United States
Department of
Agriculture

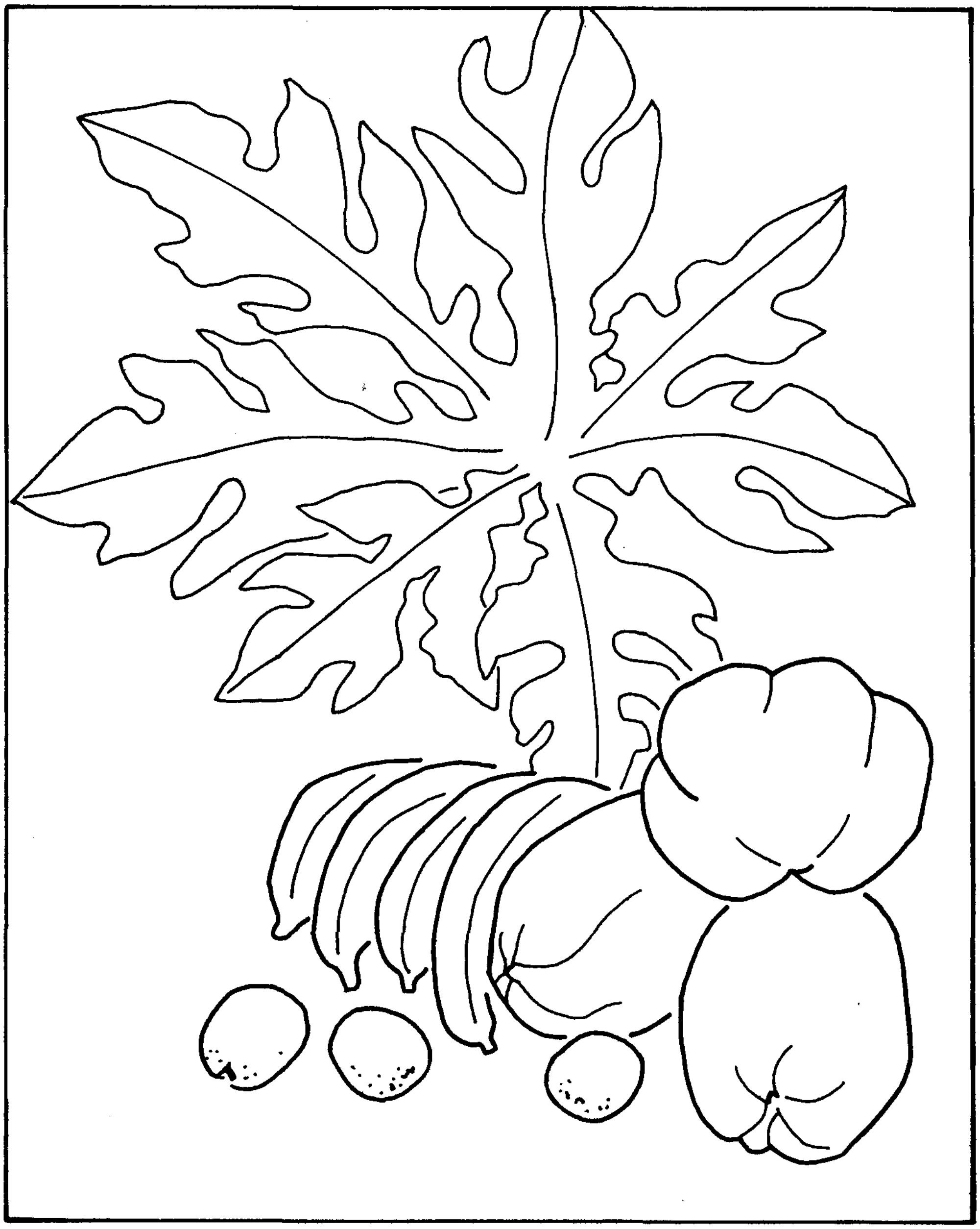
Forest
Service

Soil
Conservation
Service

Honolulu,
Hawaii

# Kilauea Agricultural Water Management Study Report

**in Cooperation with the State of Hawaii Department of Land and Natural Resources and the East Kauai Soil and Water Conservation District**



# KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY REPORT

Prepared By:

UNITED STATES DEPARTMENT OF AGRICULTURE

Forest Service
Soil Conservation Service

In Cooperation With:

STATE OF HAWAII

Department of Land and Natural Resources
East Kauai Soil and Water Conservation District

June 1984

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# PREFACE

In response to the local people's concern about the water problems in the Kilauea area of Kauai, the State of Hawaii Department of Land and Natural Resources and the East Kauai Soil and Water Conservation District requested that the United States Department of Agriculture Soil Conservation Service initiate a study to help alleviate the problems. The Kilauea Agricultural Water Management Study was the result of that request. The objective of the study was to address the problems, opportunities, and concerns in the Kilauea area. With this in mind, the study team analyzed the resources and problems in the Kilauea area, formulated alternative plans, and identified sources of implementation assistance.

The study's findings are presented in this report which contains a summary, three chapters, and six appendices containing resource and technical information. Information in this report can be used by the local people, the County of Kauai, and/or the State of Hawaii to help envision the future of the agricultural industry in the Kilauea area and to decide on a plan to achieve that desired "future." The information could also be helpful in requesting funds to implement a plan.

The Kilauea Agricultural Water Management Study is a cooperative river basin study conducted under the authority of Section 6, Public Law 83-566, the Watershed Protection and Flood Prevention Act. Cooperative river basin studies provide USDA planning assistance to Federal, State, and local governments. The study was conducted by the USDA in cooperation with the study sponsors, the DLNR and the East Kauai SWCD. The study follows guidelines described in the Soil Conservation Service's National Basin and Area Planning Manual.

USDA responsibilities in the study were managed by the USDA River Basin Field Advisory Committee composed of representatives from the Forest Service and the Soil Conservation Service. The SCS was responsible for conducting the technical studies and writing this report.

Two special committees were formed to assure public input and to provide resource data for the study. The committees are the Citizens Advisory Committee and the Resource Committee. The Citizens Advisory Committee is made up of representatives from the following groups:

- Farmers Water Association of Kilauea

- East Kauai Soil and Water Conservation District

The Resource Committee is made up of representatives from the following groups or agencies.

- USDA Soil Conservation Service

- USDA Forest Service

- U.S. Department of Interior Fish and Wildlife Service
- U.S. Department of Interior Geological Service
- State of Hawaii Department of Land and Natural Resources
- State of Hawaii Department of Agriculture
- State of Hawaii Farm Bureau
- County of Kauai Office of Economic Development
- County of Kauai Department of Planning
- County of Kauai Department of Water
- East Kauai Soil and Water Conservation District
- Hawaiiana Investment Company, Inc.
- Mary N. Lucas Trust Estate

# SUMMARY

The lack of an adequate supply of agricultural water in the Kilauea area of Kauai prevents farmers from achieving their full income potentials and limits opportunities to make more productive use of land already comitted to agriculture. In a state where over 60 percent of the fresh vegetables and melons and over 75 percent of the fresh fruits consumed locally are imported from the U.S. mainland, continued production and expansion in agricultural areas such as Kilauea are especially important. Yet, over two billion gallons of water flows unused from Kilauea's reservoirs to the ocean each year. Conserving this water would help alleviate the agricultural water problems in the Kilauea area.

## DESCRIPTION OF STUDY AREA

The study area encompasses 22,500 acres located on the north side of the Island of Kauai, the fourth largest island in the Hawaiian chain (Figure 1).

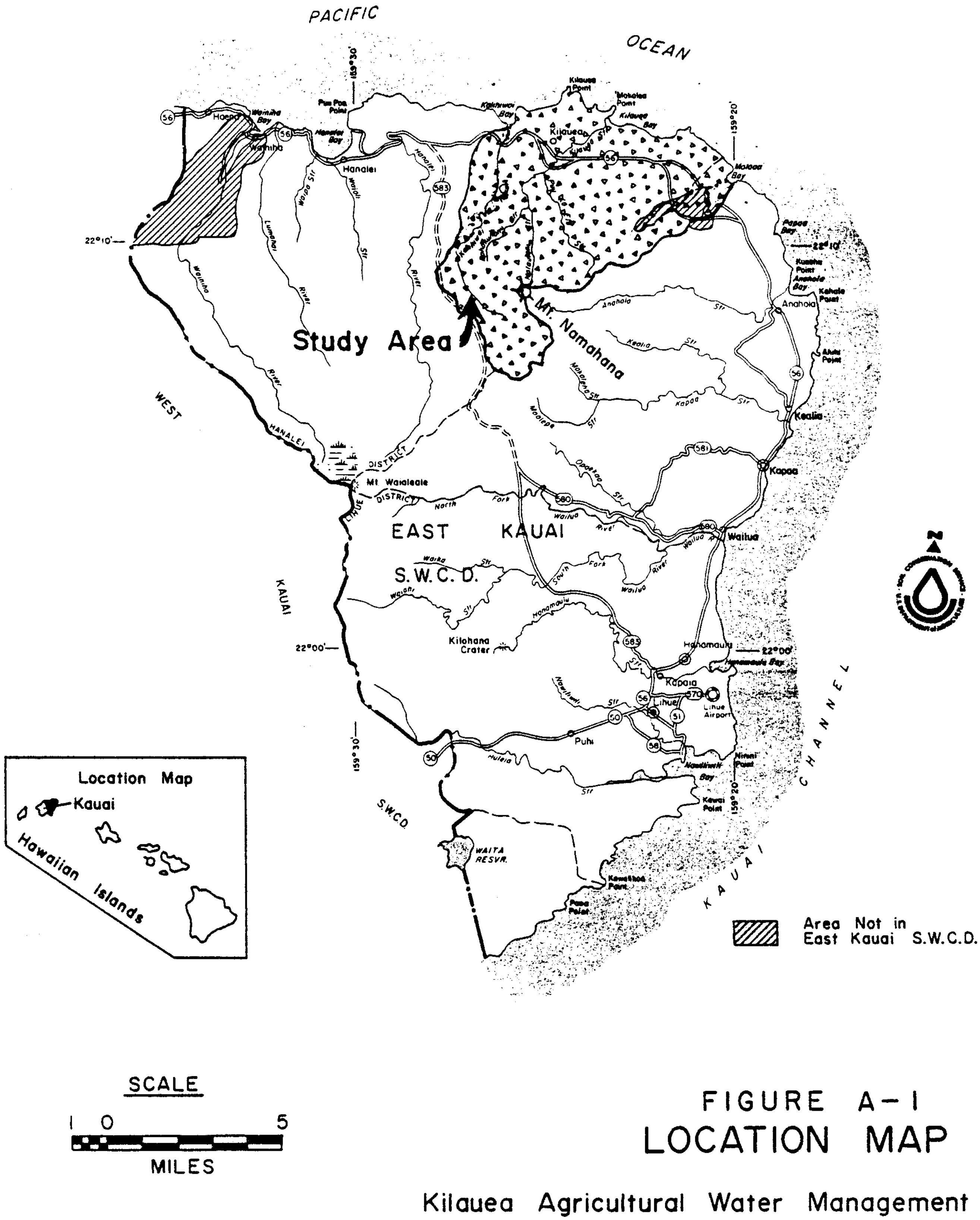
The climate in the study area is very mild. Average annual rainfall varies from 60 inches along the coastline to over 100 inches near the mountains. Average annual temperatures range from 75° F along the coastline to 68° F near the mountains.

The topography is similar to other areas on Kauai. The terrain along the coast is relatively flat, rising gradually towards the mountains before merging with the steep forested mountain area. Several streams have cut gulches that run from the base of the mountains to the sea.

The study area is rural in character, with conservation and agricultural land uses dominating the landscape. Approximately 9,830 acres are in conservation land uses such as forest reserves (9,000 acres), and shoreline and river banks (830 acres). The 205 acres in urban use are in Kilauea town, the major community in the study area. The remaining 12,465 acres in the study area are designated "agriculture" by the State's land use classification system. Of these agricultural lands, 8,550 acres are classified prime and 3,150 acres other important agricultural lands.

The entire economy was dominated by the sugar industry until the closing of the Kilauea Sugar Company plantation in 1971. The plantation held 8,000 acres, grew 4,400 to 5,000 acres of sugarcane, and employed 400 workers. Most of Kilauea's residents worked for the plantation and lived in plantation housing.

Agriculture is still the most important industry in the study area. The major agricultural industries are the production of orchard crops, livestock, truck crops, and freshwater prawns. There is a total of about 45 agricultural operations, many of which produce more than one kind of crop or agricultural commodity. These operations generate an estimated $2.6 million annually (farm value). Present agricultural land use is shown in Table 1.




# FIGURE A-1
# LOCATION MAP

## Kilauea Agricultural Water Management Study

Kilauea, Kauai, Hawaii

Table 1
Agricultural Land Use - 1982

| Land Use | Number of Operations1/ | Gross Farm Acreage2/ | Acreage Used3/ Irrigated4/ | Acreage Used3/ Nonirrigated | Idle Farm Acreage5/ |
|---|---|---|---|---|---|
| Orchards | | | | | |
| Guavas | 1 | 350 | 0 | 300 | 50 |
| Papayas | 14 | 165 | 100 | 5 | 60 |
| Bananas | 8 | 50 | 10 | 5 | 35 |
| Macadamia Nuts | 1 | 5 | 0 | 5 | 0 |
| Pasture | 15 | 6,680 | 0 | 3,845 | 2,835 |
| Feed Corn | 1 | 140 | 0 | 140 | 0 |
| Truck Crops | 14 | 60 | 30 | 0 | 30 |
| Prawns | 1 | 60 | 356/ | 0 | 25 |
| Total | 55 | 7,510 | 175 | 4,300 | 3,035 |
| Idle Ag Land | | 4,9557/ | | | |
| Total Zoned for Ag | | 12,465 | | | |

1/ Includes some double counting of operations. Some operations produce more than one kind of agricultural product.
2/ Total farm or ranch operation acreage or portion of total acreage set aside for the particular land use.
3/ Acres out of gross farm or ranch acreage actually planted in crops or grazed.
4/ Irrigated by agricultural water system, domestic water system, or private water systems.
5/ Acres out of gross farm or ranch acreage not used for production purposes. For crop farms this area may be in fallow, used for farm dwellings, buildings, or roads. For ranches (pasture) this area is mostly brush covered land on the ranch that is not grazed.
6/ Acres of ponds.
7/ Land zoned agriculture - not used for agricultural production.

## CHAPTER I - PROBLEMS, OPPORTUNITIES, AND CONCERNS

The major problems in the study area all center around the lack of an adequate agricultural water system. The major problems include reduced incomes for farmers, potential income losses, and low level use of agricultural land. If measured in losses in net farm income, these problems equal an estimated $3 million annually.

Farm income is reduced because the existing agricultural water system is not suited to modern irrigation methods. Use of the system for irrigation purposes requires extra equipment and labor. The cost of the equipment and labor increases production costs and results in lower incomes for farmers.

Farm income may be lowered further because the agricultural water system is unstable in certain places and may fail. If the system fails, some farmers would lose their only source of irrigation water and would probably lose their crops. These farmers may also lose their source of water because of unsecured water rights.

Opportunities to make more productive use of land are limited by the lack of a modern irrigation system that services all of the agricultural land in the study area. The existing agricultural water system does not service all of the existing farming areas, forcing some farmers to use the domestic water system. There are over 4,000 acres of idle agricultural lands in the study area suitable for crop production. Many of these idle acreages do not have an adequate source of agricultural water. Conserving some of the water that flows to the ocean unused would provide opportunities to service the entire study area and grow irrigated crops in areas presently idle.

The management of water resources would provide opportunities to develop hydroelectric power generation facilities and water-based recreational activities.

Farmers are also concerned about water rights because the study area's reservoirs and watersheds are owned by several private entities. The management of streamflows is a study concern because diverting water for agricultural purposes could conflict with the instream uses of water such as wildlife habitat.

## CHAPTER II - ALTERNATIVE PLANS

Ten alternative plans were formulated to address the problems, opportunities, and concerns in the study area. Nine of the ten alternative plans entail developing agricultural irrigation system(s) to service two main areas, the area around Kilauea town or the west side of the study area and the area below the Ka Loko Reservoir or the east side of the study area. The tenth plan entails developing an agricultural irrigation system and hydroelectric power generating facilities. All of the alternatives also contain land treatment measures needed to achieve the benefits of the proposed irrigation systems. Alternative Plan 9 has been identified as the National Economic Development Plan or that plan which reasonably maximizes net national economic benefits. Table 2 provides a brief summary of the ten alternative plans.

Table 2
Summary of Alternative Plans

| Item | Alternative Plan | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| I. Features of the Proposed Agricultural Irrigation System(s) | | | | | | | | | | |
| A. Acres Serviced | | | | | | | | | | |
| 1. Kilauea Town Area........ | 535 | 2,135 | 2,135 | 1,930 | 0 | 0 | 2,135 | 2,135 | 2,135 | 0 |
| 2. Ka Loko Area............ | 0 | 0 | 0 | 0 | 3,885 | 5,880 | 3,885 | 3,885 | 5,880 | 3,885 |
| Total.................. | 535 | 2,135 | 2,135 | 1,930 | 3,885 | 5,880 | 6,020 | 6,020 | 8,015 | 3,885 |
| B. Acres Irrigated | | | | | | | | | | |
| 1. Kilauea Town Area........ | 120 | 440 | 815 | 755 | 0 | 0 | 440 | 440 | 815 | 0 |
| 2. Ka Loko Area............ | 0 | 0 | 0 | 0 | 525 | 865 | 525 | 525 | 865 | 525 |
| Total.................. | 120 | 440 | 815 | 755 | 525 | 865 | 965 | 965 | 1,680 | 525 |
| C. Storage Capacity of Reservoir(s) Used | | | | | | | | | | |
| 1. Stone Dam Reservoir...... | 10.5 | 10.5 | 10.5 | 10.5 | - | - | 10.5 | - | 10.5 | - |
| 2. Ka Loko Reservoir........ | - 1/ | - | - | - | 408.9 | 408.9 | 408.9 | 408.9 | 408.9 | 408.9 |
| Total.................. | 10.5 | 10.5 | 10.5 | 10.5 | 408.9 | 408.9 | 419.4 | 408.9 | 419.4 | 408.9 |
| D. Distribution System Capacity | | | | | | | | | | |
| 1. Million Gallons Per Day.. | 1.6 | 6.3 | 11.8 | 11.0 | 8.2 | 13.1 | 14.5 | 14.5 | 24.9 | 8.2 |
| 2. Million Gallons Per Year. | 39.3 | 192.0 | 359.0 | 333.0 | 510.0 | 628.0 | 702.0 | 702.0 | 987.0 | 510.0 |
| II. Hydroelectric Power - Development Opportunities Available... | no | no | no | no | yes | yes | yes | yes | yes | yes |
| III. Annual Benefits............... | $ 64,900 | $ 795,200 | $1,583,700 | $1,446,400 | $ 661,900 | $1,369,700 | $1,457,100 | $1,457,100 | $2,953,400 | $ 721,800 |
| IV. Total Construction Cost of Irrigation System(s) 2/........ | $1,230,000 | $2,235,000 | $3,455,000 | $7,130,000 | $3,540,000 | $3,870,000 | $5,775,000 | $5,560,000 | $7,325,000 | $3,540,000 |
| V. Annual Pumping Cost........... | $ 14,900 | $ 22,100 | $ 44,600 | $ 0 | $ 0 | $ 0 | $ 22,100 | $ 0 | $ 44,600 | $ 0 |
| VI. Total Annual Cost............. | $ 203,200 | $ 341,300 | $ 488,700 | $ 997,300 | $ 479,100 | $ 521,300 | $ 820,400 | $ 762,800 | $1,010,000 | $ 524,700 |
| VII. Annual Net Benefits........... | $ -138,300 | $ 453,900 | $1,095,000 | $ 449,100 | $ 182,800 | $ 848,400 | $ 636,700 | $ 694,300 | $1,943,400 | $ 197,100 |
| VIII. Benefit-cost Ratio............ | 0.3:1 | 2.3:1 | 3.2:1 | 1.5:1 | 1.4:1 | 2.6:1 | 1.8:1 | 1.9:1 | 2.9:1 | 1.4:1 |
| IX. Potential Implementation Under Public Law 83-566 Program 3/ ... | no | no | no | no | no | no | no | no | yes | no |

1/ Reservoir not used by plan.
2/ Does not include the cost for any land and water rights, land treatment measures, or project administration and engineering services.
3/ Plans designated "no" could be implemented with an exception from the Secretary of Agriculture.

## CHAPTER III - OPPORTUNITIES FOR IMPLEMENTATION

Sources of technical and/or financial assistance to implement elements in the alternative plans include various Federal and State programs and local funding by the private sector.

Sources of Federal assistance include Public Law 566, the Watershed Protection and Flood Prevention Act; Public Law 46, the Soil Conservation Act of 1935; the Agricultural Conservation Program; and Farmers Home Administration programs.

Sources of State assistance include the Department of Land and Natural Resources Division of Water and Land Development and the Department of Agriculture's Agricultural Loan Division.

Funds for implementing plan elements could also come from the private sector. Land owners and operators in the study area could pool their resources to finance plan elements. Companies and individuals with large land holdings and agricultural interests may be willing to finance plan elements.

## APPENDICES

Six appendices contain resource and technical information developed or collected as part of the study. The information was used to develop the three chapters in this report. The appendices are listed below:

- Appendix A - Location, Climate, and Topography
- Appendix B - Human and Economic Resources
- Appendix C - Land Resources
- Appendix D - Water Resources
- Appendix E - Water Use Inventory
- Appendix F - Fish and Wildlife Inventory

# CHAPTER I
# PROBLEMS, OPPORTUNITIES, AND CONCERNS

## INTRODUCTION

Agricultural production in the Kilauea area is handicapped by the lack of an adequate agricultural water system. Present farm income is reduced, farm income may be further reduced, and opportunities to make more productive use of land committed to agriculture are limited.

The existing agricultural water system, the Kilauea Sugar Company Irrigation System, is outdated, not suited to modern irrigation methods, and the quality of the water available from the system is poor. The system cannot be considered a dependable source of water because it is structurally unstable in certain places and some water rights are not secure. The system also does not deliver water to all the farming areas in need of agricultural water. Some farmers must depend on the domestic water system for irrigation water. Other farmers have installed their own distribution pipelines from the existing agricultural water system.

The Kilauea Sugar Company Irrigation System was used as recently as 1970 to furrow irrigate over 3,000 acres of sugarcane (Table I-1 and Figure I-1). In 1982 there was a total of only 140 acres of irrigated crops in the study area. Of this, only 50 acres were irrigated by the sugar company's original distribution system and 25 acres were irrigated by private pipeline systems. Although there is a need for agricultural water, over 200 million gallons flow to the ocean unused each year (Figure I-2).

## REDUCED FARM INCOME (LACK OF ADEQUATE WATER SYSTEM)

The existing agricultural water system originally provided irrigation water for the 8,000 acre Kilauea Sugar Company plantation. Constructed in the 1800's the system consists of six reservoirs and over 34 miles of ditches, flumes, and tunnels (Figure I-3). Since the closing of the sugar company in 1971, the system has not been used extensively. The system's open distribution ditches are unsuited to modern irrigation equipment and do not permit good water management practices.

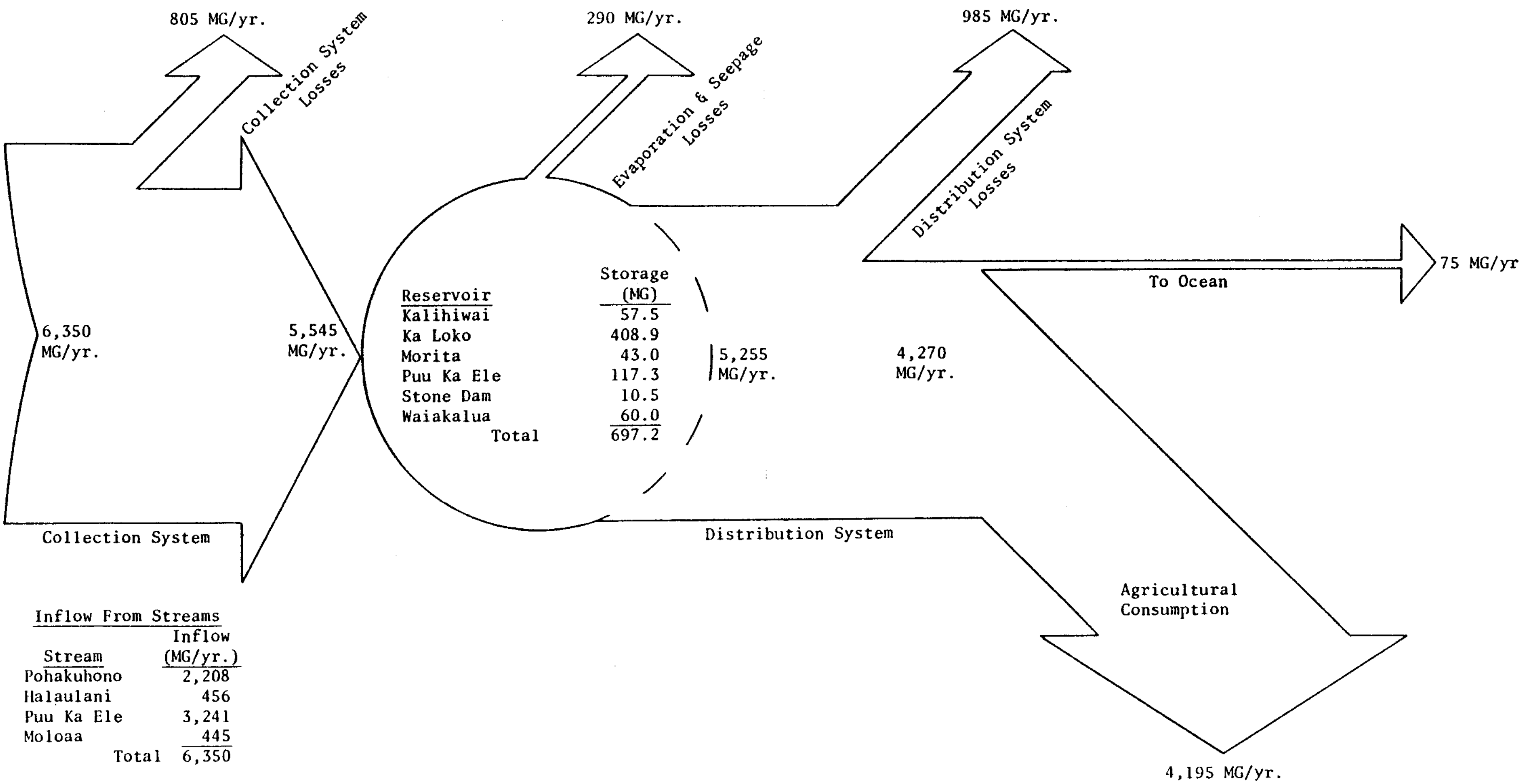
Only a small section of the original sugar company system is presently used for irrigating crops. This section consists of the Stone Dam Reservoir and the Mill Ditch distribution system. The 18,000 foot long Mill Ditch is unlined and overgrown with californiagrass and silted in. Although the water from the ditch is free, there are costs associated with using the water for irrigating crops. Farmers must pay for extra equipment such as pumps to get the water out of the ditch and filters to clean the water so it can be used in their drip irrigation systems. The farmers must also expend extra labor to clean the filters and do repair and maintenance work on the ditch. These extra costs reduce farmers' income.

Table I-1
Acres Irrigated by Water Source

| Source of Water | 1970 (Past Conditions) | | 1982 (Present Conditions) | | | | 1990 (Future Conditions) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Users | Acres Irrigated | Users | Crop Acres Irrigated 1/ | Prawn Pond Acres 2/ | Head of Livestock 2/ | Users | Crop Acres Irrigated 1/ | Prawn Pond Acres 2/ | Head of Livestock 2/ |
| I. Kilauea Sugar Company Irrigation System | | | | | | | | | | |
| A. Original Distribution System.... | 1 | 3,200 | 7 | 50 | 0 | 1,000 | 8 | 55 | 0 | 570 |
| B. Pipeline Systems 3/............. | 0 | 0 | 3 | 25 | 35 | 150 | 5 | 115 | 35 | 150 |
| II. Domestic Water System............. | 0 | 0 | 15 | 45 | 0 | 35 | 17 | 65 | 0 | 35 |
| III. Other Sources..................... | 0 | 0 | 14 | 20 | 0 | 1,315 | 14 | 20 | 0 | 1,745 |
| TOTAL.............................. | 1 | 3,200 | 39 | 140 | 35 | 2,500 | 44 | 255 | 35 | 2,500 |

1/ Orchard and truck crops.
2/ Provided water.
3/ Private pipeline systems which divert water from Kilauea Sugar Company Irrigation System.

FIGURE I-1
KILAUEA SUGAR COMPANY IRRIGATION SYSTEM EFFICIENCY
1970 (PAST CONDITIONS)



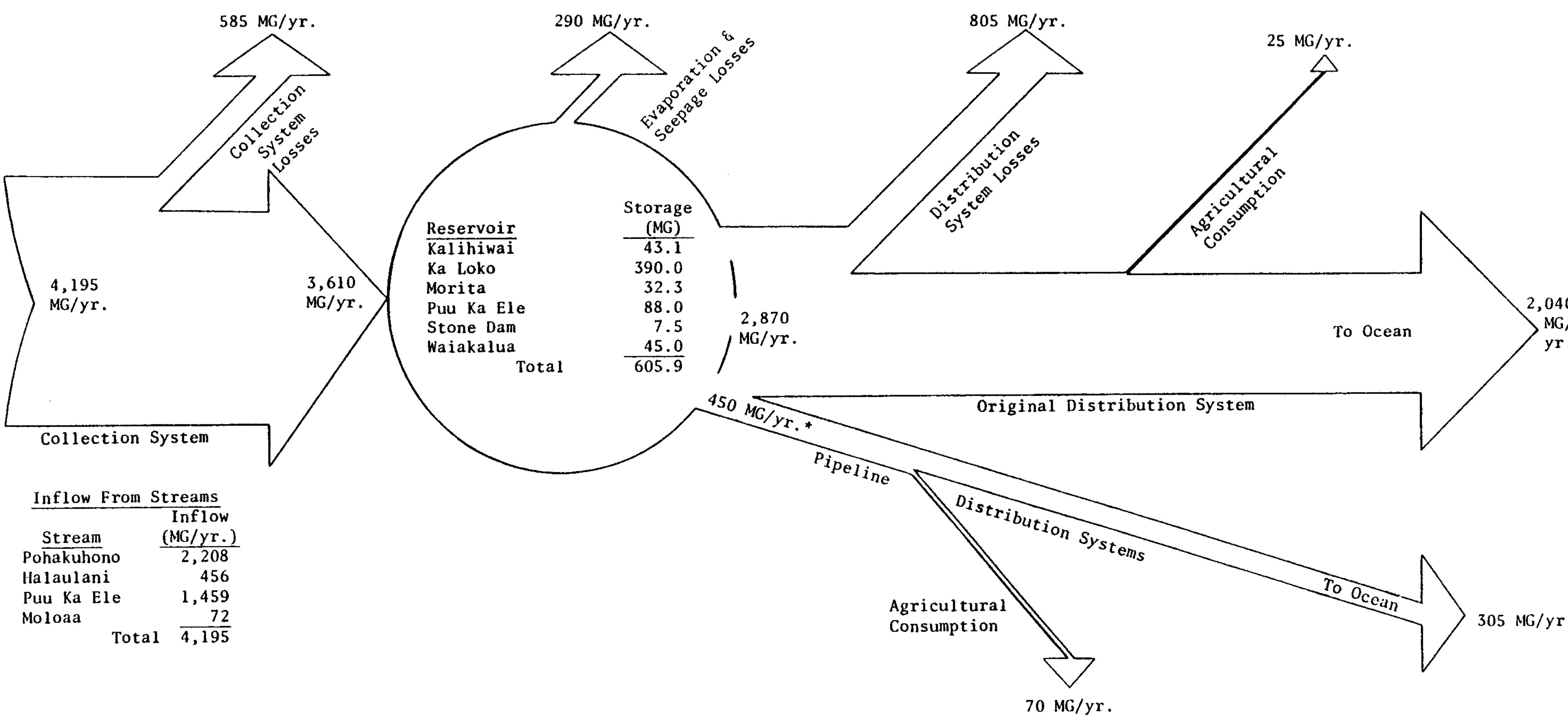

| Reservoir | Storage (MG) |
|---|---|
| Kalihiwai | 57.5 |
| Ka Loko | 408.9 |
| Morita | 43.0 |
| Puu Ka Ele | 117.3 |
| Stone Dam | 10.5 |
| Waiakalua | 60.0 |
| Total | 697.2 |

Inflow From Streams

| Stream | Inflow (MG/yr.) |
|---|---|
| Pohakuhono | 2,208 |
| Halaulani | 456 |
| Puu Ka Ele | 3,241 |
| Moloaa | 445 |
| Total | 6,350 |

| Agricultural Land Use | Acres Irrigated |
|---|---|
| Sugarcane | 3,200 |

FIGURE I-2
KILAUEA SUGAR COMPANY IRRIGATION SYSTEM EFFICIENCY
1982 (PRESENT CONDITIONS)




Inflow From Streams

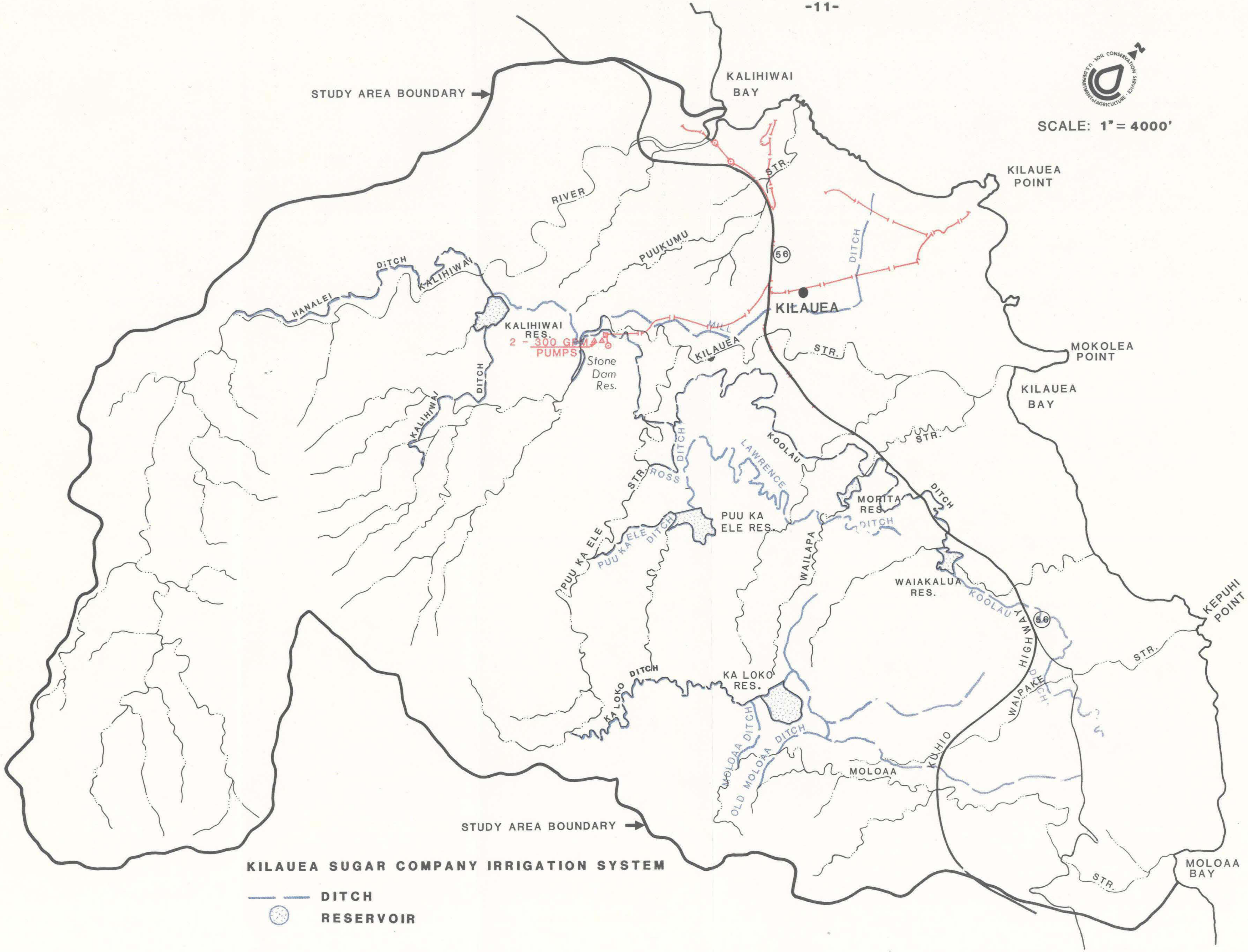
| Stream | Inflow (MG/yr.) |
|---|---|
| Pohakuhono | 2,208 |
| Halaulani | 456 |
| Puu Ka Ele | 1,459 |
| Moloaa | 72 |
| Total | 4,195 |

Acres Irrigated By Distribution System

| Distribution System | Orchard Crops | Truck Crops | Acres of Prawn Ponds1/ | Head of Livestock1/ |
|---|---|---|---|---|
| Original | 40 | 10 | 0 | 1,000 |
| Pipeline | 30 | 0 | 35 | 150 |
| Total | 70 | 10 | 35 | 1,150 |

1/ Provided water.

*Distribution system losses negligible.




**KILAUEA SUGAR COMPANY IRRIGATION SYSTEM**

DITCH

RESERVOIR

**KILAUEA WATER SYSTEM (DOMESTIC SYSTEM)**

PIPELINE

WATER TANK

WELL

FIGURE I-3

**KILAUEA SUGAR COMPANY IRRIGATION SYSTEM AND KILAUEA WATER SYSTEM**

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

Farmers who depend on the domestic water system for their supply of irrigation water are also faced with water problems. Of the 50 million gallons supplied by the domestic water system annually, 3.75 million gallons are used for agricultural purposes. The supply from the system is limited, thus the competition between domestic and agricultural users will grow more intense as additional areas are developed. Water shortages will probably occur during dry periods of the year, forcing water use restrictions.

Kauai County's Department of Water Supply, which operates the system, has limited water meters to one 5/8-inch meter per lot. Because of this limit, farmers are not able to make efficient use of their time and resources. Some farmers must spend extra time operating their irrigation systems in order to cover all their fields. The extra labor involved increases their production costs and decreases their income.

The lack of an adequate agricultural water system causes farmers' production costs to be higher and their net profits to be lower. In 1982, farm income was reduced by an estimated $8,000 (Table I-2). This amount will increase to $32,000 under projected future conditions assuming no project-type improvements are made to the existing agricultural water system.

Table I-2
Summary of Problems and Opportunities

| Problem (Cause) or Opportunity | Conditions: Present 1982 | Conditions: Future 1990 |
|---|---|---|
| I. Reduced Farm Income (Lack of Adequate Water System)... | $ 8,000 1/ | $ 32,000 1/ |
| II. Reduced Farm Income (Loss of Water Supply)........... | 0 | 48,000 1/ |
| III. Limited Agricultural Opportunities (Lack of Adequate Water Conservation and Distribution).............. | 3,000,000 1/ | 2,900,000 1/ |
| IV. Hydroelectric Power Development Opportunities.......... | 84,000 2/ | 84,000 2/ |
| Total...................... | $3,092,000 | $3,064,000 |

1/ Total annual net income in 1982 dollars.
2/ Value of 1.2 million kilowatt hours of electricity.

## REDUCED FARM INCOME (LOSS OF WATER SUPPLY)

Net farm income could be further reduced because the Mill Ditch distribution system is in poor condition and could possibly fail. If this occurs, the farmers using the ditch would lose their source of irrigation water and would probably lose their crops. Agricultural production would not be viable without a source of water.

Unsecured water rights also threaten the viability of the Stone Dam - Mill Ditch System as a water source. The farmers using the system do not have any legal agreement guaranteeing them a supply of water from the Stone Dam Reservoir. There is the possibility that the C. Brewer Company, owner of the reservoir, would divert the water for its own use. If this occurs, the farmers using the system would not have water to irrigate their crops.

The farmers using the Stone Dam Reservoir - Mill Ditch System produce crops worth an estimated $48,000 annually (net income). This amount represents potential farm income losses based on the assumption that the system will fail to operate one day (Table I-2).

## LIMITED AGRICULTURAL OPPORTUNITIES

The lack of an adequate water supply limits opportunities to make productive use of land committed to agriculture. Over 12,400 acres out of the total 22,500 acres in the study area are zoned for agricultural use. In 1982 over 6,600 acres were used for pasture and over 4,900 acres were idle. Under projected conditions (1990), over 5,800 acres will be used for pasture and 5,300 acres will be idle. Many of these areas do not have an adequate source of agricultural water. Providing a modern distribution system to capture and distribute the water presently flowing to the ocean would allow irrigated crops to be grown in pasture or idle areas.

More local agricultural production is needed to lessen the amount of produce now imported. About 60 percent of all the truck crops (fresh vegetables and melons) consumed in Hawaii are imported from the mainland United States. Over 65 percent of the bananas consumed locally are also imported from countries such as Panama and Honduras. Table I-3 shows the statewide acreage needs to meet the additional market opportunities in 1990.

Hawaii's agricultural industry was once almost entirely dependent on sugar and pineapple as export commodities. The declining viability of both the sugar and pineapple industries has emphasized the need for the agriculture industry to diversify. There are several commodities which show potential for further development as export items. Table I-4 shows the estimated statewide land requirements for these commodities.

Soil suitability ratings indicate there are over 4,000 acres of idle agricultural lands in the study area suitable for growing irrigated orchard and truck crops. If these areas were farmed at a reasonable intensity, approximately half of the area planted with crops, an additional $2.9 million in net farm income could be generated annually (Table I-2).

Table I-3
Estimated Statewide 1990 Acreage Needs for Truck Crops and Bananas

| Commodity | Production (1,000 lbs.) State | Production (1,000 lbs.) Kauai | Acres Harvested State | Acres Harvested Kauai | 1990 Additional Mkt. Opportunity for the State2/ (1,000 lbs.) | To Meet 1990 Mkt. Opportunity2/ 3/ |
|---|---|---|---|---|---|---|
| Truck Crops4/ | 70,710 | 1,460 | 4,200 | 100 | 112,566 | 3,839 |
| Bananas | 4,600 | 700 | 580 | 45 | 10,471 | 1,138 |

1/ Statistics of Hawaiian Agriculture 1981, Hawaii Agricultural Reporting Service, June 1982.
2/ Statewide Agricultural Park Action Plan, Phase I Program Assessment; prepared for: State of Hawaii, Governor's Agriculture Coordinating Committee; prepared by: H. Mogi Planning and Research, Inc., March 17, 1982.
3/ Assumes some acres cropped more than once a year.

Table I-4*
Estimated Statewide Land Requirements for Export Commodities

| Commodity | 1980 Acreage in Crop | 1990 Estimated Acreage | Additional Acreage |
|---|---|---|---|
| Flowers and Nursery | 1,447 1/ | 3,750 2/ | 2,303 |
| Macadamia Nuts | 13,400 3/ | 24,769 4/ | 11,369 |
| Papaya | 2,971 5/ | 6,500 6/ | 3,529 |
| Guava | 975 7/ | 1,328 8/ | 353 |
| Aquaculture | 500 | 5,892 9/ | 5,392 |
| Total | 19,293 | 42,239 | 22,946 |
| Approximate | 19,000 | 42,000 | 23,000 |

1/ DOA, Statistics of Hawaiian Agriculture, 1980.
2/ Ten percent average annual growth.
3/ DOA, Statistics of Hawaiian Agriculture, 1980.
4/ UH College of Tropical Agriculture and Human Resources Industry Analyses.
5/ Acres in crop, Papaya Administrative Committee Annual Report, 1980.
6/ UH College of Tropical Agriculture and Human Resources Industry Analysis, 1984 projection.
7/ DOA, Statistics of Hawaiian Agriculture, 1980.
8/ 1983 projection, Hawaii's Guava Industry, DPED, 1981.
9/ Acquaculture Development for Hawaii, 1978.

*Source of table: Statewide Agricultural Park Action Plan, Phase I, Program Assessment; prepared for: State of Hawaii, Governor's Agricultural Coordinating Committee; prepared by: H. Mogi Planning and Research, Inc., March 17, 1982.

## HYDROELECTRIC POWER DEVELOPMENT OPPORTUNITIES

Hawaii's dependence on imported oil for electricity generation makes it vulnerable to fluctuating prices. Electricity sales for the island of Kauai in 1981 were 199,452,000 kilowatt hours. Electricity needs will rise to an estimated 248,000,000 kilowatt hours in 1990 according to energy projections based on increased population.

The water stored in existing reservoirs and the abundant surface runoff in the study area provide excellent sources that could be harnessed to produce electricity. The Ka Loko, Puu Ka Ele, and Kalihiwai reservoirs are located at sufficient elevations so that installing hydroelectric facilities, such as turbine generators, to produce electricity on a large scale would be possible if piped distribution systems were installed. Turbine generators could be placed at various locations along the distribution systems. An estimated 1.2 million kilowatt hours of electricity could be generated annually if hydroelectric facilities for the three reservoirs were installed. The 1.2 million kilowatt hours, worth an estimated $84,000, represent the hydroelectric power development opportunities in the study area (Table I-2).

Two agricultural operations in the study area presently use small generators that produce enough electricity to meet their needs. Additional generators could be installed to meet the needs of individual agricultural operations.

## PUBLIC WATER-BASED RECREATION DEVELOPMENT POTENTIAL

The management of water resources provides opportunities for the development of more water-based recreational activities. Recreational activities in the study area are mostly natural resource oriented. Activities include hiking, camping, biking, fishing, hunting, swimming, diving, surfing, and scenic driving. Kilauea Park is the only park in the study area at the present time.

The opportunity to develop recreational activities is actually an incidental beneficial effect of developing irrigation systems as proposed by this study. Developing recreational activities is not an identified purpose of this study. Recreational opportunities will be identified and described, however recreational measures were not included in the development of alternative plans. Recreational opportunities will be described in terms of water surface acres with development potential for recreational activities.

## WATER RIGHTS CONCERNS

The problems associated with unsecured water rights for the Stone Dam Reservoir - Mill Ditch System users were discussed earlier (page 13). Another water rights concern expressed by the public dealt with the current ownership of the study area's reservoirs and contributing watershed areas.

After the Kilauea Sugar Company (a subsidiary of C. Brewer and Company) closed, Brewer sold some of its land parcels and let the leases expire on other parcels it held. This resulted in the divided ownership of the sugar company's irrigation system reservoirs (Table I-5). Contributing watershed areas are also owned by several entities. All of the reservoirs and all but one of the contributing watershed areas are in private ownership. Without secure water rights the risk involved in making capital investments for improving the agricultural water supply would be too high. Financial institutions would also be reluctant to lend capital to finance water development projects without secure water rights. The U.S. government would not participate in cost sharing without the securing of water rights.

Table I-5
Reservoir and Contributing Watershed Ownership

| | Ownership | |
|---|---|---|
| Reservoir | Reservoir | Contributing Watershed |
| Ka Loko | C. Brewer and Lucas Estate | State of Hawaii |
| Puu Ka Ele | C. Brewer and Lucas Estate | C. Brewer, State of Hawaii, and Lucas Estate |
| Kalihiwai | C. Brewer | C. Brewer and Dyer |
| Stone Dam | C. Brewer | C. Brewer, Dyer and Ley |
| Morita | Lucas Estate | C. Brewer and Lucas Estate |
| Waiakalua | C. Brewer* | C. Brewer and Lucas Estate |

*Ownership by C. Brewer will be conveyed to the Kilauea Farm Association after all the Waiakalua Farm subdivision lots are sold and with the stipulation that the Hawaiiana Investment Co., Inc. can use the reservoir for any future irrigation systems.

## STREAMFLOW MANAGEMENT

Streamflow management is a concern in the study area because the offstream use could compete with the instream uses of the water. The offstream use is agricultural water and the instream uses include fish and waterbird habitat, aesthetic, and recreational.

Water has been diverted from four streams in the study area to provide water for the Kilaüea Sugar Company's irrigation system since the system was constructed in the 1800's. In the initial phases of this study the public expressed concern that this study would propose new irrigation systems that would divert more or too much water from the streams. Existing Hawaii laws provide only minimum protection of the beneficial instream uses of water. This study will address this concern by identifying the amount of water diverted from the streams utilized by the proposed irrigation systems (see Table II-7 on page 57). More detailed studies, beyond the scope of this study, would be required to determine how diverting water from the streams would affect offstream uses.

# CHAPTER II
# ALTERNATIVE PLANS

## FORMULATION OF ALTERNATIVE PLANS

Ten alternative plans are presented for consideration. The plans were formulated in a systematic manner to insure that all reasonable plans were evaluated. The plans were formulated to address the objective of the study, in ways that contribute to the Federal objective of national economic development. The objective of the study was to alleviate the agricultural water problems, achieve the opportunities, and address the concerns as identified in Chapter I. Each plan consists of a system of strategies, programs, and/or structural elements which address this objective.

Many alternative plans were identified throughout the planning process. Some plans were eliminated and others were refined through additional developments and subsequent iterations. The study sponsors and the public were involved throughout the planning process through meetings and consultations.

Nine of the ten alternative plans entail developing one or two agricultural irrigation systems to service specific areas in the study area. The tenth alternative entails developing an agricultural irrigation system and hydroelectric power facilities. All of the plans include some land treatment measures needed to achieve the benefits of the proposed irrigation systems. Onfarm irrigation systems are not included as a land treatment measure. The cost of onfarm irrigation systems is considered a crop production cost and is accounted for in the benefit evaluation.

All of the alternative plans use the Stone Dam Reservoir and/or the Ka Loko Reservoir as storage facilities for the proposed irrigation systems. These two reservoirs were selected over the other four reservoirs in the study area after considering the following factors: proximity of the reservoir to the service areas, elevation and storage capacity of the reservoir, water supply from source streams, and reservoir repair cost.

The agricultural irrigation systems proposed by the alternative plans were developed to service two main areas within the study area. One area is the Kilauea town area and the other is the area below the Ka Loko Reservoir (Figure II-1). Alternative plans 1, 2, 3, and 4 all propose developing agricultural irrigation systems that use the Stone Dam Reservoir for storage and service the Kilauea town area. Alternative plans 5 and 6 propose agricultural irrigation systems that use the Ka Loko Reservoir for storage and service the Ka Loko area. Alternative plans 7 and 9 propose developing two separate irrigation systems and are actually two plans combined. Alternative Plan 7 combines plans 2 and 5, and Alternative Plan 9 combines plans 3 and 6. Alternative Plan 8 proposes the development of one irrigation system to service the areas in both plans 2 and 5. The system would use the Ka Loko Reservoir for storage and would service both the Kilauea town area and the Ka Loko area. Alternative Plan 10 proposes the same irrigation system and services the same area as Plan 5, with hydroelectric power generation facilities added.

Although several alternative plans service the same areas, the alternatives provide a different level of water supply to irrigate a different number of crop acres. The supply levels and acres irrigated were varied to give decisionmakers an opportunity to compare the benefits and costs of providing water to an area farmed at different intensities.

