hard to secure this lease because it supports the Kahuku DZ and ground maneuver operations.

b. West of the Kahuku DZ is the Kanes DZ. Air approaches and departures for both DZs will overlap the proposal site.

c. Occupants of the facility must be aware of the noise the Army generates while conducting training operations of both helicopters and fixed wing, and paradrop operations of men and equipment.

d. Application of current noise abatement guidelines, which is a 1,000 foot buffer between training and populated areas, will jeopardize the Kahuku and Kanes DZ, and ground operations on the Pomai leased area. In other words, use of such area for livestock appears to be non-compatible with adjacent military operations.

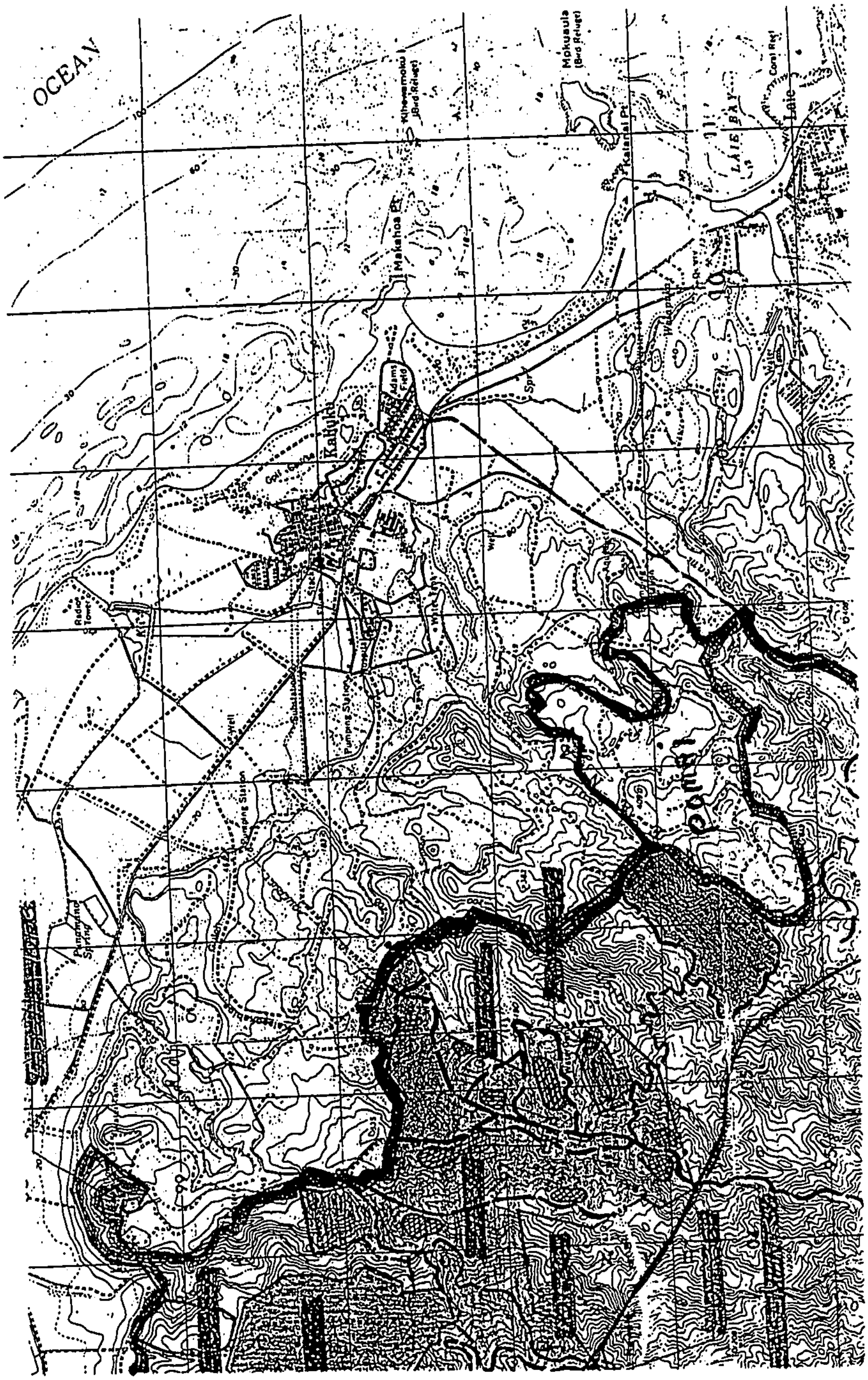
3. My point of contact is Mr. Vic Garo, Range Facility Planner, 656-2527.

Tom Ellzey

Encl

THOMAS F. ELLZEY, JR.
Colonel, AV
Director, DPTMSEC

28 JAN 93


OCEAN
Kihewamoku (Bird Refuge)
Mokuauia (Bird Refuge)
Makahoa Pt
LAIE BAY
Laie
Coral Reef
Adams Field
Kahuku
Golf Course
Radio Tower
Pumping Station
Well
Pumping Station

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Colonel Charles R. Wilson
Director of Public Works
Department of the Army
Headquarters, U.S. Army Support Command Hawaii
Fort Shafter, Hawaii 96858-5000

Dear Colonel Wilson:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter of February 4, 1993, on the proposed Oahu Livestock Agricultural Park. The concerns expressed relate to the effect of noise on dairy production from military aircraft operations at the Kahuku Training Area. The contention is that livestock use is incompatible with training use.

We do not believe that this issue will become significant, provided the military's current noise abatement guidelines are followed as noted by the Director of Plans, Training, Mobilization and Security. These are the considerations:

1) the proposed property purchase will provide a buffer in excess of 1,000 feet between the dairy facilities and the Kahuku military leases;

2) dairy operators believe that the cows will adjust to recurring noises, even aircraft; and

3) the proximity of other constraints, in particular the community and the Ki'i Refuge of the U.S. Fish and Wildlife Service, seem more sensitive to aircraft operations than the dairies.

Thank you for your comments.

Sincerely,

Yukio Kitagawa

YUKIO KITAGAWA
Chairperson, Board of Agriculture

Island Fresh

JOHN WAIHEE
Governor
MUFI HANNEMANN
Director
BARBARA KIM STANTON
Deputy Director
RICK EGGED
Deputy Director
TAKESHI YOSHIHARA
Deputy Director

DEPARTMENT OF BUSINESS,
ECONOMIC DEVELOPMENT & TOURISM

Central Pacific Plaza, 220 South King Street, 11th Floor, Honolulu, Hawaii
Mailing Address: P.O. Box 2359, Honolulu, Hawaii 96804 Telephone: (808) 586-2406 Fax: (808) 586-2377

RECEIVED FEB 1 2 1993

February 10, 1993

Mr. Brian J. J. Choy
Director
Office of Environmental Quality Control
220 South King Street, 4th Floor
Honolulu, Hawaii 96813

Dear Mr. Choy:

The Department of Business, Economic Development & Tourism is pleased to submit the enclosed comments on the Draft Environmental Impact Statement for the Oahu Livestock Agricultural Park.

The comments were provided by the Land Use Commission. Questions regarding these comments may be directed to Esther Ueda, LUC Executive Officer, at 587-3826.

Thank you for the opportunity to comment.

Sincerely,

Mufi Hannemann

Mufi Hannemann

Enclosure

cc: Dr. Paul J. Schwind
Dr. James R. Dexter

JOHN WAIHEE
GOVERNOR

ESTHER UEDA
EXECUTIVE OFFICER

STATE OF HAWAII
DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM
LAND USE COMMISSION
Room 104, Old Federal Building
335 Merchant Street
Honolulu, Hawaii 96813
Telephone: 587-3822

December 28, 1992

SUBJECT: Draft Environmental Impact Statement - Oahu Livestock Agricultural Park; TMK: 9-2-04: por. 5, por. 6; 5-6-05: 9; 5-6-06: 19 and 5-6-08: por. 2

We have reviewed the subject Draft Environmental Impact Statement (DEIS) and have the following comments to offer:

1) We confirm that the Palikea Uplands site (TMK: 9-2-04: por. 5) is within the State Land Use Agricultural District.

2) In regards to the Kahuku site, TMK: 5-6-05: 9 and 5-6-08: por. 2 are within the State Land Use Agricultural District.

Portions of TMK: 5-6-06: 19 are within the State Land Use Urban District, with remaining portions within the State Land Use Agricultural District.

3) On page 1 of the DEIS, the Kahuku site is identified as including the total parcel of TMK: 5-6-06: 19. However, on page 140 of the DEIS, the Kahuku site is identified as including only a portion of TMK: 5-6-06: 19.

Because the proposed Livestock Agricultural Park is intended to utilize agriculturally zoned lands, only a portion of TMK 5-6-06: 19 will be used. Therefore, a correction to the TMK identifications on page 1 is needed.

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Honorable Mufi Hannemann
Director
State of Hawaii
Department of Business, Economic
Development & Tourism
P.O. Box 2359
Honolulu, Hawaii 96804

Attention: Ms. Esther Ueda
Land Use Commission Executive Officer

Dear Mr. Hannemann:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter on the subject project dated February 10, 1993.

We will correct the final EIS on page 1 to reflect that only portions of TMK: 5-6-06:19 within the State Land Use Agricultural District are intended to be used for the proposed project.

Thank you for calling this omission to our attention.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

RECEIVED FEB 1 6 1993

JOHN WAIHEE
GOVERNOR

AJOR GENERAL EDWARD V. RICHARDSON
DIRECTOR OF CIVIL DEFENSE

ROY C. PRICE, SR.
VICE DIRECTOR OF CIVIL DEFENSE

PHONE (808) 734-2161

STATE OF HAWAII
DEPARTMENT OF DEFENSE
OFFICE OF THE DIRECTOR OF CIVIL DEFENSE
3949 DIAMOND HEAD ROAD
HONOLULU, HAWAII 96816-4495

RECEIVED FEB 1 6 1993

February 11, 1993

TO: The Honorable John Waihee
Governor of Hawaii
c/o Office of Environmental Quality Control

ATTENTION: Mr. Brian J. J. Choy

FROM: Roy C. Price, Sr.
Vice Director of Civil Defense

SUBJECT: OAHU LIVESTOCK AGRICULTURAL PARK; DRAFT ENVIRONMENTAL IMPACT STATEMENT

We appreciate this opportunity to comment on the Draft Environmental Impact Statement (DEIS) by the Department of Agriculture, State of Hawaii, on the island of Oahu, Ewa and Koolauloa Districts; TMK 9-02-04: 5 & 6; 5-06-05: 9, 5-6-06: 6 & 19, 5-06-08: 2.

While we do not have negative comments specifically directed at the DEIS, we do have a proposal that entails the addition of at least one new siren simulator device and the siren simulator support infrastructure to be purchased and installed by the developer. The location for the simulator normally is in any 24-hour manned office. However, for the Oahu Agricultural Livestock Park, any office that is manned during their normal working hours can be used.

Siren simulators are large, suitcase size, portable sirens, complete with built-in battery backup power. The siren simulators are triggered by the same radio system that triggers the outdoor sirens. The installation of such a device consists of a siren simulator, an antenna, an antenna cable duct, 110 volt AC electrical power and a backup source for AC electrical power, if one is available. A well planned installation of siren simulators would include the design of an antenna cable duct, typically from ground floor level to the rooftop. Additionally, either site may be suitable for a facility to house a Limited Automated Remote Collector (LARC) rain gauge. A LARC provides real-time remote rainfall data collection and information. This addition would enhance the existing rainfall LARC system and the National Weather Service and Civil Defense's ability to plan for the safety and well-being of the population at risk.

The DEIS addresses topography for both sites; Palikea with the more readily usable elevations ranging from 500-800 feet from the Ewa direction to the Kunia direction, with steeper portions with elevations exceeding 1000 feet. The proposed location also has one major named gulch that forms the eastern boundary with numerous less minor depressions. The steep terrain and numerous gulches and depressions place this area at risk from tropical cyclone and hurricane force winds being amplified by the sloping topography. Flash flooding and debris/mudslides resulting from slope instability and possible soil movement problems also need to be addressed. Kawailoa is subject to essentially the same potential problems which should also be addressed.

Our SCD planners and technicians are available to discuss this further if there is a requirement. Please have your staff call Mr. Mel Nishihara of my staff at 734-2161.

c: Dr. Paul J. Schwind
Department of Agriculture

✓ Dr. James R. Dexter
M&E Pacific, Inc.

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Mr. Roy C. Price, Sr.
Vice Director of Civil Defense
State of Hawaii
Department of Defense
Office of the Director of Civil Defense
2949 Diamond Head Road
Honolulu, Hawaii 96816-4495

Dear Mr. Price:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter of February 11, 1993. Your main concern as we understand it is the desire to locate an emergency alert siren at the proposed project. Our concerns, as noted in our letter to you dated November 29, 1992, are: 1) cost of the equipment, installation, and maintenance; and 2) effect of the loud noise if this facility were to be located very close to the dairy barns.

Please note that the proposed dairy site is about one-half mile from the urban area. We think that a site closer to the urban areas could be beneficial. We are willing to discuss this matter further with you to see how we might be able to help.

Please contact Dr. Paul J. Schwind, our Planning Program Administrator at 973-9469, if you would like to discuss this matter further.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

Island Fresh

RECEIVED APR 16 1993

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

JOHN C. LEWIN, M.D.
DIRECTOR OF HEALTH

In reply, please refer to:
92-468/epo

April 8, 1993

To: The Honorable John Waihee
Governor, State of Hawaii

From: John C. Lewin, M.D. Bruce Anderson for
Director of Health

Subject: Draft Environmental Impact Statement (DEIS)
Oahu Livestock Agricultural Park
Palikea uplands, Ewa, Oahu and Kahuku, Koolauloa, Oahu

Thank you for allowing us to review and comment on the subject document. We have the following comments to offer:

<u>Wastewater</u>

The document proposes to develop land and water which will be used for animal husbandry, dairies, grazing, waste management facilities, and other dairy operations such as calf pens, feed, and forage storage. The proposed alternative located in Palikea uplands is located in a "No Pass" Zone, above the Underground Injection Control (UIC) Line and in the critical wastewater disposal area (CWDA) as determined by the Oahu County Wastewater Advisory Committee. The proposed alternative located in Kahuku is also in the "No Pass" Zone area, above the UIC Line and in the CWDA. No new cesspools will be allowed in these areas.

The Wastewater Branch has reviewed the proposed waste management proposal and has the following comments to offer:

1. Run off control for operations on sloped upland plains may be a significant factor.

2. Wastewater discharge from confined animal facility treatment ponds or systems is not allowed except during rain-storm events. Holding ponds and wastewater facilities must be designed to prevent overflows from a 25 year - 24 hour storm event.

   In addition, from the enclosed <u>Agricultural Waste Management Policies</u> handout, page 2, paragraph 2, under <u>Department of Health Policy</u>:

   There shall be no discharge to State surface waters, publicly owned treatment works or sewage systems (HRS 342D-50). However, process waste pollutants may be discharged to navigable waters whenever rainfall events, either chronic or catastrophic, causes an overflow from a facility designed, constructed and operated to contain all generated waste waters plus the runoff from a 25-year, 24-hour storm event (40 CFR 412.13).

3. Detailed plans for manure, sludge or effluent reuse must be submitted and approved.

4. For areas above the UIC Line, wastewater ponds or treatment systems require ground water protection measures.

5. Odors, vector attraction and pathogen reduction (in regards to the neighboring community) must be appropriately addressed.

6. The Department of Health is attempting to finalize wastewater reuse guidelines. Irrigation as a means of wastewater disposal may be limited due to our proposed guidelines.

7. The preliminary waste management analysis must consider disease transmission as a factor when effluent irrigation or sludge application is used as a means of disposal. Reuse may be limited to forage crops only. Plans must be submitted and approved.

8. Effluent will probably contain higher concentrations of nutrients than domestic effluent. Nutrient management should be considered when effluent is reused for irrigation of crops.

9. We do not believe the energy potential will be fully realized by treating liquids as shown in figure 2-2 Process Flow Diagram For Dairy Waste Management. Anaerobic digesters are traditionally used to treat organic solids, which produce methane gas as a byproduct of the process. The management of liquids may be more appropriately handled by stabilization ponds rather than irrigation systems.

Both domestic and animal wastewater must be treated and disposed of according to the Department of Health's Administrative Rules, Chapter 11-62, "Wastewater Systems."

Please be aware that we are in the process of developing our animal waste guidelines. As these are developed, stricter requirements may be imposed on future projects.

If you should have any questions on this matter, please contact Mr. Dennis Tulang of the Wastewater Branch at 586-4294.

Drinking Water

1. The Department of Health still believes that the proposed project sites present serious groundwater contamination concerns. The Palikea site is adjacent to the Honouliuli Wells (state well nos. 2303-03, -04, -05, and -06) while the Board of Water Supply's Kahuku Wells (state wells

nos. 4057-15 and -16) are in the middle of the proposed Kahuku site. The vulnerable potable well locations, the large expansion potential of the agricultural park, and the already rising nitrate levels in central Oahu, create a very undesirable situation.

2. The Environmental Assessment stated that, "A theoretical analysis of ground water movement indicates a potential for infiltration at the site to reach the surrounding wells," for both sites. The Draft Waste Management Plan previously noted that nitrate contamination may take decades to materialize and be just as persistent. It went on to say that the potential impact may be relatively irreversible because treatment may be required indefinitely. Given this point of view, it is difficult to understand how groundwater contamination can be ruled out as a potential long-term adverse impact.

3. Both the Palikea and Kahuku agricultural park sites are situated above the Underground Injection Control (UIC) line. Land areas above the UIC line are generally considered to contain underground sources of drinking water. These areas should therefore be protected against all sources of groundwater contamination.

4. Page 42 of the DEIS states that approximately 55,000 to 82,000 gallons of <u>potable</u> water are needed per day for domestic and milk parlor sanitation purposes. The estimated total peak daily water demand (for the dairy and irrigated diversified agriculture activities) of 1,600,000 gallons per day will be provided from existing sources.

   For the Palikea site, the majority(?) of the water would be drawn from an existing <u>nonpotable</u> surface source, Waiahole Ditch. The DEIS fails to mention how this nonpotable source would be treated to meet the demand for potable water.

   At the Kahuku site, the majority(?) of the water would be drawn from Pump Station 1 (State well nos. 4057-01, -02, and -08), which presently serves the existing agricultural park. For both sites, the DEIS only addresses the sources supplying the "majority" of the water. It should be made very clear what other sources of water will be utilized.

5. If the potable water system serves 25 or more individuals at least 60 days per year or will have a minimum of 15 service connections, the owner of the water system (Department of Agriculture?) will be required to comply with Hawaii Administrative Rules, Title 11, Chapter 20, Rules Relating to Potable Water Systems.

6. Section 11-20-29 of Chapter 20 requires that all new sources of potable water serving a public water system be approved by the Director of Health prior to its use. Such an approval is based primarily upon the submission of a satisfactory engineering report which addresses the requirements set in Section 11-20-29.

7. Section 11-20-30 of Chapter 20 requires that new or substantially modified distribution systems for public water systems be approved

by the Director. However, if the water system is under the jurisdiction of the City and County of Honolulu, the Board of Water Supply will be responsible for the review and approval of the plans.

8. Appendix B indicates that deep well monitoring does not identify a source of contamination. It also describes the use of vadose zone monitoring as the first line of monitoring, with sampling of existing and future wells as a redundant means of monitoring. However, the manure management program described in Section 5, only monitors existing water wells for nitrogen, total dissolved solids, and fecal coliforms. Vadose zone monitoring needs to be incorporated into this monitoring plan.

9. The DEIS briefly mentions the development of replacement water sources as the only mitigative measure to groundwater contamination. For the Kahuku site, the Department of Agriculture proposes that alternative sources would be maintained by the State as a monitor well until it is "clearly" proven that contamination is occurring in the existing well as a result of the agricultural park. Rather than wait for such a vague and cumbersome process to take place, it would be more prudent to simply dedicate the new well(s) to the Board of Water Supply in exchange for water service to the agricultural park. This would eliminate the need for the Department of Agriculture to operate a public water system subject to state and federal regulation and relying upon a source of water (Pump Station 1) with a high potential for contamination (situated below most of the agricultural park).

   Similarly, at the Palikea site, the Department of Agriculture has proposed an alternative source consisting of treated surface water from an unnamed source (Waiahole Ditch?). We believe that the development of new surface water sources to replace contaminated wells will be a very difficult and expensive option. Most of the water purveyors in the state, including the Board of Water Supply, are trying to eliminate their dependence upon surface water and having to comply with the stringent requirements of the Surface Water Treatment Rule.

   We must continue to emphasize that these mitigation measures must be addressed to the satisfaction of the Board of Water Supply or any other well owner(s) whose sources of water will be at risk.

10. Figure 3-5a shows wells with incorrect numbers. There should not be three wells at different locations with the same number, 2303-03.

If you should have any questions on this matter, please contact Mr. William Wong, Chief, Safe Drinking Water Branch at 586-4258.

<u>Vector Control</u>

1. The Department of Health would like to see the following addressed in the final impact statement:

a. Contingency plans for disposal of manure and wastewater during breakdown of anaerobic digestors, and other equipment.

b. Contingency plans for storing wastewater when holding ponds must be dredged or maintained.

2. The Department of Health does not recommend the use of aquatic vegetation ponds. Aquatic vegetation in effluent ponds increases mosquito breeding by fostering breeding over the entire surface of the pond instead of only at the edges. Breeding of mosquitoes over the entire pond surface also presents problems in applying mosquito larvicides.

Solid Waste

The conceptual waste management plan presented in the Draft Environmental Impact Statement is adequate for a preliminary assessment of on-site environmental impacts, but should be pursued in greater detail to examine the benefits of utilizing an organic soil amendment in place of chemical fertilizers. The longer release time and lower leachability of organic nutrients could provide significant benefits in reduced groundwater and surface water contamination.

The discussion of market potential for the product should also be expanded once a specific site has been selected, with input from existing alternative waste management system operators and product marketers, such as Unysin (Waimanalo) and United Agro Products.

If you should have any questions on this matter, please contact Mr. John Harder of the Office of Solid Waste Management at 586-4227.

Water Pollution

A National Pollutant Discharge Elimination System (NPDES) permit is required for any discharge to waters of the State including the following:

1. Storm water discharges relating to construction activities for projects greater than five acres;
2. Storm water discharges from industrial activities;
3. Construction dewatering activities;
4. Cooling water discharges less than one million gallons;
5. Ground water remediation activities; and
6. Hydrotesting water.

Any person wishing to be covered by the NPDES general permit for any of the above activities should file a Notice of Intent with the Department's Clean

Water Branch at least 90 days prior to commencement of discharge to waters of the State.

Any-questions regarding this matter should be directed to Mr. Denis Lau of the Clean Water Branch at 586-4309.

Enclosure

c: State Department of Agriculture
M & E Pacific, Inc.
Safe Drinking Water Branch
Wastewater Branch
Vector Control
Office of Solid Waste Management
Clean Water Branch

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Honorable John C. Lewin, M.D.
Director of Health
State of Hawaii
Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801

Dear Dr. Lewin:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for the comments in your letter dated April 8, 1993. These comments are contained in five categories as follows: 1) wastewater, 2) drinking water, 3) vector control, 4) solid waste, and 5) water pollution. Each category is numbered separately. Our replies are keyed to these numbers in each category.

Wastewater

1. Runoff control is a significant factor in the overall site planning and engineering for the proposed project. The final environmental impact statement (FEIS) notes this consideration (page 207, Section Four-III). The measures proposed to address this concern are listed in the FEIS, Section Five, pages 209-210.

2. The criteria noted in this comment have been included in the preliminary design of runoff control facilities for the Kahuku site.

3. A detailed plan for manure and effluent reuse has been prepared as part of the waste management section in the draft Preliminary Engineering Report (M&E Pacific, January 1993). At the appropriate time, this information will be submitted to the Department of Health for approval.

4. A preliminary plan for ground water protection has been drafted. Please refer to Appendix L in the FEIS for additional information related to this concern.

5. Odors, vectors, and pathogen reduction have been considered in the planning and preliminary engineering. Please refer to page 208 in the FEIS.

6. If irrigation of effluent is not allowed, the conclusion that will eventually be reached is that wastewater treatment for dairies in Hawaii is cost prohibitive. None of the nearby domestic wastewater treatment plants have been designed to receive concentrated animal waste loads. Private treatment plants will have to be constructed. Treatment of animal waste effluent to secondary or higher levels of treatment in order to apply for a waste water discharge permit is not a feasible option. The dairies on Oahu would have to close if that becomes the recommendation of the Department of Health.

7. Disease transmission has been considered in the FEIS. Please refer to Appendix C and Appendix E. Specific comments on the risk assessment in these would be helpful.

8. Nutrient concentration buildup in the soil has been specifically considered in the FEIS. Appendix A is devoted to the fate and the migration of nitrogen as it is applied in treated animal waste to crops. Also Appendix L in the FEIS provides additional data monitoring and reuse potential for effluent and residuals.

9. At this time we see energy recovery not as a money-making venture for dairies, but as a means to help offset some of the cost of treatment. Enclosed are copies of two publications that provide the basis for the principal considerations and experience related to the use of biogas production and energy conversion at dairy farms. This technology is beyond the experimental stage and is being successfully applied on the mainland. One of the authors of the publications, Dr. Stanley Weeks, presented this information and discussed the potential for application here in Hawaii at a workshop in May 1992 to which the Department of Health was invited. The conclusion was that it should be kept as an option to be considered as the plan for the livestock park develops.

As far as stabilization ponds are concerned, we do not share your recommendation for use of these treatment measures in preference to anaerobic digesters, at least at the recommended site in Kahuku. The experience shows that for one reason or another, most animal waste treatment stabilization ponds turn anaerobic. Odors will be a problem, particularly when they are cleaned. As you note in comment 5 of your letter, this is a concern. An enclosed containment system, such as a concrete digester, minimizes the chance of the release of odors when wind conditions might be unfavorable.

Another problem will be mosquitoes. Permanent, year-round ponds will provide breeding grounds for insects. This will be unavoidable if permanent open stabilization ponds are used.

We have been aware that animal waste treatment guidelines are proposed. We would like to receive, and have the opportunity to comment on these, when they are in draft form.

Drinking Water

1. Our reply to the Board of Water Supply concerning ground water contamination is appropriate to repeat here in response to this comment:

Ground Water Contamination

This paragraph reiterates previous concerns of which we are aware. More than three years ago when planning for this project was first commissioned, our initial detailed analyses of project impacts looked at waste management and the potential for ground water contamination. After considerable analysis and evaluation, we now conclude that the potential risk of contamination at the site recommended (Kahuku) is insignificant. However, manure management may become critical at other sites on O'ahu as pineapple operations curtail their use for fertilization.

Lacking a specific set of comments, we offer a recapitulation of the salient features of our evaluation:

1) A closed loop waste management system, at least as complete as is practical to achieve, is preferred. See Figure 2-2, page 21.

2) A field examination of similar soils where application of manure has occurred for over 20 years was made. The conclusion is that soil moisture nitrogen concentration remains below 1 mg-N/l. See pages A-18 to A-20.

3) A nitrogen budget was calculated for manure applications on crop land to consider the potential concentrations of nitrogen that could migrate in percolating soil moisture; the order of magnitude was less than 3 mg-N/l in the percolate. See pages A-5 to A-18.

4) The concentration of percolation was compared to the background level of nitrogen in the ground water at the Kahuku site, which was measured at about 1 mg-N/l (similar to the Palikea site).

5) Considering the relative levels and quantity of recharge from sources in the system, and the magnitude of the potential increase of nitrogen from the use of manure on crop lands for fertilizer, we concluded there was about an order of magnitude difference between the estimated concentration and the maximum contaminant level (MCL) of 10 mg-N/l. See pages A-21 to A-24.

The consultant then did a sensitivity analysis. We asked the question: what would it take (in terms of manure application) by farmers to raise the concentration in the aquifer to 10 mg - N/l? The farmers would literally have to blanket the ground 4 to 6 inches deep regularly for a one-percent chance of exceeding the MCL for NO_3-N. We think the logistics and the crop results make this impractical in any case. This amount of nitrogen would drastically reduce yields, and farmers would realize the problem (as they have in the past) and abandon the practice. The conclusion is that the risk is insignificant.

The consultant performed similar analyses for pathogenic material—viruses and bacteria. The conclusion is the same: the risk is small. For bacteria it is near zero and less than one in one-thousand for viruses, not to mention that animal virus is not specific to humans as pathogens. These results are shown in Appendix C.

With respect to the ground water flow path analysis, the consultant quantified what is already generally considered to be the most probable direction of ground water flux in each region. What each model indicates is that the subsurface flow is not solely derived from the land area of the proposed agricultural park, but rather significant quantities come from the mauka regions of these aquifer systems. This means there is a great buffering effect within the underlying aquifers, which diminishes the significance of percolation occurring at the proposed sites. The hydrologic budgets which provide the basis for this conclusion are presented in Appendix B.

In summary, the DEIS stated that we have analyzed the risk at the recommended site and quantitatively characterized it as not significant. We are not saying that everywhere on O'ahu (or in Hawai'i, for that matter), the risks will be low, but for the sites considered, we conclude that they are. Also, we considered the fact that for decades cattle have grazed in the gulches near the Honouliuli wells, yet nitrogen concentrations are low in those wells. Experience and the relevant facts are the bases of our conclusion.

2. The issue here is not whether there will be an effect, but whether the effect is a significant risk relative to the benefits to be realized. The word "contamination" as used in the FEIS is not necessarily equivalent to the foregone use of a resource. It does mean that an effect is anticipated. The effects of nutrient application in the Pearl Harbor aquifer have not deterred its use, although it has been known for years that the return water carries

dissolved salts including nitrates. The elevation of these levels has historically been predictable and within health limits. If the Department of Health position is that there be no degradation of ground water quality from some as yet to be determined ambient condition due to any surface activity, then all land use changes, including urbanization, must also be stopped. If on the other hand the approach is managed risk assessment, then the data in Appendix A, B, C, and L of the FEIS provide a basis for decision-making.

3. Reply number 3 under Ground Water Contamination (page 3 of this letter), addresses this concern.

4. Pages 153 and 154 of the FEIS address the options for potable water at the Palikea site. Another option for the provision of potable water being considered for the Kahuku site is a new well. This is discussed on page 212 of the FEIS.

5. 6. and 7. Our planning for the water system will take these comments into consideration.

8. Please refer to Appendix L in the FEIS for what we recommend for environmental monitoring. We would be interested in knowing more details about the "vadose zone" monitoring being recommended. What is apparent from the considerable research done at the University of Hawaii on nitrate migration in soils is that most of the "action" is taking place in the top two feet of soil. The concentration of nitrogen in soil moisture at this level is much easier to detect and will be considerably higher than what reaches the ground water aquifer. Thus we recommend concentrating the monitoring effort here as the first line of defense in terms of environmental protection.

9. These are the considerations for the timing of a mitigation well replacement program:

a) establish an exploratory program to determine the availability and depth of an alternative source before animals are brought onto the site—this we are initiating through the exploratory well drilling program of the Department of Land and Natural Resources;
b) begin the monitoring program as explained in Appendix L of the FEIS—this we have already started with the collection of well water quality information, climatological data, and soils data;
c) continue to exchange information with the Board of Water Supply.

The policy implications of the mitigation strategy recommended in comment 9 warrant further discussion. We have several questions to offer now:

a) On what basis, considering the risk assessment and analysis completed in the environmental impact statement, could we approach the State Legislature for funds to construct a well when the present conclusion is that the probability of a significant (health limiting effect) is remote?

b) Given that the evidence shows the time scale for effects to manifest are on the order of years to decades, and not months, would we not want to first expend considerably fewer tax payers dollars trying the monitoring program first during the first few months of the project life?

c) Would we be advised to discontinue risk assessment analyses in the future if the conclusion is that regardless of the assessment outcome, the worst case scenario is to be adopted for the determination of mitigation measures?

An ongoing policy discussion would be helpful.

10. Thank you for calling these errors to our attention. The FEIS will show corrected well numbers on Figure 3-5a (page 66).

Vector Control

1. Please refer to Appendix L for additional information on proposed maintenance and operation. Should you require further details after reviewing this material, a draft preliminary engineering report is available.

2. Your concern regarding mosquitoes and aquatic vegetation ponds is noted. We believe this also applies to the stabilization ponds recommended in comment 9 in the review on wastewater. This is a matter that can be controlled in the design and construction phases of implementation.

Solid Waste

The market potential of the waste products has been discussed with farm operators in the Kahuku area. The potential exists to reduce the use of chemical fertilizer and use the treated waste products as a substitute. What is critical at this point is to provide a demonstration project that resolves issues concerning this option for waste disposal.

Water Pollution

The comment concerning the requirements of an NPDES permit is noted. The preliminary engineering report includes a draft NPDES application that considers storm water from the dairies.

Thank you again for the time you have taken to submit a thoughtful review.

Sincerely,

Yukio Kitagawa

YUKIO KITAGAWA
Chairperson, Board of Agriculture

Attachments

1) "Operating Experience with three Anaerobic Digester Systems Used for Dairy Manure," by Stanley A. Weeks, Manager, Materials Handling & Energy Research & Applied Technology, Agway Farm Research Center, Agway, Inc., pp. 159-166 (no date).

2) "Fundamentals & Issues Relative to Anaerobic Digestion on Dairy Farms—Part II of II: Utilization of Biogas," by Rick K. Koelsch, Senior Extension Associate, Department of Agricultural and Biological Engineering, Cornell University, pp. 145—157 (no date).

Operating Experience with Three Anaerobic Digester Systems Used for Dairy Manure

Stanley A. Weeks, Manager, Materials Handling & Energy Research & Applied Technology, Agway Farm Research Center, Agway Inc.

INTRODUCTION

The process of anaerobic digestion involves biochemical reactions within living organisms. It may be considered an extension of the animals' digestive system. An excellent overview of the process and system designs was provided by Abeles, et. al., (1981).

Methane production from manure has the advantage of a nearly constant feed stock supply. This is a major benefit when compared to alternative energy sources such as solar and wind.

Manure can be used to produce useful energy in the form of biogas (Approximately 60% methane) through oxygen-free digestion of the manure. Research by Jewell, et al., (1979) related actual to theoretical gas production based on destruction of volatile solids. Actual biogas production may vary considerably due to differences in feed ration and management practices.

Manure as produced by dairy cows may be used directly in the digester with no need for additional water. If large amounts of bedding are used, however, it may be necessary to add water to provide proper moisture content within the digester.

Fisher, et al., (1979) reported on operation of a farm anaerobic digester for swine manure. The digester tank was a concrete stave silo with a hoppered concrete base and solid concrete roof. Manure was pumped into the digester and effluent flowed by gravity to storage. Gas agitation was used to break up scum layers and improve heat transfer.

A vertical silo digester for dairy manure was operated successfully by Persson, et al., (1979) from 1975 to 1977. A divider wall was constructed across the digester in order to approach a two-stage design. The microbial process does occur in two definite steps (the acid forming and the methane forming stages). There was no substantial reduction in nitrogen caused by the digestion process.

Research on pilot-scale reactors showed that a cube-shaped, random mix reactor had a gas production profile similar to that observed with a daily-fed plug flow reactor (Hayes, et al., (1979). The addition of straw bedding resulted in a significant rise in gas production.

Major changes experienced with digested effluent compared to raw manure are a decrease in solids and an increase in ammonia nitrogen (Pigg, et al., (1984). Odor and weed seed control are two additional benefits.

SYSTEM DESCRIPTIONS

A biogas system has operated continuously since 1981 at the Agway Farm Research Center at Tully, N. Y. Agway's first developmental digester system was completed at the Agricultural and Technical College, Canton, N.Y. in 1983. A second developmental digester system was completed at the University of Maine's Animal Science Research Center, Orono, Maine in 1984. Design criteria are shown in Table 1.

TABLE 1.

Biogas System Designs

Location	Tully,	Canton,	Orono,
# of Cows	160	100	200
Silo Size	20' x 20'	20' x 20'	24' x 27 1/2'
Retention (days)	15	20, 24, 28	25
Temperature	99°F	99°F	99°F
Engine-Generator	16 KW	13 KW	23 KW
Manure Transfer	cutter pump	cutter pump	cutter pump
Effluent Storage	wood w/roof	wood w/roof	concrete

Initial digester vessels were concrete stave silos Poured concrete silos replaced the stave units at Orono and Tully after the Orono unit failed structurally. A special sealant was used on the interior of the silo, with foam insulation sprayed over the sealant to reduce heat loss. A concrete block wall was used to support heat pipes and concentrate incoming manure on one half of the digester where floor heat was available.

Manure was scraped by alley scrapers from free stall barns at the Tully and Orono facilities. A gutter cleaner was used at the Canton tie stall barn. In all cases manure was delivered to concrete reception pits, which could also receive manure from other locations.

Manure homogenization and transfer to the digester was accomplished with Flygt cutter pumps. Piping and valves provided for pumping manure either to the digester or direct to storage. This allowed easy loading or unloading of the digester, as well as ease of bypassing the digester when maintenance was required.

Effluent, or digested manure, flowed by gravity from the digester to storage. Sampling towers were built at all locations to allow out-flow sampling. The outflow pipe extended down close to the storage bottom to eliminate freezing and encourage surface crusting for nitrogen conservation.

The Tully digester was designed for a 15 day retention time. Longer retention times at Canton & Orono were chosen for more gas production and better odor control. Three outflow pipes at Canton allowed for 20, 24 or 28 day retention times with the same manure input.

Some of the heat energy produced by the engine was used to heat and maintain manure temperature. For best performance temperature of the manure was maintained at about the same temperature as a cow's digestive system.

Biogas produced by the digester was piped directly into the control building. The engine throttle was controlled so that engine speed and generator output changed automatically to match gas production. The tracking system eliminated the need for gas storage. Electricity from the engine-generator set was used at the dairy facility and/or fed back to the utility grid.

Heat exchangers on the engine recovered much of the heat produced. Some of the recovered heat was used to maintain temperature in the digester. At Orono, insulated lines were run from the engine to a boiler room located at the milking and processing center. Those lines carried hot water from the engine to supplement the oil-fired boiler.

A liquid-solid separation system is now being used at the Tully facility. Separated solids are used for bedding, reducing a major operating expense.

OPERATING RESULTS

Gas Production.

Biogas production from dairy manure depended on volume and characteristics of the manure, as well as retention time and temperature within the digester. Table 2 details averages for a one month operating period at the Tully digester. Biogas production averaged 72.3 ft^3 per cow per day for the period, or 4.36 ft^3 per pound of volatile solids added. Average retention time was 12 days. Sawdust bedding was used at the approximate rate of 4 pounds per cow per day.

TABLE 2.

Digester Loading from 160 Cows and Biogas Production
6/28/84-7/27/84,
Tully, N.Y.

Digester Loading	% Solids	Biogas Production
428 Ft^3 per Day	12%	11,568 Ft^3 per Day

The Canton digester was sized for 100 cows. Initial operation was with 67 cows, thus extending the retention time to 36 days. Biogas production for the Dec. 1, 1983 to Jan. 12, 1984 period averaged 5,352 ft^3 per day, or 80 ft^3 per cow per day. Large amounts of chopped hay bedding were used, creating a subsequent floating mat in the digester. A mixer was used inside the digester to eliminate the mat.

At the Orono digester, a manure loading rate of 350 ft^3 per day and retention time of 27 days, the gas production was 10,500 ft^3 per day. Sawdust bedding was also used in the barns.

In all three facilities, any significant changes in loading rate or digester temperature significantly affected gas production. Although good quality gas meters are expensive, the cost was justified since gas production was the best indicator of digester performance. The CO_2 level was monitored and averaged 40% when operation was optimum. The engine was a more sensitive indicator of gas quality than was the CO_2 tester.

Engine-Generator Performance

The tracking engine-generator set at Tully replaced a Fiat TOTEM unit which had operated 7000 hours from Sept. 1981 to July, 1983. This 15 KW unit operated at full throttle only, thus requiring a compressor and 1000 gallon storage tank. Biogas was compressed, stored, then fed at low pressure to the engine.

Table 3 shows TOTEM operating results for one 24 hour period. Energy required to operate the 5 HP compressor was approximately 20% of the electricity produced. Conversion of biogas to heat energy was efficient because the engine-generator set and heat exchangers were inside an insulated box.

Table 4 shows results of one 24 hour period for the Perennial Energy assembled engine-generator set that replaced the TOTEM. Key advantage of this unit was 24 hour operation, eliminating the need for gas compression and storage. The engine has now operated over 40,000 hours and has been overhauled three times.

TABLE 3.

TOTEM Results - 1/8/83, Tully, N.Y.

Engine-Generator Run Time	21.8 Hrs.
Biogas to TOTEM	8100 Ft^3
KWH, Net from System	218 KWH
KWH, to Operate Compressor, Etc.	60 KWH
KWH, Gross Produced	278 KWH
BTU, Heat Produced by Engine	2,571,000 BTU
BTU, to Digester	995,000 BTU
BTU, in Gas Produced (@550 BTU/Ft)	4,455,000 BTU
Efficiency, Conversion to Electricity	21%
Efficiency, Conversion to Heat	58%
Efficiency, Overall System	79%

Efficiency of the tracking engine-generator set decreased rapidly as the unit operated below full load. Proper sizing thus becomes a very important factor.

Oil analysis was used to determine oil change intervals for the engine. Engine wear metals such as cooper, iron, chromium, and aluminum increased as oil change intervals were extended. Hydrogen sulfide in biogas resulted in oil becoming acidic, especially with intermittent operation where condensation occurred.

TABLE 4.

Perennial Energy Engine-Generator
Set Results - 7/27/84, Tully, N.Y.

Engine-Generator Run Time	23.8 Hrs.
Biogas to Engine	11,325 Ft^3
KWH, Net From System	325 KWH
KWH, To Operate System	33 KWH
KWH, Gross Produced	358 KWH
BTU, To Digester	979,000 BTU
BTU, In Gas Produced (@550 BTU/Ft)	6,223,250 BTU
Efficiency, Conversion to Electricity	20%

Fertilizer Value

Fertilizer value was not reduced as a result of the digestion process. Table 5 summarizes results from 10 samples taken at the barn reception pit and digester outflow pipe at the Tully digester. Total solids reduction of 2.55% was typical for the 12 day retention time. Major change in fertilizer value was the increase in ammonia nitrogen. In this case the ammonia nitrogen increased from 44% to 53% of total nitrogen.

Another factor to consider as a result of anaerobic digestion is the carbon-nitrogen ration. Some reduction of the carbon-nitrogen ratio did take place and may be of importance especially where large amounts of sawdust bedding is used.

TABLE 5.

Comparison Of Digester Input and Digester Output
Tully, N. Y.

Variable	DIGESTER INPUT	DIGESTER OUTPUT
P_2O_5	1.66%	1.99%
K_2O	2.66%	3.27%
% Solids*	12.95%	10.40%
Vol. Solids, % T. S.	73.46%	70.34%
NH_4-N	1.50	2.38%
TKJ N	3.44%	4.45

* Values for solids are the solids content of the samples as taken on a wet basis. All other values in the table have been converted to a dry matter basis. All values the mean of 10 samples.

Operational Challenges

Cold weather was the greatest challenge to overcome when operating anaerobic digesters in the Northeast. This was especially true for the two operations with cold free-stall barns. Gravity flow manure systems would not operate if large amounts of frozen manure was scraped from the barn. Manure rams, such as those initially used at the Tully digester, created large frozen manure "logs" in the digester.

Automatic alley scrapers and cutter pumps were effective solution to cold weather problems. Scrapers removed much of the manure before freezing could occur. Cutter pumps homogenize the manure, with some water added to obtain a proper consistency of 10 to 12% solids. After the free stall barn at Tully was insulated there was a great deal of surplus heat from the engine even during winter.

The other cold weather challenge was caused due to gas line freezing. Biogas is saturated with water, and lines, tanks, etc. had to be protected from freezing Insulation and heat tapes overcame freezing problems.

Experience has shown that undigested solids will accumulate in digesters. This consists of calcite, sand, stones and other materials that settle to the floor. Periodic clean out is necessary. Also, yearly overhaul of the engine is desirable, probably at the same time as digester cleaning.

SUMMARY

1. Three biogas systems were operated successfully using dairy manure.
2. Retention time of 20-25 days should yield biogas production of 80 ft^3 and electricity production of 2.25 KWH per 1400# cow per day.
3. Cold weather challenges were significant for both manure handling and gas handling.
4. Gas compression and storage required about 20% of the electrical energy produced.
5. Continuous engine operation reduced oil contamination due to condensation
6. Fertilizer value was not reduced and some nitrogen was converted to the ammonia form.
7. Oil analysis was necessary in order to schedule oil changes and protect the engine.
8. Routine operational checks required 15 minutes per day.
9. Digester cleaning and engine overhaul should be performed once a year.

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Fundamentals & Issues Relative to Anaerobic Digestion on Dairy Farms—Part II of II: **Utilization of Biogas**

Rick K. Koelsch, Senior Extension Associate,
Department of Agricultural and Biological Engineering, Cornell University

The economic viability of anaerobic digestion is heavily dependent upon the efficient utilization of biogas. Recent research and field experiences suggest that cogeneration, production of electricity and hot water by an engine generator, is the most viable option for most dairies. A few farms may find that biogas might be used to replace heating fuels used on the farm or at a nearby business. For either option, the potential economic return must be closely examined. Anaerobic digestion technology currently provides a positive economic return for a select group of dairy farms. However, with the technology just now emerging from the research arena to commercial applications, it is suggested that dairyman follow developments in this area and plan farm modifications that will allow possible future addition of this technology.

Fundamentals of Biogas Utilization

Biogas Properties

Biogas is a gaseous fuel consisting primarily of methane and carbon dioxide (approximately 60% and 40% of total volume respectively). The methane is the energy source of biogas while carbon dioxide has no energy value. Biogas also contains small amounts of hydrogen sulfide (0.1% to 0.5% of biogas by volume), a highly corrosive gas (Koelsch, 1988).

Biogas can be used in appliances and spark ignition engines designed for natural gas and propane. The high octane rating of methane and the anticipated high rating of biogas allows it to be burned in higher compression engines resulting in greater energy efficiency (Table 1). Research has indicated that biogas can be burned successfully in engines with compression ratios up to 15 to 1 as compared to LP-gas and gasoline limitations of about 10 to 1 and 8 to 1 respectively (Neyeloff and Gunkel, 1975). Biogas has also been used in compression ignition engines (diesel) but with limited success. Thus, biogas is an acceptable fuel for existing gas fired equipment.

Some modifications must be considered in the use of biogas. The low energy density of biogas (Btu/ft^3 of fuel) requires that the nozzles controlling the flow of fuel in a boiler, furnace, or engine carburetor must be larger than used with other gas fuels (see Table 1). To deliver the equivalent energy flow as LP-gas or natural gas, a nozzle for biogas must be 2.1 and 1.3 times greater in diameter respectively. The low energy density of the fuel-air mixture also limits the maximum power output of a internal combustion engine. A biogas fueled engine will achieve 85% to 90% of the maximum power output possible for operation on LP-gas. The most annoying property of biogas relates to its corrosive nature due to the presence hydrogen sulfide. Hydrogen sulfide in biogas accelerates the decay of heat exchangers and burner units in furnaces, boilers, and water heaters and copper components such as bearings and wrist pin bushings in engines (see Figure 1). Application of biogas to existing gas fired equipment must consider the low energy density and presence of hydrogen sulfide.

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Table 1. Combustion properties of gaseous fuels (Hawkins, 1967 and Obert, 1973).

	Energy Density[1]		
Fuel	Btu/ft^3 of fuel	Btu/ft^3 of fuel-air mixture	Octane Rating
Propane[2]	2283	91.8	104
Methane[3]	896	85.3	120
Biogas	538	79.9	
Gasoline			87 - 92

1. Low heat value 2. Primary component of LP-gas. 3. Primary component of natural gas.

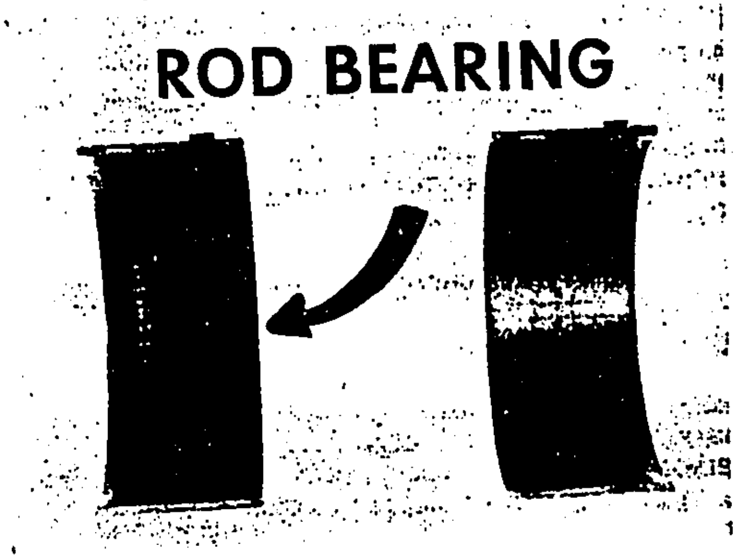

Figure 1. Presence of hydrogen sulfide in biogas can cause accelerated wear of copper components in an engine such as these rod bearings.

Potential Farm Applications

The ability of biogas to be used in heating fuel applications and spark ignition engines allows several alternative uses of biogas on the farm. Previous research and experience has indicated four critical considerations in the selection of potential application of biogas:

1. Biogas must replace high cost energy sources.
2. Biogas must be utilized as it is produced.
3. Biogas must be converted to a marketable energy source.
4. The technology for utilizing biogas must be simple.

A evaluation of energy costs suggests that replacement of electrical demand is a desirable alternative. The most expensive fuel purchased for farm consumption is electricity. A simplistic comparison on energy cost based upon equivalent units of energy reveals that electricity is two to four times more expensive than other commonly used fuels.

Table 2. Comparative cost of different energy sources (New York State Energy Office, 1988).

Source	Current Cost	Cost ($) per Million Btu's of Energy
Electricity [1]	8 to 12 ¢/kWh	23 .4 to 35.2
Electricity	6 ¢/kWh	17.60
Heating Oil [2]	$0.84 /gallon	6.06
Diesel [2]	$1.02 /gallon	7.36
Gasoline [2]	$0.93/gallon	7.75
Natural Gas [2]	$0.52 /therm	5.20
LP-gas [2]	$1.38 /gallon	14.30

$\$/\text{gallon} \times \frac{10^6 \text{ Btu}}{\$} = 0.14 \times 10^6 \frac{\text{Btu}}{\text{gallon}}$

1. Range of commercial and residential rates for upstate New York utilities.
2. Average cost for New York State.

Any viable application of biogas must consider its use as it is produced by the digester. The low energy density of compressed biogas makes storage of biogas expensive and clumsy. A 1000 gallon tank of biogas compressed to 200 psig (approximate pressure of LP-gas storage) contains the energy equivalent of less than or 8 gallons of fuel oil or diesel fuel. Storage of biogas for mobile applications or to assist with seasonal variations of stationary energy demands on a farm is impractical. Storage of biogas to counter daily variations in stationary energy demand may have some practical applications but does significantly increase the capital and operating costs of a system. Alternative applications which consume biogas as it is produced are preferred.

The conversion of biogas to a marketable energy form deserves consideration. A few farms may find that biogas can be marketed directly to a neighboring business that has high year round energy demands as a heating fuel replacement. Sales directly to natural gas pipeline are unlikely without the removal of carbon dioxide from biogas a very costly alternative (Heisler, 1981). Electricity is currently the most easily marketable energy source. Federal and state regulations of the early 1980's have established that utilities must enter into long term contracts to purchase electricity at a minimum rate of six cents per kilowatt-hour and that utilities must provide supplemental or back-up power on a non-discriminatory basis (Howansky, 1981). The potential market for electricity in New York suggests use of biogas by cogeneration.

Simplicity of the technology for using biogas is our final consideration. Replacement of heating fuels offers the use of simple and readily available technology. Gas fired boilers, water heaters and furnaces are readily adapted to the consumption of biogas. Removal of the hydrogen sulfide is essential for extended use of biogas in boilers, water heaters, and furnaces. The anaerobic digestion system at Cooperstown Holstein has successfully utilized a hydrogen sulfide scrubber consisting of an iron impregnated wood chip material contained in a tank through which the biogas must pass. A chemical reaction between the iron and hydrogen sulfide results in the removal of the hydrogen sulfide from the biogas. Over the last two years, Cooperstown Holstein has scrubbed 23,000 cubic feet of biogas a day at a total cost of $300 and 42 hours for maintenance. The use of biogas in an engine-generator also utilizes existing technology. This technology is more complex and requires a more significant commitment to maintenance. Hydrogen sulfide is also a problem for engines but can be controlled in engines with a well planned lubrication program. The success achieved in scrubbing hydrogen sulfide from biogas at Cooperstown Holstein suggests that this alternative may be worth considering for cogeneration installations. Simplicity of the technology and its maintenance generally favors the replacement of heating fuels over application of biogas to an engine.

Based upon the previously mentioned factors, three alternative applications of biogas deserve further consideration They are:

1. Use of biogas in replacement of farm heating fuels.
2. Use of biogas in replacement of heating fuels at a neighboring business.
3. Co-generation of heat and electricity from biogas.

Circumstances on individual farms must now be evaluated to select the best alternative.

Critical Issues Relative to Biogas Utilization

Selecting the Appropriate Use of Biogas

The use of biogas for replacement of farm heating fuels is the simplest and least capital intensive use of biogas. However, many dairies will find that the lower cost of heating fuels and the poor match between farm heating needs and biogas availability will result in a low return on investment. Due to the seasonal heating requirements of the digester, the least amount of biogas is available during the winter and the greatest availability of energy occurs during the summer (see Figure 2). However, most farm's heating needs peak in the winter and are relatively modest in the summer. This may result in winter heat demands that exceed the winter biogas supply while a substantial amount of biogas is wasted in the summer. It has been estimated that a 50 and 100 cow dairy would annually replace a maximum 2400 and 5600 gallons of heating oil respectively (Koelsch and Walker, 1981). The low value of heating fuels and poor match in biogas supply and heating demands counters the simplicity of use of the biogas for heating fuel replacement. Unless, a substantial need for heat exists outside of winter, the heating fuel replacement option may have limited application.

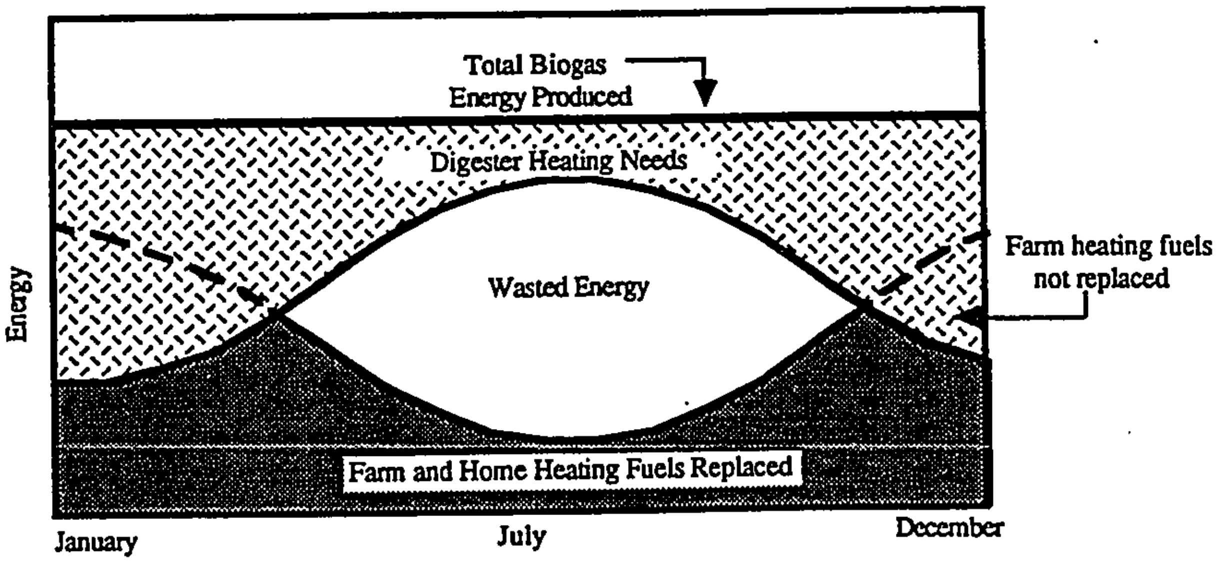

Figure 2. Seasonal balance between dairy heat needs and biogas availability.

The marketing of biogas as a heating fuel to a neighboring business may be possible if seasonal heating demands have less variation. The Cooperstown Holstein dairy has installed a digester from which biogas is supplied to a neighboring retirement home. The high heating fuel needs for laundry provided a demand with less seasonal variation. During 1988, the digester has provided all water heating needs and roughly 50% of the space heating needs (the limit of the current boiler capacity of the retirement home connected to biogas). Although peak daily biogas production is in excess of 30,000 cubic feet, on the average only about 12,600 cubic feet is sold per day to the retirement home (see Figure 3). Greater digester biogas production capacity than demand and conflicts in winter digester biogas supply and retirement home demand account for the low utilization of biogas for profit. The low price paid for the biogas (tied to heating oil price) and the modest amount of biogas used for profit has resulted in other gas utilization options being explored by this dairy. The potential of marketing of biogas to other businesses will depend on their proximity, seasonal heating demands, and price of heating energy.

For many dairies, the only gas use option that potentially will provide sufficient economic return is the co-generation option. A cogenerator is an engine generator designed to produce electricity and hot water (180 to 200°F). On average, a co-generator will recover 20% and 45% of the energy in biogas as electricity and hot water respectively (Jewell et al., 1985). The daily demand for electricity on most dairies has only modest seasonal variations which assists in maximizing the use of cogenerated electricity for replacing farm electrical demands. The heat energy recovered from a cogenerator is generally sufficient to meet peak heating demands of the digester. For a substantial part of the year, sufficient hot water is available for potential use in partially supplying nearby dwelling or dairy heat needs. However, the production of electricity accounts for most of the financial return. For most dairies, cogeneration represents the only practical use of biogas.

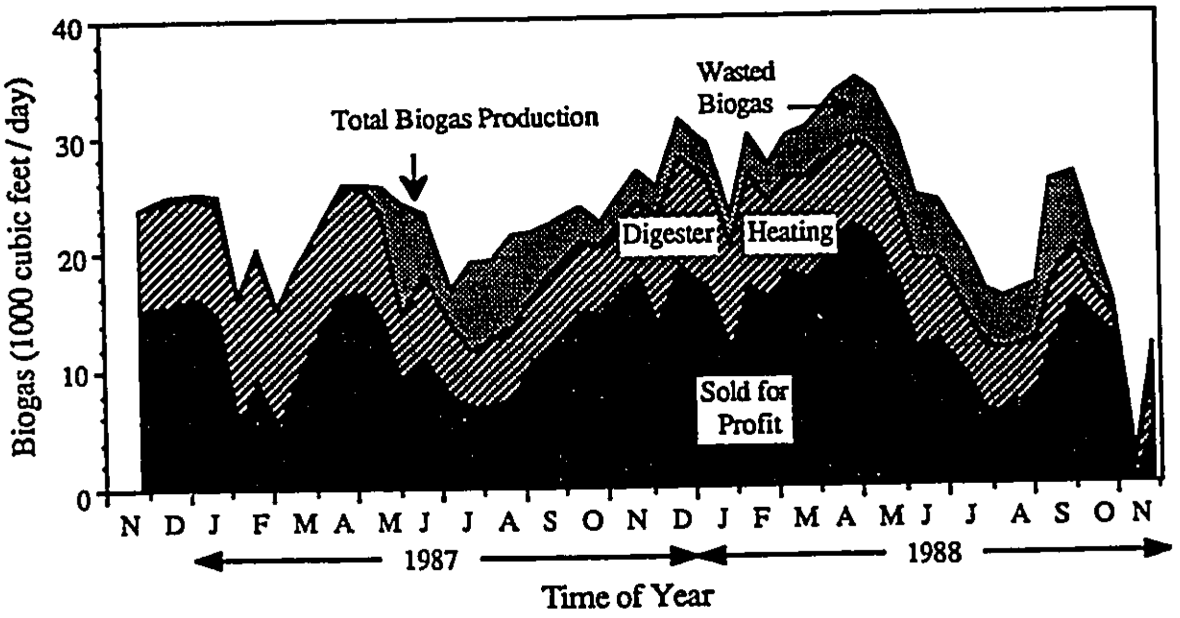

Figure 3. Biogas production and utilization vs. time of year for anaerobic digester at Cooperstown Holstein Dairy.