The water supply levels were based on the crop acres irrigated. The projected acres irrigated (1) include the acres presently irrigated, (2) assume no new collection systems or reservoirs are developed and existing delivery systems are utilized, and (3) consider the amount of land suitable for crop production according to soil suitability ratings. Soil suitability ratings indicate the relative quality of a soil for a particular use compared to other soils in the area. The ratings are based on properties that affect the growth of crops and ease of cultivation. The soils are given a rating of good, fair, or poor. Only those lands with soils rated good were considered potential areas for irrigated crop production (see Appendix C - Land Resources for more details).

Hydroelectric power facilities were added to Alternative Plan 10 to display its feasibility. Similar facilities can also be added to any of the other alternatives that contain irrigation systems that use the Ka Loko Reservoir for storage. It had been determined by previous investigations that developing hydroelectric facilities in conjunction with irrigation systems that use the Stone Dam Reservoir for storage are not feasible.

The alternative identified as the National Economic Development Plan is the plan which reasonably maximizes net national economic benefits. The Federal government can participate in the implementation of the identified NED Plan. The Federal government could participate in the implementation of another plan with an exception from the Secretary of Agriculture. Since increasing the number of irrigated acres in production increases net national economic benefits, it would seem logical that the NED Plan would be the plan which provides the most irrigation water to irrigate the most acres at the least cost. However, it may not be feasible to irrigate the "most" acres if the crops cannot be sold because of marketing problems. If implementation of the NED Plan is seriously considered, further analysis would be needed to address this issue. With the markets assumed, the NED Plan for this study is Alternative Plan 9 (Table 2, Item VII).

## DESCRIPTION AND COMPARISON OF ALTERNATIVE PLANS

The following sections provide a description of the ten alternative plans. Each plan was evaluated in terms of (1) the effectiveness of the plan to address the objectives of the study, and (2) the effects of the plan on the human environment. The following sections contain displays showing each plan's effectiveness and effects. The displays are organized in a manner so the plans can be easily compared.

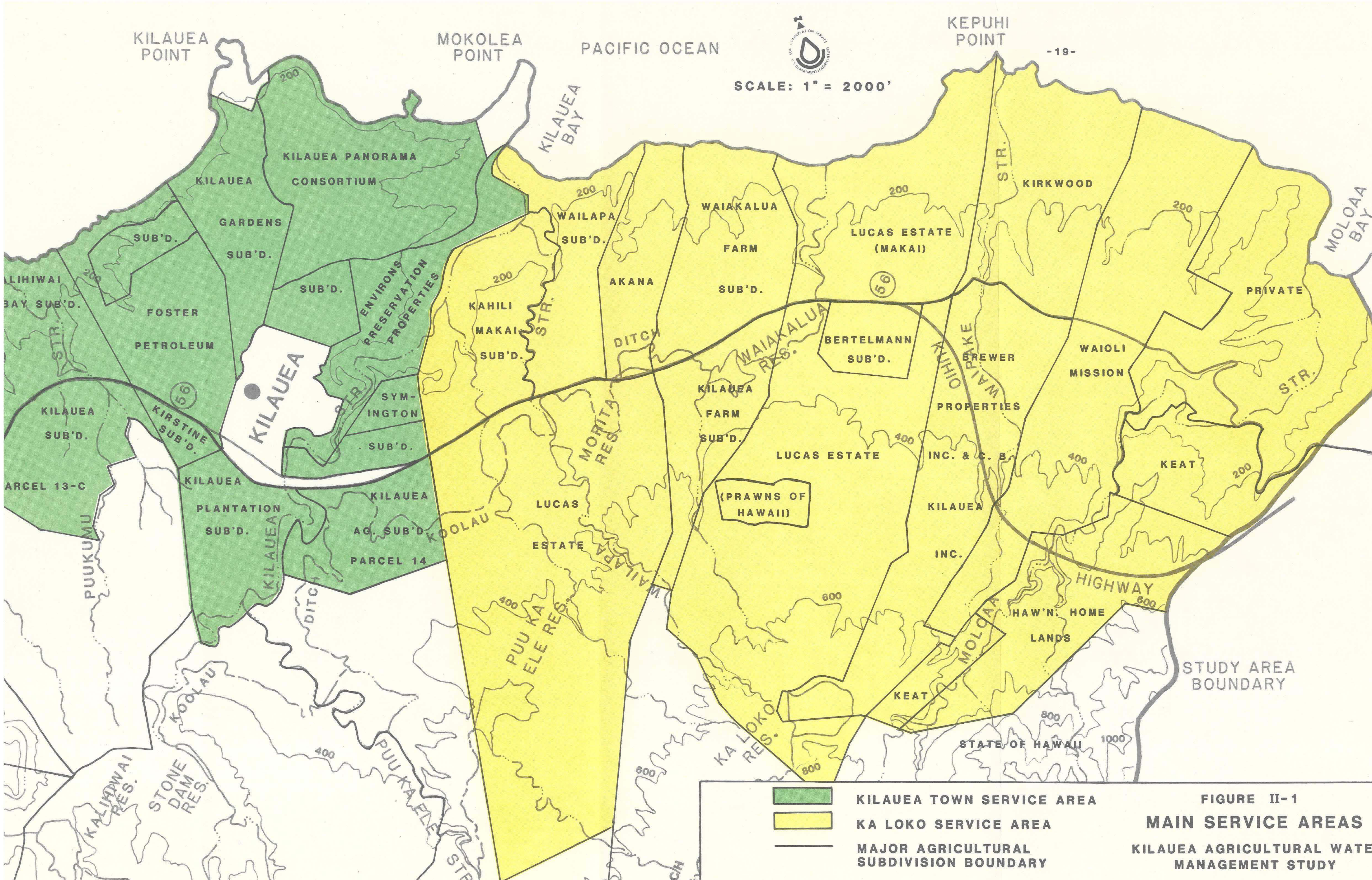



FIGURE II-1
**MAIN SERVICE AREAS**
KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## Description of the Alternative Plans

The description of the alternative plans includes the elements proposed and the operation of the irrigation systems and/or hydroelectric turbines. Maps display service areas and location of the plan elements. Table II-1 on page 50 lists the acres serviced and crop acres provided irrigation water. Table II-2 on page 51 lists the elements in each plan, Table II-3 on pages 52 and 53 displays the cost of the irrigation elements, and Table II-4 on page 54 displays the cost of the hydroelectric power elements in Alternative Plan 10.

## Effectiveness of the Alternative Plans

The alternative plans were evaluated in terms of each plan's effectiveness or extent to which it reduces the problems, takes advantage of the opportunities, and addresses the concerns of the study (Chapter I). Plan effectiveness also provides a measure of the economic benefits generated by each plan. Table II-5A on page 55 displays the effectiveness of plans 1 through 5 and Table II-5B displays the effectiveness of plans 6 through 10.

## Effects of the Alternative Plans

The alternative plans were evaluated in terms of each plan's significant effects on the human environment. The effects are displayed in three accounts: national economic development, environmental quality, and other social effects. The NED account shows effects on the national economy. The EQ account shows effects on ecological, cultural, and aesthetic attributes of significant natural and cultural resources that cannot be measured in monetary terms. The OSE account shows urban and community impacts and effects on life, health, and safety.

The effects of an alternative plan were measured as the differences between the projected conditions with the plan and projected conditions without the plan in the year 1990 (hereafter referred to as future conditions). Effects in the NED account are expressed in monetary units. EQ and OSE effects are expressed in appropriate numeric units. Monetary values are expressed in average annual equivalents using appropriate discounting and annualizing techniques, and applicable discount rate. The benefits and costs were evaluated over a 50-year period based on the life of the proposed irrigation systems. All values were discounted to present values and annualized. The applicable discount rate used for the evaluation of effects for this study is 8-1/8 percent as established by the Water Resources Council.

The NED account describes and identifies beneficial and adverse effects on the economy. Beneficial effects in the NED account are increases in the economic value of the national output of goods and services from a plan, the value of output resulting from external economies caused by a plan, and the value associated with the use of otherwise unemployed and underemployed labor resources. The NED beneficial effects for all of the ten alternative plans fell in the category of increases in the economic value of the national output of goods and services.

The increases in the economic value of the national output of goods and services were attributable to increases in net farm income due to a reduction in problems and/or the generation of electricity. The evaluation of plan effectiveness provides a measurement of the reduction in farm income losses and opportunities achieved, and will therefore be used to evaluate beneficial effects in the NED account.

The adverse effects in the NED account are the opportunity costs of resources used in implementing a plan. These adverse effects include implementation outlays, associated costs, and other direct costs. Implementation outlays include the cost for structural measures, land and water rights, project administration and engineering services, and operation and maintenance costs for the structural measures. Associated costs are costs in addition to implementation outlays for measures needed to achieve the benefits claimed during the period of analysis. The only associated costs included in any of the alternative plans are for land treatment measures. Other direct costs would include the costs of resources directly required for a plan, but for which no implementation outlays are made. There are no other direct costs included in any of the alternative plans.

The beneficial and adverse effects in the NED account are divided into two categories, agricultural irrigation and hydroelectric power, according to its origin or purpose. Also shown in the NED account is average annual net effects and the benefit-cost ratio. Average annual net effects equal average annual beneficial effects minus average annual adverse effects. Net effects are beneficial if positive and adverse if negative. The benefit-cost ratio is determined by dividing average annual beneficial effects by average annual adverse effects.

Each plan's effects in the NED account are discussed in the following narrative sections for each plan. Table II-6 on page 56 provides a summary of all the plans' effects in the NED account. Each plan's effects in the EQ and OSE accounts are not discussed in the following sections; however, significant effects are displayed in a summary table (Table II-7) on page 57.

## ALTERNATIVE PLAN 1

Alternative Plan 1 entails developing an agricultural irrigation system that would service 535 acres and provide water to irrigate 120 acres of crops in the Kilauea town area (Figure II-2 and Table II-1). The service area includes only those areas that are presently farmed or would be farmed under projected future conditions. These areas are presently serviced by the Stone Dam Reservoir - Mill Ditch agricultural water system or the County domestic water system. The proposed system would use the Stone Dam Reservoir for storage and have a piped distribution system. The system would have the capability to supply a 12-hour peak irrigation demand of 1.6 million gallons per day and an annual demand of 39.3 million gallons.

### Plan Elements (1)

Alternative Plan 1 includes the following elements:

- restoration (dredge and repair) of the Stone Dam Reservoir to store 10.5 million gallons;
- installation of a pump station with three pumps and a filtration system (total pumping capacity 1,110 gallons per minute);
- installation of a 82,000-gallon concrete tank;
- installation of 1,000 feet of 10-inch polyvinyl chloride pipe to connect the pump station to the concrete tank;
- installation of a distribution system consisting of 24,000 feet of 4- to 10-inch PVC pipe;
- securing land and water rights for the Stone Dam Reservoir; and
- securing land rights for the other structural elements.

Figure II-2 shows the location of the structural elements, Table II-2 lists the elements, and Table II-3 lists the cost of the elements.

### Agricultural Irrigation System Operation (1)

At the present time, water from the Puhakuhono and Halaulani streams is diverted into the Stone Dam Reservoir (elevation 340 feet) for storage. The proposed system would continue to do this. The pump station would lift the water from the reservoir up to the 82,000-gallon concrete tank (elevation 450 feet). Pumping the water to the tank before distribution would be necessary in order to provide enough pressure in the distribution lines. The filtration system would filter the water so it would be suitable for use in drip irrigation systems. The distribution system would transport the water by gravity from the concrete tank to the service areas.

## National Economic Development (NED) Account - Plan Effects (1)

### Beneficial Effects (1)

The beneficial effects of Alternative Plan 1 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- alleviating reduced income problems (Table II-5A); and
- eliminating potential farm income losses.

The total average annual increase in net farm income would be $64,900 (Table II-6).

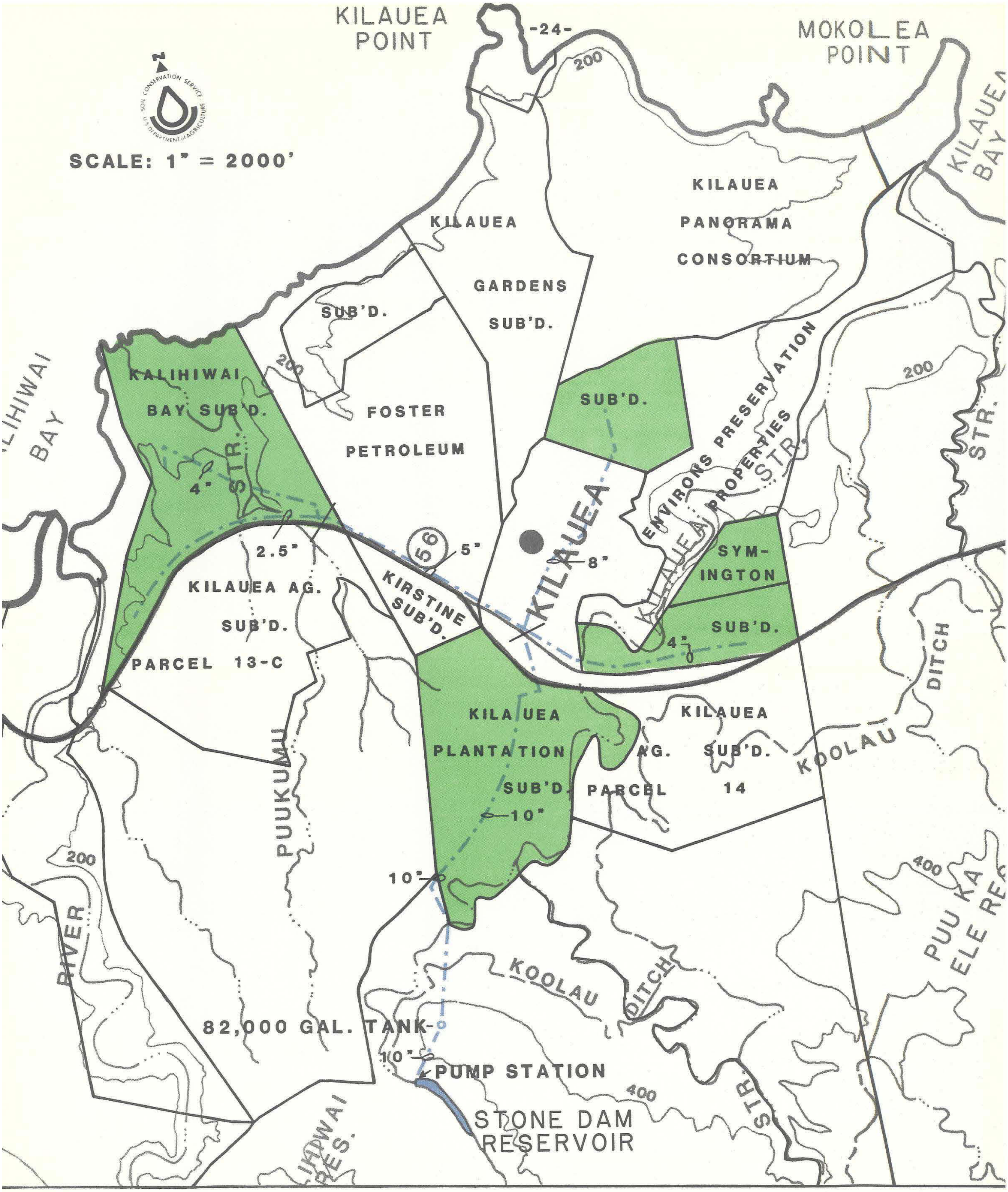
The plan would also generate incidental beneficial effects by decreasing the amount of domestic water used for agricultural purposes. The proposed irrigation system would provide water to farmers presently using the domestic water system for agricultural purposes. Thus, additional water would be available for domestic purposes. The effects of doing this are considered incidental because decreasing the amount of domestic water used for agricultural purposes is not a specified objective of this study. The effects were therefore not evaluated monetarily and are not included in the NED account. However, decreasing the amount of domestic water used for agricultural purposes is beneficial to the Kilauea community and is shown in the Other Social Effects account (Table II-7).

### Adverse Effects (1)

The plan elements proposed by Alternative Plan 1 have a total implementation cost of $1,510,000 (Table II-3). Average annual cost is $203,200.

### Net Effects (1)

Alternative Plan 1 has average annual net benefits of (-) $138,300 and a benefit-cost ratio of 0.3:1 (Table II-6).




SERVICE AREA

AG. SUB'D. BOUNDARY

PVC PIPELINE

FIGURE II-2

**ALTERNATIVE PLAN 1**

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## ALTERNATIVE PLAN 2

Alternative Plan 2 entails developing an agricultural irrigation system that would service 2,135 acres and provide water to irrigate 440 acres of crops in the Kilauea town area (Figure II-3 and Table II-1). The proposed system would use the Stone Dam Reservoir for storage and have a piped distribution system. The system would have the capability to supply a 12-hour peak irrigation demand of 6.3 MGD and an annual demand of 192 MG.

### Plan Elements (2)

Alternative Plan 2 includes the following agricultural irrigation system elements:

- restoration (dredge and repair) of the Stone Dam Reservoir to store 10.5 MG:
- installation of a pump station with three pumps and a filtration system (total pumping capacity 4,080 gpm);
- installation of a 300,000-gallon concrete tank.
- installation of 1,000 feet of 16-inch ductile iron (D.I.) pipe to connect the pump station to the concrete tank;
- installation of distribution system consisting of 51,000 feet of 2- to 20-inch PVC pipe;
- securing land and water rights for the Stone Dam Reservoir; and
- securing land rights for the other structural elements.

Figure II-3 shows the location of the structural elements, Table II-2 lists the elements, and Table II-3 lists the cost of the elements.

Alternative Plan 2 also includes the application of a land treatment measure, land smoothing, for the 320 additional acres of irrigated cropland brought into production by the proposed irrigation system. Land smoothing is considered an associated measure because it is needed to achieve the benefits claimed for the proposed irrigation system. The measure is included in Table II-2 as a plan element. The cost of the measure is included in Table II-3.

### Agricultural Irrigation System Operation (2)

The Plan 2 system would operate in the same manner as the Plan 1 system. Water from the Pohakuhono and Halaulani streams would continue to be diverted into the Stone Dam Reservoir (elevation 340 feet) for storage. The pump station would lift the water from the reservoir up to the 300,000-gallon concrete tank (elevation 450 feet). The filtration system would filter the water for use in drip irrigation systems and the distribution system would transport the water by gravity from the concrete tank to the service areas.

## NED Account - Plan Effects (2)

### Beneficial Effects (2)

The beneficial effects of Alternative Plan 2 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- alleviating reduced farm income problems (Table II-5A);
- eliminating potential farm income losses; and
- providing opportunities to make more productive use of agricultural land.

The total average annual increase in net farm income would be $795,200 (Table II-6).

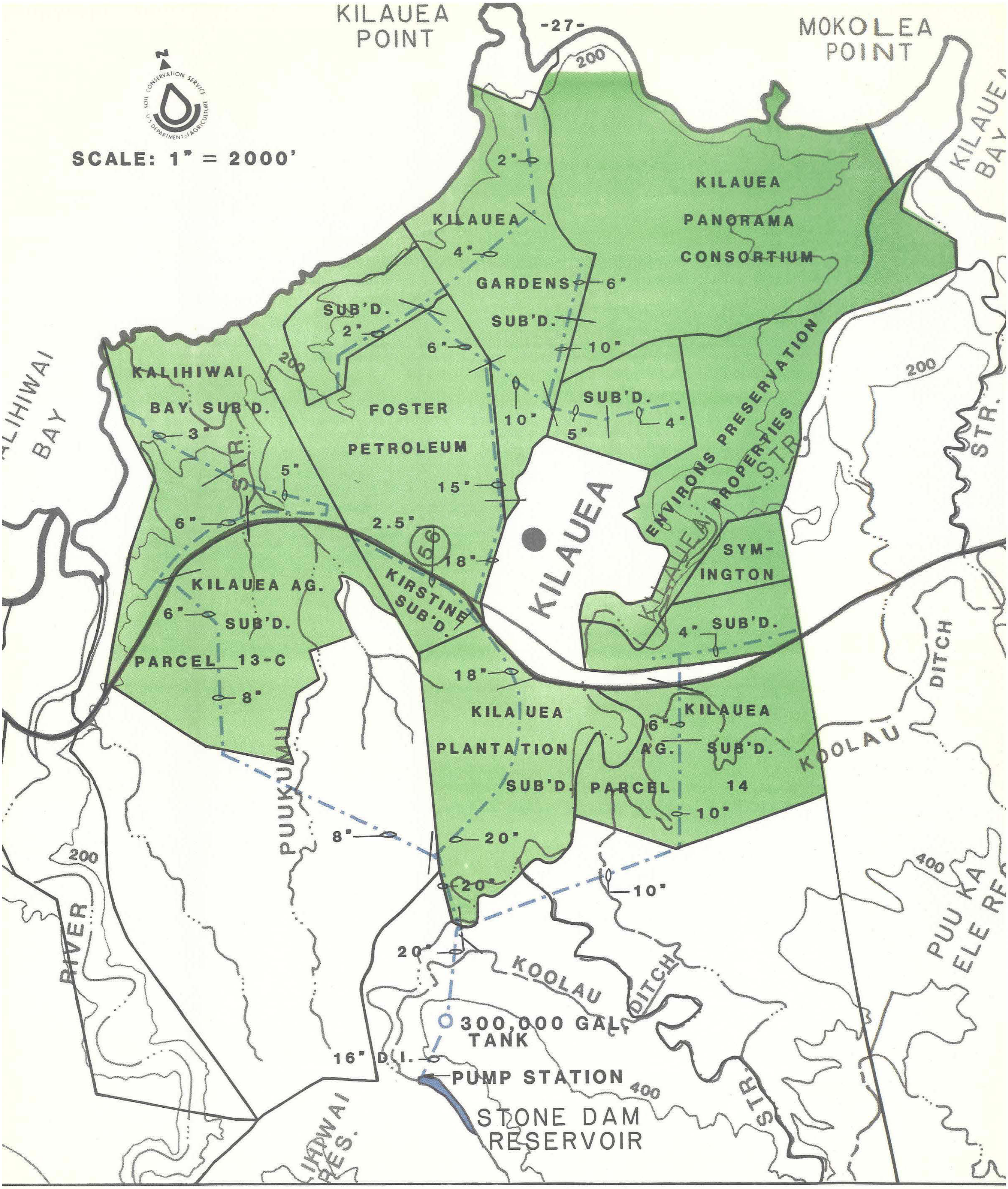
The plan would also generate incidental beneficial effects by decreasing the amount of domestic water used for agricultural purposes, as described in Plan 1 (page 23).

### Adverse Effects (2)

The plan elements proposed by Alternative Plan 2 have a total implementation cost of $2,749,000 (Table II-3). Average annual cost is $341,300.

### Net Effects (2)

Alternative Plan 2 has average annual net benefits of $453,900 and a benefit-cost ratio of 2.3:1 (Table II-6).




| | |
|---|---|
| (green) | SERVICE AREA |
| (solid line) | AG. SUB'D. BOUNDARY |
| (dash-dot line) | PIPELINE (PVC UNLESS NOTED) |

FIGURE II-3

## ALTERNATIVE PLAN 2

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## ALTERNATIVE PLAN 3

Alternative Plan 3 entails developing an agricultural irrigation system that would service 2,135 acres and provide water to irrigate 815 acres of crops in the Kilauea town area (Figure II-4 and Table II-1). The proposed system would use the Stone Dam Reservoir for storage and have a piped distribution system. The system would have the capability to supply a 12-hour peak irrigation demand of 11.8 MGD and an annual demand of 359 MG.

### Plan Elements (3)

Alternative Plan 3 includes the following agricultural irrigation system elements:

- restoration (dredge and repair) of the Stone Dam Reservoir to store 10.5 MG:
- installation of a pump station with three pumps and a filtration system (total pumping capacity 8,160 gpm);
- installation of a 600,000-gallon concrete tank;
- installation of 1,000 feet of 21-inch D.I. pipe to connect the pump station to the concrete tank;
- installation of distribution system consisting of 52,000 feet of 2.5- to 27-inch PVC or D.I. pipe;
- securing land and water rights for the Stone Dam Reservoir; and
- securing land rights for the other structural elements.

Figure II-4 shows the location of the structural elements, Table II-2 lists the elements, and Table II-3 lists the cost of the elements.

Alternative Plan 3 also includes the application of a land treatment measure, land smoothing, for the 695 additional acres of irrigated cropland brought into production by the proposed irrigation system. Land smoothing is considered an associated measure because it is needed to achieve the benefits claimed for the proposed irrigation system. The measure is included in Table II-2 as a plan element. The cost of the measure is included in Table II-3.

### Agricultural Irrigation System Operation (3)

The Plan 3 system would operate in the same manner as the systems proposed by plans 1 and 2. Water from the Pohakuhono and Halaulani streams would continue to be diverted into the Stone Dam Reservoir (elevation 340 feet) for storage. The pump station would lift the water from the reservoir up to the 600,000-gallon concrete tank (elevation 450 feet). The filtration system would filter the water for use in drip irrigation systems and the distribution system would transport the water by gravity from the concrete tank to the service areas.

## NED Account - Plan Effects (3)

### Beneficial Effects (3)

The beneficial effects of Alternative Plan 3 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- alleviating reduced farm income problems (Table II-5A);
- eliminating potential net farm income losses; and
- providing opportunities to make more productive use of agricultural land.

The total average annual increase in net farm income would be $1,583,700 (Table II-6).

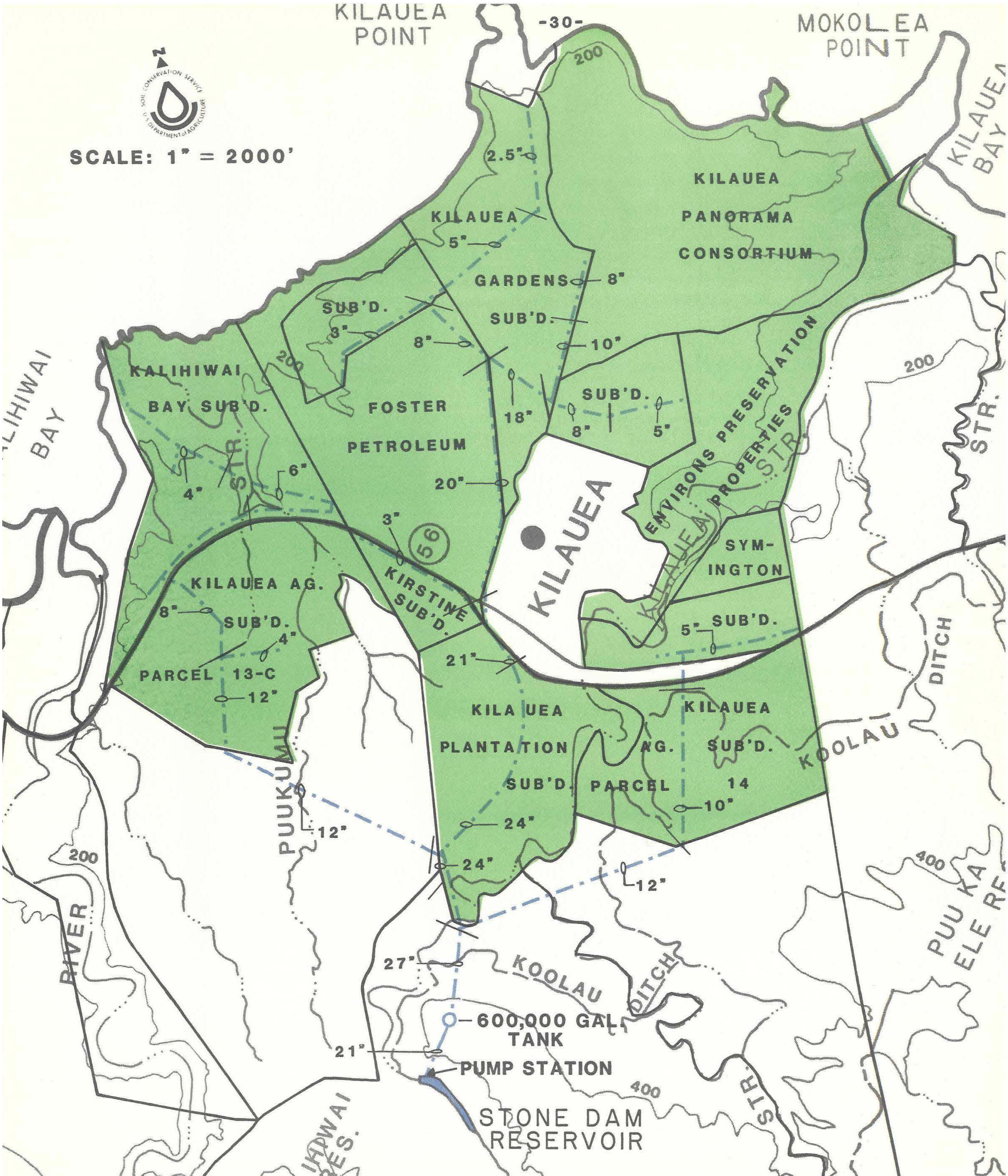
The plan would also generate incidental beneficial effects by decreasing the amount of domestic water used for agricultural purposes, as described in Plan 1 (page 23).

### Adverse Effects (3)

The plan elements proposed by Alternative Plan 3 have a total implementation cost of $4,195,000 (Table II-3). Average annual cost is $488,700.

### Net Effects (3)

Alternative Plan 3 has average annual net benefits of $1,095,000 and a benefit-cost ratio of 3.2:1 (Table II-6).




| | |
|---|---|
| [green box] | SERVICE AREA |
| [solid line] | AG. SUB'D. BOUNDARY |
| [dash-dot line] | PIPELINE (PIPES 21" OR GREATER ARE DUCTILE IRON, LESS THAN 21" ARE PVC) |

FIGURE II-4

## ALTERNATIVE PLAN 3

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## ALTERNATIVE PLAN 4

Alternative Plan 4 entails developing an agricultural irrigation system that would service 1,930 acres and provide water to irrigate 755 acres of crops in the Kilauea town area (Figure II-5 and Table II-1). The Kalihiwai Subdivision would not be serviced because of the steep topography in the area. The proposed system would use the Stone Dam Reservoir for storage and have an open concrete ditch distribution system. The system would have the capability to supply a 12-hour peak irrigation demand of 11 MGD and an annual demand of 333 MG.

### Plan Elements (4)

Alternative Plan 4 includes the following agricultural irrigation system elements:

- restoration (dredge and repair) of the Stone Dam Reservoir to store 10.5 MG;

- installation of a distribution system consisting of 46,000 feet of open concrete ditch;

- installation of outlet control structures at the end of seven concrete ditch sections;

- securing land and water rights for the Stone Dam Reservoir; and

- securing land rights for the other structural elements.

Figure II-5 shows the location of the structural elements, Table II-2 lists the elements, and Table II-3 lists the cost of the elements.

Alternative Plan 4 also includes the application of a land treatment measure, land smoothing, for the 665 additional acres of irrigated cropland brought into production by the proposed irrigation system. Land smoothing is considered an associated measure because it is needed to achieve the benefits claimed for the proposed irrigation system. The measure is included in Table II-2 as a plan element. The cost of the measure is included in Table II-3.

### Agricultural Irrigation System Operation (4)

Water from the Pohakuhono and Halaulani streams would continue to be diverted and stored in the Stone Dam Reservoir (elevation 340 feet). The concrete ditch distribution system would transport the water by gravity from the reservoir to the service areas. Farmers would have to install their own pump and filter systems.

## NED Account - Plan Effects (4)

### Beneficial Effects (4)

The beneficial effects of Alternative Plan 4 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- alleviating reduced farm income problems (Table II-5A);
- eliminating potential farm income losses; and
- providing opportunities to make more productive use of agricultural land.

The total average annual increase in net farm income would be $1,446,400 (Table II-6)

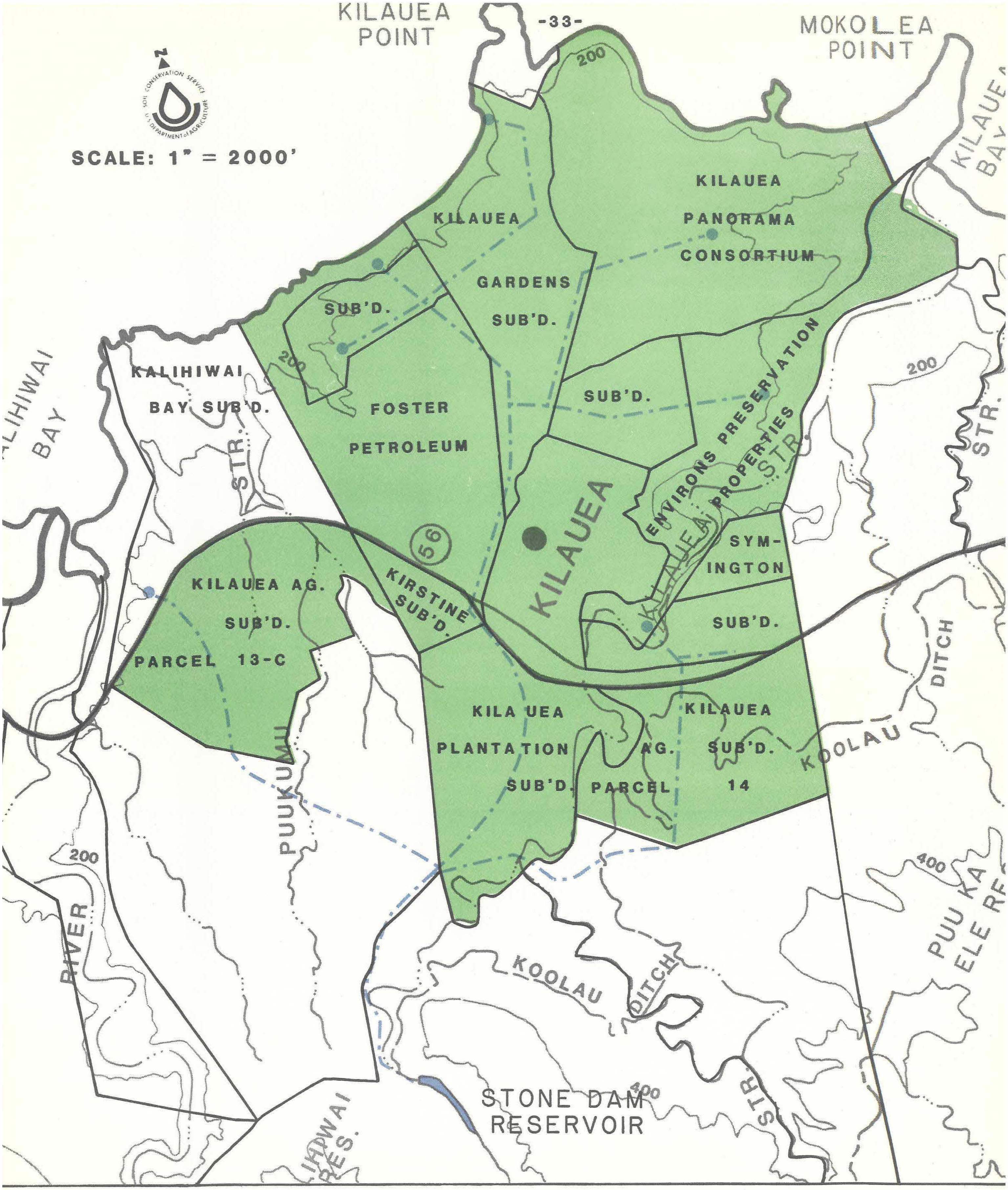
The plan would also generate incidental beneficial effects by decreasing the amount of domestic water used for agricultural purposes as described in Plan 1 (page 23).

### Adverse Effects (4)

The plan elements proposed by Alternative Plan 4 have a total implementation cost of $8,709,000 (Table II-3). Average annual cost is $997,300.

### Net Effects (4)

Alternative Plan 4 has average annual net benefits of $449,100 and a benefit-cost ratio of 1.5:1 (Table II-6).




SERVICE AREA

AG. SUB'D. BOUNDARY

CONCRETE DITCH

OUTLET CONTROL STRUCTURE

FIGURE II-5

## ALTERNATIVE PLAN 4

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## ALTERNATIVE PLAN 5

Alternative Plan 5 entails developing an agricultural irrigation system that would service 3,885 acres and provide water to irrigate 525 acres of crops in the Ka Loko area (Figure II-6 and Table II-1). The proposed system would use the Ka Loko Reservoir for storage and have a piped distribution system. The system would have the capability to supply a 12-hour peak irrigation demand of 8.2 MGD and an annual demand of 510 MG.

### Plan Elements (5)

Alternative Plan 5 includes the following agricultural irrigation system elements:

- restoration of the five-mile long Ka Loko Ditch;
- restoration (dredge and repair) of the Ka Loko Reservoir to store 408.9 MG:
- installation of a water control structure and filtration system at the Ka Loko Reservoir;
- installation of a distribution system consisting of 55,000 feet of 2.5- to 20-inch PVC or D.I. pipe;
- installation of pressure regulators along the distribution pipeline;
- securing land and water rights for the Ka Loko Reservoir; and
- securing land rights for the other structural elements.

Figure II-6 shows the location of the structural elements listed above, Table II-2 lists the elements, and Table II-3 lists the cost of the elements.

Alternative Plan 5 also includes the application of a land treatment measure, land smoothing, for the 375 additional acres of irrigated cropland brought into production by the proposed irrigation system. Land smoothing is considered an associated measure because it is needed to achieve the benefits claimed for the proposed irrigation system. The measure is included in Table II-2 as a plan element. The cost of the measure is included in Table II-3.

### Agricultural Irrigation System Operation (5)

The Ka Loko Ditch would continue to divert water from the Moloaa and Puu Ka Ele streams and transport it to the Ka Loko Reservoir (elevation 747 feet) for storage, as it does at the present time. The water control structure would regulate the flow of water from the reservoir to the distribution system. The filtration system would filter the water so it would be suitable for use in drip irrigation systems. The distribution system would transport the water by gravity from the reservoir to the service areas.

## NED Account - Plan Effects (5)

### Beneficial Effects (5)

The beneficial effects of Alternative Plan 5 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- alleviating farm income problems (Table II-5A); and
- providing opportunities to make more productive use of agricultural land.

The total average annual increase in net farm income would be $661,900 (Table II-6).

The plan would also generate incidental beneficial effects by providing a minimal amount of stockwater. Although the proposed water system was not designed to provide stockwater, ranchers would be allowed to use the system. Projected stockwater use is insignificant in comparison to the total amount of water that would be supplied by the system and would not affect the supply for irrigated crops. The effects of providing stockwater are considered incidental because providing stockwater is not a specified objective of the study. The effects were therefore not evaluated monetarily and are not included in the NED account.

### Adverse Effects (5)

The plan elements proposed by Alternative Plan 5 have a total implementation cost of $4,556,000 (Table II-3). Average annual cost is $479,100.

### Net Effects (5)

Alternative Plan 5 has average annual net benefits of $182,800 and a benefit-cost ratio of 1.4:1 (Table II-6).

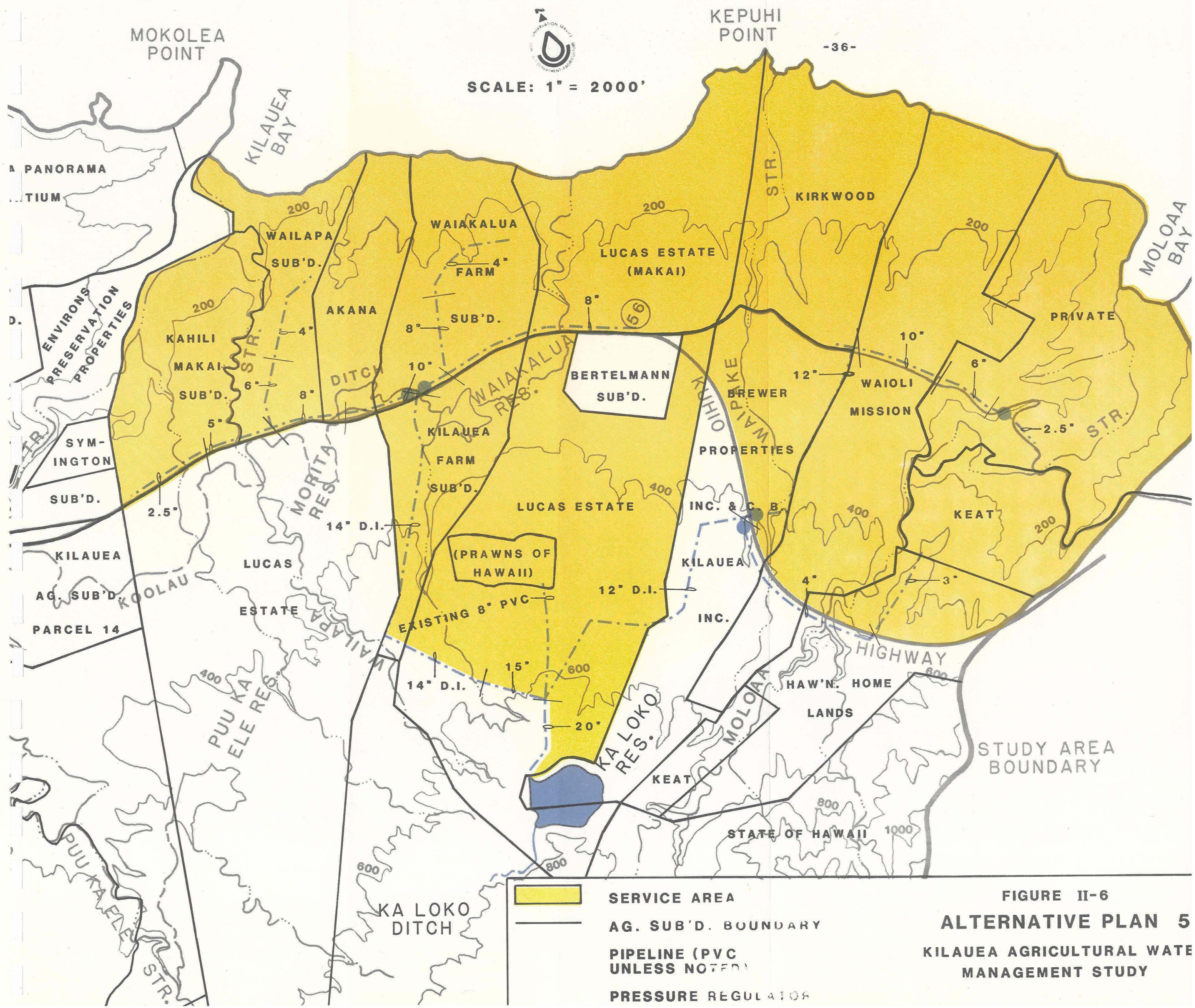



FIGURE II-6
ALTERNATIVE PLAN 5
KILAUEA AGRICULTURAL WATE[R] MANAGEMENT STUDY

## ALTERNATIVE PLAN 6

Alternative Plan 6 entails developing an agricultural irrigation system that would service 5,880 acres and provide water to irrigate 865 acres of crops in the Ka Loko area (Figure II-7 and Table II-1). The proposed system would use the Ka Loko Reservoir for storage and have a piped distribution system. The system would have the capability to supply a 12-hour peak irrigation demand of 13.1 MGD and an annual demand of 628 MG.

### Plan Elements (6)

Alternative Plan 6 includes the following agricultural irrigation system elements:

- restoration of the five-mile long Ka Loko Ditch;
- restoration (dredge and repair) of the Ka Loko Reservoir to store 408.9 MG;
- installation of a water control structure and filtration system at the Ka Loko Reservoir;
- installation of a distribution system consisting of 56,000 feet of 2.5- to 21-inch PVC or D.I. pipe;
- installation of pressure regulators along the distribution pipeline;
- securing land and water rights for the Ka Loko Reservoir; and
- securing land rights for the other structural elements.

Figure II-7 shows the location of the structural elements listed above, Table II-2 lists the elements, and Table II-3 lists the cost of the elements.

Alternative Plan 6 includes the application of a land treatment measure, land smoothing, for the 715 additional acres of irrigated cropland brought into production by the proposed irrigation system. Land smoothing is considered an associated measure because it is needed to achieve the benefits claimed for the proposed irrigation system. The measure is included in Table II-2 as a plan element. The cost of the measure is included in Table II-3.

### Agricultural Irrigation System Operation (6)

The Plan 6 system would operate in the same manner as the Plan 5 system. The Ka Loko Ditch would continue to divert and transport water from the Moloaa and Puu Ka Ele streams to the Ka Loko Reservoir (elevation 747 feet) for storage. The water control structure would regulate the flow of water from the reservoir to the distribution system. The filtration system would filter the water for use in drip irrigation systems. And, the distribution system would transport the water from the reservoir by gravity to the service areas.

## NED Account - Plan Effects (6)

### Beneficial Effects (6)

The beneficial effects of Alternative Plan 6 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- alleviating reduced farm income problems (Table II-5B); and
- providing opportunities to make more productive use of agricultural land.

The total average annual increase in net farm income would be $1,369,700 (Table II-6).

Plan 6 would also generate incidental beneficial effects by providing a minimal amount of stockwater, as described in Plan 5 (page 35).

### Adverse Effects (6)

The plan elements proposed by Alternative Plan 6 have a total implementation cost of $5,004,000 (Table II-3). Average annual cost is $521,300.

### Net Effects (6)

Alternative Plan 6 has average annual net benefits of $848,400 and a benefit-cost ratio of 2.6:1 (Table II-6).

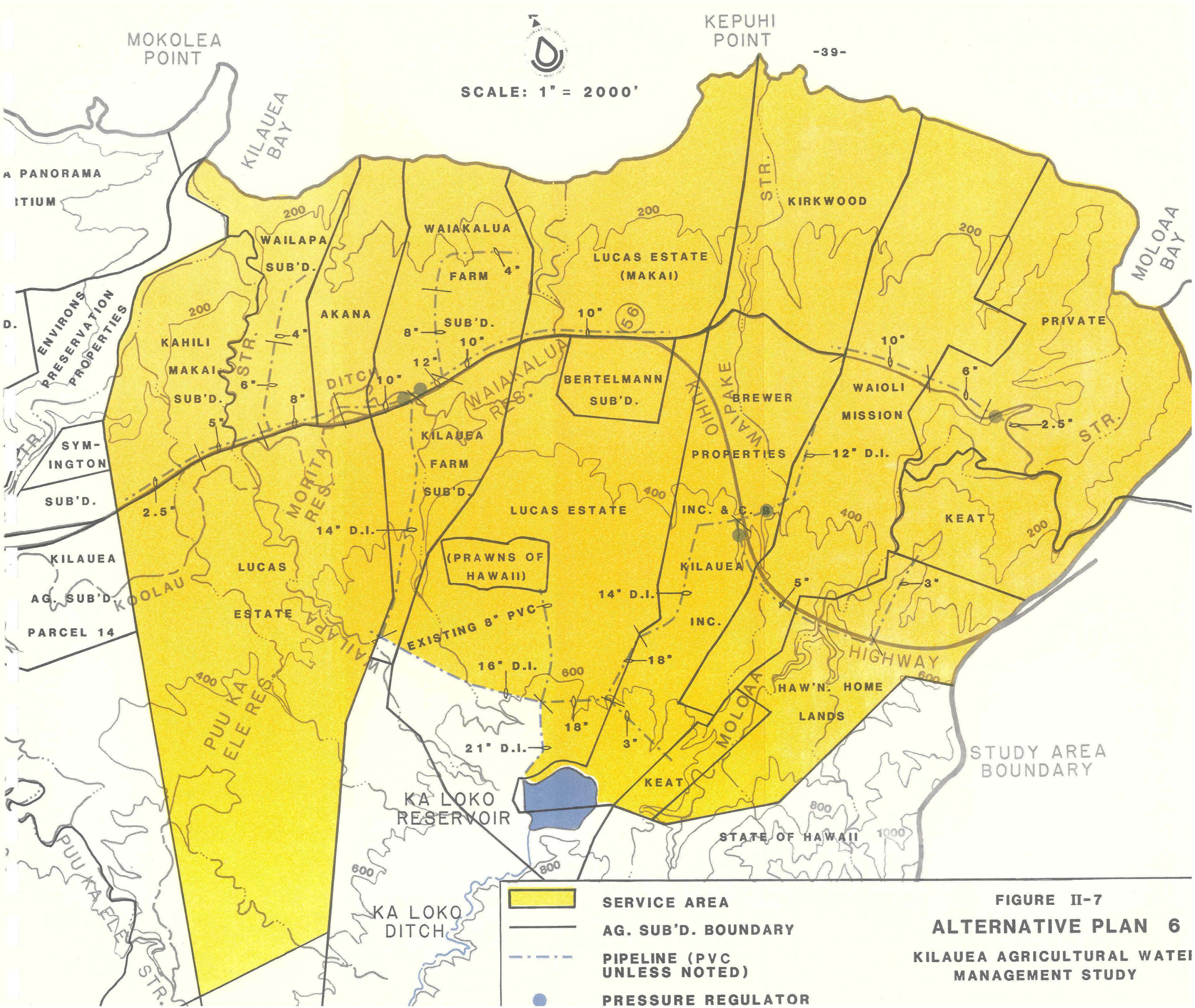



FIGURE II-7
**ALTERNATIVE PLAN 6**
KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## ALTERNATIVE PLAN 7

Alternative Plan 7 entails developing two separate agricultural irrigation systems and is actually plans 2 and 5 combined. One of the systems would service 2,135 acres and provide irrigation water for 440 acres of crops in the Kilauea town area, as proposed by Plan 2. The other system would service 3,885 acres and provide irrigation water for 525 acres of crops in the Ka Loko area, as proposed by Plan 5. The two systems would service a total of 6,020 acres and provide irrigation water for 965 acres of crops (Table II-1). The systems would have a combined capacity to supply a 12-hour peak irrigation demand of 14.5 MGD and an annual demand of 702 MG.

### Plan Elements (7)

Alternative Plan 7 includes all of the elements in plans 2 and 5. For a description of the elements in each plan see pages 25 and 34, respectively. Table II-2 lists all of the elements and Table II-3 lists the cost of the elements in Alternative Plan 7.

### Agricultural Irrigation System Operation (7)

Alternative Plan 7 includes the irrigation systems in plans 2 and 5. Each system would operate in the same manner as the system proposed by its respective plan. The systems would not be connected and would operate independently. For a description of the operation of the Plan 2 system see page 25 and for a description of the operation of the Plan 5 system see page 34.

### NED Account - Plan Effects (7)

#### Beneficial Effects (7)

The beneficial effects of Alternative Plan 7 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- alleviating reduced farm income problems (Table II-5B);
- eliminating potential farm income losses; and
- providing opportunities to make more productive use of agricultural land.

The total average annual increase in net farm income would be $1,457,100 (Table II-6).

The plan would also generate incidental beneficial effects by decreasing the amount of domestic water used for agricultural purposes and providing a minimal amount of stockwater. The effects are considered incidental because decreasing the amount of domestic water used for agricultural purposes and providing stockwater are not specified objectives of this study. The effects were therefore not evaluated monetarily and are not included in the NED account. However, decreasing domestic water used for agricultural purposes is considered beneficial to the Kilauea community and is shown in the OSE account (Table II-7).

Adverse Effects (7)

The plan elements proposed by Alternative Plan 7 has a total implementation cost of $7,305,000 (Table II-3). Average annual cost is $820,400.

Net Effects (7)

Alternative Plan 7 has average annual net benefits of $636,700 and a benefit-cost ratio of 1.8:1 (Table II-6).

## ALTERNATIVE PLAN 8

Alternative Plan 8 entails developing one agricultural irrigation system to service the areas in both alternative plans 2 and 5. The Ka Loko Reservoir would be used as a storage facility and a piped distribution system would be installed to service the Kilauea town area and the Ka Loko area (Figure II-8). The system would service a total of 6,020 acres and provide water to irrigate 965 acres of crops (Table II-1). The system would have the capability to supply a 12-hour peak irrigation demand of 14.5 MGD and an annual amount of 702 MG.

### Plan Elements (8)

Alternative Plan 8 includes the following elements:

- restoration of the five-mile long Ka Loko Ditch;
- restoration (dredge and repair) of the Ka Loko Reservoir to store 408.9 MG;
- installation of a water control structure and filtration system at the Ka Loko Reservoir;
- installation of pressure regulators along the distribution pipeline;
- securing land and water rights for the Ka Loko Reservoir; and
- securing land rights for the other structural elements.

Figure II-8 shows the location of the structural elements, Table II-2 lists the elements, and Table II-3 lists the cost of the elements.

Alternative Plan 8 also includes the application of a land treatment measure, land smoothing, for the 695 additional acres of irrigated cropland brought into production by the proposed irrigation system. Land smoothing is considered an associated measure because it is needed to achieve the benefits claimed for the proposed irrigation system. The measure is included in Table II-2 as a plan element. The cost of the measure is included in Table II-3.

### Agricultural Irrigation System Operation (8)

The irrigation system proposed by Alternative Plan 8 would operate in the same manner as the systems proposed by plans 5 and 6. The Ka Loko Ditch would continue to divert and transport water from the Moloaa and Puu Ka Ele streams to the Ka Loko Reservoir (elevation 747 feet) for storage. The water control structure would regulate the flow of water from the reservoir to the distribution system. The filtration system would filter the water for use in drip irrigation systems. And, the distribution system would transport the water from the reservoir by gravity to the Kilauea town and Ka Loko service area.

## NED Account - Plan Effects (8)

### Beneficial Effects (8)

The beneficial effects of Alternative Plan 8 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- alleviating reduced farm income problems (Table II-5B).
- eliminating potential farm income losses; and
- providing opportunities to make more productive use of agricultural land.

The total average annual increase in net farm income would be $1,457,100 (Table II-6).

The plan would also generate incidental beneficial effects by decreasing the amount of domestic water used for agricultural purposes and providing a minimal amount of stockwater. These effects were not evaluated monetarily and are not included in the NED account. However, decreasing domestic water used for agricultural purposes is considered beneficial to the Kilauea community and is shown in the OSE account (Table II-7).

### Adverse Effects (8)

The plan elements proposed by Alternative Plan 8 has a total implementation cost of $6,915,000 (Table II-3). Average annual cost is $762,800.

### Net Effects (8)

Alternative Plan 8 has average annual net benefits of $694,300 and a benefit-cost ratio of 1.9:1 (Table II-6).

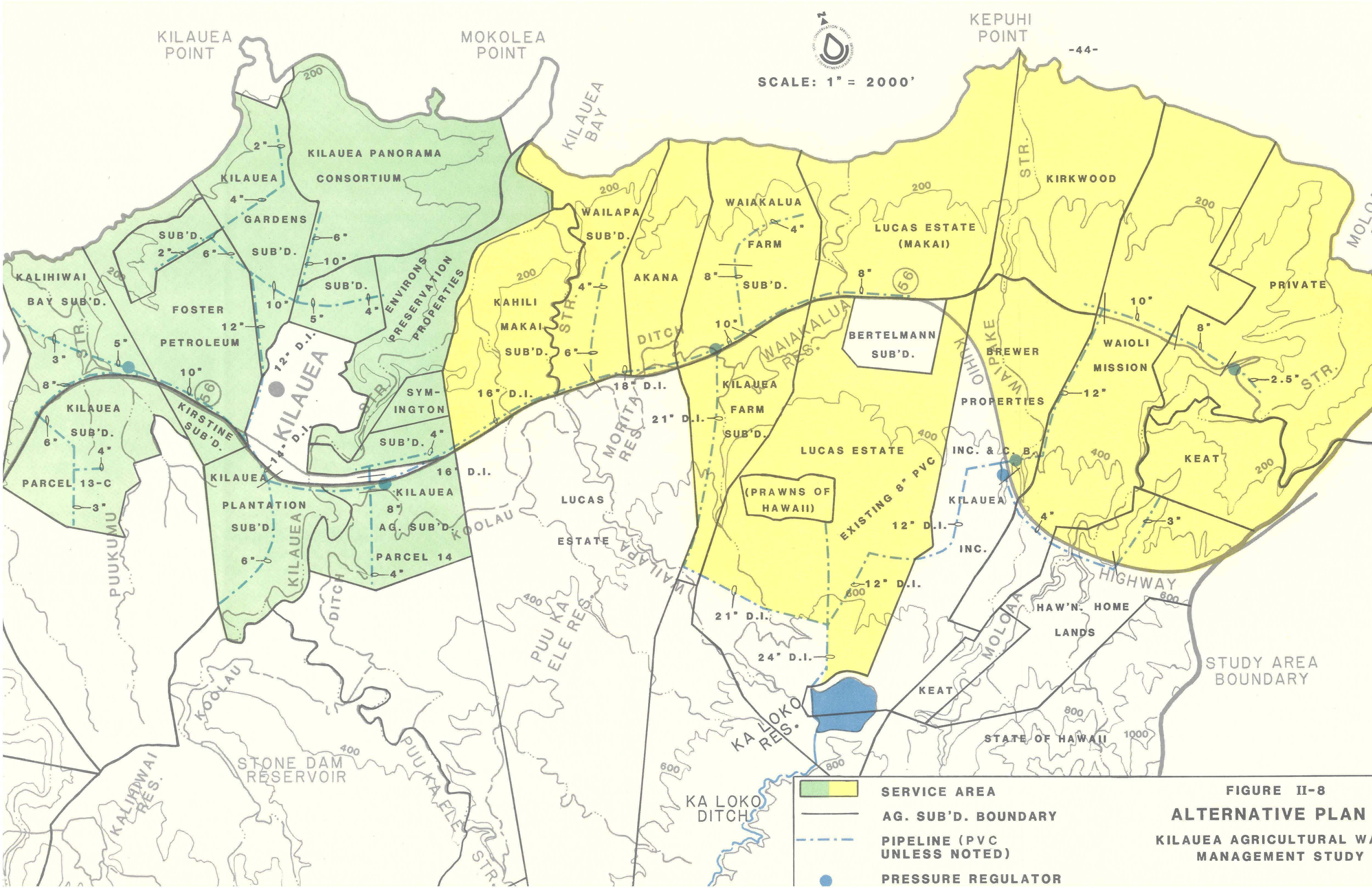



FIGURE II-8
**ALTERNATIVE PLAN**
KILAUEA AGRICULTURAL WAT[ER]
MANAGEMENT STUDY

## ALTERNATIVE PLAN 9 (NED PLAN)

Alternative Plan 9 entails developing two separate agricultural irrigation systems and is actually plans 3 and 6 combined. One of the systems would service 2,135 acres and provide irrigation water for 815 acres of crops in the Kilauea town area, as proposed by Plan 3 (Figure II-9). The other system would service 5,880 acres and provide irrigation water for 865 acres of crops in the Ka Loko area, as proposed by Plan 6. The two systems would service a total of 8,015 acres and provide irrigation water for 1,680 acres of crops (Table II-1). The systems would have a combined capacity to supply a 12-hour peak irrigation demand of 24.9 MGD and an annual demand of 987 MG.

### Plan Elements (9)

Alternative Plan 9 includes all of the elements in plans 3 and 6. For a description of the elements in each plan see pages 28 and 37, respectively. Table II-2 lists all of the elements and Table II-3 lists the cost of the elements in Alternative Plan 9.

### Agricultural Irrigation System Operation (9)

Alternative Plan 9 includes the irrigation systems proposed by plans 3 and 6. Each system would operate in the same manner as the system proposed by its respective plan. The systems would not be connected and would operate independently. For a description of the operation of the Plan 3 system see page 28 and for a description of the operation of the Plan 6 system see page 37.

### NED Account - Plan Effects (9)

#### Beneficial Effects (9)

The beneficial effects of Alternative Plan 9 are attributable to the increase in net farm income. Providing an adequate irrigation water system would increase net farm income by:

- reducing net farm income losses (Table II-5B); and
- providing opportunities to make more productive use of agricultural land.

The total average annual increase in net farm income would be $2,953,400 (Table II-6).

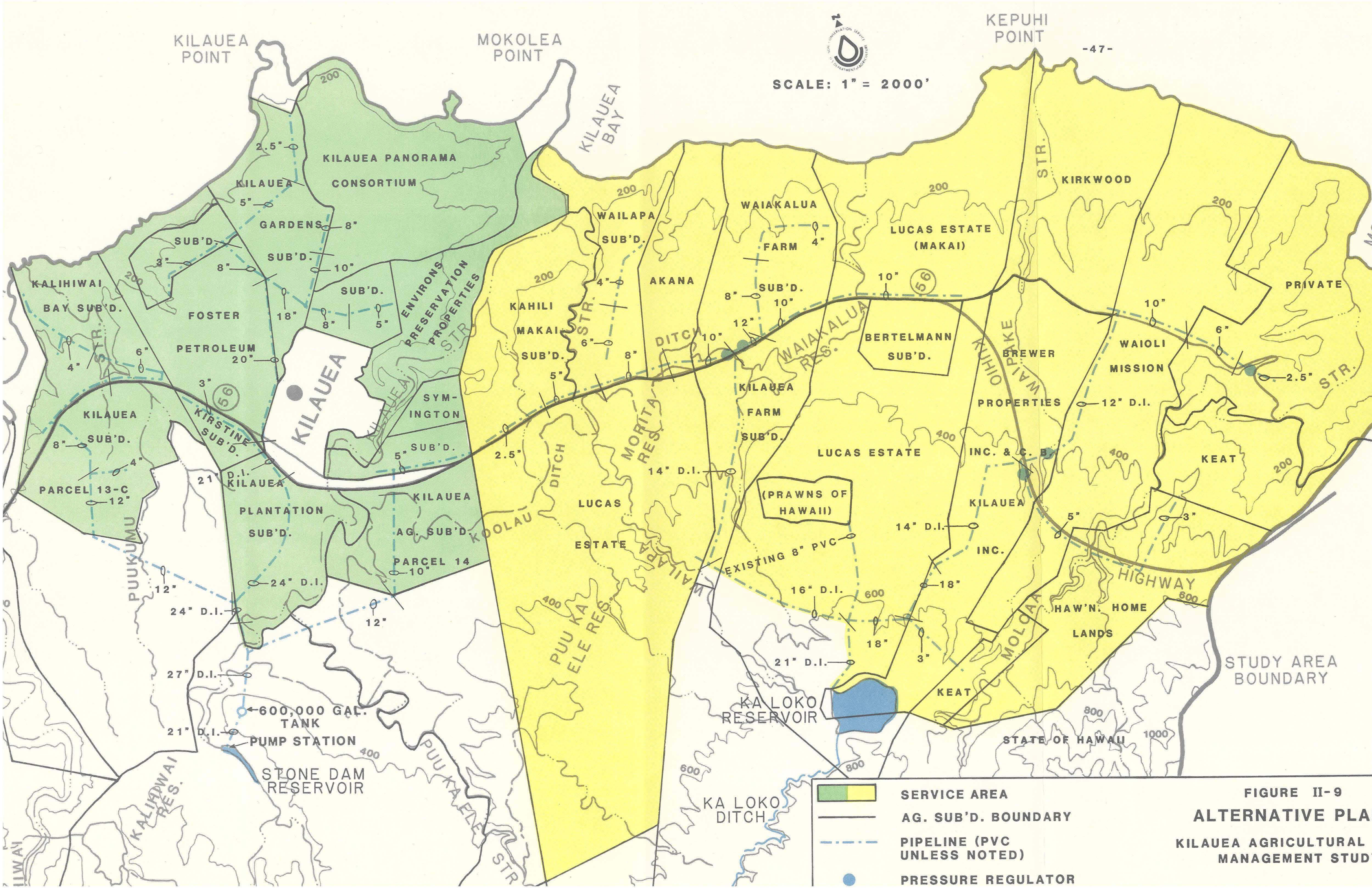
The plan would also generate incidental beneficial effects by decreasing the amount of domestic water used for agricultural purposes and providing a minimal amount of stockwater. These effects were not evaluated monetarily and are not included in the NED account. However, decreasing domestic water used for agricultural purposes is beneficial to the Kilauea community and is shown in the OCE account (Table II-7).

Adverse Effects (9)

The plan elements proposed by Alternative Plan 9 have a total implementation cost of $9,199,000 (Table II-3). Average annual cost is $1,010,000.

Net Effects (9)

Alternative Plan 9 has average annual net benefits of $1,943,400 and a benefit-cost ratio of 2.9:1 (Table II-6).


KILAUEA POINT
MOKOLEA POINT
KEPUHI POINT
SCALE: 1" = 2000'
KILAUEA BAY
KILAUEA PANORAMA CONSORTIUM
KILAUEA GARDENS SUB'D.
SUB'D.
FOSTER PETROLEUM
KALIHIWAI BAY SUB'D.
ENVIRONS PRESERVATION PROPERTIES
KILAUEA
SYM-INGTON
KIRSTINE SUB'D.
KILAUEA SUB'D.
PARCEL 13-C
KILAUEA PLANTATION SUB'D.
KILAUEA AG. SUB'D.
PARCEL 14
WAILAPA SUB'D.
KAHILI MAKAI SUB'D.
AKANA
WAIAKALUA FARM SUB'D.
LUCAS ESTATE (MAKAI)
KIRKWOOD
PRIVATE
BERTELMANN SUB'D.
WAIOLI MISSION
BREWER PROPERTIES INC. & C. B.
KILAUEA FARM SUB'D.
LUCAS ESTATE
(PRAWNS OF HAWAII)
KILAUEA INC.
KEAT
LUCAS ESTATE
HAW'N. HOME LANDS
STATE OF HAWAII
KA LOKO RESERVOIR
KA LOKO DITCH
STONE DAM RESERVOIR
600,000 GAL. TANK
PUMP STATION
EXISTING 8" PVC
HIGHWAY
KOOLAU DITCH
STUDY AREA BOUNDARY
SERVICE AREA
AG. SUB'D. BOUNDARY
PIPELINE (PVC UNLESS NOTED)
PRESSURE REGULATOR
FIGURE II-9
ALTERNATIVE PLAN
KILAUEA AGRICULTURAL W
MANAGEMENT STUDY

## ALTERNATIVE PLAN 10

Alternative Plan 10 entails developing the same agricultural irrigation system proposed by Plan 5 and hydroelectric power facilities (Figure II-10). The agricultural irrigation system would service 3,885 acres and provide water to irrigate 525 acres of crops in the Kilauea town area, as does Plan 5 (Table II-1). The system would use the Stone Dam Reservoir for storage and have a piped distribution system. The system would have the capability to supply a 12-hour peak irrigation demand of 8.2 MGD and an annual demand of 510 MG. Plan 10 also includes the installation of three hydroelectric turbines capable of generating 881,500 kilowatt hours of electricity annually.

### Plan Elements (10)

Alternative Plan 10 includes all of the elements in Plan 5 as well as hydroelectric power elements. For a description of the Plan 5 elements see page 34. The hydroelectric power elements are as follows:

- installation of three hydroelectric turbines (turbine capacities are 45, 35, and 95 kilowatts; total capacity of 175 kWh);

- modification of the distribution system pipeline (6,000 feet) to accommodate the operation of the turbines;

- installation of 2,000 feet of D.I. pipe to connect turbine No. 3 to the distribution system pipeline; and

- land rights for the 2,000 feet of D.I. pipe.

Figure II-9 shows the location of the three turbines and the irrigation system elements, Table II-2 lists all of the elements in Plan 10, Table II-3 lists the cost of the agricultural irrigation elements, and Table II-4 lists the cost of the hydroelectric power elements.

### Operation of Agricultural Irrigation System and Hydroelectric Turbines

The Plan 10 agricultural irrigation system would operate in the same manner as the Plan 5 system. The Ka Loko Ditch would continue to divert and transport water from the Moloaa and Puu Ka Ele streams to the Ka Loko Reservoir (elevation 747 feet) for storage. The water control structure would regulate the flow of water from the reservoir to the distribution system. The filtration system would filter the water for use in drip irrigation systems. And, the distribution system would transport the water from the reservoir by gravity to the service areas.

The hydroelectric turbines would not affect the operation of the irrigation system. Turbines 1 and 2 would operate during normal irrigation periods and when excess water is drained out of Ka Loko Reservoir during high rainfall periods. Turbine 3 would operate only when excess water is drained out of the reservoir.

## NED Account - Plan Effects (10)

### Beneficial Effects (10)

The beneficial effects of Alternative Plan 10 are attributable to the increase in net farm income. Net farm income would increase because the plan would:

a. Provide an adequate irrigation water system that would increase net farm income by:

   - alleviating reduced farm income problems (Table II-5B);

   - eliminating potential farm income losses; and

   - providing opportunities to make more productive use of agricultural land.

b. Provide hydroelectric power facilities to achieve opportunities to generate electricity.

The total average annual increase in net farm income would be $721,800 (Table II-6).

Plan 10 would also generate incidental beneficial effects by providing a minimal amount of stockwater, as described in Plan 5 (page 35).

### Adverse Effects (10)

Total implementation cost of the agricultural irrigation elements and the hydroelectric power elements is $4,556,000 (Table II-3) and $436,000 (Table II-4), respectively. Total average annual cost of the agricultural irrigation elements and the hydroelectric elements is $479,100 and $45,600, respectively. The total implementation cost of the plan is $4,992,000 and the total average annual cost of the plan is $524,700.

### Net Effects (10)

Alternative Plan 10 has average annual net benefits of $197,100 and a benefit-cost ratio of 1.4:1 (Table II-6).

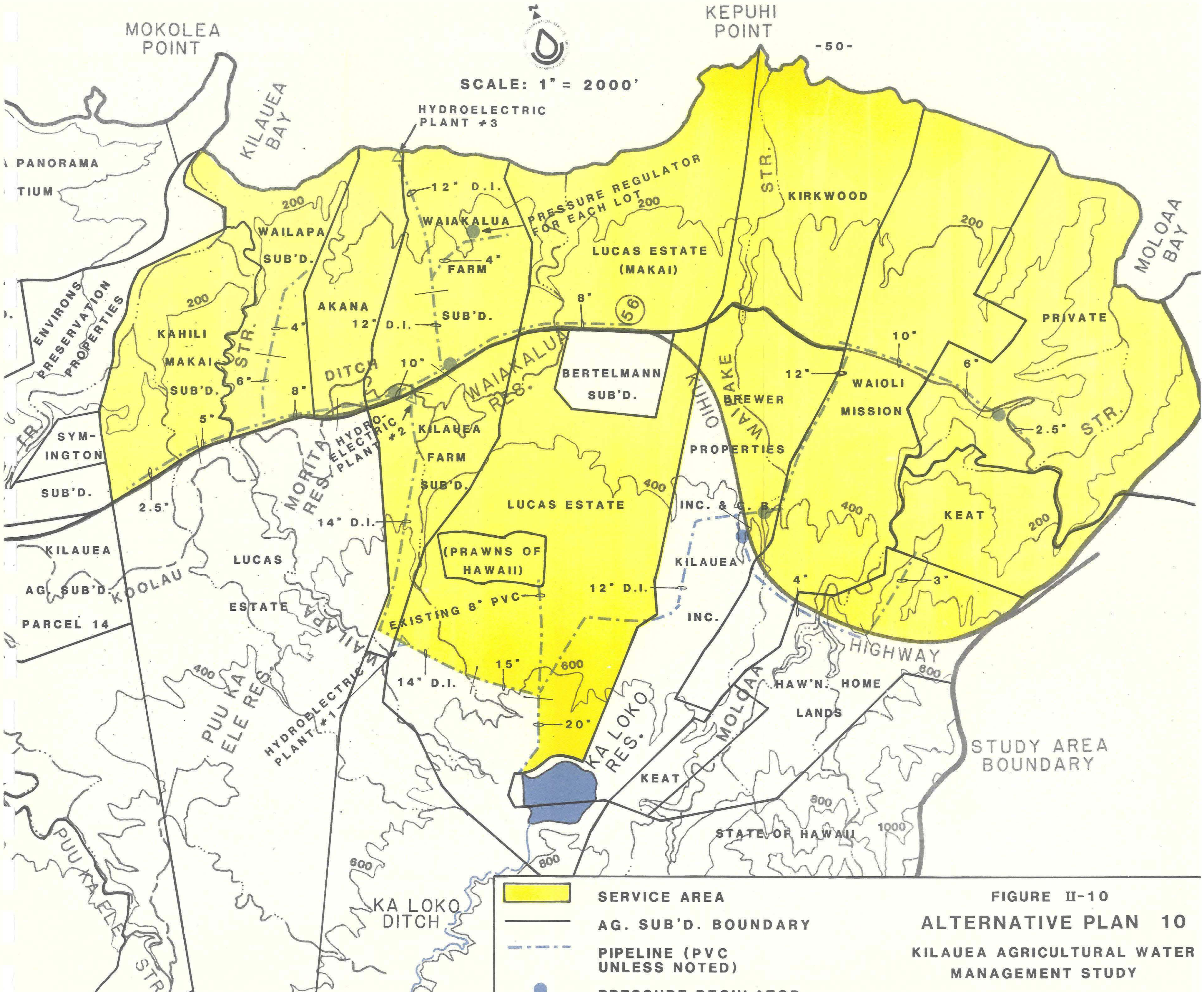



FIGURE II-10
ALTERNATIVE PLAN 10
KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

Table II-1
Summary of Service Areas and Acres Irrigated in the Study Area

| Item | Conditions | | | Alternative Plan | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Past1/ | Present2/ | Future3/ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| I. Acres Serviced by: | | | | | | | | | | | | | |
| A. Kilauea Sugar Company System | | | | | | | | | | | | | |
| 1. Original Distribution System4/ | 5,000 | 75 | 75 | 0 | 0 | 0 | 0 | 75 | 75 | 0 | 0 | 0 | 75 |
| 2. Pipeline Systems5/ | 0 | 175 | 175 | 175 | 170 | 170 | 170 | 0 | 0 | 0 | 0 | 0 | 0 |
| B. Domestic Water System6/ | 0 | 460 | 460 | 0 | 0 | 0 | 205 | 460 | 460 | 0 | 0 | 0 | 460 |
| C. Other Existing Water Systems | 0 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| D. Proposed System(s)7/ | - | - | - | 535 | 2,135 | 2,135 | 1,930 | 3,885 | 5,880 | 6,020 | 6,020 | 8,015 | 3,885 |
| E. All Water Systems | 5,000 | 790 | 790 | 790 | 2,390 | 2,390 | 2,390 | 4,500 | 6,495 | 6,100 | 6,100 | 8,095 | 4,500 |
| F. Increase Over Future Conditions | - | - | - | 0 | 1,600 | 1,600 | 1,600 | 3,710 | 5,705 | 5,310 | 5,310 | 7,305 | 3,710 |
| II. Acres Irrigated by: | | | | | | | | | | | | | |
| A. Kilauea Sugar Company System | | | | | | | | | | | | | |
| 1. Original Distribution System4/ | 3,200 | 50 | 55 | 0 | 0 | 0 | 0 | 55 | 55 | 0 | 0 | 0 | 55 |
| 2. Pipeline Systems5/ | 0 | 60 | 150 | 150 | 150 | 150 | 150 | 0 | 0 | 0 | 0 | 0 | 0 |
| B. Domestic Water System | 0 | 45 | 65 | 0 | 0 | 0 | 30 | 65 | 65 | 0 | 0 | 0 | 65 |
| C. Other Existing Water Systems | 0 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| D. Proposed System(s)7/ | | | | | | | | | | | | | |
| 1. Papayas | - | - | - | 85 | 160 | 285 | 265 | 205 | 325 | 365 | 365 | 610 | 205 |
| 2. Bananas | - | - | - | 10 | 170 | 325 | 305 | 140 | 280 | 310 | 310 | 605 | 140 |
| 3. Truck Crops | - | - | - | 25 | 110 | 205 | 185 | 85 | 165 | 195 | 195 | 370 | 85 |
| 4. Feed Corn | - | - | - | 0 | 0 | 0 | 0 | 60 | 60 | 60 | 60 | 60 | 60 |
| 5. Prawn Ponds | - | - | - | 0 | 0 | 0 | 0 | 35 | 35 | 35 | 35 | 35 | 35 |
| 6. Total | - | - | - | 120 | 440 | 815 | 755 | 525 | 865 | 965 | 965 | 1,680 | 525 |
| E. All Water Systems | 3,200 | 175 | 290 | 290 | 610 | 985 | 955 | 665 | 1,005 | 985 | 985 | 1,700 | 665 |
| F. Increase Over Future Conditions | - | - | - | 0 | 320 | 695 | 665 | 375 | 715 | 695 | 695 | 1,410 | 375 |

1/ 1970
2/ 1982
3/ Projected future conditions in the year 1990 without any project action.
4/ For past conditions, the system refers to the entire Kilauea Sugar Company distribution system. For present and future conditions and alternative plans, the system refers to the Stone Dam - Mill Ditch System.
5/ Private pipeline systems which divert water from Kilauea Sugar Company reservoirs or ditches.
6/ Acres serviced by the domestic water system include areas used for agricultural production only.
7/ Refers to the agricultural irrigation systems proposed by the alternative plans.

Table II-2
Summary of Plan Elements

| Element | Unit | Alternative Plan 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AGRICULTURAL IRRIGATION ELEMENTS | | | | | | | | | | | |
| I. AGRICULTURAL IRRIGATION SYSTEM(S) | | | | | | | | | | | |
| 1. Structural Measures | | | | | | | | | | | |
| a. Reservoir Restoration | | | | | | | | | | | |
| (1) Stone Dam Reservoir....... | MG | 10.5 | 10.5 | 10.5 | 10.5 | - | - | 10.5 | - | 10.5 | - |
| (2) Ka Loko Reservoir......... | MG | - | - | - | - | 408.9 | 408.9 | 408.9 | 408.9 | 408.9 | 408.9 |
| (3) Total Storage............ | MG | 10.5 | 10.5 | 10.5 | 10.5 | 408.9 | 408.9 | 419.4 | 408.9 | 419.4 | 408.9 |
| b. Ka Loko Ditch Restoration..... | miles | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5<br>2 |
| c. Pump Station................. | number | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| (1) Pumps.................... | number | 3 | 3 | 3 | 0 | 0 | 0 | 3 | 0 | 3 | 0 |
| (2) Total Pumping Capacity.... | gpm | 1,110 | 4,080 | 8,160 | 0 | 0 | 0 | 4,080 | 0 | 8,160 | 0 |
| d. Concrete Tank................ | number | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| (1) Storage Capacity.......... | gallons | 82,000 | 300,000 | 600,000 | 0 | 0 | 0 | 300,000 | 0 | 600,000 | 0 |
| e. Pipeline From Pump Station To Concrete Tank................ | feet | 1,000 | 1,000 | 1,000 | 0 | 0 | 0 | 1,000 | 0 | 1,000 | 0 |
| f. Distribution System(s)........ | number | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 |
| (1) Pipeline.................. | feet | 24,000 | 51,000 | 52,000 | 0 | 55,000 | 56,000 | 106,000 | 98,000 | 108,000 | 55,000 |
| (2) Concrete Ditch............ | feet | 0 | 0 | 0 | 46,000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2. Land and Water Rights | | | | | | | | | | | |
| a. Secure Land and Water Rights For Reservoir(s) | | | | | | | | | | | |
| (1) Stone Dam Reservoir....... | yes/no1/ | yes | yes | yes | yes | no | no | yes | no | yes | no |
| (2) Ka Loko Reservoir......... | yes/no1/ | no | no | no | no | yes | yes | yes | yes | yes | yes |
| b. Secure Land Rights For Other Structural Elements........... | acres | 3.1 | 6.7 | 6.8 | 33.6 | 7.5 | 7.9 | 14.2 | 9.4 | 14.7 | 7.5 |
| II. ASSOCIATED MEASURES | | | | | | | | | | | |
| 1. Land Treatment Measures (land smoothing)................ | acres | 0 | 320 | 695 | 695 | 375 | 715 | 695 | 695 | 1,410 | 375 |
| 2. Technical Assistance............ | person-days | 0 | 64 | 139 | 133 | 75 | 143 | 139 | 139 | 282 | 75 |
| HYDROELECTRIC POWER ELEMENTS | | | | | | | | | | | |
| I. HYDROELECTRIC POWER FACILITIES | | | | | | | | | | | |
| 1. Structural Elements | | | | | | | | | | | |
| a. Hydroelectric Turbines........ | number | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| (1) Total Capacity of Turbines | kWh | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175 |
| (2) Total Generating Capacity | kWh/yr. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 881,500 |
| b. Distribution System Pipeline Modification and Additional Pipeline...................... | feet | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8,000 |

1/ No indicates reservoir not utilized by plan.

Table II-3
Summary of Cost of Agricultural Irrigation Elements[1/]

| Element | Alternative Plan 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | - - - - - - | - - - - - - | - - - - - - | - - - - - - | - - - - dol | lars - - - | - - - - - - | - - - - - - | - - - - | |
| I. AGRICULTURAL IRRIGATION SYSTEM(S) | | | | | | | | | | |
| A. IMPLEMENTATION COSTS | | | | | | | | | | |
| 1. Structural Measures | | | | | | | | | | |
| a. Reservoir Restoration | | | | | | | | | | |
| (1) Stone Dam Reservoir | 455,000 | 455,000 | 455,000 | 455,000 | - | - | 455,000 | - | 455,000 | - |
| (2) Ka Loko Reservoir | - | - | - | - | 1,615,000 | 1,615,000 | 1,615,000 | 1,615,000 | 1,615,000 | 1,615,000 |
| b. Ka Loko Ditch Restoration | - | - | - | - | 255,000 | 305,000 | 255,000 | 305,000 | 305,000 | 255,000 |
| c. Pump Station | 140,000 | 210,000 | 335,000 | - | - | - | 210,000 | - | 355,000 | - |
| d. Concrete Tank | 210,000 | 470,000 | 610,000 | - | - | - | 470,000 | - | 610,000 | - |
| e. Pipeline From Pump Station To Concrete Tank | 45,000 | 100,000 | 145,000 | - | - | - | 100,000 | - | 145,000 | - |
| . Distribution System(s) | | | | | | | | | | |
| (1) Pipeline | 380,000 | 1,000,000 | 1,910,000 | - | 1,670,000 | 1,950,000 | 2,670,000 | 3,560,000 | 3,860,000 | 1,670,000 |
| (2) Concrete Ditch | - | - | - | 6,675,000 | - | - | - | - | - | - |
| Subtotal (Structural Measures) | 1,230,000 | 2,235,000 | 3,455,000 | 7,130,000 | 3,540,000 | 3,870,000 | 5,775,000 | 5,560,000 | 7,325,000 | 3,540,000 |
| 2. Land and Water Rights | | | | | | | | | | |
| a. Land and Water Rights For Reservoirs | | | | | | | | | | |
| (1) Stone Dam Reservoir | 100,000 | 100,000 | 100,000 | 100,000 | - | - | 100,000 | - | 100,000 | - |
| (2) Ka Loko Reservoir | - | - | - | - | 420,000 | 420,000 | 420,000 | 420,000 | 420,000 | 420,000 |
| b. Land Rights For Other Structural Elements | 30,000 | 75,000 | 75,000 | 390,000 | 90,000 | 95,000 | 165,000 | 115,000 | 170,000 | 90,000 |
| Subtotal (Land and Water Rights) | 130,000 | 175,000 | 175,000 | 490,000 | 510,000 | 515,000 | 685,000 | 535,000 | 690,000 | 510,000 |
| 3. Project Administration and Engineering Services | 150,000 | 270,000 | 415,000 | 945,000 | 425,000 | 465,000 | 695,000 | 670,000 | 880,000 | 425,000 |
| TOTAL IMPLEMENTATION COSTS | 1,510,000 | 2,680,000 | 4,045,000 | 8,565,000 | 4,475,000 | 4,850,000 | 7,155,000 | 6,765,000 | 8,895,000 | 4,475,000 |
| AVERAGE ANNUAL IMPLEMENTATION COSTS[2/] | 125,200 | 222,200 | 335,400 | 710,200 | 371,000 | 402,200 | 593,300 | 561,000 | 737,600 | 371,100 |
| B. AVERAGE ANNUAL OPERATION AND MAINTENANCE (O&M) COSTS | | | | | | | | | | |
| 1. Pumping Costs | 14,900 | 22,100 | 44,600 | - | - | - | 22,100 | - | 44,600 | - |
| 2. Other Costs | 63,100 | 91,300 | 96,300 | 275,200 | 101,300 | 106,300 | 192,600 | 189,400 | 202,600 | 101,300 |
| TOTAL AVERAGE ANNUAL O&M COSTS | 78,000 | 113,400 | 140,900 | 275,200 | 101,300 | 106,300 | 214,700 | 189,400 | 247,200 | 101,300 |
| C. TOTAL AVERAGE ANNUAL COST OF AGRICULTURAL IRRIGATION SYSTEM(S) | 203,200 | 335,600 | 476,300 | 985,400 | 472,400 | 508,500 | 808,000 | 750,400 | 984,800 | 472,400 |

Table II-3 (continued)
Summary of Cost of Agricultural Irrigation Elements[1/]

| Element | Alternative Plan | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | dollars | | | | | | | | | |
| II. ASSOCIATED MEASURES | | | | | | | | | | |
| A. IMPLEMENTATION COSTS | | | | | | | | | | |
| 1. Land Treatment Measure(land smoothing) | - | 64,000 | 139,000 | 133,000 | 75,000 | 143,000 | 139,000 | 139,000 | 282,000 | 75,000 |
| 2. Technical Assistance | - | 5,000 | 11,000 | 11,000 | 6,000 | 11,000 | 11,000 | 11,000 | 22,000 | 6,000 |
| TOTAL IMPLEMENTATION COSTS | - | 69,000 | 150,000 | 144,000 | 81,000 | 154,000 | 150,000 | 150,000 | 304,000 | 81,000 |
| B. TOTAL AVERAGE ANNUAL COST OF ASSOCIATED MEASURES[2/][3/] | - | 5,700 | 12,400 | 11,900 | 6,700 | 12,800 | 12,400 | 12,400 | 25,200 | 6,700 |
| III. TOTAL COST OF ALL AGRICULTURAL IRRIGATION ELEMENTS | | | | | | | | | | |
| A. IMPLEMENTATION COSTS | | | | | | | | | | |
| 1. Agricultural Irrigation System(s) | 1,510,000 | 2,680,000 | 4,045,000 | 8,565,000 | 4,475,000 | 4,850,000 | 7,155,000 | 6,765,000 | 8,895,000 | 4,475,000 |
| 2. Associated Measures | - | 69,000 | 150,000 | 144,000 | 81,000 | 154,000 | 150,000 | 150,000 | 304,000 | 81,000 |
| TOTAL IMPLEMENTATION COSTS | 1,510,000 | 2,749,000 | 4,195,000 | 8,709,000 | 4,556,000 | 5,004,000 | 7,305,000 | 6,915,000 | 9,199,000 | 4,556,000 |
| AVERAGE ANNUAL IMPLEMENTATION COSTS | 125,200 | 227,900 | 347,800 | 722,100 | 377,800 | 415,000 | 605,700 | 573,400 | 762,800 | 377,800 |
| B. AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS (IRRIGATION SYSTEMS ONLY) | 78,000 | 113,400 | 140,900 | 275,200 | 101,300 | 106,300 | 214,700 | 189,400 | 247,200 | 101,300 |
| C. TOTAL AVERAGE ANNUAL COST OF ALL AGRICULTURAL IRRIGATION ELEMENTS | 203,200 | 341,300 | 488,700 | 997,300 | 479,100 | 521,300 | 820,400 | 762,800 | 1,010,000 | 479,100 |

1/ 1983 dollars.
2/ Total implementation outlays amortized at 8-1/8% interest for 50 years (project life).
3/ There are no operation and maintenance costs for the associated measures.

Table II-4
Cost of Hydroelectric Power Elements in Alternative Plan 10 1/

| Element | Cost |
|---|---|
| I. HYDROELECTRIC POWER FACILITIES | |
| A. IMPLEMENTATION COSTS | |
| 1. Structural Measures | |
| a. Hydroelectric Turbines | $ 91,000 |
| b. Distribution System Pipeline Modification and Additional Pipeline | 287,000 |
| Subtotal (Structural Measures) | $378,000 |
| 2. Land Rights for Additional Pipeline | 13,000 |
| 3. Project Administration and Engineering Services | 45,000 |
| TOTAL IMPLEMENTATION COSTS | $436,000 |
| AVERAGE ANNUAL IMPLEMENTATION COSTS 2/ | 36,200 |
| B. AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS | 9,400 |
| C. TOTAL AVERAGE ANNUAL COST OF HYDROELECTRIC POWER ELEMENTS | $ 45,600 |

1/ 1983 price base.
2/ Total implementation outlays amortized at 8-1/8% interest for 50 years.

Table II-5A
Effectiveness of the Alternative Plans 1 through 5

| Problem, Opportunity, or Concern | Unit | Conditions: Present 1/ | Conditions: Future 2/ | Alternative Plan: 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| I. Reduced Farm Income (Lack of Adequate Water Sys.) | av. ann. dollars | 8,000 | 32,000 | 14,700 | 14,700 | 14,700 | 31,400 | 17,100 |
| Problem Reduction | av. ann. dollars | -3/ | - | 17,300 | 17,300 | 17,300 | 600 | 14,900 |
| II. Reduced Farm Income (Loss of Water Supply) | av. ann. dollars | 48,000 | 48,000 | 0 | 0 | 0 | 0 | 48,000 |
| Problem Reduction | av. ann. dollars | - | - | 48,000 | 48,000 | 48,000 | 48,000 | 0 |
| III. Limited Agricultural Opportunities | av. ann. dollars | 3,000,000 | 2,900,000 | 2,900,000 | 2,143,500 | 1,355,000 | 1,475,600 | 2,226,600 |
| Problem Reduction | av. ann. dollars | - | - | 0 | 756,500 | 1,545,000 | 1,424,400 | 673,400 |
| IV. Hydroelectric Power Development Opportunities | av. ann. dollars | 84,000 | 84,000 | 84,000 | 84,000 | 84,000 | 84,000 | 84,000 |
| Opportunities Achieved | av. ann. dollars | - | - | 0 | 0 | 0 | 0 | 0 |
| TOTAL PROBLEMS AND OPPORTUNITIES | av. ann. dollars | 3,140,000 | 3,064,000 | 2,998,700 | 2,242,200 | 1,453,700 | 1,591,000 | 2,375,700 |
| TOTAL PROBLEM REDUCTION AND OPPORTUNITIES ACHIEVED | av. ann. dollars | - | - | 65,300 | 821,800 | 1,610,300 | 1,473,000 | 688,300 |
| V. Public Water-based Recreation Development Opportunities | water surface acres | 0 | 0 | 5 | 5 | 5 | 5 | 43 |
| VI. Water Rights Concerns | | | | | | | | |
| A. Status of Water Rights | | | | | | | | |
| 1. Stone Dam Reservoir | secured/unsecured | unsecured | unsecured | secured | secured | secured | secured | - |
| 2. Ka Loko Reservoir | secured/unsecured | unsecured | unsecured | - | - | - | - | secured |

Table II-5B
Effectiveness of the Alternative Plans 6 through 10

| Problem, Opportunity, or Concern | Unit | Conditions: Present 1/ | Conditions: Future 2/ | Alternative Plan: 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|
| I. Reduced Farm Income (Lack of Adequate Water Sys.) | av. ann. dollars | 8,000 | 32,000 | 17,100 | 0 | 0 | 0 | 17,100 |
| Problem Reduction | av. ann. dollars | - | - | 14,900 | 32,000 | 32,000 | 32,000 | 14,900 |
| II. Reduced Farm Income (Loss of Water Supply) | av. ann. dollars | 48,000 | 48,000 | 48,000 | 0 | 0 | 0 | 48,000 |
| Problem Reduction | av. ann. dollars | - | - | 0 | 48,000 | 48,000 | 48,000 | 0 |
| III. Limited Agricultural Opportunities | av. ann. dollars | 3,000,000 | 2,900,000 | 1,518,800 | 1,496,300 | 1,496,300 | 0 | 2,226,600 |
| Opportunities Achieved | av. ann. dollars | - | - | 1,381,200 | 1,403,700 | 1,403,700 | 2,900,000 | 673,400 |
| IV. Hydroelectric Power Development Opportunites | av. ann. dollars | 84,000 | 84,000 | 84,000 | 84,000 | 84,000 | 84,000 | 24,100 |
| Opportunities Achieved | av. ann. dollars | - | - | 0 | 0 | 0 | 0 | 59,900 |
| TOTAL PROBLEMS AND OPPORTUNITIES | av. ann. dollars | 3,140,000 | 3,064,000 | 1,667,900 | 1,580,300 | 1,580,300 | 84,000 | 2,315,800 |
| TOTAL PROBLEM REDUCTION AND OPPORTUNITIES ACHIEVED | av. ann. dollars | - | - | 1,396,100 | 1,483,700 | 1,483,700 | 2,980,000 | 748,200 |
| V. Public Water-based Recreation Development Opportunities | water surface acres | 0 | 0 | 43 | 48 | 43 | 48 | 43 |
| VI. Water Rights Concerns | | | | | | | | |
| A. Status of Water Rights | | | | | | | | |
| 1. Stone Dam Reservoir | secured/unsecured | unsecured | unsecured | - | secured | - | secured | - |
| 2. Ka Loko Reservoir | secured/unsecured | unsecured | unsecured | secured | secured | secured | secured | secured |

1/ 1982.
2/ Projected future conditions in the year 1990 without a plan.
3/ Not applicable.

Table II-6
National Economic Development Account Summary

| Item | Alternative Plan | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | - - - | - - - | - - - | - - - | -dollars- | - - - | - - - | - - - | - - - | - - - |
| I. AVERAGE ANNUAL BENEFITS (value to users of increased output of goods and services)1/ | | | | | | | | | | |
| A. Agricultural Irrigation...... | 64,900 | 795,200 | 1,583,700 | 1,446,400 | 661,900 | 1,369,700 | 1,457,100 | 1,457,100 | 2,953,400 | 661,900 |
| B. Hydroelectric Power.......... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 59,900 |
| AVERAGE ANNUAL BENEFITS...... | 64,900 | 795,200 | 1,583,700 | 1,446,400 | 661,900 | 1,369,700 | 1,457,100 | 1,457,100 | 2,953,400 | 721,800 |
| II. AVERAGE ANNUAL COSTS (value of resources required)1/ | | | | | | | | | | |
| A. Implementation Costs | | | | | | | | | | |
| 1. Agricultural Irrigation... | 125,200 | 227,900 | 348,800 | 722,100 | 377,800 | 415,000 | 605,700 | 573,400 | 762,800 | 377,800 |
| 2. Hydroelectric Power....... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36,200 |
| Total...................... | 125,200 | 227,900 | 348,800 | 722,100 | 377,800 | 415,000 | 605,700 | 573,400 | 762,800 | 414,000 |
| B. Operation and Maintenance Costs | | | | | | | | | | |
| 1. Agricultural Irrigation... | 78,000 | 113,400 | 140,900 | 275,200 | 101,300 | 106,300 | 214,700 | 189,400 | 247,200 | 101,300 |
| 2. Hydroelectric Power....... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9,400 |
| Total...................... | 78,000 | 113,400 | 140,900 | 275,200 | 101,300 | 106,300 | 214,700 | 189,400 | 247,200 | 110,700 |
| C. Total Costs | | | | | | | | | | |
| 1. Agricultural Irrigation... | 203,200 | 341,300 | 488,700 | 997,300 | 479,100 | 521,300 | 820,400 | 762,800 | 1,010,000 | 479,100 |
| 2. Hydroelectric Power....... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44,500 |
| AVERAGE ANNUAL COSTS......... | 203,200 | 341,300 | 488,700 | 997,300 | 479,100 | 521,300 | 820,400 | 762,800 | 1,010,000 | 524,700 |
| III. NET BENEFITS1/................. | (-)138,300 | 453,900 | 1,095,000 | 449,100 | 182,800 | 848,400 | 636,700 | 694,300 | 1,943,400 | 197,100 |
| IV. BENEFIT-COST RATIO............. | 0.3:1 | 2.3:1 | 3.2:1 | 1.5:1 | 1.4:1 | 2.6:1 | 1.8:1 | 1.9:1 | 2.9:1 | 1.4:1 |

1/ 1983 dollars, 8-1/8% interest, 50-year project life.

Table II-7
Environmental Quality and Other Social Effects Accounts Summary

| Item | Unit | Conditions | | | Alternative Plan | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Past1/ | Present2/ | Future3/ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | | | | - - - -difference in comparison to future conditions- - - - | | | | | | | | | |
| I. ENVIRONMENTAL QUALITY ACCOUNT | | | | | | | | | | | | | | |
| A. Adverse Effects | | | | | | | | | | | | | | |
| 1. Ecological Attributes | | | | | | | | | | | | | | |
| a. Streamflow | | | | | | | | | | | | | | |
| (1) Kahiliholo Stream........ | MG/yr. | 3,700 | 54 | 71 | + 16 | - 202 | - 440 | - 403 | - 655 | - 823 | - 929 | - 929 | -1,334 | - 655 |
| (2) Puu Ka Ele Stream........ | MG/yr. | 2,774 | 40 | 53 | + 12 | - 151 | - 330 | - 302 | - 491 | - 617 | - 697 | - 697 | -1,000 | - 491 |
| II. OTHER SOCIAL EFFECTS ACCOUNT | | | | | | | | | | | | | | |
| A. Beneficial Effects4/ | | | | | | | | | | | | | | |
| 1. Urban and Community Impacts | | | | | | | | | | | | | | |
| a. Domestic Water Used for Agricultural Purposes........ | MG/yr. | 0 | 3.75 | 4.00 | -4.00 | -4.00 | -4.00 | -1.00 | 0 | 0 | -4.00 | - 4.00 | - 4.00 | 0 |
| b. Agricultural Jobs............ | number | | 90 | 100 | 0 | + 32 | + 70 | + 63 | + 31 | + 65 | + 63 | + 63 | + 135 | + 31 |
| c. Farm Units Producing Irrigated Crops.............. | number | 1 | 25 | 30 | 0 | + 32 | + 70 | + 63 | + 31 | + 65 | + 63 | + 63 | + 135 | + 31 |
| 2. Long-term Productivity | | | | | | | | | | | | | | |
| a. Cropland Maintained in Agricultural Production | | | | | | | | | | | | | | |
| (1) Nonirrigated Cropland.... | acres5/ | 1,500 | 455 | 825 | 0 | 0 | 0 | 0 | - 60 | - 60 | - 60 | - 60 | - 60 | - 60 |
| (2) Irrigated Cropland....... | acres5/ | 3,200 | 175 | 290 | 0 | + 320 | + 695 | + 665 | + 375 | + 715 | + 695 | + 695 | +1,410 | + 375 |
| (3) Total Cropland........... | acres5/ | 4,700 | 630 | 1,115 | 0 | + 320 | + 695 | + 665 | + 315 | + 655 | + 635 | + 635 | +1,350 | + 315 |

1/ 1970.
2/ 1982.
3/ Projected future conditions in the year 1990 without a plan.
4/ Applies to the study area only.
5/ Acres planted.

# CHAPTER III

# OPPORTUNITIES FOR IMPLEMENTATION

The ten alternative plans presented in the previous chapter provide various options that can be pursued to alleviate the problems, achieve the opportunities, and address the concerns of the study. This chapter will identify sources of technical and/or financial assistance to implement elements in the alternative plans. Sources of assistance include various Federal and State programs or authorities, and local funding by the private sector. Implementation of any plan will require that the full initiative and responsibility be exercised by the local people through their local organizations. Sources of assistance are described below and are listed in Table III-1.

## FEDERAL ASSISTANCE

### Public Law 566

Public Law 83-566, the Watershed Protection and Flood Prevention Act, enables the Soil Conservation Service to cooperate with sponsoring State and local agencies or organizations in the planning and carrying out of works of improvement for soil conservation and other purposes, including agricultural water management. High Federal priority for project planning will be given to those projects that address the nation's most critical water supply problems and preserve the nation's agricultural resource base. Under this authority, the Federal government can provide up to 100 percent of the technical assistance and finance up to 50 percent of the construction cost of the irrigation system(s) in the NED Plan. The NED Plan is the plan which reasonably maximizes net national economic benefits. As discussed in Chapter II, page 18, the NED Plan for this study is Alternative Plan 9. The remaining construction cost would be a local cost. The Federal government can participate in the implementation of another plan with an exception from the Secretary of Agriculture.

### Public Law 46

The Soil Conservation Service develops and carries out its National Soil and Water Conservation Program under Public Law 46, the Soil Conservation Act of 1935. The agency, through conservation districts, can provide up to 100 percent of the technical assistance that land owners and operators would need to plan and apply any conservation practices included in the plans.

### Agricultural Conservation Program

The Agricultural Conservation Program provides financial assistance to land owners and operators for the installation of conservation practices. This program is administered by the USDA Agricultural Stabilization and Conservation Service. This program provides financial assistance in the form of cost sharing, whereby the ASCS shares the cost of eligible practices with the land owners and operators. Cost share amounts vary according to the conservation practices.

### Farmers Home Administration Programs

The USDA Farmers Home Administration is authorized to make loans to local agencies or organizations sponsoring PL-566 projects. The sponsoring agencies or organizations can acquire loans from the FmHA to finance the local cost for plan elements.

The FmHA also makes loans for soil and water conservation purposes and provides financial management assistance to farm and ranch owners or operators for developing, conserving, and making proper use of their land and water resources.

## STATE ASSISTANCE

### Department of Land and Natural Resources

The Department of Land and Natural Resources, under its Division of Water and Land Development (DOWALD), is the agency responsible for implementing water development projects for the State. DOWALD's water development program puts emphasis on increasing the availability of agricultural water in farming communities.

### Department of Agriculture

The Department of Agriculture's Agricultural Loan Program promotes agricultural development by making credit available to qualified farmers. The Agricultural Loan Division administers this program through a revolving fund which can be used to supplement Federal and private funds or, if necessary, make direct loans to farmers. The department can finance up to $200,000 of the cost of a soil and water conservation project of an association, or up to $35,000 of an individual's project.

## PRIVATE SECTOR

Land owners and operators in the study area could pool their resources to finance plan elements. There are several companies and individuals with large land holdings that may be willing to finance plan elements because of their agricultural interests.