Cogeneration is not without problems. The complexity of cogeneration is far greater than the replacement of heating fuels in a gas fired appliance. For a cogeneration to be successful, careful planning must be devoted to the design of the cogeneration unit and support systems, managing the operation and maintenance aspects of a cogenerator, and properly estimating the potential income from this option. These topics will be highlighted in the following sections.

Design of a Co-generation System

Critical to the profitable use of biogas for cogeneration is the design of a cogenerator. Cogenerator design must consider unit durability and electrical energy efficiency. The engine generator will accumulate up to 8,700 hours each year (equivalent to about 400,000 miles on an auto engine) making durability a critical issue. In addition, small changes in the efficiency of converting biogas to electricity will substantially change the financial return of the total biogas system.

A cogenerator can be thought of as four distinct components: engine, generator, heat recovery, and controls. The engine should be a heavy duty, high compression industrial engine designed for continuous operation. Engines with proven records for continuous operation and reasonable maintenance cost are highly desirable. Commercial units with a compression ratio of 10 to 1 (units designed for LP-gas and natural gas) are readily available and generally acceptable for this application. Higher compression ratios (up to 14 to 1) are preferred but not readily available. Gas carburetion similar to systems used for natural gas should have sufficient capacity to deliver 30 cubic feet per hour of biogas to the engine per kilowatt of cogenerator capacity. Durability, proper compression ratio, and proper carburetion are critical issues in the selection of an engine.

Connection of the generator directly to the farm and utility electrical grid will allow purchase of utility electricity during peak farm power requirements and provide a market for cogenerator electricity when farm use is minimal. To allow parallel production of electricity with the utility, an induction generator is preferred. Induction generators can produce electricity in parallel with the utility with relatively simple controls and minimal potential liability concerns as compared to more standard synchronous generators (commonly used for standby electrical generation). To provide the necessary safety controls and proper connections to the electrical system, utility representatives should be involved from the initial stages of planning for a generator and electrical system. Selection of an induction generator if parallel operation with the utility is anticipated and involvement of the utility in electrical system planning are key design considerations.

Efficient recovery of heat is essential for providing the required heat for maintaining the digester's temperature. Heat should be recovered from the engine water cooling system and the engine exhaust with commercially available heat exchangers. The heat recovery system should also include an alternate means of dissipating all coolant and exhaust heat during periods of lower digester heating needs.

Unattended cogenerator operation will require a control package designed to anticipate all potential hazards as well as adjust power output based upon biogas supply. Common engine controls will shut the unit down due to high coolant temperature, low coolant level, low oil pressure, low oil level, low gas pressure, and engine over-speed. Control requirements for the electrical system will generally be defined by utility regulations and will likely include protection against reverse power (induction generators can act as induction motors), over current, ground faults, and frequency and voltage limits. In addition, controls are needed that will match engine generator load with digester gas production. Unattended operation places several unique requirements upon operation of an engine generator and requires a well planned control package.

Selection of an efficient cogenerator generally involves proper sizing of the cogenerator and use of high compression engines. Sizing of the cogeneration unit to the digester's gas production is critical to maintaining efficient operation. Over-sizing a unit will reduce income. Note the loss of efficiency of converting biogas to electricity for a cogenerator operated at lower loads as illustrated in Figure 4. Sizing to allow around-the-clock operation is also suggested to minimize the corrosive affects of the sulfur in the biogas and to eliminate the need for gas storage equipment. A rule of thumb of one kilowatt of cogenerator capacity per 10 lactating cows is a reasonable starting point. If potential gas production has been estimated, the cogenerator should have one kilowatt of capacity per 600 to 650 cubic feet of daily biogas production. The cogenerator illustrated in Figure 4 would be properly matched to a digester producing 15,000 cubic feet of biogas per day. Under this situation, the cogenerator would produce 600 kWh of electricity per day. Matching of this same cogenerator to a digester producing 7,500 cubic feet of biogas would reduce daily electricity production to less than 200 kWh. Sizing of the cogenerator to avoid inefficient part load operation is highly desirable.

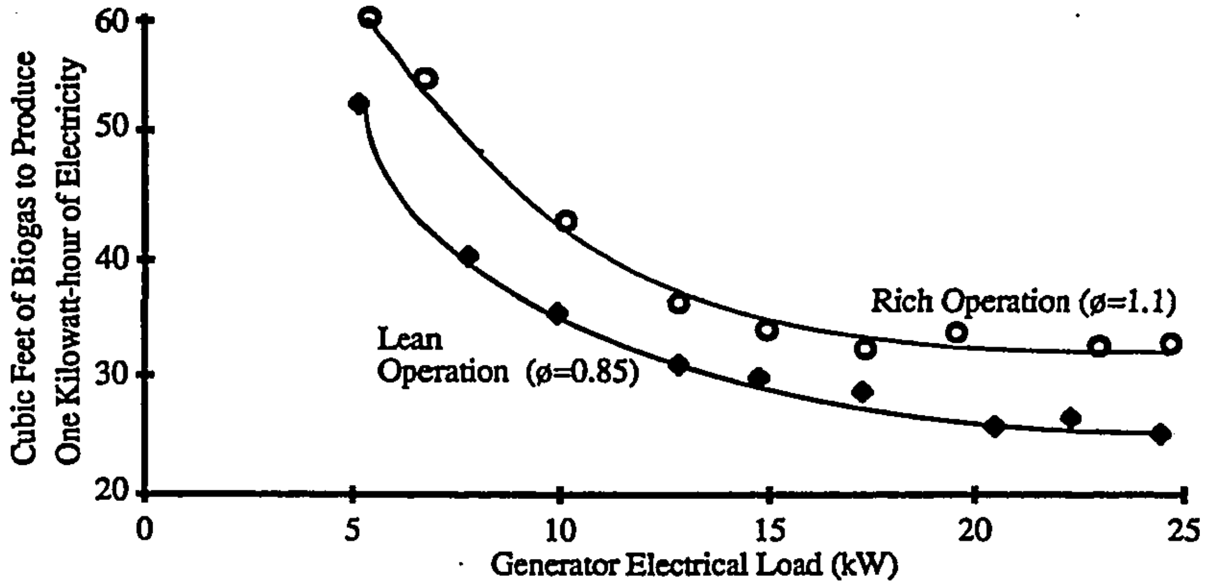

Figure 4. Operation of cogenerator at part loads or rich fuel-air mixtures results in substantially more gas being consumed per kilowatt-hour of electricity produced (Jewell, et al., 1985).

Managing and Maintaining a Cogeneration Unit

The timely availability of farm labor or service personnel for maintaining and repairing a cogenerator is a critical issue. Daily management of the cogenerator by the farm labor force has generally not involved a significant time or cost commitment. Daily checks of key performance factors (electrical production, biogas consumption, conversion efficiency), cogenerator operating conditions (water temperature, oil pressure), and cogenerator maintenance needs (oil level, preventive maintenance schedule) can be accomplished within a reasonable time frame. However, the high frequency of the intermittent maintenance and repairs (maintenance not occurring on a daily basis) required to keep the cogenerator in operation and the availability of labor for meeting these needs has proven to be a significant problem for some installations. The availability of labor requirements for the cogenerator has been the "Achilles Heel" for commercial dairy farms with anaerobic digestion systems.

A cogenerator is a complex system of moving parts, controls, and electrical components. Down time of the cogenerator at Agway's Research Farm has been minimal (less than 3%) over the past two years primarily due to their immediate attention to at least 40 different types of repairs or maintenance. Many of these maintenance items are planned as part of a preventive maintenance program including oil changes, filter changes, spark plug replacement, and engine overhauls. However, many of the repairs are difficult to anticipate including replacement of a fan motor, fuse replacement, cleaning of gas line valves and carburetor, governor linkage repair, among others. In addition, continuous operation of a cogenerator results in relatively short time intervals between maintenance needs. Oil, filter, and spark plug change intervals are defined in terms of days or weeks while major overhaul intervals are defined in terms of one to two years. Delay of an oil change a few days or a major overhaul a few months can substantially affect operation. Finally, the conflict of cogenerator maintenance with other high priority farm labor needs often results in delay of cogenerator maintenance. This conflict has been responsible for substantial cogenerator down time on two commercial farms with which the authors have maintained contact. The relative complexity of a cogenerator, rapid accumulation of operating hours, and conflicts with other farm labor needs has resulted in our conclusion that cogenerator maintenance is the weak link in the entire anaerobic digestion system.

Successful operation of a cogeneration unit is dependent upon the ability of a farm to provide for its intermittent maintenance and repair needs. These needs can be met if:

1. If sufficient farm labor is available to attend to the cogenerator needs during periods of other peak farm labor needs, or

2. Services of a local mechanic will be utilized for cogenerator maintenance, and

3. A well planned preventive maintenance program is implemented.

Whatever mix of farm labor and purchased services is utilized, it is critical that planning of any anaerobic digestion system include detailed consideration of the availability of labor and the assignment of responsibility for the maintenance of the cogenerator.

Most engine manufacturers and suppliers of engine generators can provide well planned preventive maintenance programs. If the hydrogen sulfide is removed from the biogas, a preventive maintenance program similar to those used with natural gas or LP-gas fueled engines will generally be sufficient. If hydrogen sulfide is not removed from the biogas, additional consideration must be given to the lubrication program. Accelerated wear related problems have been associated with the presence of hydrogen sulfide in biogas. To counter this problem, the following procedures should be implemented (Koelsch et al., 1985):

1. Biogas should be sampled for hydrogen sulfide using simple field procedures. Levels of 1000 to 6000 parts per million of hydrogen sulfide have been observed in biogas produced on New York dairies and are capable of causing problems with engines.

2. Only single viscosity oils designed for high sulfur fuels should be used. The oil should have a Total Base Number (TBN) rating, indicator of acid buffering capacity, of at least 10.

3. Extended oil change intervals are not suggested. Oil change intervals of 300 hours or less should be used until additional information and experience is available.

4. Oil sampling at the time of an oil change for laboratory analysis is recommended. Problems due to the presence of hydrogen sulfide can be detected in an oil analysis by high copper wear metal levels. Oil analysis that tests for 'TBN' or '% Sulfur Products' provide an even better indicator as to the buildup of corrosive conditions

in the oil. Oil analysis is inexpensive and readily available through major oil suppliers.

Energy Replacement

An energy replacement potential for alternative uses of biogas can be based upon cow equivalent numbers or expected biogas production. For co-generation of electricity and hot water a 'rule of thumb' of 2 kWh and one-seventh (1/7) gallon of fuel oil equivalent per cow equivalent per day can be used (see Table 3). Agway is currently producing slightly less than 2 kWh per cow equivalent. Addition of a cogenerator on Cooperstown Holstein's digester would result in production of almost 3 kWh per cow equivalent. The sizeable difference in potential electrical production can partially be explained by the difference in hydraulic retention time (15 day for Agway vs. 40 day Cooperstown). Knowledge of expected biogas production allows a better appraisal of energy replacement potential. For cogeneration, one kWh of electricity and one gallon of fuel oil equivalent will be produced for each 33 cubic feet and 425 cubic feet of biogas consumed by the cogenerator. Assuming that the digester has modest electrical loads (Agway's unit consumes less than 4% of electricity produced), most of this electricity is available for use or sale. However, much of the fuel oil equivalent energy would be used for heating the digester and limited income will be achieved from the recovered heat.

If biogas is used for replacement of heating fuels, it is much more difficult to estimate energy replacement. Total biogas production has the equivalent energy value of one gallon of fuel oil per 250 cubic feet of biogas. To arrive at actual heating fuel replacement, timing and quantity of digester heating demand and farm or neighboring business heating demands must be considered for an individual situation. No broad 'rules of thumb' are available for heating fuel replacement.

As an example, let us assume an estimate is to be made for a anaerobic digestion system with an anticipated daily gas production of 15,000 cubic feet (200 cow dairy). If the biogas is to be used in a cogenerator, one would anticipate the daily production of of 450 kWh (15,000÷33) of electricity and 35 equivalent gallons (15,000÷425) of fuel oil.

Table 3. Daily energy replacement potential based upon cow equivalent numbers or biogas production estimates.

	Cow Numbers	or	Ft^3 of biogas	Total
Cogeneration				
kWh of electricity	= ________ X 2	or	= ________ ÷ 33	= ________
Gallons of fuel oil equivalent	= ________ ÷ 7	or	= ________ ÷ 425	= ________
Heating Fuel Replacement				
Gallons of fuel oil equivalent	= ________ ÷ 4	or	= ________ ÷ 250	= ________

Economic Considerations

The question "Will a biogas system pay for itself on my farm?" remains the most difficult question relative to this technology. Sufficient experience has been accumulated to conclude that if properly designed and managed, a digester and gas utilization system can work on a continuous basis on dairies in the northeast. The remaining unknown for this technology is the question of economics.

The potential benefits of a biogas system include energy replacement, odor reduction, and alternative uses of digester effluent. Energy available from the digester is generally the most significant benefit. In In New York State, electrical generation provides the greatest potential profit with the ability to replace electrical use on the farm (valued at 8 to 12¢ per kWh) or market to the utility for 6¢ per kWh. The financial benefit of anaerobic digestion for odor control is a value judgement that individuals must make often dependent upon the proximity and sensitivity of neighbors. No other significant economic advantage can be attached to the use of this technology relative to manure management. Finally, digested manure may have alternative uses more valuable than as a fertilizer. The solids portion of digester effluent, when separated, has been used as animal bedding and a soil conditioner for residential markets. Sufficient manure solids can be recovered to meet all farm bedding needs. Digested manure provide a preferred feedstock for separation of solids from manure. However, current technology has yet to prove capable of removing a satisfactory level of moisture. Cooperstown Holstein's anaerobic digestion system includes solid separation equipment for producing animal bedding. However, failure of this equipment to adequately dewater the solids without requiring a significant time commitment for maintaining the equipment has resulted in the separator not being operated for the last two years. Energy represents a potential financial return for all farms while the value of odor control and solids separation will be dependent on local circumstances and state of the technology respectively.

An estimated capital cost of a biogas system for dairies in the northeast are at best a broad generalization. An effort has been made to quantify the break even capital investment an individual farm can justify. Figures 5 and 6 provide a "ball park" indication of this break even point for farms with 100 to 500 cow equivalents when energy production from cogeneration is the only income. The break-even point represents the point at which the cost of loan payment (principal plus interest) and out of pocket operating cost is equal to the value of the electricity produced. A 10 year loan and a 5% and 10% interest rate were assumed for these figures. The 5% loan rate is available through a Energy Investment Loan Program through New York State Energy Office. For a 300 cow equivalent dairy, a capital investment of $110,000 would be the break-even investment if the average value of electricity is 8¢/kWh and a 10 year loan at 5% interest is obtained. An investment less than this level would have the potential for some profit while a greater capital cost would likely result in a financial loss over the first 10 years.

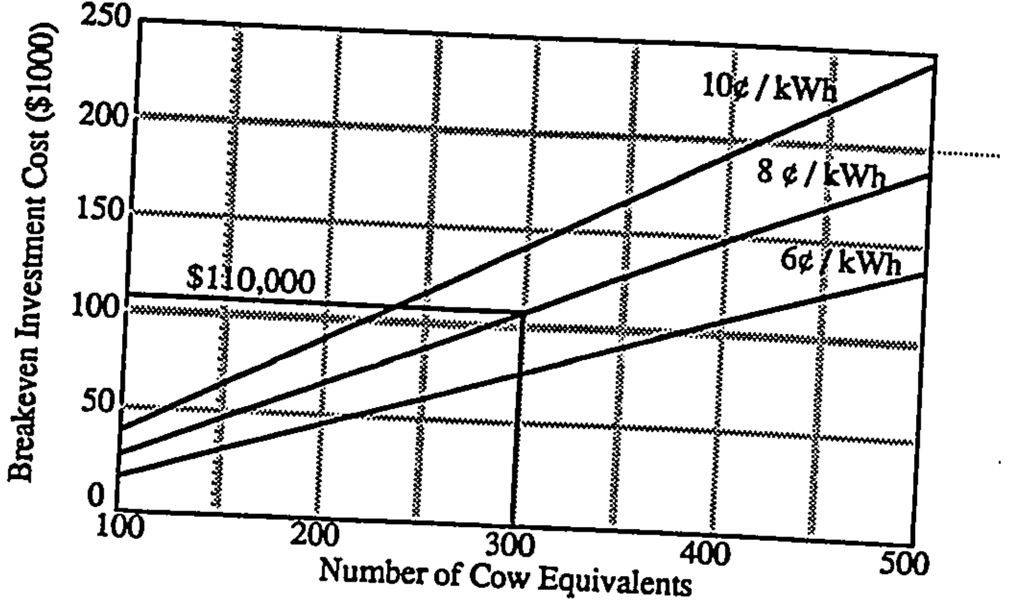

Figure 5. Biogas system capital cost at which income equals expenses. Assumes 10 year loan at 5% interest.

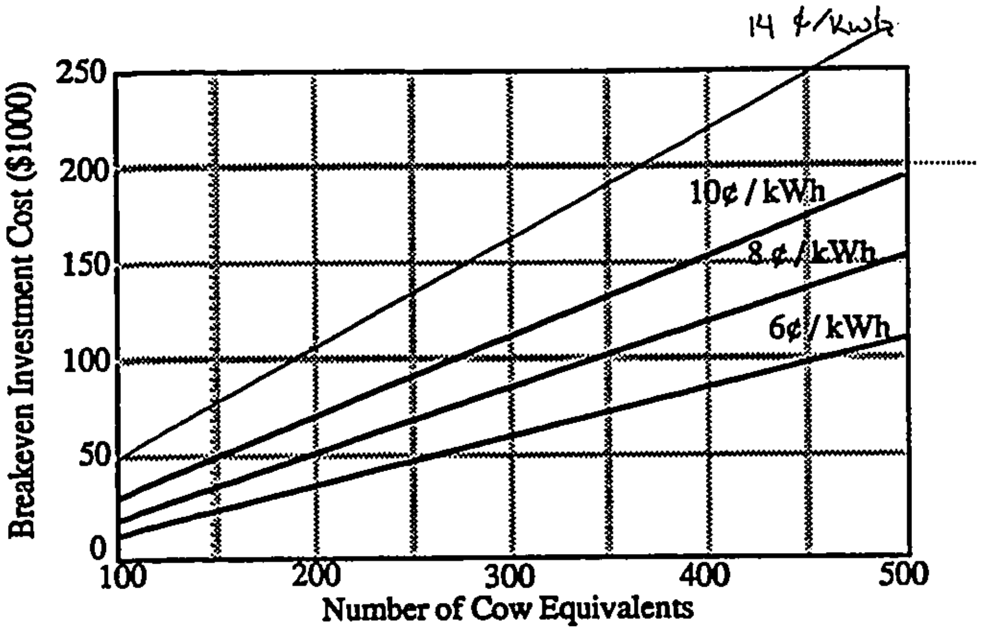

Figure 6. Biogas system capital cost at which income equals expenses. Assumes 10 year loan at 10% interest.

Table 4 provides a better procedure for estimating a break even capital investment for situations not included in Figures 5 and 6. Based upon our previous example of a digester producing 15,000 cubic feet of biogas a day and a cogenerator producing 450 kWh and 35 gallons of fuel oil equivalent a day, one would expect an annual return of $17,600. For this example, a breakeven capital investment would be approximately $120,000. Note that this example assumes an economic value has been placed upon the separation of solids for animal bedding. If this factor is not included, an investment of only $86,000 can be justified based upon this procedure. Figures 5 and 6 as well as Table 4 include many assumptions and disregard several factors. They should only be used as a preliminary procedure for providing a quick estimate as to whether or not this technology has any potential for an individual farm.

Currently, at least some of the following situations should exist for a biogas system to be viable:

- Larger dairy herds (200 or more cows),
- High electrical rates (purchase costs of 10¢ per kWh or more),or
- Economic value can be placed on odor control or alternative uses of manure solids.

Most dairies presently do not fit these categories. However, in light of the recent emergence of this technology onto commercial farms, it is suggested that dairymen plan future manure handling modifications in a manner that provides a future option for an anaerobic digestion system.

Table 4. Simplified procedure for estimating break even capital investment cost for an anaerobic digestion system.

Step 1: Estimate energy replacement value.

kWh Produced per Day X Portion Used on Farm X Purchased Electrical Cost ($/kWh) X Operating Days per Year = Purchased Electricity Value ($/year)

_____ X _____ X _____ X _____ = _____

kWh Produced per Day X Portion Sold to Utility X Price of Electricity Sold ($/kWh) X Operating Days per Year = Value of Electricity Sold ($/year)

_____ X _____ X _____ X _____ = _____

Fuel Oil Equivalent Produced (gal./day) X Portion Replacing Farm Heating Fuels X Price of Fuel Oil ($/gallon) X Operating Days per Year = Value of Farm Heating Fuels Replaced ($/year)

_____ X _____ X _____ X _____ = _____

Purchased Electricity Value ($/year) + Value of Electricity Sold ($/year) + Value of Farm Heating Fuels Replaced ($/year) = Total Annual Energy Savings

_____ + _____ + _____ = _____

Step 2: Estimate annual income potential.

Annual $ Return = Energy Replacement Value + Odor Reduction Value + Separated Solids Value - Operating Cost

_____ = _____ + _____ + _____ - _____

Step 3: Estimate break even capital investment (DeGarmo and Canada, 1973).

Breakeven Investment = Annual $ Return X Factor

_____ = _____ X _____

Factor = 7.72 for 5% interest rate
Factor = 6.14 for 10% interest rate
Factor = 5.65 for 12% interest rate

Conclusions

The method for utilizing biogas plays a critical role in the economic viability of anaerobic digestion technology. From previous research and field experiences with anaerobic digestion technology, the following conclusions can be drawn relatively to the utilization of biogas.

1. Cogeneration of heat and electricity offers the most attractive method of utilizing biogas for most dairy farms. Production of electricity by cogeneration replaces a high cost farm energy source, provides a energy source that has modest seasonal variation in farm demand, and provides an energy source that can be marketed. However, a cogenerator significantly increases the complexity, initial capital cost, and maintenance requirements of the overall system.

2. A few unique situations may allow biogas to be used for replacing heating fuel needs of the farm or at a neighboring business. A year round demand for heating fuel must be identified for this application to be considered. Use of biogas for replacing heating fuels is the simplest utilization method for biogas.

3. The relative complexity of a cogenerator, rapid accumulation of operating hours, and conflicts with other farm labor needs makes timely labor availability for cogenerator maintenance the "Achiles Heel" for an anaerobic digestion system.

4. Currently, the economic return from anaerobic digestion technology limits its current application to large dairy farms or those farms where odor control has a significant economic return. However, the relative infancy of this technology in the commercial sector warrants continued attention to future developments.

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JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P.O. BOX 621
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WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

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JOHN P. KEPPELER, II
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FORESTRY AND WILDLIFE
HISTORIC PRESERVATION PROGRAM
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

POSTED 9/4/92

REF:OCEA:KCK

File No: 93-066
DOC. ID: 1333

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SEP 4 1992

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QUALI

The Honorable Brian Choy, Director
Office of Environmental Quality Control
220 South King Street, 4th Floor
Honolulu, Hawaii 96813

Dear Mr. Choy:

Subject: Oahu Livestock Agriculture Park Environmental Assessment (EA) and Environmental Impact Statement Preparation Notice (EISPN), Pilikea or Kahuku, Oahu.

Thank you for giving our Department the opportunity to comment on this matter. We have reviewed the submitted EA and EISPN and have the following comments.

Brief Description:
The proposal involves development of a livestock agricultural park at one of two locations: Kahuku, incorporating the existing Kahuku agricultural park subdivision, or the Pilikea Uplands, Oahu. Considerable emphases on waste disposal is planned.

Division of Aquatic Resources Comments:
Based on the information supplied, we would have no concerns about the Pilikea Uplands alternative. With regard to Kahuku, we believe that an aquatic biological reconnaissance survey of the entire Ohia Gulch with special emphasis on the upper reaches should be performed as part of the EIS. Native fish and invertebrate populations may inhabit these areas. If present, they could be negatively impacted by runoff with high nutrient and sediment loads originating from the livestock operations, even if the occupied habitat is far upstream of the proposed agricultural park.

Division of Land Management Comments:
As part of the EIS process, we recommend that a site selection study be undertaken to determine the best site for this type of facility.

V4

Division of Forestry & Wildlife Comments:
The EIS needs to address the effect of the proposed project on water quality, potential for wild fire spreading to adjacent lands especially in the Honouliuli Forest Reserve and the agricultural odors to residents downward of the project.

Thank you for your cooperation in this matter. We look forward to commenting further on the draft EIS. Please feel free to call Sam Lemmo at our Office of Conservation and Environmental Affairs, at 587-0377, should you have any questions.

Very truly yours,

John P. Keppeler

for WILLIAM W. PATY

cc: Department of Agriculture

September 1, 1992

MEMORANDUM

LOG NO: 6220
DOC NO: 0921t

TO: Roger Evans, OCEA

FROM: Don Hibbard, Administrator
State Historic Preservation Division

SUBJECT: Environmental Assessment and Notice of Preparation of Environmental Impact Statement for the Oahu Livestock Agricultural Park
Honouliuli, 'Ewa and Kahuku, Ko'olauloa, O'ahu
TMK: 9-2-4: por. 5 and por. 6; 5-6-5: por. 9, -6: por. 18 and por. 19, -7: 3 and 4, -8: por. 2

HISTORIC PRESERVATION PROGRAM CONCERNS:

The Environmental Assessment indicates that archaeological reconnaissance surveys for historic sites have been completed at both the Palikea Uplands and Kahuku areas, and that the results of these surveys would provide the basis for archaeological inventory surveys that will be prepared for the draft environmental impact statement (DEIS). This is the recommended process for historic preservation review and we look forward to reviewing the inventory survey reports in the DEIS.

TD:amk

State of Hawaii
DEPARTMENT OF LAND AND NATURAL RESOURCES
Commission on Water Resource Management
Honolulu, Hawaii

AUG 31 1992

MEMORANDUM

TO: Mr. Roger C. Evans, Administrator
Office of Conservation and Environmental Affairs

FROM: Rae M. Loui, Deputy for
Water Resource Management

SUBJECT: Oahu Livestock Agricultural Parks

The following is our comment on the above subject:

The State Department of Agriculture plans to acquire lands at Palikea Uplands and at Kahuku, both on Oahu, for the establishment of livestock agricultural parks.

Because the proposed agricultural parks are to be located within designated ground water management areas, water use permits from the Commission on Water Resource Management will be required for the use of well sources for the livestock operations at both sites.

The Commission is concerned about the efficiency of measures proposed to be taken for waste disposal; specifically with regards to potential contamination of the underlying ground water, and the degradation of streamwaters from site runoff. We anticipate a detailed analysis of such water quality impacts by the DOH in its review of the project proposal.

PH:ky

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Honorable Keith W. Ahue
Chairperson
Department of Land and Natural Resources
State of Hawaii
P.O. Box 621
Honolulu, Hawaii 96809

Dear Mr. Ahue:

Response to Comments on the Environmental Assessment (EA) for the Oahu Livestock Agricultural Park

Comments by your department on the Environmental Assessment concerning this project were inadvertently omitted from the draft environmental impact statement (DEIS). Because of this omission, we are responding separately (from our response on the DEIS comments) to the DLNR letter of September 4, 1992, which provided comments from the Divisions of Aquatic Resources, Land Management, and Forestry and Wildlife. These are addressed below:

Aquatic Resources

On two occasions, field surveys of ʻŌhiʻa Gulch indicated the stream bed is entirely dry from the mauka side of Kamehameha Highway to the vicinity of the dairy sites. It is believed the stream carries storm runoff, and this only occurs after very heavy rainfall events. The DEIS (page 215) discusses the control of storm runoff from the dairy areas. All of the runoff from dairy facilities and the majority of the pasture areas will be confined in a storm water detention reservoir. The conclusion is that the impact on aquatic resources, if present during episodic runoff events, will be insignificant.

Land Management

The sites selected for the livestock agricultural park survived several rounds of preliminary screening. The basis for the site selection is discussed in the DEIS beginning on page 160. Please refer to this for additional information.

Division of Forestry & Wildlife

The DEIS addresses the following subjects at these locations:

1) water quality - pages 91-103, 202-206, and 209-211;
2) fire control - pages 155-156; and
3) agricultural odors - pages 200-202.

Note that the Palikea site is no longer being considered for the project location, and therefore there will be no impact on the Honouliuli Forest Reserve from this project.

In addition to the above comments, we received late copies of two inter-office memoranda. These are addressed below:

Commission on Water Resource Management

The water requirements for the livestock agricultural operation can be met within the allocation declared by the Department of Agriculture for the existing sources of supply at the Kahuku Agricultural Park.

The DEIS describes the measures to be taken for waste disposal and the anticipated effects upon ground water and surface water resources.

The Department of Health has been given detailed presentations concerning the magnitude of these impacts and the proposed mitigation measures.

Historic Preservation

Both sites at Palikea and Kahuku were subjected to archaeological reconnaissance. On the basis of these preliminary studies, it was clear that the Kahuku project had the potential for archaeological findings and that the Palikea site did not. The conclusion that the archaeological potential of the Palikea project is nearly nonexistent is based on field observations and the evaluation that long-term land clearance and deep plowing (historic records) have destroyed archaeological deposits. Subsequently, study resources were diverted to the Kahuku site where more emphasis was also given as the more viable site.

The results of the archaeological inventory survey for the Kahuku site are contained in the DEIS. Editorial comments from an earlier submittal of this material have been addressed by the archaeological consultant, and a revised report (included in the final EIS as Appendix J) has been forwarded to the Historic Preservation Division.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

RECEIVED FEB - 3 1993

JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

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STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P.O. BOX 621
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FILE NO.: 93-350
DOC. NO.: 2116

MEMORANDUM

TO: Mr. Brian J. J. Choy, Director
Office of Environmental Quality Control

John P. Keppeler II

FROM: f William W. Paty, Chairperson
Board of Land and Natural Resources

SUBJECT: Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park, Ewa and Koolauloa, Oahu

Thank you for giving our Department the opportunity to comment on this matter. We have reviewed the materials you submitted and have the following comments.

Brief Description:

The project involves acquisition in perpetuity of 750 to 900 acres of existing agriculturally zoned land for establishment of a livestock park with two or three dairy operators as the first tenants. Two areas, one in the Palikea Uplands in Ewa and one in Kahuku, were compared in the draft EIS, but the Kahuku site was selected subsequent to preparation of the document.

Division of Aquatic Resources Comments:

From the standpoint of protection of aquatic resources, the Palikea site would have been preferable. Extra caution will be needed at Kahuku to avoid contamination of surface or inshore marine waters. Three drainages pass through the project area: Malaekahana Stream, Keaaulu Gulch, and Ohia Gulch. None of these are known to provide significant habitat for native aquatic species. Nevertheless, it would be advisable to keep livestock out of the gulches. With careful management and attention to waste disposal, impacts on surface and inshore marine waters should be minimal. Poor management, however, could lead to the kinds of water quality and other environmental problems associated with dairy operations in Waimanalo and elsewhere.

Historic Preservation Division Comments:

This DEIS contains information on historic sites for a portion of Honouliuli ahupua'a and for two parcels in Ko'olauloa (TMK: 5-6-8: 2 and 5-6-5: 9). There is insufficient information in the DEIS for us to complete the first steps in historic preservation review for this project. Both the Honouliuli and Kahuku alternative sites were cultivated commercially for many years, so historic sites would be limited to traditional Hawaiian sites that might be found in gulches and other areas that were not cultivated, and to historic features associated with commercial agriculture. Based on a general knowledge of the historic sites in these two areas and the incomplete information contained in the DEIS, it is unlikely that the inventory and management of historic sites would be of sufficient scale to materially affect the decision to locate the agricultural park at one site or the other. It is clear, however, that there are historic preservation concerns at both alternative sites, and these will have to be addressed prior to the development of the proposed project. The first step in this process will be the production of an acceptable inventory survey report for the selected agricultural park site.

The information on historic sites at Honouliuli is based on a literature review and a reconnaissance survey. A reconnaissance survey report is not included in the DEIS. The DEIS does note that there are likely to be historic sites associated with agricultural activities within the project area, but these are not identified or described, so we are unable to comment on their significance.

The information on historic sites at the two parcels in Ko'olauloa is contained in an inventory survey report by Cultural Surveys Hawaii. We have been unable to complete our review of this report because of substantial editorial deficiencies: grammatical and structural errors which make it impossible for us to determine if sufficient information was collected from the historic sites to determine their significance. Rather than list individual instances of these many deficiencies and the questions that they raise, which is our usual procedure but which would result in a too lengthy document, we will respond directly to Cultural Surveys Hawaii with suggestions for the editorial work that we believe is necessary for this report to be reviewed. When the report is revised acceptably we will be able to complete our review.

Thank you for your cooperation in this matter. Please feel free to call Sam Lemmo at our Office of Conservation and Environmental Affairs, at 587-0377, should you have any questions.

cc: Dept. of Agriculture
M&E Pacific, Inc.

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Honorable Keith W. Ahue
Chairperson
Department of Land and Natural Resources
State of Hawaii
P.O. Box 621
Honolulu, Hawaii 96809

Dear Mr. Ahue:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your department's comments in the memorandum received on February 3, 1993.

The DLNR memorandum provided comments from the Divisions of Aquatic Resources and Historic Preservation, which are addressed below:

Surface Water Quality

We concur with your staff's observations that with careful management and attention to waste disposal, impacts on surface and inshore marine waters should be minimal. We also recognize that with poor management, serious problems may occur. There are several steps being taken to prevent the latter condition from occurring. In particular, the engineering parameters and criteria are as follows:

1) Site Planning. The dairy locations are above floodplains. Drainage structures and channels are needed to intercept and divert mauka forest runoff and prevent it from flowing through the confined dairy operations.

2) Facilities Planning. The potential dairy operators (tenants) must construct free-stall facilities for maximum capacity.

3) Storm Water Control. Storm water runoff originating around the barns and milking parlors and the majority of the pastures will be collected and confined in a storm water detention reservoir, according to NPDES permit requirements. The contents of this reservoir will be used to irrigate crop land.

4) Project Scale. The area for the dairy facilities has been minimized to the extent practicable. Approximately 60 acres out of the total 650 acres for the project site are proposed for dairy facilities.

At future stages of project development, soil erosion and drainage plans will be prepared for State-constructed facilities, and best management practices will be identified for each dairy tenant.

Historic Preservation

Both sites at Palikea and Kahuku were subjected to archaeological reconnaissance (refer to Section III. Socioeconomic Environment, pages 121-136, in the DEIS). On the basis of these preliminary studies, it was clear that the Kahuku project had the potential for archaeological findings and that the Palikea site did not. The conclusion that the archaeological potential of the Palikea project is nearly nonexistent is based on field observations and the evaluation that long-term land clearance and deep plowing (historic records) have destroyed archaeological deposits. Subsequently, study resources were diverted to the Kahuku site where more emphasis was also given as the more viable site.

Dr. Hal Hammatt of Cultural Surveys Hawaii, the firm that prepared the archaeological report, has reviewed editorial comments with Mr. Tom Dye of the Historic Preservation Division. Their revised report is appended to the FEIS as Appendix J, and it was also submitted to the Historic Preservation Division for final review.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

K

SEND COPIES TO
APPROPRIATE PARTIES

POSTED

JOHN WAIHEE
GOVERNOR

REX D. JOHNSON
DIRECTOR

DEPUTY DIRECTORS
JOYCE T. OMINE
AL PANG
JEANNE K. SCHULTZ
CALVIN M. TSUDA

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

'93 FEB 22 AM 11:21

QUALITY C

IN REPLY REFER TO:
STP 8.5038

February 18, 1993

RECEIVED FEB 23 1993

TO: Mr. Brian J. J. Choy, Director
Office of Environmental Quality Control

FROM: Rex D. Johnson
Director of Transportation

SUBJECT: Draft Environmental Impact Statement - Oahu Livestock Agricultural Park

We have no objections to the Oahu Livestock Agricultural Park as proposed by the Department of Agriculture.

The environmental impact statement should include a traffic assessment report on the selected sites for the agriculture parks. In addition, any action within our state highway rights-of-way must be coordinated with and approved by our department and all associated costs borne by the developer.

We appreciate this opportunity to provide comments.

c: Dr. Paul J. Schwind, Department of Agriculture
Dr. James Dexter, M&E Pacific, Inc.

JOHN WAIHEE
Governor

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

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State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

April 26, 1993

Honorable Rex D. Johnson
Director
State of Hawaii
Department of Transportation
869 Punchbowl Street
Honolulu, Hawaii 96813-5097

Dear Mr. Johnson:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter dated February 18, 1993, concerning the proposed project.

A traffic assessment as accepted by your department (see attached) will be included in the final environmental impact statement as Appendix K. We also acknowledge the conditions set forth in your correspondence concerning (1) coordination of action within state highway rights-of-way, and (2) assumption of associated costs.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

Attachment

JOHN WAIHEE
GOVERNOR

HAWAII DEPT OF AGR

93 APR 27 A8:19

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

REX D. JOHNSON
DIRECTOR

DEPUTY DIRECTORS
JOYCE T. OMINE
AL PANG
JEANNE K. SCHULTZ
CALVIN M. TSUDA

IN REPLY REFER TO:
STP 8.5160

April 22, 1993

TO: The Honorable Yukio Kitagawa, Chairperson
Board of Agriculture

ATTN: Mr. Paul J. Schwind, Planning Program Administrator
Planning and Development Office

FROM: Rex D. Johnson
Director of Transportation

SUBJECT: Oahu Livestock Agricultural Park Final EIS, Traffic Assessment

We wish to acknowledge receipt of the Traffic Assessment report which will be appended to the Oahu Livestock Agricultural Park Final EIS as Appendix K.

After reviewing the report, we concur with the conclusion that the proposed development of agricultural parks at both the Kunia and Kahuku sites will not adversely impact traffic on Kamehameha Highway and Kunia Road during the morning and afternoon peak periods. For the Kahuku site, we also agree that the access intersection with Kamehameha Highway must be properly designed to accommodate large vehicles and should be coordinated with our department.

In addition, any plans for work within our State highway right-of-way must be submitted to our department for review and approval and all roadway improvements costs will be borne by the developer.

Thank you for the opportunity to provide comments.

c: OEQC
M&E Pacific, Inc.

RECEIVED FEB 9 1993

University of Hawaii at Manoa

Environmental Center
A Unit of Water Resources Research Center
Crawford 317 • 2550 Campus Road • Honolulu, Hawaii 96822
Telephone: (808) 956-7361

Governor, State of Hawai'i
c/o Office of Environmental Quality Control
220 South King Street, Suite 400
Honolulu, Hawai'i 96813

Dear Governor Waihe'e:

Draft Environmental Impact Statement (DEIS)
O'ahu Livestock Agricultural Park
Ewa and Ko'olauloa, O'ahu

The State of Hawai'i Department of Agriculture, proposes to acquire in perpetuity between 550 to 900 acres of existing agriculturally-zoned land for a livestock agricultural park on O'ahu. In addition, the Department of Agriculture will oversee the construction of infrastructure facilities for waste management, water supply, and irrigation, electrical power and energy recovery systems. This project is intended to be a demonstration of new technology for the livestock industry in Hawai'i. After analysis of eighteen sites on O'ahu, two candidates - Palikea Uplands in the Kunia area and the Kahuku Agricultural Park (and adjoining parcels) have been selected. Dairy operators are expected to be the first tenants of the project. The cost of the project development is approximately $40 million over a 20-year period.

The Environmental Center has reviewed the referenced document with the assistance of Paul Ekern (Emeritus), Water Resources Research Center; Ira Rohter, Political Science; David Penn, Geography; Terry Hunt and Elizabeth Gordon, Anthropology; and Alex Buttaro, Environmental Center.

Forward

The DEIS lists "the primary reasons for selecting the Kahuku site for the Livestock Agricultural Park" (LAP) (Page I). We note that if part of the intent of this DEIS was to function as a site selection analysis, subject to public review and comment, selection of the site should be based on an examination of the environmental consequences in the final EIS, and not prior to such analysis as the above citation suggests.

The primary reason given for selecting the Kahuku site was that it would involve a expenditure of public funds (page I) based on the use of existing infrastructure.

1) To what extent are existing roads, water systems, and drainage improvements at Kahuku and Kunia, compatible with the planned livestock park infrastructure, and to what extent would they require further development and alteration?

2) How does the potential market for animal waste products from Kahuku compare to that of Kunia?

3) The expectation that "two to three dairy operators will be the first tenants of the livestock park" is identical to that of the "ultimate development of the project" providing "capacity for one-fourth of the present dairy operations on O'ahu"(p.III). According to page 32, there are now 11 dairies on O'ahu with 10 or more cows. One fourth of these is 2-3. The DEIS summary statement may be misleading and may distort the potential magnitude of the project benefits.

In the discussion of the secondary environmental impacts the DEIS states, "this document presents risk assessments of the public health aspects of these potential [adverse environmental] effects" (Summary, page V). We note that assessment of environmental impacts should not be limited to public health risk assessment, but should include those effects to ecosystems and species that may not have an impact upon public health. What other non-public health related impacts may occur?

Economic Feasibility

To what extent was the role of climatic conditions on milk production factored into the evaluation of the sites?

What role does the military play in O'ahu's dairy market? Do they import their milk? If yes, will they be willing to buy locally produced milk?

Uplands (Section B, [2] p15)

We question the economic feasibility of raising forage crops for mechanical harvest. Such crops are not likely to produce adequate returns to small-scale farming, and would require the substantial expenditure of capital for machinery. What grounds are there for the expectation that it may be economically feasible to raise forage crops?

Socioeconomic Characteristics of a Livestock Agriculutural Park (Section D, [1] page 35)

With regard to estimated spin-off effects on other economic sectors, what is the basis for assuming that "the retail value of milk consumed on O'ahu is triple the farm value" (page 35)?

General Comments

The EIS should express water requirements for dairy operations as a function of animal and areal units (Section A, page 42).

1) What are the water requirements in terms of animal and areal units?

The EIS should elaborate on the water rights issues related to Waiahole Ditch. The current leases which allow O'ahu Sugar to exercise these rights will expire in 2000, with an uncertain future beyond that point. The EIS should discuss alternative water sources for the proposed site.

2) What portion of the available flow is covered by the State's rights?

The DEIS states that "the water for the livestock operations and new diversified agricultural lot leases will be credited against the 0.98 mgd allocation declared use made by the Department of Agriculture" (p43). Our reviewers note that water uses "declared" by the Department of Agriculture at Kahuku are not an "allocation". The State Commission on Water Resource Management recently designated windward aquifers as "Water Areas", and has not yet issued allocations for water use in these areas.

Capital (Section C, pgs.44-45)

The total size of the Palikea park would be 930 acres (p.123), with 187 used for dairy and waste management operations (p. 22), leaving use of 743 acres unaccounted for. The total size of the Kahuku site is 785 acres, with 116 used for dairy and waste management, 110 for new agricultural leases, and 230 for existing leases (Pgs. 132 and 22), leaving use of 329 acres unaccounted for. The 116 acres at Kahuku will cost $2 million, but there is no comparison of how much the 187 acres at Palikea will cost, nor how the use of the remaining acreage compares between the two sites.

3) How much are the 187 acres at Palikea expected to cost, and do the uses of the remaining acres compare between the two sites?

4) Do 930 acres of Palikea land cost the same as 785 acres of Kahuku land?

5) Are all 785 acres of Kahuku land and 930 acres of Palikea land suitable for agricultural uses, and if not, how many acres at each site is unuseable?

The information provided on Table 2.4 (p.44) should be expanded, detailed, and qualified in order to allow fair and adequate assessment and comparison. In particular, "the portion of costs related to dairy relocation" for Palikea needs quantification, since not all of the land aquisition costs are related to dairy relocation ($13 million for 930 acres, 187 of which are needed for dairy).

Summary of Affected Environment

Physical Environment (Section I, p.47)

Use of annual rainfall averages for comparing evaporation/rainfall relationships can be misleading. While wet season/dry season comparisons (p.53) are more informative, monthly averages would be more appropriate for characterizing and comparing agroclimatic conditions at the sites. Regardless of the method used, there has been little attempt in the DEIS to relate these agroclimatic conditions to their influences upon dairy operations and to use them as a criteria for site selection.

1) Why are these factors considered insufficiently important to include as criteria for site selection?

The conclusion that the wetness of the Kahuku site "is a significant factor when it comes to controlling odors and treatment of animal wastes" (p.54), deserves further explanation and more prominence in summary sections of the DEIS.

The DEIS concludes that Palikea soils "are favorable for retention of constituents found in animal waste" (p. 59). The discussion of Kahuku soils (p. 64) does not address this function, thus no comparison can be made. Similar assessment of soil waste retention capability at Kahuku and subsequent comparison with Palikea conditions should appear in the EIS.

The EIS should note that, similar to aquifers underlying Palikea, windward aquifers are also Water Management Areas within which permission for groundwater withdrawal is strictly regulated by the State Commission on Water Resource Management.

The sediment delivery ratio through the water shed and into the streams and ocean should be discussed in the water-related sections (pages 102-103, and pages 191-192).

In comparing project impacts, we should consider not only their physical magnitude, but the degree to which they further degrade existing conditions in biological and social systems. Baseline conditions in Pearl Harbor are probably much less pristine than those in Kahuku, and further degradation of these (Pearl Harbor) conditions may be more socially acceptable than a degree of less advanced degradation at Kahuku. Project impacts to Kahuku coastal areas, although of lesser physical magnitude, may be more significant than impacts to Pearl Harbor. What is the rationale underlying the preparer's conclusion that "the relative project impacts will be greater to estuarine waters near the Palikea site...than the Kahuku site" (Section 3, p.103)?

Historic and Archaeological Resources

Our reviewers note that the archaeological report appears to adequately cover the issues that appear significant with regard to the Kahuku site, but note that a preservation plan might have been included for public review and comment. We suggest that the Final EIS include a preservation plan.

The Palikea archaeology review was limited to a reconnaissance survey and prehistory summary, while Kahuku was subjected to an archaeological site inventory, subsurface testing, and (incomplete) review of Land Commission records. Why was the level of review of archaeology and cultural history at Kahuku much higher than that performed for Palikea?

We note that review of Land Commission Awards (LCA) only, does not reveal the full scope of human activity and cultural significance in a particular area. The Land Commission records also include documentation of unawarded claims which are equally useful in obtaining information about land uses, site locations, and human activity in an area. Unfortunately, the unawarded claims are not indexed at the same level of detail as awarded claims, certainly a contributing factor to the fact that preparers rarely if ever include documentation from unawarded claims in their analyses. If EIS accepting authorities and others using archaeological and historical information for land use decision-making were to emphasize the inadequacies of using only awarded claims for assessment purposes, perhaps there would be greater initiative for indexing of unawarded claims and analysis of their information content.

Because site inventorying, subsurface testing, and historical review was conducted to a much lesser degree than performed for Kahuku, it is difficult to fully accept the conclusion that "preliminary fieldwork within the 930-acre project area gives clear indication that virtually all formerly cultivated sugar and pineapple lands are devoid of archaeological interest" and that "the potential for prehistoric Hawaiian archaeological sites is nearly non-existent" in agricultural areas (p.131) (emphasis added). Furthermore, "archaeological interest" and "site potential" are not the sole determinants of cultural significance and land use suitability.

The "fact that the majority of LCAs located in the ahupua‘a of Kahuku and Kaena lie on the makai side of Kamehameha Highway" (p.138) does not necessarily suggest "that both habitation sites and agricultural sites (lo‘i and kula) were centered in these areas" (p. 138), since it fails to account for land use information contained in the records of unawarded claims and also fails to analyze land uses for adjacent areas which may have been used but for which no claims were entered. Reference to "information gathered from foreign and native testimony" should specify whether or not this includes testimony recorded for unawarded claims, since this would affect the strength of the conclusion "that agricultural sites, which incorporated temporary and/or recurrent habitation sites, were once present in the uplands..."(p.138). Perhaps permanent habitation sites and other features were also present.

Our reviewers note that the longest growing season (2 years for cane) still seems to allow time for harvest before park construction would begin, or at worst the value of the crops lost to construction could be included in the assessment. Why was "land not actively cultivated" (p.163) used as a site selection criteria for the in-depth study?

18 Potential Sites

Many of the supposed disadvantages and advantages in the analyses are suspect, both in their allocation to various sites and in their overall significance. It seems that the analysis and comparison should have been carried to at least the next level, which would involve some kind of weighting or ranking of the criteria to facilitate quantitative evaluation of each site. Comparing the advantages and disadvantages of the sites as listed in the tables is of limited value without an explanation of how the tables were used to make a formal evaluation of site suitability. We suggest the following issues be considered in the evaluation of sites:

Disadvantages (p.165)

1) Kahuku: The issue of military leases is not mentioned in the DEIS text.

6) Pa‘ala‘a-mauka: How does the presence of military antennae affect site suitability?

7) Kaukahonua: The degree of existing water supply development seems to be unevenly considered. Palikea has an existing ditch system but is not connected to it.

11. Kunia: Prime agricultural land in cultivation may not be an issue if existing agricultural use may not continue due to industry decline.

Advantages (p.166)

We noted a limited diversity of advantages presented.

Presence of suitable land for pasture does not seem so important given DOA's descriptions of "free-stall" system operations.

16. Ka'ena: Why is distance from urban centers an advantage when distance from processing facilities is considered a disadvantage?

The assertion that "Water for Hawaiian Homes land may be unavailable" (p.168), neglects the provisions of State law which give Hawaiian Homes "first call" on government water and other water supply priorities. We note that the existing supply system on Moloka'i cannot provide enough water for the full agricultural development of all Hawaiian Home Lands on the island. Is the above quoted statement based on analysis of physical or institutional conditions, or both?

What is the basis for the conclusion that "West Loch is considered potentially of greater significance" (p.173) with regard to the effects on coastal recreation?

The DEIS states that "the significance of the effect [of increased time to fill wildlife refuge ponds and manage pond levels at Kahuku] is an unresolved issue" (p.207). This issue should be resolved prior to submission of a Final EIS, and if not, an explanation as to why it is deemed unresolved, and when it will be resolved, should be provided pursuant to EIS Rules Section 11-200-17(n).

The DEIS states that "f) truck traffic required for dairy operations" (p.208) is a "relatively short duration effect" (p.207).
This effect may be short in daily duration, but will probably extend over the life of the operation. This point should be clarified in the EIS.

Consultation Process (Section 7, p.221)

Our reviewers note that the Commission on Water Resource Management was not listed as being consulted in the DEIS preparation. We note that they should included in the formulation of a final EIS for this project.

Summary

The idea of sustainable agriculture that integrates growing feed stocks, forage areas, and waste treatment is excellent and appropriate for O‘ahu. But the specific solution proposed, concentrating a large number of cows (2,000) on a limited space seems problematic, and will be likely to require many mitigative schemes. This consolidating approach may not be appropriate. Dispersion of dairy farming to smaller units in different geographic areas may also be a viable alternative given the resultant reduction in concentration of dairy wastes and environmental impacts upon any one site. We suggest that various forms of the "dispersive" approach be seriously considered as an alternative to the consolidating approach discussed in this EIS. The Final EIS should contain a comparison of the the potential environmental impacts of the proposed agricultural parks, with a more detailed comparative analysis for Kahuku and Palikea.

Thank you for your time and consideration and we hope our comments are helpful.

Sincerely,
B. Alex Buttaro for
Jacquelin Miller
Associate Environmental Coordinator

CC: Dr. Paul J. Schwind
Dr. James Dexter
Roger Fujioka
Paul Ekern
Terry Hunt
David Penn
Ira Rohter
Eliazabeth Gordon
Alex Buttaro

JOHN WAIHEE
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DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

April 26, 1993

Ms. Jacqueline Miller
Associate Environmental Coordinator
Environmental Center
University of Hawaii at Manoa
Crawford 317, 2550 Campus Road
Honolulu, Hawaii 96822

Dear Ms. Miller:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter of February 8, 1993, concerning the Oahu Livestock Agricultural Park. Our response is keyed to the major headings and paragraphs in your letter. Please refer to it for the original context of the issue or question being addressed; for brevity we will omit verbatim quotations.

Foreword

1. The choice of the Kahuku site versus the Palikea site is not final. The DEIS is a recommendation, and the public's response to that recommendation is being sought. The choice will be an executive decision.
2. Concerning the tentative selection of the Kahuku site:
    a) The infrastructure with regard to water, electrical, and road improvements is more complete for dairy development at the Kahuku site than the Kunia site. There are already infrastructure components at Kahuku: paved roads; operational water transmission lines, pumps and a reservoir; and single-phase electrical service.
    b) Regarding the "market" for animal waste products, Kahuku is distinctly favored. In addition to the Kahuku Farmers Association located on the

site, other truck farmers in the immediate vicinity of the site who have been contacted are interested in experimenting with manure as an organic fertilizer. At Palikea, the choices are fewer. Sugar growers are not interested, and the pineapple growers are cutting back, or eliminating, their use of manure for fertilization.

c) The final environmental impact statement (FEIS) will be clarified to indicate that the first livestock tenant might be a single dairy operator (Summary, page III). The intent is to be able to accommodate up to two or three dairy operators. Who actually occupies the park is an executive decision following rules for selection. What is proposed is the option to include the dairies at this park site. The first tenants could also be farms for vegetables and fruit crops.

3. Non-health effects are primarily nuisances and short-lived environmental effects during construction. These are summarized on pages 207 and 208 (Section Four–III) in the FEIS.

Economic Feasibility

1. Consideration of cooler temperatures is made implicitly in the economic evaluation. The statewide average unit production is approximately 40 pounds per cow per day. The economic analysis considers an increase to 55 pounds on the average. One factor is cooler temperatures. Here, climate is one factor. Other factors include provision of well-ventilated free-stall barns which provide shade for evaporative cooling or misters.

2. The military buys local milk, usually by bid and/or negotiation with the processors.

3. The decision to raise forage is for the dairies to make. Some are doing it, and others have expressed interest in it as part of a waste management system. The price of importing feed continues to increase with time and there is interest in forage crops. At present, a dairy on Kaua'i grows corn and produces silage for feed. A Big Island dairy harvests grass mechanically for hay as supplemental feed. Others on the Big Island rely on pasture feeding. In any event, the decision will be up to the dairy operators. Some are going into supplemental forage crops.

4. To be correct, the factor should be between 2 and 3, considering the precision of estimates. If the price of fluid milk is about $2 to the farmer, it is $4.65 in

the market. Revisions will be made to clarify this situation on page 35 in the FEIS.

General Comments

1. Total water requirements for three dairies in free-stall operation are estimated here:

Average Day, mgd	
Nonpotable	*Potable*
0.025	0.004

This is a design alternative to minimize waste management requirements. The expression in terms of areal units and the like is archaic and not applicable to the methodologies used here.

Storm water runoff and effluent from the treatment system are proposed for supplemental irrigation water. Additional fresh water requirements for truck crops will depend on the acreage leased and the type of crops. Land set aside specifically for the dairy operators' facility is approximately 60 acres.

The specific terms for the potential use of Waiāhole Ditch water have not been determined. The important factor is availability at this stage. Issues on rights are not fully resolved, and are not expected to be resolved for some time.

2. The portion of Waiāhole Ditch water (total potential of approximately 22 mgd) water which can be reserved by the State has not been precisely established. That portion is considered to be on the order of millions of gallons per day, enough for a livestock park. For Kahuku, the declared amount is not likely to be withdrawn by the State Commission on Water Resource Management. For this analysis, the amounts are considered to be committed, whatever the legal mechanism.

3. The area being considered at either site includes gulches or land with steep slopes, generally unusable for livestock agriculture except perhaps low intensity grazing. Real estate transactions are made by parcels, not pockets of land, as a practical matter. However, some of these unused areas serve a purpose—a land buffer between other uses and the livestock park. In general, land in the Central O‘ahu area is going to cost more than in Kahuku. Land costs are not

the market. Revisions will be made to clarify this situation on page 35 in the FEIS.

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firm, but they are considered to be about $20,000 per acre at Kahuku versus $70,000 per acre at Palikea. Given a fixed budget for land acquisition, it is obvious that the Kahuku site will provide more land for the dollar than in Central O'ahu.

4. We believe the information in Table 2.4 (page 44) to be appropriate for the FEIS. Further details can be developed after advanced engineering and land acquisition studies are completed.

<u>Summary of Affected Environment</u>

1. Rainfall and evaporation are not the sole basis for site selection. They are important nevertheless, but other factors may be overriding. For example, availability of land (actively cropped) to absorb the animal waste in a useful way as fertilizer is more critical from the standpoint of cost. Based on rainfall alone, Palikea is more favorable for manure management (wet manure generates more odor, is more difficult to transport, and incorporate into the fields). However, free-stall dairies mitigate the impact of heavy rainfall. The over-riding factor in this case is availability of land for ultimate disposal by reclaiming fertilizer for crops.

   A similar argument can be made at most, if not all of the other sites. In other words, environmental controls can alleviate or mitigate concerns. The magnitude of the rainfall or evaporation quantities are considerations, but they will not be the sole criteria for site selection.

2. The Kahuku site includes Waialua silty clay soils that also are favorable from the standpoint of animal waste management. Their expansive nature reduces in situ permeability and permits more time for microbial action, due to the increased time for percolation to occur. We will point this out in the FEIS (page 64). Thank you for calling it to our attention.

3. We will add a note to the FEIS clarifying that both Pearl Harbor (page 65) and Windward aquifers (page 67) are water management areas.

4. Sedimentary delivery ratios would be meaningful parameters to discuss as the reviewer requests, if data were available. Neither site has sufficient data to make reliable estimates. Erosion and sedimentation rates can vary on orders of magnitude, depending upon assumptions, methods, and completeness of data. The DEIS does discuss what data is available from streams in similar hydrologic regimes. However, the conclusion that exceedence of the instream

water quality standards will occur relative to turbidity and nutrients during storms, is not likely to change after further extensive and hypothetical evaluation. Moreover, impounding storm runoff as required for the NPDES permit tends to mitigate impacts at either site.

Storm runoff will ultimately drain into two distinct types of coastal receiving waters. The relative ecological effects will be greater for the estuarine waters of West Loch following a dose-response relationship. Ecological effects are concentration-time dependent phenomena. The resident time of pollutants in the estuarine environment such as West Loch is much greater than in an open coast regime such as the rough, Kahuku shoreline. There are other considerations, but the major parameter being considered here for ranking water quality impacts is the concentration-time dependency. The State's water quality standards are organized following the same principle.

5. Given the above considerations, detailed predictions of further degradation of biological and social systems are speculation and are irrelevant. If runoff is confined on-site, the consequences are not only hypothetical and academic, but impossible to verify by data collection, monitoring, and analysis.

<u>Historical and Archaeological Resources</u>

1. In preparing the inventory survey report for the DEIS, the archaeological consultant followed the procedures established by DLNR Historic Preservation Division rules. Their procedures specifically call for a preservation plan not in the EIS, but at a later stage in the process (see Chapter 146, Rules Governing Procedures for Historic Preservation Review §13-146-3) when project plans are more specific. If these procedures are disputed, the reviewers should contact DLNR Historic Preservation Division.

2. The level of review at Kahuku was much higher than at Palikea because the reconnaissance survey at the latter did not identify any cultural remains within the boundaries proposed for land acquisition, whereas there were some areas at the boundaries for Kahuku which could conceivably be within or on the boundary of the property acquired.

3. The archaeological consultant—Cultural Surveys Hawaii—studied Land Commission Awards (LCAs) as a means of portraying the traditional land use, site patterns, and settlement for the *ahupua'a* as a whole. All LCA information available was consulted: whether the claims were awarded or not was not a

defining factor in deciding to make use of the information in the LCAs (§13-147-4b).

4. The conclusion that the archaeological potential of the Palikea project is nearly nonexistent, is based on field observations and the evaluation that long-term land clearance and deep plowing (historic records) have destroyed archaeological deposits. This is not to say that archaeological sites were not formerly present. If these cane and pineapple fields now have cultural significance, the consultants did not find evidence of it. Perhaps the reviewers could further explain their evidence and criteria for "cultural significance."

5. Related to item 3, again, all information available at the State Archives on LCAs was consulted for this study. The selectivity of the data was not based on whether or not the claims were awarded, and therefore is not relevant to the strength of the conclusions.

6. The reviewer seems uncertain about the present land use. Both sites contain fallowed sugarcane land, as noted in the DEIS. Sugarcane is not presently grown at either site. Kahuku plantation ceased operations in the early 1970s, and Oahu Sugar suspended its growing activities on lands at the Palikea site over 10 years ago.