Table III-1
Implementation Assistance

| Element | Federal | | | | State | | Private Sector |
|---|---|---|---|---|---|---|---|
| | PL-566 Tech. / Fin. | PL-46 Tech. | ACP Fin. | FmHA Loan | DLNR1/ Tech. & Fin. | DOA2/ Loan | Tech. & Fin. |
| | - - - - - - - - - - - maximum assistance available (percent) - - - - - - - - - - - | | | | | | |
| AGRICULTURAL IRRIGATION ELEMENTS | | | | | | | |
| I. AGRICULTURAL IRRIGATION SYSTEM(S) | | | | | | | |
| 1. Structural Measures | | | | | | | |
| a. Reservoir Restoration....... | 100/50 | 0 | 0 | 50 | 100 | 100 | 100 |
| b. Ka Loko Ditch Restoration... | 100/0 | 100 | 0 | 50 | 100 | 100 | 100 |
| c. Pump Station................ | 100/50 | 0 | 0 | 50 | 100 | 100 | 100 |
| d. Concrete Tank............... | 100/50 | 0 | 0 | 50 | 100 | 100 | 100 |
| e. Pipeline From Pump Station To Concrete Tank........... | 100/50 | 0 | 0 | 50 | 100 | 100 | 100 |
| f. Distribution System(s) | | | | | | | |
| (1) Pipeline............... | 100/50 | 0 | 0 | 50 | 100 | 100 | 100 |
| (2) Concrete Ditch.......... | 100/50 | 0 | 0 | 50 | 100 | 100 | 100 |
| 2. Land and Water Rights | | | | | | | |
| a. Land and Water Rights For Reservoirs.................. | 0/0 | 0 | 0 | 100 | 100 | 100 | 100 |
| b. Land Rights For Other Structural Measures......... | 0/0 | 0 | 0 | 100 | 100 | 100 | 100 |
| II. ASSOCIATED Measures (Land Treatment Measures).............. | 100/0 | 100 | 75 | 100 | 100 | 100 | 100 |
| HYDROELECTRIC POWER ELEMENTS | | | | | | | |
| I. HYDROELECTRIC POWER FACILITIES | | | | | | | |
| 1. Structural Elements | | | | | | | |
| a. Hydroelectric Turbines...... | 0/0 | 0 | 0 | 0 | 100 | 100 | 100 |
| b. Distribution System Pipeline Modification and Additional Pipeline......... | 0/0 | 0 | 0 | 0 | 100 | 100 | 100 |
| 2. Land Rights For Additional Pipeline...................... | 0/0 | 0 | 0 | 0 | 100 | 100 | 100 |

1/ Department of Land and Natural Resources.
2/ Department of Agriculture, Agricultural Loan Program.

# APPENDIX A

# LOCATION, CLIMATE, AND TOPOGRAPHY

# APPENDIX A

# LOCATION, CLIMATE, AND TOPOGRAPHY

## LOCATION

The study area is located in the Hanalei district on the northern side of the island of Kauai (Fig. A-1). Kauai is approximately 355,000 acres in size and is the fourth largest island in the Hawaiian chain. The study area is approximately 22,500 acres in size and is bordered by the Pacific Ocean to the north, Moloaa Valley to the east, Makaleha Mountains to the south, and the Kalihiwai area to the west.

Kilauea, the major community in the study area is located about 25 miles north of Lihue, the Kauai County seat, and about 150 miles northwest of Honolulu, the State capital. Honolulu is located on the island of Oahu.

## CLIMATE

Rainfall in the study area varies from an average of 60 inches annually along the coastline to over 100 inches annually near the mountains. Most of the rainfall occurs from October through May. An average of over 8 inches of rain falls during March, the wettest month of the year. June through September is considered the dry season. An average of only 3-1/2 inches of rain falls during June, the driest month of the year. Average annual rainfall in the study area is shown in Figure A-2.

Average annual temperatures range from 75°F. along the coastline to 68°F. near the mountains. Average annual temperatures decrease approximately 1°F. for every 300-foot increase in elevation up to 1,000 feet. The temperature decreases at a lower rate at elevations above 1,000 feet. Average annual temperatures at specific elevations fluctuate less than 10°F. between winter and summer months. Winter temperatures range from the low 60's to the mid-70's and summer temperatures range from the high 60's to the low 80's.

Relative humidity is moderate to high throughout the year, but is slightly higher in the wet season than the dry. Tradewinds provide a system of natural ventilation during most of the year so that periods of high temperature and humidity are seldom uncomfortable.

Although the tradewinds blow steadily during most of the year, completely cloudless skies are rare. Cloud cover averages around 60-70 percent during the daylight hours year-round.

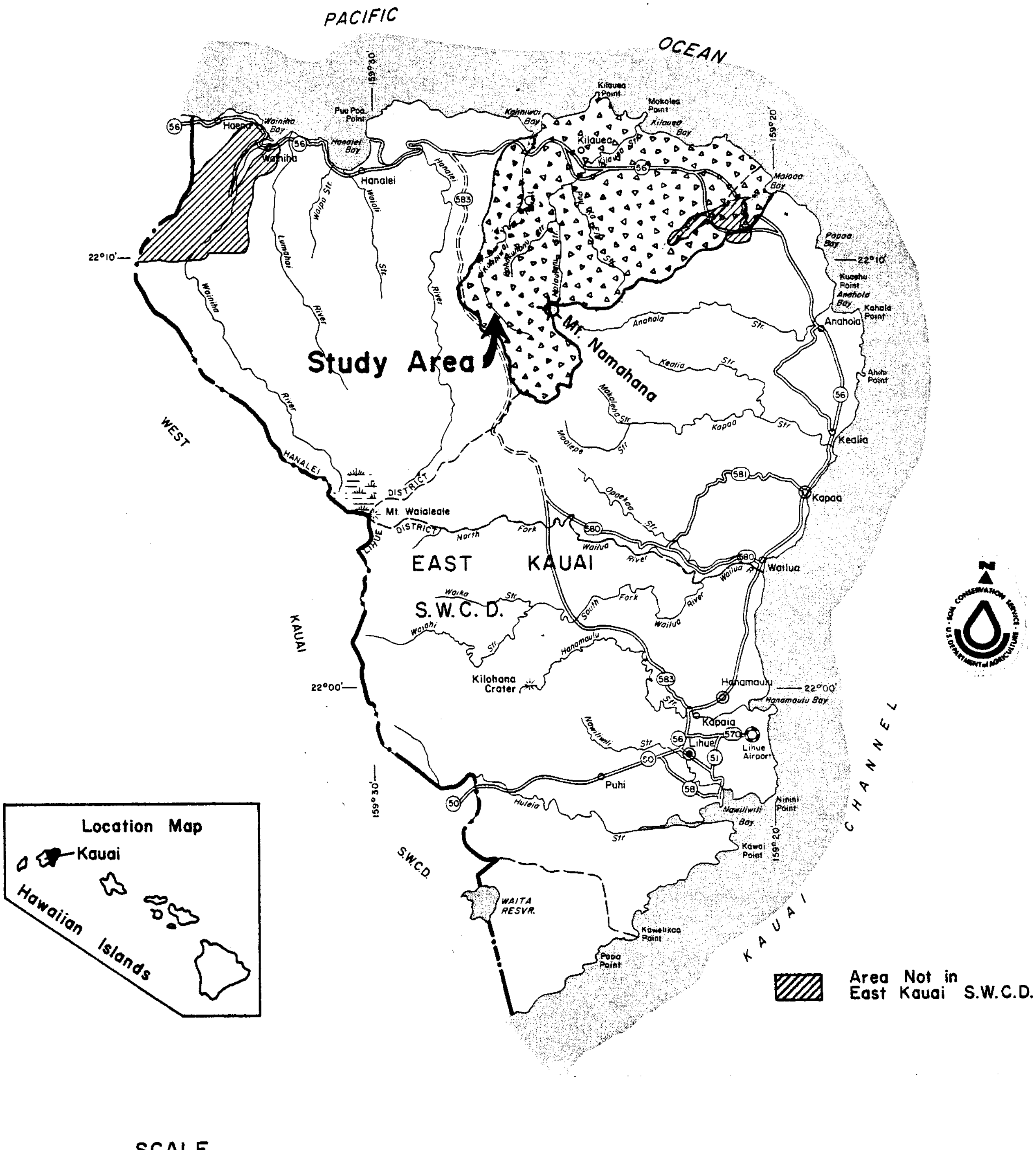



FIGURE A-1
# LOCATION MAP

Kilauea Agricultural Water Management Study

Kilauea, Kauai, Hawaii

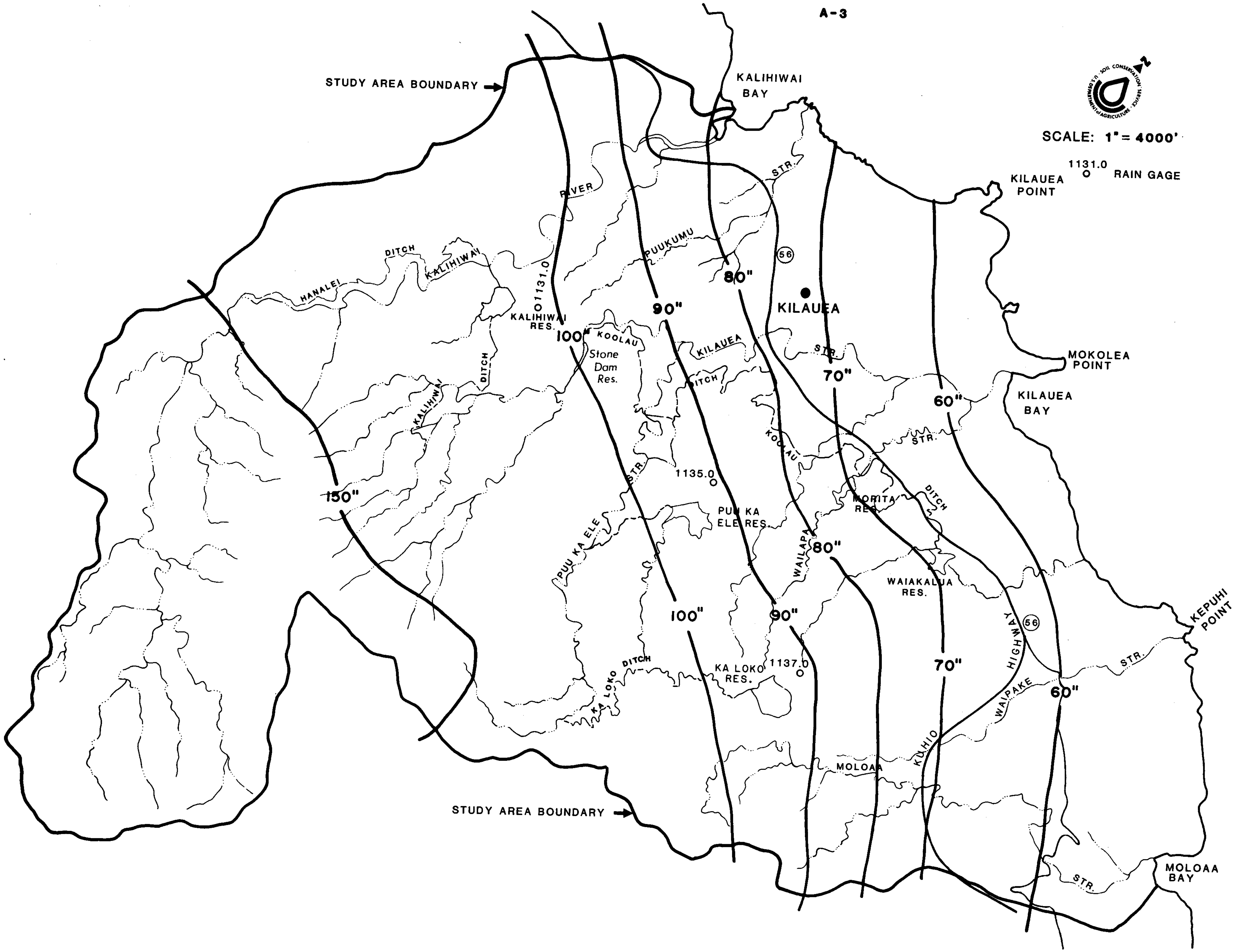



FIGURE A-2
AVERAGE ANNUAL RAINFALL

KILAUEA AGRICULTURAL WATER
MANAGEMENT STUDY

## TOPOGRAPHY

Kauai is the oldest island in the Hawaiian chain. It was formed principally from a huge shield volcano, making the central section of the island mountainous. Because the island is roughly circular in shape, the topography is similar around the island. The interior mountain ridges are more actively eroded because of the rainfall pattern. The dissection has been less intense toward the coast, resulting in amphitheater-headed valleys with wedge-shaped gently sloping uplands.

The topography of the study area is similar to other areas on Kauai. The terrain along the coast is relatively flat, rising gradually towards the mountains before merging with the steep forested mountain area. The highest elevation in the study area is about 3,000 feet. Several streams in the study area have cut gulches that run from the base of the mountains to the sea. Of the 22,500-acre study area, about 12,300 acres are gently sloping uplands, 9,100 acres are steep gulches, and 1,100 acres are alluvial valleys and terraces.

The coastline of the study area consists mainly of steep cliffs which sometimes drop 100 or more feet from cliff top to ocean. Steep high cliffs are common along the northern coastlines of all the islands, where wave action is usually very intense. There are also some relatively flat sandy beaches located around the three bays in the study area.

# APPENDIX B

# HUMAN AND ECONOMIC RESOURCES

# APPENDIX B

# HUMAN AND ECONOMIC RESOURCES

Appendix B describes the human and economic resources in the study area. It provides a detailed description of the various agricultural industries, including a description of the present industries and projections for growth; market opportunities; and water-related problems. It also provides a description of the population, commercial business activity, and tourism in the study area.

This appendix is based mainly on personal interviews with study area farmers and ranchers. They were questioned about their present operations, future plans, and their water related problems and needs. Most of the major landowners were also contacted. All of the interviewing was done by SCS personnel. Information from published sources is also used.

## POPULATION

The resident population of the study area in 1980 was 971 (Table B-1). This represents a 33 percent increase over the 1970 population.

The increase in population is somewhat misleading because it does not reflect the decrease in population experienced during the early 1970's due to the closing of the Kilauea Sugar Company. The bulk of the population growth occurred after 1977. This growth was primarily caused by the in-migration of new residents rather than by the natural increase of births over deaths.

The major population center in the study area is Kilauea town. The town, once a sugar plantation community, is now a rural "bedroom" community where many of the residents commute to and from work. The town retains its rural charm and can still be characterized as open, slow paced, and informal. The present layout of the town is an expansion of the original plantation community. Some plantation houses are still occupied and many of the former plantation office buildings are used to house new businesses.

Table B-1
Population

| Area | Population | | |
|---|---|---|---|
| | 1970 | 1977 | 1980 |
| State of Hawaii | 769,913 | 916,000 | 964,691 |
| County of Kauai | 29,761 | 36,200 | 39,082 |
| Study Area | 728 | 749 | 971 |

## ECONOMY OF THE STUDY AREA

Agriculture is by far the most important industry to the economy of the study area. Agriculture employs the most people within the study area and generates the most revenues. Farmers and ranchers produce orchard crops such as guavas, papayas, and bananas; truck crops such as green peppers, eggplant, and watermelons; beef and dairy cattle; and freshwater prawns.

Other industries that play a role in the area's economy are commercial business activity and tourism. Commercial business activity is contained within Kilauea town and consists mostly of small businesses that support community needs. There are several scenic and/or historic sites in Kilauea that can be considered tourist attractions. Although no admission is charged to view the sites, tourists often stop in local stores to shop.

About half of the work force is employed within the study area. The other half of the work force commutes to work in other parts of the island. These people are employed in the retail trade or in finance, insurance, and real estate-related jobs.

## AGRICULTURE

### History

Historically, agriculture has played a major role in the economy of the study area. The entire economy was dominated by the sugar industry until the closing of the C. Brewer and Company Kilauea Sugar Company plantation. The plantation held 8,000 acres, used 4,400 to 5,000 acres for sugar activities, and employed 400 workers. Most of the study area residents worked for the plantation and lived in plantation housing. Commercial activities were geared to the plantation community. The plantation closed in 1971 due to poor financial returns for sugar. The resulting unemployment caused the population in the study area to decline through the first half of the 1970s.

After the plantation closed, several new agricultural industries were explored. Agricultural pursuits included a large scale sorghum and feed corn operation, a large scale prawn farm, various orchard and truck crops, and various livestock operations. Unfortunately, not all of these operations have been successful.

### Present Conditions, Planned and Projected Growth

About 12,465 acres out of the 22,500-acre study area are zoned for agriculture. The study area also includes 9,830 acres zoned for conservation and 205 acres zoned for urban. The areas zoned for conservation are mostly forest reserves located in the upper watershed area or shoreline and river banks. The urban areas are part of Kilauea town or are immediately adjacent to the town.

The major agricultural industries in the study area at the present time are: orchard crops, livestock, truck crops (vegetables and melons), and prawns. Present agricultural land uses are shown in Table B-2 and Figure B-1. Total agricultural production was estimated to have a farm value of $2.6 million in 1981. Orchard crops had the highest value, followed by livestock, truck crops, and prawns.

There are about 45 agricultural operations in the study area. Many of these operations produce more than one kind of agricultural product (Table B-2). For example, a farmer may raise truck crops, papayas, and cattle.

Most of the orchard and truck crop operations are located around Kilauea town (Fig. B-1). The two major sources of water for these orchard and truck crop operations are the County of Kauai domestic water system and the Stone Dam-Mill Ditch system, part of the former Kilauea Sugar Company irrigation system. Pasture areas are located below 600 feet elevation from Kilauea town eastward to Moloaa and also along the western side of the study area. Stockwater comes from streams and springs, and from Kilauea Sugar Company irrigation system reservoirs and distribution ditches. The only aquaculture operation in the study diverts water from the Ka Loko Reservoir.

The study area has great potential for increased agricultural production. However, it is difficult to predict what the agriculture industry will be like in the future because of the water-related problems and the ever changing land use and ownership situation.

One of the major problems facing the agricultural industry in the study area is net income losses due to the lack of an adequate agricultural water distribution system. The present water systems (domestic and Kilauea Sugar Company systems) are unable to deliver enough water to the present agricultural users. There are also some water quality and water rights problems associated with using water from the sugar company's system.

At the present time, there are 4,955 acres of land zoned for agriculture that are not used for agricultural production of any kind. Some of this land is idle because of the lack of an adequate water distribution system or of any water system at all. Other idle areas are being held for speculation. Land values in the study area have skyrocketed in recent years. Agricultural land sold for about $7,000 per acre in 1978. Similar land is selling for $20,000-$30,000 per acre today. There is pressure to urbanize some of the idle areas north of Kilauea town. Some of the lots in the area zoned for agricultural use are actually country estates.

Five agricultural subdivisions were recently developed in the study area. Hawaiiana Investment Company, a subsidiary of C. Brewer, developed four of the five subdivisions. Most of the lots in two of the subdivisions, Kilauea Farm and the Waiakalua Farm have been sold. The lots in the other two subdivisions were put on sale in 1982. Most of the land in the four subdivisions have 20-year deed covenants restricting land use to agriculture until 1997. Beta Pacific Inc. developed the fifth subdivision, Kahili Makai, on former Lucas Estate land. The lots in this subdivision will be put on sale sometime in the near future. All of the lots in the five subdivisions were sold or will be sold on a fee simple basis. The lots range in size from 10-100 acres, with the average lot about 15 acres.

Another subdivision, the Wailapa subdivision, which has not been farmed since it was developed, is now showing signs of agricultural activity. A farmer has leased some of the lots and is growing papayas. The farmers in this subdivision have installed their own irrigation pipeline from the Morita Reservoir.

Hawaiiana Investment may install two agricultural water systems to service its four subdivisions. One system will use the Ka Loko Reservoir as a water source and the other system will use the Kahiliwai Reservoir as a water source.

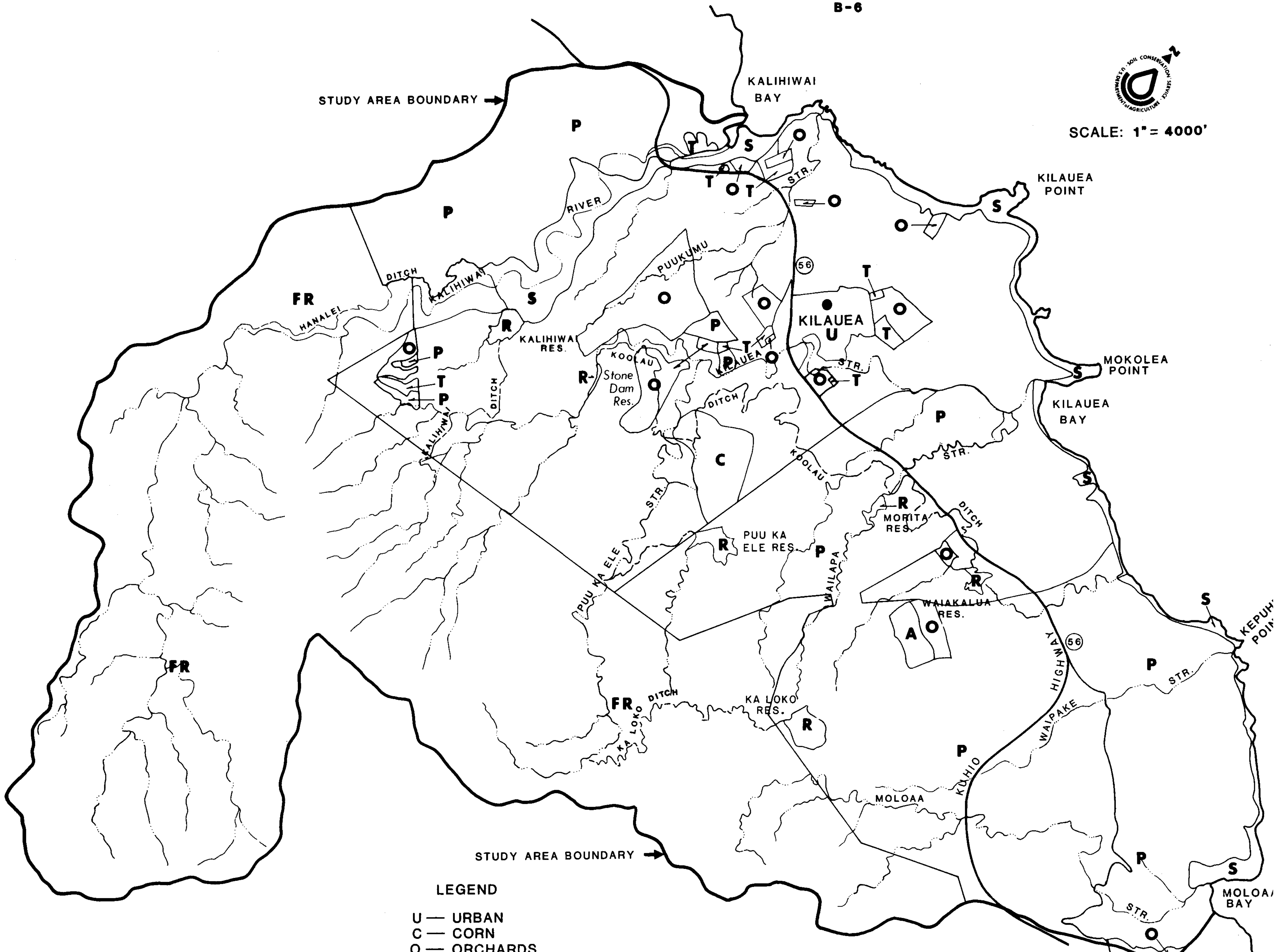
Projected land use in 1990 is shown in Table B-3 and Figure B-2. The figures are based on the future land use plans of the farmers, ranchers, and landowners in the study area. The figures include projected land use changes in the Wailapa subdivision only. Projected land use changes for the five recently developed agricultural subdivisions were not included.

About 65 percent of the farmers and ranchers in the study area were personnally interviewed. Representatives of the major landowners were also contacted.

Table B-2
Agricultural Land Use - 1982

| Land Use | Number of Operations 1/ | Gross Farm Acreage 2/ | Acreage Used 3/ Irrigated | Acreage Used 3/ Nonirrigated | Idle Farm Acreage 4/ |
|---|---|---|---|---|---|
| Orchards | | | | | |
| Guavas | 1 | 350 | 0 | 300 | 50 |
| Papayas | 14 | 165 | 100 | 5 | 60 |
| Bananas | 8 | 50 | 10 | 5 | 35 |
| Macadamia Nuts | 1 | 5 | 0 | 5 | 0 |
| Pasture | 15 | 6,680 | 0 | 3,845 | 2,835 |
| Feed Corn | 1 | 140 | 0 | 140 | 0 |
| Truck Crops | 14 | 60 | 30 | 0 | 30 |
| Prawns | 1 | 60 | 35 5/ | 0 | 25 |
| Total | 55 | 7,510 | 175 | 4,300 | 3,035 |
| Idle Ag Land | | 4,955 6/ | | | |
| Total Zoned for Ag | | 12,465 | | | |

1/ Includes some double counting of operations. Some operations produce more than one kind of agricultural product.
2/ Total farm or ranch operation acreage or portion of total acreage set aside for the particular land use.
3/ Acres out of gross farm or ranch acreage actually planted in crops or grazed.
4/ Acres out of gross farm or ranch acreage not used for production purposes. For crop farms this area may be in fallow, used for farm dwellings, buildings, or roads. For ranches (pasture) this area is mostly brush covered land on the ranch that is not grazed.
5/ Acres of ponds.
6/ Land zoned agriculture - not used for agricultural production.




LEGEND

U — URBAN
C — CORN
O — ORCHARDS
P — PASTURE
A — PRAWNS
T — TRUCK CROPS
FR — FOREST RESERVE
S — SHORELINE & RIVERWAY
R — RESERVOIR
— IDLE

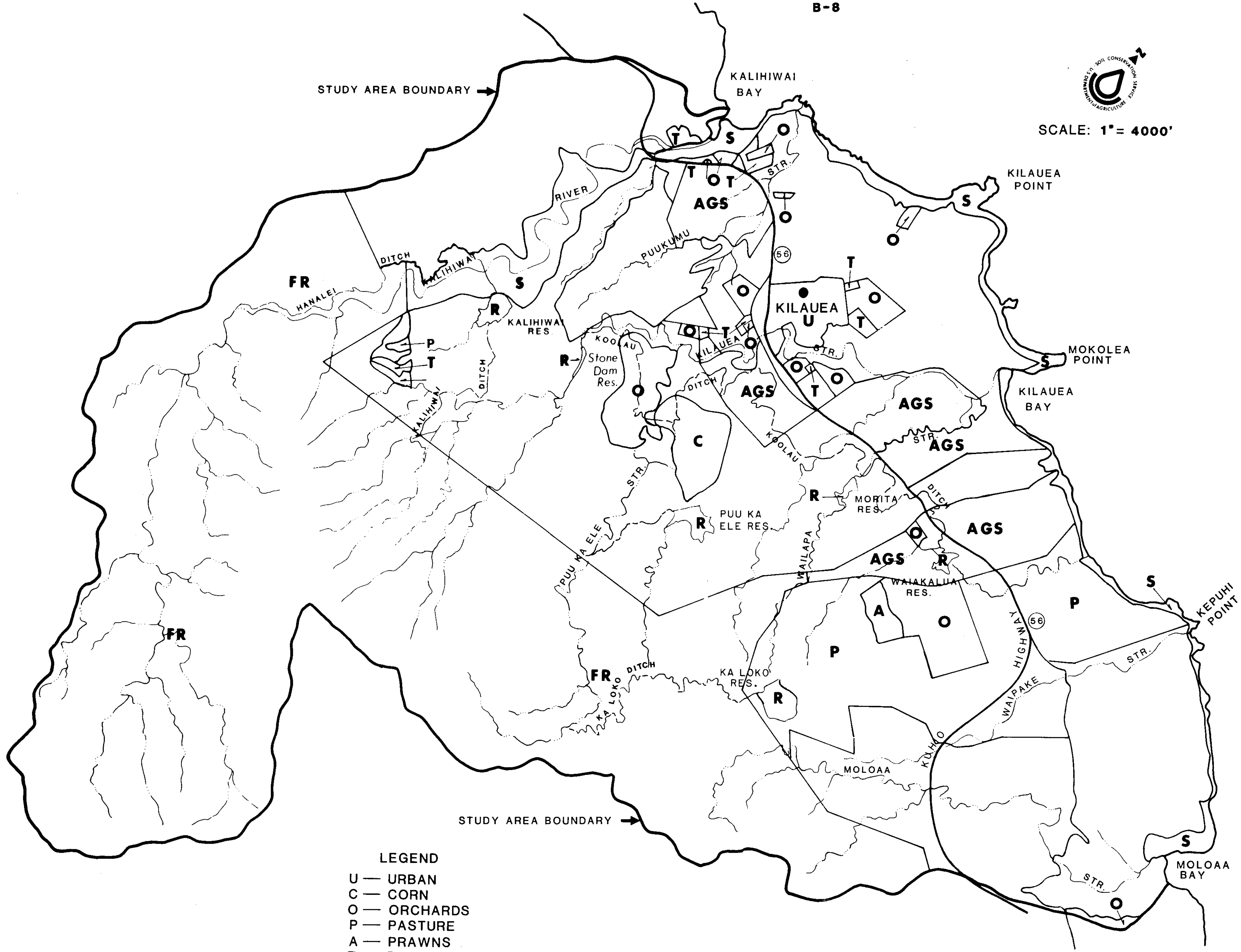
FIGURE B-1
PRESENT LAND USE

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

Table B-3
Agricultural Land Use - 1990

| Land Use | Operations[1/] | Acreage[2/] | Acreage Used[3/] Irrigated | Acreage Used[3/] Nonirrigated | Idle Farm Acreage[4/] |
|---|---|---|---|---|---|
| Orchards | | | | | |
| Guavas | 1 | 350 | 0 | 300 | 50 |
| Papayas | 16 | 255 | 185 | 5 | 65 |
| Bananas | 9 | 65 | 25 | 15 | 25 |
| Macadamia Nuts | 1 | 5 | 0 | 5 | 0 |
| Other Crops | 1 | 300 | 0 | 300 | 0 |
| Pasture | 16 | 6,620 | 0 | 3,785 | 2,835 |
| Feed Corn | 1 | 200 | 0 | 200 | 0 |
| Truck Crops | 15 | 60 | 45 | 0 | 15 |
| Prawns | 1 | 60 | 35[5/] | 0 | 25 |
| Total | 62 | 7,915 | 290 | 4,610 | 3,015 |
| Idle Ag Land | | 4,550[6/] | | | |
| Total Zoned for Ag | | 12,465 | | | |

1/ Includes some double counting of operations. Some operations produce more than one kind of agricultural product.
2/ Total farm or ranch operation acreage or portion of total acreage set aside for the particular land use.
3/ Acres out of gross farm or ranch acreage actually planted in crops or grazed.
4/ Acres out of gross farm or ranch acreage not used for production purposes. For crop farms this area may be in fallow, used for farm dwellings, buildings, or roads. For ranches (pasture) this area is mostly brush covered land on the ranch that is not grazed.
5/ Acres of ponds.
6/ Land zoned agriculture - not used for agricultural production.




LEGEND

U — URBAN
C — CORN
O — ORCHARDS
P — PASTURE
A — PRAWNS
T — TRUCK CROPS
— IDLE
R — RESERVOIR
AGS —AGRICULTURAL SUBDIVISION
FR — FOREST RESERVE
S — SHORELINE & RIVERWAY

FIGURE B-2
PROJECTED LAND USE-1990

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## Market Opportunities and Growth Potential

When discussing increased agricultural production, it is also important to consider the market opportunities and growth potential for the various industries. The information presented in the following section is based on Appendix F of the publication "Statewide Agricultural Park Action Plan, Phase I, Program Assessment." The publication was prepared for the Governor's Agricultural Coordinating Committee by H. Mogi Planning and Research, Inc.

Table B-4 presents the estimated 1990 acreage needs for truck crops and bananas. The 1990 additional market opportunity is the amount of production needed over the current market supply to fulfill 95 percent of the projected 1990 local market need. The 1990 local market need was determined by multiplying average per capita consumption rates by the projected state population in 1990. The additional harvested acres needed are the additional market opportunity divided by the average yield per crop acre. The additional planted acres are the harvested acres divided by the average number of crops grown per year.

Table B-4
Estimated 1990 Acreage Needs for Truck Crops and Bananas

| Commodity | 1980 1/ Production (1,000 lbs.) State | Production (1,000 lbs.) Kauai | Acres Harvested State | Acres Harvested Kauai | 1990 Additional Mkt. Opportunity for the State 2/ (1,000 lbs.) | 1990 Additional Acres Needed 2/ Harvested | Planted 3/ |
|---|---|---|---|---|---|---|---|
| Truck Crops 4/ | 70,710 | 1,460 | 4,200 | 100 | 112,566 | 7,971 | 3,839 |
| Bananas | 4,600 | 770 | 580 | 45 | 10,471 | 1,138 | 1,138 |

1/ Statistics of Hawaiian Agriculture 1981, Hawaii Agricultural Reporting Service, June 1982.
2/ Statewide Agricultural Park Action Plan, Phase I Program Assessment; prepared for: State of Hawaii, Governor's Agriculture Coordinating Committee; prepared by: H. Mogi Planning and Research, Inc., March 17, 1982.
3/ Planted areas = harvested acres ÷ crops grown per year.
4/ Vegetables and melons.

At the present time, Hawaii's farmers produce about 40 percent of the truck crops (fresh vegetables and melons) consumed locally. Out of the 34 basic vegetable crops, Hawaii is self-sufficient in only 13. An additional 7,971 harvested acres and 3,839 planted acres are needed to meet the additional market opportunity in 1990 (Table B-4). There is potential for local farmers to increase their share of the market for certain vegetables. These vegetables include beans, broccoli, carrots, cauliflower, celery, sweet corn, cucumbers, eggplant, ginger root, head lettuce, dry onions, green peppers, potatoes, squash, sweet potatoes, and tomatoes. Consideration must be given to Hawaii's ability to compete with mainland imports. Goals of self-sufficiency may be possible for certain vegetables if certain bottlenecks are overcome. One of the main problems is the lack of sufficient land at appropriate cost to allow expansion. Four vegetables - Chinese cabbage, mustard cabbage, head lettuce, and watercress have been identified as having potential for export to the mainland market.

Bananas are one of the major fruits being produced in quantity locally, not associated with export commodities. Hawaii was once 100 percent self-sufficient in banana production. Current market share is about 32 percent.

An additional 1,138 acres of bananas are needed to meet the additional market opportunity in 1990 (Table B-4). There is potential to meet this need and capture 100 percent of the market if certain problems are overcome. Major problems include the industry's inability to produce fruits of uniform quality and lack of sufficient suitable land.

Table B-5 presents the estimated 1990 additional market opportunity and land needs for livestock. The 1990 95-percent market demand (column 4) represents the projected 1990 population of the state multiplied by 95 percent of the average per capita consumption (column 3). The 1990 additional market opportunity (column 5) is the amount of production needed over the current 1980 market supply to meet the 1990 95-percent market demand.

Hawaii's ranches are currently able to meet almost all of the market demand for milk and eggs. The potential for these industries would be to grow with the population and the visitor industry of Hawaii. Another possibility for eggs would be to export to other Pacific Isles.

Table B-5*
Livestock - Estimated 1990 Additional Market Opportunity and Land Needs

| Commodity | State Production1/ (1,000 lbs.) | Av. per Capita Consumption (lbs.) | 1990-95% Mkt. Demand (1,000 lbs.) | 1990 Add'l Mkt. Opport. | Yield/Acre (1,000 lbs.) | Add'l Acre Need 1990 Mkt. Opport. |
|---|---|---|---|---|---|---|
| Dairy (milk) | 152,000 | 150.8 | 185,4542/ | 33,454 | 3803/ | 88 |
| Beef and Veal | 28,809 | 93.2 | 108,886 | 80,077 | N/A | N/A |
| Pork | 8,012 | 32.1 | 37,503 | 29,491 | 18 | 1,638 |
| Poultry | 7,890 | 29.7 | 34,699 | 26,809 | 175 | 153 |
| Eggs (1,000 da.) | 18,400 | 20.7 | 23,834 | 5,434 | N/A | N/A |

1/ Statistics of Hawaiian Agriculture 1981, Hawaii Agricultural Reporting Service, June 1982.
2/ 100 percent market.
3/ Current yield per existing farm acreage not producing acres.

*Source of figures in table (unless otherwise noted): Statewide Agricultural Park Action Plan, Phase I Program Assessment; prepared for: State of Hawaii, Governor's Agricultural Coordinating Committee; prepared by: H. Mogi Planning and Research, Inc., March 17, 1982.

At the present time, Hawaii's ranchers are able to supply about 30 percent of the beef and veal, 23 percent of the pork, and 24 percent of the poultry consumed locally. For these industries, it would not be realistic to expect Hawaii's ranchers to reach the 1990 additional market opportunity levels as shown in Table B-5. A realistic goal for the beef and veal industry would be to maintain the current level of feedlot cattle production with a small increase in range cattle production. A realistic goal for the pork industry would be to maintain its existing 23 percent share of the market. Pork production would have to increase by about 13 percent or one million pounds to maintain a 23 percent share of the market in 1990. There is great potential to increase poultry production and capture a larger share of the market.

Hawaii's agriculture industry was once almost entirely dependent on sugar and pineapple as export commodities. Increasing production costs, depressed markets and prices, and urban pressure have forced several sugar and pineapple plantations to shut down. Many of the remaining plantations are struggling for survival. This situation has emphasized the need to diversify the agriculture industry in Hawaii.

There are several commodities which show potential for further development as mainland U.S. and foreign export items. They include flower and nursery products, macadamia nuts, papayas, guavas, and aquacultural products. Growth in these industries over the past decade has been tremendous. Table B-6 shows the estimated land requirements for these commodities.

Table B-6*
Estimated Land Required for Export Commodities

| Commodity | 1980 Acreage in Crop | 1990 Estimated Acreage | Additional Acreage |
|---|---|---|---|
| Flowers and Nursery | 1,447 1/ | 3,750 2/ | 2,303 |
| Macadamia Nuts | 13,400 3/ | 24,769 4/ | 11,369 |
| Papaya | 2,971 5/ | 6,500 6/ | 3,529 |
| Guava | 975 7/ | 1,328 8/ | 353 |
| Aquaculture | 500 | 5,892 9/ | 5,392 |
| Total | 19,293 | 42,239 | 22,946 |
| Approximate | 19,000 | 42,000 | 23,000 |

1/ DOA, Statistics of Hawaiian Agriculture, 1980.
2/ Ten percent average annual growth.
3/ DOA, Statistics of Hawaiian Agriculture, 1980.
4/ UH College of Tropical Agriculture and Human Resources Industry Analyses.
5/ Acres in crop, Papaya Administrative Committee Annual Report, 1980.
6/ UH College of Tropical Agriculture and Human Resources Industry Analysis, 1984 projection.
7/ DOA, Statistics of Hawaiian Agriculture, 1980.
8/ 1983 projection, Hawaii's Guava Industry, DPED, 1981.
9/ Acquaculture Development for Hawaii, 1978.

*Source of table: Statewide Agricultural Park Action Plan, Phase I, Program Assessment; prepared for: State of Hawaii, Governor's Agricultural Coordinating Committee; prepared by: H. Mogi Planning and Research, Inc., March 17, 1982.

The farm value of the flower and nursery product industry has increased 167 percent, from about $10 million in 1975 to over $26 million in 1980. The 1990 estimated acreage for flowers and nursery shown on Table B-6 reflects an average annual growth rate of 10 percent.

From 1971 to 1980 the pounds of in-shell macadamia nuts produced increased 104 percent. Macadamia nuts had a farm value of $20.65 million in 1980. The 1990 estimated acreage for macadamia nuts is 24,769. This amount reflects the reasonable market potential for the industry in 1990, which is equivalent to the fully developed market in the United States.

Papaya production increased from 39.9 million pounds and $5.6 million (farmgate value) in 1975 to 48.9 million pounds and almost $10 million in 1980. Of the 48.9 million pounds produced in 1980, 45.4 million pounds were consumed as fresh fruit and 3.5 million pounds were processed. It is estimated the fresh fruit sales will reach 100 million pounds by 1984. Land requirements for an estimated 100 million pounds are 6,500 acres (Table B-6).

Guava production is one of the fastest growing sectors of diversified agriculture in Hawaii. Acres in crop increased from 356 acres in 1975 to 975 acres in 1980. Production increased from 987,000 pounds to 7,520,000 pounds and from $79,000 to $865,000 during the same time period. An estimated 1,328 acres of guavas will be in crop by 1990 (Table B-6).

In 1976, the 235 acres of aquaculture ponds in the state produced 94,000 pounds of fresh water and marine species. In 1980, there were 558 acres of ponds and production was about 320,000 pounds. Farmgate value was $209,900 in 1976 and $1,497,000 in 1980. Projected land requirements for 1990 are 5,892 acres (Table B-6).

## Description of the Agricultural Industries

### Orchard Crop Industry

The major orchard crops grown in the study area are guavas, papayas, and bananas. Production from these crops had an estimated farm sales value of $1.6 million in 1981. A five-acre macadamia orchard was recently planted in the study area, but will not be in production for about five years. Some farmers have plans to grow other types of orchard crops such as citrus trees, avocados, and lychee.

There are 20 farms in the study area that produce orchard crops. Four of these farms grow both papayas and bananas (Table B-2). Gross orchard crop farm area is 570 acres. Out of the 570 acres, 425 acres are planted.

The guava industry got a big boost in 1977 when Kilauea Agronomics, Inc., a subsidiary of C. Brewer and Company, began operation of a guava farm in Kilauea. It is the only guava farm in the study area and is the largest of its kind in the state with 350 total farm acres and 300 acres planted. Of the 300 acres, 200 acres are in full production. None of these acreages are presently irrigated although Kilauea Agronomics has the capability to irrigate all of its orchards with water from Stone Dam or the Kalihiwai or Puu Ka Ele reservoirs.

Kilauea Agronomics also has a guava processing plant capable of turning raw fruit into puree. The puree is mainly used for juice, jam, and jelly. Domestic water is used in the processing plant.

Guava trees start bearing fruit about 3 years after planting and reach full production 3 to 4 years later. Average yield at maturity is 35,000 pounds/acre/year.

Kilauea Agronomics had originally planned to expand its guava orchards to 600 acres but have since suspended those plans. Higher than anticipated yields produced an oversupply of guavas in 1981. Kilauea Agronomics may also use some additional C. Brewer lands to grow other types of orchard crop in the future.

Papaya is an important export crop for the state as well as for the study area. Hawaii's farmers produced 66.4 million pounds of papaya in 1981. About 70 percent of this production was marketed outside the state. Major markets included California and Japan.

About 13 percent of the papaya produced in the state is grown on the Island of Kauai. Kauai's farmers produced 7.2 million pounds of papaya in 1981. Of the 340 acres in papaya, 245 acres were in production and 95 acres were nonbearing-age trees.

There are 14 farms in the study area that produce papayas. These farms have a total farm area of 165 acres. About 105 of the 165 acres are presently planted (Table B-2). Two of the 14 farms have over 20 acres of papaya planted. The other farms have anywhere from 1 to 8 acres planted.

There is a 26-member papaya cooperative (Moloaa Farmers Cooperative) located in Moloaa, an area along the eastern boundary of the study area. Moloaa is the major papaya producing area in Kauai with about 300 acres in production under normal conditions. About three of the cooperative's members have papaya fields located within the study area.

Most of the farmers keep a stand of papaya for a total of 3 years. It takes almost a year for papaya trees to mature and start to bear fruit. The papayas are then harvested over a period of 2 years. Farmers obtain yields ranging from 23,000 to 90,000 pounds/acre/harvest year.

The majority of the papaya orchards are drip irrigated. Irrigation is required during the entire growth period of the plant. Water for irrigation comes from two main sources, the domestic water system and the Stone Dam-Mill Ditch system. One of the papaya farms, Kauai Papaya, uses the effluent from the Prawns of Hawaii aquaculture operation for irrigation water. The papaya farmers in Moloaa use water from the Moloaa Farmers Cooperative's well.

Seven of the 14 papaya farmers presently use the county domestic water system to irrigate their crops. Some farmers must use the domestic system because it's their only source of water. Other farmers prefer to use the domestic system although they are able to use the Mill Ditch system.

Farmers using domestic water are faced with several problems. The domestic water supply in Kilauea is limited, thus meters are limited to five-eighths of an inch in size. Because of the limited meter size, some of the farmers are not able to efficiently use all of their resources.

Some farmers are only able to irrigate small sections at a time and must sometimes irrigate 24 hours a day to cover all their fields. Different irrigation system sections must be closed and opened every 2-4 hours. This requires a lot of unnecessary labor. Other farming operations must also be adjusted to accommodate the irregular irrigation schedule.

Three out of the 14 papaya growers use the Mill Ditch for their source of water. The ditch consists of open unlined and wooden flume sections. It transports water from Stone Dam to several farming areas around Kilauea town. Some unlined ditch sections are overgrown with californiagrass and silted in. The wooden flume sections are leaky and water losses are high. Stone Dam could also use some repairs. There is the possibility that sections of the ditch will cave in. If this should occur, those farmers using ditch water would be unable to irrigate, with a subsequent loss of net crop income of an estimated $48,000 on an average annual basis.

The farmers using the ditch have spent about $1,500 making repairs to the ditch. They lined some flume sections with plastic and installed 12-inch pipe in some tunnel sections. They also carry out maintenance work on the ditches on a regular basis.

Although the ditch water is free, the cost to use it is high. Farmers must run gasoline or diesel pumps to get the water out of the ditch. Because the water quality is poor, farmers often have double filter systems to remove debris from the water. These filters must be cleaned daily to prevent clogging.

The majority of the papaya farmers using the domestic water system and the Mill Ditch indicated, through interviews, that they would be interested in using water from an agricultural water system if one were developed.

Seven out of the 14 present farmers plan to expand their operations in the near future. Some of the farmers plan to expand their plantings on their present farm areas, others plan to acquire additional land. Projected papaya acreage in 1990 is shown in Table B-3.

The banana industry in the state was once larger than it is at the present time. In 1960, Hawaii's farmers produced almost 7 million pounds of bananas and commanded 100 percent of the Hawaii market. Since then, Hawaii's farmers have gradually lost their share of the market. In 1981 they produced only 6 million pounds of bananas and supplied about one-third of the total amount consumed in Hawaii. About 10 million pounds of bananas were imported from countries such as Panama and Honduras.

About 17 percent of the bananas produced in Hawaii are grown on Kauai. Kauai's farmers produced 1 million pounds of bananas in 1981. Of the 75 acres of bananas in crop, 60 acres were in production and 15 acres were nonbearing trees.

At the present time, there are eight farms that produce bananas in the study area (Table B-2). These farms have a total of 15 acres planted.

Of the total 15 acres, 10 acres are drip irrigated and 5 acres are non-irrigated. Five farmers use the domestic water system and one uses the Mill Ditch system for their supply of irrigation water. Two farmers do not irrigate their banana crops.

The banana farmers using the domestic water system and the Mill Ditch system are faced with the same kind of water problems as the papaya farmers (see pages B-13 and B-14).

Once planted, a banana orchard can be kept anywhere from 5 to 25 years. Harvesting usually begins about 15 months after planting. Williams Hybrid is the most common variety of banana grown in the study area. Average yield is 40,000 pounds/acre/year.

Two of the banana farmers in the study area plan to plant a total of 15 additional acres of bananas within the next 2 to 3 years. This would double the number of acres presently planted. Both of these farmers will plant in their present farm areas. Additional acres of bananas will also probably be planted in other areas of the study area. Projected banana acreage in 1990 is shown in Table B-3.

Livestock Industry

Hawaii's ranchers produced 28.3 million pounds (dressed weight) of beef and 150 million pounds of milk in 1981. The value of cattle and milk production rank 3 and 5, resepctively, behind sugar and pineapple production in the state. About two-thirds of the beef consumed in Hawaii came from the U.S. mainland or from foreign countries. Almost all of the fresh milk consumed in Hawaii is produced locally.

Kauai's ranchers accounted for an estimated 3.1 million pounds of beef and 5 million pounds of milk produced statewide in 1981.

There are 15 ranches in the study area that produce livestock. Eleven produce beef cattle, two produce horses, one produces dairy cattle, and one produces both beef cattle and swine. Two of the 15 ranches also produce truck and orchard crops.

Beef and dairy cattle production are the major livestock industries in the study area. Only a small number of horses and swine are raised. The following discussion of the livestock industry will therefore be limited to beef and dairy cattle production.

Beef cattle production is the major livestock industry in the study area. There are 12 ranches in the study area that raise beef cattle. These ranches graze about 2,200 head of cattle on 3,315 acres of the gross ranch acreage of 6,044. Many of the 2,729 ungrazed acres are brush covered or otherwise not suitable for grazing because of terrain or location. Most of the ranches are cow-calf-type operations.

Eleven of the 12 ranches are relatively small in size with herds of 10-100 head and grazing areas of 12-220 acres. The one large beef cattle operation, Princeville Cattle Company, has about 4,260 acres of land in the study area, of which 2,440 acres are grazed. The ranch has about 1,800 head of cattle in the study area.

Princeville Cattle Company grazing lands are divided into two main areas. The grazing area located between Moloaa and Kilauea town is mainly utilized for the ranch's cattle breeding operations. Most of this area is leased from the Lucas Estate. The other grazing area is located just west of the Kalihiwai River. This area is leased from the Princeville Development Corporation.

The Lucas Estate grazing land is under a 10-year lease that recently expired. Lucas Estate will not be renewing this lease. Princeville is slowly shifting its operations into the area west of Kalihiwai. The ranch will also be reducing the scale of its operations somewhat. Lucas Estate will probably lease out its land for pasture on a short-term lease basis.

Most of the smaller ranches use streams and springs as a source of stockwater. The Princeville Ranch uses streams, ditches, and reservoirs for stockwater.

Many of the ranches using streams and springs as a source of stockwater do not have any other source of water available. Many areas are not serviced by the domestic water system. One rancher who does not have any water source at all is forced to pump water out of a neighbors ditch and haul it to his property for his cattle.

The banks of the reservoirs, ditches, and streams often deteriorate as cattle walk along or stand on the banks to drink water. Cattle wading in the water can also cause water quality problems.

The inadequate distribution of stockwater does not allow ranchers to efficiently use all of their pastures for grazing. Cattle often congregate around water sources. Areas near water sources are often overgrazed while other areas further away are often underutilized.

All of the ranchers interviewed indicated that they would be interested in using an agricultural water system if one were available.

The dairy cattle industry is also an important livestock industry in the study area. Meadow Gold Dairy has the only dairy operation on Kauai. The dairy's cattle replacement operation is located in the study area. The dairy's milking operation is located in the southwest part of the island, in Waimea.

The dairy leases 636 acres of land in the study area from Waioli Mission. About 530 acres are grazed. The dairy has about 300 head of cattle in this area.

Meadow Gold also grows feed corn in the study area. They lease 140 acres of land from C. Brewer (Table B-2). The 140 acres are located near the Kilauea Agronomics guava orchards above Kilauea town. The dairy is also planning to use about 60 acres of the Waioli Mission land to grow feed corn. The corn is used as supplemental feed for the dairy's operations. Average yield is 19.5 tons per acre per crop and 1 to 2 crops are grown a year. The dairy does not presently irrigate the corn located above Kilauea town and does not plan to irrigate the corn to be grown in the Waioli Mission land unless a source of irrigation water is available.