<u>18 Potential Sites</u>

1. The reviewer questions the advantages and disadvantages of the different sites, but the remedy that is proposed is a subjective weighting system. Presumably this will add more objectivity to the screening process. The listing of advantages and disadvantages shown in Table 4.1 (pages 165-166) is not intended to be exhaustive. It does point out that most sites have more disadvantages than advantages. This is the conclusion of the screening process—that any location on O‘ahu is likely to be problematic, but not impossible.

   Any objective weighting system would be helpful, if the reviewer who questioned the explanation provided details. It would be valuable to know how to balance trade-offs without being "suspect." For example, how would one balance the fact that the UIC line precludes most of the sites, and restrict consideration to coastal areas where temperatures are highest (and milk production lower), and put dairies again in competition with urban and recreational uses?

The reviewer's additional points are addressed:

a) As far as the Department of Agriculture is concerned, there is no issue relative to military leases at the Kahuku site. The agricultural site, including the proposed livestock operations area, has previously been the subject of an environmental impact statement (1984). No significant impact of military operations in areas mauka of the proposed project was noted at that time. None is anticipated as a result of the proposed project.

b) Military antennae emit electromagnetic fields. There is currently a scientific and community debate concerning the long-term health effects of living or working near these facilities.

c) The Palikea site is connected to the existing Waiāhole Ditch system. In fact, consideration was given, in early site planning, to repairing existing pipelines from the ditch, rehabilitating abandoned pump stations next to the ditch, and utilizing existing reservoirs at the Palikea site for water storage.

d) True, prime agricultural land in cultivation may not be an issue if existing agricultural use is discontinued. However, Oahu Sugar was still planting in 1992. There is about a four-year cycle considering harvest and processing of a crop. The problems of the dairy industry are immediate, and some operators have to find a solution now or risk closing their operations.

Advantages

1. Suitable land for pasture for dry cows and calves is still a consideration. Dry cows remain at the dairy until their next lactation period begins. To the extent these animals can graze on pasture, it lowers the operator's cost during this non-productive period. A dairy operator has a considerable stake invested in the calves. It is the dairy's future. There is about a six-month period until they are strong enough to be shipped to neighbor island ranches for maturing. Grazing land for a limited number of animals is highly desirable.

2. Distance from urban centers is an advantage, considering that residential neighborhoods are generally intolerant of nuisances caused by agricultural operations in general and dairy odors in particular. However, the processing plants where the raw milk is shipped are in urban Honolulu. Greater distance

and longer travel time and traffic conditions will therefore increase the dairy operator's cost of getting the product to the processor.

3. The statement concerning water and Hawaiian Homes land on page 168 in the DEIS contains a typographical error. It should read "water *from* Hawaiian Homes land may be unavailable." We will correct the FEIS. Thank you for calling it to our attention.

4. West Loch is a part of the Pearl Harbor estuary. This is particularly impacted by discharges including urban and agricultural storm runoff. Estuaries, because of longer residence times than open coastal waters such as at Kahuku, amplify the effects of mass emissions from the land adjacent to the waters. Parameters which frequently violate State water standards in Pearl Harbor include nitrogen, phosphorous, turbidity, fecal coliform, and temperature (Water Quality Management Plan for the City and County of Honolulu, 1990).

5. Thank you for clarifying the EIS rules as they pertain to unresolved issues, in particular the significance of effects upon the wildlife refuge ponds at Kahuku. We will continue to coordinate the project aspects with the U.S. Department of Interior, Fish and Wildlife Service.

6. The FEIS will be corrected to note that truck traffic will extend over the life of the project (pages 207-208).

Consultation Process

1. The Commission on Water Resource Management has indeed been a consulted party. We will correct the list of consulted parties in the FEIS to reflect this fact. Thank you for calling it to our attention.

Summary

We agree with your comment that sustainable agriculture which integrates food, forage, and waste treatment is the ideal situation. It is also true that concentration of dairies into one central area has problems, but there are advantages. The strategy for dispersing dairies has problems also:

a) there are economics of scale that will be negated by separate agricultural parks;

b) the choice of sites acceptable to the general public is quite limited; and

c) the monitoring and administrative oversight is simplified by fewer sites.

Suggestions from the dairies who have implemented the waste treatment processes being considered here have cautioned that the typical dairy farmer will need special operator assistance. Besides, public health regulations will probably require certified operators to maintain the treatment works. Farmers are not expected to be certified operators of treatment plants. Farmers want to farm, and there is enough to do in farming without trying to become experts in treatment operations. The unit costs for operation become too high for several separate systems in place of one.

The number of choices for sites for dairies is quite limited. It will be difficult, for example, to find three or four sites without environmental and community concerns, located close to existing farms that can utilize the animal waste as part of their nutrient management.

Thank you for the time spent on your thorough review. I believe it will improve the final EIS.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

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Thank you for the time spent on your thorough review. I believe it will improve the final EIS.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

BOARD OF WATER SUPPLY
CITY AND COUNTY OF HONOLULU

RECEIVED FEB 19 1993

COPY

February 11, 1993

Mr. Yukio Kitagawa, Chairman
Department of Agriculture
State of Hawaii
1428 South King Street
Honolulu, Hawaii 96814

Attn: Dr. Paul Schwind

Dear Mr. Kitagawa:

Subject: Draft Environmental Impact Statement (DEIS) for the Proposed Oahu Livestock Agricultural Park, TMK: 9-2-4: 5 and 6 (Palikea Uplands Site); 5-6-5: 9, 5-6-6: 6 and 19, 5-6-8: 2 (Kahuku Site)

We are still evaluating the proposed project and will complete our review by February 20, 1993.

If you have any questions, please contact Bert Kuioka at 527-5235.

Very truly yours,

KAZU HAYASHIDA
Manager and Chief Engineer

cc: Office of Environmental Quality Control
✓M & E Pacific, Inc.

BOARD OF WATER SUPPLY
CITY AND COUNTY OF HONOLULU

RECEIVED FEB 25 1993

COPY

February 22, 1993

The Honorable John Waihee
Governor, State of Hawaii
c/o Office of Environmental Quality Control
220 South King Street, 4th Floor
Honolulu, Hawaii 96813

Dear Governor Waihee:

Subject: *Draft Environmental Impact Statement (DEIS) Dated December 1992 for the Proposed Oahu Livestock Agricultural Park, TMK: 9-2-4: 5 and 6 (Palikea Uplands Site); 5-6-5: 9, 5-6-6: 6 and 19, 5-6-8: 2 (Kahuku Site)*

Thank you for the opportunity to comment on the DEIS for the Oahu Livestock Agricultural Park. Our previous comments of September 23, 1992 on the Environmental Impact Statement Preparation Notice are still applicable.

We have the following additional comments to offer:

1. The DEIS identifies and assesses the risks of groundwater contamination through the Nitrogen and Pathogenic Pathways Analyses. We reiterate our concerns regarding the potential for contamination of potable groundwater resources by the development of a livestock agricultural park at either of the proposed sites. The Groundwater Flow Path Analysis indicates the Palikea site is adjacent to and directly upgradient from the Honouliuli Wells, (Figure B-1), which supplies the majority of water to the new Ewa, Kapolei and Ko Olina developments. The Kahuku site is also in proximity to and directly upgradient from our Kahuku Wells, (Figure B-4), which are our sole source of water for Kahuku Town.

2. The extent and frequency of the groundwater monitoring program should be discussed. The DEIS proposes a vadose (unsaturated soil zone) monitoring plan for the bulk of the first line monitoring and sampling of existing and future wells as redundant back-up. The vadose monitoring information should be expanded to include discussion on the viability and reliability of this monitoring method.

3. In reference to Section 5 - II, page 212, and to our November 17, 1992 letter to the Department of Agriculture (DOA), regarding "certification as to cause"; it shall be DOA's responsibility to clearly prove that the contamination is <u>not</u> from the livestock agricultural park after a determination has been made by the Board of Water Supply that the existing wells are contaminated.

COPY

The Honorable John Waihee
Page 2
February 22, 1993

4. An acceptable alternative potable well site should be identified and fully developed, with production and standby well facilities that are connected to the existing water system, by DOA as part of the proposed project to insure continuous domestic water service in the event our existing wells become contaminated by the livestock agricultural park. The well(s) location and plans and specifications should be submitted for our review and approval.

5. If our existing wells are contaminated by the livestock agricultural park and it becomes necessary to replace the sources with the alternate well(s), the developer shall dedicate the alternate well(s) and associated improvements to the Board of Water Supply. In turn, the contaminated wells will be dedicated to DOA for use as a nonpotable source.

6. We have no water system serving the Palikea site and the Kahuku water system is fully committed and has no surplus capacity. Therefore, the developer would have to install a complete water system including source, storage and pipelines to accommodate the domestic requirements of the proposed project. A water master plan should be submitted for our review and approval.

7. We concur with the proposal to investigate nonpotable irrigation sources such as brackish and re-used water.

If you have any questions, please contact Bert Kuioka at 527-5235.

Very truly yours,

KAZU HAYASHIDA
Manager and Chief Engineer

cc: Department of Agriculture
✓M & E Pacific

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Mr. Kazu Hayashida
Manager and Chief Engineer
Board of Water Supply
City and County of Honolulu
630 South Beretania Street
Honolulu, Hawaii 96843

Dear Mr. Hayashida:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for reviewing the DEIS through your letter dated February 22, 1993. Our responses follow the order of your comments:

1. Ground Water Contamination

This paragraph reiterates previous concerns of which we are aware. More than three years ago when planning for this project was first commissioned, our initial detailed analyses of project impacts looked at waste management and the potential for ground water contamination. After considerable analysis and evaluation, we now conclude that the potential risk of contamination at the site recommended (Kahuku) is insignificant. However, manure management may become critical at other sites on O'ahu as pineapple operations curtail their use for fertilization.

Lacking a specific set of comments, we offer a recapitulation of the salient features of our evaluation:

1) A closed loop waste management system, at least as complete as is practical to achieve, is preferred. See Figure 2-2, page 21.

2) A field examination of similar soils where application of manure has occurred for over 20 years was made. The conclusion is that soil moisture nitrogen concentration remains below 1 mg-N/l. See pages A-18 to A-20.

3) A nitrogen budget was calculated for manure applications on crop land to consider the potential concentrations of nitrogen that could migrate in percolating soil moisture; the order of magnitude was less than 3 mg-N/l in the percolate. See pages A-5 to A-18.

4) The concentration of percolation was compared to the background level of nitrogen in the ground water at the Kahuku site, which was measured at about 1 mg-N/l (similar to the Palikea site).

5) Considering the relative levels and quantity of recharge from sources in the system and the magnitude of the potential increase of nitrogen from the use of manure on crop lands for fertilizer, we concluded there was about an order of magnitude difference between the estimated concentration and the maximum contaminant level (MCL) of 10 mg-N/l^{-}. See pages A-21 to A-24.

The consultant then did a sensitivity analysis. We asked the question: what would it take (in terms of manure application) by farmers to raise the concentration in the aquifer to 10 mg - N/l? The farmers would literally have to blanket the ground 4 to 6 inches deep regularly for a one-percent chance of exceeding the MCL for NO_3-N. We think the logistics and the crop results make this impractical in any case. This amount of nitrogen would drastically reduce yields, and farmers would realize the problem (as they have in the past) and abandon the practice. The conclusion is that the risk is insignificant.

The consultant performed similar analyses for pathogenic material—viruses and bacteria. The conclusion is the same: the risk is small. For bacteria it is near zero and less than one in one-thousand for viruses, not to mention that animal virus is not specific to humans as pathogens. These results are shown in Appendix C.

With respect to the ground water flow path analysis, the consultant quantified what is already generally considered to be the most probable direction of ground water flux in each region. What each model indicates is that the subsurface flow is not solely derived from the land area of the proposed agricultural park, but rather significant quantities come from the mauka regions of these aquifer systems. This means there is a great buffering effect within the underlying aquifers, which diminishes the significance of percolation occurring at the proposed sites. The hydrologic budgets which provide the basis for this conclusion are presented in Appendix B.

In summary, the DEIS stated that we have analyzed the risk at the recommended site and quantitatively characterized it as not significant. We are not saying that everywhere on O'ahu (or in Hawai'i, for that matter), the risks will be low, but for the sites considered, we conclude that they are. Also, we considered the fact that for decades cattle have grazed in the gulches near the Honouliuli wells, yet nitrogen concentrations are low in those wells. Experience and the relevant facts are the bases of our conclusion.

2. Ground Water Monitoring Program

The proposed environmental monitoring and protection, including ground water, is discussed in pages 213-214 of the DEIS. Specific comments on this material would have been helpful.

Additional information is to be included in the final EIS as Appendix L, "Site Operations and Environmental Monitoring." It contains details on the soil monitoring program. It may be of particular interest to review the discussion on pages Appendix L-7 through L-9 concerning irrigation rates for effluent, hydrologic budgets, and the results of soil moisture sensor readings in the proposed project area. The conclusion is that applied water (rainfall plus irrigation) could not exceed plant transpiration and evaporative rates more than one month during the year. But due to the expansive nature of in situ soils, there will be a reduction in infiltration rate during rainy periods.

The implications for ground water protection are clear. Again, local experience confirms the expected outcomes. For example, truck farms have operated in the area proposed for manure application for nearly 20 years. Manure, in this case chicken manure, has been part of the fertilizer program in the past. Presently, chemical fertilizers are predominant because of the ease of application and more readily mobile in the soil. Yet the water wells adjacent to these fields have a typically low nitrogen content—1 mg-N/l.

3. Certification as to Cause

We concur in principle. More specifics are needed on the criteria for making any kind of determination. If indeed, the proposed livestock agricultural park is the cause of contamination, then the department intends to take any emergency remedial action. Otherwise, the issue is one of speculation and conjecture outside of fact and experience.

4. Acceptable Alternative Potable Well Site

We have requested that the Department of Land and Natural Resources include funds for exploratory well drilling for the proposed project. Our consultant has contacted your hydrology section concerning possible locations for potential wells.

Contingent upon the outcome of this exploratory well program, our preliminary engineering work has included plans and budget estimates for new wells, pumping, transmission, and storage facilities. These costs are to be included in the construction cost estimate in the preliminary engineering report (M&E Pacific, January 1993). At the appropriate time, this information will be made available for your review.

5. Dedication of New Wells

We concur with the content of this paragraph.

6. Lack of Source Capacity

Planning for potable and nonpotable water at the Kahuku (recommended) site has been based upon the assumption that the Department of Agriculture will develop and operate a private system.

7. Nonpotable Irrigation Sources

These are being considered in the preliminary engineering for the Kahuku site.

Thank you again for your cooperation on this project.

Sincerely,

Yukio Kitagawa

YUKIO KITAGAWA
Chairperson, Board of Agriculture

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These are being considered in the preliminary engineering for the Kahuku site.

Thank you again for your cooperation on this project.

Sincerely,

Yukio Kitagawa

YUKIO KITAGAWA
Chairperson, Board of Agriculture

DEPARTMENT OF TRANSPORTATION SERVICES
CITY AND COUNTY OF HONOLULU
HONOLULU MUNICIPAL BUILDING
650 SOUTH KING STREET
HONOLULU, HAWAII 96813

FRANK F. FASI
MAYOR

JOSEPH M. MAGALDI, JR.
DIRECTOR

AMAR SAPPAL
DEPUTY DIRECTOR

RECEIVED JAN 25 1993

TE-5272
PL92.1.450

January 12, 1993

The Honorable John Waihee
Governor, State of Hawaii
c/o Office of Environmental
  Quality Control
220 South King Street, 4th Floor
Honolulu, Hawaii 96813

Dear Governor Waihee:

Subject: Livestock Agricultural Parks -
Kahuku and Ewa Uplands
Draft Environmental Impact Statement
TMK: 5-6-5: 9; 9-2-04: 5 and 6;
5-6-6: 6 and 19; 5-6-8: 2

This is in response to your request for our review of the Draft Environmental Impact Statement for the Oahu Livestock Agricultural Parks project.

Our reply to the Environmental Assessment for this project dated August 18, 1992 is still applicable.

Should you have any questions, please contact Wayne Nakamoto of my staff at 523-4190.

Sincerely,

(for) JOSEPH M. MAGALDI, JR.
Director

cc: State Department of Agriculture
M & E Pacific, Inc.

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Mr. Joseph M. Magaldi
Director
Department of Transportation Services
City and County of Honolulu
650 South King Street
Honolulu, Hawai'i 96813

Dear Mr. Magaldi:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter dated January 12, 1993, concerning the subject project. You indicated that comments in a previous letter dated August 18, 1992, are "still applicable."

Our reply to that letter, dated November 30, 1992, addresses those comments.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

Attachment

JOHN WAIHEE
Governor

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

November 30, 1992

Mr. Joseph M. Magaldi, Jr.
Director
Department of Transportation Services
City and County of Honolulu
650 South King Street
Honolulu, Hawaii 96813

Dear Mr. Magaldi:

Subject: Response to Comments on Environmental Assessment (EA) and Notice of Preparation of Environmental Impact Statement (EIS) for Oahu Livestock Agricultural Park

Thank you for your response dated August 18, 1992.

The topics addressed in your letter include:

(1) Use of City and County of Honolulu design standards for roads to be dedicated to the City and County of Honolulu.

(2) Review of preliminary road master plan and construction drawings.

The Department of Agriculture intends to maintain roads within the livestock agricultural park. A road master plan will be submitted in conjunction with subdivision plan revisions. Construction drawings in turn will be submitted for review by the City and County of Honolulu.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

YK:lt

Island Fresh

RECEIVED FEB 1 1993

POLICE DEPARTMENT
CITY AND COUNTY OF HONOLULU
801 SOUTH BERETANIA STREET
HONOLULU, HAWAII 96813 - AREA CODE (808) 529-3111

FRANK F. FASI
MAYOR

MICHAEL S. NAKAMURA
CHIEF

HAROLD M. KAWASAKI
DEPUTY CHIEF

OUR REFERENCE ES-LK

January 29, 1993

The Honorable John Waihee
Governor of Hawaii
c/o Office of Environmental Quality Control
220 South King Street, 4th Floor
Honolulu, Hawaii 96813

Dear Governor Waihee:

We have reviewed the draft environmental impact statement for the proposed Oahu Livestock Agricultural Park and have only one comment. The section on "Police" on page 155 contains one error: the command that would service this project is District 4, not District 3.

Thank you for the opportunity to comment.

Sincerely,

MICHAEL S. NAKAMURA
Chief of Police

By
CHESTER E. HUGHES
Assistant Chief of Police
Support Services Bureau

cc: Department of Agriculture
M&E Pacific, Inc.

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Mr. Michael S. Nakamura
Chief of Police
Police Department
801 South Beretania Street
Honolulu, Hawaii 96813

Attention: Chester E. Hughes
Assistant Chief of Police
Support Services Bureau

Dear Chief Nakamura:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter dated January 29, 1993, which pointed out an error concerning the command that would service the project in Kahuku. We will correct the final environmental impact statement to read District 4, not District 3, on page 156.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

Hawaiian Electric Company, Inc. • PO Box 2750 • Honolulu, HI 96840-0001

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William A. Bonnet
Manager
Environmental Department

January 26, 1993

The Honorable John Waihee
Governor, State of Hawaii
c/o Office of Environmental Quality Control
220 South King Street, 4th Floor
Honolulu, Hawaii 96813

Dear Governor Waihee:

Subject: **Draft Environmental Impact Statement (DEIS)**
Oahu Livestock Agricultural Park
Ewa and Koolauloa, Oahu

We have reviewed the subject DEIS, and have no comments at this time on the proposed project. HECO shall reserve further comment pertaining to the protection of existing transmission facilities within the proposed development areas when construction plans are finalized.

Sincerely,

cc: Brian J.J. Choy
Dr. Paul J. Schwind
Dr. Jemes R. Dexter

An HEI Company

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Mr. William A. Bonnet
Manager, Environmental Department
Hawaiian Electric Company, Inc.
P.O. Box 2750
Honolulu, Hawai'i 96840-0001

Dear Mr. Bonnet:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter dated January 26, 1993, concerning the subject project. Although you have no specific comments at present, we acknowledge your request to reserve further comment until construction plans are finalized.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

SEND COPIES TO
APPROPRIATE PARTIES

POSTED
FEB - 1 1993

The Hawai'i — Lā'ieikawai Association, Inc.
P.O. Box 720, Ka'a'awa, Hawai'i 96730 • Phone (808) 237-7015/(808) 237-7339 • Fax (808) 237-8968

February 1, 1993

Memo to: Office of Environmental Quality Control

From: Dr. Jim Anthony, Executive Director

Subject: O'ahu Livestock Agricultural Park Draft EIS

We wish to be accorded consulted party status with respect to the above referenced EIS. We oppose this project for a number of reasons: environmental in particular.

'93 FEB -2 P12:58
OFC. OF ENVIRON.
QUALITY CONT.

bc: Dr. Paul J. Schwind, Dept. of Agriculture
✓Dr. James Dexter, M&E Pacific Inc.

RECEIVED FEB 4 1993

The Hawai'i — Lā'ieikawai Association, Inc. is a non-profit corporation whose activities include research and education related to Hawaiian cultural issues and the environment

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Dr. Jim Anthony
Director
The Hawai'i-Lā'ieikawai Association, Inc.
P.O. Box 720
Ka'a'awa, Hawai'i 96730

Dear Dr. Anthony:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

We acknowledge your request to be a consulted party for the subject project.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

SEND COPIES TO
APPROPRIATE PARTIES

POSTED
FEB -3 1993

The Nature Conservancy of Hawaii

• 1116 SMITH STREET • SUITE 201 • HONOLULU, HAWAII • 96817 • PH: (808) 537-4508 • FAX (808) 545-2019

February 4, 1993

RECEIVED FEB 9 1993

'93 FEB -5 P12:59

OFC. OF EN[illegible]
QUALITY [illegible]

Governor, State of Hawaii
c/o Office of Environmental Quality Control
220 South King Street, 4th Floor
Honolulu, Hawaii 96813

Subj: Oahu Livestock Agricultural Park

Dear Governor Waihee;

I have reviewed the draft environmental impact statement on the proposed Oahu Livestock Agricultural Park. The Honouliuli Preserve, currently under the management of The Nature Conservancy of Hawaii, shares a property boundary with the northwest corner of the proposed Palikea site. (enclosure)

The Honouliuli Preserve is home to more than 45 rare plant and animal species, and contains some of the last remaining habitat on Oahu for native forest birds. Additionally, the preserve protects species of Hawaiian plants found nowhere else in the world and several rare native land snail species. Part of the Conservancy's mission is to ensure that these and other native plant and animal species are protected in perpetuity. Threats include introduced, non-native plants and animals.

The project as outlined in the site proposal presents two possible impacts to Honouliuli Preserve. First, if cattle were to escape onto preserve property, they could damage native plants. However, since the proposal includes measures for a fence, this problem is minimized. Second, a threat may exist if alien plants not currently found on Oahu are introduced for cattle grazing. These plants could alter native ecosystems if they spread into the preserve. This could be mitigated by choosing plants already found in the area or used elsewhere on Oahu.

Thank you for considering the potential environmental effects of the agricultural park on one of Hawaii's native natural areas. Please contact me if I can provide further information.

Sincerely,

Barrie Fox Morgan

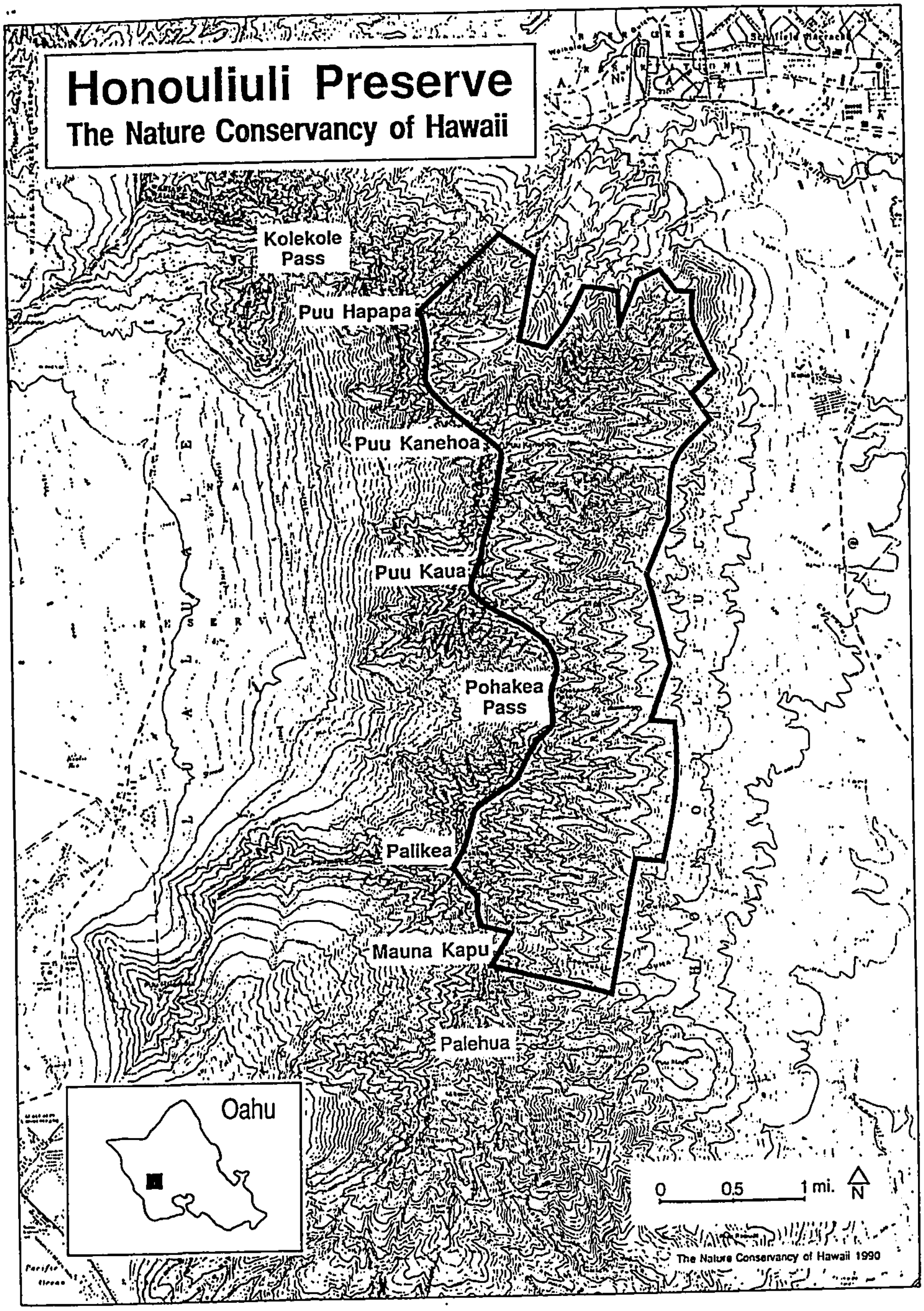
Barrie Fox Morgan
Director, Oahu/Lanai Programs

c: Dr. Paul J. Schwind
Dept. of Agriculture
✓Dr. James Dexter
M&E Pacific, Inc.

Enclosure

International Headquarters, 1815 North Lynn Street, Arlington, Virginia 22209

Recycled Paper



Honouliuli Preserve

The Nature Conservancy of Hawaii

The Nature Conservancy of Hawaii 1990

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Ms. Barrie Fox Morgan
Director, Oahu/Lanai
The Nature Conservancy of Hawaii
1116 Smith Street, Suite 201
Honolulu, Hawaii 96817

Dear Ms. Morgan:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter of February 4, 1993, on the Oahu Livestock Agricultural Park.

You mentioned potential cattle impacts within the Honouliuli Preserve. This is a good point that is generally applicable to all sites. You may have information that would be helpful in our planning.

As you are no doubt aware, beef cattle are being grazed in the gulches and some slopes since discontinuation of sugarcane at Palikea. It would be helpful to know the number of incidents of cattle escaping and climbing the higher slopes into the preserve. Perhaps you could share recollections or accounts of these incidents with us.

We will evaluate the requirements for fencing of the preferred site at Kahuku. Dairy operators often remark that dairy cows will not wander far from feed and water, even if left to pasture.

Thank you for calling this to our attention.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

Island Fresh

JAN 1 - 1993

January 13, 1993

Dear Dr. Schwind,

I address the following remarks to the Environmental Impact Statement for the proposed Oahu Livestock Agricultural Park. Thank you for taking the time to discuss the matter during our phone conversation last week.

Sincerely,

William Harris

William Harris M.D.
1765 Ala Moana Blvd. #1880
Honolulu, HI 96815
(808) 941-8151

January 13, 1993

THE OAHU LIVESTOCK AGRICULTURAL PARK: A DISSENTING VIEW

Animal agriculture is, in general, costly and inefficient. The consumption of animal foods results in medical costs which are borne by the taxpayers. Government intrusion into the free market is unwise and probably unconstitutional to begin with, but intrusion on the side of animal agriculture is irrational as well.

Dairy products are advertised on the basis of their calcium content, and meat is recommended for its protein. These nutritional mis-perceptions depend critically on the sorting of foods by nutrient/weight ratio, rather than the more scientific nutrient/Calorie ratio. In a calcium/Calorie sort the first dairy product trails a dozen leafy green vegetables. While some meats and fish still *lead* the protein/Calorie sort, foods like broccoli and chard have the edge over hamburger and sirloin.

Using USDA 1988 market price data[1] and USDA nutrient data[2], the following graphs were constructed, showing the calcium/*cost* and protein/*cost* ratios for various foods. Included are free market fruits and vegetables, USDA price supported dairy and field crops, and other animal source foods which receive de facto supports from price supported feed grains. In these charts no cost adjustments have been made to reflect the tax dollars which have been already been used to grow the feed grains. In the absence of price supports it seem likely the grain farmers would charge more for less feed grain and the price of animal source food would go up still more.

(Please see graphs entitled "Calcium and Cost, 1988" and "Protein and Cost, 1988").

The efficiency with which animals convert plants to animal food for human consumption varies by species.[3] The following chart indicates that chickens waste ~ 100 - 26 = 74% of the plant protein they eat to make eggs; young sheep waste ~ 100 -2.5 = 97.5% of the plant Calories they ingest to produce lamb.

(Please see graph entitled "Conversion Efficiency").

Animal food and field crop protein production clearly requires more land than horticulture[4] (e.g. cabbage, snap beans, and green peas):

(Please see graph entitled "Land Use Efficiency").

The conversion efficiency and land use efficiency of animal source foods reflect, among other things, the rate at which food animals utilize and contaminate the water supply, waste fossil fuel, and degrade the environment, over and above the rate at which plant agriculture does the same. If we were to factor in the feed grain price supports, plus conversion and land use efficiency losses, the picture for animal foods would be even more dismal than the nutrient/cost charts indicate.

However, even without adjusting for these factors, the leaders in the calcium/cost and protein/cost graphs, are *not* dairy products and meats, but various plant foods. They retain their nutritional and economic advantages with or without price supports.

The U.S. medical budget was about $760 billion in 1991. It's projected to go to $2 trillion by AD 2000. About $577 billion of the initial figure went for patient care and $270 billion of *that* went to the treatment of diseases now known to be partly the result of animal source food consumption.

There are multiple factors in the cause of most disease. Risk factors such as inactivity, smoking, and heredity, are also involved, but World Health Organization, and Food and Agriculture Organization data show that many diseases correlate with animal food consumption. Correlation does not prove causality; however, there are other clinical and experimental sources which confirm and illuminate the apparent causal relationship between animal fat and animal protein for the following diseases:

(Please see graph entitled "Estimated U.S. Medical Costs")

Should you be interested in the statistical method used to arrive at the estimate of ~ $112 billion/year I will be happy to provide it. Please note that many conditions such as obesity and ovarian cancer are not included, (WHO does not keep incidence rates) although they are probably also related.

Hawaiian citizens no doubt have the right to make poor food choices, but the government should not be footing the bill. One can understand the idea of rescuing agricultural land from non-agricultural development, but there is no rational basis for handing it over to the least efficient, least healthy, and most environmentally degrading segments of agriculture, the dairy and livestock interests. First choice for this land should go to horticultural food crop growers who are, at present, specifically excluded from the USDA price support system[5].

Sincerely,

William Harris M.D.
1765 Ala Moana Blvd. #1880
Honolulu, HI 96815

REFERENCES

1. United States Department of Agriculture. *Agricultural Statistics, 1989*. United States Government Printing Office. Washington, 1989. Table 623.

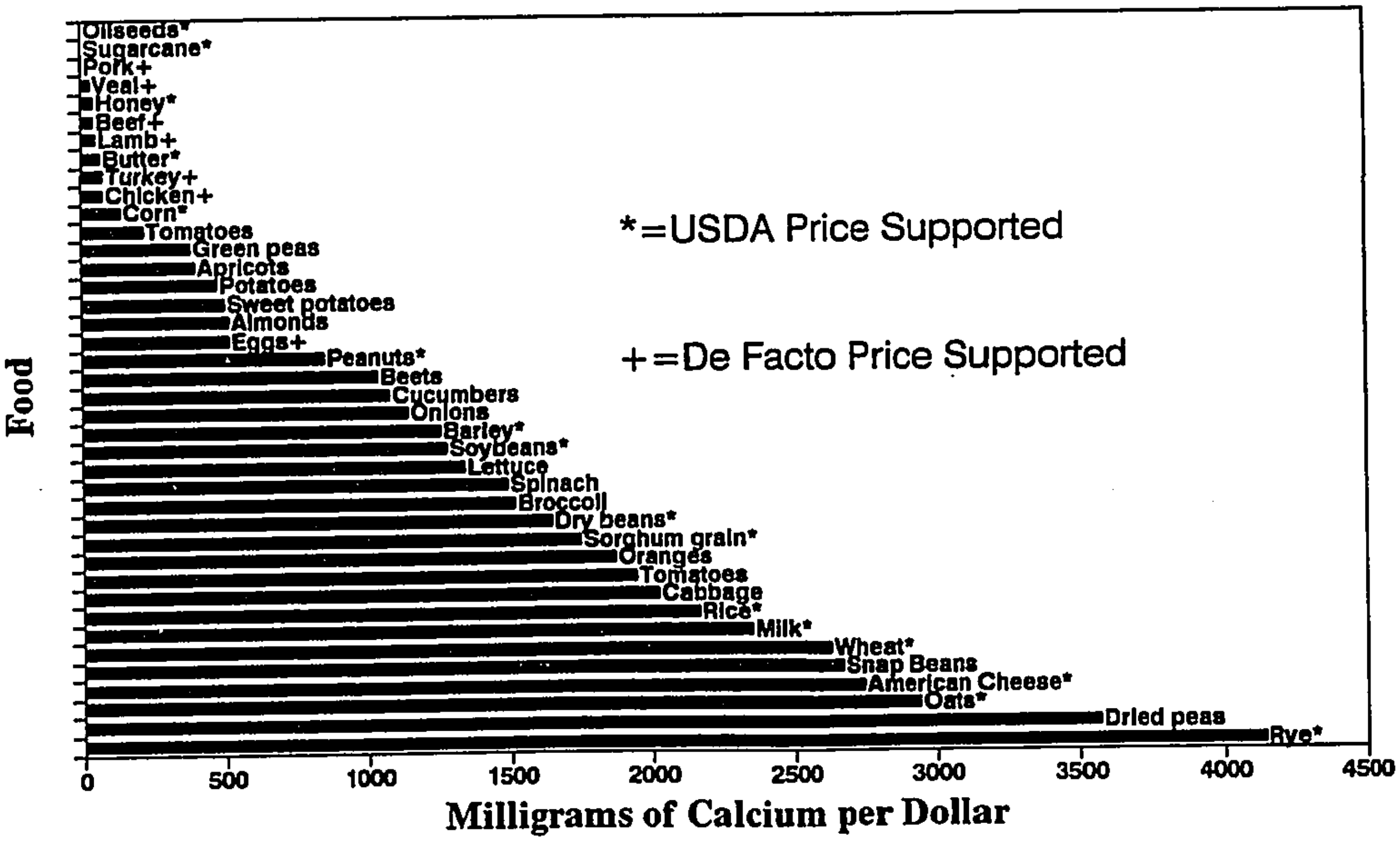
2. United States Department of Agriculture. *Composition of Foods*. Agriculture Handbook No. 8. U.S. Government Printing Office. Washington, DC 20402, 1963.

3. Scientific American. *Human Nutrition*. W.H Freeman. San Francisco, 1978. ISBN 0-7167-0183-9. p 35.

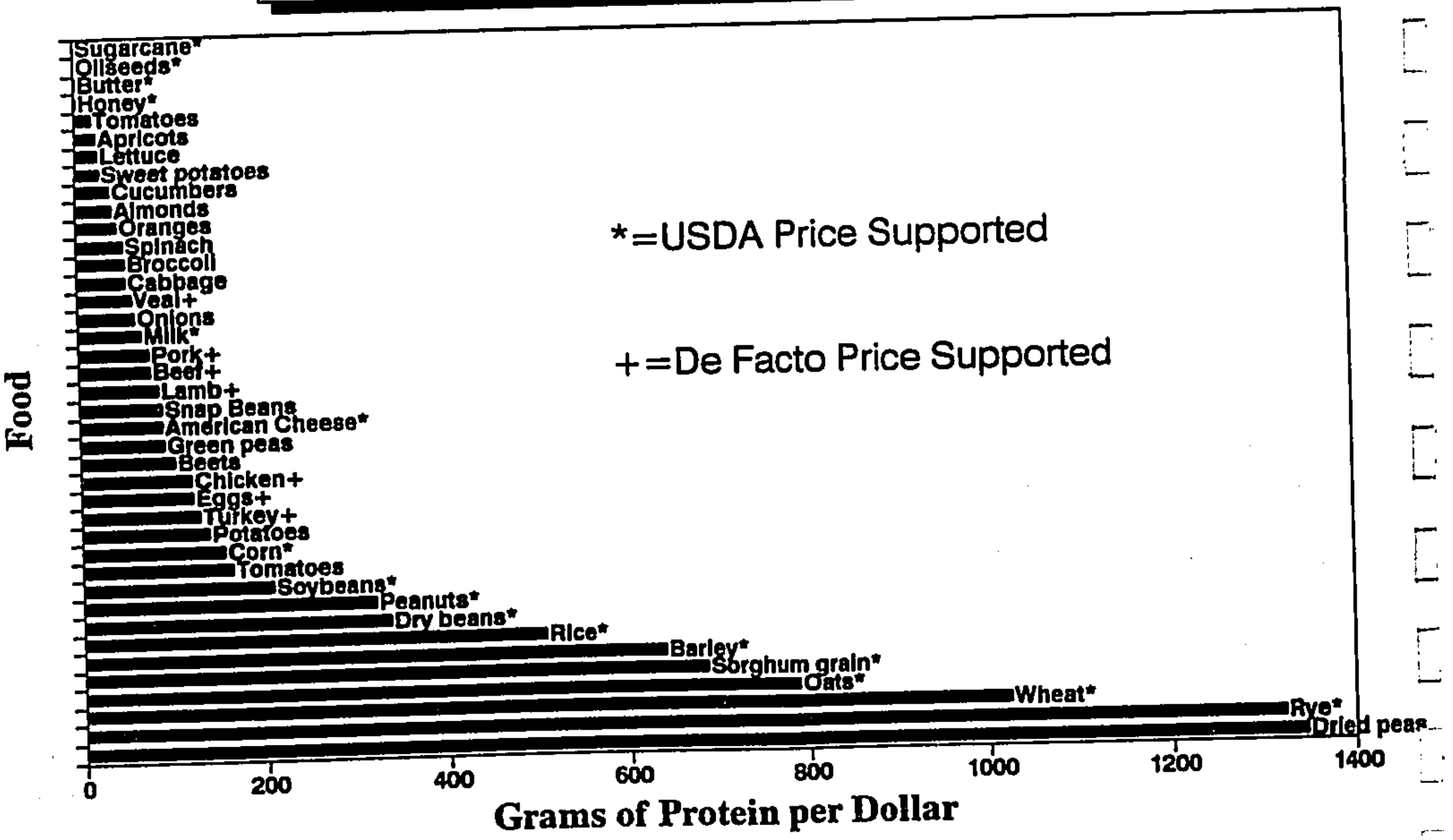
4. Spedding CRW. *The Biology of Agricultural Systems*. Academic Press. London, 1975. ISBN 0-12-656550-3. p 107.

5. United States Department of Agriculture. Economic Research Service. *Provisions of the Food, Agriculture, Conservation, and Trade Act of 1990*. Agriculture Information Bulletin Number 624. Washington, 1991. p vii.

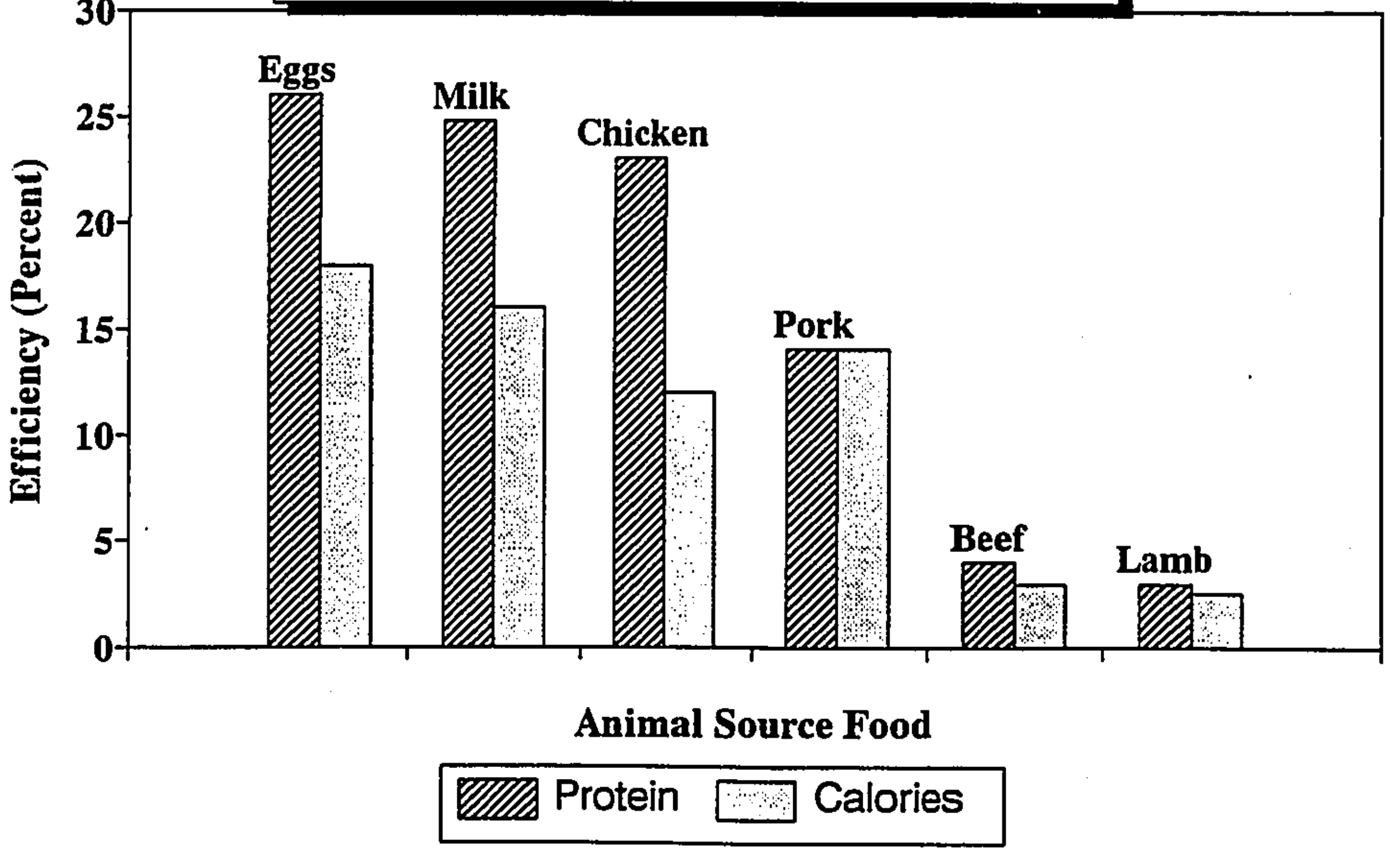
Calcium and Cost, 1988
(At Market Prices Paid to Farmers)

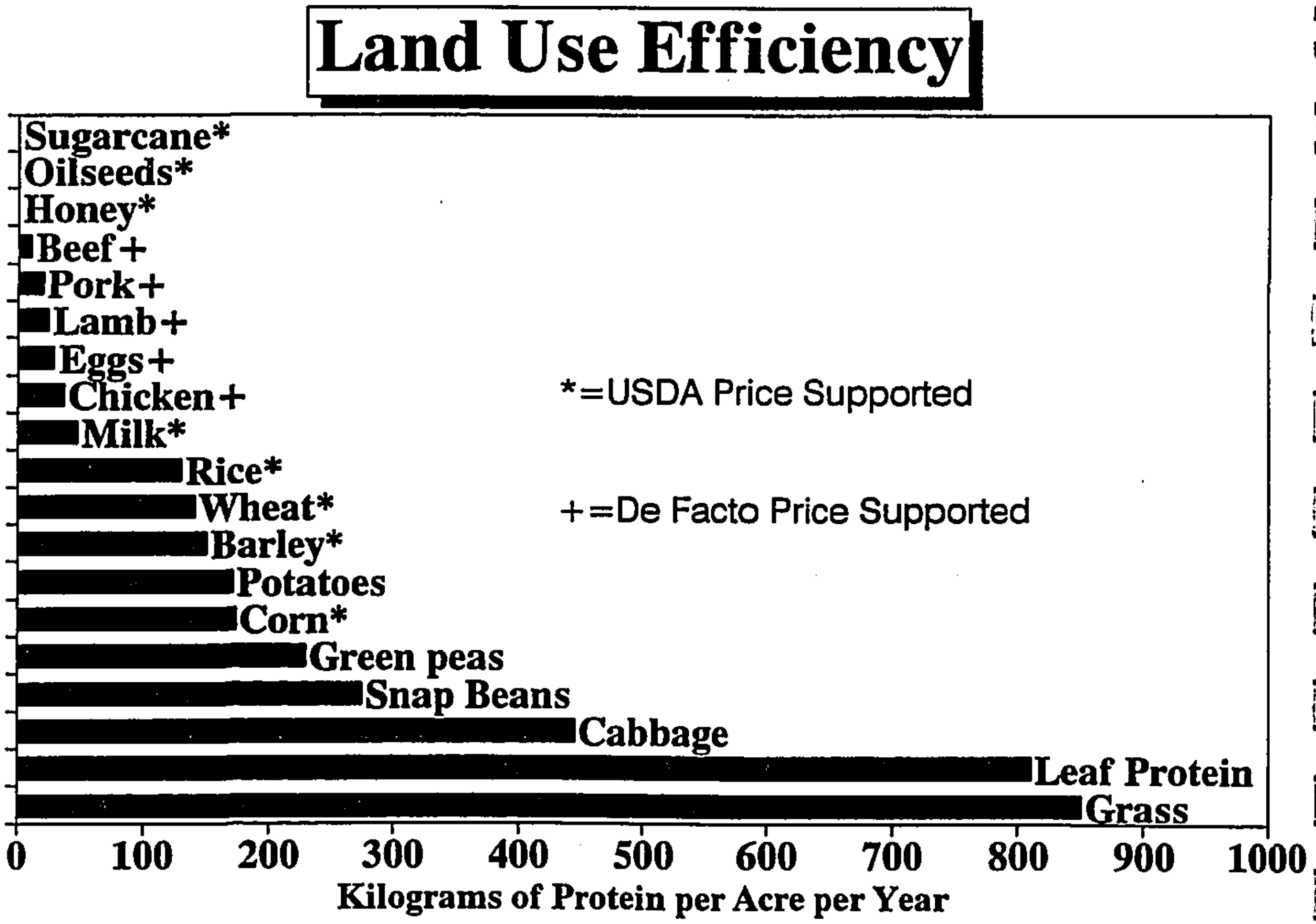


Protein and Cost, 1988
(At Market Prices Paid to Farmers)



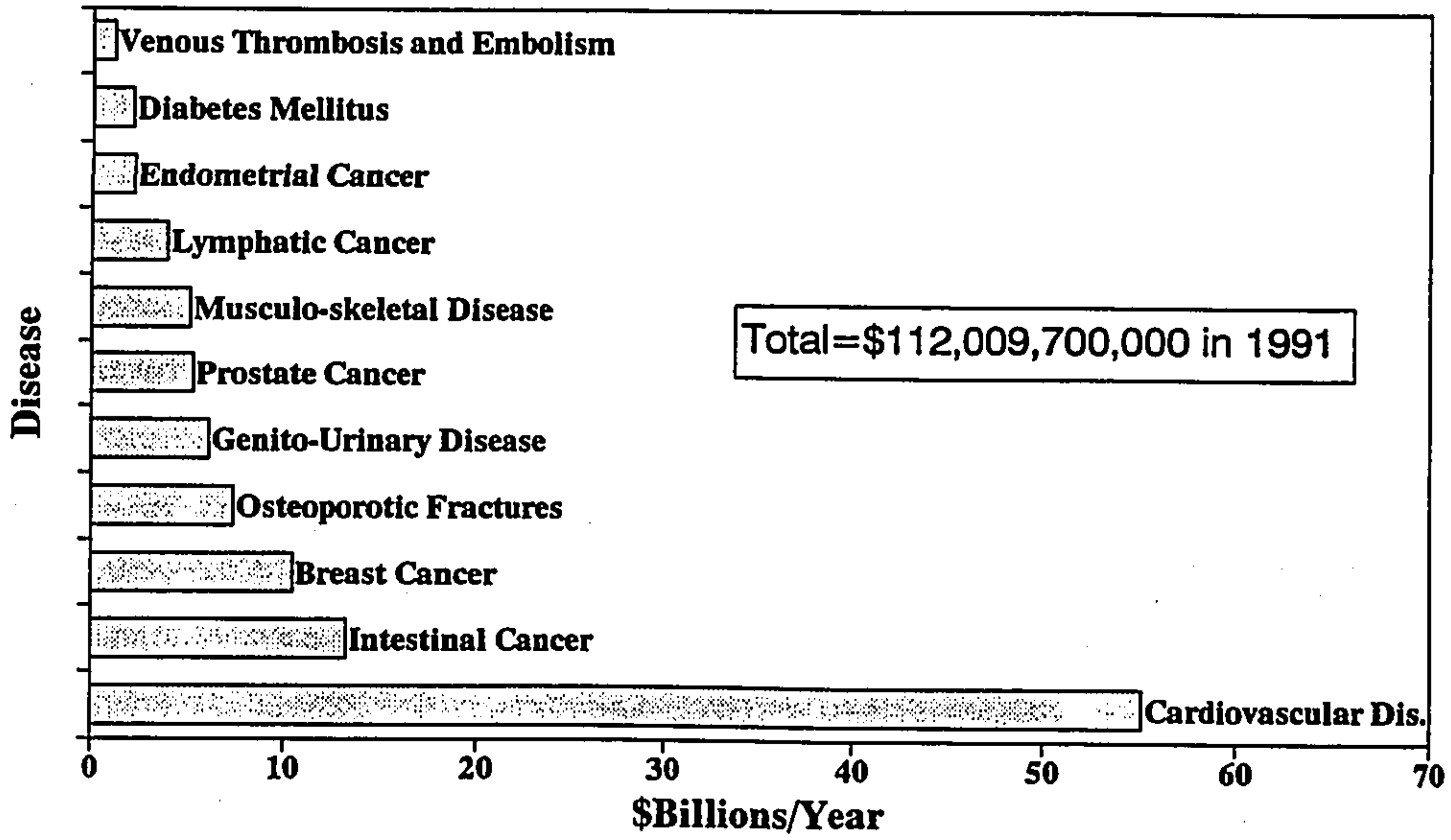
Conversion Efficiency
From Plant to Animal Food





Land Use Efficiency

Estimated U.S. Medical Costs
Resulting From Animal Source Food



JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Dr. William Harris
1765 Ala Moana Blvd., #1880
Honolulu, Hawai'i 96815

Dear Dr. Harris:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for the comments in your letter dated January 13, 1993. You expressed concern on developing a livestock agricultural park and on the animal industry in general.

The mission of this project is helping the small, family-owned and operated dairies that are being directly displaced in Wai'anae.

From the standpoint of efficiency of food production, there are practical considerations. Milk provides a healthy food alternative for O'ahu. The draft environmental impact statement refers to a site less than 60 acres in the Kahuku Agricultural Park for dairy operations. If fully developed, approximately 13,000 gallons of milk are expected from dairies in a controlled, free-stall environment. This is about one-third of the milk supplied to the Honolulu market. We believe that setting aside 60 acres out of a total 388,900 acres on O'ahu for this purpose is a reasonable commitment.

Vegetable and fruit production incur costs also and are not necessarily cheaper alternatives for nutrients from milk. Some crops, as experience has shown, suffer from the year-round attacks of insects, disease, and competitive plants. The agricultural products that have been economically successful already fill a niche in the market place. The alternative of milk is still necessary; not for everyone, but for a significant segment of our population.

The Department of Agriculture implements legislative policy. That policy is to provide suitable public lands at reasonable cost with long-term tenure for commercial agriculture for both plant and animal farming. The Kahuku Agricultural Park supports fruit and vegetable crops. The proposal under consideration is providing the same opportunity to the family-owned and operated dairies in Wai'anae.

Island Fresh

Concerning waste disposal, an extensive amount of engineering has already gone into evaluation of processes that reclaim animal waste for reuse as soil amendment and fertilizer. A lot of attention is being given in Hawai'i to manure management and reuse on the farm. It reduces the energy and costs required to import commercial chemical fertilizers, it helps improve farming on clay soils, and it helps to protect the environment from uncontrolled release of nutrients by reusing them in crop growth. These factors are considered in planning of the proposed project.

The proposed project does not provide capacity for all of the present market demand. There are over 7,500 cows presently on O'ahu, at most. This project can accommodate less than a third of the total. The preservation of the industry means O'ahu consumers will have alternatives for their choice of nutrition. There is a demand for fresh whole milk, approximately 40,000 gallons per day during the peak season. We expect that milk production will continue to be a significant part of diversified agriculture in the foreseeable future because of the nutritional value for children and for women with infants. Otherwise, Hawai'i will become totally dependent on mainland suppliers for milk.

You expressed concerns about constitutionality of the proposed project. Article XI of the State Constitution lays out the mandate of this department to "conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency, and assure the availability of agriculturally suitable lands." Hawai'i's food production is one of our goals; this is a stated objective of the Department of Agriculture in its 1991 State Agriculture Functional Plan. The mission statement in the Plan is to increase the overall level of agricultural development in Hawai'i, including diversified agriculture. The agricultural parks program is a vital tool for meeting the objectives of the program.

In conclusion, personal nutritional habits and accompanying private sector investment are matters of individual choice. Our mission is providing for choices in nutrition by maintaining maximum agricultural productivity to attain and maintain a steady supply of island-fresh products.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

RECEIVED
JAN 26 1993
PLANNING/DEVELOPMENT OFFICE
DEPARTMENT OF AGRICULTURE

Ruth E. Heidrich, M.S.
1415 Victoria St. #1106
Honolulu, HI 96822
Ph (808) 536-4006

January 26, 1993

Dr. Paul Schwind
Hawaii Department of Agriculture
P.O. Box 22159
Honolulu, Hawaii 96823-2159

Dear Dr. Schwind,

Having just been made aware of the proposal to create a livestock agriculture park, I am writing to ask you to consider creating instead a horticultural agriculture park.

I am very interested in this issue as a result of having been diagnosed with breast cancer and discovering through epidemiological data that the more animal products people eat, the greater the incidence of not only breast cancer but the other three most common kinds of cancer as well. There is also a very clear correlation between animal product consumption and the incidence of heart disease, stroke, diabetes, kidney disease, osteoporosis, and obesity.

A study recently published through Harvard University cites the correlation between dairy products and childhood onset diabetes in young children. Another study released about two years ago cites the correlation between dairy consumption and ovarian cancer. More and more pediatricians are noting that middle ear infections are caused by dairy products and recommending that children not be given cows milk.

Another very significant impact of animal agriculture will be on the environment. Besides being grossly inefficient, (it takes 16 pounds of grain to produce 1 pound of meat), the grazing of animals is deadly to the land. Not only do cows overgraze, but their hooves pack down the soil so compactly that nothing else can grow. This creates the process of desertification and the negative effects of this phenomenon are finally being recognized by those most concerned with saving our croplands.

Then there's the problem with waste disposal. The situation of the contamination of our drinking water and the oceans from the dairies in Waimanalo was recently highlighted in our newspapers. One cow produces as much waste as 16 humans and the livestock in this country produce twenty times as much excrement as the entire human population of the country. Much of this waste ends up in our water. This does not even address the waste of our precious water supplies so limited on our relatively isolated island environment. A quote from *Newsweek*, "The water that goes into a 1,000 pound steer would float a destroyer."

In looking to the future, as this information gets more widely disseminated, the demand for animal food including dairy products will decrease. The demand for grains, vegetables and fruits will increase. This is the direction that we should be aiming and planning for.

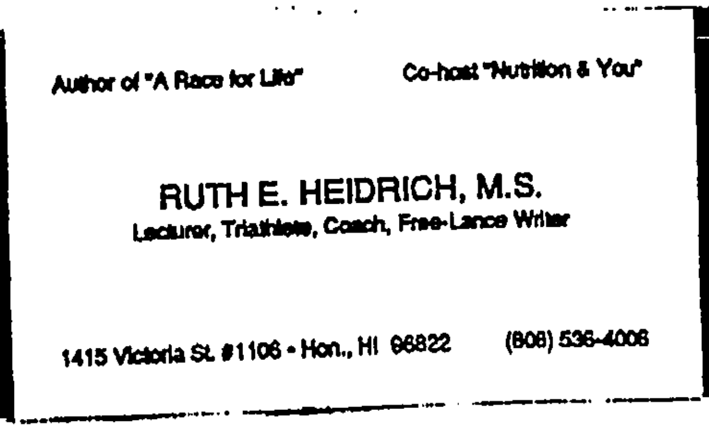
One last thought. If you have lived here for any length of time, then you recall from time to time that we've been threatened with shortages of various items due to our dependence on shipping from the mainland. We should be striving to greater self-sufficiency on our most critical need -- food. One acre of land can produce many more pounds of plant food than animal food. This is the direction we must be heading for these reasons: our own health, the health of our land, and the most efficient use of all our resources.

Sincerely,

Ruth E Heidrich

Ruth E. Heidrich

bc: Jim Brewer 1/27/95



Author of "A Race for Life"　Co-host "Nutrition & You"

RUTH E. HEIDRICH, M.S.
Lecturer, Triathlete, Coach, Free-Lance Writer

1415 Victoria St. #1106 • Hon., HI 96822　(808) 536-4006

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

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Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

April 26, 1993

Ms. Ruth E. Heidrich
1415 Victoria Street, #1106
Honolulu, Hawai'i 96822

Dear Ms. Heidrich:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for the comments in your letter dated January 26, 1993.

Your letter expressed concern regarding the advisability of developing a livestock agricultural park and your preference for a horticultural park.

General nutritional advice (please refer to the accompanying brochure) recommends that the majority of foods consumed be low in fat, high-volume, and high-fiber foods. However, note that low-fat dairy products are still considered part of the nutritional "food guide pyramid," but in much more modest quantities than vegetable, fruit, and complex carbohydrate groups. This is because they are rich sources of essential minerals and nutrients. For certain groups within the population, for example infants and adolescents, the recommended intake of calcium is easier to achieve with milk. For example, a teen-age girl would require four cups of beans, three cups of tofu, or two cups of watercress to obtain the equivalent calcium in a glass of milk. Deficiency in the adolescent years is believed to be related to later problems in life including osteoporosis and heart disease. It seems that if one is going to live "low on the pyramid" as you recommend, it is necessary to know the quantity of plant products that must be substituted, and insure they are prepared in a form that is palatable. From a practical standpoint, the amount of public education that is needed—and given active lifestyles of today's adolescents—we maintain that it is more risky to promote total abstinence from milk and milk products.

From the standpoint of the food production efficiency, there are practical considerations. Milk provides a healthy food alternative for consumers. The site plan considered in the draft environmental impact statement proposes less than 60 acres be set aside on the Kahuku Agricultural Park for dairy operations. If fully developed, approximately 13,000 gallons of milk could be produced from dairies in a confined environment. This is about one-third of the milk supplied to the Honolulu market. We believe that using 60 acres out of a total 388,900 acres on O'ahu is a reasonable commitment to help the dairy farmers.

Vegetable and fruit production incur costs also and are not necessarily cheaper alternatives for nutrients from milk. Some crops, as experience has shown, suffer from year-round attacks of insects, disease, and competitive plants. The agricultural products that have been economically successful already fill a niche in the market place. Milk is still necessary; not for everyone, but for a significant segment of our population.