The rainfall in the area located above Kilauea town is sufficient so irrigation during most of the year isn't necessary. However, the corn would benefit from irrigation during dry periods. The Waioli Mission corn area is located at a much lower elevation and rainfall averages less than 60 inches per year. Feed corn production in this area will be limited unless irrigation is applied.

Stockwater comes from several sources. A two-inch pipeline transports water from the Ka Loko Ditch to a water trough. The Ka Loko Reservoir is the source of water for the ditch. Both the ditch and the reservoir were part of the plantation's irrigation system. Streams, springs, and troughs provide stockwater in other areas.

The dairy is faced with the same kind of water problems as the beef cattle ranchers. They expressed interest in using an agricultural water system if one were available. The dairy would use the water for stock and would also consider irrigating its feed corn during dry periods.

Truck Crop Industry

In 1981, Hawaii's farmers harvested 4,250 acres and produced 72 million pounds of truck crops (fresh vegetables and melons). However, over 60 percent of the market supply of truck crops consumed in Hawaii was imported from the U.S. mainland.

Kauai's farmers accounted for less than 3 percent of the total state truck crop production in 1981. They harvested 100 acres and produced 1.61 million pounds of truck crops.

There are 14 farms in the study area that produce truck crops. Most of these farms also produce orchard crops and/or livestock. These farms range in size from 5 to 165 acres.

The major truck crops grown in the study area are: bell peppers, cucumbers, eggplant, tomatoes, watermelons, and sweet corn. About 30 acres of truck crops are planted during any one period of time. Farmers grow 1 to 3 plantings of the same crop every year.

Study area farmers harvested 46 acres and produced about 725,000 pounds of truck crops in 1981. These crops had an estimated farm sales value of $295,000.

Farmers usually drip or sprinkler irrigate their truck crops. Most of the farmers use the domestic water system, although several farmers use the Mill Ditch. Farmers using both these water sources face the same kind of water problems as the orchard crop farmers (see pages 13 and 14).

Only one of the farmers has definite plans to increase his plantings of truck crops. New farmers in the agricultural subdivisions will probably also plant some truck crops. Projected truck crop acreage in 1990 is shown in Table B-3.

## Aquaculture

Aquaculture is a rapidly growing industry in Hawaii. The production of freshwater prawns is the leading aquaculture industry. The acres of prawn ponds have increased from 1.5 in 1970 to 558 in 1980. Prawn production has increased from 4,300 pounds to 320,000 pounds over the same period. The current market is equally divided among the hotel/restaurant, retail, and export segments.

Prawns of Hawaii is the only prawn farm in operation in the study area at the present time. At one time, C. Brewer's Kilauea Agronomics (see Guava section) had 100 acres of prawn ponds as part of their operations. The effluent from the ponds was used to irrigate their guava orchards. However, the prawn operation was closed in 1980, 4 years after it started. The ponds have since been drained and filled, and guavas have been planted on the site.

Prawns of Hawaii has 35 acres of ponds on their 60-acre farm site. This is the maximum amount of ponds that can be accommodated on the farm. Production ponds are 1-1/2 to 2 acres in size and nursery ponds are 1/2 acre in size. The average prawn production of 1,600 pounds/acre/year is among the highest yields in the state. The wholesale price in 1981 was about $4.00/pound.

The farm presently pipes water from the nearby Ka Loko Reservoir. The water is filtered to remove debris and fish larva before being used in the prawn ponds. A hydroelectric generator has been installed along the pipeline from the Ka Loko Reservoir. It is capable of generating over 15 kilowatt hours/day for the farm's use.

As far as we know, no new farmers plan to raise prawns or other aquatic species in the study area in the near future. An adequate supply of water would be essential to the development of any new aquaculture operation. About 25,000 gallons of water are required per pond acre per day.

## COMMERCIAL BUSINESS ACTIVITY

Kilauea town is the only area with commercial business activity in the study area. Most of the town's businesses support community needs. A few businesses are tourist oriented.

Although there is no land in Kilauea town zoned commercial, commercial activity is centered in two areas. The largest concentration of businesses evolved from the old plantation town center. The area is about 3.5 acres in size and consists mostly of old plantation buildings that have been renovated. Businesses include stores and medical offices.

The other area of commercial activity is located at the town entrance off Kuhio Highway. Businesses in this area include a service station, convenience store, and a post office.

## TOURISM

Tourism has replaced sugar as the leading industry on the island of Kauai. Although the study area is not a major tourist destination, tourists often stop in Kilauea on their way to the Princeville Recreation-Resort Community. Princeville is one of the four major destination areas on Kauai.

There are several scenic and/or historic features in Kilauea that can be considered tourist attractions. The views from the Kilauea Lighthouse and Crater Hill are spectacular. The town of Kilauea itself can also be considered a tourist attraction. Its rural charm is reminiscent of the plantation days and many features of the old plantation still remain. None of these attractions generate any direct income because no admission is charged for viewing any of the sites. However, many tourists stop at the local stores in Kilauea to make purchases. Some stores have geared up to cater to tourists.

# APPENDIX C

# LAND RESOURCES

# APPENDIX C
# LAND RESOURCES

Appendix C inventories and describes the land resources in the study area. Knowledge of the characteristics of the land resources and its potential for agricultural production is important to land use planning and the protection of productive agricultural land.

Appendix C contains a soil survey, land classification ratings, and soil suitability ratings for the study area. The soil survey describes the extent, location, and properties of the soils in the study area. The land classification ratings identify the extent and location of the best lands for agricultural production. The soil suitability ratings indicate the relative quality of the soil for a particular use compared to other soils in the area. This appendix also includes a section on land use and ownership.

## LAND USE AND OWNERSHIP

### State Land Use Districts

The State of Hawaii, in order to insure orderly development and use of land, enacted the State Land Use Law in 1961. This law established four land use districts: urban, rural, agriculture, and conservation. These districts are defined as follows:

Urban district includes lands presently in urban use plus sufficient reserve areas to accommodate foreseeable urban growth. The County of Kauai regulates land use within this district.

Rural district , created as a result of an amendment to the law in 1961, includes areas composed of small farmlots with a minimum of one-half acre in size and also low density residential lots with no more than one house per half acre. Land use regulations in the rural districts are established by the State Land Use Commission and administered by the County of Kauai. There are no rural district lands in the study area.

Agricultural district includes lands used for agricultural purposes and lands with potential for cultivation. Agricultural purposes include the growing of sugarcane, truck and orchard crops, ranching, and aquaculture. Like the rural districts, land use regulations in the agricultural districts are established by the State Land Use Commission and administered by the County of Kauai.

Conservation district includes lands managed to protect watershed cover and water supplies, preserve scenic areas, provide for recreation areas, preserve examples of terrestrial and aquatic natural areas including flora and fauna, prevent floods and soil erosion, and control the use of renewable and nonrenewable natural resources. The State Department of Land and Natural Resources is responsible for the subzoning and establishing and enforcing of land use regulations on state and privately owned lands in the conservation district.

Table C-1 shows the acres in each land use district in the study area and on Kauai. The state land use district boundaries in the study area are shown in Figure C-1.

Table C-1
State Land Use Districts

| Class | Study Area (acres) | Study Area (percent) | Island of Kauai (acres) | Island of Kauai (percent) |
|---|---|---|---|---|
| Urban | 205 | 0.9 | 10,817 | 3.1 |
| Rural | 0 | 0 | 1,233 | <0.1 |
| Agriculture | 12,465 | 55.4 | 143,118 | 40.6 |
| Conservation | 9,830 | 43.7 | 198,732 | 56.3 |
| TOTAL | 22,500 | 100.0 | 353,900 | 100.0 |

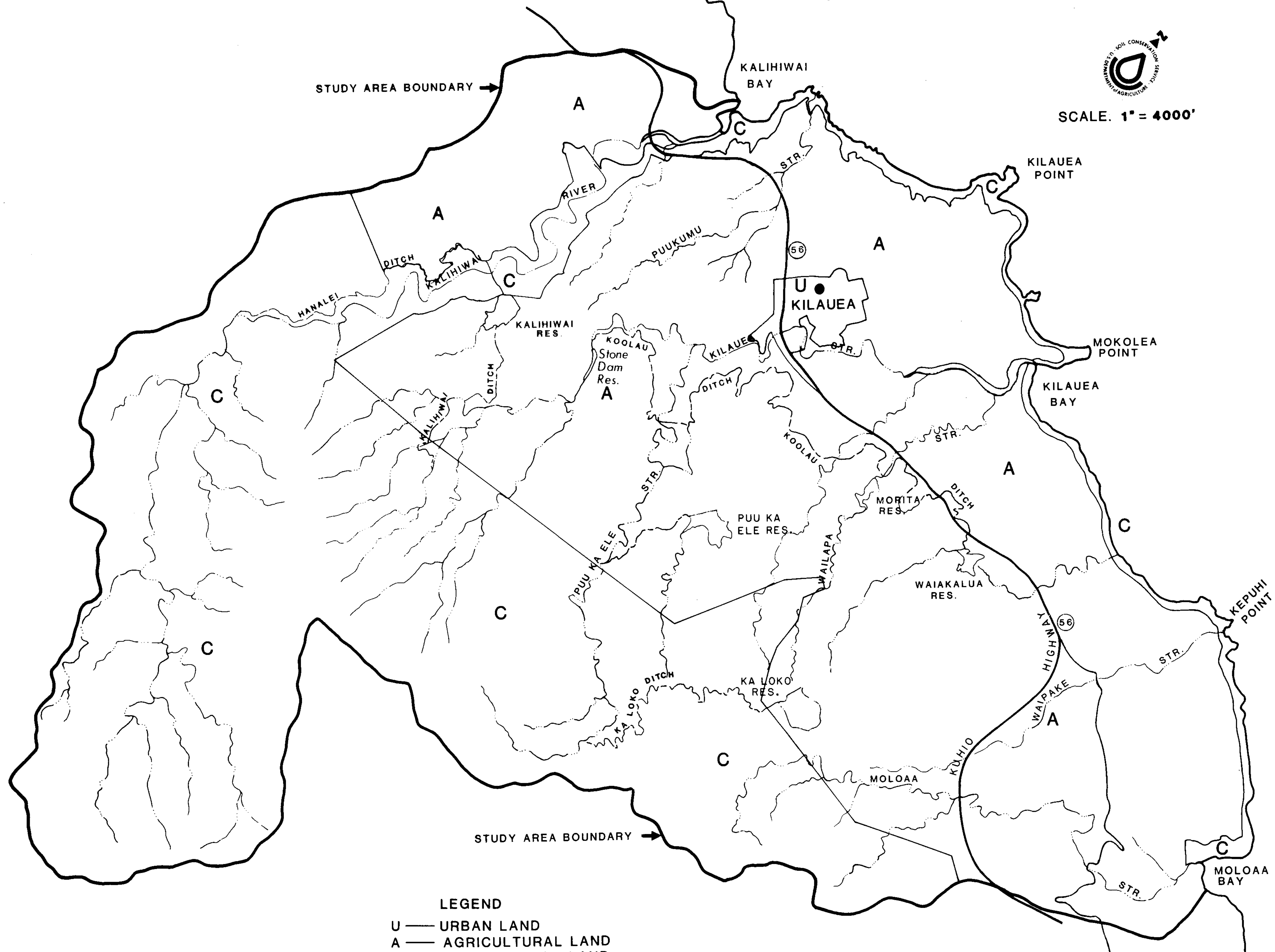



FIGURE C-1

STATE LAND USE DISTRICT BOUNDARIES

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## Present Land Use

Sugarcane was the dominant crop in the area until the closing of the 8,000-acre Kilauea Sugar Company in 1971. Since then many different crops have been grown. Among the more extensively grown crops were corn and sorghum.

Today, many agricultural subdivisions are planned in this area. Present land use is shown in Table C-2. A map showing present land use is included in Appendix B (Figure B-1, page B-6).

Table C-2
Present Land Use

| Land Use | Acres 1/ | Percent |
|---|---|---|
| Urban | 205 | 0.9 |
| Agriculture | | |
| Orchards | | |
| Guavas | 350 | 1.6 |
| Papayas | 165 | 0.7 |
| Bananas | 50 | 0.2 |
| Macadamia Nuts | 5 | <0.1 |
| Pasture | 6,680 | 29.7 |
| Feed Corn | 140 | 0.6 |
| Truck Crops | 60 | 0.3 |
| Prawns | 60 | 0.3 |
| Idle | 4,955 | 22.0 |
| Total Agriculture | 12,465 | 55.4 |
| Conservation | | |
| Forest Reserve | 9,000 | 40.0 |
| Shoreline and River Banks | 830 | 3.7 |
| Total Conservation | 9,830 | 43.7 |
| TOTAL | 22,500 | 100.0 |

1/ Agricultural acreages represent gross farm acres for crops, gross ranch acres for crops, gross ranch acres for pasture, and prawn pond acres for prawns.

## Landownership

The majority of the land in the study area is in private ownership (Table C-3 and Figure C-2). The major landowners include various subsidiaries of C. Brewer and Company with approximately 3,600 acres, the Mary N. Lucas Trust Estate with approximately 2,800 acres, the Princeville Development Corporation with approximately 1,700 acres, and Consolidated Oil and Gas, Inc. with approximately 4,000 acres.

Table C-3
Landownership

| Owner | Acres | Percent |
|---|---|---|
| State of Hawaii | 2,329 | 10.4 |
| U.S. Government | 31 | 0.1 |
| County of Kauai | 9 | <0.1 |
| Private | 20,131 | 89.5 |
| TOTAL | 22,500 | 100.0 |

## SOILS

Soils are a natural resource and soil properties exert a strong influence on the manner in which man uses or can use land. A knowledge of soils is important to land use planning, to protect the resources, and to improve the quality of the environment.

A soil survey provides a scientific soils inventory that can help individuals, planners, consultants, and legislators in planning the best use of land. The soil survey shows the location and extent of the soil in an area and contains information about soil properties that can be used in judging the suitability of land for many uses.

The soil pattern in the study area is largely determined by rainfall. Other factors that influence the soil pattern include temperature and physiographic patterns.

Nineteen types of soils or soil series and eight miscellaneous land types have been identified in the study area. Miscellaneous land types are areas with little or no identifiable soil. These land types however, have been classified and given names, like soil series. One of the soil series and three of the land types are located on steep sideslopes; five of the soil series and four of the land types are located on the bottom lands, coastal plains, and terraces; and the remaining 13 soil series and one land type are on the uplands.

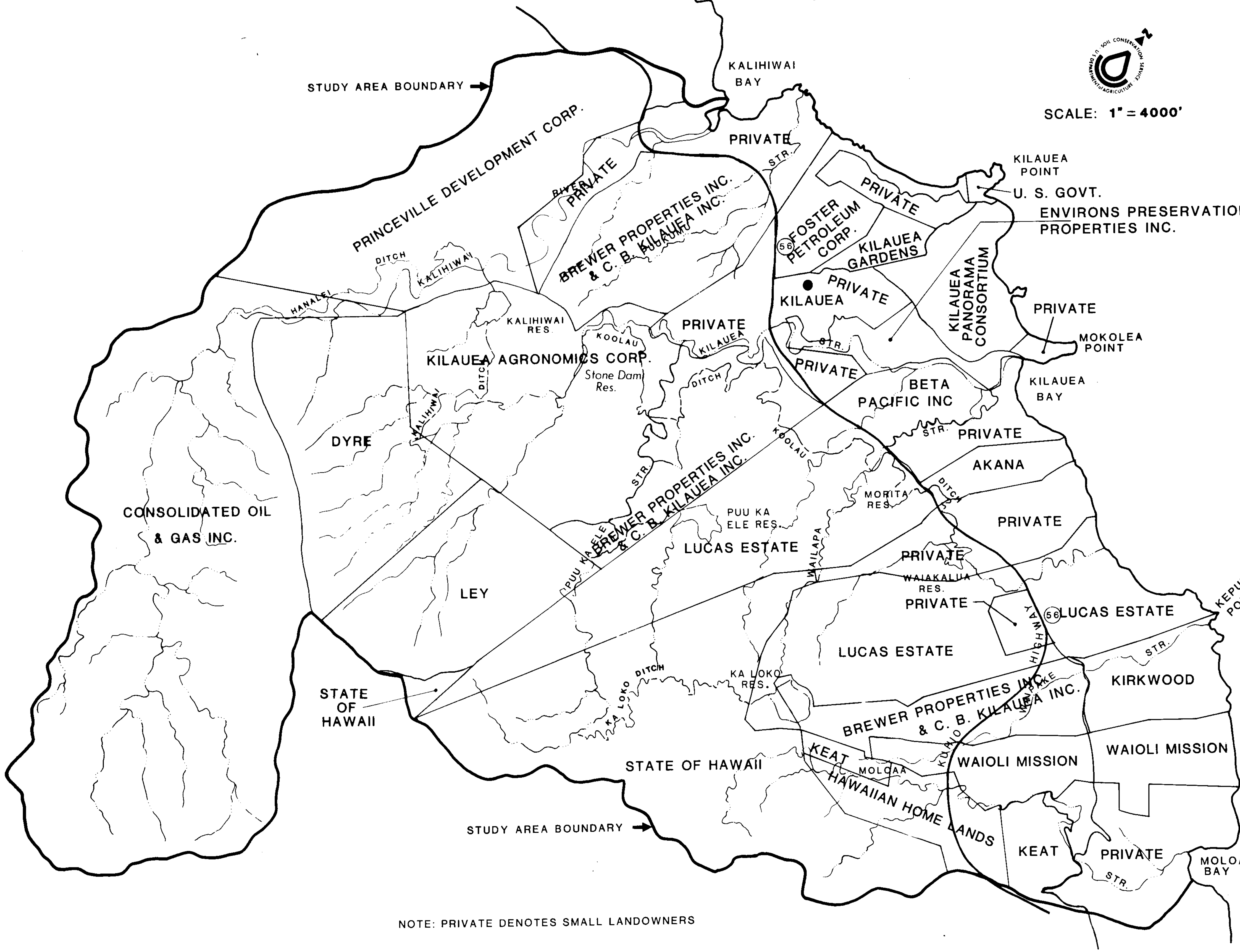



FIGURE C-2

LANDOWNERSHIP

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

Each of the soil series and miscellaneous land types are briefly described in the following section. Detailed information about the soil series and land types is contained in the Soil Conservation Service (SCS) publication entitled "Soil Survey of the Islands of Kauai, Oahu, Maui, Molokai, and Lanai." Copies of this publication are available at the SCS state office in Honolulu.

## Soils on the Steep Sideslopes

The Hihimanu soils, the only soil series located on the steep sideslopes, can be described as deep and well-drained. The three land types located on the steep sideslopes are Rock outcrop, Rough broken land, and Rough mountainous land. These land types are usually shallow in depth and found over weathered rock fragments. These land types are poorly suited to farming.

## Soils on the Bottom Lands, Coastal Plains, and Terraces

Hanalei and Kolokolo are the soil series and Marsh is the land type located on the bottom lands. The Hanalei soils are somewhat poorly drained and frequently flooded. The Kolokolo soils are occasionally flooded and extremely stony. Marsh consists of wet, periodically flooded areas covered dominantly by grasses and bulrushes or other herbaceous plants.

Mokuleia is the only soil series and Beaches, Dune Land, and Fill land are the land types located on the coastal plains. The Mokuleia soils are recent alluvium overlying coral sand. Beaches consist of light-colored sand derived from coral. Dune land consists of hills and ridges of sand-sized particles drifted and piled by wind. Fill land consists of bagasse and slurry from sugar mills or material from soil excavations.

Hanamaulu and Pohakupu soil series are on coastal plains and terraces. Both of these soils are well-drained alluvium derived from the uplands.

## Soils on the Uplands

The 13 soil series located on the uplands are Halii, Hulua, Ioleau, Kalapa, Kapaa, Koolau, Kunuweia, Lawai, Lihue, Makapili, Pooku, and Puhi. The only land type on the uplands is Badland.

The Halii, Hulua, and Kunuweia soils have very gravely surfaces. The Halii soils are well-drained to moderately well-drained. Hulua soils have a cemented layer at depths of 10 to 20 inches and are poorly drained. The Kunuweia soils are well-drained and usually found on ridge tops.

The Koolau soils are poorly drained and have a high water table within one or two feet from the surface.

The nine remaining soils located on the uplands can all be described as deep, well-drained, and derived from basic igneous rock. The soils found at lower elevation have moderate inherent fertility and respond readily to fertilization. The soils become less productive as the elevation and rainfall increases and the intensity of sunlight decreases.

The Badland land type consists of steep or very steep, nearly barren land, ordinarily not stony.

# LAND CLASSIFICATION

## Agricultural Lands of Importance to the State of Hawaii

In Hawaii, where land is limited, it is imperative that serious consideration be given to preserving prime agricultural lands. Indiscriminate conversion of prime agricultural lands for urban expansion should be controlled by continued application of the state's Land Use Law. Protection of prime agricultural lands is vital to the long-term significance of agriculture in Hawaii.

In 1975, the Soil Conservation Service initiated a nationwide inventory to identify the extent and location of the nation's best lands for the production of food, feed, fiber, and forage. A system to classify three classes of agriculturally important lands was established. These classes were prime, unique, and other important agricultural lands.

Prime and unique farmlands are some of the most important resources of the nation. These exceptional lands can be farmed continuously or nearly continuously without degrading the environment. They produce the most food, feed, fiber, and forage crops with the least amount of energy. They respond exceptionally well to fertilizer and other chemical applications with limited loss of residues by leaching or erosion. These lands are the most responsive to management and require the least investment for maintaining productivity.

In Hawaii, the classification system and criteria were reviewed by an ad hoc committee comprised of local, state, and federal representatives. They accepted the national criteria for prime agricultural lands and developed statewide criteria for unique and other important agricultural lands. This system, Agricultural Lands of Importance to the State of Hawaii (ALISH), was adopted by the State Board of Agriculture on January 28, 1978.

The classification of agriculturally important lands does not in itself constitute a designation of any area to a specific land use. Actual land use is subject to the State Land Use Commission, County Planning Commission, and County Council. The classification should, however, provide decision-makers with an awareness of the long-term implications of various land use options for agricultural production in Hawaii.

Agricultural Lands of Importance to the State of Hawaii for the study area is shown in Table C-4 and Figure C-3 (stored in back cover pocket). A definition of and criteria for prime, unique, and other important agricultural lands follows:

### Prime Agricultural Land

Prime agricultural land is land best suited for the production of food, feed, fiber, and forage crops. With land and water management, this land has the soil quality and moisture supply and the growing season needed to economically produce sustained high yields of crops.

Table C-4
Agricultural Lands of Importance to the State of Hawaii

| Class | Study Area (acres) | Study Area (percent) | Island of Kauai (acres) | Island of Kauai (percent) |
|---|---|---|---|---|
| ALISH Classification | | | | |
| Prime | 8,550 | 38 | 54,916 | 16 |
| Unique | 0 | 0 | 388 | <1 |
| Other Important | 3,150 | 14 | 36,673 | 10 |
| Subtotal | 11,700 | 52 | 91,977 | 26 |
| Land Not Considered | 10,800 | 48 | 261,923 | 74 |
| Total | 22,500 | 100 | 353,900 | 100 |

Prime agricultural land meets the following criteria:

1. The soils have a dependable and adequate moisture supply and good water storage capacity.
2. The soils have a mean annual temperature and growing season suitable for growing the prevailing crops.
3. The soils are neither too acid nor too alkaline for vigorous plant growth.
4. The water table is either lacking or so deep that it does not adversely effect plant growth.
5. The soils are not salty or otherwise limited in the root zone.
6. The soils are not flooded frequently during the growing season.
7. The soils do not have a serious erosion hazard.
8. The soils transmit water readily and without drainage problems.
9. The soils are not so stony in the surface layer as to cause difficulty in cultivating with large equipment.
10. The soils have stability characteristics which permit the use of large equipment.

## Unique Agricultural Land

Unique agricultural land is land other than prime agricultural land that is presently used for the production of specific high-value food crops. This land has the special combination of soil quality, growing season, temperature, humidity, sunlight, air drainage, elevation, aspect, moisture supply, or other conditions that favor the production of a specific crop of high quality and high yield when the land is treated and managed according to modern farming methods. In Hawaii, examples of such crops are coffee, taro, rice, watercress, and nonirrigated pineapple.

## Other Important Agricultural Land

Other important agricultural land is land other than prime or unique agricultural lands 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 Hawaii yet they exhibit properties such as seasonal wetness, erodibility, stoniness, limited rooting zone, slope, flooding, or droughtiness that exclude them from the prime and unique agricultural lands classifications. Two examples are lands which do not have adequate precipitation or an adequate irrigation supply to qualify as prime agricultural land and lands which have similar characteristics and properties as unique agricultural land, except that the land is not currently in use for the production of a "unique" crop. These lands can be farmed satisfactorily by applying greater amounts of fertilizer and other soil amendments, drainage improvement, erosion control practices, flood protection, and produce fair to good crop yields when managed properly.

Other criteria which may qualify lands as other important agricultural land are:

1. The land has slopes less than 20 percent, is presently in crop or has cropping potential, has a moisture supply which is adequate for the commonly grown crops, and is not classified as prime or unique agricultural lands.

2. The land has slopes less than 35 percent, is presently used for grazing or has grazing potential, has sufficient available water capacity, has less than 10 percent rock fragments in the surface layer, and is not classified as prime or unique agricultural lands.

3. The land has thin organic soils underlaid by Aa lava with adequate moisture and temperature conditions for the commonly grown crops.

## Other Criteria for Classifying Land

Any land identified as other important agricultural lands or as unique agricultural lands must not include areas where the production of crops could result in misuse of soil, water, and related resources.

Soil conditions are only one of several criteria necessary for the identification of prime agricultural lands. Factors that may not be evident from a soil survey and may require onsite evaluation are:

1. Frequency of flooding - some map units may include both prime and non-prime agricultural lands because of the variation in flooding frequency.

2. Irrigation - some map units may not separate soils with a developed irrigation water supply that is dependable and is of adequate quality from soils without such supplies.

3. Water table - some map units may include both drained and undrained soils with only drained areas meeting prime agricultural land criteria.

Land Not Classified

Land not considered for classification include:

1. Developed urban areas greater than 10 acres in size.

2. Natural or artificial (man-made) enclosed bodies of water of more than 10 acres.

3. Forest reserves. (Prime forest land mapping has been done for the upper watershed areas of the study area.)

4. Public land uses such as parks and historic sites.

5. Land with slopes in excess of 35 percent.

6. Military installations, except undeveloped areas over 10 acres.

## SOIL SUITABILITY

Soil suitability ratings for orchard crops and truck crops were developed for the study area. Soil suitability ratings indicate the relative quality of a soil for a particular use compared to other soils in the area. The ratings are based on properties that affect the growth of crops and ease of cultivation. The soils are rated in its natural state, that is, the soils are not modified in any unusual manner other than which is considered normal practice. The suitability of the soils for pasture use was also evaluated; however, no ratings were developed.

### Soil Suitability Ratings for Orchard Crops

The major orchard crops grown in the study area are guavas, papayas, and bananas. A small macadamia nut orchard was recently planted and farmers have plans to grow other types of orchard crops such as citrus, avocados, and lychee. Gross orchard crop farm area is 570 acres, out of which 425 acres are planted.

The properties considered in rating the suitability of the soils for orchard crops were slope, stoniness, rooting depth, flood hazard, and drainage. The soils were given a rating of good, fair, or poor. The ratings are defined below.

A rating of good means the soils have properties favorable for growth of climatically adapted orchard crops.

A rating of fair means the soils have properties moderately favorable for the growth of climatically adapted orchard crops.

A rating of poor means the soils have one or more properties unfavorable for the growth of climatically adapted orchard crops. Overcoming the unfavorable property requires special farming methods, extra maintenance, or costly modification of the soil or site.

The soil suitability ratings for orchard crops in the study area are shown in Table C-5 and Figure C-4 (in back pocket).

Table C-5
Soil Suitability Ratings for Orchard Crops

| Rating | Acres | Percent |
|---|---|---|
| Good | 7,400 | 32.9 |
| Fair | 2,100 | 9.3 |
| Poor | 13,000 | 57.8 |
| TOTAL | 22,500 | 100.0 |

## Soil Suitability Ratings for Truck Crops

The major truck crops grown in the study area are bell peppers, cucumbers, eggplant, tomatoes, watermelons, and sweet corn. Total truck crop farm acreage in the study area is 60 acres, with about 30 acres planted during any one period of time. Farmers make one to three plantings of the same crop per year.

The properties considered in rating the suitability of the soils for truck crops were slope, stoniness, rooting depth, flood hazard, and drainage. The soils were given a rating of good, fair, or poor. The ratings are defined below:

A rating of good means the soils have properties favorable for machine cultivation and the growth of climatically adapted truck crops.

A rating of fair means the soils have properties moderately favorable for machine cultivation and the growth of climatically adapted truck crops. One or more soil properties make these soils less desirable than those rated good.

A rating of poor means the soils have one or more properties unfavorable for machine cultivation and the growth of climatically adapted truck crops. Overcoming the unfavorable property requires special farming methods, extra maintenance, or costly modification of the soil or site.

The soil suitability ratings for truck crops in the study area are shown in Table C-6 and Figure C-5 (in back pocket).

Table C-6
Soil Suitability Ratings for Truck Crops

| Rating | Acres | Percent |
|---|---|---|
| Good | 4,500 | 20.0 |
| Fair | 2,900 | 12.9 |
| Poor | 15,100 | 67.1 |
| TOTAL | 22,500 | 100.0 |

## Soil Suitability for Pasture

Ranching operations encompass 6,680 acres in the study area. Approximately 3,845 acres are grazed and 2,835 acres are brush covered.

Pasture conditions in the study area vary widely. Pastures can be found at elevations near sea level all the way up to 600 feet. Rainfall in these areas range from 50 inches annually near sea level to 125 inches annually at 600 feet. As a result, a wide range of grasses and legumes are grown, and stocking rates vary from one animal unit per 8 acres in the drier areas to one animal unit per acre in the wetter areas.

Except for the very steep gulches, the entire study area could potentially be used for pasture. Land used for orchard and truck crops are well suited for pasture. Therefore, no soil suitability ratings for pasture were developed.

# APPENDIX D

# WATER RESOURCES

# APPENDIX D
# WATER RESOURCES

The primary purpose of Appendix D is to provide an inventory of the existing water resources in the study area and to identify additional sources of water that can be developed for agricultural purposes. Appendix D provides information about the existing water systems; the occurrence, quantity, and quality of the water resources; and the potential sources for additional supply. It also describes the water rights situation and hydroelectric power development potential in the study area.

## EXISTING WATER SYSTEMS

### Kilauea Water System

The Kilauea Water System is a domestic water system owned by the County of Kauai and operated by the County's Department of Water. The system services residents in Kilauea town and the surrounding areas (Figure D-1). The system is also used for agricultural purposes by some farmers in the service area.

Utilizing two 300-gallon-per-minute (gpm) pumps, this system draws basal water from two deep wells and stores it in a 250,000-gallon tank located on Kamooka Ridge, elevation 430 feet. A piped distribution system transports the water from the tank to the service areas. The distribution pipeline is being extended easterly along the Kuhio Highway to provide domestic water to the two new C. Brewer agricultural subdivisions.

In 1981, the system had 351 customers of which 11 qualified for agricultural water rates. During that year, its customers used a total of 49.9 million gallons (MG) of water, 46.15 MG were used for domestic purposes, and 3.75 MG were used for agricultural purposes.

### Kilauea Sugar Company Irrigation System

The Kilauea Sugar Company Irrigation System was constructed in the late 1800's by the Kilauea Sugar Company. The system was used to irrigate 3,200 acres of the company's over 4,000 acres of sugarcane. The system consisted of six reservoirs and a collection and distribution system consisting of over 34 miles of ditches, flumes, and tunnels (Tables D-1 and D-2, and Figure D-2).

Since the closing of the Kilauea Sugar Company's operations in 1971, the irrigation system has fallen into disrepair with only minimal maintenance being done by the system's few users. Although sedimentation has reduced the total storage capacity of the six reservoirs from 697.2 MG to an estimated 605.9 MG, all of the reservoirs, except for the Puu Ka Ele Reservoir, are in good or fair condition (Table D-1). The 34 miles of ditches, flumes, and tunnels are in much worse shape, with over 23 miles inoperable and over 7 miles in poor condition (Table D-2).

Table D-1
Kilauea Sugar Company Irrigation System Reservoirs

| Reservoir | Elevation (feet) | Surface Area (acres) | Original Storage[1/] (MG) | Present Storage (MG) | Present Condition |
|---|---|---|---|---|---|
| Kalihiwai | 397 | 30.0 | 57.5 | 43.1 | good |
| Stone Dam | 340 | 5.0 | 10.5 | 7.5 | good |
| Puu Ka Ele | 411 | 30.6 | 117.3 | 88.0 | poor |
| Morita | 326 | 12.5 | 43.0 | 32.3 | good |
| Waiakalua | 285 | 16.2 | 60.0 | 45.0 | good |
| Ka Loko | 747 | 43.0 | 408.9 | 390.0 | fair |
| Total | - | 137.3 | 697.2 | 605.9 | - |

1/ Original storage when constructed.

Table D-2
Kilauea Sugar Company Irrigation System - Ditches, Flumes, and Syphons

| Structure Number1/ | Ditches, Flumes, Syphons | Function2/ | Height x Width | Ditches (ft.) | Iron Flumes (ft.) | Flumes (ft.) | Syphons (ft.) | V-Flumes (ft.) | Total (ft.) | Total (miles) | Present Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Hanalei Ditch - Stream to Kalihiwai Reservoir......... | C | 4'x 5' | 17,600 | - | 724 | 1,543 | - | 19,867 | 3.76 | inoperable |
| 2 | Kalihiwai Ditch - Stream to Kalihiwai Reservoir......... | C | 4'x 8' | 7,500 | - | - | - | - | 7,500 | 1.42 | good |
| 3 | Kalihiwai Res. to Mill Ditch..... | B | 4'x 5' | 4,500 | 110 | - | - | - | 4,610 | 0.87 | poor |
| 4 | Mill Ditch - Stone Dam to Lighthouse Road............ | D | 4'x 8' | 13,500 | - | 70 | - | - | 13,570 | 2.57 | poor |
| 5 | Mill Ditch - Lighthouse Road to Field 4 3/.................. | D | 4'x 8' | 3,500 | - | - | - | - | 3,500 | 0.66 | poor |
| 6 | V-Flume Mill Drain 3/............. | D | - | - | - | - | - | 5,198 | 5,198 | 0.98 | inoperable |
| 7 | Koolau Ditch - Stone Dam to Waiakalau Reservoir......... | B | 4'x 6' | 33,000 | 1,162 | 170 | - | - | 34,332 | 6.50 | inoperable |
| 8 | Ross Ditch...................... | B | 3'x 4' | 3,500 | - | 135 | - | - | 3,635 | 0.69 | inoperable |
| 9 | Puu Ka Ele Ditch - Stream to Puu Ka Ele Reservoir........ | C | 4'x 6' | 4,500 | - | - | - | - | 4,500 | 0.85 | good |
| 10 | Lawrence Ditch - Puu Ka Ele Reservoir to Field 25............... | D | 4'x 6' | 20,500 | 619 | 40 | - | - | 21,159 | 4.01 | inoperable |
| 11 | Field 18 Flume 3/................ | D | 12"x12" | - | - | 252 | - | - | 252 | 0.05 | inoperable |
| 12 | Field 20 Flume Diam. Syphon 3/.... | D | 20" | - | - | - | 79 | - | 79 | 0.01 | inoperable |
| 13 | Field 20 - Flume 3/............... | D | 18"x24" | - | - | 190 | - | - | 190 | 0.03 | inoperable |
| 14 | Ka Loko Ditch - Stream to Ka Loko Reservoir........... | C | 6'x 8' | 16,470 | - | - | - | - | 16,470 | 3.12 | inoperable |
| 15 | Ka Loko Outlet to Field 25....... | D | 3'x 3' | 3,000 | - | - | - | - | 3,000 | 0.57 | inoperable |
| 16 | Moloaa Ditch - Stream to Ka Loko Ditch | C | 6'x 6' | 2,500 | - | - | - | - | 2,500 | 0.47 | poor |
| 17 | Ka Loko Outlet to Field 43....... | D | 4'x 5' | 7,500 | - | - | - | - | 7,500 | 1.42 | poor |
| 18 | Old Moloaa Ditch................ | B | 3'x 3' | 5,500 | - | - | - | - | 5,500 | 1.04 | inoperable |
| 19 | Field 26 Flume 3/................. | D | - | - | - | 700 | - | - | 700 | 0.13 | inoperable |
| 20 | From Top 33 to 37................ | D | - | 7,600 | - | - | - | - | 7,600 | 1.44 | good |
| 21 | Koolau Ditch - Waiakalua Reservoir to Field 30............ | D | 4'x 6' | 12,900 | 279 | 180 | 40 | - | 13,399 | 2.54 | inoperable |
| 22 | From Top 43 to 45 (gov't. road).. | D | - | 6,600 | - | - | - | - | 6,600 | 1.25 | poor |
| | Total.......................... | - | - | 170,170 | 2,170 | 2,461 | 1,662 | 5,198 | 181,661 | 34.41 | - |
| | Converted to Miles.............. | - | | 32.23 | 0.41 | 0.47 | 0.32 | 0.98 | 34.41 | - | - |

1/ Corresponds to structure numbers on Figure D-2.
2/ Letter denotes the structure's function: Collect water, Distribute water, or transport water Between reservoirs and/or Both collect and distribute water.

3/ Structure not shown in Figure D-3.

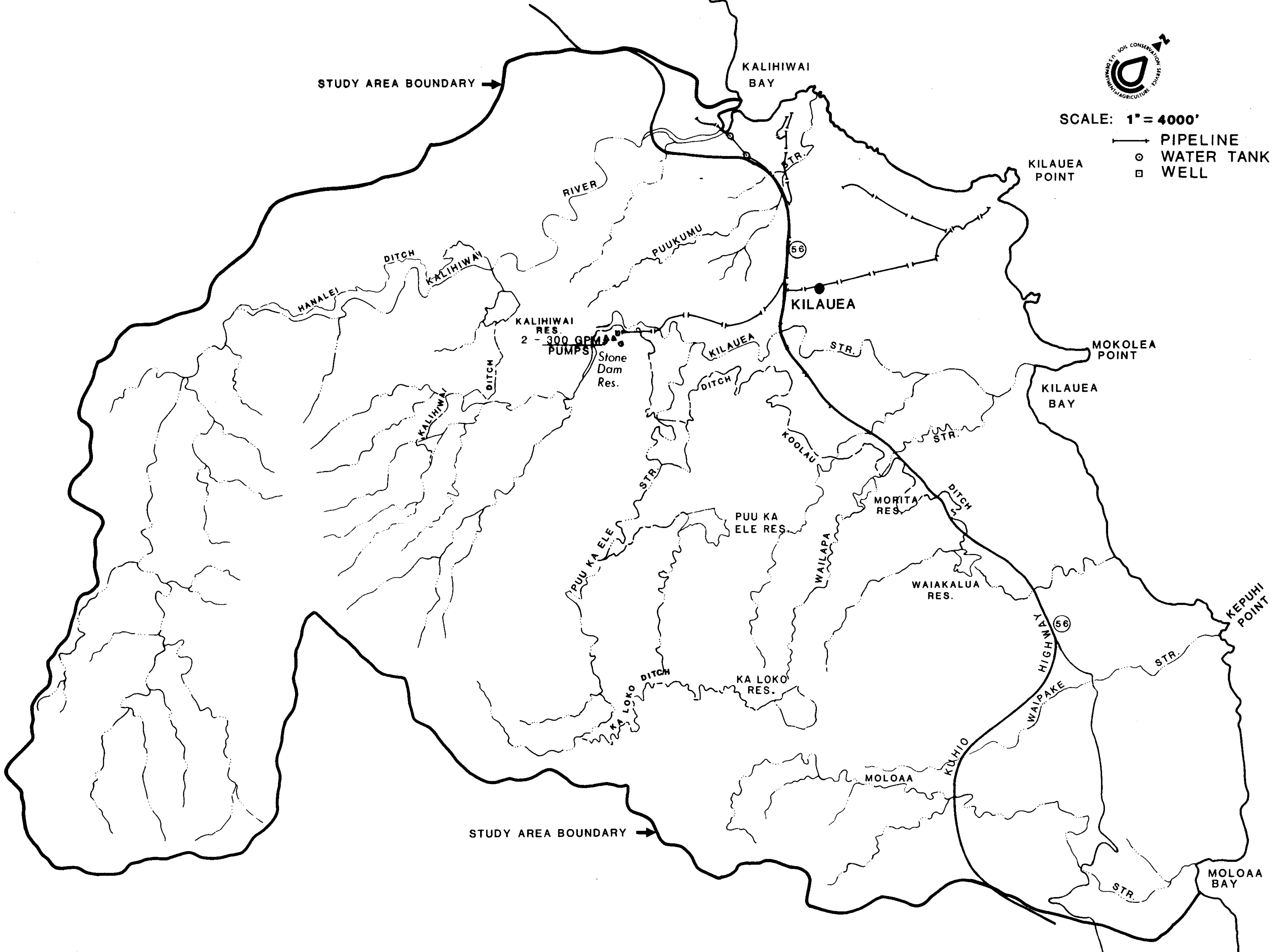



FIGURE D-1
KILAUEA WATER SYSTEM

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

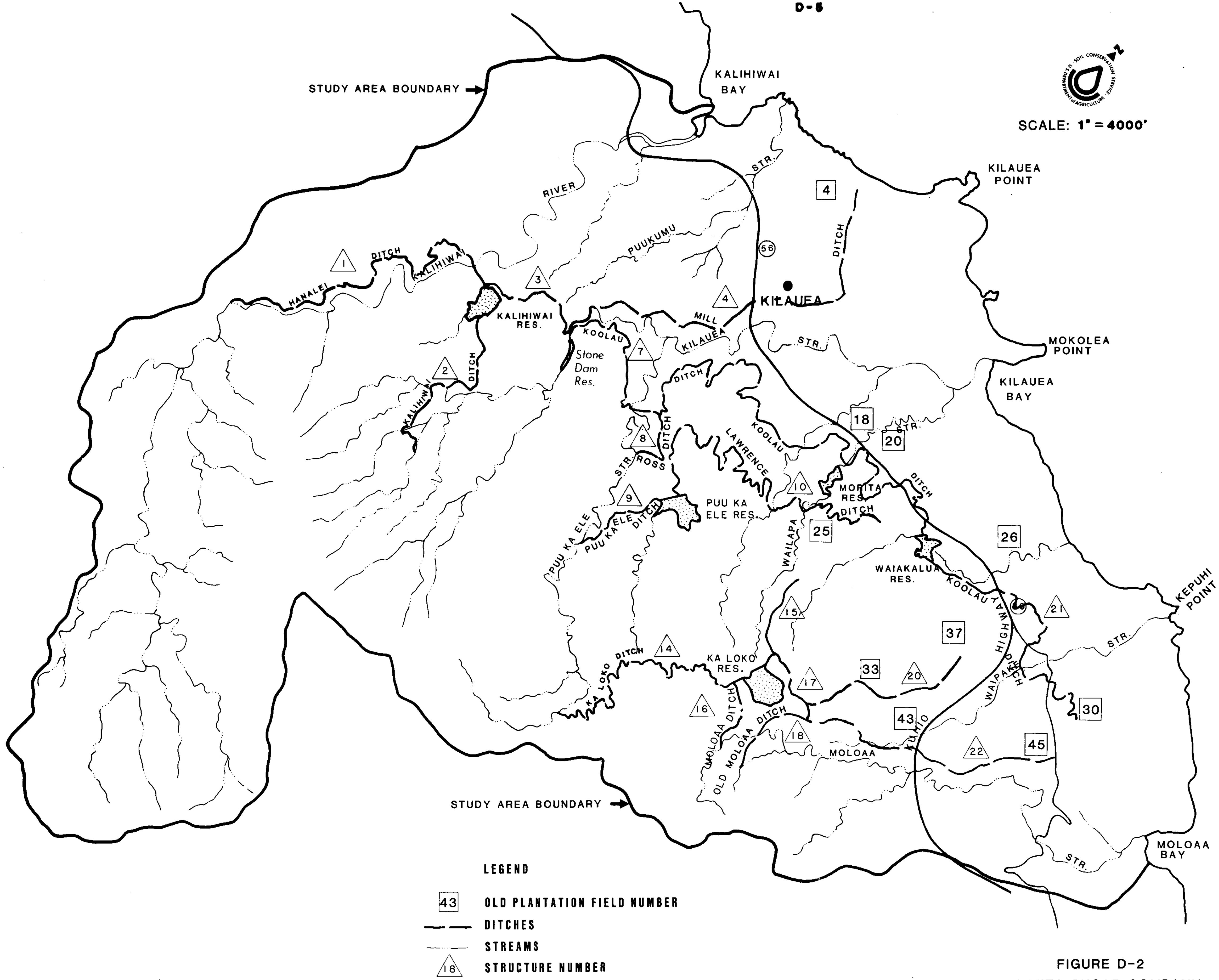



FIGURE D-2
KILAUEA SUGAR COMPANY
IRRIGATION SYSTEM

KILAUEA AGRICULTURAL WATER
MANAGEMENT STUDY

A more detailed description of the condition of the reservoirs and major water collection and distribution structures is presented in the following section. Many of the collection and distribution structures will not be described because these structures did not show potential for development as elements to be used in any new agricultural water systems.

Kalihiwai Ditch

The Kalihiwai Ditch (structure 2 in Table D-2 and Figure D-2) diverts water from the Pohakuhonu Stream and transports it to the Kalihiwai Reservoir. The ditch is in good condition and would require only minor maintenance-type work and repairs to return it to full operation. Grass and roots in the ditch would have to be removed and the control gates at the wasteway would have to be repaired.

Kalihiwai Reservoir

A visual inspection conducted by SCS engineers indicates that the Kalihiwai Reservoir's embankment is in good condition, although there is a substantial growth of grass and trees on it. The earthen spillway is overgrown with grass. The 24-inch outlet gate is operational and Kilauea Agronomics installed a 24-inch polyvinyl chloride pipeline from the outlet gate to supply water to its prawn farm operation. Since the closing of the prawn operation in 1980, the pipeline has not been used. Sedimentation has decreased the reservoir's storage capacity from 57.5 MG to an estimated 43.1 MG.

Stone Dam

The Stone Dam is a grouted rock embankment with present storage of about 7.5 MG. The dam stores water from the Pohakuhonu and Halaulani streams, which flow directly into it, and from runoff from the watershed area above. The dam is in good condition and its outlet gate is still operational.

Mill Ditch

The Mill Ditch is an open distribution ditch which runs from Stone Dam down through Kilauea town to the coastline. The ditch consists of two major sections, one about 2.6 miles long and the other about .7 miles long (structures 4 and 5 in Table D-2). Although the ditch is in poor condition, it still supplies water to a few crop farms located below Kilauea town. The ditch is overgrown with californiagrass and silted in. The wooden flume section just below Stone Dam is leaky and has high transmission losses.

Koolau, Ross and Lawrence Ditches

The Koolau, Ross, and Lawrence ditches are in very poor condition and are inoperable. A survey done by Belt, Collins and Associates, Ltd., an engineering firm, found most of the iron and wood flume sections either completely rotted or in poor condition. Belt, Collins conducted the survey in 1977 for the C. Brewer Corporation. Foundations and trestles supporting these flumes are collapsing or rotting. Earth ditch sections are poorly formed and in some cases livestock have destroyed portions of the ditch. Rehabilitation of these ditches to their original capacities would be very costly.

Puu Ka Ele Ditch

The Puu Ka Ele Ditch (structure 9 in Table D-2 and Figure D-2) diverts water from the Puu Ka Ele Stream and transmits it to the Puu Ka Ele Reservoir. The ditch is in good condition but would require some maintenance-type work to restore it to full operation. Silt, logs, weeds, and roots in the ditch would have to be removed. The sediment at the ditch's intake at Puu Ka Ele Stream would also have to be removed.

Puu Ka Ele Reservoir

A 1980 Corps of Engineers' report indicates that the Puu Ka Ele Reservoir is in poor condition. There are seepage zones along the length of the dam and a dense growth of trees on the downstream face of the dam, the 18-inch outlet is inoperable, and the emergency spillway and the bridge over it are very deteriorated. The reservoir's existing stone armor is probably ineffective because the upstream face of the reservoir has been eroded by wave action. Sedimentation has reduced the reservoir's storage capacity from 117.3 MG to an estimated 88 MG. The reservoir is presently not utilized for agricultural purposes, although cattle drink from overflow streams leading from the reservoir.

Ka Loko Ditch

The Ka Loko Ditch (structure 14 in Table D-2 and Figure D-2) was used to divert water from the Puu Ka Ele Stream and transmit it to the Ka Loko Reservoir. A recent storm damaged sections of the ditch, rendering it inoperable.

Ka Loko Reservoir

Field surveys conducted by SCS engineers indicate that the structural stability of the Ka Loko Reservoir is questionable because of the seepage observed at the toe of the embankment and the dense growth of hao, guava, and palm trees on the downstream face of the embankment. Sedimentation has decreased the storage capacity of the reservoir from 408.9 MG to an estimated 390 MG. The control valve at the inlet is in working order and the emergency spillway, an uncontrolled concrete section, is in good condition.

## AVAILABILITY OF SURFACE WATER

There is an abundance of surface water available within the Kilauea area for agricultural use. It originates from runoff in the higher elevations as well as from the discharge of high-level ground water sources that feed the various streams. On a daily basis an average of 100 million gallons per day (MGD) of rainfall occurs in the area. The Kilauea Irrigation System in the past captured an average of 17 MGD[1/] of this rainfall.

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1/ Includes 2.17 MGD from Hanalei Ditch.

The highest three reservoirs would provide a substantial supply of water with average flows into Ka Loko, Puu Ka Ele and Kalihiwai reservoirs estimated at 2.5, 1.7, and 3.9 MGD, respectively. This is based on 34 years of stream gage data. The flow into Kalihiwai Reservoir is the average flow of U.S. Geological Survey (USGS) gage 16095900 rather than 16096000 (Figure D-3). Flows at the former gage were diverted by a wasteway gate for domestic use and now could be rerouted into Kalihiwai Reservoir. Further, Stone Dam, with a capacity of 75 MG, captures only a small portion of the average flow of 12.6 MGD from Halaulani and Pohakuhonu streams.

Based on an average daily flow, a substantial supply of surface water is available. However, this does not give an accurate estimate of the system's capacity during drought periods when irrigation demand is most critical. As a preliminary estimate, Belt Collins and Associates proposed a safe yield of 5.8 MGD based on a water budget study for a single drought period in 1953 that had a recurrence interval of 20 years. However, major significance should not be attached to this estimate since it was based on only a single event and assumed a constant crop demand.

To get a more precise estimate on the capacity of the system, water budget analyses should be done using varying crop demands, inflow and outflow data, and reservoir storage capacities. All available data, except for crop demand (see Appendix E - Water Use Inventory) are contained in the supplements to this report.

There are seven stream and ditch gaging stations within the Kilauea area where the USGS was or is operating continuous recorders (Table D-3 and Figure D-3). Supplement A-1 to A-6 contain monthly yield data for Ka Loko Ditch (16094200), Puu Ka Ele Ditch (16095000), Kalihiwai Ditch above wasteway (16095900), Kalihiwai Ditch near Kilauea (16096000), Pohakuhonu Stream near Kilauea (16097500) and Halaulani Stream at altitude 400 feet near Kilauea (16097500). In addition, flow duration and annual yield curves were developed for stations on Pohakuhonu and Halaulani streams in the event additional development of these sources are considered (Supplement B-1 to B-4).