The Department of Agriculture implements legislative policy. That policy is to provide suitable public lands at reasonable cost with long-term tenure for commercial agriculture for both plant and animal farming. The Kahuku Agricultural Park supports fruit and vegetable crops. The proposal under consideration is providing the same opportunity to the family-owned and operated dairies in Wai'anae.

Concerning waste disposal, an extensive amount of engineering has already gone into evaluation of processes that reclaim animal waste for reuse as soil amendment and fertilizer. A lot of attention is being given in Hawai'i to manure management and reuse on the farm for crops. The idea here is to foster symbiosis between plant and animal agriculture.

The proposed project does not provide capacity for all of the present market demand. There are over 7,500 cows presently on O'ahu. This proposed project can accommodate less than a third of the total. The preservation of the industry means O'ahu consumers will have alternatives for their choice of nutrition. There is a demand for fresh whole milk, approximately 40,000 gallons per day during the peak season. We expect that milk production will continue to be a significant part of diversified agriculture in the foreseeable future because of the nutritional value for children and for women with infants. Otherwise, Hawai'i will become totally dependent on mainland suppliers for milk.

You expressed concerns about constitutionality of the proposed project. Article XI of the State Constitution lays out the mandate of this department to "conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency, and assure the availability of agriculturally suitable lands." Hawai'i's food production is one of our goals; this is a stated objective of the Department of Agriculture in its 1991 State Agriculture Functional Plan. The mission statement in the Plan is to increase the overall level of agricultural development in Hawai'i, including diversified agriculture. The agricultural parks program is a vital tool for meeting the objectives of the program.

In conclusion, changing personal nutritional habits and accompanying private sector investment are matters of individual choice. Our mission is providing for choices in nutrition by maintaining maximum agricultural productivity to attain and maintain a steady supply of island-fresh products.

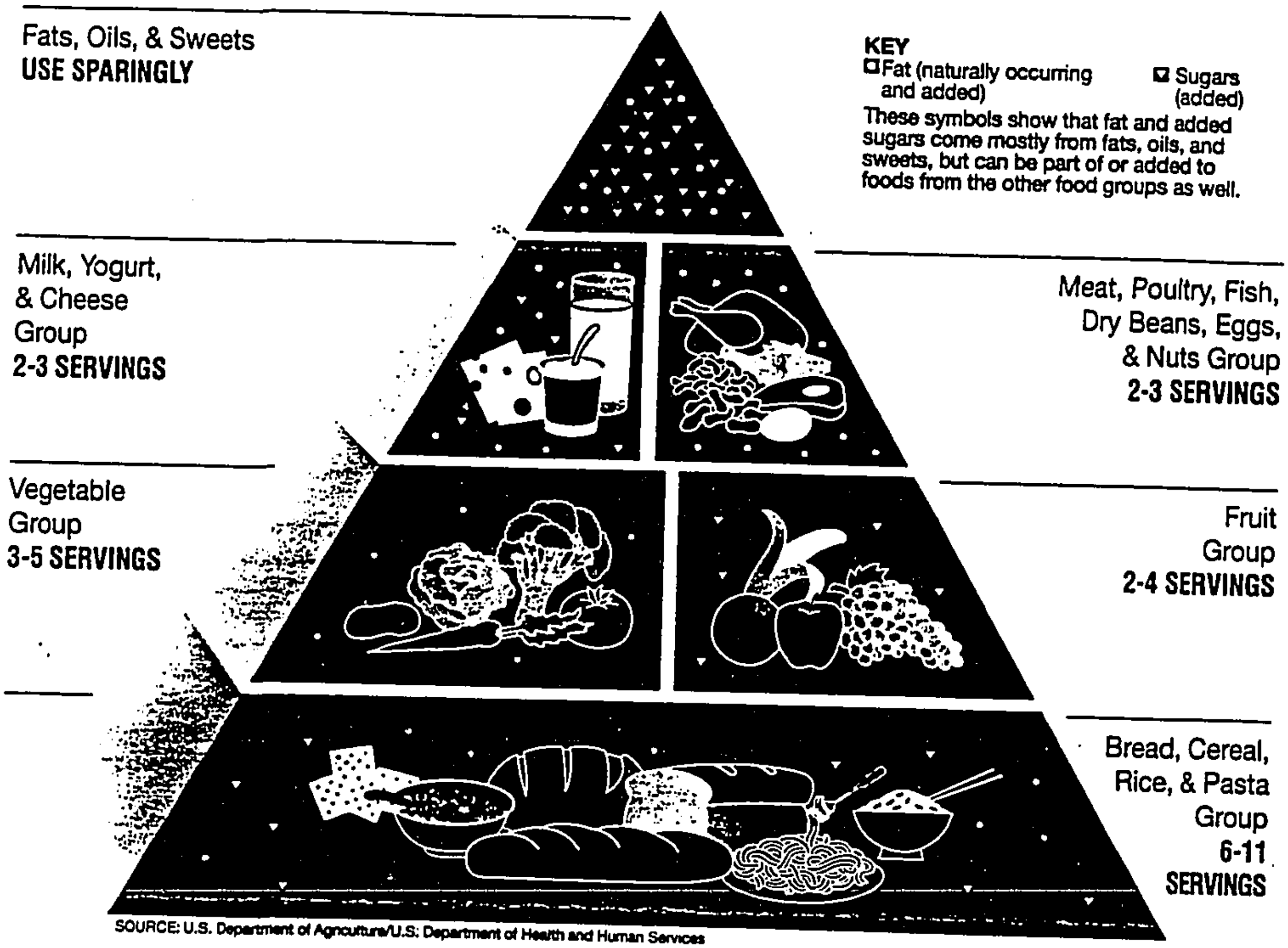
Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

Attachment

Food Guide Pyramid

A Guide to Daily Food Choices



These symbols show that fat and added sugars come mostly from fats, oils, and sweets, but can be part of or added to foods from the other food groups as well.

SOURCE: U.S. Department of Agriculture/U.S. Department of Health and Human Services

Use the Food Guide Pyramid to help you eat better every day. . .the Dietary Guidelines way. Start with plenty of Breads, Cereals, Rice, and Pasta; Vegetables; and Fruits. Add two to three servings from the Milk group and two to three servings from the Meat group.

Each of these food groups provides some, but not all, of the nutrients you need. No one food group is more important than another — for good health you need them all. Go easy on fats, oils, and sweets, the foods in the small tip of the Pyramid.

To order a copy of "The Food Guide Pyramid" booklet, send a $1.00 check or money order made out to the Superintendent of Documents to: Consumer Information Center, Department 159-Y, Pueblo, Colorado 81009.

U.S. Department of Agriculture, Human Nutrition Information Service, August 1992, Leaflet No. 572

How to Use The Daily Food Guide

What counts as one serving?

Breads, Cereals, Rice, and Pasta
1 slice of bread
1/2 cup of cooked rice or pasta
1/2 cup of cooked cereal
1 ounce of ready-to-eat cereal

Vegetables
1/2 cup of chopped raw or cooked vegetables
1 cup of leafy raw vegetables

Fruits
1 piece of fruit or melon wedge
3/4 cup of juice
1/2 cup of canned fruit
1/4 cup of dried fruit

Milk, Yogurt, and Cheese
1 cup of milk or yogurt
1-1/2 to 2 ounces of cheese

Meat, Poultry, Fish, Dry Beans, Eggs, and Nuts
2-1/2 to 3 ounces of cooked lean meat, poultry, or fish
Count 1/2 cup of cooked beans, or 1 egg, or 2 tablespoons of peanut butter as 1 ounce of lean meat (about 1/3 serving)

Fats, Oils, and Sweets
LIMIT CALORIES FROM THESE
especially if you need to lose weight

The amount you eat may be more than one serving. For example, a dinner portion of spaghetti would count as two or three servings of pasta.

How many servings do you need each day?

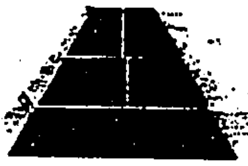
	Women & some older adults	Children, teen girls, active women, most men	Teen boys & active men
Calorie level*	about 1,600	about 2,200	about 2,800
Bread group	6	9	11
Vegetable group	3	4	5
Fruit group	2	3	4
Milk group	**2-3	**2-3	**2-3
Meat group	2, for a total of 5 ounces	2, for a total of 6 ounces	3 for a total of 7 ounces

*These are the calorie levels if you choose lowfat, lean foods from the 5 major food groups and use foods from the fats, oils, and sweets group sparingly.

**Women who are pregnant or breastfeeding, teenagers, and young adults to age 24 need 3 servings.

A Closer Look at Fat and Added Sugars

The small tip of the Pyramid shows fats, oils, and sweets. These are foods such as salad dressings, cream, butter, margarine, sugars, soft drinks, candies, and sweet desserts. Alcoholic beverages are also part of this group. These foods provide calories but few vitamins and minerals. Most people should go easy on foods from this group.



Some fat or sugar symbols are shown in the other food groups. That's to remind you that some foods in these groups can also be high in fat and added sugars, such as cheese or ice cream from the milk group, or french fries from the vegetable group. When choosing foods for a healthful diet, consider the fat and added sugars in your choices from all the food groups, not just fats, oils, and sweets from the Pyramid tip.

Livestock Ag Park DEIS

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JAN 8 1993

(Dept. of Ag. stamp)

Eliot Jay Rosen MSW,LMT
2419 Pauoa Rd Suite E
Honolulu, Hawaii, 96813

To Whom It May Concern,

The purpose of this brief letter is to voice my concern regarding the proposed use of substantial portions of state land for the raising of cattle. It is my conviction that supporting plant agriculture instead, to be performed by disenfranchised native Hawaiians, would fulfil a dual need- that of empowering indigenous Hawaiians and at the same time protecting the aina.

It is generally accepted that all land use decisions should take into consideration both the short and long term effects on the eco-community of living organisms residing on the land as well as the protection of the land itself. The fact is however that power and politics all too often unduly influence land use issues. By selectively seeking out native Hawaiians who wish to cultivate their lands, we will in effect be giving them the "reparations" that in this 100th anniversary year they justly deserve. Or will we again be seduced by those with the loudest voices and thickest wallets?

As was exhaustively illustrated in such books as Beyond Beef by Jeremy Rifkin and Diet for a New America, by John Robbins, "animal agriculture" not only does little to meet the present and future needs of the people of Hawaii but does positive harm, to the invaluable natural resources of soil and water.

The effect of dairy products and beef on human health is also a growing concern and by now well-documented in the most prestigious scientific journals in the United States and around the world. Heart disease, osteoporosis, anemia, food-born diseases and adult onset diabetes are some of the diseases associated with the consumption of dairy and meat.

Please take some of these points into consideration when deciding how to use these state lands.

Sincerely,

Eliot Jay Rosen

Eliot Jay Rosen MSW LMT

c: ✓Dr. James Dexter, M&E Pacific, Inc.

JOHN WAIHEE
Governor

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
Deputy to the Chairperson

FAX: 973-9613

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96823-2159

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

April 26, 1993

Mr. Eliot Jay Rosen
2419 Pauoa Road, Suite E
Honolulu, Hawai'i 96813

Dear Mr. Rosen:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for the comments in your undated letter received January 28, 1993.

You have expressed concern regarding the proposed use of substantial portions of state lands for raising cattle and suggested instead plant agriculture to be performed by disenfranchised native Hawaiians.

There are several issues raised in your comments, and they are being addressed in ongoing programs and actions by different governmental and community organizations. Let's go over the salient features of the proposed project.

This project is intended to help the family-owned dairies that now face the possibility of losing their land leases. They must find another site or close down operations. These dairies supply a significant portion of the total milk demand on O'ahu. The alternatives for milk supply include importation from the mainland to meet the demand. Ultimately milk will come from the mainland if not produced locally. Consumption will not decrease because of shrinkage of the local supply.

Nutrition is another issue that you raised. You mentioned the diseases attributable to dairy products and beef. One thing is certain—milk and its products are not for everyone. For many, milk continues as a valuable source of nutrition not otherwise practical. The choice is the people's to make. The department's mission is providing the means for that choice.

The issue of public policy concerning the dairy industry is determined by the legislative bodies at the state and federal levels. The department does indeed support plant agriculture as well. In fact, the proposed project envisions a symbiosis between plant and animal agriculture at Kahuku by growing crops with organic fertilizer from manure and supplanting the importation of chemical fertilizer.

Note also that the recommendation for dairy operations in Kahuku is the free-stall operation. Basically, the cows are housed in such an operation to protect them from the elements while protecting the environment from uncontrolled emissions from manure and waste products. The overall waste management system is intended for reclamation of manure for fertilizer in plant agriculture.

The department is promoting the maximum agricultural productivity of the land in consonance with its ecology. Moreover, the department is intent on providing people the choices of nutrition of island-fresh quality.

Thank you for your concern and input.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

RECEIVED FEB 11 1993

January 28, 1993

Cynthia Smith
724-A Alewa Dr.
Honolulu, HI 96817
(808)595-5316

Dr. Paul Schwind
HI Department of Agriculture
P.O. Box 22159
Honolulu, HI 96823

Dear Dr. Schwind:

I am writing to express my strong opposition to the Oahu Livestock Agricultural Park in Kahuku. I am an instructor of history at Honolulu Community College, and have done a great deal of research into the area of animal agriculture and its environmental impacts for a public speech that I gave. Even the most cursory evaluation of the available research indicates that the environmental risks associated with animal agriculture are very high. The history is clear. Animal agriculture inevitably destroys the surrounding environment. History also clearly displays the sobering lesson that attempts to "manage" environmental pressures and destruction have been useless at best, and even in some cases have increased the speed of environmental decline.

Your draft EIS mentions, (all too briefly), the inevitable effects of a large concentration of domestic animals. Your rather vague statements about mitigating measures are misleading. Mitigation is extremely difficult, if not impossible when talking about domestic animal agriculture, and even if mitigation were possible, the very term itself denotes that some destruction of the environment would occur. In addition, some of the outlined mitigation measure, such as use of chemical control of insects would obviously add to the destruction of that ecosystem.

The clear alternative for this land, although sadly missing from your statement, is to have the land used for responsible (i.e. organic) plant agriculture which can be done without disruptive effects to the environment. This would also employ workers, and add to the diversity of our economy, while providing an additional source of non-imported, healthy food. This is much more desirable than bringing a large concentrated population of non-native animals into an ecosystem which because of its isolated nature is notoriously fragile.

The inevitable erosion which follows livestock production, as well as the corruption of the water supplies is far too great a cost for Hawaiian nature and citizens to bear. I am in fact appalled by your statement that there "may be adverse environmental impacts". Of course there will be. Anyone who is conversant with the existing literature and history is aware that since the time of Mesopotamia there has been environmental destruction associated with livestock. In Hawaii, the story is obvious from the destroyed rainforests and massive erosion that afflicts Maui, Kauaii etc directly attributable to livestock. Your hedging on this issue is either disingenuous, or dishonest; I can accept neither from an office which has a responsibility to its citizens to protect their land. Please evaluate this plan with a comprehensive and honest eye to the true costs. I would rather my son have a decent environment than the temporary (and illusory) economic benefits you describe; benefits which could be achieved with plant agriculture. Thank you for you time and attention.

Sincerely,

Cynthia Smith

JOHN WAIHEE
Governor

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814-2512

YUKIO KITAGAWA
Chairperson, Board of Agriculture

ILIMA A. PIIANAIA
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FAX: 973-9613

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Honolulu, Hawaii 96823-2159

April 26, 1993

Ms. Cynthia Smith
724-A ʻĀlewa Drive
Honolulu, Hawaiʻi 96817

Dear Ms. Smith:

Response to Comments on the Draft Environmental Impact Statement (DEIS) for the Oahu Livestock Agricultural Park

Thank you for your letter dated January 28, 1993, concerning the Oʻahu Livestock Agricultural Park project. Your comments are generally against animal agriculture and in favor of plant agriculture. Your views are well taken. However, others disagree. Ultimately, public policy on this matter is decided by our legislative bodies at the state and federal levels.

There are indeed historical accounts of mismanaged livestock farms where the environmental risks have been high. There are also accounts of well-managed farms where such risks do not exist. Guidelines for dairy management and beef cattle have evolved over the years to minimize or eliminate such risks. Plant agriculture also has its guidelines for minimizing environmental risks. Guidelines are all aimed at achieving compatibility with the ecology of the land. In the case of the Kahuku project, the focus is on developing a symbiosis between animal and plant agriculture rather than focusing on the differences between the two.

This proposed project is intended to help the dairy farmers who are faced with the possibility of losing their land leases. They must either move their operation or shut down completely. They are primarily the family-owned dairies in Waiʻanae who contribute significantly to the milk supply for Oʻahu.

Our department is intent on helping the dairy farmers in order to maintain the maximum level of agricultural productivity in this state, thereby continuing to provide the choices of food to meet the nutritional needs of the people.

The draft EIS refers to the free-stall method as the choice of dairy management for the Kahuku site. It is unlike the way dairies operate on the dry Wai'anae coast. The free-stall is a more expensive but necessary way of operation for the Kahuku area. In the free-stall system, the dairy cows are basically housed from the elements while protecting the environment from uncontrolled emissions of manure and waste products. The waste management system is planned to ultimately reclaim manure for its fertilizer value for use in the adjoining Kahuku farms. Reclamation can supplant imported chemical fertilizers being used for crops in a symbiotic relationship between animal and plant agriculture.

Thank you for your comments on the draft EIS.

Sincerely,

Yukio Kitagawa
YUKIO KITAGAWA
Chairperson, Board of Agriculture

APPENDIX J

ARCHAEOLOGICAL INVENTORY SURVEY OF THE PROPOSED 785-ACRE KAHUKU AGRICULTURAL PARK

Report By
CULTURAL SURVEYS HAWAII

July 1992
Revised February 1993

Archaeological Inventory Survey of the Proposed 785-Acre Kahuku Agricultural Park

by

Mark Stride
Tamara Craddock
and
Hallett H. Hammatt, Ph.D.

for

M and E Pacific, Inc.

Cultural Surveys Hawaii
Revised February 1993

Archaeological Inventory Survey of the Proposed 785-Acre Kahuku Agricultural Park

by

Mark Stride
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M and E Pacific, Inc.

Cultural Surveys Hawaii
July 1992

ABSTRACT

Cultural Surveys Hawaii was requested by M and E Pacific, Inc. to undertake an archaeological site inventory survey for the approximately 785-acre proposed Kahuku Ag Park Project (T.M.K. 5-6-8:2) in the *ahupua'a* of Kahuku and Keana, island of O'ahu. The survey and limited subsurface testing were conducted in the months of May and June 1992. The project area includes land presently under cultivation as well as former cultivated sugarcane and pineapple fields. Only very limited portions of the project area have not been modified for commercial agriculture and contain archaeological sites. Sites include rock shelters on limestone bluffs, wall structures and agricultural terraces. Throughout the project area is evidence of sugarcane and pineapple irrigation flumes and ditches. There are a total of sixty-three (63) Land Commission Awards in the *ahupua'a* of Kahuku and three (3) in the *ahupua'a* of Keana. No Land Commission Awards lie in the present project area, the majority of the Land Commission awards are *makai* of the project area.

The project area originally consisted of 1666 acres but was later revised to 785 acres. The original project area was divided into four areas: Area 1, 1B, 2 and 3 but was later revised to Area 2 and 3 only (Fig 3 & 4). At the time of the revision the majority of the original project area had been surveyed and a total of 21 archaeological sites were located, but only seven were in the present project area (State Site numbers 4510-4516). Limited subsurface testing was conducted at three of the archaeological sites. Site 4513 Feature B (Terrace), Site 4515 Feature B (Overhang Shelter), and Site 4516 Feature B (Overhang Shelter) were each tested with a single test trench (Trenches 1, 2, and 3). A human burial was discovered during the excavation of Trench 2, Site 4515 Feature B. The sites are concentrated on the west side of Ohia Gulch with one site located on a limestone bluff in the *makai* portion of the project area. Charcoal samples taken from sites 4515 and 4516 were Radiocarbon dated and revealed evidence of the prehistoric occupation of these sites. It is our recommendation that all seven sites be preserved.

ACKNOWLEDGEMENTS

We would like to thank Dr. James Dexter of M and E Pacific, Inc. for his continued support and cooperration through this project. Also, Dr. Paul Schwind and Mr. Yukio Kitagawa in their support through the State Department of Agriculture.

Recognition is given to Kaleo Ahina, Brian Colin, Susan Crotty, Ed Duncan, Aron Suzuki, who with the authors comprised the field crew. We would like to thank Bryce Myers for preparing the site maps. We would also like to thank Dr. Thomas Dye for providing access to information about the project area. Our appreciation is extended to the staff of the State Archives and the Bishop Museum Archives for their assistance in retrieving data related to this project.

Our sincere gratitude to Victoria S. Creed, Ph.D., her loyalty and expertise was unsurpassed in putting this report together.

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GLOSSARY

Aeolian	-deposited by the wind
A-horizon	-a soil layer characterized by the accumulation of organic matter at the ground surface
Ahu	-heap, pile, collection, mass, altar, shrine; a traplike stone enclosure made by fishermen for fish
Ahupua'a	-a traditional Hawaiian land unit extending from the mountain to the sea
Ali'i	-chief, chiefess, nobility
Archaeological feature	-the discrete remains of post activity preserved in the ground
Artifact	-any object made by man
B-horizon	-a subsurface soil layer characterized by clay accumulation
Carbonate	-Calcium carbonate
cmbs	-centimeters below soil surface
Flake	-a piece of stone struck from a larger piece
Historic	-in Hawaii, the period after the landing of (post contact) Captain Cook in 1778.
'ili	-a small land unit, a subdivision of an ahupua'a
in situ	-the place of original deposition
loko	-fishpond.
lo'i	-a wetland taro field
makai	-towards the sea
mala	-garden
mauka	-towards the mountains
midden	-faunal and floral remains from archaeological deposits, usually food remains

morai	-word used in Tahiti and by many sailors of the 18th century for a temple, or *heiau* in Hawaiian.
ohana	-a kin group of extended families
pedogenic	-related to soil forming processes
pedogenic carbonate	-naturally occurring carbonate precipitated in a soil horizon
profile	-the vertical section of the ground
soil texture	-describes the size of the mineral grains in soil
soil structure	-describes the aggregates of soil particles
stratigraphic boundary	-the contact between two distinct strata
stratum	-a visually distinct layer of sediment
volcanic glass	-a structureless cooled lava which occurs naturally in lava flows and was used by Hawaiians as small cutting tools.

I. INTRODUCTION

At the request of M and E Pacific, Inc., Cultural Surveys Hawaii conducted an archaeological inventory survey of the approximately 785-acre proposed Kahuku Agricultural Park, located in the *ahupua'a* of Kahuku and Keana, island of O'ahu (Figs. 1-4).

A. Scope

The scope of work was designed to satisfy the State and County inventory survey level requirements for an Enviromental Impact Statement and includes the following items:

1. A complete ground survey of the entire project area for the purpose of site inventory. All sites were located, described, and mapped with an evaluation of function, interrelationships, and significance. Documentation included photographs and scale drawings of selected sites and complexes. All sites were assigned State Site numbers.
2. Limited subsurface testing was done to determine the depth and quantity of cultural materials within the archaeological sites and to obtain datable samples for chronological information.
3. Research was done on historic and archaeological background, including search of historic maps, written records, Land Commission Awards, and Native Testimony. This research focuses on the specific area with general background on the *ahupua'a* and district and emphasizes settlement pattern information.
4. Preparation of this survey report which included the following:
    a. A topographic map of the survey area showing all archaeological sites and site areas;
    b. Description of all archaeological sites with selected photographs, scale drawings, and discussions of function;

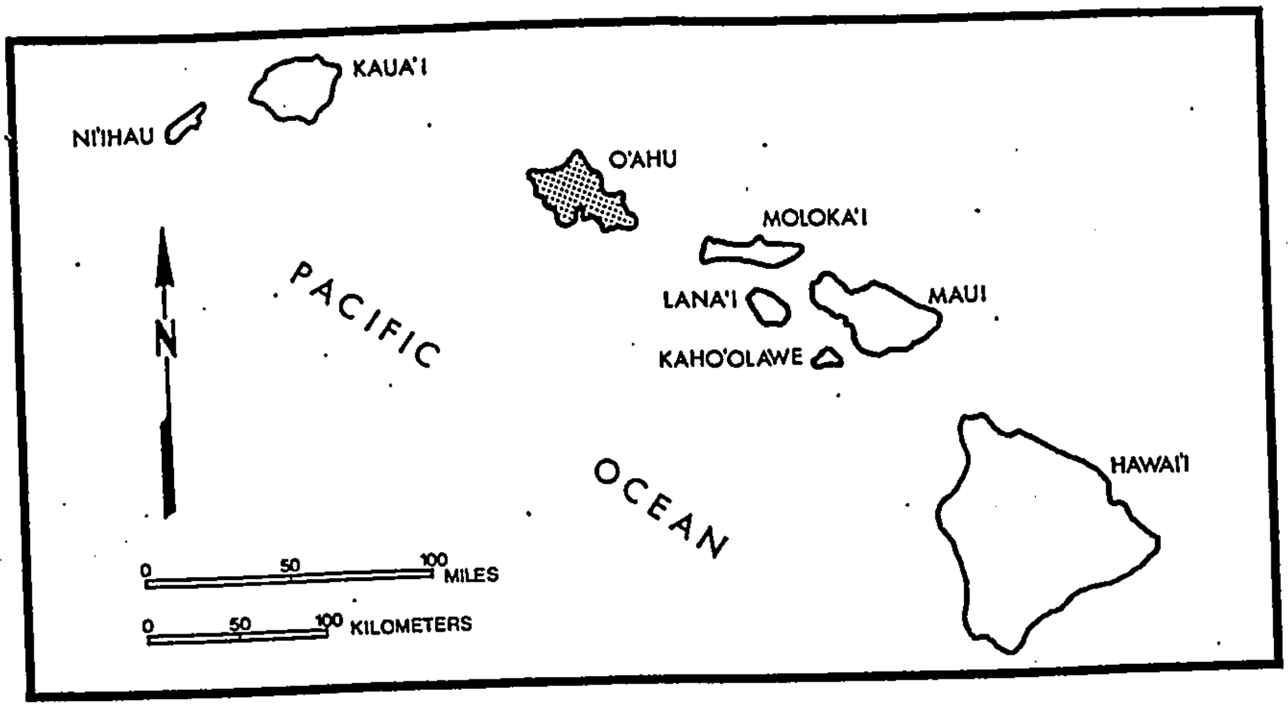


Fig. 1 State of Hawai'i

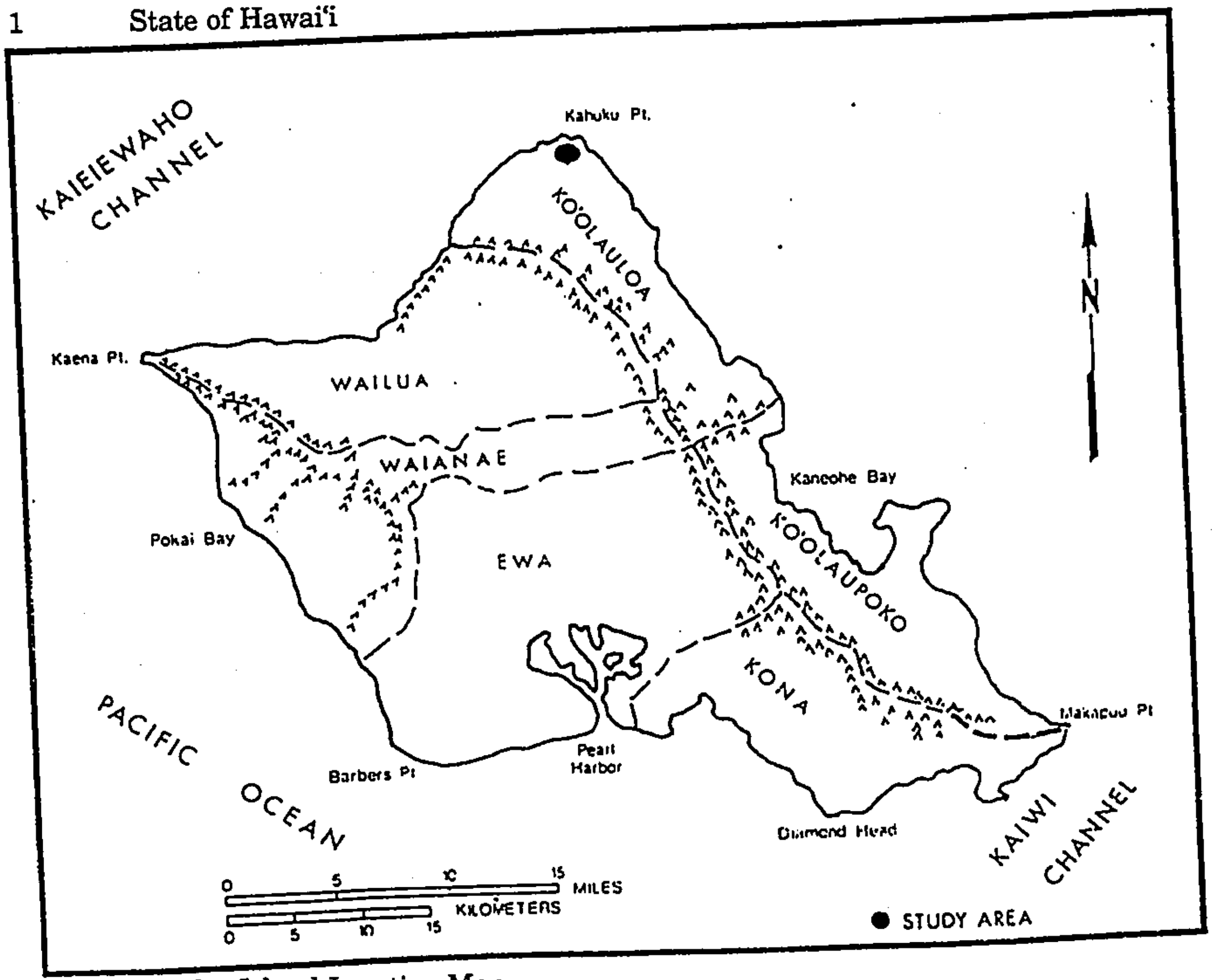


Fig. 2 O'ahu Island Location Map

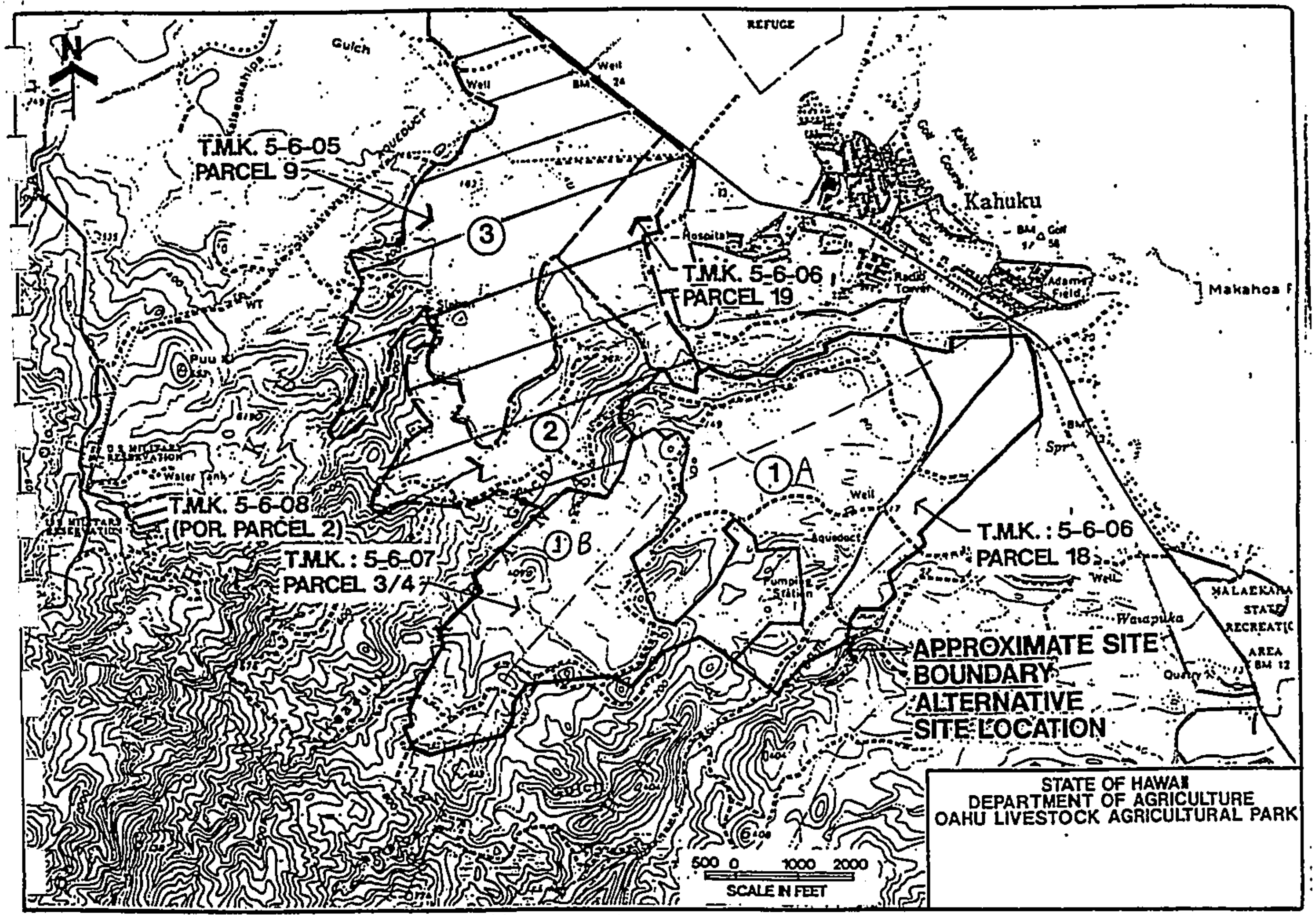


Fig. 3 USGS Kahuku Quad Map Showing Project Area (Shaded)

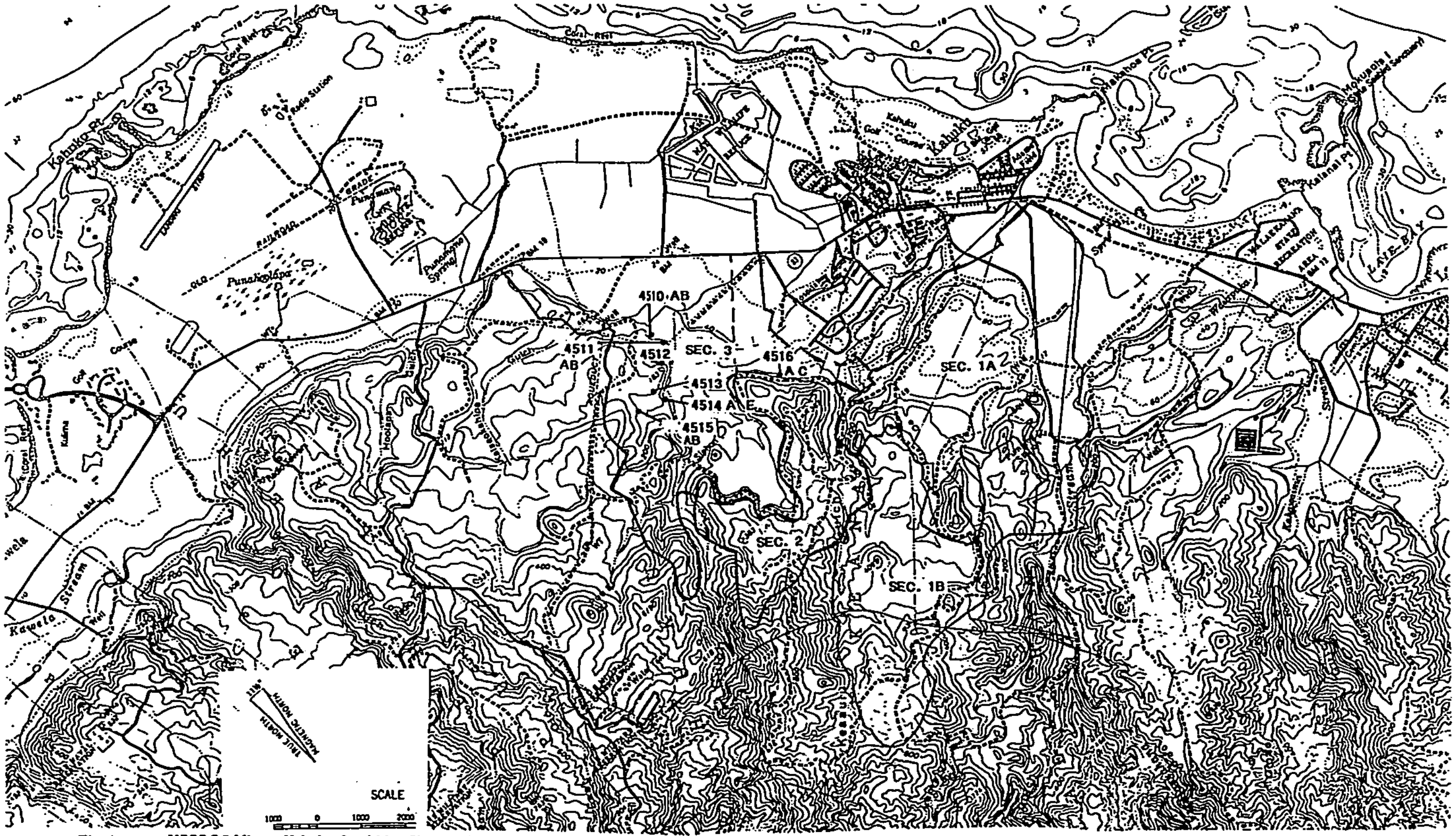


Fig. 4 USGS 7.5 Minute Kahuku Quad Map Showing Site Locations

c. Historical and archaeological background sections summarizing prehistoric and historic land use as they relate to the archaeological features;

d. A summary of site categories, their significance in an archaeological and historic context;

e. Recommendations based on all information generated which will specify what steps should be taken to mitigate impact of development on archaeological resources - such as data recovery (excavation) and preservation of specific areas. These recommendations were developed in consultation with the landowner and the State and County agencies.

The project area is located on the northeast shore of the island of O'ahu, directly behind the town of Kahuku, on the *mauka* side of Kamehameha Highway, and is divided into two sections: Area 2, portion of T.M.K. 5-6-08 Parcel 2 and T.M.K. 5-6-05 Parcel 9. The project area was originally divided into four sections: Area 1 T.M.K. 5-6-05 Parcel 18, Area 1B T.M.K. 5-6-07 Parcel 3/4, Area 2 T.M.K. 5-6-08 Parcel 2, and Area 3 T.M.K. 5-6-05 Parcel 9.

The project area later comprised Areas 2 and 3 only. Area 2 presently consists of feral sugarcane and/or pineapple fields. Some southern portions of the project area remain uncultivated on steep hillsides and on the crest of ridges and knolls. No archaeological sites were observed in these areas. Area 3 consists of a broad, relatively flat land in the northern portion with the steep ridges of Ohia Gulch in the southeast portion of Area 3. Seven archaeological sites were found in Area 3 along the limestone cliffs of Ohia Gulch. The northern portion of Area 3 is presently cultivated by various crops such as corn, banana, papaya, eggplant, watermelon, small fields of green onion, etc.

A total of 21 archaeological sites were located in the originally proposed project area (see Fig. 4). Only seven of these archaeological sites are in the revised project area. Most of the project area has been modified for the cultivation of commercial crops, therefore, the remaining sites exist only in the undisturbed areas which are the uncultivated hills, limestone bluffs, outcrops and gully slopes. The seven sites located were all along the west side of Ohia Gulch in Area 3. Each site was identified and the significance of each site designated. Site types consist of overhang shelters, wall structures and terraces. Significance and recommended treatment of the recorded sites were determined on the basis of site conditon, complexity and apparent function.

B. Survey Methods

Fieldwork was conducted over a period of 18 working days in the months of May and June, 1992 by a crew of four to five archaeologists who proceeded to describe and map all the archaeological sites within the project area and who also did limited subsurface testing for cultural deposits at three of the seven sites.

The main access to the project area was gained from the Military Reservation Road at the northwest end of the project area. Another access gained through a gate at a paved road at the northeast end of the project area led to several cultivated field areas on the east side of Ohia Gulch.

The crew of four to five archaeologists systematically surveyed the property in pedestrian sweeps spaced at 10 to 15 meter intervals, depending on the visibility of the terrain. Because most of the project area was extensively used for sugarcane and pineapple cultivation, the survey was focused mainly on areas that had not been modified for commercial agriculture. These uncultivated areas included the steep hillsides and crests of ridges and knolls, and the edges of Ohia Gulch. Visibility was often hindered by dense vegetation along the stream channel of Ohia Gulch. No sites were located **here and were in fact, it is an unlikely location because this area is in the flood zone. Moreover, it was also apparant that the area has been heavily impacted historically (by ulldozing). Sweeps were generally conducted from *mauka* to *makai* (southwest to northeast) portions. Specific attention was directed towards the upper sides of the gulch where archaeological sites such as overhang shelters and burials were likely to occur.

In general, the field crew experienced good visibility conditions. Ground cover consisted of a canopy of *koa haole* (*Leucaena leucocephala*) and in Ohia Gulch large banyan trees (*Ficus* sp.) and underneath the canopy was California grass or para grass (*Brachiaria mutica*). Because of the greater possibility of finding overhang shelters in Ohia Gulch the field crew did sweeps at 5-10 meter intervals. On the ridgelands above the gulch the sweeps were genrally the 10-15 meter intervals. Typically, one archaeologist followed the base of the gulch while three to four archaeologists scouted in and around limestone boulder outcrops along the edge of the gulch.

Cultural Surveys Hawaii has confidence that the entire project area was adequately surveyed and that all archaeological remains were located.

C. Testing Methods

Limited subsurface testing was conducted at three of the seven sites. These sites consists of site 4513 (CSH Site 4) Feature B, 4515 (CSH Site 6) Feature B, and site 4516 (CSH Site 21) Feature B. Cultural material was screened through a 1/8 inch mesh screen. Midden and artifacts were collected and charcoal samples were also taken for carbon dating.

During excavations each trench was excavated to bedrock or sterile soil and a profile was drawn showing the various strata of soil. A human burial was revealed during the excavation of Trench 2, site 4516 (CSH Site 6) Feature B. The burial was exposed only to the extent necessary to confirm that it was in fact a human burial. The information was recorded, (***the State was consulted), and then the trench was backfilled to prevent further disturbance to the location.

D. Project Area Description

The present project area lies on the northeast end of the Ko'olau Mountain Range of O'ahu in the *ahupua'a* of Kahuku and Keana in the town of Kahuku. It is bordered to the north by Kamehameha Highway, to the south by the foothills of the Ko'olau Mountain Range, to the west by Ohia Gulch, and to the east by Keaaulu Gulch. The area comprising the project area begins at approximately the 20-foot elevation and extends to the 275-foot elevation. The proposed agricultural park project area covers 785 acres which is presently under cultivation and also consists of abandoned sugar cane and pineapple fields and scrub. Cultivated areas are located mainly along the relatively level Kamehameha Highway border where crops of corn, watermelon, papaya, eggplant, etc. are grown. Ironwood trees, sugar cane and banana are often used as windbreaks between fields. The uncultivated areas lie along the south-half of the project area where the terrain is more undulating, and where vegetation consists of abandoned cane fields mixed with *koa haole* thickets and Christmas Berry (*Schinus terebinthifolius*) scrub. Thickets of *koa haole*, paragrass and Guinea grass (*Panicum maximum*) occur along roadsides and in abandoned or vacant areas. Remnants of old flumes and irrigation ditches occur in many of the former cane fields.

Much of the uplands above Kahuku Village was once planted in sugar cane and pineapple. These fields were established whereever possible except on steep hillsides and on the crests of ridges gullies and knolls. Presently these fields are in various stages of abandonment. Some areas which have been abandoned for many years have been taken over largely by *koa haole*, while other areas still contain dense stands of feral sugar cane. The isolated knolls and ridges are vegetated with such species as Ulei (*Osteomeles anthyllidifolia*), Java plum (*Eugenia cumini*), Christmas berry, ironwood (*Casuarina* sp.) and various grasses.

Soil Types

The major soil types and their distribution in the project are as follows (Foote et al. 1972):

Waialua silty clay 0-3% slopes (WkA) - majority of Area 3 in the flat lands. This soil is on smooth coastal plains. Permeability is moderate. Runoff is slow, and the erosion hazard is no more than slight. This soil is used for sugarcane, truck crops, and pasture. WkA lies in all previously or current sugarcane land. Kamehameha Highway cuts through the *makai* portion of WkA while the mauka edge ends just before the foothills of the Koolau Mountain Range.

Waialua silty clay 3-8% slopes (WkB) - also found in the flat lands of Area 2 and 3. Soil runoff is slow and the erosion hazard is slight. This soil is used for sugarcane,truck crops and pasture. WkB lies in previous or current sugarcane and also at the foothills of the Koolau Mountain Range. A small portion lies on the *makai* side of Kamehameha Highway.

Lahaina silty clay 3-7% slopes (LaB) - This soil is on smooth uplands. Permeability is moderate. Runoff is slow, and the erosion hazard is slight. This soil is used for sugarcane and pineapple. Small acreages are used for truck crops, pasture and homesites. LaB is found in the flatlands below the foothills and near the Kahuku Hospital.

Lahaina silty clay 7-15% slopes (LaC) - On this soil runoff is medium and the erosion hazard is moderate. This soil is used for sugarcane and pineapple. Small acreages are used for truck crops, pasture, and wildlife habitat. LaC is found above and below the foothills on agricultural lands and near elevated drop offs.

Paumalu silty clay 3-8% slopes (PeB) - This soil is on the uplands. On this soil runoff is slow and the erosion hazard is slight. This soil is used for sugarcane and pasture. PeC is found in the uplands near small gulches.

Paumalu silty clay 8-15% slopes (PeC) - On this soil, runoff is slow to medium and the erosion hazard is slight to medium. This soil is used for sugarcane and pasture. PeC is found in small gulches and upland agricultural flatlands.

Paumalu silty clay 15-25% slopes (PeD) - This soil occurs as small, irregularly shaped areas. Permeability is moderately rapid. Runoff is medium, and the erosion hazard is moderate. This soil is used for pasture and sugarcane. PeD is found just above the foothills where the terrain is level.

Paumalu - Badland complex (Pz) - Badland consists of nearly barren land that has remained after the Paumalu soils were removed by wind and water erosion. This complex is used for pasture and military purposes. Pz is found throughout the project area on hills, in gulches and on flat barren lands.

Haleiwa silty clay loam, 2-6% slopes (HeB) - This soil consists of well-drained soils on fans and in drainageways along the coastal plains. On this soil runoff is slow and erosion hazard is slight. This soil is used for sugarcane, pineapple, and truck crops. HeB is found in Ohia Gulch.

Kaena clay, 2-6% (KaB) - This soil has a profile that of Kaena stony clay, 6-12% slopes, except that there are few or no stones in the surface layer. Runoff is slow, and the erosion hazard is slight. This soil is used for sugarcane, truck crops, pasture and urban development. KaB was found just below the foothills near the hospital.

Kaena clay, 6-12% slopes (KaC) - This soil has a profile like that of Kaena stony clay, 6-12% slopes, except that there are few or no stones in the surface layer. This soil is used for sugarcane and pasture. KaC is found on the upper flatlands.

Kaena stony clay, 12-20% slopes (KaeD) - On this soil runoff is medium and the erosion hazard is moderate. This soil is used for sugarcane, pasture, and homesites. KaeD is found below the foothills on flat agricultural lands.

Coral outcrop, (CR) - Coral outcrop consists of coral or cemented calcareous sand on the island of O‘ahu. The coral reefs formed in shallow ocean water during the time the ocean stand was at a higher level. Small areas of coral outcrop are exposed on the ocean shore, on the coastal plains, and at the foot of the uplands. Elevations range from sea level to approximately 100 feet. CR is found mostly in the *makai* portion of the project area.

Vegetation

Vegetation consists mostly of abandoned sugarcane found on flat lands, depressions, wide gulches, and gentle to moderate slopes. *Koa haole* thickets have replaced the former sugarcane fields in several areas and are also frequently found on flat areas, in gulches, on gentle to moderate slopes and at the perimeter of cultivated areas. On steeper rocky slopes, guava, *koa haole* and Christmas Berry scrub dominate. On ridge crests and knolls that have remained undisturbed, the dominant vegetation is Ulei scrub. Banyans occur on isolated mounts of boulders and debris within cane fields, on knolls that have been reforested and in the major drainages that are not dominated by *koa haole*. The vegetation adjacent to the deeply eroded stream channels is extremely thick and lush with tall grasses dominant.

Geology

The geology of Kahuku is unusual in the Hawaiian Islands. It is dominated by basal limestone rather than lava. Because of this, the topography of the area is controlled by the erosion of the limestone through various former stands of the sea level. It is not a typical alluvial valley downcut by streams. Rather the erosion of the limestone has created a terrain of hills and saddles with the stream erosion playing a minor role.

II. HISTORIC BACKGROUND

The project area is located within the *ahupua'a* of *Kahuku* and *Keana*. It is bounded on the north by Hanakaoe *ahupua'a*, on the south by *Malaekahana ahupua'a*, and lies within Koolauloa District at the northern-most tip of the island of O'ahu. The *ahupua'a* was traditionally a land unit extending from mountain into the sea, providing its inhabitants with all the basic resources necessary for life.

A. The Legend of Kahuku

According to Hawaiian legend this area was once a floating island. Blown about by the trade winds, it was said that the people of Koolauloa District attached the small floating island with their fishhooks to the larger island of O'ahu. In Archaeology of O'ahu, McAllister tells of this site:

> Site 271. Polou, formerly a pool of water sea side of the Kahuku mill.
>
> A story is told that Kahuku was once a land afloat, wafted about by the winds, drifting over the ocean. Just how it came to Oahu is not told, but old Hawaiians point out Polou, the place where Kahuku is fastened to Oahu. Formerly it was possible to dive into the pool and when a depth of 40 fathoms was reached, a shelf of rock was found upon which to rest. Forty fathoms deeper *Punakea* (white line from coral) was by which Kahuku was made fast could be seen. This hook was intricately fashioned of Kawila (*Alphitonia excelsior*). Seaward of the Waialee Industrial School, in another pool of water, known as Kalou, is the spot where Kahuku is attached to Waialee (Site 257). In the immediate vicinity of Polou was a stone known as Kanaloa.

According to *Geologic Map and Guide of the Island of Oahu, Hawaii* (Stearns), various stands of the sea, one given the named *Kahuku* and the other *Kahipa* are visible in the District of Koolauloa. In the Kahuku area there exists "beach limestone of the 55-foot stand of the sea which is overlain unconformably by stream-laid conglomerate which in turn is overlain by reef of the 95-foot stand of the sea and lithified dunes formed during the minus 60-foot stand of the sea."

It is easy to make a correlation between the Hawaiian legend of the floating island and the two depths found in the pool with the scientific fact of the two stands of the sea and the visible differences between the lava foundations and the limestone attachment making the legend a description explanation for the the geology of the lands of Koolauloa to its people in prehistoric times.

B. Early History, 1779-1846

The first historical reference to Kahuku was in 1779 when the H.M.S. *Resolution* passed along the north side of O'ahu. Lieutenant James King wrote:

> It [O'ahu] is by far the finest island of the whole group. Nothing can exceed the verdure of the hills, the variety of wood and lawn, and the rich cultivated valleys, which the whole face of the country displayed [McAllister 1933:153].

On February 28, 1779, in the journal of the *Resolution* now captained by Charles Clerk, due to the untimely death of Captain James Cook at Kealakekua Bay on February 14, we find:

> Run round the Noern [Northern] Extreme of the Isle [O'ahu] which terminates in a low point rather projecting [Kahuku Point]; off it lay a ledge of rocks extending a full Mile into the Sea, many of them above the surface of the Water: the Country in this neighborhood is exceedingly fine and fertile: here is a large Village, in the midst of it is run up a high pyramid doubtlessly part of a Morai [Beaglehole 1967:572].

In 1794, British Captain George Vancouver noted:

> ...In every other respect our examination confirmed the remarks of Captain King: excepting, that in point of cultivation or fertility, the country did not appear in so flourishing a state, nor to be so numerously inhabited, as he represented it to have been at that time, occasioned most probably by the constant hostilities that had existed since that period [Vancouver 1798(3):71].

It is presumed from these early descriptions that in the thirteen years that separated Captain King's voyage from Captain Vancouver's, the environment of Kahuku had undergone significant changes. The probable cause for the decrease in cultivation was the decline in population due not only to "the constant hostilities" of the inhabitants, but also to the spread of venereal disease and other diseases introduced by Cook's expedition in 1778, as well as other visiting ships in the years that followed. In 1833, E.O. Hall wrote of the Koolauloa District, "Much taro land lies waste, because the diminished population of the district does not require its cultivation" (McAllister 1933:153).

C. Land Commission Awards 1846-1855

Between 1846 and 1855, the concept of private ownership of property was introduced to the Hawaiian Islands, radically departing from the local traditional land tenure system. Kuykendall wrote:

> The old feudal arrangement of joint and undivided ownership had given place to the system of individual allodial tenures, and aliens had been admitted to the enjoyment of the same rights as Hawaiian subjects in the ownership and use of land [Kuykendall 1968:298].

This time of land division in Hawai'i (between 1849-1953) is known as the period of the Great Mahele. At this time all the lands of Hawai'i were divided. According to Kelly:

> The results of the division of land under the Mahele of 1848 and the Kuleana Grant of 1849 were approximately as follows:

Crown lands reserved for the king's use	984,000 Acres
Lands granted to 245 chiefs	1,619,000 Acres
Government lands	1,495,000 Acres
Lands granted to 9,337 commoners	28,000 Acres
TOTAL	4,126,000 Acres

> [Kelly 1965:321-322].

The breakdown of the above table into percentages is as follows:

Crown lands reserved for the king's use	24%
Lands granted to 245 chiefs	39%
Government lands	36%
Lands granted to 9,337 commoners	1%
TOTAL	100%

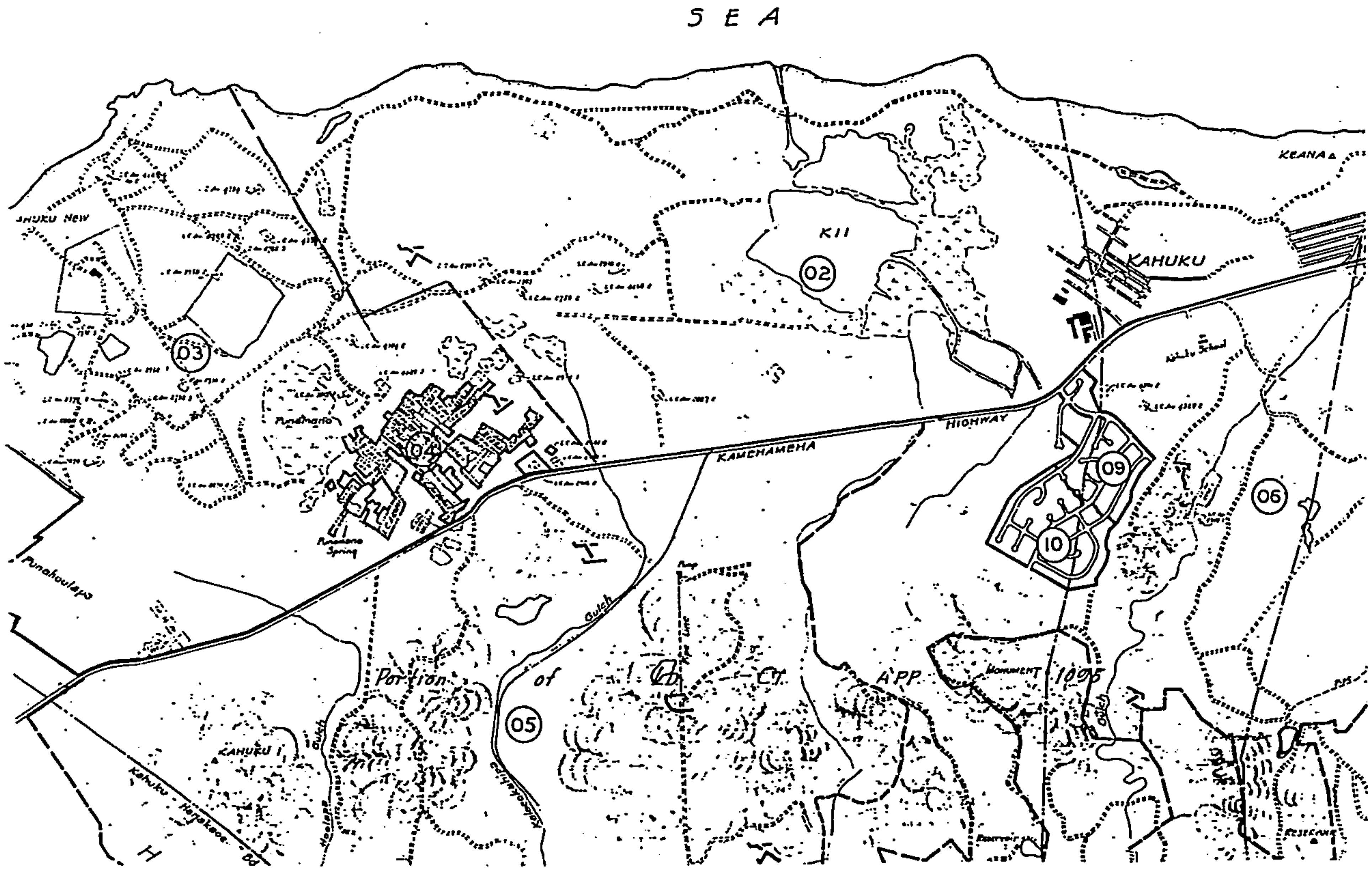


Fig. 5 Tax Map of Kahuku Showing LCAs

The *ahupua'a* of Kahuku fell into the category of Crown Lands of King Kamehameha III and one half (½) of the *ahupua'a* of Keana became Government Land with the other half awarded to Kinimaka (770 Acs 1/2 Ahp). Within the *ahupua'a* of Kahuku were 63 Land Commission Awards and 3 Land Commission Awards in the *ahupua'a* of Keana (Table I & II).

D. Settlement Patterns as Indicated by LCAs 1847-1850

Although no LCAs are recorded in the present project area, a large cluster of LCAs is located northwest of the project area, between Hoolapa Gulch and Kalaeokahipa Gulch on the *makai* side of Kamehameha Highway in the *ahupua'a* of Kahuku. The three LCAs in the *ahupua'a* of Keana are located near the entrance to Keaaulu Gulch (Fig. 5).

The recorded Native Register and their supporting Foreign Testimony presented before the Board of Commissioners in the mid 1800s provide most of the information about traditional land use in the area by native Hawaiians.

According to the Native Register (Appendix D & E), agricultural activity was taking place throughout the *ahupua'a* of Kahuku and Keana. From the uplands (*mauka*) to the sea (*makai*), *lo'i*, *mala*, and *kula* are reported, as well as, *hala* groves, fish ponds, 'salt land', watercourses, *kukui*, *wiliwili*, and *koa* trees for canoes.

Crops cultivated included:

Traditional -

wauke (Broussonetia papyrifera), noni (Morinda citrifolia), 'awa (Piper methysticum), pili (Heteopogon contortus), 'uala (Ipomoea batatas), ohi'a (Metrosideros polymorpha), mai'a (Musa paradisiaca), ti (Cordyline terminalis), 'ulu (Cocos nucifera), kalo (Colocasia esculenta), koa (Acacia koa), kukui (Aleurites moluccana), olona (Touchardia latifolia), ipu 'awa'awa (Lagenaria siceraria), wiliwili (Erythrina sandwicensis), aka'akai (Scirpus validus), lama

(Diospyros hillebrandii), hala (Pandanus odoratissimus).

Non-traditional -

'alani (Citrus sinensis), tobacco (*Nicotiana glauca*), watermelon (*Citrullus vulgaris*).

Everything needed to sustain life was cultivated here: *wauke* (paper mulberry) for making *kapa*, the traditional Hawaiian cloth used for clothing and bedding; *noni* (Indian mulberry) was used for a variety of medicinal purposes and for dyes; *pili*, a grass used for thatching houses; *lama*, a wood used in hut building; *hala*, the leaves of which are used for mats, baskets and hats; *ipu 'awa'awa*, a gourd made into containers to hold water, food and personal effects, and these gourds were also fashioned into a variety of musical instruments and utensils; *koa*, a tree commonly used in making canoes; *'awa*, a plant used to make a narcotic drink often used in ceremonies; sweet potato, banana, taro, oranges, onions, breadfruit, sugarcane, ti, watermelon and salt. *'Uala* (sweet potato) seems to be the staple in this area as apposed to the traditional *kalo* (taro), since most of the claims report *'uala* planted rather than taro.

It was common practice for planters to give names to their *'ili, mo'o, lo'i* or a group of *lo'i*, as well as to groves, fish ponds and water courses. This tradition was practiced throughout Kahuku and Keana. Reading the Native Claims it is easy to see the need for such a tradition since most of the claims deal with a *kula* in one area, *lo'i* in another, *malas*, *hala* trees, *koa* trees and *ha pa'akai* (salt beds) in various other areas throughout the district. Their house claim can be in yet another location altogether (Appendix D & E). Kalua, from the *ahupua'a* of Keana (LCA 4329), simply states in his claim, "Because these claims of mine are so very scattered it is not practical to tell you, the Commissioners, of their boundaries."

Therefore, one can hypothesize, through the Native Claims, that the majority of the population had homes near and around the ocean side in Kahuku and Keana with areas of cultivation throughout the district. This pattern of land use most likely dates back to the earliest inhabitants, with legends to support this statement from McAllister's site 261. Stated as follows:

Site 261 - Small water hole, called Punamano, pointed out by Kahiona, Kaleo, and Luika Kaio in the flat limestone plain of Kahuku Point. It is about 15 ft. in diameter and brackish in taste. My informants told this story:

> One time when the people of Kahuku were fishing they caught a small shark. Putting him in a calabash of water they carried him to their house near the beach. Here he was cared for and put in larger and larger calabashes as he grew bigger. Finally having outgrown even the largest calabash that could be found, it was decided to place him in one of the pools of brackish water which came to be known as Punamano. A man and woman living near the pool became guardians. They had lived in their grass huts with a breadfruit tree near the pool and taro and potato patches near the mountains for several years when the brother of the woman came to live with them. Sometime after, the man and his wife went to the mountains to gather taro and potatoes. The brother, who was staying at home, thought that he would like to have some food prepared when his sister and her husband returned. He climbed the breadfruit tree and gathered several, throwing the fruit into the water instead of on the ground, where it would have been bruised in the fall. After picking enough for a few days he descended the tree and gathered most of the fruit from the bank.. Two had floated to the middle of the pond and he could not reach them. Now this man knew of the shark that lived in the water, but he had frequently bathed in the pool and no thought of fear crossed his mind as he swam to the breadfruit. He did not know, however, that his sister had warned the shark not to allow anyone to steal breadfruit when they were gone. When the sister and her husband returned they could not find the brother. Neither was the shark to be found, but they saw the breadfruit floating in the pool and a reddish color to the water. They guessed what had occurred. For nearly a mile they followed the bloody trail until they came to the spring known as Punahoolapa. Not only was the brother never seen, but the shark has never been seen to this day. A plantation pump now marks the site of the spring, near the sea side of the road (McAllister: 152-153).

Table I: LCAs in the *Ahupua'a* of Kahuku

LOCAL	AWARDEE	L.C.A.	BOO	PAGE	R.P.	BOOK	PAGE	AREA	No. of Pcs.
Kahuku	Aaiki	3778	6	50	525	2	615	0.82 Ac	1
Kahuku	Hao	2705	6	45	*****	*****	*****	0.42 Ac	3
Kahuku	Haui	2704	6	52	335	2	285	0.96 Ac	1
Kahuku	Holoaia	2706	6	11	244	2	143	0.85 Ac	2
Kahuku	Hoolae	2716	6	10	8000	34	185	0.60 Ac	2
Kahuku	Kaaikaula	4449	6	46	255	2	165	2.17 Ac	4
Kahuku	Kaaumakua	2906	6	34	*****	*****	*****	0.15 Ac	1
Kahuku	Kai	2870	6	53	253	2	161	0.88 Ac	2
Kahuku	Kaihikapu	2872	6	59	529	2	623	1.49 Ac	2
Kahuku	Kaihupailani	4458	6	51	532	2	629	2.57 Ac	2
Kahuku	Kailiuku	2932	6	36	*****	*****	*****	0.68 Ac	2
Kahuku	Kainalu	2892	6	40	252	2	159	1.02 Ac	2
Kahuku	Kaio	4394	6 6	31	256 7265	2 27	167 59	1.89 Ac	3
Kahuku	Kalahana	2934	6	13	*****	*****	*****	0.47 Ac	1
Kahuku	Kalaweaumo	2826	6	57	250	2	155	1.19 Ac	3
Kahuku	Kaluau	2916	6	45	527	2	619	1.17 Ac	2
Kahuku	Kamalama	2909	6	48	*****	*****	*****	0.25 Ac	1
Kahuku	Kanahuna	2827	6	49	523	2	611	1.75 Ac	2
Kahuku	Kaohele	2861	6	12	524	2	613	1.61 Ac	2
Kahuku	Kapaiaala	3868	6	52	531	2	627	1.21 Ac	2
Kahuku	Kau	4388	6	47	1355	5	285	1.87 Ac	3
Kahuku	Kauihawale	2928	6	54	251	2	157	0.96 Ac	2
Kahuku	Kauihikai	2936	6	59	*****	*****	*****	0.52 Ac	2
Kahuku	Kaukaha	4341	6	10	526	2	617	2.30 Acs	2
Kahuku	Kaumi	4393	6	51	332	2	279	1.05 Acs	1
Kahuku	Kaumualii	4422	6	38	249	2	153	2.39 Acs	2
Kahuku	Kawaa	2918	6	36	519	2	603	0.40 Ac	2
Kahuku	Keakaokawai	2914	6	62	*****	*****	*****	0.82 Ac	2
Kahuku	Keawe	2887	6	35	5472 3514-A	21 21	599 599	0.578 Ac	1
Kahuku	Keaweleikini	2931	6	41	333	2	281	1.03 Acs	1
Kahuku	Keino	2867	6	53.60	241	2	139	1.56 Acs	2
Kahuku	Kekipi	4384	6	32	246	2	147	1.32 Acs	3
Kahuku	Kekua	2913	6	30	337	2	289	0.47 Ac	2
Kahuku	Kekuauli	2935	6	59	*****	*****	*****	0.12 Ac	1
Kahuku	Kiha, Iosua	2864	6	38	520	2	605	0.88 Ac	2
Kahuku	Kuapuu	4374	6	50	245	2	145	1.60 Acs	3

Table I (continued)
LCAs in the *AHUPUA'A* of KAHUKU

LOCATI	AWARDEE	L.C.A.	BOO	PAGE	R.P.	BOOK	PAGE	AREA	No. of Pcs.
Kahuku	Kupaihea	4390	6	41	521	2	607	0.92 Ac	2
Kahuku	Kuhoopohopo	4428	6	42	341	2	297	0.51 Ac	1
Kahuku	Kula	4383	6	42	342	2	299	0.09 Ac	1
Kahuku	Kapau	2880	6	40	338	2	291	0.52 Ac	2
Kahuku	Kupihea	2885	6	44	*****	*****	*****	0.13 Ac	1
Kahuku	Lokea	3809	6	33	334	2	283	0.27 Ac	1
Kahuku	Luiki	2690	6	43	339	2	293	1.33 Acs	2
Kahuku	Luamea	2691	6	35	*****	*****	*****	1.03 Acs	2
Kahuku	Makakiekie	2785	6	61	*****	*****	*****	0.60 Ac	2
Kahuku	Makaokalai	2787	6	37	1348	5	271	0.73 Ac	2
Kahuku	Makilo	2779	6	33	530	2	625	1.15 Acs	2
Kahuku	Makole	2782	6	37	243	2	141	0.50 Ac	2
Kahuku	Malailua	2775	6	47	534	2	633	1.45 Acs	3
Kahuku	Male	3723	6	11	331	2	277	0.67 Ac	1
Kahuku	Manukeokeo	2781	6	12	533	2	631	1.09 Acs	3
Kahuku	Maui	2783	6	54	*****	*****	*****	0.25 Ac	1
Kahuku	Mauoli	2788	6	57	257	2	169	1.09 Acs	3
Kahuku	Napoe	2758	6	58	247	2	149	1.69 Acs	2
Kahuku	Nauluhao	3958	6	44	254	2	163	1.71 Acs	3
Kahuku	Niau	3951	6	47	260	2	175	1.22 Acs	2
Kahuku	Pakanaka	2744	6	56	*****	*****	*****	0.38 Ac	2
Kahuku	Pakui	3813	6	55	248	2	151	2.21 Acs	3
Kahuku	Pahanui	2730	6	56	258	2	171	2.31 Acs	3
Kahuku	Palu	2738	6	34	518	2	601	0.51 Ac	3
Kahuku	Polena	2729	6	31	517	2	599	2.02 Acs	2
Kahuku	Pukawale	2732	6	60	336	2	287	2.10 Acs	2
Kahuku	Puu	2723	6	32	522	2	609	1.15 Acs	2
Kahuku	Uha	2681	6	39	240	2	137	2.10 Acs	2
Kahuku	Uka	3748	6	43	528	2	621	1.27 Acs	1
Kahuku	Umeume	2679	6	54	259	2	173	1.42 Acs	2
Kahuku	Waanui	2698	6	58	340	2	295	0.75 Ac	3
Kahuku	Waiaulaa	2702	6	14	*****	*****	*****	0.93 Ac	1

Table II: LCAs in the *Ahupua'a* of Keana

LOCATI	AWARDEE	L.C.A.	BOO	PAGE	R.P.	BOOK	PAGE	AREA	No. of Pcs.
Keana	Kalawaiaman	4391	6	63	3516	15	285	2.67 Acs	2
Keana	Kinimaka	7130	3	242	5693	22	293	770 Acs 1/2 Ahp	1
Keana	Kuapuhi	4329	6	14	6247	23	661	0.71 Ac	2

Although no LCAs are located in the project area it is most probable that Ohia Gulch once contained *lo'i* and *kula* similar to that of Keaaulu Gulch. Agricultural features were probably scattered throughout the lower zones and flood plains of Ohia Gulch but were abandoned before the time of the Mahele. This conclusion is made by the information gathered from testimonies of LCAs surrounding the project area.

E. Ranching in Kahuku 1850-1880

In 1850 to 1851, Charles Gordon Hopkins purchased from Kamehameha III the *ahupua'a* of Kahuku and along with the purchase of several other *ahupua'a* on the north shore of O'ahu, he (Hopkins) established a cattle and sheep ranch known as the Kahuku Ranch (Korn 1958:211-212). It is also to be noted that in 1851 Hopkins became the agent for the rental and sale of the Crown Lands of Kamehameha III.

The natives became concerned for their lush and legend-filled homeland. Kahuku and the hala trees in whose shade it had slept through the centuries, was being threatened by a new kind of white stranger. The herds and flocks ran over the small homesteads scattered here and there through the land, stripping it of verdure. The Hawaiians asked in vain for protection of their trees and vegetable patches. They wrote to the missionary, Emerson, who urged them to build fences and appealed to authorities on their behalf asking that government pounds be set up to enforce newly established trespass laws. At the same time the hala forests began to disappear, the Hawaiian population also began to disappear. Once well-populated, Kahuku became a lonely sheep and cattle ranch, famous for its prize English breeds and its imported water fowl (Wilcox, 1975 p.16).

According to an informant of J.G. McAllister, Mrs. John Kaleo said:

> "She [Mrs. John Kaleo] remembers the time when trees, now found only on the mountains, covered the Kahuku plain, now a rather desolate, windswept area" (McAllister, 1930,p.153).

One can surmise that Mrs. John Kaleo could remember the Kahuku plain before and during the depletion of its vegetation due to the over-grazing of the sheep and cattle of the Kahuku Ranch. The relationship between cattle and the natural environment of Hawai'i has been described by Professor Bryan:

> Since the coming of the whites there have been many causes...that have been at work bringing about a change in the natural conditions. Chief among the disturbing elements, however, have been the cattle. As early as 1815 they were recognized as a serious menace to the native forests. *Roaming at will through the forests they and other animals, as goats and* pigs, have done untold damage, and brought about conditions that have been most serious in many places...[Bryan 1915:226-227].

During the mid-19th century, road construction connected Kahuku with the city of Honolulu. Kuykendall authored:

> On Oahu, what came to be called the "round-the-island road" --ancestor of Kamehameha Highway--extended from Honolulu to Ewa, thence across the central plateau to Waialua: from that place it ran along the coast past Kahuku and Kualoa to Kaneohe, where it joined the road which came over the Nuuanu *pali* from Honolulu. In 1856, for the first time, a four-wheeled carriage drawn by a pair of horses was driven over the portion of this road between Honolulu and Kahuku. Three years later a Captain Coffin is reported to have driven with a carriage and span of horses from Honolulu to Kahuku one day in ten hours and to have returned the following day in eight hours [1968:25].

In 1866, the Kahuku Ranch was purchased from Hopkins by Robert Moffitt and by 1873, H.A. Widemann had gained control and ownership of the entire Kahuku Ranch, which included the *ahupua'a* of Kaunala, Pahipahialua, 'Opana 1 &2, Kawela, Hanakaoe, 'O'io 1 & 2, Ulupehupehu, Punalau, Kahuku, Malaekahana, Keana, and a part of Laie (*Ibid.*:138). On January 19, 1874, Widemann sold Kahuku Ranch to Julius L. Richardson who in turn sold the entire ranch to James Campbell.

In 1889, George Bowser described the Kahuku Ranch as follows:

> Kahuku Ranch. Main Road, Kahuku: Proprietor, James Campbell, Esq., of Honouliuli: Manager, W.R. Buchanan: postoffice address, Kahuku, 38 miles from Honolulu, at the northern point of Oahu: 23,608 acres occupied as a cattle ranch: extends 14 miles along the coast, in close proximity to the sea. A valuable fishery is attached to this property [Bowser 1880:409].

Although the sugar plantation took on the major role of industry at Kahuku, the Kahuku Ranch continued operations until the mid-20th century.

F. Sugar and the Railroad at Kahuku: 1890-1971

On November 19, 1889, James Campbell leased much of his Kahuku and Honouliuli lands to Benjamin Franklin Dillingham (Kuykendall 1967:69). This lease of 50 years, from January 1, 1890 to December 31, 1935, was a part of Dillingham's development plan involving the sugar industry and a railroad on O'ahu (Kuykendall 1967:68) (Fig. 6).

Dillingham's proposed plan, in 1886, called the "Great Land Colonization Scheme," involved the development at Kahuku and Honouliuli of sugarcane plantations that would be irrigated by artesian well water (Dillingham 1886:73-80). It is portentous to note here that there are several legends that deal with the tapping of water from the ground of the Koolauloa District. According to McAllister:

> Site 258 - Small fresh-water fishpond known as Kapi or Punaulua, Waimea side of Kawela Bay. Not more than 100 feet wide. The legend concerning it, according to Luika Kaio and Kahiona Apuakehau who drove with me to the site, and Plunket, the Hawaiian forest ranger who acted as interpreter, is as follows:
>
> There were once gathered on the beach near this site a great many people. This was long before Europeans had come and when there were not many Hawaiians, so that a gathering of this size was enough to occasion the comments of a stranger who approached. This was Kane, but the people did not recognize him. 'Why are so many of you gathered here?' he inquired. 'To catch the oio. A large school swims near in the water,' they replied. 'Those

> are not oio,' said Kane, 'they are eel.' But the people only laughed. Certainly they knew oio when they saw them. Who was this stranger to dispute the words of Kamaainas? So Kane wagered that they were eel, and the people wagered against him. The canoes with the long, large nets were launched and the school surrounded. Great was their surprise when they found the fish to be eel. Who could this strange man be? That evening Kane accompanied them up to the mountains. It was a long trip up the valley to reach the springs of fresh water, and the people were tired. They stopped at the entrance of the valley for rest, and here in the presence of all the people, Kane struck the stone known as Waikane, from which the water immediately poured forth and has been flowing almost to this day (McAllister 1933:152).
>
> Site 259 - Large stone, known as Waikane, beside the stream bed on the mountain side of Kawela Bay and at the foot of the palis in the land Hanakaoe.
>
> Long ago the Hawaiians had to go far up the valley in order to get fresh water, but when Kane struck the stone, water flowed from it and continued to flow up to the time the plantation built a pump just below the rock (McAlister 1933:152)

Dillingham had commissioned a study of water supply at Kahuku by J.D. Schuyler and G.F. Allardt. This study noted:

> The Kahuku Rancho. This well-known rancho occupies the extreme northerly point of the island, extending from the crest of the mountains to the sea, and from Waimea river on the west to Laie on the east. It is thirty-eight miles distant from Honolulu, either by the Waialua or the Pali road. Its position on the windward side, with high mountains rearing up rapidly from the level of the belt of valley land along the coast, gives it abundant moisture and clothes it in perpetual verdure. Cattle roaming over its hills and valleys are all fat and sleek, and water is bursting out in places all along the coast, generally near the foot of the hills, or about midway between the foot-hills and the ocean.
>
> ...The general level of the land is about twenty feet above tide [Schuyler & Allardt 1889:3].

On December 10, 1889, Dillingham subleased a large portion of the Kahuku tract to James B. Castle who promoted the Kahuku Plantation Company, and chartered it on January 30, 1890 from the Hawaiian government to cultivate sugarcane (Kuykendall 1967:69). James Campbell, Benjamin F. Dillingham and James B. Castle, together with Lorrin A. Thurston, as a principal, and the M.S. Grinbaum & Company as plantation agents, were the key players in the development of the Kahuku Plantation (Fig. 6). Mr. Dillingham's interest was prompted by his desire to promote and enhance his Oahu Railway & Land Company. The Kahuku Plantation first relied on pumped spring water, stream water, and rain to irrigate the sugarcane, but latter resorting to artesian wells as its main source of water supply.

No record appears to survive which cites the date the railroad was started at Kahuku Plantation. Annual reports do not appear prior to 1893. However the road must have been started soon after the January 30, 1890 charter, for the Baldwin Locomotive Works records note an order for the first Kahuku motive power, *Keana*, on February 2, 1890 and a second order for *Kahuku* in 1891.

The first recorded report that a railroad actually existed in Kahuku comes from the first annual report. September 1, 1893 until August 31, 1894, the annual report recorded an expense of $3,596,40 for railway materials and an expenditure of $2,765.59 for labor costs for the same. According to Condé and Best, Sugar Trains, which the majority of the information on the trains in Kahuku is taken directly from, little data was recorded on the trains, other than the ordinary problems that Hawaiian sugar plantations dealt with. Condé and Best used this 1897 entry as an example, the manager reported,

> The mile of railroad that came last year was put in next to the landing as that portion of the track was all eaten up by rust. most of the road through the plantation was all rebuilt and regraded. The two miles that have been ordered, will be put in the road opposite the Mormon Settlement, as that is in very bad shape. Whatever material is taken out of that portion that is any good, will be used in repairing other track.

In the co-partnership arrangement between members of the Castle family and Alexander and Baldwin, the plantation agency was changed in 1900 to the A. & B. This co-partnership brought about expansions in the rail system and by 1903 the rails extended all the way through the Laie Plantation, which had a contract with the Kahuku mill to handle their cane.

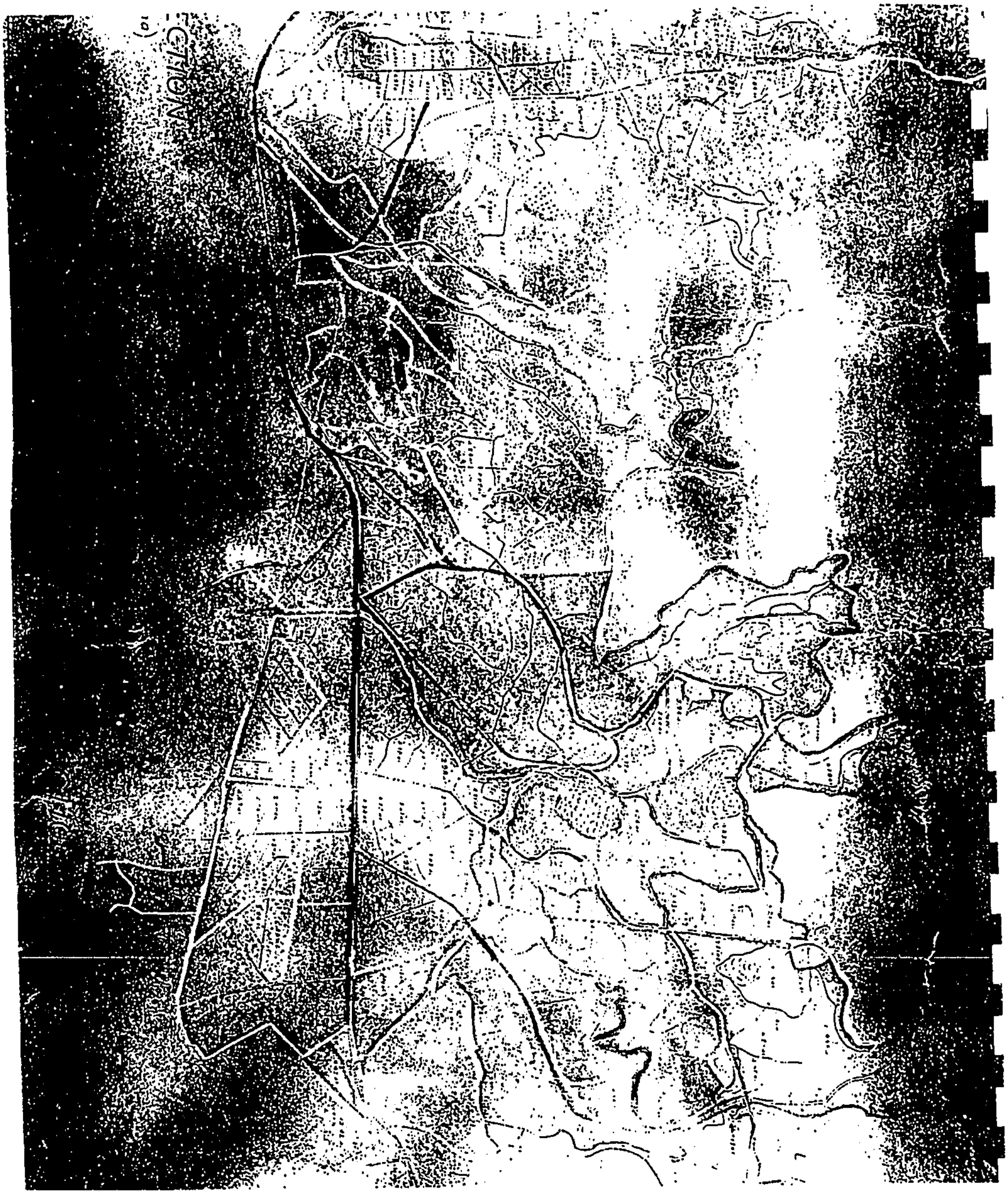


Fig. 6 Kahuku Plantation Field Map, 1935 (Bishop Museum collection)

World War II did not slow down the Kahuku Plantation's drive to improve its sugar production, the manager commented:

> Additions were made to the railroad lines, in some instances, heavy for light rail was substituted on existing lines, in others, extensions were made to the upper lands. Additions were also made to the rolling stock. Gasoline tractors displaced work animals for hauling cane in the mill yard. All these involved an expenditure of $37,000.

By the early 1930s many Japanese and Filipinos, some Portuguese and a few Korean and Chinese were working the Kahuku cane fields accepting the paternalistic plantation life where pay was low but supplemented by a system of bonuses plus housing, water, fuel, medical care, even recreational facilities provided at low cost or free.

In 1931 the Kahuku Plantation was still expanding. Under the caption of "Laie Purchase," the 1931 Manager's report for the year comments,

> Your company acquired the lease of Zion Securities agricultural lands and the transfer of leases previously held by them through Laie Plantation for a period of 25 years, dating from July 1, 1931 Koolau Railway Company Ltd., was also bought from the Zion Securities Corporation. This railroad will be disincorporated as soon as possible and become purely a plantation railroad. (Of the transaction the Treasurer's Report for the same year notes Kahuku Plantation bought 1500 shares of the Koolau Railway at a cost of $11,025.64 and also assumed the debts of that railway amounting to $13,974.36, effecting a total outlay of $25,000.

Also in 1931 Gilmore's *Hawaii Sugar Manual* reported on the Kahuku plantation.

> Transportation Equipment – All cane is delivered to the mill by cars. The plantation railroad system consists of 20 miles of 36" gauge track on permanent roadbed. In addition have 2.73 miles of portable track to extend down the cane rows for loading in the fields.
>
> The rolling stock consists of: 255 Hawaiian type cane cars of 5-ton capacity; solid end and straight-up stake siding. Also fifteen 5-ton flat cars for transporting rail; one 10-ton flat car and two 1000-gal. tank cars.
>
> Locomotives consist of two 15-ton and one 22-ton Baldwin make. The locomotives are fired by fuel oil, having one 300-bbl. steel tank for fuel supply.
>
> The cost of the locomotives and car stands the Company $74,819 and that of the railroad proper $53,160.
>
> Have 23 mules, but don't use them in preparation of land: using for light plowing where necessary, but mainly for light hauling. The tractors are used for pulling the cane cars in the field, straddling the portable track.

By 1950 the Kahuku Plantation had gone "diesel." The Honolulu *Star Bulletin* remarked on the retirement of steam power at Kahuku and in the issues of August 7, 1950 reported,

> **KAHUKU PLANTATION STEAM LOCOMOTIVE TO BE IN COLLECTION**
>
> From Kahuku's sugar cane fields to famed Cliff House of San Francisco. That's the last "run" of s team locomotive #1 of the Kahuku Plantation Company. The one time mainstay of Kahuku's railroad left Kahuku for the Gold Gate last month.
>
> It was sold to the Cliff House for a nominal sum, which plans to add it to its collection of all types of vehicles used since 1800 when the Cliff House was built.
>
> Iron Horse #1 is one of the last two steam locomotives formerly used at the North Shore, Oahu plantation. The plantation's cane hauling is now done by diesel locomotive.
>
> The last remaining steam locomotive is "K. P. Co. No. 3," according to the Transportation Superintendent, Ralph Makaiau; old No. 3 is still in running condition. It is being kept for emergency use this year, after which it will be retired.
>
> The plantation's management is now considering its final disposal. One suggestion is that it be set up permanently in a place of honor across from the plantation business offices.

By the year 1953 most sugar plantation had given up the use of trains for hauling cane, Kahuku Plantation still incorporated the trains in the transport of their cane to the mill. The Honolulu *Advertiser* for October 18, 1953, remarked on this.

> Inside Merchant Street – A partial change from railroad to truck hauling of cane to the mill will be made by Kahuku Plantation Company. In recent years a considerable part of Kahuku's harvested cane has been trucked to the edges of the field and transferred to railroad cars.
>
> Kahuku's railroad equipment will definitely continue to be operated next year but if all goes well there is at least a strong choice that the plantation will be out of the railroad business in 1955. Lihue Plantation Co. on Kauai, and Kahuku are the two remaining Hawaiian Sugar Plantations still using railroads to haul harvested cane to their mills. The first major switch from rails to trucks for cane hauling in Hawaii's sugar industry occurred in 1936.

November 7, 1954, the Honolulu *Advertiser* printed:

> **KAHUKU TAKING LAST CANE TRAINS OUT OF SERVICE**
>
> The last of the Kahuku Plantation Col.'s cane hauling trains will be

dispenses with this weekend. Two diesel locomotives and many cane cars will go out of service as Kahuku's harvest season comes to an end.

The familiar sight of trains passing thru' Kahuku community on their way to the mill with their loads of sugar cane will no longer be seen by the residents and will probably be missed by old timers.

The *Advertiser* reported on March 21, 1955:

ENGINE BELLS ARE STILLED AT KAHUKU PLANTATION CO.

Within a few weeks Hawaiian railroading will be minus two locomotives that are destined for a narrow-gauge mainline in Central America. Their shipment, around the first of April to Costa Rica brings down the final curtain on railroading operations at Oahu's Kahuku Plantation Co.

The locomotives, a 45-ton Whitcomb and a 35-ton Cummins, are not the colorful steam engines that were once a familiar sigh on most plantations, but are modern diesel workhorses.

The engines are currently sitting in big crates in Kahuku's mill yard waiting to be trucked to Honolulu and hoisted aboard a freighter. The diesels are scheduled to be used for switching on the Northern Railway of Costa Rica.

Kahuku ended its railroading operations late last year and has since torn up its remaining trackage. This year Kahuku started hauling all of its cane crop by truck and is now operating a fleet of six 20-ton cane hauling units.

In its last days, Kahuku's railroad was run by three locomotive engineers and one locomotive engineer-mechanic. Jimmy Barros, engineer and mechanic, is still in the cane hauling business at Kahuku this year but behind the wheel of a big yellow tractor-trailer. The end of Kahuku's railroad also ended a gather-son tradition in railroading. Jimmy Barros is the son of the late Manual Silva Barros, a steam locomotive engineer in the hey day of island railroading. Manual Barros was chief engineer on the Koolau Railroad of the old Laie plantation and was at the throttle of most of the old Baldwin locomotives of North Oahu, some of which dated to the early 1890's.

Two other locomotive engineers at Kahuku, Manual Gomez and John Bayes, have moved far afield from railroading. They are trainmen turned painters and are now wielding brushes at Kahuku plantation. The fourth engineer, Manual Mandrigues, has retired.

Railroads have been an integral part of Kahuku's operations since the plantation's founding in 1889. Kahuku at one time operated four steam locomotives and 300 cane cars on 40 miles of permanent track that wound back into the valleys of the Koolau Range.

The Lihue Plantation Co. on Kauai is the only remaining plantation that operates a railroad. Besides Lihue there are three other operating railroads in the islands-Kahuku Railroad Company, on Maui, the oldest railroad in Hawaii; short OR&L trackage in Honolulu, and 46 miles of U.S.

Navy mainline.

In April of 1955, railroad use at Kahuku came to an end when the *Advertiser* announced on April 14,

> **KAHUKU LOCOMOTIVES TO COSTA RICA FIRM**
>
> The last and only two diesel electric locomotives owned by the Kahuku Plantation Co., were loaded aboard the *Steel Architect* Wednesday morning on the first leg of their two-ship trip to San Jose, Costa Rica.
>
> The locomotives weigh 35 and 45 tons respectively and have been purchased by the Northern Railroad Co., in the tiny Central American country.
>
> Kahuku Plantation officials said sale of the locomotive marks the shift from railroad to trucking operations. The two diesels however, will merely find themselves working for a different sugar company.
>
> Castle & Cooke, Ltd., agents for the Isthmian freighter, said the locomotives will be unloaded at Christobal, Canal Zone, and transshipped to Port Limon, Costa Rica.

The Kahuku Plantation was a pioneer in its time. The hospital there was the only medical facility from Waialua to Kaneohe. Their plantation had pioneered concrete stoves for laborer's cottages and sanitation drains that were used as models for other plantations. Kahuku provided the first plantation day nursery and a high school. They had the biggest baseball diamond, the first golf course, and among the earliest lighted night courts for volleyball and tennis. Not surprisingly they innovated inter-village sports events and Kahukuans held many individual and team sports awards. Their laboratories pioneered the carbonation of white raw sugar using the native limestone around Kahuku for filter, and they devised the money-saving use of molasses as mill-fuel. They discovered that night lighting of the fields prevented tasseling and would increase the sugar yield of cane (Wilcox, 1975, p.36).

The Kahukuans of this period shared a strong feeling of pride in their home plantation and the town that grew up as a result of it. Hawai'i had the highest paid sugar workers in the world competing in a low cost world sugar market and finally, for Kahuku, they priced themselves right out of the competition.

The Kahuku Plantation Company operated for 80 years. In November 1971, the plantation officially closed (*Star-Bulletin* 12/1/71).

G. Summary

In summary, the northern end of the island of Oahu in the district of Koolauloa, was, in a sense, once a land afloat. According to its geology, it appeared once, then disappeared below the sea level and returned again. However, these geologic events occurred long before settlers arrived in the islands. The radiocarbon dates from the sites in this project area are fairly late ones (A.D. 1420-1945). Carbon dates from elsewhere on the windward coast of O'ahu show settlement beginning around A.D. 500 and centupling between 1100-1200 and increasing steadily up to the time of Western contact (1778). Inferring from the Native and Foreign Testimony of surrounding area LCAs, we assume that crops reported in these documents were the kind cultivated in this area during the earliest settlement of the area. Taking into consideration the existing evidence of general settlement elsewhere in Hawai'i and our temporary rock shelters in the project area along with the neighboring LCA data, we surmise that the inhabitants of the Kahuku area had permanent housing near the shore and *lo'i* associated with wetlands and were doing seasonal agriculture inland with temporary shelters for overnight stays and storage.

Contact with 'Western Civilization' in 1778 brought with it changes and devastating diseases which had a drastic effect on the pre-existing population. Early accounts westerners note first the flourishing and then the devastated status of the Kahuku area. Small pox as well as the introduction of sheep and cattle ranching in

Kahuku had a devastating effect on the landscape. The lands of Kahuku and Keana took on a new dry, windswept look. It is reasonable to assume that the majority, if not all, of the temporary inland habitations as well as any type of native agriculture was abandoned at this time.

By 1850 the project area was no longer being farmed traditionally. The land was being used for grazing of cattle and sheep. In 1890 the sugar industry moved into the area with the majority of the inhabitants at that time working for the plantation. Since the closing of the plantation in 1971, diversified agriculture and tourism are the main enterprises.

III. PREVIOUS ARCHAEOLOGY

Listed in the Appendix A are the earliest recordings of archaeological remains in the Kahuku area beginning with Thrum in 1911. McAllister, Handy, and Sterling and Summers also record sites in the area (Fig. 7) and their findings are also listed in Appendix A.

Recently, Pfeffer and Hammatt (1992) conducted a historic reconnaissance of the Waialua to Kahuku area for a powerline project and noted that many archaeological sites may be present in the neighborhood of the study area, particularly along the shoreline areas. Sites are likely to be present in the upland areas such as our project area, but by comparaison they would be fewer in number.

Archaeological Consultants of Hawaii (ARCH) conducted a survey in 1990 that partially coincides with our present project area, however, this report is unavailable at this time.

Bertell Davis (1981), in his reconnaissance survey of Hawaiian Wind Farm Project Area at Kahuku, located a religious site, 2 habitations and a boundary marker. He has suggested that "these sites were once associated with upland *kula* (dryland) and/or forest zoned agriculture and represent an aboriginal response to conditions of persistent wind, high annual rainfall and low topographic relief developed stream channels" (Davis, 1981:1).

Aki Sinoto (1981) did a reconnaissance survey of the Ki'i and Punamano Wetland Refuge Units in Kahuku. He relocated 2 of McAllister's sites (Puumano Spring and Ki'i Fishpond).

Chiniago (1981) conducted a cultural resources reconnaissance of the Kahuku Agricultural Park Project Area for Wilson Okamoto and Associates and demonstrated "that the project area had been the focus of considerable prehistoric activity," This report

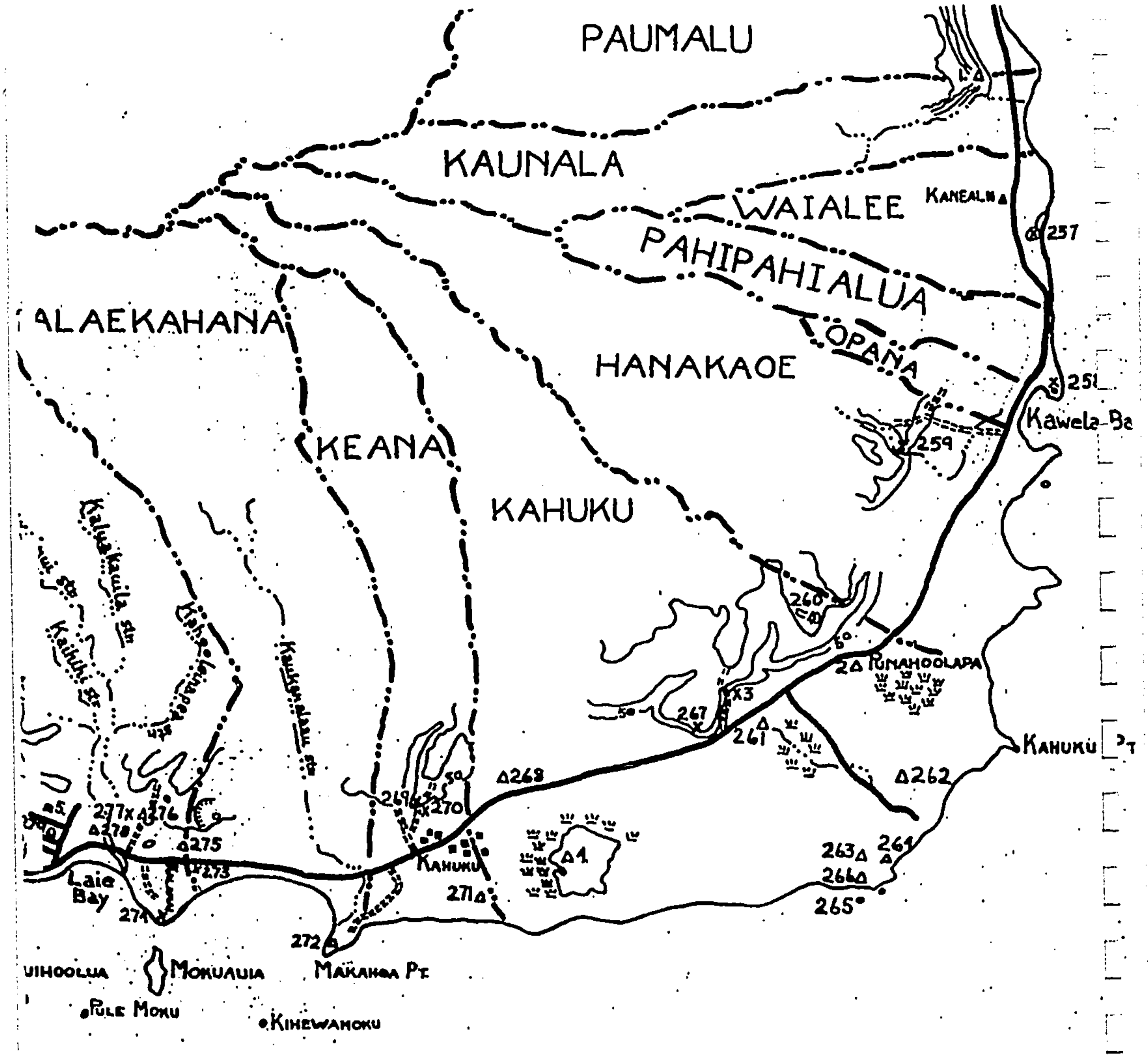


Fig. 7 McAllister and Sterling & Summers Sites

suggests that the paucity of findings in this area is due to the heavy modifications of commercial agriculture.

In the field investigations of Chiniago for Kahuku Agricultural Park (1979) no structural remains were discovered but some scatterings of cultural materials were located.

Barrera (1979) conducted a survey and salvage excavations in an area being developed by the Kahuku Housing Corporation, just inland of the post office at Kahuku (Fig. 8). Five sites were recorded. These included wall structures, mounds, 1 cave, and an enclosure. His excavations revealed that these sites were associated with historic farming.

> Site 1425 - "This site consists of two walls constructed of multiple-stacked limestone slabs, situated...adjacent to the limestone cliff."
>
> Site 1426 - "This is a coral-slab-lined depression measuring 4.1 meters in length, 0.95 meter in width and 1.05 meters in depth. A large metal pipe enters the feature in the southeast corner and this fact, indicate that the feature was most probably associated with irrigation of the surrounding sugarcane fields."
>
> Site 1427 - "This is a complex of seven features [three walls, three mounds and one cave] situated on the north slope of [a] limestone knoll."
>
> Site 1428 - "This is a wall of limestone fragments located at the top of the limestone cliff on the south side of the survey area."
>
> Site 1429 - "This is a mound of earth enclosed on two sides by crude limestone fragment walls."

Stephan D. Clark (1979) conducted a reconnaissance survey for Department of Housing and Community Development, City and County of Honolulu, on December 28, 1978. The approximately 57.3-acre proposed Koolauloa Housing Project area and Park Expansion Area in Kahuku are located directly west of Kahuku High and Elementary School.

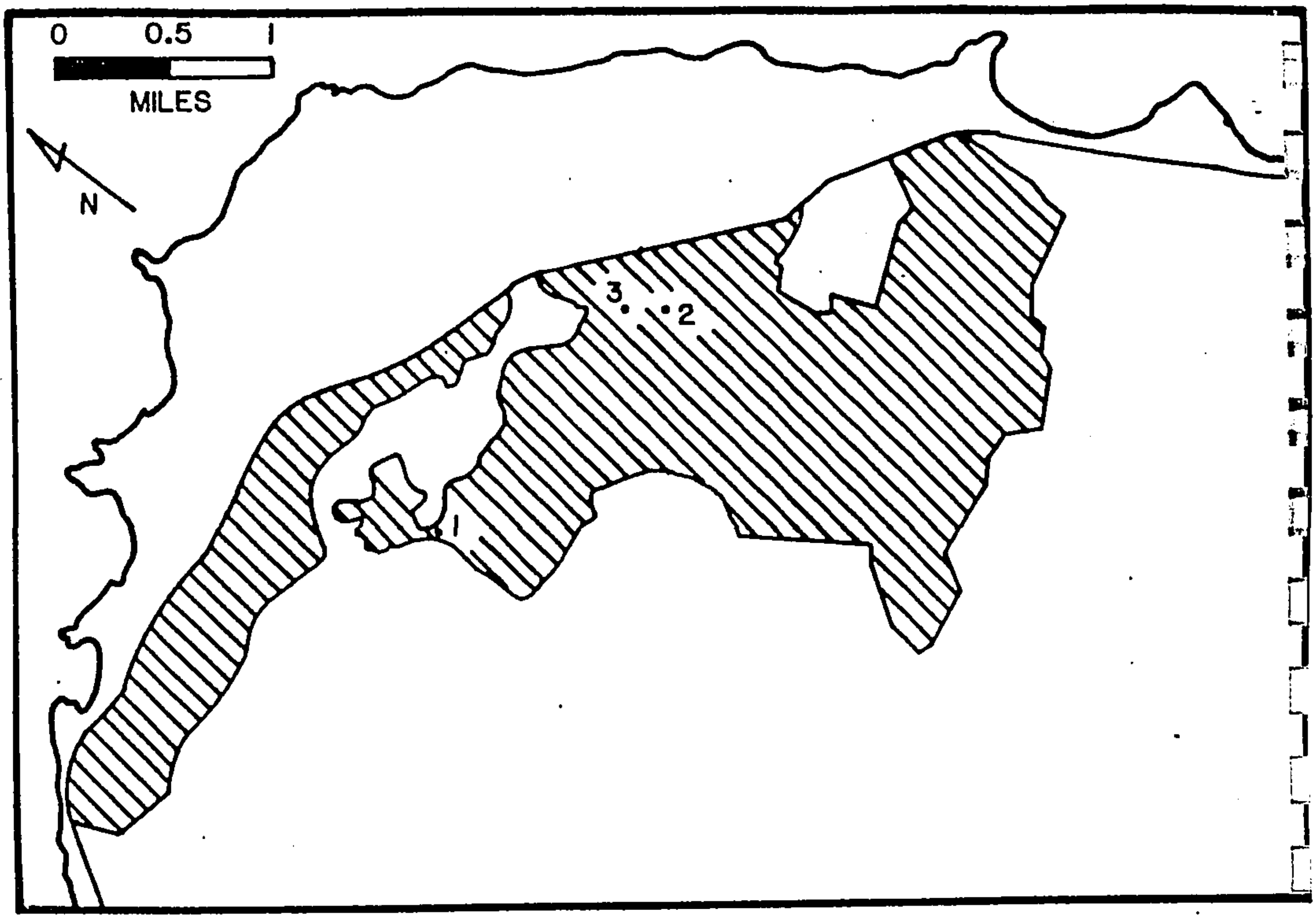


Fig. 8 Map of Area Surveyed by Barrera Showing 3 Possible Site Areas (Barrera, 1981)

A "sacred way," located in the northeast section of the proposed housing area was visited. It was considered a "sacred way" by the Hawaiians working at Kahuku Plantation in the 1930's and earlier. Clark's report notes:

> "During the early plantation days at Kahuku, no structures of any sort were built on it, in deference to the Hawaiian's beliefs; however, flowers and trees planted on the "sacred way" were acceptable to the Hawaiians. The area is a little over 60 meters in length with undetermined width. No physical features (e.g. rock alignments) mark its boundaries, and it was noted that no structures are presently built on it."
> "McAllister's site #269, is probably a small heiau, or ko'a, situated on the northwest edge of a coral outcrop in the park expansion area. The physical description fits the one provided by McAllister. It is a rectangular, raised platform 4.8 x 2.9 meters in size with a maximum height of 1.5 meters."
> " The staff also visited on elevated coral outcrop which is scheduled of extensive modification (i.e. leveling) for road construction. there are numerous cracks, crevices, and cave shelters in the outcrop--many of which were probably missed by this survey. However, on the north face, on the first ledge below the top the Conklins pointed out a small "shelter" containing skeletal and wood remains. The skeletal remains are probably human and represent only one burial (rib fragments were observed). The wood remains show distinct modifications. It is uncertain whether the skeletal and wood remains represent the same or different time periods. No other artifacts or midden were seen; however, crudely constructed walls and shelters, utilizing natural coral outcrops, are present on the ledge in front of (north of) the burial, and extend to the west for about 35 meters. Other walls and stacked coral mound features were seen on the slopes below and were flagged with pink surveyors tape. these sites were previously unrecorded."
> " A small section of the fairly steep coral cliff slope, located along most of the southern border of the project area, was only briefly surveyed due to lack of time. Many cave shelters were seen but those inspected contained no burials or cultural remains. A probable historic wall about 60 meters in length and built with coral slabs was seen, as well as an historic grave, indicated by a deteriorated wooden grave marker with the year 1945 barely discernable.

In August of 1979 Rose Schilt conducted a 4-acre Archaeological Reconnaissance Survey of Proposed Extension, Kahuku Elementary School for Department of Accounting and General Services. A total of four sites were found during her survey. She found a rock shelter and a platform, both previously recorded by McAllister, a mound, and an overhang shelter.

Paul Rosendahl (1977), in his survey of military lands, documented three (3) sites in ‘O‘io Gulch Kahuku, close to our project area. In this survey he located a complex of possible agricultural terraces and a habitation platform.

Thomas Dye (1977) conducted a reconnaissance survey adjacent to the Kuilima resort at Kahuku in 1977, and recorded two sites of cultural layers in sand dunes.

> 50-Oa-F4-14 - "This site was discovered as an extensive, grey-to-greyish-brown sandy deposit exposed in several places along the windblown *makai* face of the high sand dunes at Kahuku Point."
>
> 50-Oa-F4-15 - "A black layer, 26 cm thick, was found exposed in a backhoe cut along an old railway alignment."

J. Halley Cox (1970: 97) mentions a boulder on the beach at Keana on which there is a single petroglyph of a human figure.

Table III: Kahuku Agricultural Park Site Inventory

CSH SITE #	STATE SITE #	TYPE	FUNCTION	MAP	PROB. AGE	SIGNIFICANCE
1A	50-80-02-4510A	Overhang Shelter	Temp. Hab.	X	P	D,E
1B	50-80-02-4510B	Overhang Shelter	Temp. Hab.	X	P	D,E
2A	50-80-02-4511A	Overhang Shelter	Temp. Hab.	X	P	C,D,E
2B	50-80-02-4511B	Overhang Shelter	Temp. Hab.	X	P	D,E
3	50-80-02-4512	Enclosure	Poss. Hab.	X	P	D
4A	50-80-02-4513A	Wall Stucture	Wall	X	P	D
4B	50-80-02-4513B	Terrace	Prob. Ag.	X	P	D
4C	50-80-02-4513C	U-shaped Enclosure	Temp. Hab.	X	P	D
4D	50-80-02-4513D	Cobble Paved Terrace	Walkway	X	P	D
4E	50-80-02-4513E	Overhang Shelter	Temp. Hab.	X	P	D,E
5	50-80-02-4514	Terrace	Temp. Hab.		P	D
6A	50-80-02-4515A	Overhang Shelter	Temp. Hab.	X	P	D,E
6B	50-80-02-4515B	Overhang Shelter	Temp. Hab.	X	P	D,E
21A	50-80-02-4516A	Wall Structure	Temp. Hab.	X	P	D
21B	50-80-02-4516B	Overhang Shelter	Temp. Hab.	X	P	D,E
21C	50-80-02-4516C	Wall Structure	Temp. Hab.	X	P	D

IV. SURVEY RESULTS

A total of seven archaeological sites were located in the presently proposed Kahuku Agricultural Park which includes Area 2 and 3 only (see Figure 4).

A. Kahuku Site Descriptions

State Site #	50-80-02-4510	**CSH Site :** 1
Site Type:	Overhang Shelters	
Function:	Temporary habitation	
Total Features:	2	
Dimensions:	84 m.^{2}	
Location:	Ohia Gulch	

Description: Site 4510 (CSH 1) (Fig. 9) is comprised of two rock overhangs (Features A & B) in a coral/limestone cliff which lie between a large break in the cliff wall. These overhang shelters are located at the northwest end of Ohia Gulch overlooking the flood plain. Both features A and B are open to the east and contain a small litter of kukui nut and water rounded stones. On the exterior of Feature A is a leveled soil area. Feature B also has a small leveled soil area on the exterior of the shelter. The surrounding vegetation consists of Christmas berry, *koa haole*, and *Macaranga* trees. Farther down slope towards the flood plain is tall California grass.

Located directly below Feature B are the remnants of a cement irrigation ditch associated with the cultivation of sugarcane and pineapple. The irrigation ditch appears to have been running along the ridge of Ohia Gulch and a flume was constructed over Feature B and down into the flood plain.

Feature A consists of a rock overhang. The entrance measures 1.2 m. wide by 1.2 m. high and the shelter is 1.8 m. deep. The interior consists of fairly level soil with loose cobbles on the surface. The level soil area on the exterior of Feature A measures 14 m. N/S by 5.5 m. E/S and there are fragments of kukui nut scattered about the level soil terrace. A stone step is placed between Features A & B.

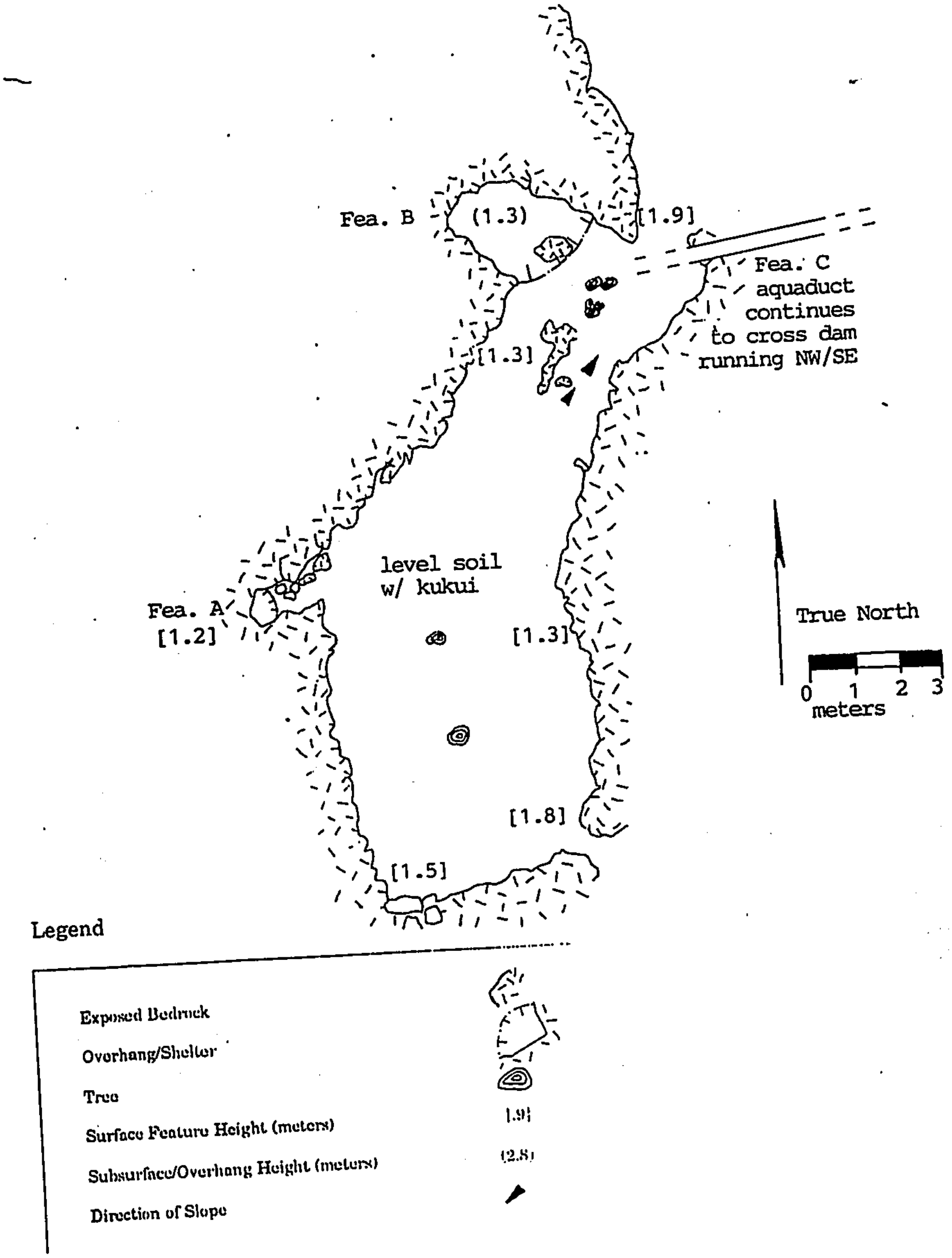


Fig. 9 State Site # 50-80-02-4510, Plan View

Feature B consists of an overhang shelter located approximately 5 meters to the northeast of Feature A along the same limestone cliff. The entrance measures 2.4 m. wide by 1.5 m. high and the overhang is 2.4 m. deep. Midden and modern pieces of wood and nails were also observed on the surface of the interior. The level soil area outside this feature measures 2.7 m. N/S by 3 m. E/S. No midden or artifacts were observed in this area.

Both Features A and B have fair excavation potential because of the soil content and the evidence of surface midden. The soil depth is estimated to be 50 cm. These features are both temporary habitation shelters.

The irrigation ditch, located directly below Feature B, is one of many ditches evident throughout the project area. A cement dam structure, also located below Feature B, in the flood plain to channel water to other irrigation ditches. The dam structure is the only remaining intact section. Most of the cement ditches throughout the project area have been destroyed by dozing or natural weathering.

CSH Site : 2

State Site	50-80-02-4511
Site Type:	Overhang Shelters
Function:	Temporary Habitation Shelters
Total Features:	2
Dimensions:	600 m.^{2}
Location:	Ohia Gulch

Description: Site 4511 (CSH 2) (Fig. 10) consists of two overhang shelters located *mauka* of CSH 1 along the west side of Ohia Gulch along the limestone cliffs. The total area of this site is 40 meters N/S by 15 meters E/W. Both overhangs are open to the east. The coral/limestone cliffs overhangs are modified to create a shelter. The vegetation in this area is *koa haole*, Christmas berry, California grass, and a Banyan tree.

Feature A consists of a overhang shelter measuring 16 m. wide (E/W) by 7 meters

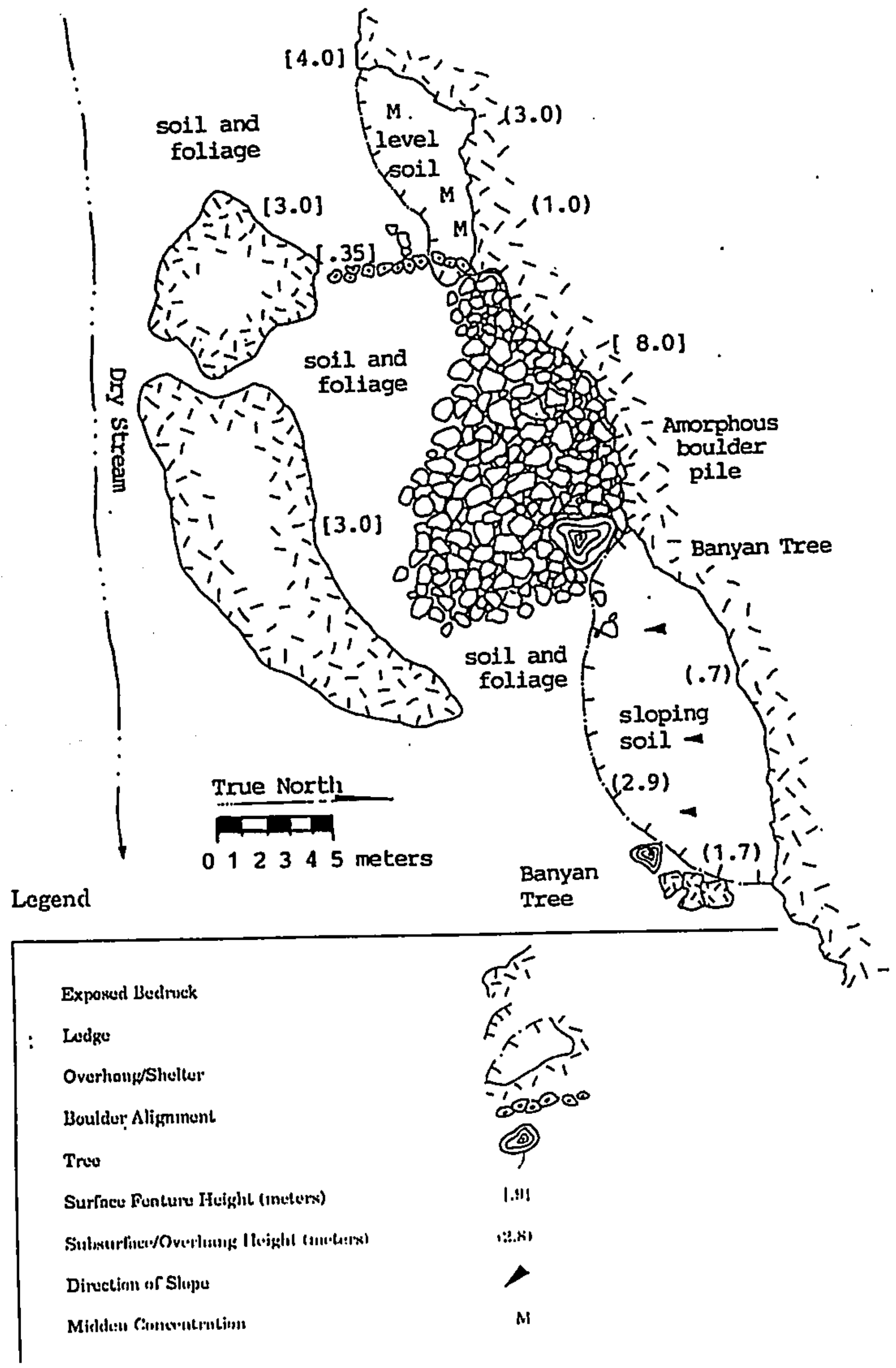


Fig. 10 State Site # 50-80-02-4511, Plan View

deep (N/S) with a maximum ceiling height of 2.9 meters. The surface is a sloping soil surface fairly rock free. The surface area is compact silty soil with scattered midden consisting of kukui nut shells and marine shell midden. No artifacts were observed.

A large boulder pile is located between Feature A and B along the same limestone cliff. The boulder pile measures 14 meters E/W by 9 meters N/S. This may have been a structure at one time but is presently heavily disturbed by the growth of a large banyan tree and possibly from bulldozer push from the above flat ridge land.

Feature B consists of a overhang shelter located 13 meters to the west of Feature A. This features measures 9 meters wide (E/W) by 5 meters deep (N/S) and has a maximum ceiling height of 2 meters at the entrance. The interior of this shelter consists of fairly level soil surface with goat bones scattered about. Midden, including kukui nut and marine shell, was also observed on the surface of the interior of this shelter. At the northeast end of this shelter is small boulder alignment, approximately 2 meters long, oriented in a N/S direction. A metal site tag marker was observed at the entrance to this feature (ACH 5/2A; Coral Res. 10-16-90).

Both features remain in fair condition and have good excavation potential due to the thick soil deposit and evidence of cultural material scattered about the interior surface of this shelter. The estimated soil depth for these shelters is 70 cm.