Mean monthly rainfall and pan evaporation data for selected stations are found in Supplement C-1. Stage-storage curves for the Puu Ka Ele and Kalihiwai reservoirs are in Supplement D-1 and D-2. A survey done in September 1982 indicated sediment has decreased the capacity of Puu Ka Ele Reservoir by about 25 percent.

Table D-3
Stream and Ditch Gages

| USGS Number | Name | Period of Record | Elevation (Ft.) | Discharge (cfs) Max. | Mean | Min. | Drainage Area (SM) |
|---|---|---|---|---|---|---|---|
| 16094200 | Ka Loko Ditch near Kilauea | 1933-1968 | 754.0 | 98.0 | 3.84 | 0.08 | 0 |
| 16095000 | Puu Ka Ele Ditch near Kilauea | 1933-1966 | 426.0 | 32.0 | 2.70 | 0 | 0 |
| 16095200 | Ross Ditch near Kilauea | 1956-1967 | 341.0 | 17.0 | 3.58 | 0 | 0 |
| 16095900 | Kalihiwai Ditch above Wasteway | 1960-1965 | 413.4 | 50.0 | 6.06 | 0.34 | 0 |
| 16096000 | Kalihiwai Ditch near Kilauea | 1934-1966 | 409.2 | 45.6 | 2.39 | 0 | 0 |
| 16097000 | Pohakuhonu Stream near Kilauea | 1957-1972 | 401.7 | 2710.0 | 8.21 | 1.00 | 1.73 |
| 16097500 | Halaulani Stream at altitude 400 ft. near Kilauea | 1959-1980 | 391.8 | 2070.0 | 11.30 | 1.80 | 1.90 |

## WATER RIGHTS

Much of the watershed area that contributes to the flow into the various reservoirs is privately owned. The six reservoirs in the area are also privately owned. Therefore, the issue as to the rights for use of this water and reservoirs will have to be resolved and assured at some time. Table D-4 lists the owner(s) of the reservoirs and the respective contributing watersheds.

Table D-4
Reservoir and Contributing Watershed Ownership

| | Ownership | |
|---|---|---|
| Reservoir | Reservoir | Contributing Watershed |
| Ka Loko | C. Brewer and Lucas Estate | State of Hawaii |
| Puu Ka Ele | C. Brewer and Lucas Estate | C. Brewer, State of Hawaii, and Lucas Estate |
| Kalihiwai | C. Brewer | C. Brewer and Dyer |
| Stone Dam | C. Brewer | C. Brewer, Dyer and Ley |
| Morita | Lucas Estate | C. Brewer and Lucas Estate |
| Waiakalua | C. Brewer* | C. Brewer and Lucas Estate |

*Ownership by C. Brewer will be conveyed to the Kilauea Farm Association after all the Waiakalua Farm subdivision lots are sold and with the stipulation that the Hawaiiana Investment Co., Inc. can use the reservoir for any future irrigation systems.

## POTENTIAL FOR ADDITIONAL SUPPLY

### Surface Water

In the event that additional surface water must be developed, there are other alternatives that could be explored. One alternative would be to reactivate the Hanalei Ditch which previously diverted water from the Kalihiwai River into the Kalihiwai Reservoir. Past records indicate that the average annual flow is about 2.2 MGD with no flows at times due to regulation of the ditch intake. However, if the intake was not regulated, a larger portion of the stream flow could be diverted, probably averaging about 15.5 MGD. Reactivating this ditch would probably require substantial cost in repairing the ditch and replacing the inverted siphon across the Kalihiwai River.

Another alternative is to increase the storage capacity of Stone Dam to intercept a larger portion of the high flows from the Halaulani and Pohakuhonu streams. The average annual flows in both streams total 12.6 MGD with peak discharges in excess of 1,300 MGD. Stone Dam, with only a 7.5 MG storage capacity, can capture only a small amount of this flow and spills the remaining flow into the Mill Ditch and Kahiliholo Stream. Increasing the storage capacity by 100 MG could increase the safe yield by about 2.2 MGD[1/].

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1/ "The Kilauea Irrigation Water System, Island of Kauai," Department of Land and Natural Resources, February 18, 1976 (unpublished report).

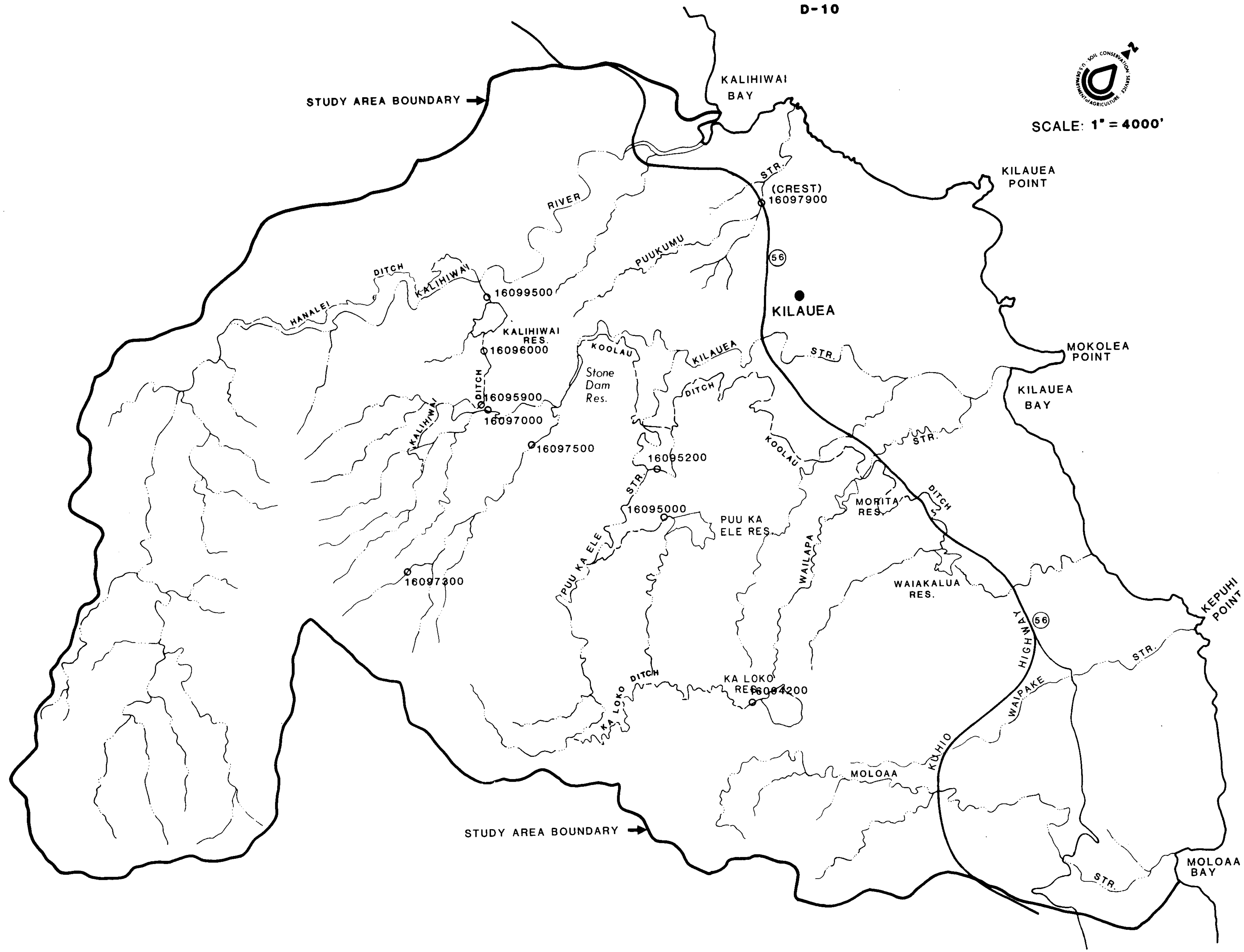



FIGURE D-3
STREAM GAGING STATIONS
KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## Ground Water

Ground water could also be developed to meet the agricultural needs in the Kilauea area. Ground water in the Kilauea area occurs as either basal, perched or dike impounded (Figure D-4).

At present, only the domestic system has developed any ground water sources (in Kilauea). The Kilauea Water System taps basal ground water at about elevation 16 feet and the Kalihiwai Water System's source previously tapped perched water at Kalihiwai Tunnel 2 at elevation 190 feet above the mouth of Kalihiwai River. This latter system has now been incorporated into the Kilauea Water System.

Basal water in the area usually occurs under water table conditions in the permeable Napali volcanic series; but in some cases when it is overlain with the poorly permeable Koloa lavas, artesian conditions exist. Development of basal water probably is not economically feasible due to the high pumping and development costs and also the design yield in the past has been less than 500 gpm--too small for agricultural demands.

Perched water scattered throughout the area lies atop either the impermeable Koloa lavas or other sedimentaries. Due to its occurrences in small discontinuous bodies with design yields less than 300 gpm, it does not warrant development for agricultural purposes.

Water impounded by "dikes" intruding Napali lava in the Kekoiki Ridge east of Kalihiwai River (Figure D-4) could possibly yield a dependable source of ground water due to its volume and high head. Dikes above Halaulani Stream could be developed by long tunnels.

## WATER QUALITY

The chemical quality of both ground water and surface water is excellent for agricultural purposes. Total dissolved solids for the domestic ground water wells and tunnels are less than 200 milligrams/liter, while chloride and sodium concentrations are less than 100 milligrams/liter. Records of surface water quality at station 16097500 Halaulani Stream are well within these limits also.

Although the chemical quality of the surface water in all the Kilauea area streams is excellent, the quality of the water decreases as it is diverted and transmitted away from the streams by the Kilauea Sugar Company Irrigation System. The water picks up sediment and debris as it flows through the mostly unlined distribution ditches. The quality of the water in the ditches, once suitable for the furrow irrigation method used in the past, is not suitable for use in modern drip irrigation systems. The farmers who currently use the water from the sugar company's ditches must use filter systems to cleanse the water.

## HYDROELECTRIC DEVELOPMENT POTENTIAL

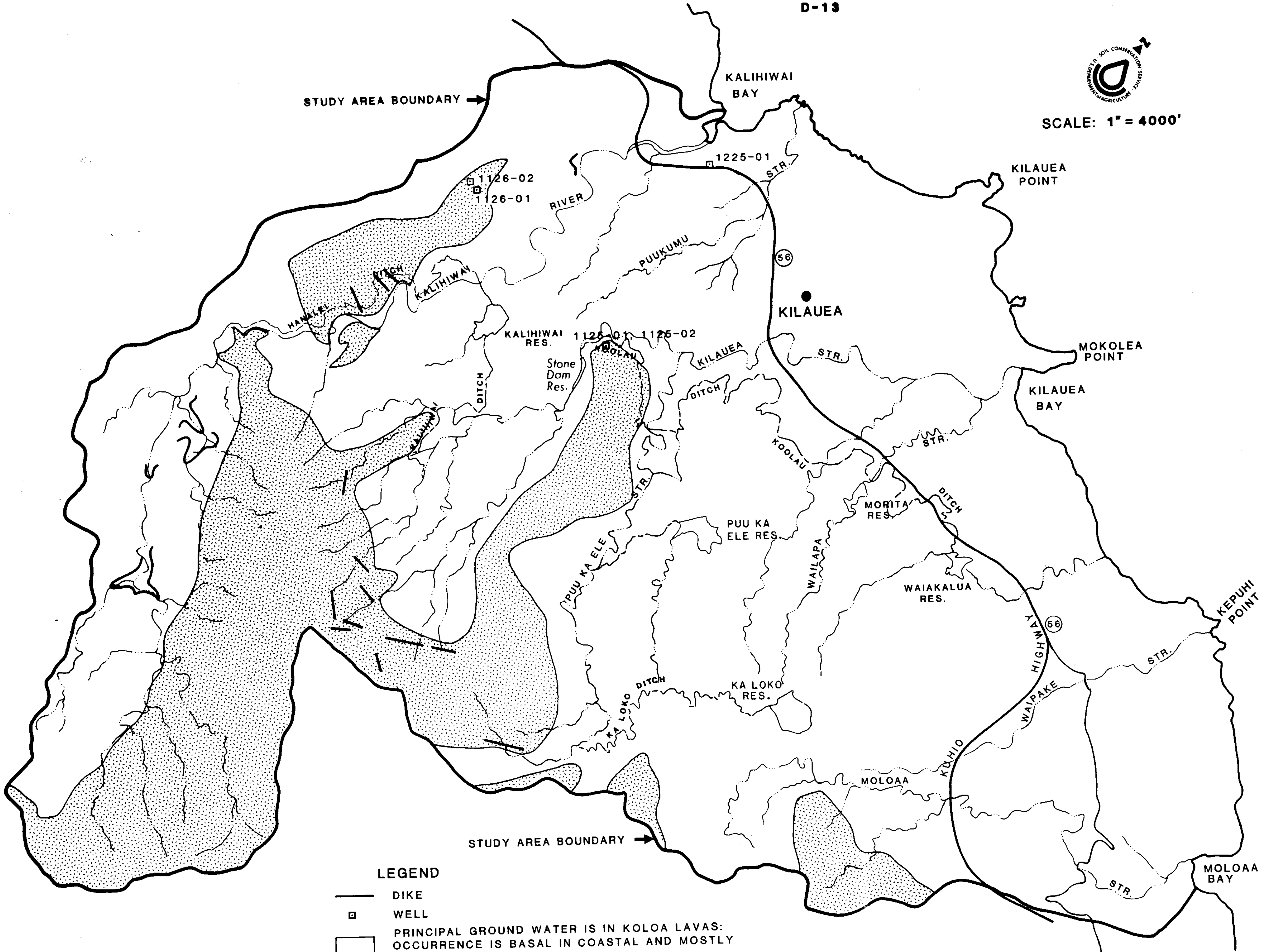
The water stored in the existing reservoirs and the abundant surface runoff in the area provide excellent sources that could be harnessed for power. If piped distribution systems were installed from the Ka Loko, Puu Ka Ele, or Kalihiwai reservoirs, generating electricity by installing hydroelectric power facilities would be possible. The three reservoirs are located at sufficient elevations and the topography below them is steep enough so that hydroelectric facilities could operate. Assuming that the piped distribution systems would run from the reservoirs down through the service areas and end somewhere in the vicinity of the Kuhio Highway, the head available from the three reservoirs is as follows:

Table D-5
Available Head

| Reservoir | Feet |
|---|---|
| Ka Loko | 460 |
| Puu Ka Ele | 130 |
| Kalihiwai | 110 |

If turbine generators were placed at various locations along the piped distribution systems, a total of 1.2 million kilowatt hours of electricity could be generated annually.

Small scale generators could also be installed to meet the needs of individual agricultural operations. Two agricultural operations in the study area presently use small generators that produce enough electricity to meet their needs.




## LEGEND

- DIKE
- WELL
- PRINCIPAL GROUND WATER IS IN KOLOA LAVAS: OCCURRENCE IS BASAL IN COASTAL AND MOSTLY PERCHED IN INLAND AREAS
- PRINCIPAL GROUND WATER IS IN NAPILI LAVAS: OCCURRENCE IS BASAL IN LOW-LYING AREAS AND MOSTLY DIKE-IMPOUNDED AT HIGH LEVELS IN INTERIOR MOUNTAINOUS AREAS

FIGURE D-4
GROUND WATER MAP
KILAUEA AGRICULTURAL WATI
MANAGEMENT STUDY

SUPPLEMENTS

Supplement
A-1

MONTHLY YIELD(MG)

Station:16094200 Name:Kaloko Ditch near Kilauea

| OCT/APR | NOV/MAY | DEC/JUN | JAN/JUL | FEB/AUG | MAR/SEP | |
|---|---|---|---|---|---|---|
| 51. | 117. | 165. | 216. | 103. | 128. | 1933. |
| 67. | 87. | 62. | 83. | 64. | 47. | 1933. |
| 34. | 36. | 70. | 101. | 65. | 39. | 1934. |
| 137. | 130. | 147. | 120. | 82. | 152. | 1934. |
| 137. | 172. | 119. | 104. | 95. | 154. | 1935. |
| 31. | 73. | 75. | 49. | 59. | 110. | 1935. |
| 81. | 112. | 190. | 124. | 68. | 153. | 1936. |
| 143. | 163. | 74. | 157. | 187. | 132. | 1936. |
| 184. | 93. | 95. | 110. | 96. | 170. | 1937. |
| 170. | 231. | 63. | 111. | 150. | 39. | 1937. |
| 140. | 134. | 111. | 127. | 140. | 148. | 1938. |
| 132. | 121. | 153. | 104. | 158. | 73. | 1938. |
| 73. | 77. | 93. | 100. | 136. | 140. | 1939. |
| 200. | 150. | 95. | 85. | 56. | 42. | 1939. |
| 92. | 151. | 102. | 76. | 58. | 192. | 1940. |
| 84. | 240. | 81. | 107. | 152. | 117. | 1940. |
| 161. | 112. | 89. | 109. | 93. | 108. | 1941. |
| 36. | 103. | 53. | 80. | 102. | 109. | 1941. |
| 133. | 91. | 86. | 86. | 116. | 153. | 1942. |
| 161. | 134. | 155. | 118. | 94. | 64. | 1942. |
| 43. | 59. | 228. | 194. | 82. | 146. | 1943. |
| 105. | 203. | 129. | 82. | 81. | 37. | 1943. |
| 50. | 54. | 87. | 51. | 113. | 148. | 1944. |
| 77. | 89. | 54. | 84. | 44. | 37. | 1944. |
| 35. | 32. | 74. | 38. | 23. | 72. | 1945. |
| 283. | 103. | 37. | 39. | 41. | 25. | 1945. |
| 44. | 63. | 147. | 198. | 140. | 100. | 1946. |
| 178. | 72. | 52. | 110. | 80. | 45. | 1946. |
| 36. | 117. | 194. | 82. | 36. | 133. | 1947. |
| 121. | 124. | 60. | 108. | 102. | 125. | 1947. |
| 66. | 189. | 164. | 143. | 93. | 139. | 1948. |
| 61. | 140. | 91. | 85. | 192. | 76. | 1948. |
| 45. | 92. | 120. | 225. | 158. | 114. | 1949. |
| 64. | 93. | 63. | 62. | 77. | 42. | 1949. |
| 51. | 75. | 94. | 171. | 95. | 102. | 1950. |
| 156. | 114. | 61. | 54. | 122. | 63. | 1950. |
| 40. | 44. | 113. | 109. | 110. | 201. | 1951. |
| 135. | 60. | 31. | 34. | 74. | 61. | 1951. |
| 143. | 156. | 253. | 126. | 114. | 165. | 1952. |
| 110. | 118. | 107. | 122. | 65. | 52. | 1952. |
| 104. | 165. | 105. | 134. | 110. | 118. | 1953. |
| 110. | 57. | 46. | 34. | 41. | 25. | 1953. |
| 22. | 58. | 60. | 45. | 112. | 153. | 1954. |
| 86. | 117. | 136. | 152. | 127. | 85. | 1954. |
| 91. | 173. | 178. | 131. | 104. | 147. | 1955. |
| 120. | 82. | 54. | 53. | 90. | 34. | 1955. |
| 99. | 187. | 84. | 120. | 70. | 59. | 1956. |
| 78. | 82. | 90. | 66. | 86. | 48. | 1956. |
| 166. | 104. | 60. | 84. | 50. | 64. | 1957. |
| 36. | 30. | 31. | 58. | 120. | 34. | 1957. |
| 52. | 103. | 156. | 110. | 85. | 80. | 1958. |
| 60. | 106. | 54. | 175. | 130. | 114. | 1958. |
| 152. | 103. | 75. | 63. | 66. | 44. | 1959. |

Supplement
A-1 (cont'd)

| | | | | | | |
|---|---|---|---|---|---|---|
| 107. | 90. | 40. | 58. | 116. | 92. | 1959. |
| 52. | 145. | 115. | 98. | 110. | 103. | 1960. |
| 128. | 141. | 88. | 103. | 90. | 101. | 1960. |
| 265. | 53. | 55. | 61. | 115. | 95. | 1961. |
| 206. | 115. | 115. | 79. | 97. | 74. | 1961. |
| 187. | 128. | 164. | 92. | 76. | 100. | 1962. |
| 111. | 78. | 56. | 66. | 87. | 61. | 1962. |
| 47. | 77. | 108. | 153. | 45. | 159. | 1963. |
| 139. | 142. | 180. | 139. | 116. | 67. | 1963. |
| 78. | 46. | 42. | 169. | 68. | 222. | 1964. |
| 138. | 168. | 88. | 180. | 97. | 74. | 1964. |
| 200. | 233. | 74. | 96. | 50. | 104. | 1965. |
| 105. | 97. | 81. | 104. | 81. | 60. | 1965. |
| 144. | 197. | 48. | 68. | 117. | 100. | 1966. |
| 69. | 87. | 60. | 75. | 118. | 64. | 1966. |
| 119. | 212. | 93. | 111. | 85. | 53. | 1967. |
| 83. | 154. | 78. | 136. | 172. | 70. | 1967. |
| 55. | 158. | 226. | 103. | 50. | 164. | 1968. |
| 127. | 106. | 50. | 45. | 41. | 40. | 1968. |

Supplement
A-2

MONTHLY YIELD(MG)

Station:16095000 Name:Puu Ka Ele Ditch near Kilauea

| OCT/APR | NOV/MAY | DEC/JUN | JAN/JUL | FEB/AUG | MAR/SEP | |
|---|---|---|---|---|---|---|
| 92. | 143. | 80. | 24. | 134. | 129. | 1933. |
| 112. | 131. | 110. | 130. | 96. | 67. | 1933. |
| 55. | 51. | 88. | 100. | 78. | 56. | 1934. |
| 129. | 173. | 202. | 182. | 114. | 135. | 1934. |
| 167. | 206. | 184. | 138. | 97. | 171. | 1935. |
| 98. | 88. | 76. | 82. | 129. | 139. | 1935. |
| 120. | 135. | 176. | 101. | 86. | 131. | 1936. |
| 123. | 213. | 92. | 203. | 137. | 110. | 1936. |
| 129. | 21. | 71. | 119. | 16. | 13. | 1937. |
| 98. | 98. | 91. | 148. | 174. | 104. | 1937. |
| 73. | 61. | 101. | 84. | 66. | 61. | 1938. |
| 142. | 136. | 141. | 105. | 144. | 34. | 1938. |
| 90. | 118. | 95. | 121. | 49. | 47. | 1939. |
| 87. | 111. | 123. | 123. | 89. | 80. | 1939. |
| 116. | 94. | 98. | 82. | 70. | 75. | 1940. |
| 74. | 93. | 66. | 98 | 107. | 113. | 1940. |
| 53. | 0. | 3. | 32. | 78. | 113. | 1941. |
| 86. | 114. | 59. | 79. | 110. | 120. | 1941. |
| 90. | 66. | 88. | 91. | 48. | 66. | 1942. |
| 83. | 56. | 38. | 85. | 52. | 34. | 1942. |
| 65. | 85. | 54. | 22. | 42. | 74. | 1943. |
| 79. | 134. | 140. | 129. | 124. | 116. | 1943. |
| 74. | 65. | 79. | 61. | 84. | 46. | 1944. |
| 80. | 111. | 63. | 106. | 60. | 45. | 1944. |
| 49. | 49. | 90. | 52. | 43. | 115. | 1945. |
| 47. | 40. | 49. | 46. | 59. | 41. | 1945. |
| 54. | 75. | 73. | 89. | 14. | 100. | 1946. |
| 101. | 69. | 56. | 112. | 93. | 68. | 1946. |
| 46. | 45. | 11. | 75. | 46. | 123. | 1947. |
| 103. | 134. | 68. | 138. | 127. | 112. | 1947. |
| 65. | 32. | 4. | 72. | 62. | 60. | 1948. |
| 21. | 33. | 77. | 92. | 122. | 119. | 1948. |
| 76. | 66. | 0. | 12. | 18. | 86. | 1949. |
| 71. | 86. | 58. | 67. | 83. | 51. | 1949. |
| 55. | 86. | 102. | 44. | 4. | 50. | 1950. |
| 68. | 87. | 68. | 60. | 97. | 73. | 1950. |
| 49. | 56. | 67. | 37. | 16. | 10. | 1951. |
| 48. | 66. | 38. | 43. | 80. | 75. | 1951. |
| 147. | 134. | 54. | 3. | 82. | 134. | 1952. |
| 116. | 114. | 123. | 123. | 74. | 72. | 1952. |
| 99. | 124. | 8. | 10. | 18. | 39. | 1953. |
| 83. | 61. | 50. | 44. | 48. | 33. | 1953. |
| 37. | 65. | 57. | 30. | 58. | 97. | 1954. |
| 78. | 98. | 97. | 143. | 63. | 35. | 1954. |
| 82. | 94. | 9. | 1. | 60. | 100. | 1955. |
| 106. | 91. | 68. | 72. | 76. | 88. | 1955. |
| 82. | 20. | 3. | 14. | 1. | 1. | 1956. |
| 78. | 162. | 121. | 80. | 146. | 100. | 1956. |
| 84. | 19. | 8. | 52. | 6. | 15. | 1957. |
| 25. | 15. | 42. | 65. | 129. | 94. | 1957. |
| 50. | 79. | 7. | 82. | 14. | 3. | 1958. |
| 12. | 17. | 23. | 102. | 33. | 108. | 1958. |
| 79. | 17. | 62. | 44. | 46. | 64. | 1959. |

Supplement
A-2 (cont'd)

| | | | | | | |
|---|---|---|---|---|---|---|
| 71. | 99. | 46. | 62. | 123. | 99. | 1959. |
| 57. | 95. | 33. | 94. | 34. | 134. | 1960. |
| 103. | 108. | 81. | 100. | 97. | 92. | 1960. |
| 46. | 16. | 1. | 44. | 34. | 64. | 1961. |
| 76. | 83. | 103. | 70. | 84. | 76. | 1961. |
| 72. | 0. | 20. | 51. | 2. | 15. | 1962. |
| 82. | 85. | 87. | 77. | 80. | 51. | 1962. |
| 44. | 60. | 77. | 25. | 25. | 69. | 1963. |
| 30. | 36. | 111. | 99. | 84. | 72. | 1963. |
| 73. | 50. | 39. | 91. | 60. | 29. | 1964. |
| 73. | 90. | 84. | 140. | 72. | 53. | 1964. |
| 106. | 23. | 8. | 22. | 50. | 74. | 1965. |
| 36. | 89. | 53. | 83. | 66. | 55. | 1965. |
| 135. | 50. | 0. | 48. | 39. | 58. | 1966. |
| 53. | 68. | 34. | 59. | 91. | 28. | 1966. |
| 33. | 3. | 1. | 1. | 32. | | 1967. |

MONTHLY YIELD(MG)

Station:16095900 Name:Kalihiwai Ditch above wasteway near Kilauea

| OCT/APR | NOV/MAY | DEC/JUN | JAN/JUL | FEB/AUG | MAR/SEP | |
|---|---|---|---|---|---|---|
| | 139. | 102. | 116. | 139. | 140. | 1960. |
| 148. | 67. | 68. | 65. | 90. | 129. | 1961. |
| 188. | 114. | 106. | 70. | 87. | 67. | 1961. |
| 122. | 102. | 126. | 109. | 92. | 186. | 1962. |
| 146. | 111. | 53. | 62. | 93. | 46. | 1962. |
| 52. | 88. | 72. | 97. | 37. | 160. | 1963. |
| 224. | 222. | 134. | 157. | 75. | 78. | 1963. |
| 96. | 59. | 44. | 157. | 92. | 289. | 1964. |
| 135. | 159. | 77. | 151. | 83. | 78. | 1964. |
| 153. | 275. | 231. | 153. | 105. | 139. | 1965. |
| 247. | 206. | 80. | 134. | 92. | 76. | 1965. |
| 180. | 294. | 163. | 95. | 129. | 74. | 1966. |
| 54. | 67. | 54. | 117. | 148. | 71. | 1966. |
| 127. | 152. | 76. | 111. | 141. | 255. | 1967. |
| 186. | 181. | 84. | 89. | 152. | 67. | 1967. |
| 103. | 210. | 246. | 125. | 62. | 192. | 1968. |
| 163. | 135. | 57. | 76. | 31. | 63. | 1968. |

Supplement

A-4

MONTHLY YIELD(MG)

Station:16096000 Name:Kalihiwai Ditch near Kilauea

| OCT/APR | NOV/MAY | DEC/JUN | JAN/JUL | FEB/AUG | MAR/SEP | |
|---|---|---|---|---|---|---|
| | | | 105. | 103. | 101. | 1934. |
| 68. | 14. | 52. | 66. | 95. | 68. | 1935. |
| 102. | 71. | 83. | 86. | 142. | 130. | 1935. |
| 75. | 75. | 50. | 27. | 85. | 93. | 1936. |
| 47. | 60. | 92. | 127. | 114. | 98. | 1936. |
| 108. | 41. | 33. | 24. | 59. | 49. | 1937. |
| 106. | 103. | 95. | 213. | 117. | 93. | 1937. |
| 82. | 72. | 75. | 64. | 74. | 72. | 1938. |
| 116. | 105. | 70. | 126. | 105. | 78. | 1938. |
| 107. | 96. | 152. | 65. | 60. | 55. | 1939. |
| 40. | 57. | 110. | 142. | 102. | 92. | 1939. |
| 113. | 72. | 46. | 60. | 72. | 91. | 1940. |
| 70. | 82. | 102. | 152. | 130. | 79. | 1940. |
| 33. | 50. | 60. | 81. | 77. | 93. | 1941. |
| 88. | 148. | 79. | 127. | 131. | 108. | 1941. |
| 94. | 41. | 57. | 81. | 70. | 33. | 1942. |
| 33. | 21. | 38. | 41. | 52. | 81. | 1942. |
| 79. | 86. | 16. | 50. | 56. | 92. | 1943. |
| 104. | 95. | 86. | 103. | 119. | 133. | 1943. |
| 77. | 70. | 58. | 60. | 81. | 59. | 1944. |
| 88. | 131. | 58. | 130. | 72. | 49. | 1944. |
| 67. | 78. | 107. | 66. | 52. | 162. | 1945. |
| 42. | 58. | 53. | 52. | 103. | 60. | 1945. |
| 97. | 76. | 66. | 89. | 49. | 73. | 1946. |
| 54. | 66. | 60. | 131. | 116. | 75. | 1946. |
| 62. | 114. | 69. | 78. | 56. | 129. | 1947. |
| 62. | 122. | 97. | 65. | 90. | 69. | 1947. |
| 82. | 80. | 51. | 100. | 89. | 62. | 1948. |
| 66. | 77. | 68. | 98. | 105. | 98. | 1948. |
| 40. | 80. | 8. | 44. | 47. | 76. | 1949. |
| 85. | 91. | 61. | 76. | 115. | 50. | 1949. |
| 72. | 111. | 110. | 33. | 9. | 84. | 1950. |
| 94. | 92. | 64. | 54. | 116. | 68. | 1950. |
| 39. | 80. | 53. | 43. | 79. | 55. | 1951. |
| 29. | 58. | 29. | 41. | 135. | 101. | 1951. |
| 146. | 132. | 55. | 23. | 72. | 111. | 1952. |
| 112. | 123. | 132. | 135. | 78. | 82. | 1952. |
| 144. | 71. | 13. | 43. | 86. | 43. | 1953. |
| 76. | 50. | 46. | 38. | 37. | 20. | 1953. |
| 22. | 48. | 5. | 25. | 90. | 40. | 1954. |
| 60. | 112. | 63. | 135. | 45. | 78. | 1954. |
| 79. | 99. | 13. | 8. | 72. | 111. | 1955. |
| 163. | 144. | 85. | 119. | 167. | 105. | 1955. |
| 84. | 44. | 23. | 49. | 8. | 94. | 1956. |
| 119. | 159. | 121. | 70. | 113. | 9. | 1956. |
| 63. | 25. | 7. | 73. | 19. | 84. | 1957. |
| 121. | 53. | 35. | 62. | 155. | 60. | 1957. |
| 40. | 59. | 5. | 89. | 38. | 38. | 1958. |
| 47. | 69. | 53. | 148. | 97. | 120. | 1958. |
| 109. | 13. | 4. | 5. | 26. | 48. | 1959. |
| 90. | 93. | 16. | 62. | 59. | 65. | 1959. |
| 31. | 85. | 5. | 24. | 50. | 99. | 1960. |
| 44. | 53. | 78. | 41. | 94. | 113. | 1960. |

Supplement

A-4 (cont'd)

| | | | | | | |
|---|---|---|---|---|---|---|
| 15. | 11. | 4. | 22. | 48. | 101. | 1961. |
| 68. | 7. | 6. | 19. | 55. | 36. | 1961. |
| 46. | 2. | 3. | 39. | 21. | 8. | 1962. |
| 38. | 24. | 25. | 47. | 62. | 28. | 1962. |
| 34. | 38. | 43. | 18. | 13. | 34. | 1963. |
| 29. | 3. | 1. | 7. | 36. | 64. | 1963. |
| 66. | 32. | 34. | 31. | 32. | 20. | 1964. |
| 5. | 18. | 37. | 116. | 71. | 58. | 1964. |
| 54. | 8. | 32. | 10. | 44. | 17. | 1965. |
| 34. | 41. | 21. | 53. | 77. | 62. | 1965. |
| 50. | 5. | 18. | 37. | 46. | 39. | 1966. |
| 40. | 52. | 38. | 91. | 76. | 28. | 1966. |

Supplement
A-5

MONTHLY YIELD(MG)

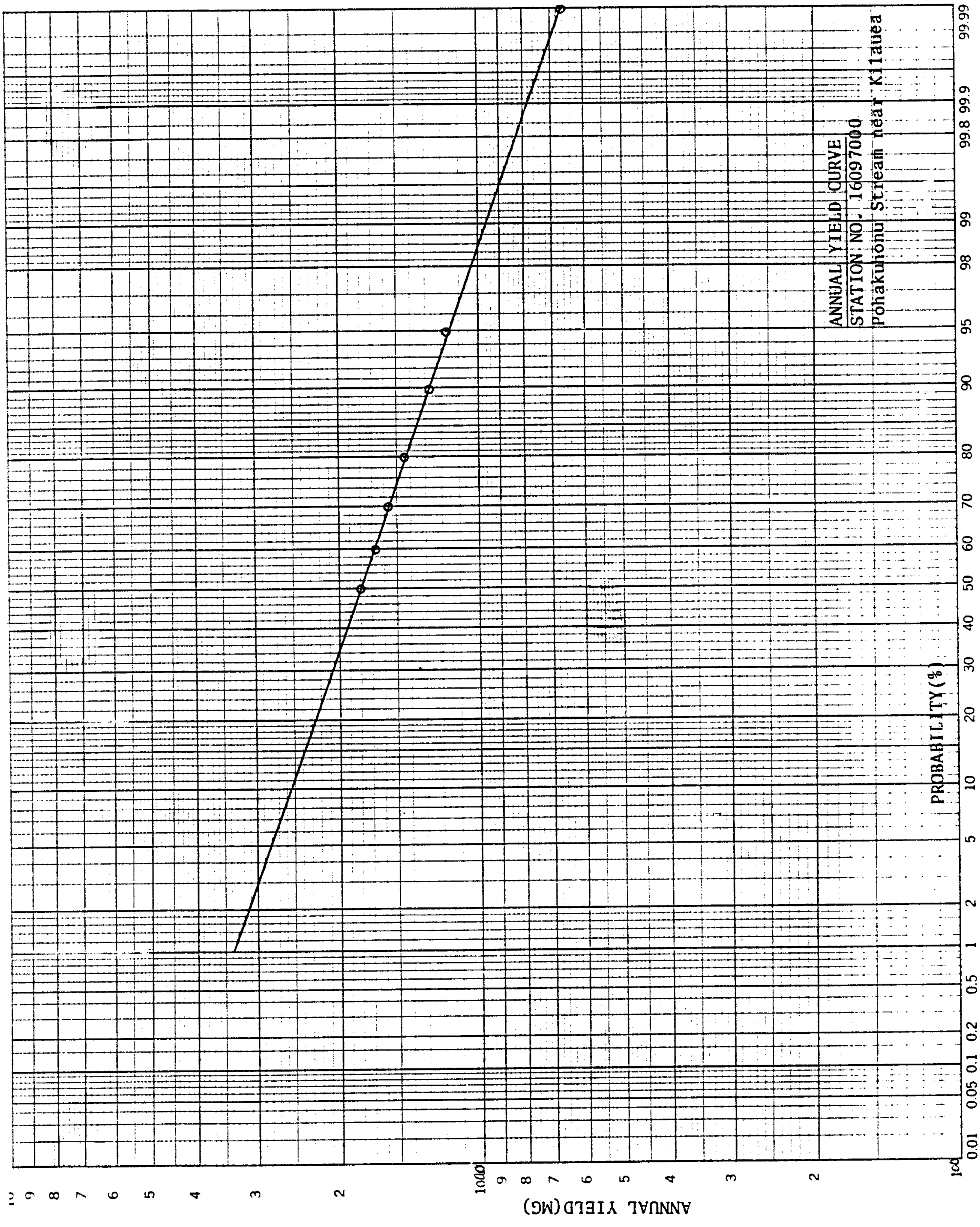
Station:16097000 Name:Pohakuhonu Stream near Kilauea

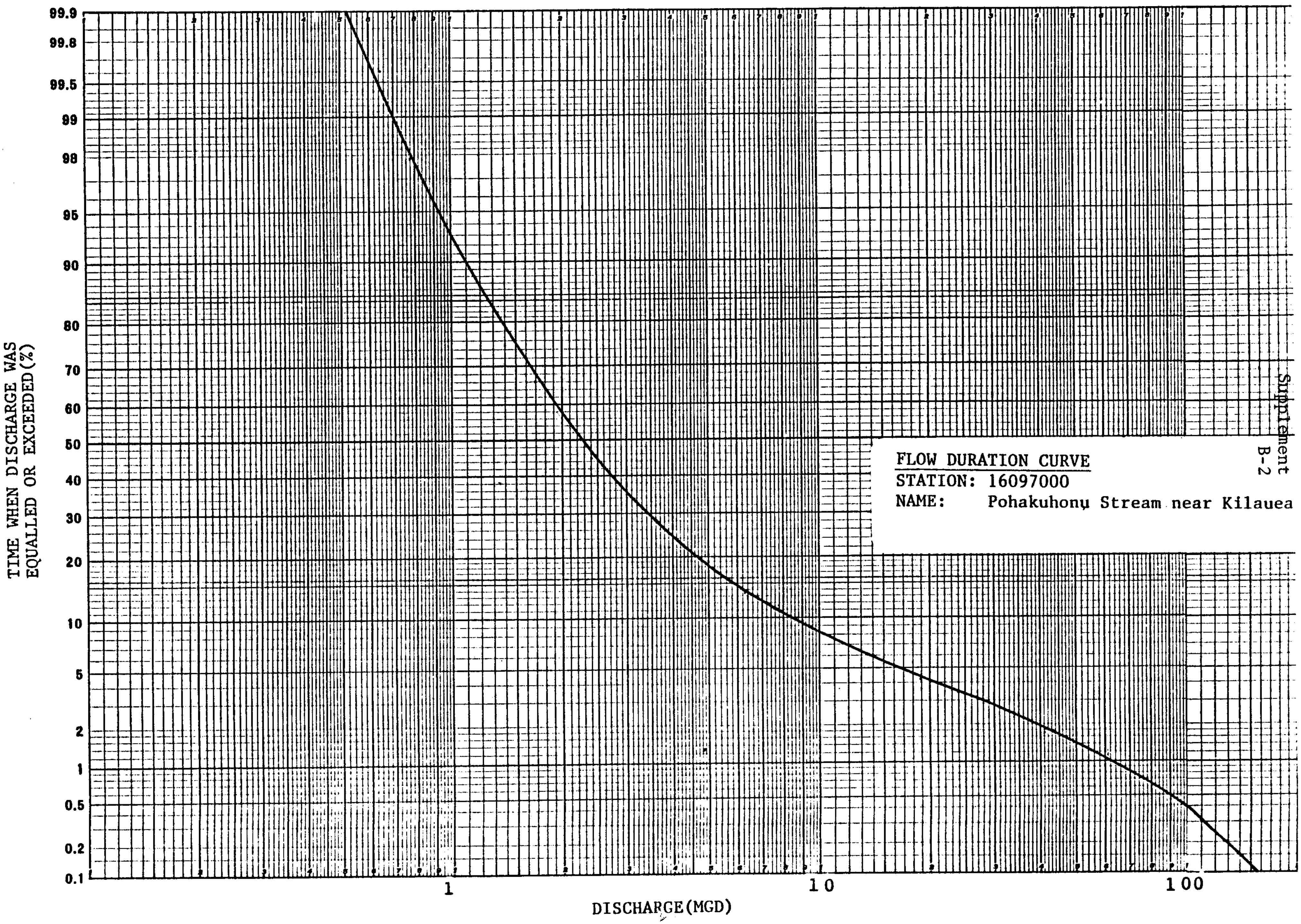
| OCT/APR | NOV/MAY | DEC/JUN | JAN/JUL | FEB/AUG | MAR/SEP | |
|---|---|---|---|---|---|---|
| | 83. | 430. | 71. | 99. | 50. | 1958. |
| 49. | 93. | 46. | 170. | 312. | 140. | 1958. |
| 325. | 172. | 151. | 103. | 105. | 40. | 1959. |
| 127. | 74. | 29. | 53. | 352. | 136. | 1959. |
| 52. | 279. | 97. | 147. | 182. | 645. | 1960. |
| 238. | 123. | 74. | 128. | 84. | 79. | 1960. |
| 233. | 101. | 115. | 104. | 155. | 115. | 1961. |
| 218. | 166. | 133. | 73. | 112. | 85. | 1961. |
| 185. | 114. | 230. | 172. | 122. | 336. | 1962. |
| 230. | 132. | 60. | 61. | 78. | 40. | 1962. |
| 33. | 62. | 79. | 81. | 38. | 293. | 1963. |
| 384. | 293. | 168. | 207. | 78. | 66. | 1963. |
| 81. | 41. | 32. | 194. | 82. | 508. | 1964. |
| 168. | 239. | 69. | 192. | 96. | 70. | 1964. |
| 233. | 363. | 420. | 275. | 131. | 324. | 1965. |
| 515. | 368. | 87. | 143. | 64. | 46. | 1965. |
| 186. | 551. | 136. | 67. | 147. | 45. | 1966. |
| 39. | 43. | 34. | 95. | 138. | 44. | 1966. |
| 135. | 231. | 30. | 178. | 254. | 472. | 1967. |
| 244. | 371. | 32. | 86. | 198. | 40. | 1967. |
| 39. | 375. | 482. | 127. | 32. | 355. | 1968. |
| 204. | 110. | 51. | 73. | 96. | 73. | 1968. |
| 209. | 304. | 240. | 453. | 235. | 275. | 1969. |
| 151. | 318. | 45. | 116. | 53. | 74. | 1969. |
| 87. | 127. | 205. | 241. | 43. | 29. | 1970. |
| 98. | 90. | 38. | 95. | 51. | 48. | 1970. |
| 39. | 250. | 170. | 88. | 53. | 201. | 1971. |
| 639. | 58. | 31. | 36. | 24. | 25. | 1971. |
| 27. | 63. | 206. | 81. | 122. | 39. | 1972. |
| 197. | 37. | 44. | 249. | 37. | 48. | 1972. |

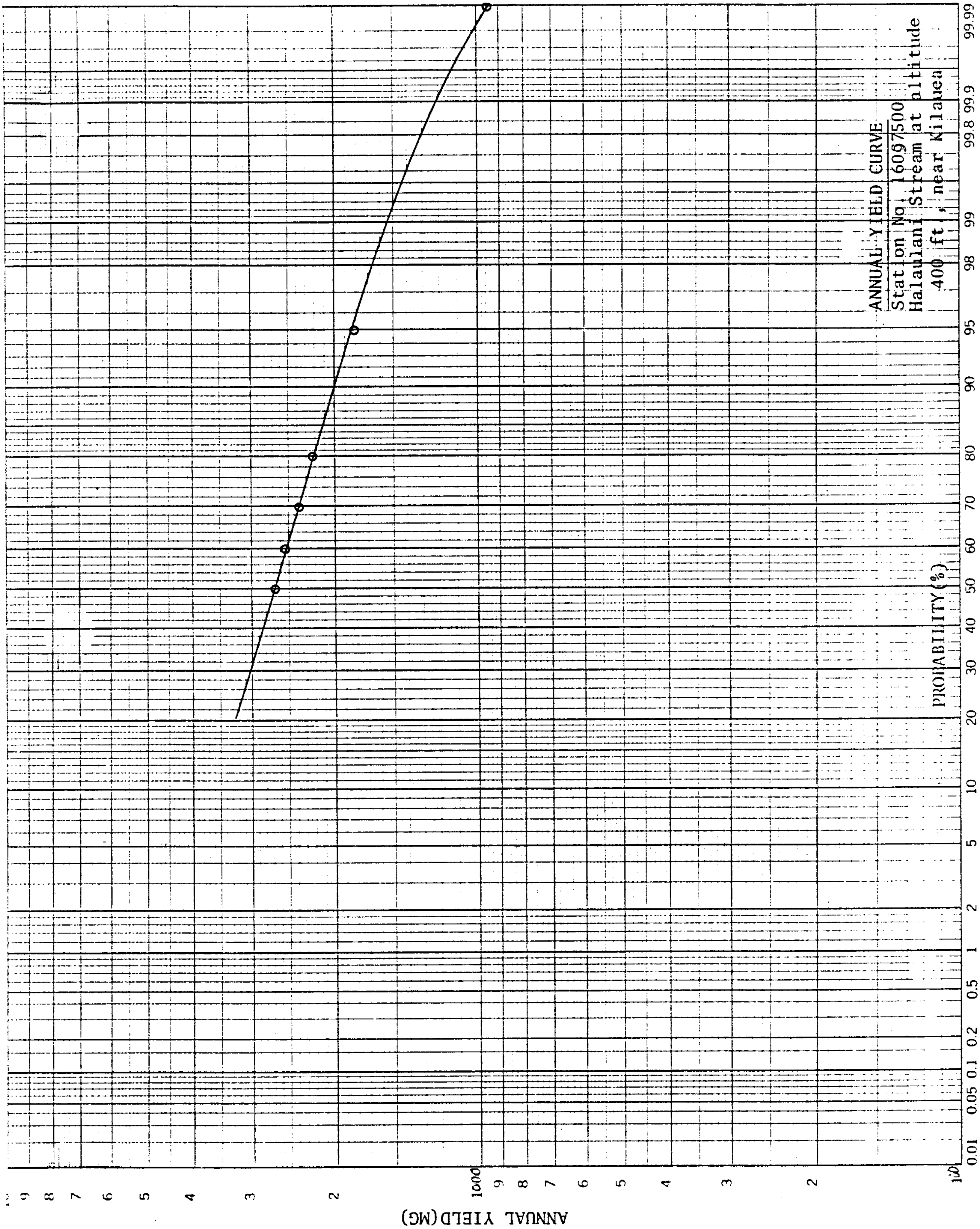
# MONTHLY YIELD(MG)

Station:1609750 Name:Halaulani Stream near Kilauea

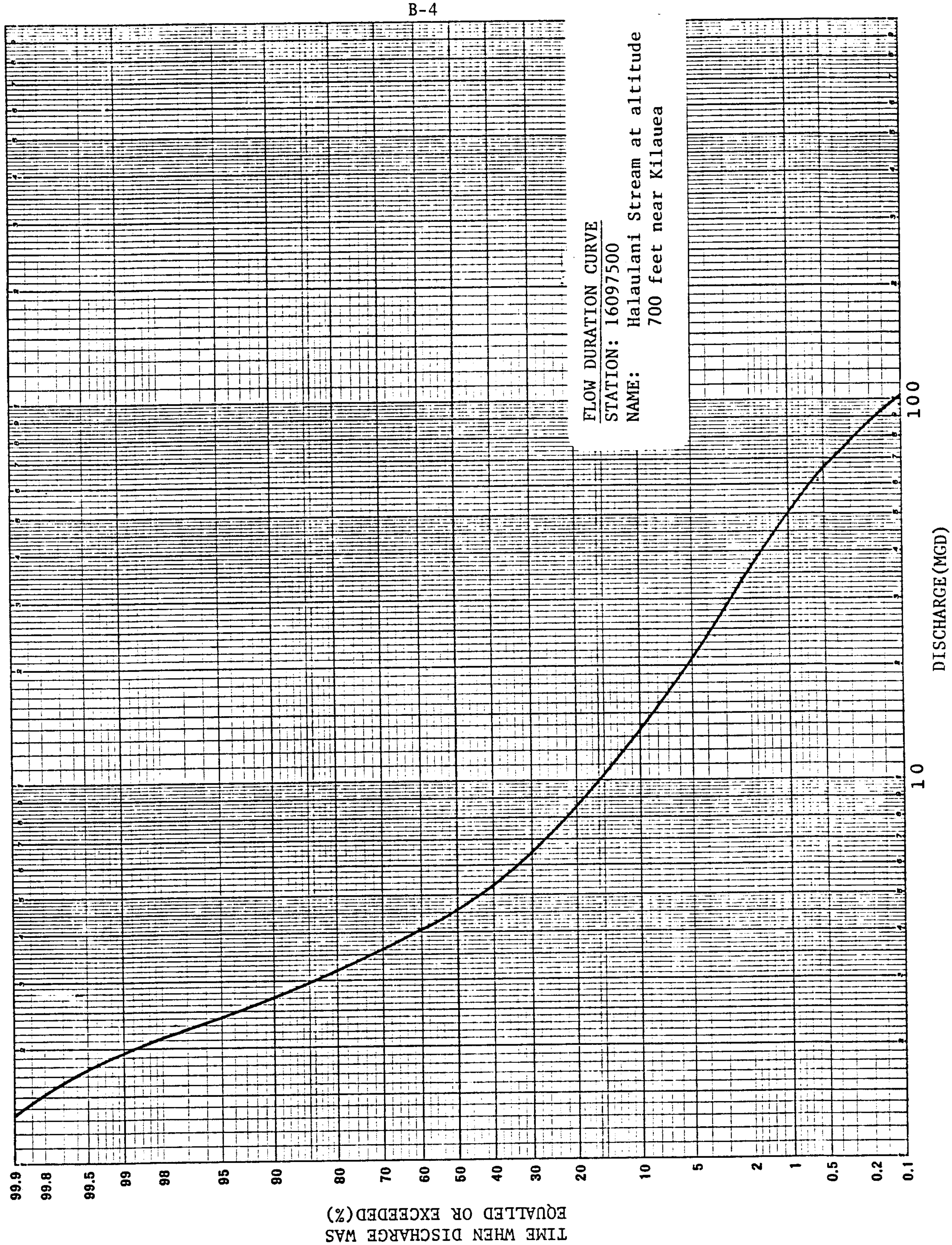
| OCT/APR | NOV/MAY | DEC/JUN | JAN/JUL | FEB/AUG | MAR/SEP | |
|---|---|---|---|---|---|---|
| | | 487. | 167. | 174. | 134. | 1958. |
| 128. | 200. | 113. | 347. | 425. | 225. | 1958. |
| 154. | 242. | 255. | 189. | 155. | 105. | 1959. |
| 227. | 177. | 83. | 124. | 363. | 188. | 1959. |
| 101. | 317. | 191. | 196. | 194. | 603. | 1960. |
| 270. | 204. | 148. | 198. | 186. | 192. | 1960. |
| 329. | 140. | 199. | 159. | 211. | 133. | 1961. |
| 326. | 242. | 215. | 144. | 189. | 145. | 1961. |
| 272. | 194. | 315. | 247. | 180. | 384. | 1962. |
| 365. | 245. | 119. | 148. | 203. | 114. | 1962. |
| 100. | 152. | 162. | 149. | 75. | 352. | 1963. |
| 482. | 381. | 233. | 286. | 173. | 145. | 1963. |
| 183. | 115. | 98. | 307. | 155. | 544. | 1964. |
| 267. | 317. | 145. | 312. | 160. | 141. | 1964. |
| 339. | 521. | 475. | 314. | 214. | 312. | 1965. |
| 564. | 450. | 176. | 252. | 150. | 121. | 1965. |
| 269. | 635. | 244. | 149. | 243. | 122. | 1966. |
| 111. | 130. | 109. | 187. | 266. | 115. | 1966. |
| 251. | 342. | 155. | 274. | 302. | 567. | 1967. |
| 365. | 450. | 123. | 208. | 326. | 109. | 1967. |
| 115. | 371. | 521. | 254. | 109. | 404. | 1968. |
| 301. | 207. | 94. | 128. | 159. | 78. | 1968. |
| 233. | 272. | 295. | 304. | 291. | 280. | 1969. |
| 203. | 274. | 109. | 322. | 178. | 208. | 1969. |
| 213. | 196. | 259. | 308. | 116. | 92. | 1970. |
| 192. | 209. | 137. | 236. | 161. | 161. | 1970. |
| 129. | 450. | 371. | 227. | 161. | 325. | 1971. |
| 681. | 168. | 103. | 117. | 89. | 78. | 1971. |
| 99. | 169. | 349. | 245. | 329. | 156. | 1972. |
| 365. | 136. | 162. | 352. | 136. | 120. | 1972. |
| 181. | 135. | 90. | 129. | 161. | 282. | 1973. |
| 159. | 233. | 104. | 114. | 79. | 92. | 1973. |
| 135. | 318. | 314. | 167. | 144. | 197. | 1974. |
| 531. | 319. | 214. | 216. | 132. | 235. | 1974. |
| 103. | 325. | 177. | 560. | 211. | 252. | 1975. |
| 223. | 151. | 90. | 101. | 85. | 76. | 1975. |
| 89. | 229. | 136. | 306. | 232. | 459. | 1976. |
| 329. | 168. | 122. | 184. | 146. | 99. | 1976. |
| 161. | 111. | 125. | 124. | 158. | 130. | 1977. |
| 322. | 280. | 167. | 185. | 183. | 102. | 1977. |
| 123. | 188. | 146. | 106. | 78. | 116. | 1978. |
| 218. | 292. | 564. | 256. | 308. | 190. | 1978. |
| 315. | 365. | 200. | 173. | 531. | 138. | 1979. |
| 112. | 200. | 178. | 131. | 144. | 105. | 1979. |
| 112. | 223. | 237. | 210. | 101. | 365. | 1980. |
| 407. | 410. | 342. | 437. | 191. | 292. | 1980. |