CSH Site : 3

State Site #:	50-80-02-4512
Site Type:	Enclosure
Function:	Temporary Habitation Shelter
Total Features:	1
Dimensions:	13.1 m. N/S by 3 m. E/W
Location:	Ohia Gulch

Description: Site 4512 (CSH 3) (Fig. 11) consists of an enclosure located *mauka* of site CSH 2 on the west side of Ohia Gulch along the upper edges of the limestone cliffs. This site measures 13.1 meters N/S by 3 m. E/W and is constructed of stacked small to

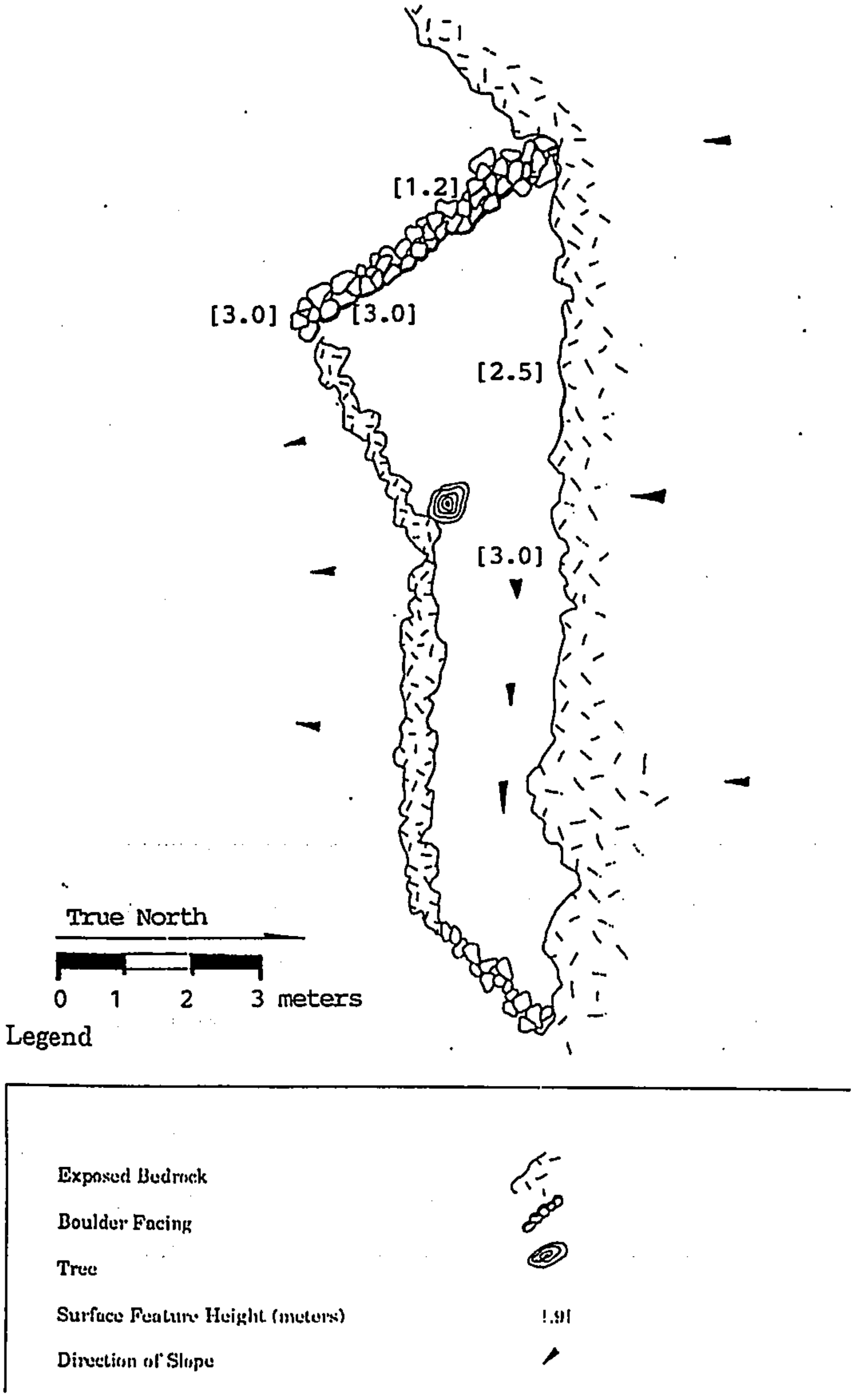


Fig. 11 State Site # 50-80-02-4512, Plan View

medium limestone boulders utilizing the natural walls of the surrounding limestone bluff to form an enclosure. The walls range from 30 cm high to 1.2 meters high, and average 75 cm thick. The naturally formed walls range from 2.5 meters to 3.5 meters high. The enclosure interior consists of level soil with grass and shrub. The surrounding vegetation consists of *koa haole*, California grass, and banyan trees. No midden or indigenous artifacts were observed at this feature, although historic bottles, a sewing machine, and rusted pots and pans were observed directly to the east of this enclosure.

This feature has poor archaeological excavation potential because of its shallow soil deposit and absence of any visible prehistoric cultural material.

State Site #: 50-80-02-4513 **CSH Site :** 4
Site Type: Wall Segments/Terraces/Enclosure/Overhang
Function: Permanent Habitation
Total Features: 5
Dimensions: 28 m. NE/SW by 12 m. NW/SE
Location: Ohia Gulch
Testing: 1 m.^{2}

Description: Site 4513 (CSH 4) (Fig. 12) complex consists of five designated features, A - E located on the west side of Ohia Gulch along the limestone cliffs in fairly level area. The total site measures 28 m. NE/SW by 12 m. NW/SE. These features are located on a large limestone outcrop sloping down toward a intermittent stream. The surrounding vegetation consists of banyan and *koa haole*.

Feature A consists of a wall segment 8 meters long, oriented generally in a NE/SW direction, averaging 1.75 meters thick and 60 - 80 cm. high. This wall is constructed of stacked limestone boulders and slabs. Both the NE and SW ends of the wall abut a limestone outcrop. No surface midden or artifacts were observed at this feature. Although this wall remains in fair condition the excavation potential is poor.

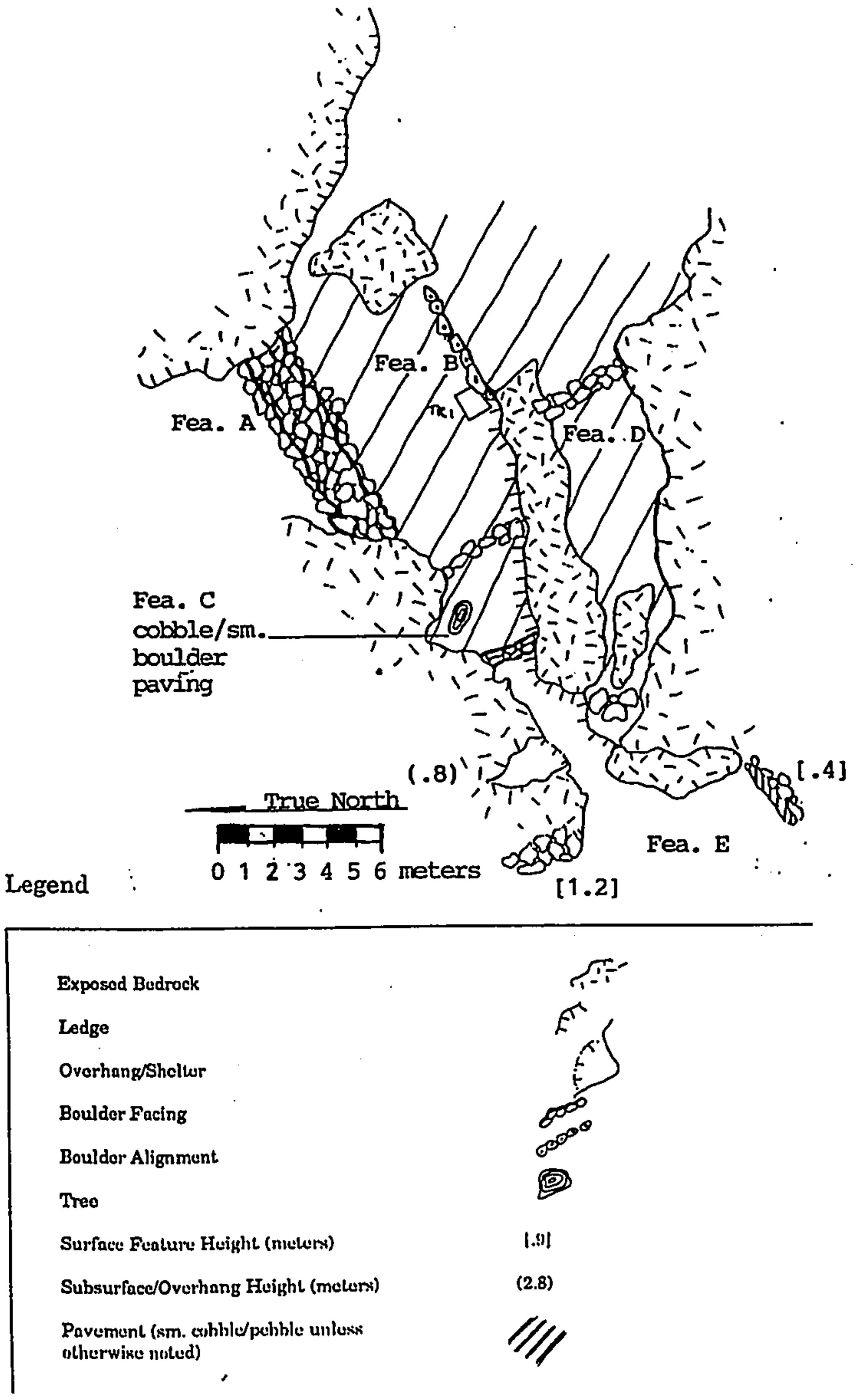


Fig. 12 State Site # 50-80-02-4513, Plan View

Feature B consists of a cobble paved terrace located directly to the south of Feature A. The entire terrace and paved area measures 9 m. NE/SW by 5 m. NW/SE. Approximately 5 m. of facing is visible with the paved area extending to the base of Feature A and to the west towards Feature C. The terrace is constructed of layered limestone slabs and cobbles. The southern end of the terrace abuts a natural limestone outcropping approximately 1 meter high which acts to semi-enclose the area. At the northern end of the terrace is a collapsed wall. No midden or artifacts were observed at this terrace. The feature remains in fair condition and has fair excavation potential.

Feature C consists of a U-shaped enclosure located to the west of Feature B. This feature is open to the east and has a raised paved interior. The back walls of this enclosure (south side) utilize the natural limestone outcropping to form the enclosure. These natural walls average 2 m. high also. The interior of this feature is a raised level paving approximately 40 cm. high. It is paved with small limestone cobbles and slabs. The interior measures 4 m. E/W by 3 m. N/S. No midden or artifacts were observed on the surface of this feature. A metal site tag marker was found on the back wall (ACH Temp #S1b, Coral Res, 10-16-90).

This feature remains in fair condition and has fair to good excavation potential.

Feature D consists of a limestone cobble paved terrace located south of Features B and C. This terrace and paved area measure 7 m. E/W by 3.5 m. N/S. The relative flatness of this feature provides a open area. The only remaining facing of this terrace is visible on the south end of the terrace and utilizes a natural outcropping of limestone.

No midden or artifacts were observed on the surface of this feature. This feature remains in fair condition and the excavation potential is fair.

Feature E consists of an overhang shelter and two small rock alignments located

12 m. south of Feature A. The overhang shelter measures 3 m. wide at the entrance, 6.5 m. deep and 80 cm. high. The interior consists of shallow level soil with scattered goat bones about the surface. On the overhang is a silver tag which reads ACH L Temp S-K Coral Reserve 10/16/90. Approximately 3.5 m. southeast of the overhang is small rock alignment with upright slabs. This alignment measures 3 m. long, (oriented roughly NE/SW), is 50 cm. thick and 40 cm. high. Located 3 m. to the east of the overhang is another alignment constructed of small limestone boulders and cobbles. This alignment measures approximately 2.5 m. long (oriented roughly N/S), and is 50 cm. thick and 1.2 m. high. No midden or artifacts were observed.

This feature remains in fair condition. The overhang shelter has fair to poor excavation potential because of the shallow soil deposit.

CSH Site : 5

State Site #:	50-80-02-4514
Site Type:	Terrace
Function:	Temporary Habitation
Total Features:	1
Dimensions:	1.5 m.^{2}
Location:	Ohia Gulch

Description: Site 4514 (CSH 5) consists of a single terrace located directly downslope of Site 4 near the dry streambed. This terrace measures 3 meters roughly N/S, 50 cm. wide, and approximately 75 cm. high. This terrace is constructed of small to medium size limestone boulders and slabs. This terrace retains a level soil area, and is fairly rock free. No midden or artifacts were observed at this site. This feature has fair excavation potential because of its possible thick soil deposit.

CSH Site : 6

State Site #:	50-80-02-4515
Site Type:	Overhang Shelters
Function:	Temporary Habitation
Total Features:	2
Dimensions:	14 m. N/S by 10 m. E/W
Location:	Ohia Gulch
Testing:	1 m.^{2}

Description: Site 4515 (CSH 6) (Fig. 13) consists of two overhang shelters designated as Features A and B. This site is located at the base of a large limestone bluff southeast of CSH site 4. The surrounding vegetation consists of *koa haole*, Christmas berry, California grass and Banyan trees.

Feature A, the southern-most shelter, measures 5 m. wide (E/W) by 4 m. deep and is approximately 2 m. high. The soil floor interior is level and contains a few scattered boulders and cobbles as well as a small scatter of midden, including kukui nut and small mammal bones (goat). This feature is in good condition and has good excavation potential. The estimated soil depth is 60 cm. minimum

Feature B is another overhang shelter located north of Feature A. This shelter measures 4 m. wide (NE/SW) by 1 m. deep and 1.4 m. high. The interior of this shelter consists of rocky soil with a scatter of goat bones. This feature is also in good condition and has good excavation potential.

CSH Site : 21

State Site #:	50-80-02-4516
Site Type:	Wall Structures and Overhang Shelter
Function:	Temporary Habitation
Total Features:	3
Dimensions:	193$^{m.2}$
Location:	*mauka* of Koolauloa Housing Project
Testing:	1 m. x .5 m.

Description: Site 4516 (CSH 21) (Figs. 14, 15, 16) consists of two wall structures and a overhang shelter located on a small limestone outcrop in the northeastern portion of

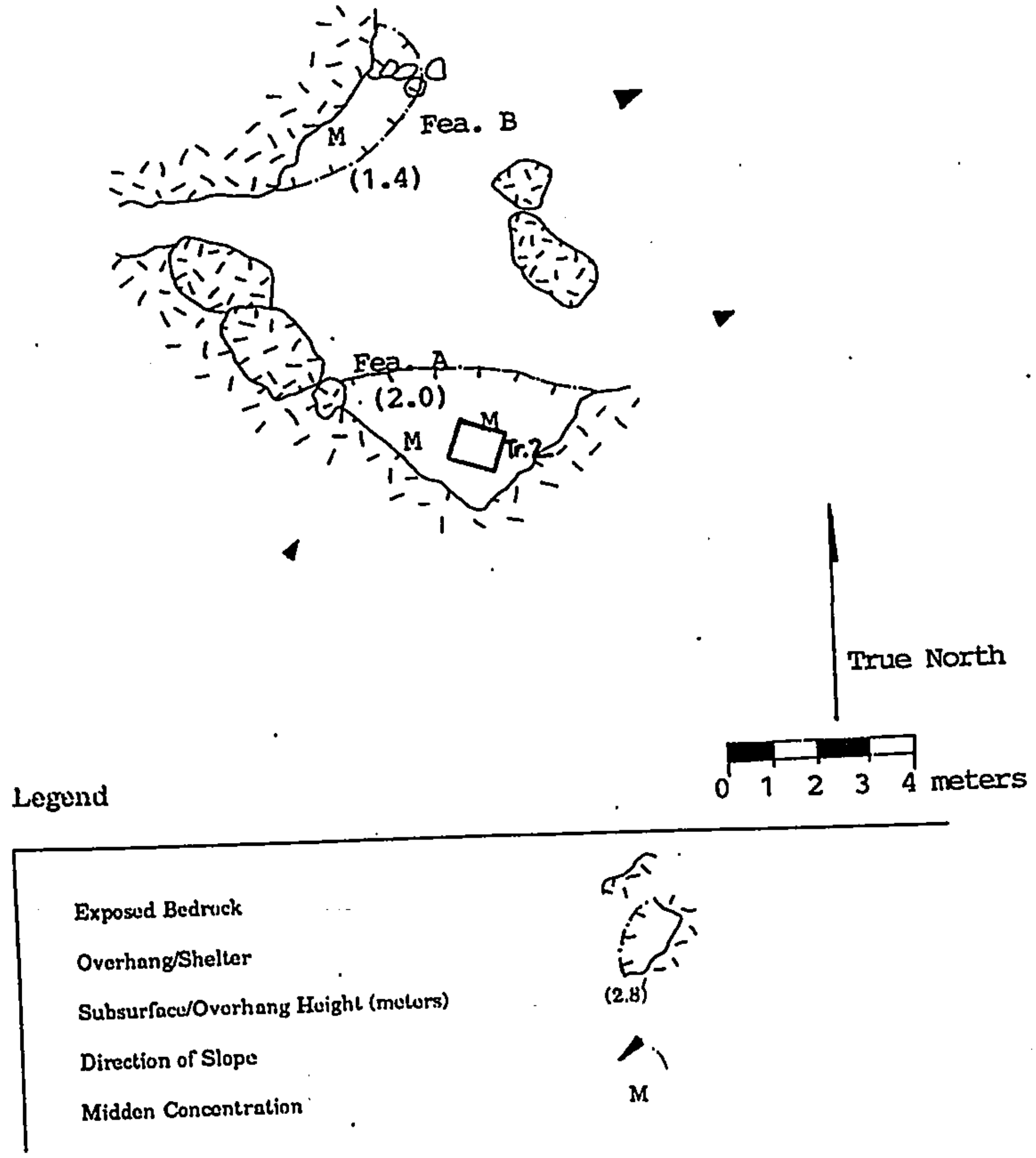
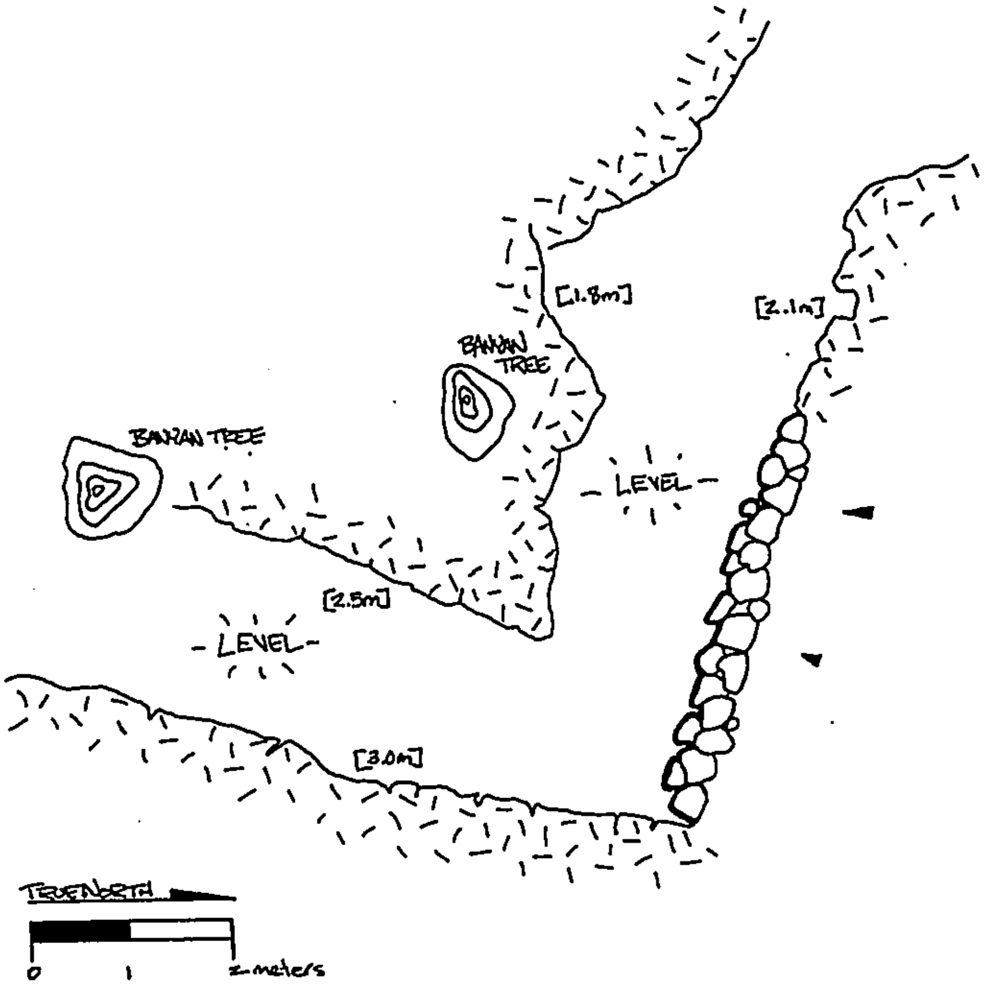


Fig. 13 State Site # 50-80-02-4515, Plan View of Features A & B



Legend

Exposed Bedrock

Boulder Facing

Tree

Surface Feature Height (meters) [.9]

Direction of Slope

Fig. 14 State Site # 50-80-02-4516, Plan View of Feature A

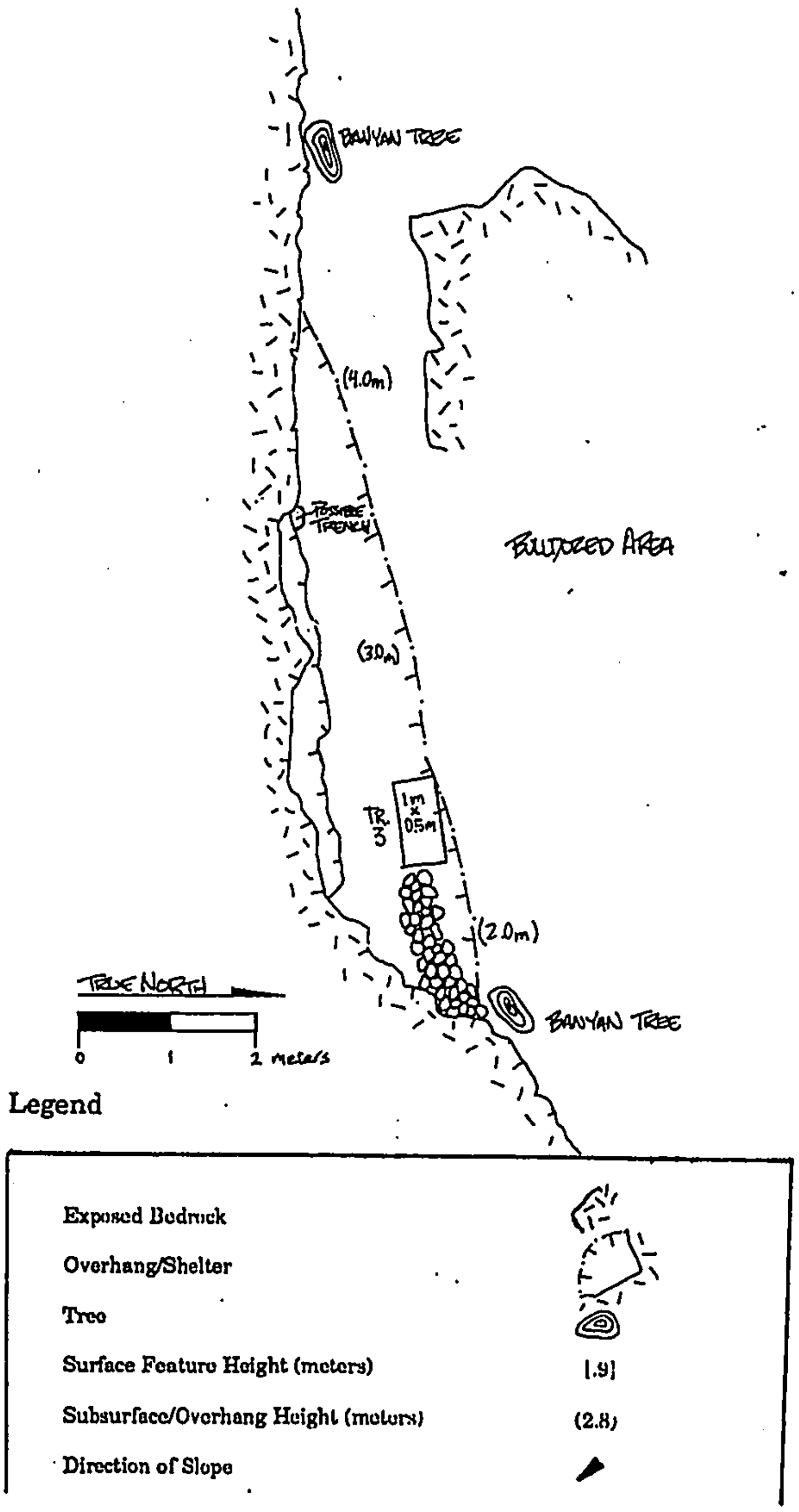


Fig. 15 State Site # 50-80-02-4516, Plan View of Feature B

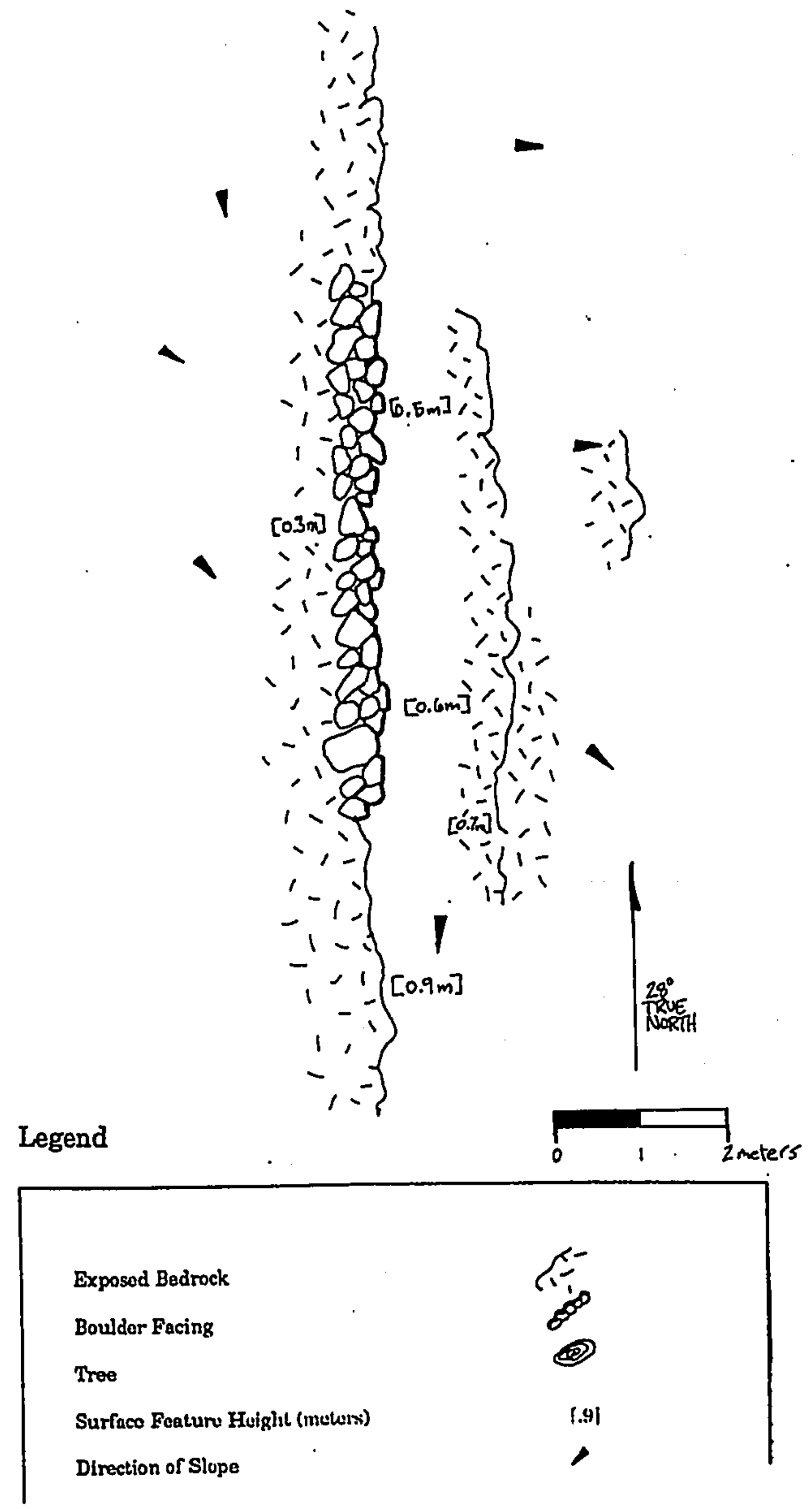


Fig. 16 State Site # 50-80-02-4516, Plan View of Feature C

the project area. These features have been designated as Features A (Wall section), B (Overhang shelter), and C (Wall section). These features are located on the south side of the limestone outcrop. The surrounding vegetation consists of *koa haole*, Christmas berry, guava, noni, California grass, and banyan trees. The surrounding terrain is very level, obviously bulldozed, with remnants of old sugarcane and pineapple irrigation systems visible. On the west side of the outcrop is a bulldozer push pile of boulders and soil. Remnants of the irrigation ditches, constructed of cement, have been heavily damaged by bulldozing. Modern trash is scattered about the surface of the outcrop.

Feature A consists of a short wall section, 4.3 meters long, oriented roughly N/S. This feature is located on the south side of the limestone outcrop. The wall is constructed of stacked, medium size limestone slabs, 4-6 courses high. The east end of the wall abuts a natural sandstone wall while the west end of the wall utilizes the natural limestone outcropping. No cultural material was observed at this feature, although modern trash is scattered about the outcrop.

Southeast of this wall are two smaller wall sections probably also associated with this feature. The walls are of similar construction. They are situated in a area where there is a break in the limestone outcrop. They stand 30 - 50 cm. high, 1 - 2 meters long, and are 50 - 60 cm. wide. Both walls are constructed of medium size limestone slabs.

Feature B consists of an overhang shelter located approximately 15 meters to the west of Feature A at the base of the limestone outcrop. The overhang measures 9.5 meters wide, 2 meters deep, and a maximum ceiling height of 3 meters. Evidence of the piling of limestone slabs is visible at the west end of the feature. Located at the east end of the overhang is a possible trench measuring approximately 50 cm. x 50 cm. The soil floor of the overhang interior is fairly level but has some scattered rocks. A few pieces of shell midden and mammal bone were observed on the surface of the soil floor. This feature has good excavation potential.

Feature C consists of a low, faced wall located northwest of Feature B. This feature is constructed of small to medium limestone slabs stacked 3 - 5 courses high. No midden or artifacts were observed at this feature.

There is the possibility that in the past there may have been additional archaeological sites or features at this outcrop, but due to the cultivation of sugarcane and pineapple the area has been heavily disturbed. The destruction of former archaeological sites is probable throughout the entire project area.

The irrigation ditches and flumes seen throughout the project area were not given site numbers. They are associated with the commercial cultivation of sugarcane and are considered to be no longer significant. The ditches are constructed of cement, are approximately 8 inches wide by 8 inches high, and were found on the edges of fields wherever sugarcane was once grown.

B. Testing Results:

A total of three test trenches were excavated at three sites during the inventory phase of the survey, State Site 50-80-02-4513 Feature B (Terrace), State Site 50-80-02-4515 Feature A (Overhang Shelter), and State Site 50-80-02-4516 Feature B (Overhang Shelter). Each site was tested for cultural deposits, to better determine their functions, and to collect charcoal samples for possible carbon dating. The trenches were designated as trenches 1, 2, and 3. Both Trenches 1 and 2 were 1 $_{m2}$ units and Trench 3 was a 1 m. x .5 m. unit. Each trench was excavated to bedrock or sterile soil. Levels were designated to each strata. All soil was screened through 1/8 inch steel mesh screens to recover any midden or artifacts. Charcoal was also collected for carbon dating.

State Site 50-80-02-4513 Feature B Trench 1

Trench 1 was excavated at Site 50-80-02-4513 Feature B terrace. A one meter square test unit was excavated in the central portion of the terrace.

Stratigraphy

The excavation of Trench 1 revealed two stratigraphic units (Figure 17). Stratum I, 0 - 70 cm., consisted of mostly limestone cobbles and slabs with a filtered A - horizon, fine to medium grain (5YR2.5/1 Black). Stratum II, 70 - 80 cm., was a slightly compact (5Y2.5 3/3) dark reddish brown, medium to large grain containing many limestone cobbles. This layer directly overlies bedrock.

Cultural Material

No cultural material was collected from the excavation of Trench 1. Although no cultural material was collected during the excavation of this trench, this feature has been designated as part of a permanent habitation complex because of its size, construction, and location to other features.

State Site 50-80-02-4515 Feature A Trench 2

Trench 2 was excavated at Site 50-80-02-4515 Feature A, a overhang shelter. A one-meter square test unit was excavated in the soil floor interior in the southeast portion of the overhang shelter. A human burial was found during the excavation of this unit.

Stratigraphy

The excavation of Trench 2 revealed three stratigraphic units, Strata I, II, and III (Figure 18). Stratum I, 0-20/30 cm., was a loose dark brown, fine to medium grain A -

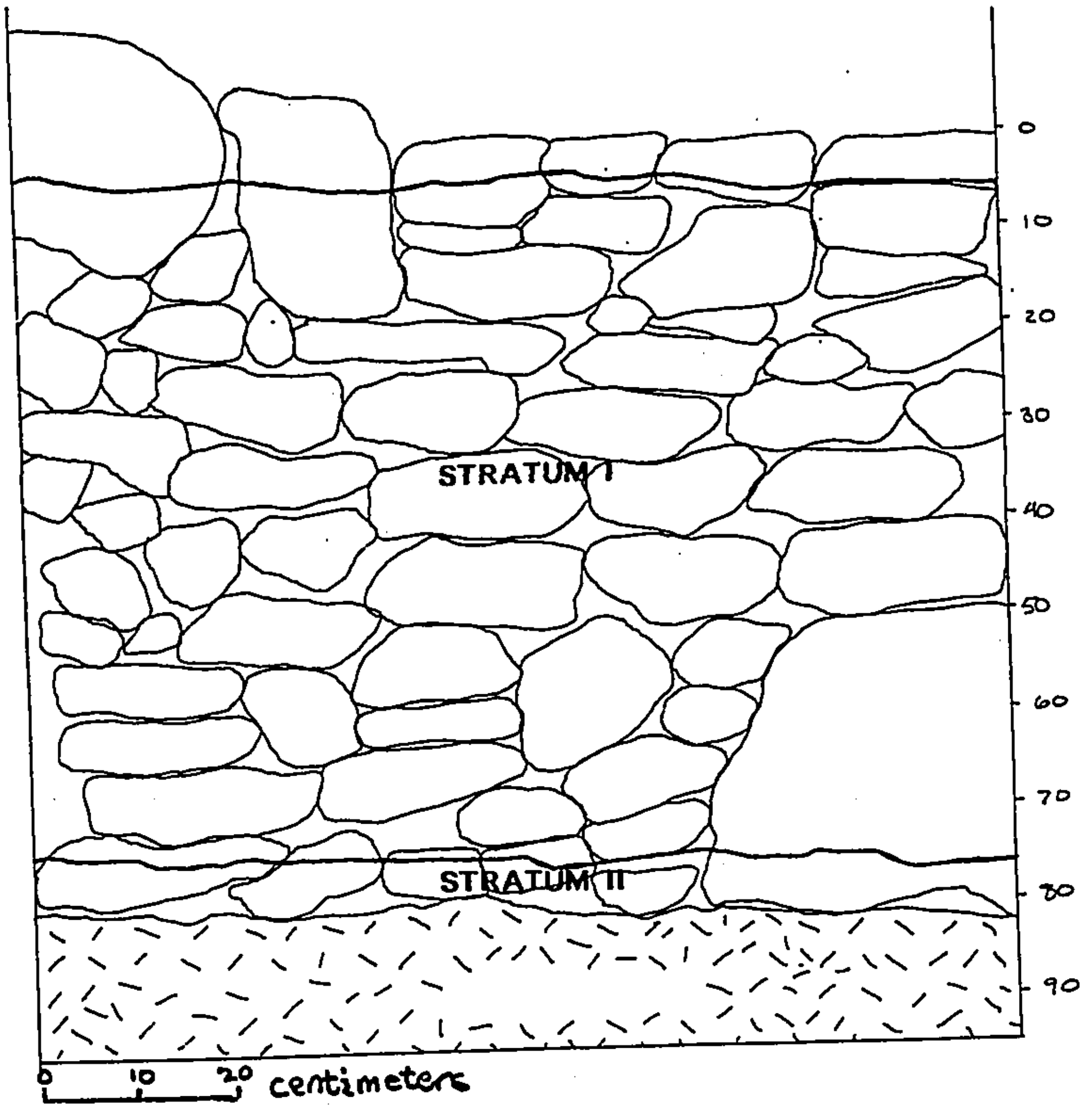


Fig. 17 State Site 50-80-02-4513, Feature B, Trench 1 Profile

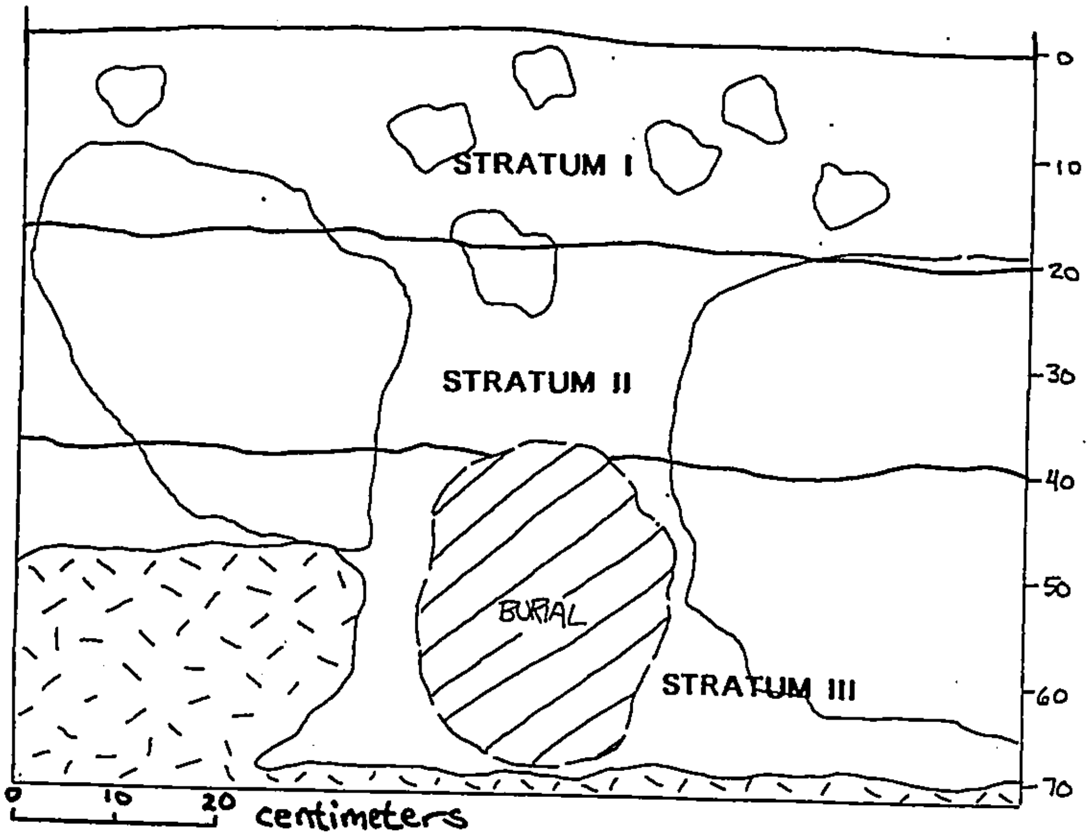


Fig. 18 Site 50-80-02-4515, Feature A, Trench 2 Profile

horizon (5YR 3/2). Also incorporated in this level are small to medium size limestone cobbles. Stratum II, 20/30-40 cm., was a light brown, fine to medium grain, silty level (5YR 4/2 Brown/dark brown). This level incorporated larger boulders extending down into the Stratum III level. During the removal of Stratum II, it was recognized that the west half of the trench consisted of loose burial pit fill. The burial pit originates from the base of Stratum II and is intrusive into the Statum III level, meaning it postdates Stratum III. Stratum III, 40-70 cm., was a slightly compact yellow brown containing many cobbles and pebbles (5YR 6/6 Reddish yellow). This level was sterile with evidence of decomposing bedrock.

Cultural Material

Cultural material was collected from all three stratigraphic units during the excavation of Trench 2 (Table III). Cultural material collected includes both midden and artifacts, and also charcoal samples to be analyzed and carbon dated.

Midden was collected from all three stratigraphic units. Stratum I produced a total of 92.6 grams of marine invertebrate, 5.6 grams of unsorted bones, 114.2 grams of kukui nut, and 491 grams of charcoal. Stratum II produced a total of 218.9 grams of marine invertebrate, 22.7 grams of unsorted bones, 82.7 grams of kukui nut, and 9.3 grams of charcoal. Midden collected from the Stratum III level was collected from the boundary between the Stratum II and Stratum III levels. Stratum II is contemporaneous with the occupation of this feature.

Artifacts were collected from the Strata I and II levels only. Artifacts collected from Stratum I included one shell bead, 35 volcanic glass flakes, one basalt adze flake, and some gourd fragments. Artifacts collected from Stratum II included one he‘e (octopus) lure sinker (basalt), and 40 volcanic glass flakes. No historic artifacts were found during the excavation of Trench 2. No artifacts were found below the Stratum II level.

Human Burial

During the excavation of Trench 2 a human burial was discovered at 40 cm., in a pit originating in Stratum II. The burial was located in the west face of the trench in a clearly visible pit, flexed and articulated with the skull oriented to the west, and the skeleton placed on its right side. One associated artifact was observed with the burial, a stick, 65 cm. long and 2 cm. in diameter, worked on both ends. This stick was found on the top of the burial. Judging by the length of the long bones and the size of the skull, the burial appears to be a juvenile. The burial was recorded and the trench was backfilled to prevent any further disturbance.

Radio Carbon Sample

A charcoal sample was collected from the base of the burial pit. The radiocarbon date reveals that this site was probably utilized during prehistoric times (Table IV) but because it is below the burial, the burial would postdate it. This feature has been designated as a temporary habitation shelter.

State Site 50-80-02-4516 Feature B Trench 3

Trench 3 was excavated at State Site -4516 Feature B, an overhang shelter. This one-meter x 50 cm. test unit was excavated in the central portion of the soil floor area.

Stratigraphy

The removal of 5 cm. of the limestone slab paving revealed three stratigraphic units (Figure 19), Strata I, II and III. Stratum I, 0 - 40 cm., consisted of a very loose dark brown and fine grain (5YR 3/1 very dark gray). This level contained organic material and many cobbles. Stratum II, 40 - 70 cm., was a loose, brown, fine to medium grain,

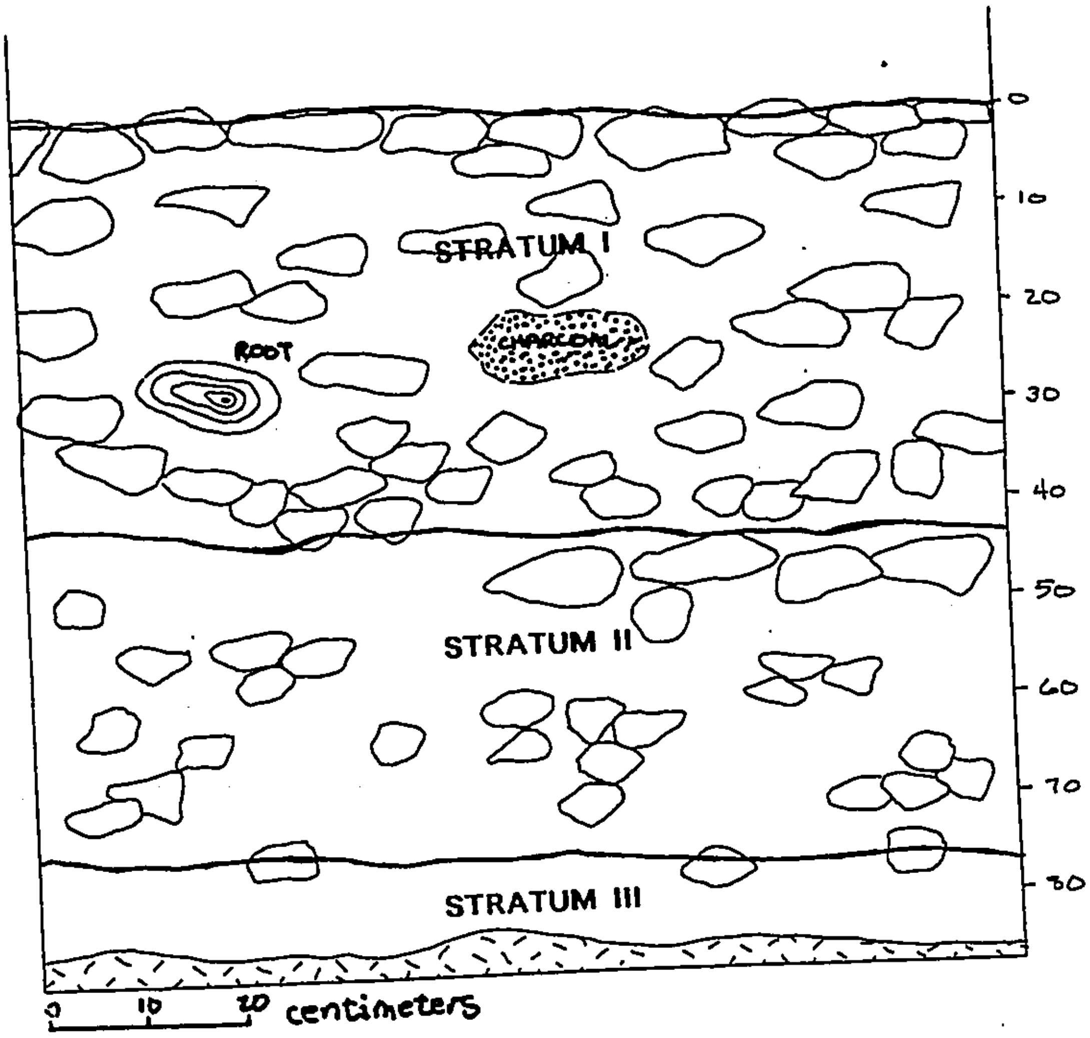


Fig. 19 Site 50-80-02-4516, Feature B, Trench 3 Profile

containing many pebbles with less cobbles (5YR 4/3 Reddish brown). Stratum II is contemporaneous with the occupation of this feature. Stratum III, 70 - 80 cm., was a very compact, sterile, yellow soil, with decomposing bedrock (5YR 6/6 Reddish yellow).

Cultural Material

Cultural material, which included midden and artifacts, was collected from all three stratigraphic units. Two charcoal samples were also collected to be analyzed and carbon dated (Table IV).

Midden was collected from all three stratigraphic units. A total of 13.9 grams of unsorted bones were collected from the surface of Trench 3. Stratum I produced a total of 410.9 grams of marine invertebrate, 25.6 grams of unsorted bones, 4.2 grams of kukui nut and 193.3 grams of charcoal. Stratum II produced a total of 115.1 grams of marine invertebrate, 14.8 grams of unsorted bones, .4 grams of kukui nut, and 164.5 grams of charcoal. Stratum III produced a total of 13.4 grams of marine invertebrate, .1 grams of unsorted bones, .2 grams of kukui nut and 15.3 grams of charcoal. Cultural material collected from the Stratum III level was collected from the boundary between the Strata II and III levels.

Artifacts were collected from the Stratum I level only. Artifacts collected include one basalt flake, one volcanic glass flake and three chalcedony flakes. No other artifacts were collected during the excavation of Trench 3.

Radio Carbon Samples

The two charcoal samples sent for radiocarbon dating revealed two separate time periods of occupation. The first sample was taken from the Stratum I level, 10-20 cm. The date retrieved from this sample was 1660-1945 A.D. The second sample was taken from the Stratum III level, 70-80 cm. This sample revealed a date of 1420-1650 A.D.

which suggests that this shelter was utilized during prehistoric times and consistently into early historic times.

Based on the amount of midden collected and the artifact selection we have designated this feature as a temporary habitation shelter.

Table IV: Carbon Dating

CSH Acc#	Beta Analytic Acc#	Provenience	C14 Age B.P.	C13/C12 Adjusted Age	C13 Adjusted Age	Klein Age
1	54250	CSH6 Tr2	60+60 B.P. Str. III 40-50 cm.	-24.3 0/00	70+60	1665-1940, 1675-1715 1800-1930
2	54251	CSH 21A Tr3	20+50 B.P. Str. I 10-20	-20.0 0/00	100+/-50	1660-1945
3	54252	CSH 21B Tr3	290+50 B.P. Str. III 70-80	-20.9 0/00	350+/-50	1420-1650

V. SUMMARY

Description

A total of seven archaeological sites were located and identified within the proposed Kahuku Agricultural Park project area. Sites 4510 - 4515 are located in the *ahupua'a* of Kahuku along the west side of Ohia Gulch, and site 4516 is located in the *ahupua'a* of Keana on a coral limestone outcrop in the *makai* portion of the project area, directly *mauka* of the Koolauloa Housing Project. Site types include wall sections, overhang shelters, terraces and enclosures.

These sites contain evidence of Hawaiian habitation that is indicated by midden and artifacts collected during the excavation of sites 4515 and 4516. There is an absence of agricultural sites, probably due to the modification of the land for the commercial cultivation of sugarcane. The southeast side of Ohia Gulch probably once contained traditional Hawaiian agricultural sites which have since been obliterated.

The most significant sites within the project area are the overhang shelters: Site 50-80-02-4510 Features A and B, 50-80-02-4511 Features A and B, 50-80-02-4515 Features A and B, and 50-80-02-4516 Feature B. The functional determination of temporary habitation or recurrent habitation is suggested by the presence of midden and the location of these sites. Both Sites, 50-80-02-4511 Feature B and 50-80-02-4516 Feature B, have constructed modifications on the exterior of the overhang shelters. The preservation of the features in all of these overhang shelters appear to be fair to good state.

Testing

Limited subsurface testing was conducted at overhang shelters 50-80-02-4515 Feature B and 50-80-02-4516 Feature A, and the Site 50-80-02-4513 Feature B terrace. No cultural material was collected during the excavation of Site 50-80-02-4513 Feature B. A fair amount of midden and artifacts were collected during the excavation of the overhang shelters. The excavation of Site 50-80-02-4516 Feature A revealed a human burial. This one burial suggests a possibility of additional burials in the remaining overhang shelters. Based upon the fair amount of midden and artifacts collected, we suggest that these shelters were utilized as temporary and/or recurrent habitation shelters.

Dating

Three charcoal samples were sent to Beta Analytic Inc. for Radiocarbon dating analysis. One sample was sent from Site 4515 Feature B, Trench 2, from the 40-50 centimeter level, and two samples were taken from Site 4516 Feature B, Trench 3, from the 10-20 cm. and 70-80 cm. levels. The dates derived from these samples strongly suggest prehistoric habitation. The samples taken from Trench 3 revealed dates of 1420-1650 A.D. and 1660-1945 A.D. indicating habitation from prehistoric into early historic times. The date derived from the carbon retrieved from Trench 2 indicates a prehistoric cultural layer. A burial, overlying this cultural layer, postdates the time period given by the radiocarbon dating.

Site Functions

Only one site located within the project area has been designated as permanent habitation, Site 50-80-02-4513 Features A-E. This site consists of wall structures (Feature A), two cobble paved terraces (Feature B and D), a U-shaped enclosure (Feature C) and a overhang shelter with rock alignments (Feature E). A single test trench was excavated at Feature B. Although no cultural material was collected during the excavation of this terrace, the size and complexity of this site suggests it is a permanent habitation complex.

The remaining six sites have been designated as temporary and/or recurrent habitation sites. The locality of these sites and evidence of cultural material both collected and observed suggest that these sites were utilized while tending to formerly present agricultural features.

In summary, the fact that the majority of the LCAs, located in the *ahupuaʻa* of Kahuku and Keana, lie on the *makai* side of the Kamehameha Highway suggests that both habitation and agricultural sites (*loʻi* and *kula*), were centered in these *makai* areas. Through information gathered from Foreign and Native Testimony, we can conclude that agricultural sites, which incorporated temporary and/or recurrent habitation sites, were once present in the uplands of the *ahupuaʻa* of Kahuku and Keana.

The remains of the Kahuku Plantation irrigation system is visible throughout the entire project area where sugarcane was once grown. Remnants of cemented irrigation ditches and flumes, which watered large fields of sugarcane and/or pineapple (many of which are impacted by erosion and/or bulldozing), are spread throughout the project area. The remains of these ditches are not considered significant archaeological sites.

Site significance evaluations are summarized in Table III. A total of seven sites, judged to be significant, are present in the project area. These sites are evaluated for significance according to the criteria established for the National and State Registers. The seven criteria which are listed and briefly applied to the archaeological sites in the project area as follows:

A. The site reflects major trends or events in the history of the state or nation.

-This criteria does not apply to the project area.

B. The site is associated with the lives of persons significant in our past.

-We know of no sites in the project area that fall into this category.

C. Site is an excellent example of a site type.

There are no sites in the project area that fall into this category.

D. Site may be likely to yield information of the prehistory or history.

All sites within project area fall into this criteria.

E. Site has cultural significance to Hawaiians or other ethnic groups.

-This category includes religious sites (*heiau*), sites containing human burials or other sites judged to be of cultural significance. All overhang shelters have been designated with criteria E because of the possibility of burials.

F. Not significant (NS)

-No sites within project area fall into this criteria.

G. No Longer Significant

-No archaeological sites within the project area fall into this criteria.

All overhang shelters have been designated with criteria D because a human burial was unearthed during the excavation of overhang shelter site 4515 Feature A. Other shelters contain deep soil deposits and are potential burial places.

VI. RECOMMENDATIONS

It is our recommendation that the burial (Site 4515) and all potential burials (sites 4510 Features A and B, 4511 Features A and B, 4513 Feature E, and 4516 Features A and B) be preserved. All other sites significant for information content (criteria D) that cannot be avoided in the development of the Agricultural Park should be data recovered before they are developed. Those that will not be impacted should be preserved in place.

All further mitigation including data recovery and preservation measures should be presented in a plan to be reviewed and approved by the State Historic Preservation Division.

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Appendix A : Early Archaeology in the Kahuku Area

A. McAllister

In 1930 J. Gilbert McAllister conducted a survey of the more prominent archaeological remains on Oahu (Fig 7). His report includes the following descriptions of the area:

> "She (Mrs. John Kaleo) remembers the time when trees, now found only on the mountains, covered the Kahuku plain, now a rather desolate, windswept area.
>
> "It hardly seems possible that this barren region could have been otherwise, yet Captain King who saw only the northern tip of Oahu (from Kaneohe Bay to Waialua), says: 'It (oahu) is by far the finest island of the whole group. Nothing can exceed the verdure of the hills, the variety of wood and lawn, and the rich cultivated valleys. which the whole face of the country displayed." Thirteen years later (1801?) Vancouver says of Kahuku and the surrounding territory: 'Our examination confirmed the remark of Capt. King except in that in point of cultivation or fertility, the country did not appear in so flourishing a state, nor to be so numerously inhabited, as he represented it to have been at that time, occasioned most probably by the constant hostilities that had existed since that period." In 1838 Hall Makes the general statement in regard to Koolauloa: "Much taro land now lies waste, because the diminished population of the district does not require its cultivation.'" [McAllister 1930: 153].

The following entries are his descriptions of the sites found in the Kahuku area [Figure 3].

> <u>Site 257</u> - Fishpond Known as Kalou, sea side of the Waialee Industrial School.
>
> Said to have been in its best condition when Kaluhi was konohiki of this district. There was formerly a 'Kane stone' in the immediate vicinity. This is also the place where Kahuku is attached Waialee.

<u>Site 258</u> - Small fresh-water fishpond known as Kapi or Punaulua, Waimea side of Kawela Bay. Not more than 100 ft. wide. The legend concerning it , according to luika kaio and Kahiona Apuakehau who drove with me to the site, and Plunket, the Hawaiian forest ranger who acted as interpreter, is as follows:

> There were once gathered on the beach near this site a great many people. This was long before Europeans had come and when there were not many Hawaiians, so that a gathering of this size was enough to occasion the comments of a stranger who approached. This was Kane, but the people did not recognize him. " Why are so many of you gathered here?" he inquired.

> " To catch the oio. A large school swims near in the water," they replied. " Those are not oio," said Kane, " they are eel." but the people only laughed. Certainly they knew oio when they saw them. Who was this stranger to dispute the words of kamaainas? So Kane wagered against him. The canoes with the long, large nets were launched and the school surrounded. Great was their surprise when they found the fish to be eel. Who could this strange man be? That evening Kane accompanied them up to the mountains. It was a long trip up the valley to reach the springs of fresh water, and the people were tired. They stopped at the entrance of the valley for rest, struck the stone known as Waikane, from which the water immediately poured forth and has been flowing almost to this day.

Site 259 - Large stone, known as Waikane, beside the stream bed on the mountain side of Kawela Bay and at the foot of the palis in the land of Hanakaoe.

> Long ago the Hawaiians had to go far up the valley in order to get fresh water, but when Kane struck the stone, water flowed from it and continued to flow up to the time the plantation built a pump just below the rock.
>
> Near the beach and in line with Waikane was a fishing shrine called Pahipahialua.

Site 260 - Puuala Heiau, said to have been located on the ridge overlooking Kahuku ranch. There is now no evidence of any type of a structure on this bare hill.

Site 261 - Small water hole, called Punamano, pointed out by Kahiona, Kaleo, and Luika Kaio in the flat limestone plain of Kahuku Point. It is about 15 ft. in diameter and brackish in taste. My informants told this story:

> One time when the people of Kahuku were fishing they caught a small shark. Putting him in a calabash of water they carried him to their house near the beach. Here he was cared for and put in larger and large calabashes as he grew bigger. Finally having outgrown even the largest calabash that could be found, it was decided to place him in one of the pools of brackish water which came to be known as Punamano. A man and woman living near the pool became guardians. They had lived in their grass huts with a breadfruit tree near the pool and taro and potato patches near the mountains for several years when the brother of the woman came live with them. Sometime after, the man and his wife went to the

mountains to gather taro and potatoes. The brother, who was staying at home, thought that he would like to have some food prepared when his sister and her husband returned. He climbed the breadfruit tree and gathered several, throwing the fruit into the water instead of on the ground, where it would have been bruised in the fall. After picking enough for a few days he descended the tree and gathered most of the fruit from the bank.. Two had floated to the middle of the pond and he could not reach them. Now this man knew of the shark that lived in the water, but he had frequently bathed in the pool and no thought of fear crossed his mind as he swam to the breadfruit. He did not know, however, that his sister had warned the shark not to allow anyone to steal breadfruit when they were gone. When the sister and her husband returned they could not find the brother. Neither was the shark to be found, but they saw the breadfruit floating in the pool and a reddish color to the water. They guessed what had occurred. For nearly a mile they followed the bloody trail until they came to the spring known as Punahoolapa. Not only was the brother never seen, but the shark has never been seen to this day. A plantation pump now marks the site of the spring, near the sea side of the road.

Site 262 - Kukio pond, a natural basin filled with brackish water, located about 300 ft. from the sea, Kahuku point.

The pond was formerly much larger and contained many kinds of fish. It is said to have been surrounded by a large Hawaiian settlement.

Mrs. John Kaleo is probably the only survivor and her former friends and relatives have been buried in shallow graves in the sand between the pond and the sea.

Site 263 - Keanakua fishing shrine (ko'a) Kahuku Point. Flat coral rocks, 1 ft. to 2 ft. in size, are standing on end inclosing an area 5.5 ft wide by 11 ft. long. The stones stand 1.5 ft. high. The interior has been filled with smaller coral stones and is said formerly to have been evenly paved. Recently relic hunters have mistaken this shrine for a grave and disturbed the paving when digging in search of curios.