ANNUAL YIELD CURVE
STATION NO. 16097000
Pohakuhonu Stream near Kilauea
PROBABILITY(%)
ANNUAL YIELD(MG)
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
100
1000


FLOW DURATION CURVE
STATION: 16097000
NAME: Pohakuhonu Stream near Kilauea
TIME WHEN DISCHARGE WAS EQUALLED OR EXCEEDED (%)
99.9
99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
1
10
100
DISCHARGE (MGD)


ANNUAL YIELD CURVE
Station No. 16097500
Halaulani Stream at altitude
400 ft , near Kilauea
PROBABILITY (%)
ANNUAL YIELD (MG)
1000

Supplement
B-4

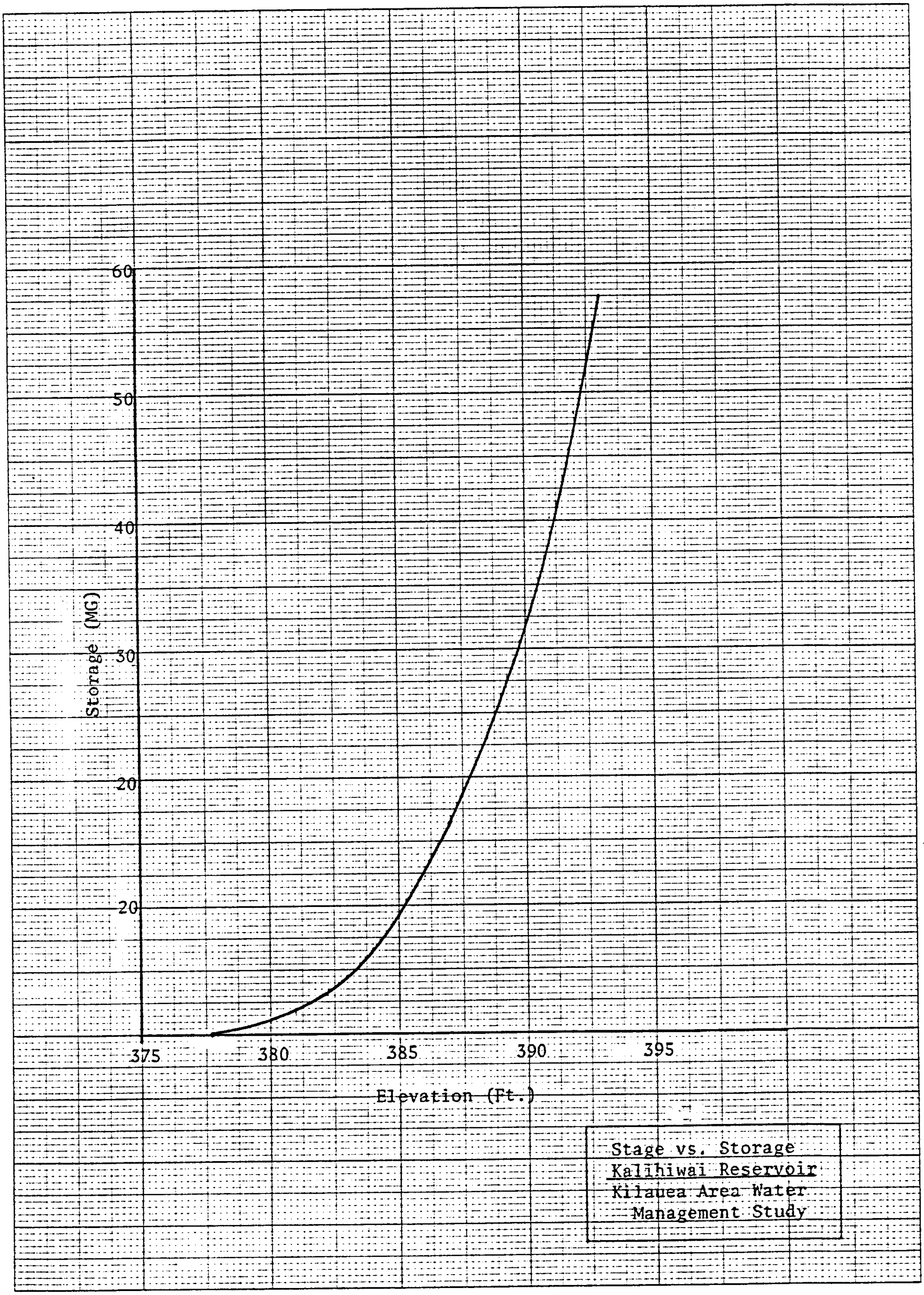


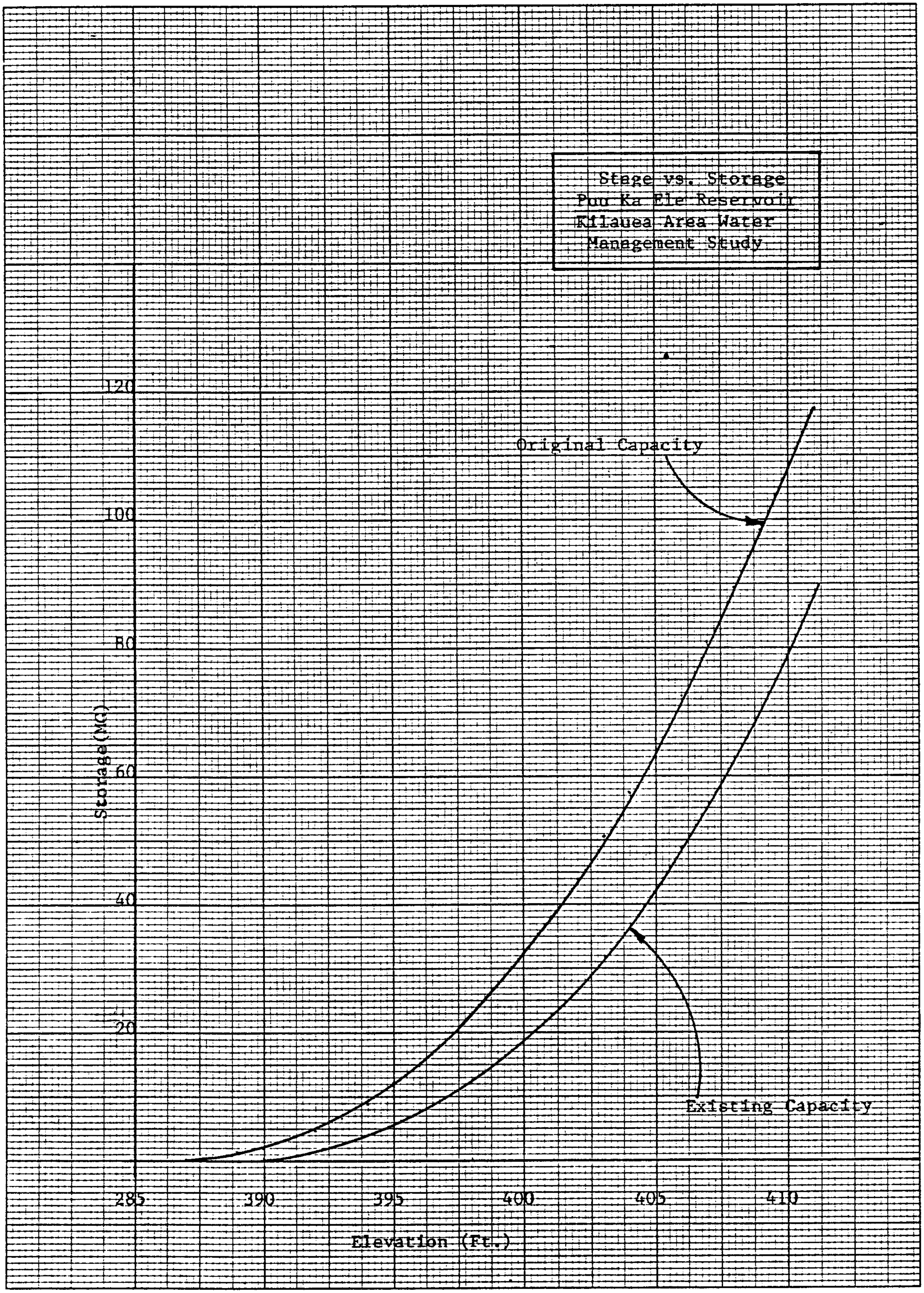
Mean Monthly Rainfall (inches)

| Rain Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1137.0 | 10.3 | 7.6 | 10.3 | 9.1 | 7.1 | 4.6 | 6.0 | 6.5 | 4.7 | 7.5 | 9.8 | 9.5 | 92.6 | Ka Loko |
| 1135.0 | 9.7 | 7.6 | 10.1 | 9.0 | 4.8 | 4.8 | 6.6 | 6.9 | 5.1 | 6.9 | 9.2 | 9.3 | 92.7 | Puu Ka Ele |
| 1131.0 | 9.8 | 8.4 | 11.6 | 9.3 | 8.9 | 5.6 | 8.1 | 8.4 | 5.8 | 7.6 | 10.0 | 11.0 | 104.8 | Kalihiwai |

Mean Monthly Pan Evaporation (inches)

| Pan Evap Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1135 | 3.78 | 3.79 | 4.54 | 4.95 | 7.32 | 6.83 | 7.18 | 7.31 | 5.99 | 4.99 | 3.19 | - | |
| 1141.2 | 4.54 | 4.03 | 5.41 | 4.87 | 5.36 | 6.22 | 6.33 | 5.82 | 5.56 | 5.28 | 4.27 | - | |


60
50
40
30
20
20
Storage (MG)
375
380
385
390
395
Elevation (Ft.)
Stage vs. Storage
Kalihiwai Reservoir
Kilauea Area Water
Management Study


Stage vs. Storage
Puu Ka Ele Reservoir
Kilauea Area Water
Management Study
Original Capacity
Existing Capacity
Storage (MG)
120
100
80
60
40
20
285
390
395
400
405
410
Elevation (Ft.)

# APPENDIX E

# WATER USE INVENTORY

# APPENDIX E
# WATER USE INVENTORY

Appendix E describes present water use in the study area, estimates crop, prawn, and livestock water requirements, and identifies the water development needs for irrigation and livestock water. Information on crop and livestock water requirements are presented in a manner to be used for the design of agricultural water systems and individual on-farm irrigation systems.

## METHOD OF CONSUMPTIVE USE DEVELOPMENT

Weather is one of the most significant risk factors in agriculture. Rainfall is seldom adequate throughout the year to supply water to obtain optimum yields. During the growing period, one or more periods may occur when rainfall does not meet crop water needs. Due to the uncertainty of rainfall, installation of irrigation systems prevent the occurrence of water deficits and maximizes crop production and quality.

The Modified Penman[1/] equation is used to estimate the crop water needs. Temperature, wind, solar radiation, humidity, soils, rainfall, and elevation are variables used to estimate evapotranspiration. Rainfall data from 18 climatological stations were considered. When temperature or solar radiation data was not available at the climatological station, it was estimated from other stations in the study area.

Consumptive use, often called evapotranspiration, includes water used by plants in transpiration and growth, and the evaporation from the adjacent soil and precipitation intercepted by plant foilage.

Evapotranspiration rate considers the average water demand of four crop development stages. The average was used to account for the different water demands over the growing season and rate of crop development. Four stages in crop development are:

- initial stage: germination and early growth when there is minimum crop cover over the soil;
- crop development stage: from end of initial stage to attainment of effective full ground cover;
- mid-season stage: from effective full ground cover to the start of maturing; and
- late season stage: end of mid-season until full maturity or harvest.

Rainfall probability of occurrence was calculated using the Log Pearson Type III frequency analysis. Rainfall available for crop use is derived from this probability of rain.

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1/ Renner, Dean M., "Estimating Consumptive Use in Hawaii," Technical Note, Engineering No. 14, USDA-SCS, Honolulu, Hawaii, May 1980.

Crop water requirements for papaya, guava, banana, corn, and truck crops are shown for areas which are presently being cultivated or have the potential to be grown. Demands shown in Figures E-2, E-3, and E-4 are the gross annual irrigation requirements. Gross annual irrigation requirements are determined from the net irrigation requirements for the specific crop by considering the method of irrigation field application efficiency. Net irrigation requirement is the portion of the evapotranspiration that will not be satisfied by rain. Rainfall was found to be sufficient for crop water needs during a few months of the year.

Peak daily crop water requirements are determined from the month with the highest potential crop water needs, assuming no rainfall. Peak demand usually occurs during the mid-season crop stage. Peak daily irrigation requirement is the peak daily water requirement considering the field application efficiency. A printout of the irrigation water requirement calculations is shown in Figure E-1.

## IRRIGATION WATER PROJECTION

Water needs to obtain optimum crop production have been projected for papaya, guava, banana, corn, and truck crops, and for livestock water. Papaya and guava have similar consumptive use requirements; therefore, one map displays their water needs. The cultivation of banana requires the most irrigation water, while truck crops are the least demanding.

Projected water requirements data are presented in such a manner as to be used in the design of an irrigation system in the study area and individual on-farm irrigation systems, and water management or scheduling. The volume of water demand per acre is shown on an annual and monthly distribution basis.

Existing reservoir storages may be compared to the potential requirements to determine the adequacy of the supply. Peak irrigation demands are also shown and may be used to determine system capacities. Annual and monthly distribution of irrigation water projections are based on annual effective rainfall that occurs 80 percent of the time, or 8 out of 10 years. Peak irrigation demands are projected assuming no rainfall occurs. Livestock water requirements are projected for annual rainfall occurring 90 percent of the time, or 9 out of 10 years.

Papaya, guava, and truck crops are drip irrigated with a field application efficiency of 80 percent. Field application efficiency is the percentage of water applied that is used by the plant. Banana and field corn are sprinkler irrigated with a field application efficiency of 65 percent.

Monthly irrigation requirements are in 1,000 gallons per acre per month and are related to the gross annual irrigation requirement maps. The 80 percent probability monthly rainfall values are listed below their respective monthly gross irrigation requirements. Gross irrigation requirements are based on rainfall; therefore, rainfall less than the listed may require supplemental water. The crop consumptive use determined by the Modified Penman Method is shown in the tables.

Figure E-1

Irrigation Water Requirements

Date: 10/81

Station: 1134.0 KILAUEA

Crop: PAPAYA Quad Sheet: K-9

Ave Wind = 8.00 mph

Net Application Depth = 5.80 in
Field Application Efficiency = 80.00 %

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kc | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.80 | 0.60 | 0.60 | 0.60 | 0.60 | |
| ETo in/mo | 3.72 | 3.92 | 4.96 | 5.40 | 6.20 | 6.90 | 6.82 | 7.13 | 6.00 | 4.96 | 3.90 | 3.41 | |
| ETcrop in/mo | 2.23 | 2.35 | 2.98 | 3.24 | 3.72 | 4.14 | 4.09 | 5.70 | 3.60 | 2.98 | 2.34 | 2.05 | 39.42 |
| Ave Rain in | 7.26 | 5.65 | 8.17 | 6.18 | 5.09 | 3.37 | 4.60 | 4.52 | 4.18 | 5.21 | 7.22 | 6.98 | 68.30 |
| 50 % Rain in | 7.06 | 5.49 | 7.94 | 6.01 | 4.95 | 3.28 | 4.47 | 4.39 | 4.06 | 5.07 | 7.02 | 6.79 | 66.40 |
| 50 % Eff Rain in | 4.07 | 3.30 | 4.69 | 3.75 | 3.26 | 2.33 | 3.05 | 3.29 | 2.73 | 3.19 | 4.07 | 3.89 | 41.61 |
| Net Irr Req in | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 1.81 | 1.04 | 2.42 | 0.87 | 0.00 | 0.00 | 0.00 | 6.60 |
| Gross Irr Req in | 0.00 | 0.00 | 0.00 | 0.00 | 0.58 | 2.26 | 1.30 | 3.02 | 1.09 | 0.00 | 0.00 | 0.00 | 8.25 |
| Actual Kc | 1.09 | 0.84 | 0.94 | 0.69 | 0.53 | 0.34 | 0.45 | 0.46 | 0.46 | 0.64 | 1.04 | 1.14 | 8.63 |
| Modified Kc= 0.435 | | | | Mean= 0.719 | | | | | Standard Deviation= 0.284 | | | | |
| 60 % Rain in | 6.67 | 5.19 | 7.51 | 5.68 | 4.68 | 3.10 | 4.23 | 4.15 | 3.84 | 4.79 | 6.64 | 6.42 | 62.78 |
| 60 % Eff Rain in | 3.88 | 3.15 | 4.47 | 3.57 | 3.11 | 2.22 | 2.90 | 3.13 | 2.60 | 3.04 | 3.88 | 3.71 | 39.65 |
| Net Irr Req in | 0.00 | 0.00 | 0.00 | 0.00 | 0.61 | 1.92 | 1.19 | 2.57 | 1.00 | 0.00 | 0.00 | 0.00 | 7.30 |
| Gross Irr Req in | 0.00 | 0.00 | 0.00 | 0.00 | 0.77 | 2.40 | 1.48 | 3.22 | 1.25 | 0.00 | 0.00 | 0.00 | 9.12 |
| Actual Kc | 1.04 | 0.80 | 0.90 | 0.66 | 0.50 | 0.32 | 0.43 | 0.44 | 0.43 | 0.61 | 1.00 | 1.09 | 8.22 |
| Modified Kc= 0.414 | | | | Mean= 0.685 | | | | | Standard Deviation= 0.271 | | | | |
| 70 % Rain in | 6.29 | 4.89 | 7.08 | 5.35 | 4.41 | 2.92 | 3.98 | 3.92 | 3.62 | 4.51 | 6.25 | 6.05 | 59.16 |
| 70 % Eff Rain in | 3.68 | 2.99 | 4.25 | 3.39 | 2.95 | 2.11 | 2.76 | 2.97 | 2.47 | 2.89 | 3.69 | 3.53 | 37.67 |
| Net Irr Req in | 0.00 | 0.00 | 0.00 | 0.00 | 0.77 | 2.03 | 1.33 | 2.73 | 1.13 | 0.09 | 0.00 | 0.00 | 8.09 |
| Gross Irr Req in | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 | 2.54 | 1.67 | 3.41 | 1.41 | 0.11 | 0.00 | 0.00 | 10.11 |
| Actual Kc | 0.99 | 0.76 | 0.86 | 0.63 | 0.48 | 0.31 | 0.40 | 0.42 | 0.41 | 0.58 | 0.95 | 1.03 | 7.81 |
| Modified Kc= 0.393 | | | | Mean= 0.651 | | | | | Standard Deviation= 0.258 | | | | |
| 80 % Rain in | 5.87 | 4.57 | 6.61 | 5.00 | 4.12 | 2.73 | 3.72 | 3.66 | 3.38 | 4.21 | 5.84 | 5.64 | 55.23 |
| 80 % Eff Rain in | 3.47 | 2.82 | 4.01 | 3.20 | 2.78 | 1.98 | 2.60 | 2.80 | 2.32 | 2.72 | 3.48 | 3.32 | 35.50 |
| Net Irr Req in | 0.00 | 0.00 | 0.00 | 0.04 | 0.94 | 2.16 | 1.49 | 2.90 | 1.28 | 0.26 | 0.00 | 0.00 | 9.07 |
| Gross Irr Req in | 0.00 | 0.00 | 0.00 | 0.05 | 1.18 | 2.70 | 1.87 | 3.63 | 1.59 | 0.32 | 0.00 | 0.00 | 11.34 |
| Actual Kc | 0.93 | 0.72 | 0.81 | 0.59 | 0.45 | 0.29 | 0.38 | 0.39 | 0.39 | 0.55 | 0.89 | 0.97 | 7.36 |
| Modified Kc= 0.370 | | | | Mean= 0.614 | | | | | Standard Deviation= 0.243 | | | | |
| 90 % Rain in | 5.34 | 4.16 | 6.01 | 4.55 | 3.75 | 2.48 | 3.39 | 3.33 | 3.08 | 3.83 | 5.31 | 5.14 | 50.26 |
| 90 % Eff Rain in | 3.20 | 2.60 | 3.70 | 2.95 | 2.56 | 1.82 | 2.39 | 2.58 | 2.14 | 2.51 | 3.21 | 3.06 | 32.72 |
| Net Irr Req in | 0.00 | 0.00 | 0.00 | 0.29 | 1.16 | 2.32 | 1.70 | 3.13 | 1.46 | 0.47 | 0.00 | 0.00 | 10.52 |
| Gross Irr Req in | 0.00 | 0.00 | 0.00 | 0.36 | 1.45 | 2.90 | 2.12 | 3.91 | 1.83 | 0.59 | 0.00 | 0.00 | 13.15 |
| Actual Kc | 0.86 | 0.66 | 0.75 | 0.55 | 0.41 | 0.26 | 0.35 | 0.36 | 0.36 | 0.51 | 0.82 | 0.90 | 6.79 |
| Modified Kc= 0.341 | | | | Mean= 0.566 | | | | | Standard Deviation= 0.225 | | | | |

The gross annual irrigation and livestock water requirements are plotted on 1:24,000 scale topographic maps. Copies of these maps are on file in the state office of the Soil Conservation Service, Honolulu, Hawaii.

## CROP DESCRIPTION AND WATER REQUIREMENTS

### Papaya

Papaya is a rapid growing, hollow-stemmed, short-lived, perennial plant native to tropical America. The papaya's place of origin is not known but wild or semi-wild naturalized forms are often found in the tropical lowlands of Central and South America. Portuguese and Spanish sailors distributed the papaya to other tropical and subtropical areas.

It is not known when papaya was introduced to the Hawaiian Islands. It may have been brought in between 1800 and 1823 by Don Marin, a Spanish horticulturist who settled in Hawaii. Others believe papaya arrived from Asia and the South Sea islands before the Europeans' appearance on the islands.

Papaya plants can attain heights of 5 to 25 feet or more under favorable climatic conditions. It is usually single stemmed and bears a crown of palmately lobed leaves. The base of the stem may grow up to a foot in diameter. The fruit varies from round to eliptical with five shallow grooves. The fruit is 6 to 12 inches long, yellow or green and yellow, thin skinned; the pulp is white to orange or red, sweet, and juicy; the central space ordinarily is lined with small, hard, knobby, black seeds, covered with a gelatinous coat, and a smooth glistening skin.

Papaya is usually eaten as a fresh fruit. It may also be baked, stewed, cooked with other fruits in jam, or candied. The juice can be extracted for a refreshing drink. The fresh pulp is a good source of calcium, sugar, and vitamins A, C, and G.

### Guava

Guava is a tree or shrub, 6 to 25 feet high, and a native of tropical America. Guava was introduced to Hawaii by Don Marin. It is a common vegetation cover along roads, pastures, and in waste areas. In some districts it is considered a pest.

The fruit resembles a lemon in size, shape, and color. The interior is quite different--a solid pink or cream colored, pleasantly acid pulp, within which is a juicier pulp full of small, hard kidney-shaped seeds. Jelly, jam, and juice are prepared from the guava on a commercial scale. Guava, raw or cooked, contains iron, calcium, and phosphorous, and a vitamin C content exceeding that of oranges.

Both papaya and guava have a year-round growing season. Papaya is usually cultivated a minimum of three years. Guava orchards do not require replanting if properly maintained. Crop water requirements shown are the weighted average for year-long irrigation. Peak daily water need is based on a mature plant during the month with the highest evaporation.

Gross annual irrigation requirements for papaya and guava in the study area vary from less than 5 inches per year (136,000 gallons per acre per year) to more than 15 inches per year (407,000 gallons per acre per year). The guava and papaya orchards are drip irrigated with a field application efficiency of 80 percent.

Mean annual rainfall varies from 80 inches above Kuhio Highway to 50 inches along the coast. Papaya or guava planted above Kuhio Highway may require supplemental irrigation during the four drier months from June to September. Supplemental irrigation for 6 months may be needed along the coastal plains. Monthly gross irrigation requirements and consumptive use demand for papaya and guava are shown in Table E-1.

The peak daily crop requirements for 70-, 80-, and 90-percent field application efficiencies of drip irrigation for papaya and guava are shown in Table E-2. The peak daily values are related to the annual gross irrigation values shown on the maps.

The gross annual irrigation requirements for papaya and guava are shown in Figure E-2. The areas mapped for papaya and guava exceed the existing irrigated areas for these crops. No attempt was made to delineate papaya and guava areas that are not feasible for irrigation on an economic basis.

Banana

At the time of Hawaii's "discovery" by the Europeans, 50 varieties of banana existed in the islands. Banana, introduced by the early Polynesian voyagers, was an important item in their diet. The species is thought to have originated in India. Descendants of these plants are growing wild in Hawaii today, deep in the valleys, gullies, and well up the mountain slopes where they were formerly planted.

Of the many varieties of crops that are cultivated in the study area, banana has the highest demand for water. From long or short underground stems, the plants develop quickly, usually to considerable size. After fruiting, the plant is cut down and new plants sprout from the base. Because the fruit ripens all year, the plants are at various stages of growth in an orchard. A year-long growing season was used to calculate the gross annual irrigation requirements.

Banana grown near the coast will require 35 inches per year or 950,000 gallons per acre per year of irrigation. As banana is planted farther inland, irrigation requirements decrease to 10 inches per year or 271,000 gallons per acre per year in the uplands, due in part to the higher rainfall. These values are based on an effective rainfall of 80 percent chance and irrigation being applied by sprinklers with a field application efficiency of 65 percent. Banana gross annual irrigation requirements are shown in Figure E-3. Monthly gross irrigation and consumptive use demand are shown in Table E-3.

Peak daily banana water requirements are shown in Table E-4. Varying field application efficiencies of 60, 65, and 70 percent are presented as an aid in the design and selection of irrigation system capacities.

Areas mapped for the gross irrigation requirements greatly exceed the present areas devoted to banana cultivation. This does not indicate that the entire area will eventually be in bananas. Mapping of the entire area was done for ease in presentation.

## Truck Crops

The early Polynesians brought food plants such as coconut, taro, sugarcane, banana, and other useful plants to their new home. Since the time of Captain Cook's landing in 1778, a large variety of plants and seeds has been introduced to the islands. These include ornamental and food plants, weeds, and wayside plants. Food plants or truck crops in the study area include tomatoes, bell pepper, melons, cucumbers, eggplants, or fruiting plants.

Truck crop growing period ranges from a low of 45 days (cucumber) to a high of 150 days (tomato and melon). Assuming water is applied through a drip system, 5 inches per year or 136,000 gallons per acre per year will be needed above Kuhio Highway. Areas lying near the Pacific Ocean will need 15 inches per year or 407,000 gallons/acre/year. Gross annual irrigation requirements are shown in Figure E-4. Monthly gross irrigation and consumptive use demand are listed in Table E-5 and are related to the gross annual values.

Truck crop peak daily irrigation requirements for 70, 80, and 90 percent field application efficiencies are shown in Table E-6. Peak daily values are related to the gross annual requirements.

Areas mapped for gross annual irrigation requirements greatly exceed the presently farmed areas. This does not imply that the area mapped will eventually be cultivated with truck crops or is suitable for farm operations.

## Field Corn

Production of corn grain and corn silage in the study area is looked upon as being technically feasible. Therefore, feed corn irrigation requirements are addressed in this report. No attempt was made concerning the economic viability.

Considering the soils, land slope, solar radiation, humidity, and temperature, the area makai of the town of Kilauea is the most suitable area for corn and crops. Irrigation may be needed during the drier months, April to October.

Gross annual irrigation requirements shown in Figure E-5 and Table E-7 are based on sprinklers as the method of application. A 65 percent field application efficiency was used in the calculations.

Annual irrigation needs range from a high of 25 inches per year at the coast below the town of Kilauea to a low of 5 inches per year above Kuhio Highway. Rainfall above Kuhio Highway may deter farming operations due to its intensity and frequency during the wetter months.

Varying field application efficiencies of 60, 65, and 70 percent for peak daily needs are listed in Table E-8. Peak daily crop requirements increase from 4,800 gallons per acre per day along the coast to 5,500 gallons per acre per day above Kuhio Highway.

Gross annual requirements are shown for the entire study area. The objective is to show the water needs if corn is grown.

TABLE E-1

Papaya and Guava

Gross Irrigation Requirements - Monthly Distribution
80 Percent Chance Annual Rainfall

| Item | Annual | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
| Gross Irr. Req. (1,000 gal./ac.) | 136 (5)1/ | 0 | 0 | 0 | 0 | 0 | 43 | 6 | 66 | 21 | 0 | 0 | 0 |
| 80% Rainfall (in.) | 80.5 | 8.5 | 6.5 | 8.9 | 7.5 | 6.4 | 4.2 | 6.0 | 5.7 | 4.3 | 6.1 | 8.4 | 8.0 |
| Consumptive Use (in.) | 34.9 | 2.0 | 2.1 | 2.7 | 2.8 | 3.2 | 3.5 | 3.6 | 5.1 | 3.1 | 2.8 | 2.1 | 1.9 |
| Gross Irr. Req. (1,000 gal./ac.) | 271(10)1/ | 0 | 0 | 0 | 0 | 22 | 65 | 44 | 87 | 47 | 6 | 0 | 0 |
| 80% Rainfall (in.) | 57.8 | 6.4 | 5.3 | 7.0 | 5.9 | 4.4 | 2.7 | 3.7 | 3.6 | 2.8 | 4.2 | 6.3 | 5.5 |
| Consumptive Use (in.) | 37.5 | 2.1 | 2.2 | 2.8 | 3.1 | 3.6 | 4.0 | 4.0 | 5.3 | 3.5 | 2.8 | 2.2 | 1.9 |
| Gross Irr. Req. (1,000 gal./ac.) | 407(15)1/ | 0 | 0 | 0 | 5 | 41 | 93 | 73 | 120 | 70 | 5 | 0 | 0 |
| 80% Rainfall (in.) | 50.8 | 6.5 | 4.6 | 5.9 | 5.2 | 3.5 | 1.8 | 2.6 | 2.6 | 2.0 | 4.4 | 6.0 | 5.7 |
| Consumptive Use (in.) | 38.4 | 2.1 | 2.3 | 2.9 | 3.2 | 3.6 | 4.1 | 4.0 | 5.6 | 3.5 | 2.9 | 2.2 | 2.0 |

1/ Annual requirements in inches.

TABLE E-2

Papaya and Guava

Peak Daily and Gross Irrigation Requirements

| Gross Annual Irrigation Requirements | | Peak Daily ETcrop | Peak Daily Irrigation Requirements | | |
|---|---|---|---|---|---|
| (in./yr.) | (1,000 gal./ac./yr.) | (1,000 gal./ac./day) | (1,000 gal./ac./day) (percent efficiency) | | |
| | | | 70 | 80 | 90 |
| 5 | 136 | 4.6 | 6.6 | 5.8 | 5.1 |
| 10 | 271 | 4.9 | 7.0 | 6.1 | 5.4 |
| 15 | 407 | 5.0 | 7.1 | 6.2 | 5.6 |

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

FIGURE E-2

PAPAYA & GUAVA

GROSS ANNUAL IRRIGATION REQUIREMENTS

80 PERCENT CHANCE ANNUAL RAINFALL

80 PERCENT IRRIGATION EFFICIENCY

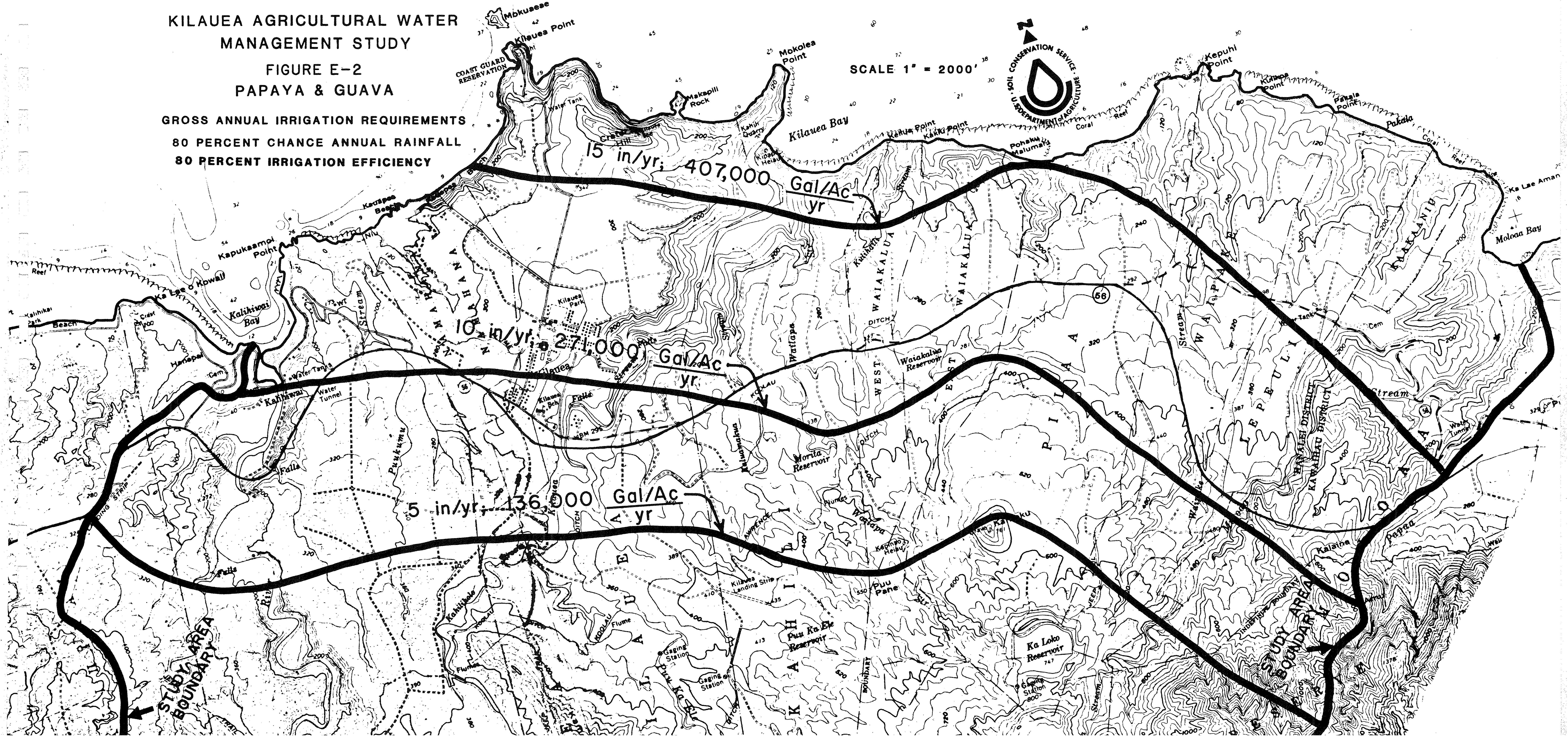


TABLE E-3

Banana

Gross Irrigation Requirements - Monthly Distribution
80 Percent Chance Annual Rainfall

| Item | Annual | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross Irr. Req. (1,000 gal./ac.) | 271(10)1/ | 0 | 0 | 0 | 2 | 14 | 84 | 38 | 71 | 56 | 6 | 0 | 0 |
| 80% Rainfall (in.) | 84.2 | 8.7 | 6.9 | 9.5 | 8.1 | 6.8 | 4.7 | 6.4 | 6.2 | 4.7 | 6.5 | 8.8 | 8.5 |
| Consumptive Use (in.) | 48.7 | 2.8 | 3.0 | 3.7 | 4.1 | 4.6 | 5.3 | 5.2 | 6.1 | 4.5 | 3.8 | 3.0 | 2.6 |
| Gross Irr. Req. (1,000 gal./ac.) | 407(15)1/ | 0 | 0 | 0 | 6 | 35 | 110 | 68 | 102 | 65 | 21 | 0 | 0 |
| 80% Rainfall (in.) | 71.4 | 7.3 | 5.2 | 7.8 | 6.7 | 5.6 | 3.8 | 5.2 | 5.2 | 4.5 | 5.3 | 7.4 | 7.4 |
| Consumptive Use (in.) | 49.4 | 2.8 | 3.0 | 3.8 | 4.1 | 4.7 | 5.4 | 5.3 | 6.2 | 4.6 | 3.9 | 3.0 | 2.6 |
| Gross Irr. Req. (1,000 gal./ac. | 543(20)1/ | 0 | 0 | 0 | 10 | 46 | 135 | 79 | 136 | 102 | 35 | 0 | 0 |
| 80% Rainfall (in.) | 66.1 | 7.3 | 5.9 | 7.5 | 6.5 | 5.4 | 2.8 | 4.8 | 3.8 | 3.0 | 4.6 | 8.2 | 6.3 |
| Consumptive Use (in.) | 50.7 | 2.9 | 3.1 | 4.0 | 4.2 | 4.9 | 5.5 | 5.4 | 6.3 | 4.7 | 4.0 | 3.1 | 2.6 |
| Gross Irr. Req. (1,000 gal./ac.) | 679(25)1/ | 0 | 0 | 0 | 20 | 77 | 147 | 115 | 150 | 118 | 47 | 5 | 0 |
| 80% Rainfall (in.) | 58.6 | 6.6 | 5.5 | 7.1 | 6.2 | 4.6 | 2.6 | 3.7 | 3.6 | 2.6 | 4.2 | 6.5 | 5.4 |
| Consumptive Use (in.) | 51.4 | 2.9 | 3.1 | 4.0 | 4.3 | 5.0 | 5.6 | 5.5 | 6.5 | 4.8 | 4.0 | 3.1 | 2.6 |
| Gross Irr. Req. (1,000 gal./ac.) | 815(30)1/ | 0 | 13 | 7 | 30 | 97 | 166 | 134 | 177 | 135 | 56 | 0 | 0 |
| 80% Rainfall (in.) | 53.9 | 6.2 | 4.5 | 6.0 | 5.6 | 3.8 | 2.1 | 3.1 | 2.9 | 2.6 | 4.4 | 6.6 | 6.1 |
| Consumptive Use (in.) | 52.8 | 3.0 | 3.2 | 4.0 | 4.4 | 5.1 | 5.7 | 5.6 | 6.6 | 5.2 | 4.1 | 3.2 | 2.7 |
| Gross Irr. Req. (1,000 gal./ac.) | 950(35)1/ | 0 | 16 | 20 | 62 | 107 | 168 | 160 | 187 | 158 | 55 | 17 | 0 |
| 80% Rainfall (in.) | 46.4 | 6.2 | 4.5 | 5.8 | 4.4 | 3.3 | 1.6 | 2.3 | 2.6 | 1.8 | 4.2 | 4.8 | 4.9 |
| Consumptive Use (in.) | 54.6 | 3.2 | 3.3 | 4.2 | 4.6 | 5.1 | 5.8 | 5.8 | 6.8 | 5.4 | 4.2 | 3.3 | 2.9 |

1/ Annual requirements in inches.

TABLE E-4

Banana

Peak Daily and Gross Irrigation Requirements

| Gross Annual Irrigation Requirements (in./yr.) | Gross Annual Irrigation Requirements (1,000 gal./ac./yr.) | Peak Daily ETcrop (1,000 gal./ac./day) | Peak Daily Irrigation Requirements (1,000 gal./ac./day) (percent efficiency) 60 | 65 | 70 |
|---|---|---|---|---|---|
| 10 | 271 | 5.3 | 8.9 | 8.2 | 7.6 |
| 15 | 407 | 5.6 | 9.3 | 8.6 | 8.0 |
| 20 | 543 | 5.7 | 9.5 | 8.8 | 8.2 |
| 25 | 679 | 5 9 | 9.8 | 9.0 | 8.4 |
| 30 | 815 | 6.0 | 9.9 | 9.2 | 8.5 |
| 35 | 950 | 6.1 | 10.2 | 9.4 | 8.8 |

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

FIGURE E-3
BANANA

GROSS ANNUAL IRRIGATION REQUIREMENTS
80 PERCENT CHANCE ANNUAL RAINFALL
65 PERCENT IRRIGATION EFFICIENCY

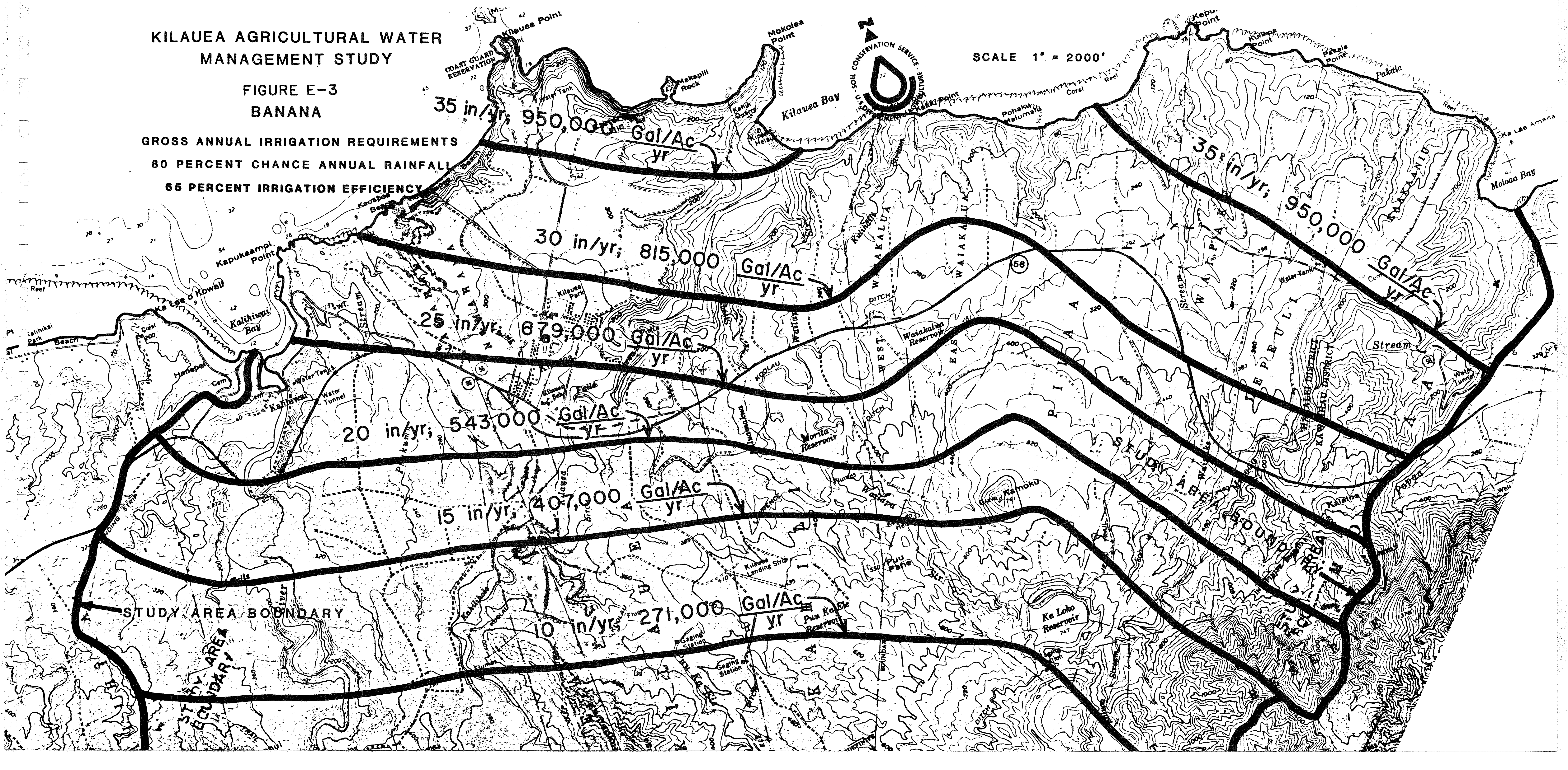


TABLE E-5

Truck Crops

Gross Irrigation Requirements - Monthly Distribution
80 Percent Chance Annual Rainfall

| Item | Annual | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross Irr. Req. (1,000 gal./ac.) | 136 (5)1/ | 0 | 0 | 0 | 0 | 0 | 50 | 12 | 48 | 26 | 0 | 0 | 0 |
| 80% Rainfall (in.) | 80.5 | 8.5 | 6.5 | 8.9 | 7.5 | 6.4 | 4.2 | 6.0 | 5.7 | 4.3 | 6.1 | 8.4 | 8.0 |
| Consumptive Use (in.) | 35.9 | 2.0 | 2.2 | 2.8 | 3.0 | 3.3 | 3.8 | 3.8 | 4.8 | 3.3 | 2.9 | 2.1 | 1.9 |
| Gross Irr. Req. (1,000 gal./ac.) | 271(10)1/ | 0 | 0 | 0 | 0 | 13 | 69 | 33 | 95 | 49 | 12 | 0 | 0 |
| 80% Rainfall (in.) | 63.4 | 6.0 | 6.0 | 7.4 | 7.7 | 5.2 | 2.6 | 4.6 | 2.9 | 2.8 | 4.0 | 8.6 | 5.6 |
| Consumptive Use (in.) | 37.4 | 2.1 | 2.2 | 2.9 | 3.1 | 3.5 | 4.0 | 4.0 | 5.1 | 3.5 | 2.9 | 2.2 | 1.9 |
| Gross Irr. Req. (1,000 gal./ac.) | 407(15)1/ | 0 | 0 | 0 | 5 | 46 | 90 | 74 | 108 | 70 | 14 | 0 | 0 |
| 80% Rainfall (in.) | 54.5 | 6.6 | 4.9 | 6.5 | 5.4 | 3.8 | 2.3 | 3.1 | 3.3 | 2.5 | 4.4 | 6.0 | 5.7 |
| Consumptive Use (in.) | 38.7 | 2.2 | 2.3 | 2.9 | 3.1 | 3.7 | 4.1 | 4.1 | 5.3 | 3.6 | 3.1 | 2.3 | 2.0 |

1/ Annual requirements in inches.