This was the shrine resorted to when the weather was bad and the seas high. Here the Hawaiians made offerings to propitiate the gods of the sea and if everyone was in proper condition and the ceremony correctly performed, the waves would be calmed.

Site 264 - Natural depressions in the stones on the coral outcrops, Kahuku beach.

Formerly used for making salt, according to Mrs. Kaleo.

Site 265 - Two stones known as Kanoa in the water about 250 ft. from the beach just opposite from Kalaewila heiau, Kahuku Point.

> Many years ago a woman who lived on this beach was frequently seen to swim to these stones and disappear. At times she would be gone for as much as a week. Sometimes she was seen to put her clothes in a watertight calabash and swim away. When she returned she usually wore a kou lei . It was finally discovered that this was the entrance to another land, known as Ulukaa or Kahunà Moku.

Site 266 - Kalaewila heiau, on a slight elevation at Kahuku.

> A foundation of large coral rocks, 1 ft. to 2 ft. in size, can still be traced, marking off a rectangle 42 ft. by 44 ft. A low line of coral stones 20 ft. from the sea end indicates an interior division. From its small size and location one would assume that is was a fishing shrine, but Mrs. Kaleo emphatically states it to be a heiau, the drums of which she has heard many times.

Site 267 - The many caves in the porous formation were used as places of burial by the old Hawaiians. On the Waimea side is an overhanging ledge where formerly hung two stalactites from which water continually dripped. They very closely resembled the breasts of a woman, and this was said to be Nawaiuolewa, a goddess of the region. Some years ago, a white man removed on of the stalactites, or breasts, according to the story, and the water immediately stopped dripping from the other.

Site 268 - Old fishpond known by the name of its guardian (mo'o), Kaauhelemoa, once located on the Waimea side of Kahuku.

> Kaauhelemoa was half man and half chicken, a being of supernatural power who could change himself at will into a man or a chicken. The pond is said to have been fed by a spring. The area has now been turned into cane.

Site 269 - Platform, near the mountain side of the Kahuku mill in Keana on elevation near cave.

A rectangular platform measuring 16.5 by 10 ft. with the long side facing due north. The sea side is from 3.5 to 4 ft. high, and the mountain side averages around 3 ft. It is a solid mass of flat coral slabs. Around the base the stones are standing on end to height of about 1.5 ft. Above this the stones are placed horizontally, one on top of the other. This platform has been there for many years. The exposed surfaces of the stones are weathered and old-looking. Mrs. Barker remembers that around 1900 it was considered an old Hawaiian altar. Jerry Fisher, who drew my attention to the site, says that it is known as a heiau among Europeans. None of the Hawaiians who drove about with me to point out places of interest mentioned this site. It is unlike any Hawaiian platform that I have seen, as it is exceptionally high and has a combination of stones usually either placed vertically, joining what is called an unu, or horizontally, forming a fishing shrine (ko'a). If it were closer to the sea, there would be little hesitation in saying that it was probably a fisherman's altar. It is at least three-quarters of a mile from the shore in a direct line.

Site 270 - Rock shelter known as Keana, near the mountain side of the public

school, Kahuku.

In former times this cave was the home where lived a mother and her two sons. One day, having occasion to journey to a distance, she left them with this injunction: "If during my absence you hear the sound of thunder, keep still, make no disturbance, don't utter a word. If you do it will be your death." During her absence there sprang up a violent storm of thunder and lightning, and the young lads made an outcry of alarm. Thereupon a thunderbolt struck the dead, turning their bodies into stone, two pillar-shaped stones standing at the mouth of the cave are pointed out in confirmation of the truth of the legends. [Emerson: 1925: 233

The rocks stand out prominently; one is much larger than the other and can easily be seen from the school grounds.

Site 271 - Polou, formerly a pool of water, sea side of the Kahuku mill.

A story is told that Kahuku was once a land afloat, wafted about by the winds, drifting over the ocean. Just how it came to Oahu is not told, but old Hawaiians point out Polou, the place where Kahuku is fastened to Oahu. Formerly it was possible to dive into the pool and when a depth of 40 fathoms was reached, a shelf of rock was found upon which to rest. Forty fathoms deeper Punakea (white lime from coral) was reached and on looking toward Malaekahana, the hook by which Kahuku was made fast could be seen. This hook was intricately fashioned of Kawila. Seaward of the Waialee Industrial School, in another pool of water, known as Kalou, is the spot where Kahuku is attached to Waialee. In the immediate vicinity of Polou was a stone known as Kanaloa.

Site 272 - A few rocks at Makahoa, all that remain of a fishing shrine which was on the point. The fish brought here were the oio.

Formerly a fishpond was located near the point and was known as Waipunaea. There are traditions about the mullet coming to this point from Pearl Harbor. To this day schools of mullet come around the island to this northern point of Malaekahana. They go no farther, and their apparent disappearance still mystifies the Hawaiians.

Site 273 - Foundation of the house (kahuahale) of Manuwani, keeper of the god of Malaekahana.

Only a few large rocks remain by the site of the railroad track, but the site has great importance in the eyes of the natives because of the prominence of the kahuna Manuwahi. About this area is said to have been a rather large Hawaiian settlement, which formerly was level land, but which owing to the removal of flora has formed into dunes The site was pointed out by a descendant of Manuwahi, Kaniona Apuakehau, a very old Hawaiian living in Laie. The Hawaiians are still proud that the distinct of Malaekahana was never conquered by Kamehameha I. This is not recorded in Hawaiian history so far as I know.

The legend collect by Rice (Hawaiian Legends pg 113) tells the story of Kamehameha's sending out Kanalaiu, who was unable to subdue Manuwahi because this powerful kahuna was aided in battle by the gods. After the battle, Kanalaiu joined forces with Manuwahi and is still spoken of by the older natives as the chief who revolted against Kamehameha. Many skeletons were unearthed in plowing the cane fields of the region and in digging the foundations for the beach houses, indicative, some think, of many battles in the region.

Site 274 - Site known to Hawaiians as a fishing shrine on the land known as Kalanai, which is now included in the division of Laie but formerly belonged to Malaekahana.

The fish brought to this shrine were the kala and enenue. Several flat rocks have been placed on end; one is placed flat. Innumerable remains of fish were found about the stones and on the west side of the rocks.

Skeletal remains were found on the northwest side at an average depth of 2 feet. The body was partially flexed. The upper portion of the body was lying on its back, with the head thrown back so that the mandible was uppermost. The legs had been flexed. The entire length of the burial, from head to knee, was 4 feet. The maximum length of the right femur was 17 inches. The head was lying toward the south, and the lower portion was toward the sea.

Site 275 - Waiapuka, a pool on the Kahuku side of Laie in Malaekahana, inland from the road in the midst of a cane field.

Waiapuka is made famous by the legend of Laieikawai. Without guidance it is difficult to find, for it is hidden from sight even from the surrounding elevations or from the tops of the highest pines which line the road. The pool is oval in shape, measuring about 30 ft. by 60 ft. with the water about 10 ft. below the level of the surrounding plain. Tides are said to affect the pool On the Laie side is a small crevice in the rock, which is said to open into the cavern in which Laieikawai was hidden. Natives of the region remember when it was possible to swim through an underwater entrance, and it is said that the chamber could accommodate three or four people. Within the last 25 years silt has filled the pool, and it is no longer possible to enter the hidden chamber. The pool is significant in the minds of the Hawaiians because it was here that Waka hid Laieikawai until she reached maturity.

Site 276 - Waikuukuu, Kahuku side of the of Paeo fishpond, about 100 ft. up on the low ridge.

A narrow but deep crevice in the ground with water at the bottom. This is affected by the tides and the depth of the water in Waiapuka may be judged by the height of the water in this opening. The place is now being used for dumping garbage.

Site 277 - Paeo fishpond, mountain side of the bridge on the Kahuku side of Laie.

This was once a large horseshoe-shaped pond that was famous for the size of its fish. It is now dry and overgrown with weeds. On the Kahuku bank is chalice-shaped stone about 3 ft. high, where Hauwahine, the goddess (moo) of the pond, is said to have been frequently seen combing her long black hair. This was a very sacred stone and could not be approached, nor would the old Hawaiians use the pond when a blanket of leaves and other refuse (aamoo) covered the water, for it was believed that then Hauwahine was present. When the water was clear, Hauwahine had departed to a Kailua.

Site 278 - Hanapepe, elevation near the first bridge on the Kahuku side of Laie.

A portion of this elevation was once a very sacred place where the akua stone, Kamehaikana, was worshipped. This is said to have been a female fish god, and the first fish were brought as an offering.

In addition to the sites enumerated above, McAllister mentions two places of legendary or mythological interest, to which he did not assign site numbers:

> "Kane and Kanaloa lived in the vicinity of the ridge [near Site 267]; but that was at the time when the Kahuku plain was still under water, and waves lapped about Kalaiokahipa. The brothers are said to have obtained fish by dipping into two holes on opposite sides of a large rock which now lies in the cane field."

> "Apparently Kane, who was joined by Kanaloa, lived at Opana for some time, for just outside of Kawela Bay there are rocks, horseshoe in shape and known as Papaamui, where these brothers were wont to scoop for fish."

B. Handy

The following statements are from E. S. Craighill Handy's 1940 survey of Hawaiian *horticultural practices.*

> Waialee - There is a small group of terraces formerly known as Kanealii, now abandoned for lack of water, around the house of Mrs John Baker, just east of the Boys' Industrial School and inland of Kamehameha Highway. The large terraces now cultivated seaward of the Industrial School are of recent construction.

> Pahipahialua - According to Judge Rathburn there were no terraces along this stream.

> Opana - Touching Opana and extending into Hanakowe was a small spring-watered terrace area named Kawela (same name as the bay). McAllister (sites 258, 259) says that according to legends told him by his informants there was 'formerly' no fresh water at Kawela Bay (in Opana), but that the gods Kane and Kanaloa struck water from a rock now 'known as Waikane. and at the foot of the cliff in the land Hanakoae,' and that water 'continued to flow up to the time the plantation built a pump just below the rock.'

> Hanakoae - According to Judge Rathburn there were no terraces along the Hanakoae, Oio, or Kaalaea stream beds in this *ahupua'a*; the only terraces were those watered by the springs, mentioned under Opana.

> Kahuku - Inland from the Kahuku ranch house is Kaainapele Spring. Terrace symbols are shown south of the ranch house (U.S.G.S. topographic map, 1917), but Judge Rathburn says that these flats were built by Chinese before 1890 for rice paddies. They were irrigated with artesian water, but the water turned brackish and the paddies were abandoned. They were never used for taro. The 1917 map shows extensive terrace areas in the

swampland seaward of the Oahu Railway, stretching 1.5 miles south of Kukio Pond. These were originally terraces, were later planted to rice, and are now under sugar cane. According to John Kaleo, there is a small group of terraces, south of this swampland, named Kaukaha. North of Kukio Pond was also a small area. It is reported that there were no terraces up Kahuku Stream or Kaohiaae, its upland branch. Kaleo names 11 localities where terraces were formerly cultivated.

Keana - There are said to have been no terraces up this stream, and Kaleo knows of none on the level land below.

Malaekhana - There were terraces in this *ahupua'a*, irrigated by Kaukanalaau Stream.

C. Thrum

> "A Kapa-beating log of peculiar sound, unlike any other known on the island, which was placed in its waters at the close of kapa-making season to keep it smooth and free from cracks that would impart an impression to the cloth in its manufacture, was missed, and, believing it to have been stolen, search was made all through the Koolau, Wialua and other districts 'til at last it was found in use at Waipahu. Recognizing it by its resonant tone, it was claimed by the searching owner, and right thereto by those in possession was vigorously maintained. To test the truth of ownership as claimed, the Ewa people accompanied the claimant back to Kahuku to visit the scene and witness a test of the underground stream theory. A bundle of ti leaves were gathered, which was wrapped together and consigned to the waters of punahoolapa. In the course of a few days they were lost to sight, whereupon the party set out for Ewa, and after careful watching, as predicted, the bundle of ti leaves came forth on the bosom of the waters of the Waipahu stream. The kapa log was thereupon recognized as the rightful property of the Kahuku claimant" [Thrum 1911: 130].

D. Sterling and Summers

In 1962, Elspeth Sterling and Catherine Summers published a compilation of information concerning Hawaiian archaeological and historical sites, legends, myths, and tales. The following quotations are taken from this publication, rather than from the original sources.

The following describes a trip through Kahuku in 1826.

Started from Oio...Taking about an Eastern course we walked over a level country and considerably extended...The mountains along here do not rise very abruptly near the shore but are seen towering in a Southern and Eastern direction. The land over which we traveled 'til breakfast time, the distance of 5 or 6 miles in length and from 1 to 2 miles in breadth, the natives say floated in from the sea and connected itself with the shores of the island... This tract is beautified with lauhala and some other trees, and is the only scenery of the kind we have met with, most of our course on the West and Northern part of the island laying over barren sand... (Chamberlain n.d.).

The following was taken from an 1861 newspaper article.

In Kahuku is a spring called Puna-mano and it was there that a man was destroyed by a shark. The shark was found when it was small by a man and a woman who went fishing at the beach with a draw net at night. They wanted to save the shark so they let it go free in the spring. On the bank of the spring, they planted a breadfruit tree. Later as the shark grew in size so did the breadfruit tree till it bore fruit. They wondered at the disappearance of the breadfruit, and thought that the fruits might have been blown down by the gusts of wind. Upon looking under the tree, they came to the conclusion that they must have been stolen for not one was found there.

One day they wanted to go to the upland to farm but were a little worried about the breadfruits lest all be stolen by the thief. Therefore they spoke certain words in command to the shark, ' We are going to the upland, so watch our breadfruit tree.' They went up.

The own brother of the woman who owned the shark was the one who went after the breadfruit as soon as they were gone and so he was killed. The man went to get some taro, lighted the imu and because he longed for roasted breadfruit he climbed the tree in secret. When he threw fruits down they tolled and fell into the spring. He descended and reached out into the spring but before he seized them, the shark leaped and devoured him. The sister returned with her husband from their farming and while on the plain love for her brother welled up in her, and it seemed as though he were dead. When they reached the brother's house, the imu and taro were seen there but he was not to be seen. Instead a new spring had appeared near by, about ten fathoms from the shark's spring. There they saw the water reddened with blood and the man's cluster of love (scrotum) was also found there. It seemed as though there was a passage beneath from one spring to the other. The shark was never seen again after that." [Kuapuu 186]

The following is from a 1952 newspaper article.

"During World War II, the Army threw up an airfield at Kahuku, Oahu, and built barracks about the runway...The runways faced the sea and were in line with the main barracks, a building placed upon a knoll which looked right down onto the runway. In fact, the door of the barracks was on a line with the runway.

Boys recruited and drafted in Hawaii were placed in the barracks along with Mainland soldiers. The Hawaii Nisei were soon dissatisfied and asked their captain to be moved out of the main barracks into smaller barracks off to one side. The captain asked why they were dissatisfied. The boys said they were being disturbed in their sleep. Some said they were choked in their sleep. Others said they had bad dreams. The captains dismissed their plea with a laugh.

The Hawaii soldiers persuaded a group of haoles who lived in a smaller barracks to change places with them. The captain had no objection. Soon the haole boys were complaining to the captain of being choked in their sleep. The captain inquired about and tried to learn why there should be *pilikia* in that one barracks.

An old Hawaiian who had lived all his life in the community gave him the answer.

It seems that the airfield runways had been constructed right over the bath Marchers in the Night took when going to the ruins of a old *heiau* in the mountains. These marchers were dead chiefs and their retinue who most often gathered on the nights of Ku, Akua, Lono and Kane for reunions in the old *heiau*.

To make matters worse, the door of the barracks was right on the path of the marchers. The hawaiian advised the captain to close that door and to open another at the side of the building.

If you don't believe this story, ask Major Henry Lindsey, retired." [Taylor 1952]

E. Miscellaneous Sources

The site map for the Kahuku area on file at the State Historic Preservation Office indicates that many of McAllister's sites are no longer in existence. The only ones shown are Sites 257 and 258, 265, 267, 270, 275 and 277, all of which are outside of the present survey area. This same map shows four additional sites, none of which are in the survey area, as follows:

Site 1038 - "Near Kahuku Point, on the northern tip of Oahu, a sub-surface midden deposit lies exposed by the waves. A few coral blocks form a small circle among the vegetation on the surface and fragments of historic glass show that the site was occupied into relatively recent times. The cultural level below the surface however, shows evidence of a prehistoric occupancy for the site. The soil is dark with the charcoal from fires, and packed with the remains of Hawaiian foods: shellfish, fish and sea urchin. The deposit measures some 20 cm. in thickness and covers an area of approximately 300 meters."

Site 1039 - "Large cave with internal retaining wall."

Site 1055 - "Shelter Cave."

Site 2501 - "This burial platform is located on a small Air Force installation in Kahuku and is well hidden in a dense thicket of Haole Koa and Christmas Berry. It is one of the few burial platforms known to exist on the island of Oahu.

"The main section of the platform is rectangular shaped. It is about 8 meters wide along the NE edge and narrows to about 4 meters just north of the slope. The length from these two points is 16.5 meters. the SW end of the platform has a slope that is three meters long and ends in a point. The total height difference between the top of the slope and the bottom is 5 meters."

Appendix B: Midden, Artifact and Charcoal Catalogs

APPENDIX B: INDIGENOUS ARTIFACT CATALOG

CULTURAL SURVEYS HAWAII
PROJECT: KAHUKU

Acc #	State Site 50-80-02-	Trench	Stratum	Depth (cm)	# pieces	Length (cm)	Width (cm)	Thickness (cm)	Weight (gm)	Material	Function	Comments
1	4515A	2	I	0-10	1	0.8	0.8	0.3	0.3	Shell	bead	
2	4515A	2	I	0-10	35	0.4/2.0	0.3/1.6	0.2/1.4	13	V-glass	flakes	
3	4515A	2	I	0-10	1	1.8	1.2	0.2	0.4	Basalt	adz	flake
4	4515A	2	I	0-10	18	0.4/1.9	0.3/1.6	0.2/0.4	2.1	Gourd	fragments	
5	4515A	2	II	10-20	1	5.5	3.1	3	91	Basalt	lure	
6	4515A	2	II	10-20	28	0.2/2.0	0.2/0.8	0.1/0.4	6.2	V-glass	flakes	
7	4515A	2	II	20-30	12	0.4/1.1	0.3/0.9	0.1/0.2	1.4	V-glass	flakes	
8	4516B	3	I	0-10	3	1.8/2.7	1.8/1.2	0.4/0.6	4.8	Chalcedony	flakes	
9	4516B	3	I	10-20	1	5.7	4.9	2.4	98.9	Basalt	flake	
10	4516B	3	I	20-30	1	1.1	0.7	0.1	0.2	V-glass	flake	

APPENDIX B: MIDDEN CATALOG

CULTURAL SURVEYS HAWAII
PROJECT: KAHUKU

State Site 50-80-02	4515A	4515A	4515A	4515A	4515A	4515A	4516B	4516B	4516B	4516B	4516B	4516B	4516B	4516B	4516B
Trench	2	2	2	2	2	2	Surface	3	3	3	3	3	3	3	3
Depth/Stratum	0-10/I	10-20/II	20-30/II	30-40/II	40-50/III	50-60/III		0-10/I	10-20/I	20-30/I	30-40/I	40-50/I	50-60/II	60-70/II	70-80/III
Cellana sp.		2.7	0.3	0.5											
Conus sp.	3.2	3.9	1.2							7.5					
Cymatium sp.										0.6					
Cypraea caputserpentis	39.3	22.8	12.2	4.9	0.6			1.9	8.7	30.6	7.2	8.6	13.8	15	4.6
Nerita picea	13.1	22.4	6.4	5.4				2.6	34.3	21.8	8.8	4.3	12.7	11.4	3.9
Littorina sp.	2.1	1.1							0.3	1.5	0.7		0.6	0.7	0.1
Strombus maculatus	6	19.6	4.7	2.7				0.3	46	25.7	5.5	4.7	5.4	.5.7	0.9
Thaididae sp.	0.6	0.5							0.1	1.1		2	1	0.1	0.3
Turbo sandwichensis	0.2		0.5					1.4		1.2				0.3	
Tellina palatam	4.4	4.1	0.4	0.4						0.2	0.9		0.7	0.2	
Periglypta reticulata		1.1													
Isognomon sp.	1.1							1.3							
Brachidontes crebristriatus	3	11.1	1	1.6				1.1	38.3	19.2	6.8	6.4	7.4	4.8	0.8
Unidentified	12.5	21.5	15.4	7.4	0.7	1.5		0.6	22.6	21.7	11.2	3.5	15.2	9.6	2.3
Total mollusca	85.5	110.8	42.1	22.9	1.3	1.5	0	9.2	150.3	131.1	41.1	29.5	56.8	47.8	12.9
Echinoderm	7.1 .	11.5	4.6	4.7					24.9	14.2	3.7	3.7	5.3	3.7	0.5
Crustacea		2.6	8.6	11.1	2.4	0.7			1.4	0.8	0.4	0.6	0.9	0.6	
Total Marine Invertebrate	92.6	124.9	55.3	38.7	3.7	2.2	0	9.2	176.6	146.1	45.2	33.8	63	52.1	13.4
Bones (unsorted)	5.6	10.3	2.8	9.6	2		13.9	0.5	2.4	14.4	3.7	4.6	11.1	3.7	0.1
Kukui nut	114.2	60.5	19.5	2.7	2.5	0.6				3.8	0.3	0.1		0.4	0.2
Total Midden	212.4	195.7	77.6	51	8.2	2.8	13.9	9.7	179	164.3	49.2	38.5	74.1	56.2	13.7
Land snail	7.6	11	24.1	21.4	0.3	0.2			3.6	4.9	4.3	1.8	4.3	5.6	1.4

APPENDIX B: CHARCOAL CATALOG

CULTURAL SURVEYS HAWAII
PROJECT: KAHUKU

Acc #	State Site 50-80-02-	Trench	Stratum	Depth (cm)	Weight (gm)	Description
C-1	4515A	2	I	0-10	491	small to medium chunks
C-2	4515A	2	II	10-20	270	small to large chunks
C-3	4515A	2	II	20-30	104	small to medium chunks
C-4	4515A	2	II	30-40	85.3	small to medium chunks
*C-5	4515A	2	III	40-50	39.2	small to medium chunks
C-6	4515A	2	III	50-60	1.8	small chunks
C-7	4516B	3	I	0-10	4.2	small to medium chunks
*C-8	4516B	3	I	10-20	11	small chunks
C-9	4516B	3	I	20-30	96	small to medium chunks
C-10	4516B	3	I	30-40	82.1	small to medium chunks
C-11	4516B	3	II	40-50	27	small to medium chunks
C-12	4516B	3	II	50-60	63.3	small chunks
C-13	4516B	3	II	60-70	58.9	small to medium chunks
*C-14	4516B	3	III	70-80	15.3	small to medium chunks

* = Samples sent for carbon dating

Appendix C: Photo Appendix

Fig. 20 Project Area, View to East

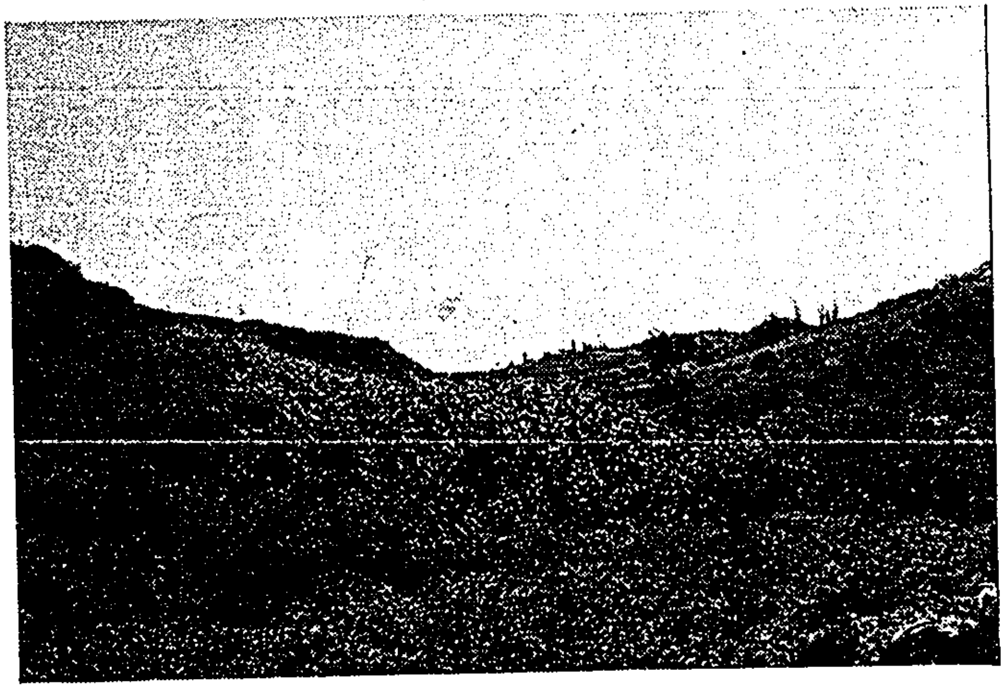

Fig. 21 Ohia Gulch, View to Northeast

Fig. 22 Site 4510, Feature A

Fig. 23 Site 4510, Feature B

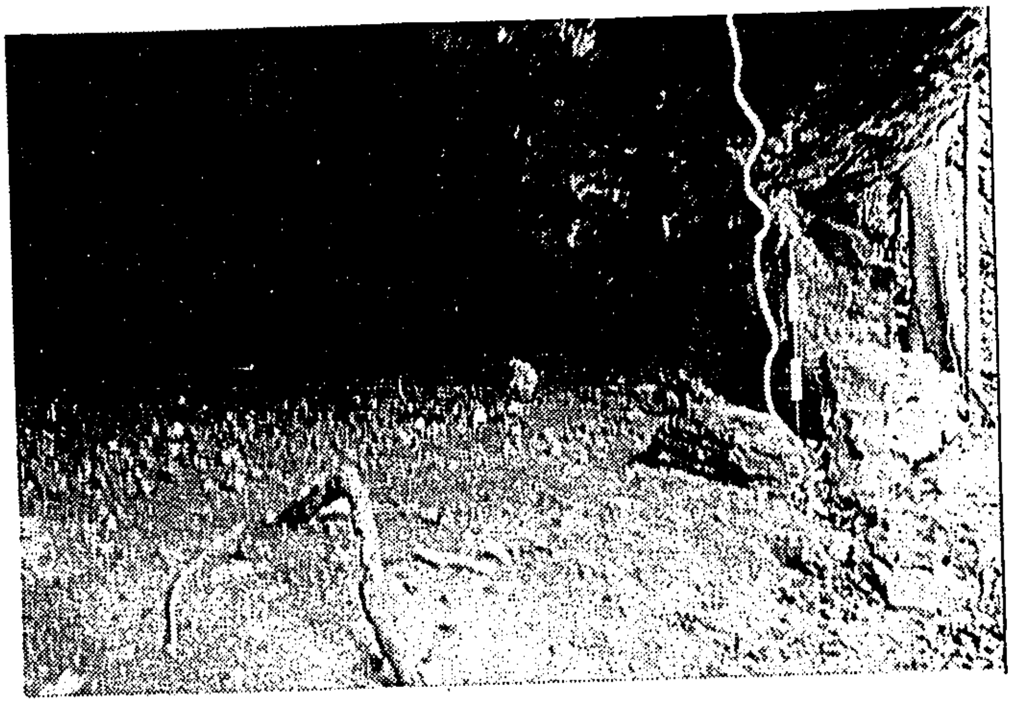

Fig. 24 Site 4511, Feature A

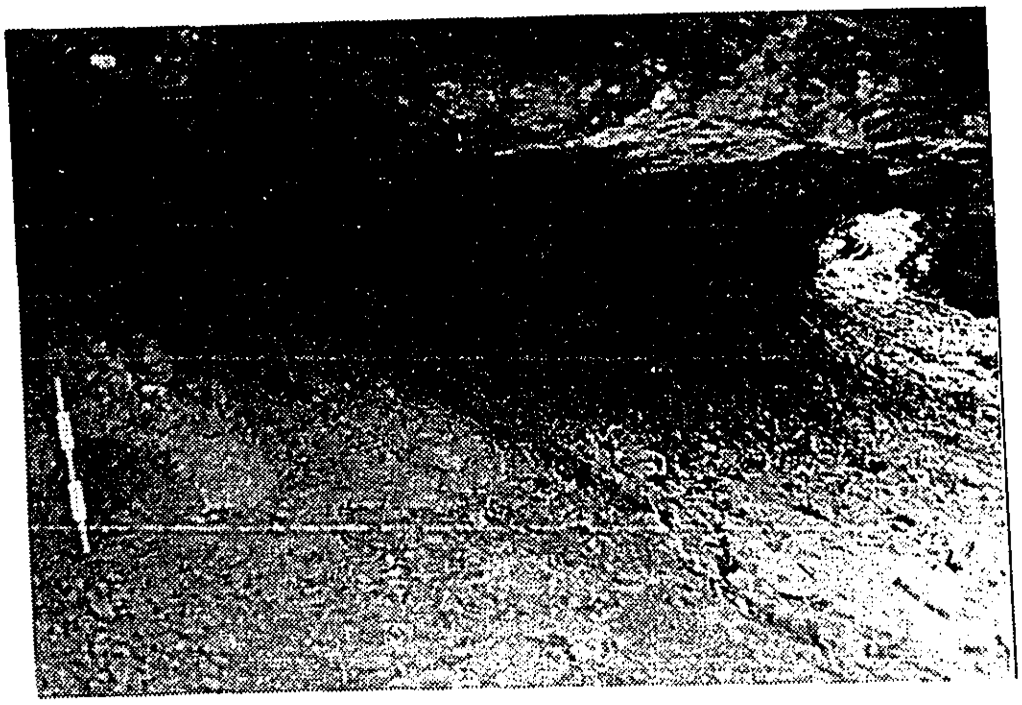

Fig. 25 Site 4511, Feature B

Fig. 26 Site 4512, Enclosure

Fig. 27 Site 4513, Feature A

Fig. 28 Site 4513, Feature B

Fig. 29 Site 4513, Feature C

Fig. 30 Site 4515, Feature A

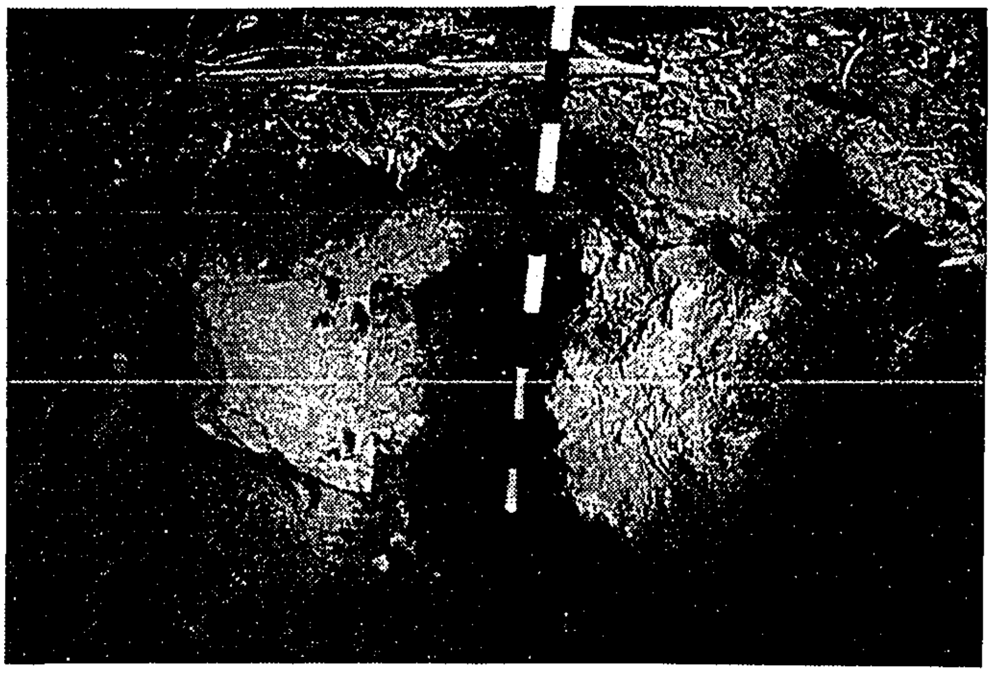

Fig. 31 Site 4515, Trench 2, Burial

Fig. 32 Site 4516, Feature A

Fig. 33 Site 4516, Feature C

Fig. 34 Site 4516, Feature B

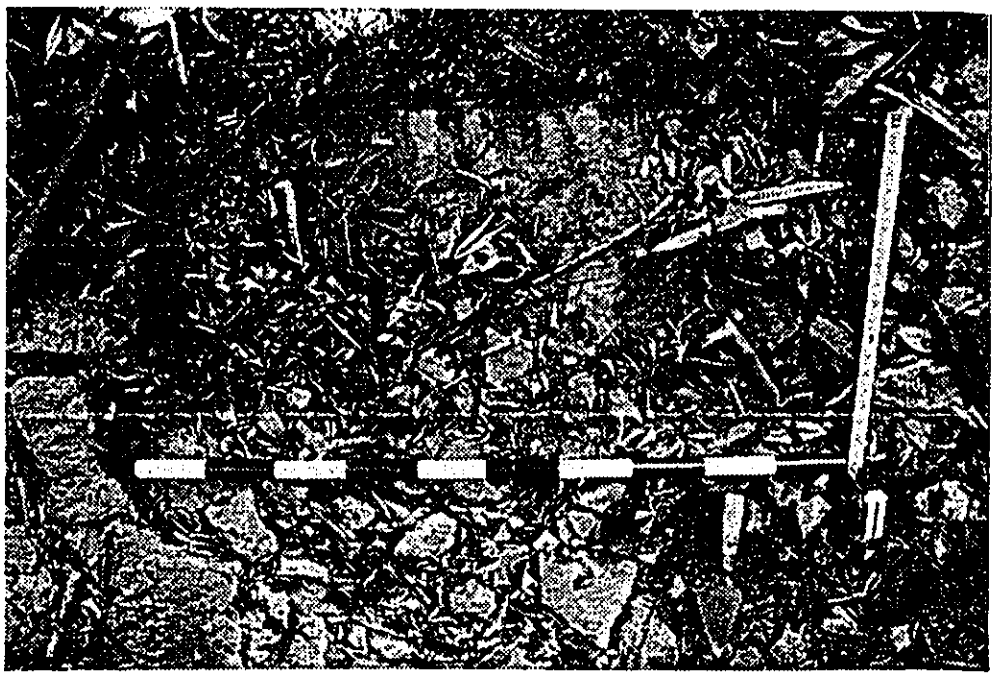

Fig. 35 Site 4516, Feature B, Trench 3, Pre-Excavation

Fig. 36 Site 4516, Trench 3, Post Excavation

Fig. 37 Site 4516, Sugar Cane Irrigation System, Visible Throughout Project Area

Appendix D: LCA Native Testimony of Kahuku

No. 3778 Aaiki Kahuku, Dec. 24, 1847

Land Commissioners, Greetings: I, the one whose name is below, hereby state my claim which I got in the year 1846 in the ʻili at Ahamau, Ahupuaʻa of Kahuku, Island of Oahu. There are five taro loʻi, two banks of a watercourse, one kula land. Furthermore, I indicate a kula, a wooded upland, with banana, noni, pili [grass], wood, growing at Ahamau. In the ʻili of Ao is a valley with noni and banana. Those are my claims which I state to you, the Land Commissioners. My house is another claim, at Wiwikalani.

AAIKI X his mark

No. 2705 Hao Kahuku, January 1, 1847

To the Land Commissioners, respectful greetings: I, Hao, Hereby state my claim for land at Kahuku, of Poohalulu. There is 1 loʻi, bounded on the north by a hala, on the east south and west by kula. There is a hala grove named Maona and also one named Kaohai. There are two noni gardens *mauka* of Akamau, two ʻawa gardens, one koa tree for a canoe, and two sweet potato patches. My house claim is at Kahuku, and is surrounded by kula. My right of occupancy was from the time of Kamehameha I.

HAO X his mark

No. 2704 Haui Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, respectful greetings: I, Haui, hereby state my claim for land at Kahuku. The name of the moʻo is Kuapuu; there are six loʻi and the watercourse, bounded on the north by a kula, on the east by Kekipi's, on the south by Makilo's, on the west by Kueulu's. There is a kula land, Ahamau, a fish pond named Kuhiwa, and a loʻi at Kii. At Keana I have a wiliwili tree. My right of occupancy was from the time of Kamehameha I.

HAUI X his mark

No. 2706 Holoaia Kahuku, Oahu, Jan. 5, 1848

To the Land Commissioners, respectful greetings: I, Holoaia hereby state my claim for land at Kahuku. The name of the moʻo is Puulu. There are two loʻi, bounded on the north by Uha's, on the east by Mooni's, on the south by Palu's on the west by a koʻele loʻi. At Lanahu are 2 loʻi, adjoining those of Uha and Peilalau. I also have a row [or cluster] of hala trees named Kamoku, and Konihowai is the name of another, and another is at Puulu. My right of occupance is from the time of Kamehameha 2.

HOLOAIA X his mark

No. 2716 Hoolae Oio, Oahu, Jam. 5, 1848

To the Land Commissioners, respectful greetings: I, Hoolae, hereby state my claim for land at Oio. There are two gardens of 'awa, taro, banana, wauke, sugarcane. There are seven koa canoe trees. There is kula land cultivated in sweet potato, gourd and akaakai [Translator's note: the word akaakai means bulrush, however, onions were also called by this name, and since this is kula land it probably should be translated as onions].
At Hanakaoe is a cultivated upland, two gardens, and a kula were sweet potato is grown.
At Kahuku I have five lo'i at Lanahu and two lo'i at Uwalahui.
My houselot is at Oio and is bounded on the north by Kekohai's houselot, on the east by a kula, on the south by Kekuauli's lot, on the west by the sea. My right of occupancy is from the time of Kamehameha III.

HOOLAE X his mark

No. 3748 Uha Kahuku, December 31, 1847

To the Land Commissioners, Greetings: I, Uho, am a claimant of land in the 'ili of Ahamau, with seven taro lo'i, a kula, an upland with pili grass, a koa tree, a kukui tree, an 'ohi'a tree, and all the vegetation. Also, there is a salt land at Ahamau. The boundaries are: north, the seashore, east, Haui's [land], west, Mauoli's [land], south, Waimea mountain. 2. A kula is at Poohalulu, planted with wauke, watermelon, sugar cane, and such things. 3. Five taro lo'i and the banks of a watercourse at puulu. The three things below are scattered. 4. Two taro lo'i at Kahani, some [other] lo'is at Ahamau, and a house at Poohalulu. I acquired these lands before the enactment of the Law.

NO. 4449 Kaaikaula Kahuku, Oahu Dec. 31,1947

To the Land Commissioners, Greetings: I, Kaaikaula, am a claimant for land at Ahamau. There are seven taro lo'i, a kula, and a wooded upland. The things planted are banana, watermelon; there is a koa canoe tree, pili grass. salt pans, a kai [fishery/shore area], and similar things at my place. The boundaries are: on the north, Uha's [land], on the east, Kaoaka's lo'i, on the west Kaunu's [land], on the south, a mountain area of Waimea. I have a claim for a watercourse named Kalai, bounded on the north by a taro mo'o for Mauoli, on the east by the taro mo'o of Kalai, on the south by a watercourse, on the west by Lonohuakini. A fish lo'i is at Pooohalulu, bounded on the north by some houses, and on the east, south and west by kula. Furthermore there are two clusters of hala at Poohalulu. In the Ahupua'a are four clusters of hala. At Ahamau are seven hala trees and the house also, which is in the mo'o. My right of occupancy is from the time of Kamehameha I.

KAAIKAULA

No. 2906 Kauumakua Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, Respectful Greetings: I, Kaaumakua, hereby state my claim for land at Kahuku. The name of the mo'o is Kakala. There is one lo'i, bounded on the north by Kaukaha's [land], on the east by Lonopuakauila's [land], on the south by

Kauahi's [land], on the west by Kaumualii's [land], and a coconut tree. At Ulupehupehu are some alani [orange?] trees, and a mala of ʻawa. At Ikemaka I have one loʻi, bounded on the north by Kapaiaaala's [land], on the east by Holoaia's [land], on the south by a pali, on the west by a kula.

KAAUMAKUA

No. 2870 Kai Kahuku, Oahu, Jan. 4, 1847

To the Land Commissioners, Respectful Greetings: I, Kai, hereby state my claim for land at Kahuku. The name of the moʻo is Papaiole. There are 12 loʻi, bounded on the north and west by Palena's [land], on the east by a kula, on the south by Kaihikapu's [land]. One other loʻi is next to that of Keino. A kula land, Kalehuawai, has five ʻili and one taro loʻi. At Kaoma are four ʻili. At Hamea are two ʻili a shore land named Kaa, a cluster of hala trees and the mala named Poohalulu. There is a mala wauke at Mookini and one at Lua____. Mauka is a koa canoe tree. My house claim, at Kahuku, is surrounded by kula. [My right of occupancy] is from the reign of Kamehameha III.

KAI X his mark

[Translator's note: I think the use of ʻili in this claim implies small land areas which are used by the claimant, and not an ʻili in the sense of the next lower subdivision of land than the ahupuaʻa.]

No. 2872 Kaihikapu Kahuku, Oahu, Jan. 4, 1847

To the Land Commissioners, Respectful Greetings: I, Kaihikapu, hereby state my claim for land at Kahuku. The name of the moʻo is Hahane. There are thirteen loʻi, bounded on the north and west by Palena's land, on the east by kula, on the south by houselot, on the west, also, by Keino's [land]. There are five loʻi in another place at Amo in Keino's land, there is kula land, of Hakane, salt land, of Hakakaualii, shore land, of Mokalaihi, and mountain land, of Ao. There is a mala wauke at Ahamau [and] a mala of sweet potato. My house claim is in Kahuku, bounded on the north by loʻi land, on the east by land fence, on the south by Keino ma's lot, on the west by loʻi land. My right of occupancy is from the time of Kamehameha I.

KAIHIKAPU X his mark

No. 4458 Kaihupailani Kahuku, Oahu, January 1, 1847

To the Land Commissioner, Greetings: I, Kaihupailandi am a claimant for land in the Ahupuaʻa. There are seven taro loʻi, also a kula. The boundaries are: on the north, Kawaa's loʻi, on the east, Kaluau's loʻi, west, Kupau's [loʻi], on the south, Makaokalani's taro loʻi. Also, there is a kula at Waokahala, planted in wauke, a wooded upland at Ahamau, a koa tree, a kukui tree, and similar things. My house, also, is in the Ahupuaʻa.

[My occupancy has been] from the reign of Kamehameha III.

KAIHUPAILANI

No. 2932 Kailiuku Kahuku, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Kailiuku, an the konohiki of Kahuku, and I hereby state my claim for land at Kahuku. At Puaakea are two lo'i bounded on the north by Lokoea's [land], on the east by Pahanui's [land], on the south by Kaukopa's [land], on the west by Waanui's [land]. One lo'i is in another place, adjoining that of Namokueha, on the south is the Government Road, on the west is Kalahana's [land]. There is a lo'i in another place, next to that of Kaukaha and the lo'i ko'ele. At Oio is a mala of banana, taro, sugar cane and 'awa, two koa canoe trees, a kula planted in sweet potato and gourd, also a lo'i. There is a hala grove named Waihinalo and a fish pond which is mine. At Hanakaoe I have some malas of sweet potato, and gourd. At ulupehupehu are some malas of sweet potato. My house claim is at Kahuku, bounded on the north by a lo'i ko'ele, on the east by a kula, on the south by the Government Road, on the west by the bank of a lo'i.
My right of occupancy is from the time of Kamehameha I.

KAILIUKU X his mark

No. 2892 Kainalu Punalau, Oahu, Jan. 11, 1848

To the Land Commissioners, Respectful Greetings: I, Kainalu, hereby state my claim for land at Kahuku. The name of the mo'o id Kauaiki. There are four lo'i and two watercourses, bounded on the north by Manukeokeo's [land], on the east also by Manukeokeo, on the south by Kauhiwahine's land, on the west by the kula. I have six lo'i in various places and one watercourse, therefore it is not possible to describe their boundaries. There is kula land at Lanahu planted in wauke and banana, another kula at Haleaniani and a pali uwala [steep place planted in sweet potato] at Amo. At Niukolu is a mala of sweet potato and there is also one at Punalua. My houselot is at Punalau, bounded on the north by the sea, on the east by Kika's houselot, on the south by a land fence, on the west by Kaohele's houselot. My right of occupancy is from the time of Kamehameha II.

KAINULU X his mark

No. 4394 [Kaio] Kaanaana Kaluanui, Oahu, January 11, 1848

To the Land Commissioners, Greetings: I, Kaanaana, am a claimant of land in the 'ili of Kaihiuki, with four lo'i, and the watercourse is the fifth [item]. There is also a kula, and my house is there. The boundaries are' on the north, Paakaua, on the east and south, Paakaua also, on the west is Kiiwahaole. The time [when I got it] was 1845.

KAANAANA X his mark

No. 2934 Kalahana Ulupehupehu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Kalahana, hereby state my claim for land at Kahuku. The name of the mo'o is Pohakuooma. There is one lo'i bounded on the north by Namokueha's [land], on the east by Kailiuku's [land], on the south by the Government Road, on the west by the konohiki's lands. At Oio I have a cultivated kula which is in the upland, one koa canoe tree, and three mala of wauke. There is a salt land.

My right of occupancy is from the reign of Kamehameha III.

KALAHANA X his mark

No. 2826 Kalaweaumoku Kahuku, Jan. 1, 1847

To the Land Commissioners, Respectful Greetings: I, Kalaweaumoku, hereby state my claim for land at Kahuku. It is named Mookini and is bounded on the north by Pahanui's land, on the east by Luiki's land, on the south my Male's land, on the west by Palu's [land]. There are four lo'i in another place, next to Luiki's land, bounded on the north by Nauluhao's [land], on the east by Kahulihana's [land]. There is a watercourse adjoining Pahanui
s [land], a kula land [planted in] wauke, sugar cane, gourd, banana and sweet potato, and upland planted in noni. At Punalau I have a mala planted with noni. At Ulupehupehu is a mala planted in wauke, noni, banana, 'awa, and sugar cane. There is the salt land at Ahamau. My house claim is bounded on the north by Nauluhao's [land], on the east, south and west it is surrounded by hala trees.

KALAWEAUMOKU X his mark

There are two coconut trees, two fish ponds, a clump of hau.
These claims are at Kahuku.

No. 2916 Kaluau Kahuku, Jan. 4, 1848

To the Land Commissioners, Respectful Greetings: I, Kaluau, hereby state my claim for land at Kahuku. The name of the mo'o is Kanenelu. There are five lo'i and a watercourse, bounded on the north by Maui's [land], on the east by Polena's [land], on the south by Kimo's [land], on the west by Kawaa's [land]. One lo'i is in another place, next to that of Kawaa; a lo'i and a watercourse is in the land of Kimo. A mala of wauke is at Ahamau [and] a mala of 'olena [turmeric], a kula, Hamea, and a kuahiwi, Kaulahelani. My house lot is at Kahuku and is bounded on the north by a lo'i, on the east and south by a land fence, on the west by a kula. My right of occupancy is from the time of Kamehameha I.

KALUAU

No. 2909 Kamalama Punalau, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Kamalama, hereby state my claim for land at Punalau. There are three lo'i, surrounded by kula, a kula cultivated in sweet potato and gourd. At Ulupehupehu is a cultivated kula.
At Kahuku I have a claim for one lo'i, which is surrounded by kula. At Kaunala is one koa canoe tree. My house claim is at Punalau, bounded on the north by the sea, on the east by Kainalu's fence, on the south by a land fence, on the west by Kaohele's fence.
My right of occupancy is from the reign of Kamehameha III.

KAMALAMA X his mark

No. 2827 Kanahuna Kahuku, Jan. 1, 1847

To the Land Commissioners, Respectful Greetings: I, Kanahuna, hereby state my claim for land at Kahuku, named Mana, with six lo'i, bounded on the north by Makilo's [land], east, by Loha's lo'i, south by the land of Kakala, on the west by Manukeokeo's and Lonopuakauila's [land]. There is a kula land, Hanapaua, Hokakala, Kalimaloa. The salt Land is Ahamau. There are three koa canoe trees.
My right of occupancy at this place is from the time of Kamehameha I.

KANAHUNA X his mark

No. 2861 Kaohele Kahuku, Jan. 3, 1847

To the Land Commissioners, Respectful Greetings: I, Kaohele, hereby state my claim for land at Kahuku. The name of the mo'o is Lanahu. There are five lo'i bounded on the north by Kaihu's holua [a sliding place for sport}, on the other three sides by kula. There is also a cultivated kula adjoining with Uwalakui on the east.
At Ulupehupehu are some malas of sweet potato and gourd.
A mala pali* is at Makapala, some mala of sweet potato and gourd. Mauka of Ulupehupehu are some hala trees. At Oio are some hala trees. My house claim is at Punalau, bounded on the north by a Kalawaone[*#], on the east by Kainalu's lot, south by a land fence on the west by a kula.
My right of occupancy is from the time of Kamehameha II.

KAOHELE X his mark

[* either a steep mala or one at the foot of a pali]
[*# curved beach, bigger than a cove, smaller than a bay] (D.B.)

No. 3868 Pila Paalaa, Oahu, January 4, 1848

To the Land Commissioners, Greetings and thanks: I Pila, hereby stat my claim for land at Paalaa. the name of the mo'o is Moewai. There are sixteen lo'i and the pahupahu [old offshoots from original plantings of taro], bounded on the north by the flowing stream, on

the east by a kula, on the south by a pali, on the west by cultivated kula land. My right of occupancy is from the present reign of Kamehameha III. I hereby describe my land of Kahalolua, which is bounded on the north by the land of Hii, on the east by the land of Haupu, on the south by the land and kula of Maio, on the west by the land of Ululani. This is one lo‘i.
It is finished.

PILA

No. 4388 Kau Kahuku, Oahu, January, 1, 1848

To the Land Commissioners, Greetings: I, Kau, am a claimant of land at Ahamau which I state to you five taro oi‘i and one water course makes the sixth [claim]. The boundaries are: on the north, the lo‘i of Kaaikaula, on the east, the lo‘i of Aaiki, on the south, the watercourse, on the west, the lo‘i of Umeume. Furthermore there is one lo‘i at Amo, bounded on the north, east and west by the lo‘i of Keino, on the south by the kula. Futher, there is a kula at Poohalulu, with wauke, sweet potato, banana, bounded on the north by the kula of Kuapuu, on the east by some hala trees for Kaaikaula, on the south by a kula for Aaiki, on the west by a kula for the ahupua‘a. Also, the house, which is at Amo. My right of Occupancy is from the time of Kamehameha I

KAU

No. 2928 Kauihaiwale Kahuku, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Kauihaiwale, hereby state my claim for land at Kahuku. The name of the mo‘o is Laauki, with three lo‘o, bounded on the north by Kekipi‘s [land], on the east by Umeume's [land], on the south by Makilo's [land], on the west by Uha's [land]. Two of my lo‘i are in the land of Hawi, one lo‘i is in the land of Kaaikaula. There is a kula land named Manono, a mala of wauke at Kapahukowali, a mala of sweet potato is at Koula. There are four mala, a salt land, and one koa canoe tree. My houselot is at Kahuku, bounded on the north by a mala of wauke, on the east by a taro lo‘i, on the south and west by kula.
My right of occupancy is from the reign of Kamehameha III.

KAUIHAIWALE X his mark

No. 2936 Kauaihikai Oio, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Kauaihikai, hereby state my claim for land at Oio, some malas of ‘awa, banana, wauke, sugar cane, two koa canoe trees, and some malas of sweet potato and gourd from the upland to the sea. At Hanakaoe are some malas of noni, aka‘akai [onions] and sweet potato, and a hala grove. At Kawela is a mala of noni. At Ulupehupehu are four malas of sweet potato. At Kahuku I have a claim for two lo‘i at Kanahu, three lo‘i at Uwalakui. My house claim is at Oio, bounded on the north by a pig pen, on the east by a hala grove, on the south by Pakanaka's [land], on the west

by the sea.
My right of occupancy is from the reign of Kamehameha III.

KAUAIHIKAI

No. 4341 Kaukaha Kahuku, Oahu, January 8, 1848

To the Land Commissioners, Respectful Greetings: I, Kaukaha, hereby state my claim for land in Kahuku. The name of the mo'o is Lanahu. There are seven lo'i. The boundaries are: on the north, Haa, on the east, Mooni's [lo'i], on the south, lo'i ko'ele, on the west, kula land. At Nahookahala I have a claim for three lo'i adjoining Lokoea's. On the east is Umen's and Lonoapuakauila's [land], on the north is Manukeokeo's [land]. At Punamano I have eleven lo'i, surrounded by kula. A cultivated kula land is Kauleokeu, with one mala. The sugarcane kula is mine. My house claim is at Kahuku. It is bounded on the north by the pasture and on the east, south and west by kula. My right of occupancy is from the time of Kamehameha I.

KAUKAHA X his mark

No. 4393 Kaumi Kahuku, Oahu, January 1, 1848

To the Land Commissioners, Greetings: I, Kaumi, hold land at Ahumau, with four taro lo'i, and also a watercourse, which makes the fifth [item]. The boundaries are: on the north, Kula's [land], on the east, Kaaikaula's [land], on the west, Kupaihea, on the south, Paauki. On the kula are banana, sweet potato, sugar cane and all such things. There is a wooded upland, with 'awa, koa kukui and all such things. My house is at Poohalulu.

KAUMI X his mark

No. 4422 Kaumolii Dec. 31, 1847

To the Land Commissioners, Greetings: I, Kaumolii, am a claimant of land and kula. I have six taro lo'i at Nanahu, and a weed-grown lo'i makes the seventh. The boundaries of these lo'is are: on the north, Wahokakala, on the east, Kalimalaa, west, the kula, south, Puulu. Further, I have two lo'i at Wahokakala, which I cultivate under someone. I have one other lo'i at Puulu, and my house is there and kula. There is a kula at Luahine with wauke, a salt land, plantings of sweet potato, banana, watermelon and all such things also a mala of 'awa. At Ahamau is a kula of wauke, banana, a planted hala tree, and a mala of noni, which are mine. At Ulupehupehu are some malas of 'awa, trees [for wood], bananas, a koa canoe tree.

KAUMUALII

No. 2918 Kawaa Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, Respectful Greetings: I, Kawaa, hereby state my claim for land at Kahuku. The name of the mo'o is Luahine. There is one lo'i, bounded on all sides by Luamea's lo'is. My house lot is in Kahuku, bounded on the north, east and south by kula land, on the west by the bank of a lo'i. My right of occupancy is from the time of Kamehameha I.

KAWAA X his mark

No. 2914 Keakaokawai Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, Respectful Greetings: I, Keakaokawai, hereby state my claim for land at Kahuku. The name of the mo'o is Kiiliilii. There are seven lo'i, bounded on the north by Nauluhao's [land], on the east by a kula, on the south by Makakiekie's [land], on the west by Kupaihea's [land]. There is a kula land named Kawelohale. There is a kula land named Kiipunawai, with four lo'i within it, a clump of hau and a mala of sweet potato. At Ahamau is a mala of wauke. My house claim is at Kahuku and is surrounded by kula. My right of occupancy is from the time of Kamehameha II.

KEAKAOKAWAI X his mark

No. 2887 Keawe Kahuku, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Keawe, hereby state my claim for land at Kahuku. The name of the mo'o is Luahime. There are three lo'i, bounded on the north by Kawaa's [land] on the east by Kaluau's [land], on the south by lo'i ko'ele, on the west by Paukoa's [land]. A mala of sweet potato is at Ahamau, and at Keana I have a mala of 'awa. My houselot is at Kahuku, and is surrounded by kula. My right of occupancy is from the time of Kamehameha I.

KEAWE

No. 2931 Keaweleikini Kahuku, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Keaweleikini, hereby state my claim for land at Kahuku. The name of the mo'o is Ahamau. There are five lo'i, bounded on the north by Kaaikaula's [land], on the east by Kupaihea's [land], on the south by Kekipo's [land], west, by Kaumi's [land]. There is kula planted in sweet potato, gourd and wauke. In the upland are two koa canoe trees. At Keana is one mala of 'awa. My right of occupancy is from the reign of Kamehameha III.

KEAWELEIKINI X his mark

No. 2867 Keino Kahuku, Oahu, Jan. 3, 1847

To the Land Commissioners, Respectful Greetings: I, Keino, hereby state my claim for land at Kahuku. The name of the mo'o is Amo. There are three lo'i, bounded on the north by Kaihikapu's [land], on the east by my houselot, on the south by Kaluau's houselot, on the west by Kanakaole's [land]. One lo'i is in another place, adjoining those by Kanakaole's [land]. One lo'i is in another place, adjoining those of Kaluamea, Kaihupeelani, and Kupau. There is a cultivated kula at Limalaa. At Amo, is a cultivated kula which goes into the seashore. There is a shore land and a kala [sweet potato?] land named Kaloaloa. There is a kula land on the east of Kahipa. My houselot claim is in Kahuku, bounded on the north by Kaihikapu's lot, on the east and south by the land fence, on the west by my lo'is. My right of occupancy is from the time of Kamehameha I. There is a salt land [and] a mala wauke in the upland.

KEINO X his mark

No.4384 Kekipi

The Land Commissioners: Greetings: I, The one whose name is below, hereby state my claim for land which was gotten from my kupunas who got it in the time of Kamehameha I. Two taro lo'i are at Ahamau and two banks of a watercourse. Two taro lo'i are at Kahauloa, also in Ahamau, and also the kula is at Kalimaloa. Another kula is at Makapala and another kula is at Poohalulu. Also, there is a wooded upland at Ahamau, with pili grass, a kukui tree, 'ohi'a tree, tree, and other similar things. These claims are in the ahupua'a of Kahuku on the Island of Oahu.

KIKIPI X his mark

No. 2913 Kekua Punalau, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Kekua, hereby state my claim for land at Punalau. There is one lo'i bounded on the north and east by kula land, on the south by Kaopupahi's [land], on the west by Kanehekili. There is cultivated kula and shore land. Mauka of Ulupehupehu is a mala of wauke and a mala of banana and some alane [orange] trees. At Amo is a pali uwala [steep sweet potato planting]. At Kiakolu is a mala of sweet potatoes. At Kahuku, in Ahamau, is one lo'i adjoining that of Makilo. At Mookini is one lo'i adjoining that of Luika, and there is another lo'i there adjoining that of Kalaweaumoku.
My right of occupancy is from the time of Kamehameha I.

KEKUA X his mark

No. 2935 Kekuauli Oio, Oahu, January 5, 1848

To the Land Commissioners, Respectful Greetings: I, Kekuauli, hereby state my claim for land at Oio, a kula planted in sweet potato and gourd and a pali uwala [steep sweet potato planting]. At Ulupehupehu is a valley planted in sweet potato. At Kahuku are two lo'i at Lanahu and one at Ualakui. My houselot is at Oio, bounded on the north and east

by <u>kula</u>, on the south by a land fence, on the west by the sea.
My right of occupancy is from the reign of Kamehameha III.

KEKUAULI X his mark

No. 2864 Iosua Kiha Punalau, Oahu, Jan. 3, 1847

To the Land Commissioners, Respectful Greetings: I, Kiha, the <u>konohiki</u> of Punalau, hereby state my claim for land at Punalau. There is one <u>lo'i</u>, bounded on the north by a <u>kula</u> land, on the east and south by <u>kula</u>, on the wet by Kaopupahi's [land]. There is also <u>kula</u> land, mountain land and shore land. I am the <u>konohiki</u> of Ulupehupehu, <u>kula</u> land and mountain land. At Kahuku I have a claim for one <u>lo'i</u>, bounded on the north and west by Palu's [land], on the east by Kailiuku's [land], on the south by Kupihea's [land]. There is also a <u>kula</u> land, Mookini. My house claim is at Punalau, bounded in the north by the sea, on the east by the <u>kula</u>, on the south by the land fence, on the west by Kainalu's [land].
My right of occupancy is from the time of Kamehameha I

IOSUA KIHA X his mark

No. 4374 Kuapuu Kahuku, Oahu, Dec. 31, 1847

To the Land Commissioners, Greeting: I, Kuapuu, hereby state my claims for land, a <u>kula</u> at Paohalulu, and twentyfour taro <u>lo'i</u>, which are bounded on the north by Waiula, on the east by east Paohalulu, on the west by Uulakui, on the south by ______. The valuable things on the <u>kula</u> are <u>hala</u>, <u>wauke</u>, some <u>'ili</u> of sweet potatoes, bananas, and <u>pili</u> grass. There is also the fishery of Pauwela. All these things are at Paohalulu. My right of occupancy upon the land is from the time of Kamehameha III, until the present. There remains the houselot. Which is at [no name].

KUAPUU X his mark

No. 4390 Kupaihea Kahuku, Oahu, Dec. 31, 1847

To the Land Commissioners, Greetings: I, Kupaihea, am a claimant at Ahamau, with two taro <u>lo'i</u>, the watercourse, three <u>kula</u>, a fishery, and a wooded upland. The boundaries are: on the north a <u>kula</u>, on the east, Kahaumuku, on the west, Kuapuu, on the south, Paauki. There are wauke, sweet potatoes, bananas, <u>papapa</u> [bean], and similar things planted on the <u>kula</u>. I have a fishery also at Ahamau. My house is a Paohalulu.

KUPAIHEA X his mark

No. 4428 Kuhoopohopo

No. 4383 Kekipi

The Land Commissioners: Greetings: I, the one whose name is below, hereby state my claim for land which was gotten from my kupunas who got it in the time of Kamehameha I. Two taro lo'i are at Ahamau and two banks of a watercourse. Two taro lo'i are at Kahauloa, also in Ahamau, and also the kula is at Kalimaloa. Another kula is at Makapala and another kula is a Poohalulu. Also, there is a wooded upland at Ahamau, with pili grass, a kukui tree, 'ohe'a tree, koa tree, and other similar things. These claims are in the ahupua'a of Kahuku on the Island of Oahu.

KEKIPI X his mark

No. 2880 Kupau Kahuku, Jan. i, 1847

To the Land Commissioners, Respectful Greetings: I, Kupau, hereby state my claim for land at Kahuku. The name of the mo'o is Makapala. There are four lo'i and the edge or bank of a watercourse. The boundaries are: on the north, Umeume's lo'is, on the east Kawaa's [land], on the south, a Government Road, on the west, Pukawale's [land].
2. A kula land is planted in sweet potato, noni, sugar cane and banana [and] a cultivated upland. At Malaekahana is the claim for my two mala of noni, two mala of wauke and two koa canoe trees. At Laie I have a claim for one lo'i, bounded on the north and south by Kamamae's [land], on the east by Kaloana's [land], on the west by Amaka's [land]. My house claim is bounded on the north by a land fence, on the east, south and west by kula land. My right of occupancy is from the time of Kahahana.

KUPAU X his mark

No. 2885 Kupihea Punalau, Oahu, Jan. 3, 1847

To the Land Commissioners, Respectful Greetings: I, Kupihea, hereby state my claim for land at Punalau, consisting of one lo'i bounded on the north and west by a kula, on the east by Kaopupahi's [land], on the south by Maulua's [land]. There is also a kula land, mountain land, and a kai [shore area or fisher]. At Ulupehupehu are some mala of sweet potato. At Kahuku are two lo'i, bounded on the north by Kiha's [land], on he east by Kalaweaumoku's [land], on the south by Holoaia's [land], on the west by Kailiuku's [land]. My house claim is at Punalau. My right of occupancy is from the time of Kamehameha I.

KUPIHEA X his mark

No. 3809 Lokea Kahuku, Oahu, Dec. 31, 1847

To the Land Commissioners, Greetings: I, Lokea, am a claimant for land and kula at Puaakea, consisting of seven taro lo'i and the kula. The crops planted are sweet potato, wauke, watermelon, pili grass. The kula is at Kakala; another kula is at Kalimaloa. My house is at Puaakea. My right of occupancy is from the time of Kamehameha I.

LOKEA

No. 2690 Luiki Kahuku, Oahu, Dec. 31, 1847

To the Land Commissioners, respectful greetings: I, Luiki, hereby state my claim for land at Kahuku. The name of my mo'o is Mookini. There are six lo'i, two watercourse banks and the kula land of Mookini. The boundaries of the six lo'i and the two watercourses are: on the north, Akamau, on the east, Napoe's, on the south, Hale's, on the west, Kalaweaumoku's.
At Ulupehupehu is my claim for a wauke garden and a banana plantation.
My house claim is at Kahuku and is bounded on the north by the land fence, on the east by the weed grown kula, and likewise on the south, on the west, a kula.
The occupation of my claim has been from the time of Kamehameha I.

LUAMEA X his mark

No. 2691 Luamea Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, respectful greetings: I, Luamea, hereby state my claim for land at Kahuku. The name of the mo'o is Luahine. There are 12 lo'i, and two watercourses, bounded on the north by Kaihupulani's, on the east by Kalauau's, on the south by Makaokalai's, On the west by Kapau's. A cultivated kula land and a shore area, named Kaipauloa, and a watercourse is in another place adjoining the land of Makaokalai. Some wauke gardens are at Akamau. At Puulu is a banana plantation, a mountain land, named Kaulohilani. Three trees for koa canoes are in Waialua at Kalehunui, two hala trees and one kukui tree.
The lot claim is at Kahuku; it is surrounded by kula.
The occupation of my claim has been from the time of Kamehameha I.

LUAMEA X his mark

No. 2785 Makakiekie Kahuku, Oahu, Jan. 1, 1848

To the Land Commissioners, Respectful Greetings: I, Makakiekie, hereby state my claim for land at Kahuku. The name of the mo'o is Puulu. There are seven lo'i, bounded on the north by those of Keakaokawai, on the east by a kula, on the south by Pukawale's [land], on the west by Kupaihea's [land]. One lo'i and the watercourse adjoins those of Maui and Kuapuhi and kula. There is kula land at Kawelohale and Kii, two clusters of hala trees. At Ahamau are some gardens of sweet potato and gourd. There is a shore area called Kaohana. In the upland are some gardens of wauke, 'awa and noni, and seven koa canoe trees. In another place is a watercourse adjoining Maui's. At Keana are one 'awa garden, and five koa canoe trees. There is a mountain land, Kalapaweo. My house claim is at Kahuku, bounded on all sides by the kula. There is a fish pond for me, close to my house. My right of occupancy is from the time of Kamehameha I.

MAKAKIEKIE X his mark

No. 2787 Makaokalai Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, Respectful Greetings: I, Makaokalai, hereby state my claim for land at Kahuku. At Luahine is one lo'i and two watercourses, bounded on the north by Kawaa's [land]], on the east by a lo'i ko'ele, on the south by Keino's [land], on the west by Kawaa's [land]. There is also another lo'i, adjoining that of Kaihupiilani. There ia a fishpond named Kumuhakane. There is also another area, Hanumoha. There are two gardens of sweet potato and wauke. There are two 'awa gardens. There are four koa canoe trees. At Keana are two 'awa gardens and three koa trees. My houselot is at Kahuku, bounded on all sides by the kula. My right of occupancy is from the time of Kamehameha I.

MAKAOKALAI X his mark

No. 2779 Makilo Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, Respectful Greetings: I, Makilo, hereby state my claim for land at Kahuku. The name of the mo'o is Paaiki. There are eight lo'i, and four watercourses. On the north is Kekipi's [land], on the east is Umeume's [land], on the south is Pukawale's [land], on the west is Kuelu's [land]. The kula land is Kuhiwa, also Hoahale. My right of occupancy is from the time of Kamehameha III.

MAKILO

No. 2782 Makola Kahuku, Jan. 3, 1847

To the Land Commissioners, Respectful Greetings: I, Makoli, hereby state my claim for land at Kahuku. The name of the mo'o is Ahamau. There are four lo'i, bounded on the north by lo'i ko'ele, on the east, by Mauoli's [land], on the south lo'i ko'ele, on the west by Pahanui's [land]. I also have watercourse adjoining the konohiki's [land]. At Lanahu are three lo'i adjoining those of Kaohele. I also have a kula land at Hiu, a row [or cluster] of hala trees, also a salt land. At Punalau is a banana garden, with [also] noni, wauke, hala, and six koa canoe trees. At Ahamau is one koa canoe tree. Two fish ponds [and] a sweet potato kula are at Amo. At luahine is a wauke garden. At Kahala is a garden of banana, wauke and sweet potato. My house claim is at Kahuku, bounded on the north by the sea, on the east and south by a land fence, on the west by Napoe's lot. My right of occupancy of these places is from the time of Kamehameha II.

MAKOLE X his mark

No. 2775 Malailua Kahuku, Oahu, Jan. 3, 1847

To the Land Commissioners, Respectful Greetings: I, Malailua, hereby state my claim for land at Kahuku. The name of the mo'o is Kanaiki. There are six lo'i, bounded on the north

by the lo'i konohiki, on the east by Palu's [land], on the south by a lo'i po'alima, on the west by a lo'i ko'ele, on the west by Aie's [land]. At Kawela I have a claim for one lo'i, bounded on the north by Kaunahi's [land], on the east by Mumuku's [land], on the south by Kaopu's [land], on the west by Muli's [land]. At Kahuku I have one lo'i, bounded on the north and the east by Kekua, on the south by Puahiki, on the west by Kawaaloa. At Pahipahialua is a garden of banana, wauke and sugar cane and three koa canoe trees. Three koa canoe trees are at Kaunala [and] a noni garden.
My house claim is at Pahipahialua.

MAHOE X his mark

No. 3723 Male Kahuku, Oahu, January 1, 1848

To the Land Commissioners, Greetings: I, Male, an a claimant in the 'ili of Keahupuaa, with seven taro lo'i, bounded on the north by Napoe, on the east by a kula, on the west by Palama, on the south by Kalahana. Furthermore, I have some "jump" claims: at Makapala, three taro lo'i, at Puulu, eight lo'i and five kula, at Ahamau, two fish ponds, one bathing pool and my house. The ahupua'a is Kahuku. My occupancy of these claims has been from the time of Kamehameha I.

MALE

No. 2781 Manukeokeo Punalau, Jan. 3, 1847

To the Land Commissioners, Respectful Greetings: I, Manukeokeo, hereby state my claim for land at Kahuku, in Uwalakui. There are four taro lo'i and three lo'i overgrown with grass of herbage. The boundaries are, on the north, Puahiki's [land], on the east Kanahuna's [land], on the south, Lonopuakauila's [land], on the west, a sugar cane kula. There is a lo'i in another place, next to that of Malailua and Kaukaha and Kaumualii. At Punalau is a garden of sweet potato. At Lanahu is a garden of banana and wauke. At Amo is a gourd garden. At Punalau is a gourd garden. My house claim is at Punalau and is bounded on the north by Kaohele's lot, on the east by a kula, on the south by the land fence, on the west by a kula. I have had the right of occupancy on these places from the year of our Lord 1842.

MANUKEOKEO X his mark

No. 2783 Maui Kahuku, Jan. 1, 1847

To the Land Commissioners, Respectful Greetings: I, Maui, hereby state my claim for land in Kahuku. The name of the mo'o is Kahoku. There are six lo'i, bounded on the north by Pukawale's lo'is, on the east by a kula, on the south by Puu
s [land], on the west, by Kaihupeelani's [land]. One lo'i is in another place, adjoining those of Napoe and Pukawale. There is kula land cultivated in wauke, sugar cane, banana, sweet potato, a clump of hau and a cluster of hala trees from Pukokonue to Pukokoiki.

There is an upland cultivated in wauke, sweet potato, and two koa canoe trees, at Ahamau. At Poohalulu is a sweet potato garden and a cluster of hala trees. My house lot is here in Kahuku, surrounded by the kula. My right of occupancy is from the time of Kamehameha I.

MAUI X his mark

A single lo'i adjoining mine, was for my makua, and is for me. The kula of Kupunawai, a cluster of hala trees at Kaupoo, a wauke garden, two noni gardens, two 'awa gardens, and the cultivated kula of Kawelahale are for me.

No. 2788 Mauoli Kahuku, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Mauoli, hereby state by claim for land in Kahuku. The name of the mo'o is Lonohonuakini. There are eight lo'i, bounded on the north by a kula, on the east by Kueulu's [land], on the south by a lo'i ko'ele, on the west by Makole's [land]. I have two lo'i in the land of Makole, two lo'i in the land of Kueulu, In the land of Uha are kula land and five gardens. At Hanapaua is one garden. At Poohalulu is one garden. At Waiula is one garden. At Manono is a taro lo'i. In the upland are some gardens of banana and wauke. There are two salt lands. There are two houselots close to the seashore, named Kukui and Kahala.
My right of occupancy is from the reign of Kamehameha III.

MAUOLI X his mark

No. 2758 Napoe Kahuku, Jan. 1, 1847

To the Land Commissioners, Respectful Greetings: I, Napoe, hereby state my claim for land at Kahuku. The name of the mo'o is Puulu. There are four lo'i and four watercourses, bounded on the north by Kalaweaumoku's [land], on the east by Pili's [land], on the south by Male's [land], on the west by Luiki's [land]. There is another lo'i in another place, adjoining that of kanahuna and of Kainalu and of Kaimualii. Another lo'i is at Hanapaua. There is kula wauke land, three wauke gardens, one at Puaakea, one at Makapala, and one at Hakane. Two fish ponds are at Panalau. Seven hala trees, two noni gardens and a sweet potato garden are in Kahuku. At Ulupehupehu is a garden of banana, wauke and sugarcane. At Oio are three koa canoe trees. At Punalau is one koa canoe tree. Here at Kahuku are four koa canoe trees. My house claim is at Kahuku, bounded on the north by the sea, on the east and south by kula, on the west by a pond which is mine.

NAPOE X his mark

No. 3958 Nauluhao Kahuku, Oahu, Dec. 31, 1847

To the Land Commissioners, Greetings: I, Nauluhao, hereby state my claim for land at Ahamau. There are eleven taro lo'i, a kula, a wooded upland, with breadfruit, 'ohi'a, kukui, koa, ti leaves, noni, and everything else that grows there. I also have a salt land. The boundaries are: north, the seashore, east, a hala and Pukoko, west, Nani, south, Kiiliilii. Also, there is one lo'i at Kahauloaa. A second lo'i is at Kalai. A place cultivated in wauke, sweet potatoes and watermelon is at Niu. These claims are at Ahamau. Also, there is a kula named Waiula, which is at Kalimaloa. Another kula, named Hawea, is at Luahine. My right of occupancy, to this day, is from the time of Kamehameha I. My house is at Kalimaloa. There remains a koa canoe tree at Ahamau.

NAULUHAO X his mark

No. 3951 Niau Kahuku, Oahu, Dec. 31, 1847

To the Land Commissioners, Greetings: I, Neau, am a claimant of land at Puohalulu. There are twenty-three taro lo'i, also a kula, with sweet potato, sugar cane, banana, wauke, watermelon, pili grass. There is also a kai [shore area, or fishery], of Kakaako. The boundaries are: on the north, the sea, on the east, Ahamau, on the west and south is Kuapuu's [land]. Furthermore, there are two clumps of hala and one is in Kuapuu's [land], making the third. The occupancy has been from the time of Kamehameha II, except the house.

NIAU X his mark

No. 2744 Pakanaka Oio, Oahu, Jan. 5, 1848

To the Land Commissioners, Respectful Greetings: I, Pakanaka, the konohiki of Oio, hereby state my claim for land at Oio. It is mountain land, a garden of banana, 'awa, sugarcane, and wauke. There are nine koa canoe trees, a kula planted in sweet potato and gourd, two lo'i, a grove of hala trees, and salt bed land,
At Kahuku is one lo'i adjoining those of Kaihiholua and Lonoopuakauila. My houselot is at Oio, bounded on the north by that of Kauahikai, on the east by kula, on the south by I's [land], on the west by the sea.
My right of occupation is from the time of Kamehameha I.

PAKANAKA X his mark

No. 3813 Pakui Kahuku, Oahu, Dec. 31, 1847

To the Land Commissioners, Greetings: I, Pakui, am a claimant of land and kula at Ahamau. There are ten taro lo'i, a kula, a wooded upland, a fishery, and a salt land. The boundaries are: north, Kekipi's [land], east, Ainaio, west, Aaiki, south, Pueu. Another lo'i is in Kaio's [land], in Ahamau. Furthermore, there are two kula. One is at Poohalulu in Niau's mo'o, planted with wauke, sweet potato, banana and watermelon. Another kula is at Poohalulu in Kuapuu's [land], planted as aforementioned. There is also kula at Keahupuaa, with wauke, sweet potato, watermelon, banana, and such things. Also, I have a house at Poohalulu. Here are some remaining claims: a mala of 'awa at Luahine, a mala of noni at Puulu, a koa canoe tree at Ahamau.

PAKUI

No. 2730 Pahanui Kahuku, Oahu, Dec. 31, 1847

To the Land Commissioners, Greetings: I, Pahanui, an a claimant of land at Keahupuaa. There are five taro lo'i, two banks of a watercourse and also a kula. wauke, banana, sweet potato, noni, hala, pili, and such things are planted in my , which is bounded on the north and east by Ahamau, on the south by Palu, on the west by Puaakea.
2. There is a kula planted in wauke and the salt land. There are sweet potato, sugarcane, noni, wood from the upland, olona, 'ohi'a, kukui and such things at Ahamau, which is bounded on the north by the seashore, on the east by Mauoli, on the south by Napoe, on the west by the kuahiwi [mountain] of Waimea. My houselot is at Punakaipo. I have held these claims from the time of Kamehameha II.

PAHANUI X his mark

No. 2738 Palu Kahuku, Oahu. Jan. 1848

To the Land Commissioners, respectful greetings: I, Palu, hereby state my claim for land in kahuku. The name of my mo'o is Mookini, there are ten lo'i and the watercourse, bounded on the north by Mooni's [lo'i], on the east by Kalaweaumoku's [lo'i], on the south by a ko'ele lo'i, on the west by Malailu's and Mooni's [lo'i]. A cultivated kula is mauka, a garden of noni and of 'awa, named Namakana. At Oio are two koa canoe trees, at Ulupehupehu is one koa canoe tree. There is a salt land at Ahamau, a wauke garden and a row of hala trees. My houselot is at Kahuku, and is surrounded by kula.
My right of occupation is from the time of Kamehameha I.

PALU X his mark

No. 2729 Polena Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, respectful greetings: I, Polena, hereby state my claim for land at Kahuku. The name of the mo'o is Luahine. There are seventeen lo'i, bounded on the north by the kula, on the east by Kaihikapu's land, on the south by Kaluau's land, on the west by Maui's land. There are cultivated kulas named Uwalapahupahu, Mamakaloa and Luahine. There is a sea shore land, named Puhikaawe. At Keana are two 'awa gardens, and a garden of breadfruit and 'ohi'a. My houselot is at Kahuku and is bounded on the north east and west by a kula, on the south by a salt bed.
My right of occupancy is from the time of Kamehameha I.

POLENA X his mark

No. 2732 Pukawale Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, respectful Greetings: I, Pukawale, hereby state my claim for land at Kahuku, a mo'o named Kuha. There are five lo'i, bounded on the north by those of Makakiekie, on the east by a kula, on the south by Maui's [lo'i], on the west by Kupaikia's [lo'i]. There is a shore area--the name of the sea [fishery] is Keekee, [and] a mountain area.

At Makapala are two lo'i, bounded on the north by Umeume's, on the east by Kupau's, on the south by a kula, on the west by a ko'ele lo'i. There is a cultivated kula named Makapala, another kula is Mauiloa, and there is another valley [or gulch]. At Keana are two wauke gardens and two koa canoe trees. My houselot is at Kahuku and it is surrounded by kula.

I have had the right of occupancy since the time of Kamehameha I.

PUKAWALE X his mark

No. 2723 Puu Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, respectful greetings: I, Puu, hereby state my claim for land at Kahuku. The name of the mo'o is Kauleokeu. There are six lo'i, bounded on the north by those of Niau, on the east by those of Lohea, on the south by those of Heea, on the west by those of Kuapuu. There is a cultivated kula, [at] Kauleokeu. A taro land is named Punamano. The kula land of Kaiea goes down to the sea. The shore land is Luaehu and Punawai.

My house claim is at Kahuku, bounded on the north by a salt bed, on the east by a hau clump, on the south and west by kula.

[It has been held] from the time of Kamehameha III, being the year of our lord 1845.

PUU X his mark

No. 2681 Uha Kahuku, Oahu, Jan. 5,1848

To the Land Commissioners, respectful Greetings: I, Uha, hereby state my claim for land at Kahuku. The name of the mo'o is Kauniniwai. There are six lo'i and it is bounded on the north by the kula, on the east by Kekipi's, on the south by Kaaikaula's and Pakui, on the west by Kaaikaula's also. I have four lo'i at Kaleinalaa; next to Hooni's is a kula land named Meeakalili. At Kakala is a garden of sweet potato, gourd and banana. At Haleaniani are some wauke gardens. At Ulakapala is a garden of banana, wauke, sugar cane and gourd. At Pualu is a sweet potato garden. At Pumaia is a pit with banana and 'awa. At Kalehuawai is a garden of 'awa, banana, taro [and] a hau grove named Kukio. At Mookini is a wauke plantation, and in the upland is a noni garden named Kaluaalea [and] one *koa* wa'a [koa tree large enough to make a koa canoe?].

I have occupied [these places] during the reign of Kamehameha III.

UHA X his mark

No. 3748 Uha Kahuku, December 31, 1847

To the Land Commissioners, Greetings: I, Uha, am a claimant of land in the ʻili of Ahamau, with seven taro loʻi, a kula, an upland with pili grass, a koa tree, a kukui tree, an ʻohiʻa tree, and all the vegetation. Also, there is a salt land at Ahamau. The boundaries are: north, the seashore, east, Haue's [land], west, Mauoli's [land], south, Waimea mountain. 2. A kula is at Poohalulu, planted with wauke, watermelon, sugar cane, and such things. 3. Five taro loʻi and the banks of a watercourse at Puulu. The three things below are scattered. 4. Two taro loʻi at Kahani, some [other] loʻis at Ahamau, and a house at Poohalulu. I acquired these lands before the enactment of the Law.

UHA

No. 2679 Umeume

To the Land Commissioners, Respectful greetings: I, Umeume, hereby state my claim for land at Kahuku.
The name of the moʻo is Paauiki. There are 6 loʻi. The boundaries are: north, Kaaikaula's, east, Kau's, south, Kuwahapuhi's, west, Makilo, a kula land, a cultivated upland. In another place is one loʻi, at Punamano. Three loʻi are at Mookini. A kula is cultivated in wauke, sweet potato and gourds. at Punalau is a banana and noni patch. At Ulupehupehu are three wauke, banana, sugar cane and sweet potato patches. Here at Kahuku is a puna paʻakai [brackish spring?] and my two hala trees. My houselot is here in Kahuku. Its boundaries are surrounded by kula.

UMEUME

No. 2698 Waanui Ulupehupehu, Oahu, Jan. 5, 1848

To the Land Commissioners, respectful greetings: I, Waanui, hereby state my claim for land at Kahuku. The name of the moʻo is Puaakea, and I have two loʻi. On the north is Lokea's, on the east is Kailiuku's, on the south is Kaukaha's land, on the west is Napoe's land.
At Oio I have some gardens of wauke, noni, and a kula cultivated in sweet potato.
At Ulupehupehu are some gardens of sweet potato and gourd. My houselot is at Ulupehupehu. On the north is the sea, on the east and the south is kula, on the west is the houselot of Kane.
My right of occupancy is from Kamehameha III.

WAANUI X his mark

No. 2702 Waialua Kahuku, Oahu, Jan. 4, 1848

To the Land Commissioners, respectful greetings: I, Waialua, hereby state my claim for land. They are kula lands, named Waihamohamo, Haamala and Puukamanu, and a row of hala trees [at] Kaupoo, a hala tree at Koolina, a puna pa'akai [brackish spring] and a row of hala [at] Mahukini. My house claim is at Kahuku and is bounded on the north, south and west by a kula, on the east by a row of hala. My right of occupation was from the time of Kamehameha I.

WAIALUA X his mark

Appendix E: LCA Native Testimony of Keana

No. 4391 Kalawaiamanu Keana, oahu, January 3, 1848

To the Land commissioners, Greetings: I, Kalawaiamanu, am a claimant in the ʻili in Louana [?]. There are three ʻili weuweu, one ʻili of sweet potato, one ʻili of wauke, bounded on the north by the kula, on the east and west by sugarcane, on the south by the pali. Here are the "jump' lands: At Halulu is sugarcane, wauke. At Kahalau is breadfruit and noni. At Keaaulu is a breadfruit, and noni. At Kapuou is noni. At Kealahaka is ʻawa, sugar cane, and banana. At Paos is ʻawa. At Uumhalu is a kula planted in sweet potato and watermelon.
My house is at Nonoula. My right of occupancy is from the time of Kamehameha II.

KALAWAIMANU

No. 7130 Kinimaka Homolulu, Oahu, Feb. 9, 1848

Greetings to the Land Commissioners of the Hawaiian Islands: I hereby state my claim for land: Kalahiku, Hawaii. Maihi. Onoulimalo, Molokai. 1/2 Keana, Oahu, Koolaulau. I am, respectfully,

KINIMAKA

/Note in margin in English: Certificate of division:

Ahupuaʻa	District	Island
Maihi	Kona	Hawaii
Kalahiki		"
Onoulimaloo		"
1/2 Keana	Koolauloa	Oahu
Feb. 9, 1848		

No. 4329 Kalua Laie, Dec. 31, 1847

To the Land Commissioners, Greetings: I, Kalua, am a claimant of land in Laie, in the ʻili of Kumupali. There are five loʻi, one kula from the sea to the kuahiwi, and one kula house lot. The boundaries are: on the north, the land of Amaka, on the east, the land of Kalimanui, on the west, Puni's land, on the south, the land of Kaloana. Here are my claims which I cultivate in various places. In the ʻili of Kahikaele are six kula, no loʻi, no houselot. Because these claims of mine are so very scattered it is not practical to tell you, the Commissioners, of their boundaries. My right of occupancy of these places is from my kupunas until the present.

KALUA X his mark

APPENDIX K
TRAFFIC ASSESSMENT

APPENDIX K

TRAFFIC ASSESSMENT

A traffic impact analysis study was conducted for a livestock agricultural park at two proposed sites: Kunia and Kahuku. The analysis involved adding the traffic volumes which would be generated by the proposed project to current traffic volumes to determine if reductions in level of service would result.

Both proposed project sites are located alongside two-lane highways. The Kunia site is accessed via Kunia Road in Central O'ahu. The Kahuku site is alongside Kamehameha Highway on the North Shore. The following table summarizes daily, AM and PM peak hour traffic (two-way) volumes at State Department of Transportation counting stations in the vicinity of the project sites:

	Kamehameha Highway	*Kunia Road*
SDOT Station Number	26-F	C-9-D
Location	Ki'i Bridge	Waiahole Reservoir
Date of count	August 27-28, 1992	April 13-14, 1992
Daily volumes	7130	9267
AM peak hour volume	387	904
PM peak hour volume	627	904

Two-way peak hour volumes are shown since level of service on two-lane highways is based on two-way rather than one-way volume.

The preliminary engineering report forecast that the proposed project would generate an average of 41 round trips per day, with 33 worker-related commuter trips and the remainder delivery-related truck trips. For the purposes of this analysis, the worst-case scenario was assumed where all commuter trips would occur in the AM and PM peak hours. Delivery trips by trucks were assumed to be made during the midday off-peak. Hence, 82 vehicles per day were added to the current daily highway volumes and 33 vehicles per hour were added to the current peak-hour traffic volumes.

The current (without project) and forecast (with project) traffic volumes were analyzed with the Highway Capacity Manual (1985) procedure for determining levels of service on two-lane highways. The procedure compares traffic volumes against the carrying capacity of the roadway to generate levels of service ranging from A (best) to F (worst). Level of service D is generally acknowledged as the minimum acceptable level of service. The results of the analysis are presented below:

		Current		Forecast	
		Volume	LOS	Volume	LOS
Kahuku,	AM peak	387	B	420	B
	PM peak	627	C	660	C
Kunia,	AM peak	904	D	937	D
	PM peak	904	D	937	D

For both locations and both peak periods, the levels of service do not change from curent to forecast conditions. This indicates that the proposed project would not have an adverse traffic impact at either location.

Due to the large vehicles (up to WB-50) projected to enter the project site, the access intersection with the main highway should be designed to accommodate these vehicles.

APPENDIX L

SITE OPERATIONS AND ENVIRONMENTAL MONITORING

APPENDIX L
SITE OPERATIONS
AND ENVIRONMENTAL MONITORING

A. Overview

This appendix presents information which will enable the reader to understand how resource conservation practices can be incorporated into the operation of the proposed project. There are several considerations: 1) soil conservation and grazing management, 2) ground and surface water protection, and 3) waste management (and other utility) operations in the interest of safety, effectiveness, and environmental protection.

B. Land Resources

1. Soil Conservation

a. Facility Construction. An erosion control plan should be submitted with the construction drawings. This plan should reflect the project construction phasing (to be determined) and should be based on the City and County of Honolulu Erosion Control Standard.

b. Agricultural Practices. Best management practices to reduce erosion and control sedimentation from agricultural activities should be developed by each dairy operator, with technical assistance from the Soil Conservation Service.

2. Grazing Management

The amount of forage that a mature dairy cow consumes and the rate of forage growth are considered, theoretically, to establish a preliminary density limit for grazing on steep slopes (12 to 15 percent). A mature cow, assumed to weigh 1,300 pounds, must consume 1.5 to 2 percent of her weight in dry matter per day for maintenance energy. This equates to 4,305 kg per year:

$$1{,}300 \text{ lb} \times 0.4536 \frac{\text{kg}}{\text{lb}} \times 0.02 \times 365 \text{ day/yr} = 4{,}305 \text{ kg/yr}$$

A stand of guinea grass, assuming sufficient soil moisture, can produce 21 wet tons per acre of growth a year. Assuming 90 percent moisture content, this equates to 1,905 kg/year dry matter:

$$21 \text{ tons/yr/ac} \times 2{,}000 \frac{\text{lb}}{\text{ton}} \times 0.4536 \frac{\text{kg}}{\text{lb}} \times 0.1 = 1{,}905 \text{ kg/yr/ac of dry matter}$$

Guinea grass can be grazed on a two-month cycle in the summer months and a three-month cycle in cooler winter months. It should not be grazed closer than 10 inches. Assuming a mature height of 4 feet (96 inches) and a remaining cover of one foot (12 inches) after grazing for erosion control purposes, approximately 75 percent of the growth can be grazed. Thus the acreage limitation for good cover on steep grazing land is:

$$4{,}305 / 1{,}905 / 0.75 = 3.0 \text{ acres per animal unit, say 3 acres/animal unit}$$

This is considered the minimum acreage per animal unit. This is equivalent to approximately one-third animal unit per acre. A 300-pound calf could be considered 0.2 animal units on weight basis. If one considers only the 19 acres adjacent to the waste management site for pasture, about six dry cows or 30 calves can be pastured year-round. Additional pasture may be leased on *mauka* or *makai* properties not on the project site.

The grazing density will depend on rotational techniques, irrigation efficiency, infestations by noxious weeds and insects, and local weather patterns. Thus adjustment of the grazing density will be required from time to time.

On-site mitigation will be used to reduce erosion hazards, particularly from sloping areas used for grazing. The recommended measures include:

a) intensive grazing land management; and
b) land use controls.

The first measure consists of supervised rotation of a portion of the dairy herds by grazing managers in paddocks where density can be closely supervised. The U.S. Soil Conservation Service and the University of Hawaii, Cooperative Extension Service should be consulted concerning the reduction in soil erosion and implementation of best management practices. The second measure is discussed next.

The conclusion of the erosion risk assessment in the Environmental Impact Statement is that grazing management is acceptable on moderate slopes; however, grazing pressure should be controlled and grazing in severely sloping areas should be avoided. There are two considerations for these controls:

1) a covenant in the lease agreement to enforce compliance by operators with respect to on-site herd replacement and allowable grazing density; and

2) restrictions concerning grazing other than in permitted areas.

It is recommended that the administration of the agricultural park include a resource manager to monitor and assist operators with grazing and manure management issues.

C. Water Resources

1. Ground Water

a. Manure Management. Protection of ground water resources from excessive concentration of nitrogen requires manure management practices. These practices can also improve farm productivity. The elements of the manure management plan are:

(1) soil fertility testing;
(2) manure nutrient testing; and
(3) liquid injection systems for concentrated liquid application, or dilution, nutrient removal, sedimentation, disinfection, and spray irrigation of effluent.

Soil fertility testing can be done with technical assistance from county extension agents and the US Soil Conservation Service. The critical parameters to test are macronutrients—nitrogen, phosphorus, and potassium. However, other micronutrients and soil salinity can be requested, particularly salinity. Laboratory assistance can be obtained from the Agricultural Diagnostic Service Center at the University of Hawaii, College of Tropical Agriculture and Human Services, for a nominal fee. The results of the soil fertility tests can be used to match manure fertilizer application to crop requirements. The elements of soil sampling are explained in Circular 428, prepared by the University of Hawaii Cooperative Extension Service, "Take Good Soil Samples for Fertility Recommendations," by Wade McCall, 1968.

The fertilizer value of the manure from the waste treatment process can be initially based on preliminary values shown in the American Society of Agricultural Engineers Standards. This figure related nitrogen, phosphorus, and potassium concentration to specific gravity. A hydrometer can be used to test the specific gravity and thus relate a particular volume of liquid manure from a digester to its fertilizer equivalent. These values should be updated using samples from stored manure on the agricultural park. The fertilizer value will vary depending on the age after treatment, whether it is incorporated immediately into the soil, and the animal ration to a smaller degree. Assistance with fertility testing can be obtained from University of Hawaii extension personnel.

Liquid injection systems are recommended if liquid manure slurry application is used because:

(1) incorporation into the soil immediately after application reduces nitrogen loss due to ammonium volatilization;

(2) there is a reduction in nuisances associated with manure on the soil, such as odors and flies; and

(3) there is a reduction in risk of surface runoff stripping the manure and fertilizer from the field before planting.

Spray irrigation, after a series of steps to remove nitrogen, reduce salinity, control pH, and reduce sediment, can be used for slurry mixed with storm water. Follow-up irrigation with fresh water is recommended after each application.

b. Monitoring. The following table identifies the monitoring and reporting recommended for the manure management plan. The reports should be collected into a manure management notebook which should be kept with the agricultural park maintenance office.

TABLE 1 – RECOMMENDED MONITORING PLAN FOR GROUND WATER PROTECTION

Factor	Frequency	Agent
Soil Fertility	Annually	US Soil Conservation Service
Animal Head Count	Monthly	Dairy Operator
Water Consumption	Monthly	Dept. of Agriculture
Manure Generation	Monthly	Dept. of Agriculture
Acres Fertilized	Monthly	Dept. of Agriculture
Existing Well Water	Quarterly	Dept. of Agriculture

The purpose of this monitoring is to correlate possible long-term changes in groundwater quality with manure application.

2. Surface Water

a. Storm Water Management.

The concept of storm water management is to confine (collect) the runoff from the dairy operations storm in order to store potential pollutants which could be deleterious in the downstream waters. The nutrients in these waters are beneficial for crop production if applied in measured amounts using the effluent irrigation system. Runoff exceeding the storage capacity of the collection works will be discharged. The magnitude of the design storm is selected to be the 25-year, 24-hour storm event. Events exceeding this magnitude are considered catastrophic in nature and the first priority is to protect downstream property from instantaneous release of stored runoff.

Another aspect of the monitoring for NPDES compliance is the frequency of discharge. The conditions of the permit for a future discharge will include reporting to the Department of Health, the frequency of intermittent spills, in addition to other reporting requirements.

D. Site Operations

There are several important operational functions that will need to be performed at the livestock agricultural park. These relate to the functional areas:

1) Drainage;

2) Animal Waste Management;

3) Water Supply; and

4) Roadways.

Electrical utility operation and maintenance will be performed by HECO, HTCO, and Oceanic CATV companies.

Drainage ways will need cleaning and periodic repair. Most of the major drainage ways have steep side slopes generally 1.5 horizontal to 1 vertical. The sides of these can be lined with cement material to reduce sloughing, but inevitably some cracks in the liner and slides will occur. In addition, the vegetation will have to be cut back to prevent clogging the channel.

Animal waste management requires operational labor by both the dairy operators and the Department of Agriculture. The responsibilities can be demarcated at the lot line, for the most part. The dairy operators must be responsible for the transfer of manure to the central waste management facility. The requirements include:

1) operating the scraping system to collect manure in a central container— a reception pit for each confined dairy facility;

2) pumping the reception pit to the liquid/solid separator;

3) separating the solid residuals from the manure in order to facilitate pumping the liquid to the central facility;

4) composting the solid residuals to reduce the odor and bacterial growth within the residuals, and arranging for disposal off-site; and

5) pumping the pressate from the liquid/solid separator pit to the digester.

At the central waste management facility, the amount of separated liquid received from each dairy can be measured by flow-monitoring devices. A separate digester is recommended for each dairy A reserve one-million-gallon anaerobic lagoon is also proposed as an alternative standby to receive overflows and influent when the digesters or control equipment undergoes maintenance or during process disruptions.

The most significant component of site operations is the digester operations. A constant temperature and mixed fluid should be maintained in the digester. Each digester-control assembly should be equipped with heat circulation pipes, draw-off pipes, sludge recirculation pumps, mixing pipes, a boiler, heat exchanger, and pumps to control the heating fluid circulation.

A full-time crew is necessary to manage the waste management system. A minimum of three, or possibly four full-time employees, augmented by additional part-time employees, is considered necessary.

The management of effluent and residuals handling must be accomplished by the central waste management crew. Residuals include sludge and grit from the digester, sediment from the ponds, and excess vegetation. The effluent discharge from the digesters can be disposed in several ways:

1) the liquid slurry can be drained off into tanks mounted on trailers by farmers using a ripper plow to incorporate it into cropland;

2) the liquid can be flushed into the mixing basin and diluted with stored storm runoff from where it can be pumped to aquatic ponds to promote vegetation growth and evaporation; and

3) the liquid can be passed through the same process as 2) above but mixed with greater amounts of storm runoff in the NPDES reservoir and pumped to *makai* croplands and *mauka* pastures for irrigation.

There are several operational functions that must be performed in connection with each of these disposal options:

1) Slurry injection — opening valves to fill tractor-drawn slurry spreaders;

2) Aquatic evaporation — opening dilution water line valves at *irrigation reservoir to facilitate mixing and dilution of the digester* effluent; overseeing the operation of the aquatic pond distribution pump and valve operation into the ponds;

3) Aquatic renovation/effluent irrigation — operations involved with the second option above; overseeing the operation of the effluent pump system; and monitoring the quality of the effluent; and removing aquatic plant growth for disposal.

The critical parameters that should be periodically (monthly) checked in the effluent include total dissolved solids, total suspended solids, total nitrogen, phosphorus, and potassium. A sample can be drawn from a draw-off spigot in the pumping facility.

Effluent irrigation must balance several factors:

1) the quantity of storage capacity in the NPDES detention reservoir that should be reserved to avoid discharging storm runoff after minor storm events;

2) the concentration of dissolved solids and nitrogen in the effluent versus limitations on optimum crop production; and

3) the optimum moisture content of the soil that is desirable from crop production standpoint.

The third requirement has to consider that in addition to effluent, fresh water must be applied to continuously purge the lines and sprinkler heads of sediment particles to prevent clogging.

The limiting factor is expected to be the irrigation rate which creates excessive salt concentrations in the soil. High nitrogen content can also lead to poor harvests. The range of irrigation limits based on the treatment system proposed herein are suggested below:

Site Capacity (head)	Effluent Use (mgd)	Remark
1,200	0.014	60 acres of cropland
2,000	0.067	300 acres of cropland

The upper limit, 2,000-head, results in a large nitrogen load on cropland. Nitrogen loading on cropland is estimated to be approximately 500-600 pounds ac-yr. Considering volatilization losses of approximately 20 percent, this equates to 400-480 pounds/ac-yr. Salinity concentrations of the effluent will be more than 1,000 mg/l. The increase in load from 1,200- to 2,000-head may require a different aquatic vegetation type (in addition to more land area) for pretreatment to achieve the desired removal. A small site capacity operations may be successful in utilizing evaporative ponds growing California grass. However, greater nitrogen uptake is needed for the larger site capacity, assuming 300 acres is the upper limit of disposal area. Water hyacinth has an uptake rate approximately one order of magnitude greater than other aquatics (such as duckweed or California grass). However, it is less tolerant to salinity and therefore needs much greater quantities of dilution water to grow in the salt-rich effluent.

The recommended irrigation quantities do not exceed crop requirements including rainfall. The irrigation rates shown above equate to the following crop application amounts:

Site Capacity (head)	Effluent Use/mgd	GPD/Acre	Inch/Day
2,000	0.067	223	0.008
1,200	0.014	223	0.008

The average rate applied by the Kahuku Farmers Association is approximately 1,700 gpd/acre or 0.06 in/day. The maximum month in 1992 was 1,940 gpd/acre or 0.071 in/day. The optimum crop irrigation application for vegetables is considered to be 0.2 in/day. This is required to offset crop consumption and evaporative losses. However, this can be supplied in part by rainfall on the crops. Average daily rainfall amounts (in/day) at the site are estimated as:

January	0.21	July	0.07
February	0.16	August	0.08
March	0.17	September	0.06
April	0.12	October	0.10
May	0.08	November	0.16
June	0.05	December	0.17

Considering the highest average rainfall month, January, the sum of rainfall, average irrigation, and peak effluent irrigation is more than 0.2 in/day (0.21 + 0.061 + 0.008 = 0.279 in/day). However, in the remaining months, the total is less than 0.2 in/day. If it is assumed that irrigation rates are not reduced in the wettest periods (although existing experience shows they are), then the amount of time that total applied water exceeds plant and evaporative rates is only one month of the year. The consideration is then what effect this magnitude of deep percolation may have.

The supporting data (beginning on page Appendix L-13) show some of the soil moisture sensor, infiltration rate, and rainfall readings collected at the Kahuku Agricultural Park in 1992. In general, rainfall amounts of 0.5 inch or less have little effect on soil moisture at the 6- or 12-inch depth (see page Appendix L-16). Rainfall amounts of one inch have an effect at the 6-inch depth but very little at the 12-inch depth (see page Appendix L-15). The majority of the evaporative loss of this soil moisture occurred within a one-day interval. Note that these sensor readings are at a plot of bare soil; cropped areas would exhibit greater soil moisture uptake. Thus the tentative conclusion is that, on average, the combination of all possible moisture inputs on cropped areas in the wet season does not pose a significant threat in terms of leaching nitrogen to the ground water aquifer.

Furthermore, as the Table SOLUS_I.XLS (page Appendix L-13) and accompanying figure indicate, infiltration rates are reduced at the 12-inch depth with increasing soil saturation (lower soil suction). The decrease can be as much as 50 percent of the dry soil-state value. The significance is that additional time is required to infiltrate which allows for more plant uptake, microbial activity, and volatilization losses to occur.

Another conclusion of the weather station data is that infiltration can decrease on order of magnitude depending upon the amount of rainfall received over previous periods before a heavy rainfall event. The figure RAININF.XLS (page Appendix L-14) shows the significant decrease in infiltration rate with antecedent rainfall.

The significance is that natural inputs of water, i.e., large storms, will have a significantly lower impact in terms of producing deep percolation which may carry concentrations of dissolved solids. Thus a natural dampening mechanism exists to equilibrate levels of minerals such as nitrate in the ground water aquifer.

Residuals management at the central waste management facility includes the following activities:

1) periodic removal of sediment accumulation in the aquatic ponds;

2) aquatic vegetation harvesting;

3) dry sediment disposal; and

4) grit removal from the digesters.

The sludge deposited in the aquatic ponds should be excavated during the dry season and dried in the drying beds provided nearby. Paved beds are recommended to provide a firm surface for vehicle movement. A small front-end loader can perform the transfer to the drying beds. Only a portion of the pond should be excavated if California grass is grown for nitrogen removal to allow a source for regrowth.

The aquatic vegetation recommended at this time is California grass. Dry cows or heifers can be used to graze the ponds during dry months for forage. Other aquatic vegetation will require mechanical harvesters.

The dry soil and vegetation (if not consumed by dairy cows) will be the responsibility of the central waste management crew to dispose of. Options include adding it to composted residuals from a dairy on-site and selling it for soil amendment, or landfilling the material.

The digesters should be degassed and drained annually for maintenance. Access can be through a maintenance hatch on the concrete tank. The removal of grit, unclogging of drains and recirculation pipes, and necessary replacement of heating pipes in the heat exchanger can be done at this time.

A number of safety precautions must be followed for digester cleaning. Methane is explosive when mixed with air. To reduce the presence of explosive gases, the digester may be isolated (no feed influent) but operated normally for a couple of weeks until methane generation is negligible. The reserve open anaerobic lagoon must be used for this period. After mixing the supernatant and sludge as thoroughly as possible, it must be drained to the mixing basin. The tank must be purged of gas and the access opened for maintenance work. Entry into a confined space such as this requires trained personnel and special equipment. OSHA requirements should be identified in the final design or operation and maintenance manual. Anaerobic digester cleaning is discussed in Manual of Practice No. 16 of the Water Pollution Control Federation (now known as the Water Environment Federation).

Roadway maintenance will continue to be a Department of Agriculture responsibility unless roads can be brought up to City and County of Honolulu standards. Periodic road repairs can be contracted to a local construction company.

Water supply operations will include:

1) overseeing the pump operations at Pump Station No. 1; and

2) overseeing chlorination operation of potable water supply to dairies and effluent irrigation supplied to croplands and pastures.

At this time, the establishment of the source of potable water is an unresolved issue. It may be that Pump Station No. 1 water will be required on an interim basis; in this case chlorination and operation of the system will be the responsibility of the Department of Agriculture. Should a new potable source be developed with cooperation of the Board of Water Supply, then presumably the potable water operation will be under their auspices.

E. Summary

A preliminary set of recommendations has been provided in this appendix in the interest of environmental protection and safe, effective operation of the proposed livestock agricultural park. Additional details concerning operation can be completed at the design phase of the project.

F. Bibliography

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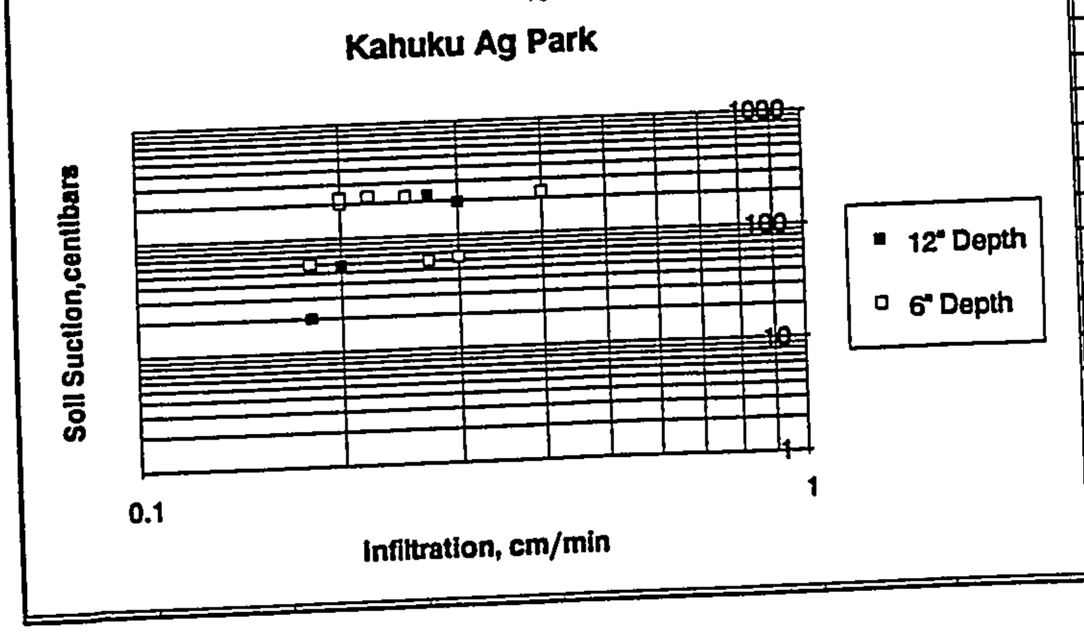
Water Pollution Control Federation. 1989. *Anaerobic Sludge Digestion*. Manual of Practice No. 16.

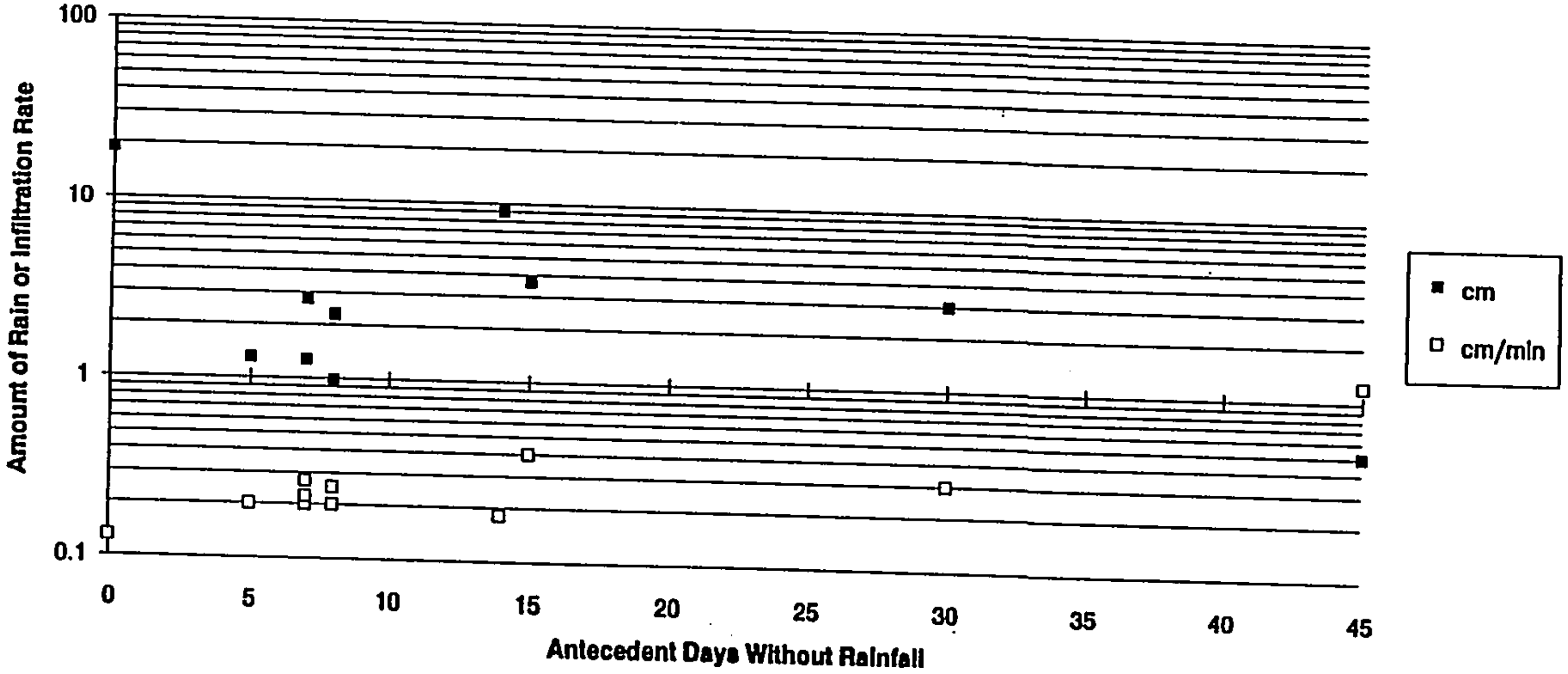
SOLUS_I.XLS

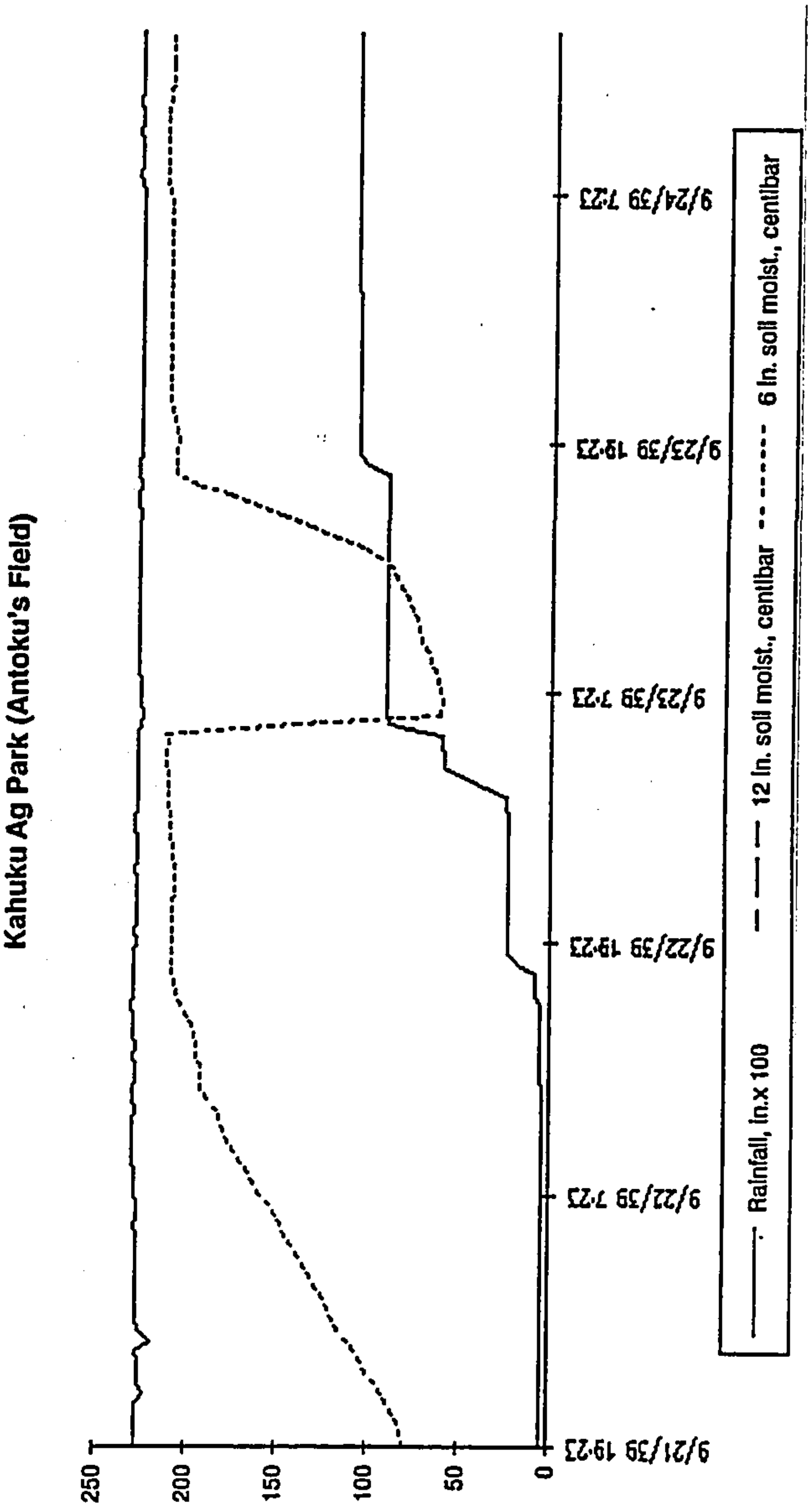
SOLUS Weather Station & Infiltration Data							
				Lowest Value For			
Date Uploaded	Anteced Days	Rainfall cm	Infiltration cm/min	12" probe centibars	6" probe centibars	Soil Moist. Gr/Gr	Remarks
7/31/92	-	-	1.22	17	21	0.27	Sensors Equilibrating
8/14/92	15	3.7	0.4	223	225	0.3	
8/18/92	5	1.3	0.2	217	220	0.32	
9/18/92	30	3	0.3	195	64	0.35	
9/24/92	7	2.7	0.27	225	60	0.35	
10/9/92	8	1.0	0.25	227	222	0.29	
10/22/92	14	9.0	0.18	20	60	0.48	Based on interpolating 12/92
11/13/92	8	2.3	0.2	57	204	0.35	
11/19/92	7	1.3	0.2	220	224	0.35	
12/4/92	7	1.3	0.22	228	228	0.36	
12/31/92	0	18.8	0.13	228	228.	0.55	Sensors not responding
Average	10.1	4.4	0.32	169	160	0.36	
							Note: Shading Indicates Estimated Values

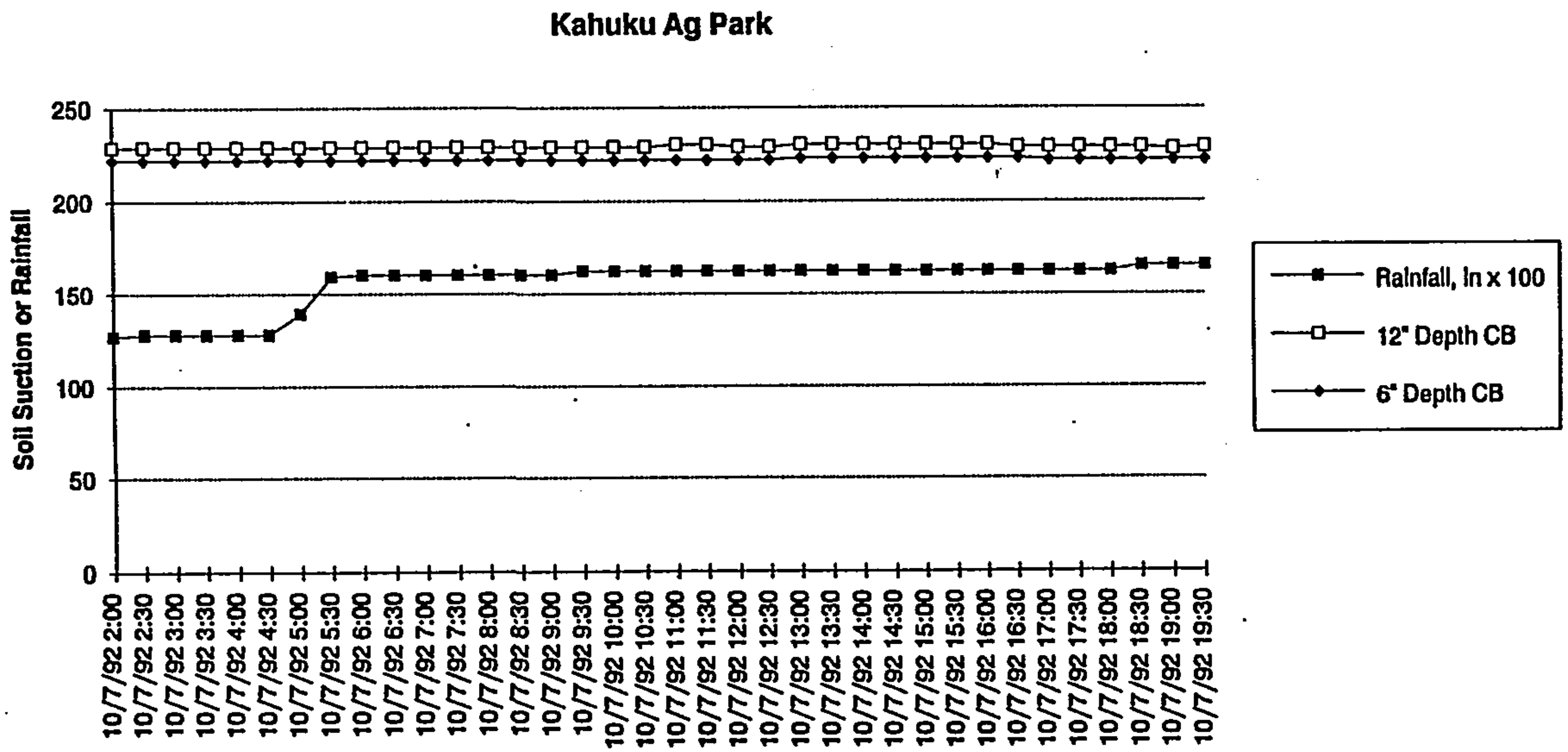


RAININF.XLC

KAHUKU AG PARK RAINFALL & INFILTRATION




Kahuku Ag Park (Antoku's Field)
250
200
150
100
50
0
9/21/39 19:23
9/22/39 7:23
9/22/39 19:23
9/23/39 7:23
9/23/39 19:23
9/24/39 7:23
Rainfall, in.x 100
12 in. soil moist., centibar
6 in. soil moist., centibar


Kahuku Ag Park
Soil Suction or Rainfall
0
50
100
150
200
250
10/7/92 2:00
10/7/92 2:30
10/7/92 3:00
10/7/92 3:30
10/7/92 4:00
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10/7/92 18:30
10/7/92 19:00
10/7/92 19:30
Rainfall, In x 100
12" Depth CB
6" Depth CB

END SHEET