TABLE E-6

Truck Crops

Peak Daily and Gross Irrigation Requirements

| Gross Annual Irrigation Requirements (in./yr.) | Gross Annual Irrigation Requirements (1,000 gal./ac./yr.) | Peak Daily ETcrop (1,000 gal./ac./day) | Peak Daily Irrigation Requirements (1,000 gal./ac./day) (percent efficiency) 70 | 80 | 90 |
|---|---|---|---|---|---|
| 5 | 136 | 4.4 | 6.3 | 5.5 | 4.9 |
| 10 | 271 | 4.6 | 6.6 | 5.8 | 5.1 |
| 15 | 407 | 4.8 | 6.9 | 6.0 | 5.3 |

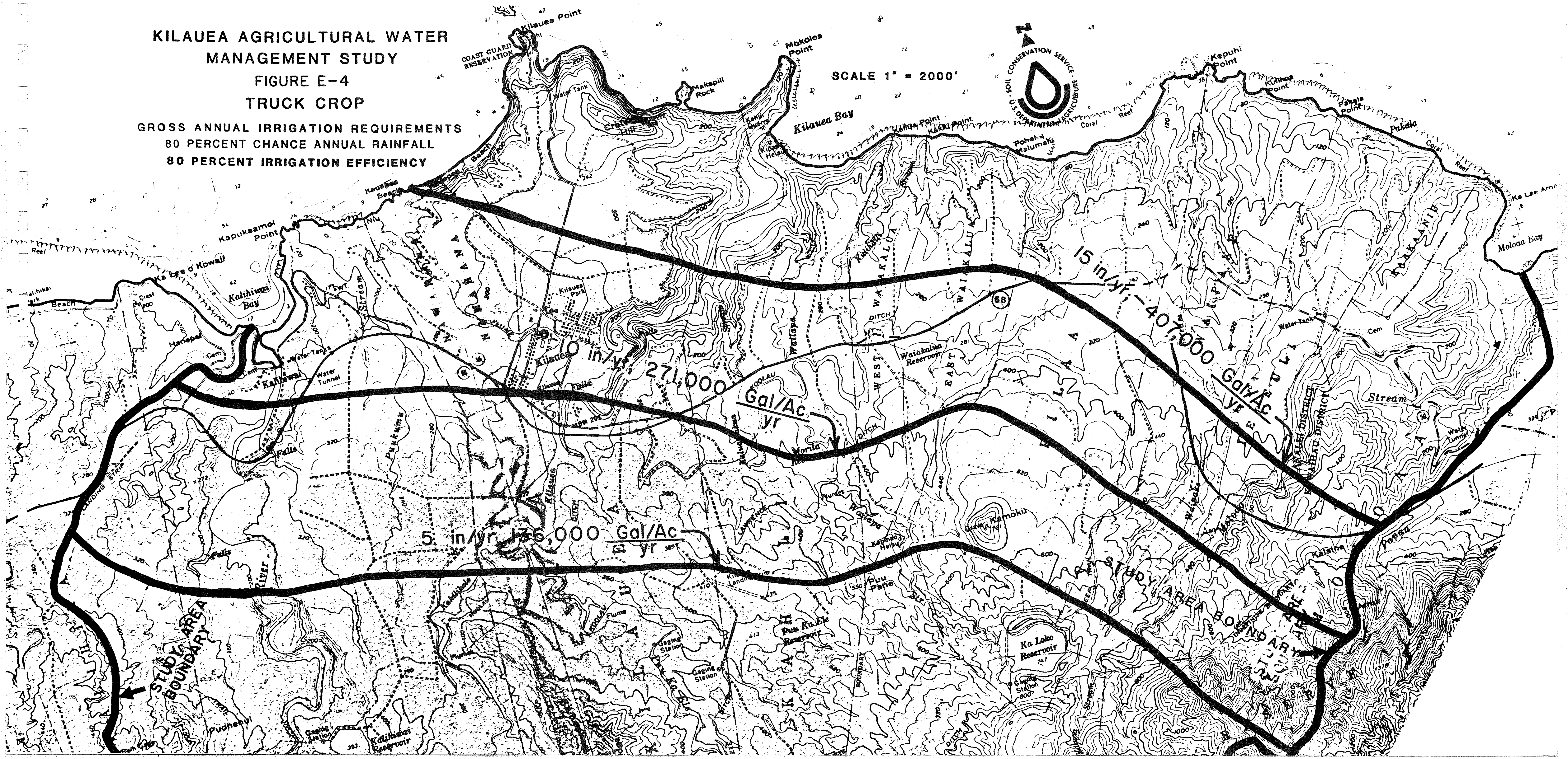

KILAUEA AGRICULTURAL WATER
MANAGEMENT STUDY
FIGURE E-4
TRUCK CROP
GROSS ANNUAL IRRIGATION REQUIREMENTS
80 PERCENT CHANCE ANNUAL RAINFALL
80 PERCENT IRRIGATION EFFICIENCY
SCALE 1" = 2000'
SOIL CONSERVATION SERVICE
U.S. DEPARTMENT OF AGRICULTURE
15 in/yr, 407,000 Gal/Ac/yr
10 in/yr, 271,000 Gal/Ac/yr
5 in/yr, 136,000 Gal/Ac/yr
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
Kilauea Point
Mokolea Point
Kilauea Bay
Kepuhi Point
Moloaa Bay
Kalihiwai Bay
Kapukaamoi Point
Ka Loko Reservoir
Kilauea

TABLE E-7

Field Corn

Gross Irrigation Requirements - Monthly Distribution
80 Percent Chance Annual Rainfall

| Item | Annual | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
| Gross Irr. Req. (1,000 gal./ac.) | 136 (5)1/ | 0 | 0 | 0 | 0 | 0 | 48 | 8 | 58 | 22 | 0 | 0 | 0 |
| 80% Rainfall (in.) | 82.9 | 8.4 | 6.6 | 9.2 | 7.9 | 6.6 | 4.5 | 6.2 | 5.9 | 4.6 | 6.3 | 8.5 | 8.2 |
| Consumptive Use (in.) | 37.6 | 2.1 | 2.3 | 2.9 | 3.1 | 3.5 | 4.0 | 3.9 | 5.3 | 3.4 | 2.9 | 2.2 | 2.0 |
| Gross Irr. Req. (1,000 gal./ac.) | 271(10)1/ | 0 | 0 | 0 | 0 | 0 | 87 | 31 | 92 | 61 | 0 | 0 | 0 |
| 80% Rainfall (in.) | 69 | 8.6 | 5.8 | 7.6 | 5.4 | 5.7 | 3.0 | 5.0 | 4.7 | 3.1 | 5.2 | 7.8 | 7.1 |
| Consumptive Use (in.) | 38.8 | 2.2 | 2.4 | 3.0 | 3.1 | 3.6 | 4.1 | 4.0 | 5.5 | 3.6 | 3.0 | 2.3 | 2.0 |
| Gross Irr. Req. (1,000 gal./ac.) | 407(15)1/ | 0 | 0 | 0 | 3 | 38 | 94 | 67 | 121 | 69 | 15 | 0 | 0 |
| 80% Rainfall (in.) | 57.7 | 6.4 | 5.3 | 7.0 | 5.9 | 4.4 | 2.7 | 3.7 | 3.6 | 2.8 | 4.2 | 6.3 | 5.4 |
| Consumptive Use (in.) | 40.2 | 2.3 | 2.4 | 3.0 | 3.2 | 3.7 | 4.3 | 4.2 | 5.7 | 3.8 | 3.1 | 2.4 | 2.1 |
| Gross Irr. Req. (1,000 gal./ac.) | 543(20)1/ | 0 | 0 | 0 | 8 | 59 | 122 | 95 | 149 | 102 | 8 | 0 | 0 |
| 80% Rainfall (in.) | 52.7 | 6.6 | 4.7 | 6.2 | 5.4 | 3.6 | 1.8 | 2.7 | 2.6 | 2.1 | 4.6 | 6.4 | 6.0 |
| Consumptive Use (in.) | 41.4 | 2.3 | 2.5 | 3.1 | 3.3 | 3.9 | 4.4 | 4.3 | 5.9 | 4.0 | 3.1 | 2.5 | 2.1 |
| Gross Irr. Req. (1,000 gal./ac.) | 679(25)1/ | 0 | 4 | 3 | 27 | 77 | 140 | 116 | 170 | 113 | 29 | 0 | 0 |
| 80% Rainfa-l (in.) | 42.7 | 5.7 | 3.9 | 5.1 | 4.1 | 3.0 | 1.4 | 2.1 | 2.4 | 1.7 | 3.8 | 4.9 | 4.6 |
| Consumptive Use (in.) | 42.3 | 2.4 | 2.5 | 3.1 | 3.4 | 4.0 | 4.5 | 4.4 | 6.1 | 4.0 | 3.2 | 2.5 | 2.2 |

1/ Annual requirements in inches.

TABLE E-8

Field Corn

Peak Daily and Gross Irrigation Requirements

| Gross Annual Irrigation Requirements | | Peak Daily ETcrop | Peak Daily Irrigation Requirements | | |
|---|---|---|---|---|---|
| (in./yr.) | (1,000 gal./ac./yr.) | (1,000 gal./ac./day) | (1,000 gal./ac./day) (percent efficiency) | | |
| | | | 60 | 65 | 70 |
| 5 | 136 | 4.8 | 8.0 | 7.4 | 6.9 |
| 10 | 271 | 5.0 | 8.3 | 7.7 | 7.2 |
| 15 | 407 | 5.2 | 8.7 | 8.1 | 7.5 |
| 20 | 543 | 5.3 | 8.8 | 8.2 | 7.6 |
| 25 | 679 | 5.5 | 9.1 | 8.4 | 7.8 |

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

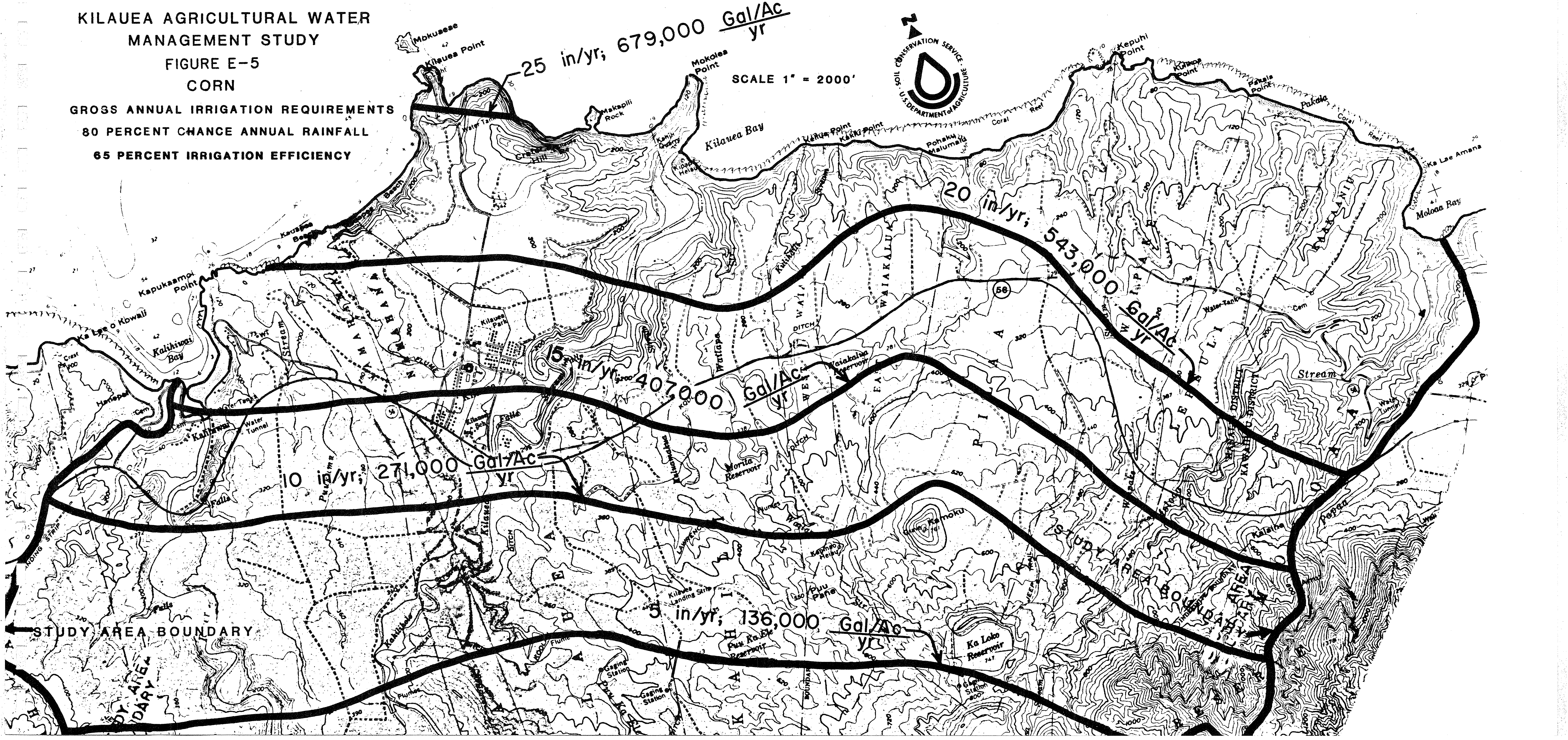
FIGURE E-5

CORN

GROSS ANNUAL IRRIGATION REQUIREMENTS

80 PERCENT CHANCE ANNUAL RAINFALL

65 PERCENT IRRIGATION EFFICIENCY



## LIVESTOCK WATER REQUIREMENTS

Animals obtain water from three sources: water that is (1) consumed as free water, (2) contained in feed, and (3) made available through metabolic processes. Stockwater demands shown in this report are the supplies which will be needed with practical utilization of the pasture areas.

Annual water demands are shown in Figure E-6 and monthly distribution and peak daily needs are listed in Table E-9. The water needs are based on stocking rates of two acres per animal unit in areas with 80 inches of annual rainfall, decreasing to 3 acres per animal unit in annual rainfall areas of 50 inches. These stocking rates assume proper pasture management practices are followed.

Water needs were calculated at each of the 19 climatological stations. The 90 percent chance annual rainfall was distributed into monthly rainfall values. These monthly rainfall values were used to compute the peak daily and monthly animal water needs.

Mean annual rainfall also determined the potential stocking rates. Potential stocking rate is an index of the amount of forage that may be removed by animals without causing deterioration of the vegetative cover. Higher rainfall regions have a higher water demand because of the increased stocking rate.

Potential water needs will supply the water that the animal drinks. Annual water needs along the shoreline are less than 1,400 gallons per acre per year. Grazing areas near the mountains have a higher stocking rate; therefore, over 2,600 gallons per acre per year will be needed.

TABLE E-9

Livestock Water Requirements - Monthly Distribution
90 Percent Chance Annual Rainfall

| Peak Daily Water Requirement | Annual Water Requirement | | | Monthly Water Requirement (gal./ac./mo.) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (gal./ac./day) | (gal./ac./yr.) | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
| 4.4 | 1,400 | 100 | 100 | 100 | 110 | 130 | 140 | 130 | 130 | 130 | 120 | 100 | 110 |
| 6.0 | 1,800 | 130 | 140 | 130 | 130 | 160 | 180 | 160 | 170 | 180 | 160 | 120 | 140 |
| 7.9 | 2,200 | 170 | 180 | 150 | 170 | 190 | 220 | 190 | 190 | 210 | 200 | 160 | 170 |
| 9.2 | 2,600 | 190 | 200 | 170 | 190 | 230 | 280 | 230 | 250 | 270 | 240 | 170 | 180 |

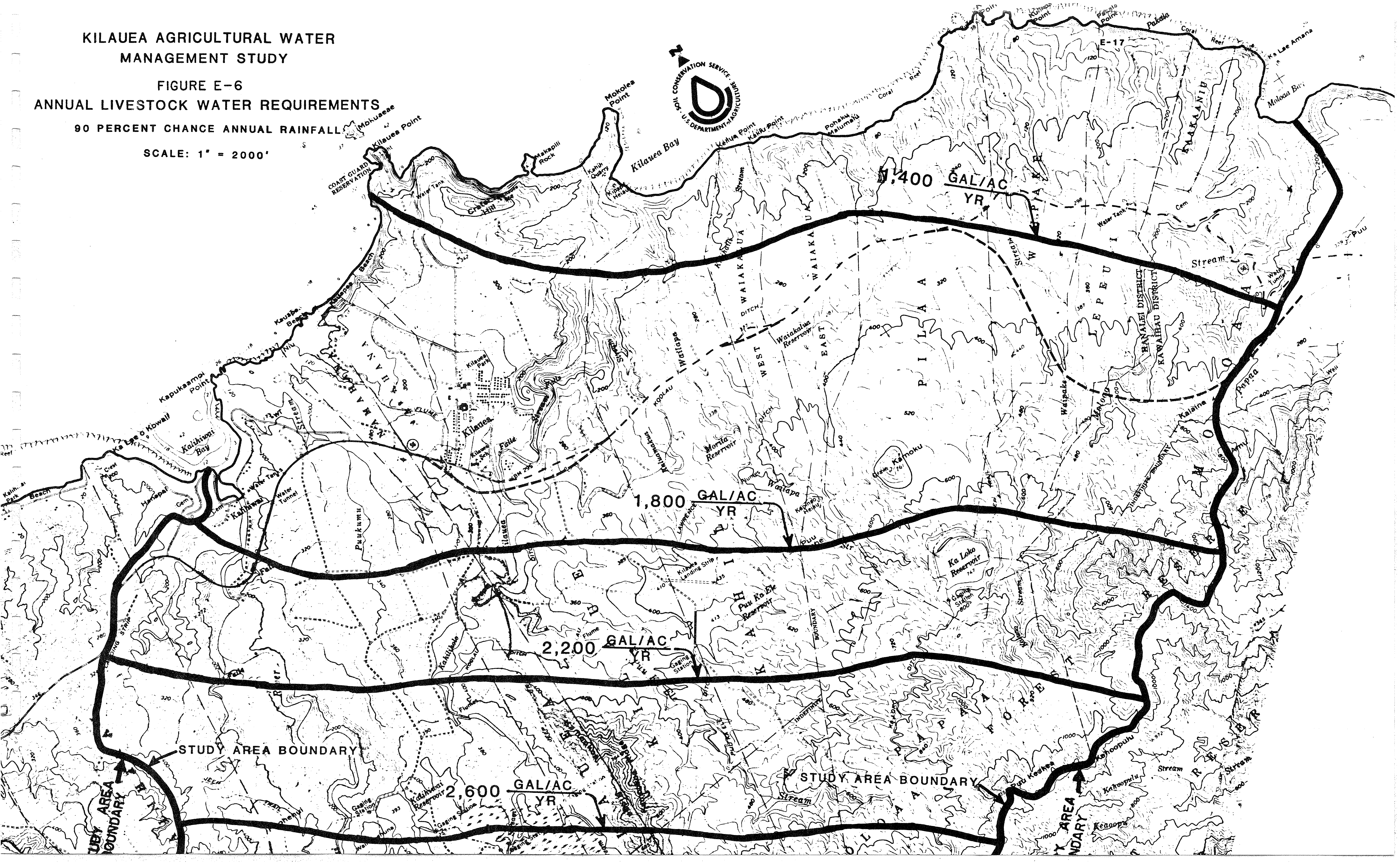
KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

FIGURE E-6

ANNUAL LIVESTOCK WATER REQUIREMENTS

90 PERCENT CHANCE ANNUAL RAINFALL

SCALE: 1" = 2000'



## PRAWN WATER REQUIREMENTS

Twenty-five acres of prawn ponds presently use 500-850 gallons per minute per day of water. Annual demand of water for the prawn ponds is based on 500 gallons per minute. Eight hundred and fifty gallons per minute are used as the peak daily demand.

## PRESENT WATER USE

The study area water needs are supplied by Kauai County's Department of Water and private systems. The department supplies domestic and agricultural water to the homes and farms located near the town of Kilauea and the Kalihiwai areas. Private systems supply agricultural water to areas below their storage facilities.

### County Water System

County water is pumped from a well into a 250,000-gallon tank located at elevation 430 on Kamookoa Ridge. The pump station consists of two 300 gallons per minute pumps. The distribution system reaches homes along the coast near Kalihiwai Bay and the Kilauea lighthouse and to homes on the Lihue side of Kilauea Stream. This system supplied 351 users in November 1981. Eleven users qualified for the agricultural water rates. Annual water used was 49.90 million gallons; 46.15 million gallons for domestic purposes, and 3.75 million gallons for farm operations. Table E-10 lists the bimonthly water used in 1981.

TABLE E-10

1981 Kilauea Water Use

| Month | Domestic (1,000 gal.) | Agriculture (1,000 gal.) |
|---|---|---|
| Jan. | 7,000 | 89 |
| Mar. | 8,103 | 576 |
| May | 7,466 | 588 |
| Jul. | 7,347 | 697 |
| Sep. | 8,366 | 783 |
| Nov. | 7,874 | 1,017 |
| Total | 46,156 | 3,750 |

### Private Water Systems

Sugarcane was grown on 4,400-5,000 acres in the Kilauea area. In November of 1971, the Kilauea Sugar Company closed operations. The sugar company received irrigation water from six reservoirs through an open ditch system. These reservoirs are the Kalihiwai, Ka Loko, Morita, Puu Ka Ele, and Stone Dam. The ditch system has not been maintained and is in need of repair.

Following is a description of the water used from each reservoir:

#### Kalihiwai Reservoir (57 MG)

A 12-inch PVC pipe previously installed to supply water to the now abandoned prawn ponds is available to irrigate the guava orchard.

Ka Loko Reservoir (410 MG)

Water from this reservoir is used for prawns, papayas, corn, and cattle operations. There are 25 water surface acres of prawn ponds. The prawn ponds use 500-850 gallons per minute per day of water. Five acres of papayas are grown below the ponds. Water from Ka Loko Reservoir is supplied through an 8-inch PVC pipe to the ponds and papaya field.

Area surrounding the pond and papaya field is currently grazed by cattle. An open ditch supplies the cattle operations below Kuhio Highway. Flow in the ditch is approximately 200 gpm. Cattle drink from the ditch causing deterioration of the banks. A 2-inch PVC pipe to a trough located below Kuhio Highway is the only pipe distribution in the area.

Morita Reservoir (43 MG)

A privately-owned 8-inch PVC pipe has recently been installed to irrigate crops in the Wailapa Subdivision below Kuhio Highway. Cattle also drink directly from the reservoir.

Puu Ka Ele (117 MG) and Waiakalua (60 MG) Reservoirs

At the present time water is not utilized extensively for agricultural purposes, although cattle do drink in overflow streams from the reservoir.

Stone Dam (10 MG)

This small reservoir supplies water to the farmlots located around Kilauea town. Water is transported to the farmlots through the Mill Ditch System which consists of open earth and wooden flume sections. The Mill Ditch may supply 2 c.f.s. but the water must be filtered for trickle irrigation systems, and the reliability of flow is questionable due to sloughing of the banks into the channel and poor maintenance.

## IRRIGATION WATER NEEDS

### 1982 Water Needs

Approximately 140 acres are presently irrigated in the study area. The majority of the farm operations are located around Kilauea town. Crops grown are papaya, guava, banana, corn, and truck crops. The 1982 agricultural water needs are 38 million gallons per year with a peak demand of 0.9 million gallons per day. Water needs for 1982 are shown in Table E-11. The 140 acres listed under study area include the Kilauea town area.

TABLE E-11

1982 Irrigation Water Needs
80 Percent Chance Annual Rainfall

| Location | Area Irrigated (acres) | Annual Irrigation Needs (MG/yr.) | Peak Irrigation Needs (MGD) |
|---|---|---|---|
| 1982 | | | |
| Kilauea Town Area | 95 | 33 | 0.6 |
| Study Area | 140 | 38 | 0.9 |

## LIVESTOCK WATER USE AND NEEDS

There is no livestock water distribution system in the study area. Livestock drink directly from reservoirs, streams, springs, and ditches in the area. There are 15 operations raising 2,600 head of cattle, horses, and swine on approximately 3,800 acres. This is an average stocking rate of one animal unit for every 1.5 acres, resulting in overgrazing. Overgrazing has deteriorated the plant community and reduced the quality and quantity of grazable forage. Reduced conception rates, livestock gains, weaning weights, and in extreme cases loss of livestock from starvation, are other results of poor grazing management in the study area.

The stockwater needs listed in Table 12 were developed assuming a proper grazing management system is followed. The acreage listed is grazable land and not the total area. The stockwater needs are for the pasture areas in 1982 and 1990.

The water development needs for livestock are:

1. Provide a distribution system.

2. Develop a grazing management system.

TABLE 12

Livestock Water Needs
90 Percent Chance Annual Rainfall

| Year | Acres | Annual Water Requirements (1,000 gallons/year) | Requirements (gallons/day) |
|---|---|---|---|
| 1982 | 3,800 | 7,011 | 23,000 |
| 1990 | 2,100 | 3,904 | 12,500 |

# APPENDIX F

# FISH AND WILDLIFE INVENTORY

# APPENDIX F

# FISH AND WILDLIFE INVENTORY

The purpose of Appendix F is to identify fish and wildlife species and/or habitat elements that may be affected by measures proposed by the study.

It should be emphasized that, because of the very limited biological survey and inventory data available, this report is not a project assessment. It is intended as a preliminary overview of the existing fish and wildlife situation and cannot be regarded as complete.

Any specific alternatives proposed in the study will require further studies in order to evaluate their effects on fish and wildlife resources in the study area.

## VEGETATIVE ZONES

For the purpose of this appendix, the study area can be divided into three distinct vegetative or habitat areas: the upper elevation forest reserve zone (6,760 acres), the middle elevation transition zone (6,485 acres), and the lower elevation rural area (9,255 acres).

1. Upper Elevation Forest Reserve

   The upper elevation forest reserve area extends from approximately 2,000 feet elevation to a line that varies between 800 and 1,000 feet in the study area. This area is categorized as native forest and offers habitat for threatened and endangered forest birds and endangered plants. Feral pigs roam the forested areas and are actively hunted. Since there will be no modifications or planned improvements and access is difficult to many parts of this area, a detailed study was not recommended. The area, for the most part because of the steep slopes, is relatively inaccessible and is expected to remain generally undisturbed from the effects of man.

2. Middle Elevation Transition Zone

   This portion of the study area extends from the lower limits of the forest reserve to about 500 feet elevation. The upper elevation portion is made up of forest reserve, which gradually intersperses into mixed agricultural lands and scattered clumps of forested areas. The lower elevation portion is more open and has more agricultural land use primarily consisting of grazing land and some scattered small farms. Although incidental occurrences of proposed threatened and endangered plants may be present, most of the vegetation in the area would be expected to be exotic.

Three irrigation water storage reservoirs (Kalihiwai, Puu Ka Ele, and Ka Loko) are located in this vegetative zone and offer habitat for shore birds and waterfowl. Their location is shown in Figure F-1, which identifies fish and wildlife habitat types in the study area. Kalihiwai and Ka Loko reservoirs are bounded by both introduced vegetative types and areas of native plants. These native plant areas may offer potential habitat for endangered plant species. If modifications should be considered in these native areas, more detailed studies should be made to determine the effects of any changes.

Representative vegetative species adjacent to these reservoirs are as follows:1/

Kalihiwai Reservoir

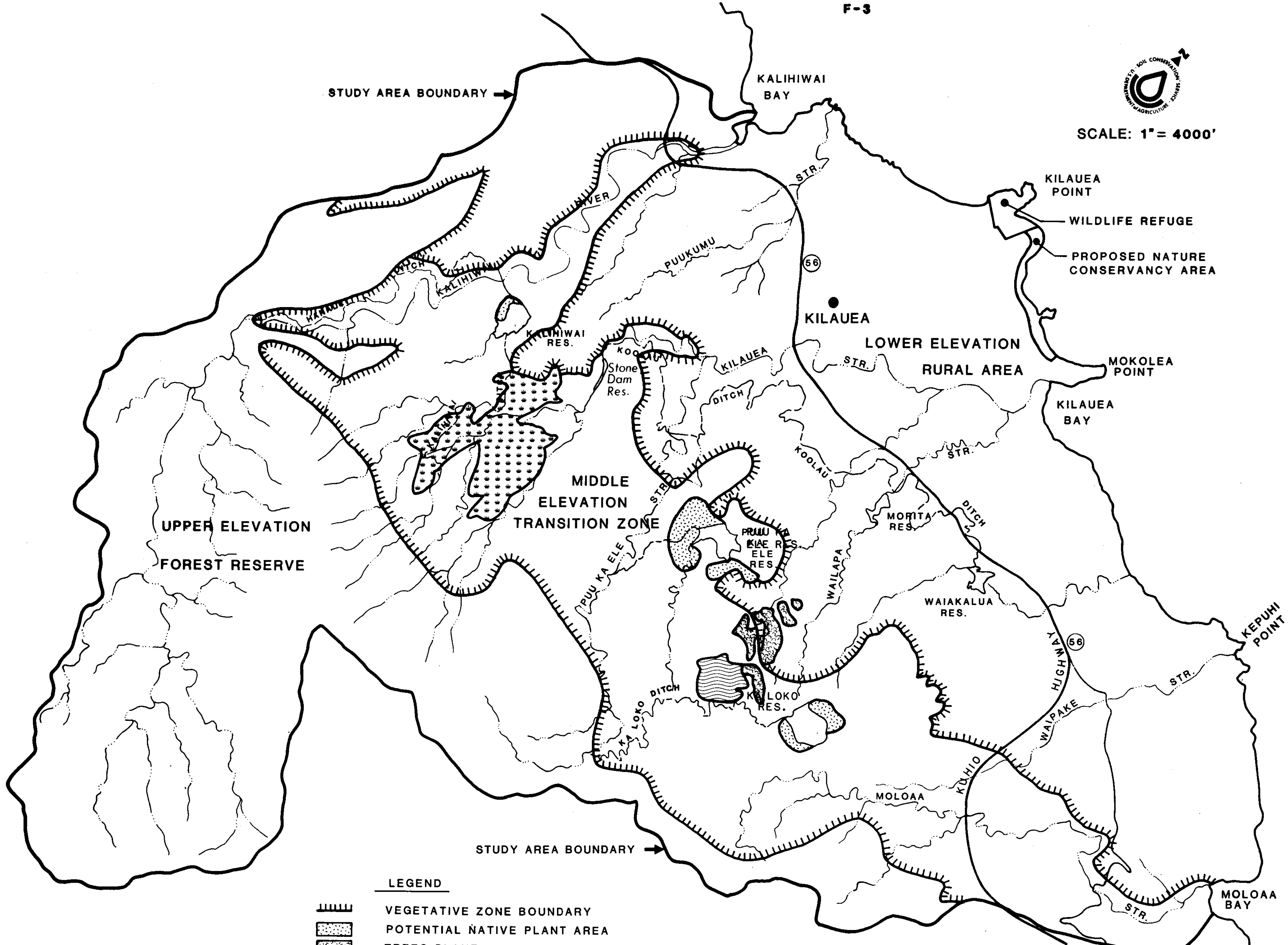
Exotic plants occur on the flat and gentle slopes of the reservoir; however, the steep slopes found next to the reservoir have native species. Uluhe fern (Dicranopteris linearis) and 'ohia trees (Metrosideros polymorpha) are common plants below the dike. The designated native areas may contain plant species that are being considered for classification as rare, endangered, or threatened in northeast Kauai.

On the disturbed flat on gentle sloping lands, dominant ground cover includes grasses such as californiagrass (Brachiaria mutica), and paspalum (Paspalum sp.), and occasional trees and shrubs. Introduced species common to the area are:

| | |
|---|---|
| ageratum | Ageratum conyzoides |
| cecropia | Cecropia obtusifolia |
| desmodium | Desmodium spp. |
| elephants-foot | Elephantopus mollis |
| guava | Psidium guajava |
| hau | Hibiscus tiliaceus |
| honohono | Commelina diffusa |
| indigo | Indigofera suffruticosa |
| Java-plum | Eugenia cumini |
| kamole | Ludwigia octavalvis |
| lantana | Lantana camara |
| mauna-loa | Canavalia cathartica |
| *'ohia | Metrosideros polymorpha |
| oakfern | Christella dentata |
| pluchea | Pluchea odorata |
| sensitive plant | Mimosa pudica |
| shoebutton ardisia | Ardisia humilis |
| strawberry guava | Psidium cattleianum |
| swordfern | Nephrolepis exaltata |
| thimbleberry | Rubus rosaefolius |
| *uluhe fern | Dicranopteris linearis |
| vervain | Stachytarpheta urticaefolia |

*Native species.

1/ Reservoir Vegetative Survey data collected on a field reconnaissance by John W. Bedish, U.S. Department of Agriculture, Soil Conservation Service, and Carolyn Corn, State Botanist, Hawaii State Department of Land and Natural Resources, on April 29-30, 1982.




LEGEND

- VEGETATIVE ZONE BOUNDARY
- POTENTIAL NATIVE PLANT AREA
- TREES PLANTED BY STATE DIVISION OF FORESTRY & WILDLIFE (EUCALYPTUS)
- MOLUCCA ALBIZZIA PLANTED BY STATE DIVISION OF FORESTRY & WILDLIFE
- WETLAND AREA
- RESERVOIR

**FIGURE F-1**

**KILAUEA FISH AND WILDLIFE HABITAT MAP**

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

## Ka Loko Reservoir

The reservoir is bounded by two slopes with native species where threatened and endangered plants on the proposed Hawaii State list of threatened and endangered plants may be present. The vegetation on the western and eastern sides of the reservoir is largely composed of introduced species. Grazing cattle impact the west side. Representative plants near the reservoir are:

| | |
|---|---|
| albizzia | *Albizia* spp. |
| avocado | *Persea* spp. |
| balloon plant | *Gomphocarpus physocarpus* |
| cecropia | *Cecropia obtusifolia* |
| citrus | *Citrus* spp. |
| elephants-foot | *Elephantopus mollis* |
| hau | *Hibiscus tiliaceus* |
| honohono | *Commelina diffusa* |
| kukui | *Aleurites moluccana* |
| laua'e | *Phymatosorus scolopendria* |
| liliko'i | *Passiflora edulis* |
| mango | *Mangifera indica* |
| neke | *Cyclosorus interruptus* |
| *'ohia | *Metrosideros polymorpha* |
| octopus-tree | *Brassaia actinophylla* |
| *pala'a | *Sphenomeris chinensis* |
| *pandanus | *Pandanus* spp. |
| Philippine orchid | *Spathoglottis plicata* |
| pluchea | *Pluchea odorata* |
| shoebutton ardisia | *Ardisia humilis* |
| strawberry guava | *Psidium cattleianum* |
| swordfern | *Nephrolepis exaltata* |
| *uluhe fern | *Dicranopteris linearis* |

*Native species.

Puu Ka Ele Reservoir

Exotic plants surround the reservoir with the possible exception of one or two inlets on the south side. There is little chance of proposed threatened or endangered plants occurring close to this reservoir. Grasses such as Paspalum sp., and trees such as shoebutton ardisia (Ardisia humulis), ironwood (Casuarina sp.), hau (Hibiscus tiliaceus), and an introduced palm dominate the site. Other plants include:

| | |
|---|---|
| Asiatic pennywort | Centella asiatica |
| broad-leaved plantain | Plantago major |
| californiagrass | Brachiaria mutica |
| cecropia | Cecropia obtusifolia |
| christmasberry | Schinus terebinthifolius |
| desmodium | Desmodium spp. |
| guava | Psidium guajava |
| honohono | Commelina diffusa |
| Java plum | Eugenia cumini |
| lantana | Lantana camara |
| oakfern | Christella dentata |
| pala'a | Sphenomeris chinensis |
| *pandanus | Pandanus spp. |
| pluchea | Pluchea odorata |
| popolo | Solanum aculeatissimum |
| sensitive plant | Mimosa pudica |
| strawberry guava | Psidium cattleianum |
| swordfern | Nephrolepis exaltata |
| uluhe fern | Dicranopteris linearis |
| vervain | Stachytarpheta urticaefolia |
| yellowwood-sorrel | Oxalis corniculata |

*Native species.

3. Lower Elevation Rural Area

This zone runs from sea level to approximately 500 feet in elevation. It is made up primarily of pasture, small farms, stream channels, and small urbanized areas. Existing vegetation is largely exotic with only isolated occurrences of threatened and endangered plants on steeper slopes or rocky coastlines expected.

The Morita and Waiakalua reservoirs located in this area are close to the highway where weedy species are common. All observed plants around the reservoirs are exotics with the surrounding land either pasture or abandoned pastureland. Dominant trees near the reservoirs include Java plum (*Eugenia cumini*) and hau (*Hibiscus tiliaceus*). Other plants common to the area include:

| | |
|---|---|
| African tuliptree | *Spathodea campanulata* |
| ageratum | *Ageratum houstonianum* |
| cecropia | *Cecropia obtusifolia* |
| christmasberry | *Schinus terebinthifolius* |
| desmodium | *Desmodium* spp. |
| dropseed | *Sporobolus indicus* |
| fuzzy rattlepod | *Crotalaria incana* |
| glenwoodgrass | *Sacciolepis indica* |
| guava | *Psidium guajava* |
| *hala | *Pandanus* spp. |
| hau | *Hibiscus tiliaceus* |
| indigo | *Indigofera suffruticosa* |
| ironwood | *Casuarina* spp. |
| jobs-tears | *Coix lachryma-jobi* |
| koa haole | *Leucaena leucocephala* |
| lantana | *Lantana camara* |
| miki palala | *Cassia occidentalis* |
| nutgrass | *Cyperus rotundus* |
| oakfern | *Christella dentata* |
| partridgepea | *Cassia leschenaultiana* |
| perennial foxtail | *Setaria geniculata* |
| pluchea | *Pluchea odorata* |
| rosemyrtle | *Rhodomyrtus tomentosa* |
| sandbur | *Cenchrus echinatus* |
| sourgrass | *Trichachne insularis* |
| sour paspalum | *Paspalum conjugatum* |
| Spanish needles | *Bidens pilosa* |
| Star-of-Bethlehem | *Laurentia longiflora* |
| vervain | *Stachytarpheta urticaefolia* |
| wild bushbean | *Phaseolus lathyroides* |

*Native species.

## HABITAT VALUES

### Reservoirs

Table F-1 lists some information about each reservoir. Table F-2 lists the aquatic species that live in the Kahiliwai, Morita, and Puu Ka Ele reservoirs. Information for the Ka Loko, Stone Dam, and Waiakalua reservoirs is not available because these reservoirs have never been surveyed. Similar fish species probably can be found in these reservoirs.

Table F-1.--Reservoir Physical Data

| Name | Elevation (ft.) | Surface Area (ac.) | Storage (MG) |
|---|---|---|---|
| Kalihiwai | 397 | 30.0 | 57.5 |
| Kaloko | 747 | 43.0 | 408.9 |
| Morita | 326 | 12.5 | 43.0 |
| Puu Ka Ele | 411 | 30.6 | 117.3 |
| Stone Dam | 340 | 5.0 | 10.5 |
| Waiakalua | 285 | 16.2 | 60.0 |

The following indicated aquatic species are known to occur in the Puu Ka Ele, Morita, and Kalihiwai reservoirs:

Table F-2.--Reservoir Fisheries Data[2/]

| Species | Puu Ka Ele | Morita | Kalihiwai |
|---|---|---|---|
| Largemouth bass (*Micropterus salmoides*) | X | X | X |
| Bluegill (*Lepomis macrochirus*) | X | X | X |
| Chinese catfish (*Clarias fuscus*) | X | X | X |
| Dojo (*Misgurnus anguillicaudatus*) | X | X | X |
| Tilapia (*Tilapia mossambica*) | X | X | X |
| Wild guppy (*Poecilia reticulata*) | X | X | X |
| Tucunare (*Chichla ocellaris*) | | | X |
| Tahitian prawn (*Macrobrachium lar*) | | | X |

These three reservoirs receive up to an estimated 50 man-hours of fishing pressure per week by Kilauea residents, according to a local resident fisherman.

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2/ Ahuimanu Productions, 1977, "An Ornithological Survey of Hawaiian Wetlands."

The Hawaiian Water Birds Recovery Plan, which is endorsed by the U.S. Fish and Wildlife Service, recognizes the Puu Ka Ele Reservoir as the primary habitat for the Hawaiian coot. The plan recommends protection of this reservoir as well as secondary habitats including the Morita, Waiakalua, Ka Loko, and Kalihiwai reservoirs.

Wetlands[2/][3/][4/]

Many river valleys of Kauai are characterized by at least some wetland vegetation, usually near the mouth where waters are calmer and riverbanks less steep. Kilauea Valley, located 5 miles east of Hanalei near the small town of Kilauea, is one such example.

The wetland here is largely confined to the estuarine environment of Kilauea Stream. Sediment-laden waters are slowed by a large sand dune--site of an ancient heiau and the broken remains of a roadway spanning the mouth of the estuary--before emptying into Kilauea Bay.

*Scirpus validus*, *Paspalum vaginatum*, *Bacopa monnieria*, *Hibiscus tiliaceus* and a very small thicket of *Rhizophora mangle* comprise the vegetative cover at the water's edge. These have a stabilizing influence on the underlying alluvium. On higher ground, the land is generally dry with *Psidium guajava* and *Schinus terebinthifolius* forming occasional closed forest cover. Between these areas is an intermediate region with *Brachiaria mutica*, *Cummelina diffusa*, *Cyperus alternifolius*, and occasional *Scirpus validus* cover. This is likely a seasonally flooded portion of the marsh. Other species noted at this site are listed in Table F-3.

As a biological system, this type of wetland is very productive. Silt is continually deposited from upstream and the pulsating action of the tides continually cycles nutrients, wastes, and water. Among birds seen are the Hawaiian coot and the indigenous great frigatebird, a gracefully soaring sea bird.

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2/ Ahuimanu Productions, p. F-7.

3/ Elliot and Hall, 1977, "Wetlands and Wetland Vegetation of Hawaii."

4/ U.S. Fish and Wildlife Service, 1978, "Stream Channel Modification in Hawaii." FWS/OBS-78/16.

Table F-3.--Partial Plant Species List for Kilauea Valley, Kauai

| | | Cover | Abundance |
|---|---|---|---|
| MONOCOTYLEDONAE | | | |
| CYPERACEAE | | | |
| *Cyperus alternifolius | umbrella-sedge | 1 | O |
| Cyperus polystachyus | -- | 1 | R |
| **Scirpus validus | great bulrush | 2 | A |
| GRAMINEAE | | | |
| *Brachiaria mutica | californiagrass | 2 | A |
| **Paspalum vaginatum | seashore paspalum | 3 | V |
| DICOTYLEDONAE | | | |
| COMPOSITAE | | | |
| *Pluchea indica | Indian pluchea | 1 | R |
| *Pluchea odorata | Pluchea | 1 | R |
| MALVACEAE | | | |
| *Hibiscus tiliaceus | hau | 2 | O |
| RHIZOPHORACEAE | | | |
| **Rhizophora mangle | American mangrove | 1 | R |
| SCROPHULARIACEAE | | | |
| **Bacopa monnieria | water hyssop | 2 | A |

*Faculative species
**Obligate species

1 = <5% cover; 2 = 5-25%; 3 = 26-50%; 4 = 51-75%; 5 = 76-100%

R = Rare; O = Occasional; F = Frequent; A = Abundant; V = Very abundant

## Wildlife Refuges

The U.S. Fish and Wildlife Service manages a 31-acre refuge at Kilauea Point for the protection of sea birds, under a cooperative agreement with the U.S. Coast Guard. The location of the refuge is shown in Figure F-1. The area includes a 1,000-foot-long, 150-foot-high, steep-sided peninsula. The introduced shrubby vegetation in the area recently has been replaced with native sea edge plants including Scaevola spp., Euphorbia spp., Pandanus spp., and others in several locations on the refuge. The refuge provides habitat for 31 wildlife species including wedge-tailed shearwaters, red- and white-tailed tropicbirds, and red-footed boobies. Green sea turtles (Chelonia mydas), a threatened species, can commonly be seen feeding in near-shore waters. There is one recorded sighting of an endangered Hawaiian monk seal (Monachus schauinelandi). Spinner dolphins (Stenella longirosiris) and humpback whales (Megaptera noviaengliae) also use the offshore waters.

In addition, a privately owned area between Kilauea Point Refuge and Mokolea Point is being proposed as a wildlife sanctuary for the red-footed booby and the Laysan albatross (see Figure F-1.)

## Upland and Avian Wildlife Species

While much of the wildlife habitat in the study area has not been surveyed, some information is known.

The upper elevation forest reserve offers habitat for threatened and endangered forest birds. Areas within the Moloaa Forest Reserve are regarded by the Department of Land and Natural Resources as important Newell's shearwater habitat. A sizable Newell's shearwater (Puffinus puffinus newelli) nesting colony is established on the ridgeline just west of Puu Ehu.5/ It is felt that there is considerable additional habitat that may be used by the shearwater, which is a threatened endemic sea bird only known to nest successfully on Kauai.

Other important wildlife includes the Hawaiian duck (Koloa) which inhabits the streams, ditches, and reservoirs in the study area. The Hawaiian coot and gallinule are known to occupy the existing ditches, reservoirs, and marshes in the study area. On rare occasions, the Hawaiian stilt uses reservoir shorelines during periods of low water levels. All four of these water birds are classified as endangered.

Wildlife known to occur in the study area including threatened, endangered, and endemic or indigenous species are identified in Table F-4.5/

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5/ Excerpts from Field Observation Notes, collected between 1968 and 1982, by Tom Telfor, Wildlife Biologist, Division of Forestry and Wildlife, Hawaii State Department of Land and Natural Resources.

Table F-4.--Wildlife known to occur within the Kilauea Watershed 5/

Birds:

| | |
|---|---|
| Wedge-tailed Shearwater* | Puffinus pacificus chlororhynchus |
| Newell's Shearwater (T)* | Puffinus puffinus newelli |
| White-tailed Tropicbird* | Phaethon lepturus dorotheae |
| Red-tailed Tropicbird* | Phaethon rubricauda rothschildi |
| Red-footed Booby* | Sula sula rubripes |
| Great Frigatebird* | Fregata minor palmerstoni |
| Hawaiian Stilt (E)* | Himantopus mexicanus knudseni |
| Hawaiian Coot (E)* | Fulica americana alai |
| Hawaiian Gallinule (E)* | Gallinula chloropus sandvicensis |
| Hawaiian Duck (Koloa)* (E) | Anas wyvilliana |
| Mallard* | Anas platyrhynchos |
| Pintail* | Anas acuta |
| Northern Shoveler* | Anas clypeata |
| Lesser Scaup* | Aythya affinis |
| American Wigeon* | Anas americana |
| Black-crowned Night Heron* | Nycticorax nycticorax hoactli |
| Cattle Egret | Bubulcus ibis |
| Wandering Tattler* | Heteroscelus incanus |
| Golden Plover* | Pluvialis dominica |
| Ruddy Turnstone* | Arenaria interpres |
| Common Mynah | Acridotheres tristis |
| Barred Dove | Geopelia striata |
| Spotted Dove | Streptopelia chinensis |
| House Sparrow | Passer domesticus |
| House Finch | Carpodacus mexicanus |
| Mockingbird | Mimus polyglottos |
| Spotted Munia | Lonchura punctulata |
| Northern Cardinal | Cardinalis cardinalis |
| Hawaiian Owl (Pueo)* | Asio flammeus sandwichensis |
| Barn Owl | Tyto alba |
| Western Meadowlark | Sturnella neglecta |
| Ring-necked Pheasant | Phasianus colchicus |
| Elepaio* | Chasiempis sandwichensis |
| Amakihi* | Loxops virens |
| Anianiau* | Loxops parvus |
| Akepa* | Loxops coccineus |
| Apapane* | Himatione sanguinea |
| Iiwi* | Vestiaria coccinea |
| Hwa-Mei | Garrulax canorus |
| Shama | Copsychus malabaricus |
| Greater-necklaced Laughing Thrush | Garrulax pectoralis |
| Japanese White-eye | Zosterops japonicus |

(T) = Threatened
(E) = Endangered
* = Endemic or Indigenous

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5/ Telfor, p. F-10.

Table F-4.--Wildlife known to occur within the Kilauea Watershed[5/] (Cont'd)

Mammals:

| | |
|---|---|
| Feral Pig | Sus scrofa |
| Feral Dog | Canis familiaris |
| Feral Cat | Felis catus |
| Roof Rat | Rattus rattus |
| Norway Rat | Rattus norvegicus |
| Polynesian Rat | Rattus exulans hawaiiensis |
| House Mouse | Mus musculus |
| Hawaiian Bat (E)* | Lasiurus cinereus semotus |

Reptiles:

Not surveyed, but probably include: Mourning Gecko, Tree Gecko Stump-toed Gecko, House Gecko, Metallic Skink, Moth Skink and Snake-eyed Skink.

Amphibians:

| | |
|---|---|
| Giant Neotropical Toad | Bufo marinus |
| American Bullfrog | Rana catesbeiana |
| Wrinkled Frog | Rana rugosa |

(T) = Threatened
(E) = Endangered
* = Endemic or Indigenous

5/ Telfor, p. F-10.

## STREAMS AND RIVERS[4/6/7/]

There are eight streams and one river that may be affected by the study. The eight streams are the Halaulani, Kahiliholo, Kilauea, Moloaa, Pohakuhonu, Puu Ka Ele, Puukumu, and Wailapa; and the Kalihiwai River.

Some data are available for Kalihiwai River, and for the following streams: Puukumu, Kilauea and its upper tributary Puu Ka Ele, and Moloaa. Although Waipake Stream may not be affected by the proposed measure, available data are included.

### Kalihiwai River

The stream was described as having moderate to high water quality and natural values. It flows to the ocean continuously year-round. Three stream diversions and two road crossings were recorded.[4/] From information supplied by the Division of Aquatic Resources, Department of Land and Natural Resources, the following species are known to exist in Kalihiwai Stream:

#### Crustaceans

| | | |
|---|---|---|
| Exotic: | Tahitian prawn | *Macrobrachium lar* |
| Native: | spineless shrimp | *Atya bisulcata* |
| | crooked-walking shrimp | *Macrobrachium grandimanus* |

#### Fish

| | | |
|---|---|---|
| Exotic: | Java tilapia | *Tilapia mossambica* |
| | swordtail | *Xiphophorus helleri* |
| Native: | aholehole | *Kuhlia sandvicensis* |
| | mullet | *Mugil cephalus* |
| | 'o'opu 'akupa | *Eleotris sandwicensis* |
| | 'o'opu nakea | *Awaous stamineus* |
| | 'o'opu naniha | *Awaous genivittatus* |

#### Mollusks

| | | |
|---|---|---|
| Native: | hihiwai | *Neritina granosa* |

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4/ USFWS, p. F-8.

6/ Excerpts from Field Observation Notes made by John Maciolek, Fisheries Biologist, U.S. Fish and Wildlife Service, between 1975 and 1979.

7/ Information supplied by Don Heacock, Aquatic Biologist, Division of Aquatic Resources, Hawaii State Department of Land and Natural Resources.

Mullet are harvested commercially. There is also some subsistence fishing done by families that have kuleanas.

Samples were taken from the main stream above the estuary up to 450 feet elevation. This reach is regarded as a popular 'o'opu nakea angling area. It is characterized as having many large deep pools and is relatively undisturbed by cattle or riparian development.

The largest pool occurs at 50 feet elevation and appears to be the upstream limit of 'o'opu naniha, 'opae-'oeha'a, aholehole, and hihiwai. The main abundance of hihiwai in the system was in the tail riffle of the pool. Tilapia and swordtails were also present in the pool. Other species observed in the upstream areas, in order of abundance, included Cheumatopysche analis, swordtail, tilapia, 'o'opu nakea, Macrobrachium lar, and Atya bisulcata.6/

The terminus area discharges freshwater to the ocean from a sinuous estuary-like basin through jumbled beach rock slabs. 'Opae-'oeha'a were observed as very abundant. Other species observed, in order of abundance, included aholehole and 'o'opu 'akupa. Poeciliids and tilapia have been described as abundant at the head end of the basin. One Clarias spp. was collected with a shocker. About 1976, storm-shifted sand filled the mouth of the basin, burying the rocky habitat.6/

Puukumu Stream

Water quality and natural values are described as low to moderate. Some stream channel alteration was reported, but no existing stream diversion was indicated. The stream has five road crossings.4/

Biological sampling (U.S. Fish and Wildlife Service, 1978) revealed the presence of one native crustacean, Atya bisulcata; and two exotic crustaceans, Tahitian prawns (Macrobrachium lar) and crayfish (Procambarus clarkii). One exotic fish, the swordtail (Xiphophorus helleri), was also found.4/

Puu Ka Ele Stream

This stream is a headwater tributary of Kilauea Stream. Its upper portions are diverted in part by the Ka Loko Ditch. Species observed in order of abundance included amphipods, Lymaea, Chironomids, tipulids, damsel fly nymphs, and Atya.6/

Kilauea Stream

This stream is described as having moderate to high water quality and natural values, although limited water is diverted for consumptive use. It provides continuous flow to the ocean year-round. There are seven road crossings on the stream. Kilauea Stream supported both a commercial and a recreational fishery at one time.4/

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4/ USFWS, p. F-8.

6/ Maciolek, p. F-13.

Biological sampling and other information supplied from the State Department of Land and Natural Resources revealed the presence of the following crustaceans, fish, and mollusks:

Crustaceans

Exotic

| | |
|---|---|
| crayfish | Procambarus clarkii |
| Samoan crab | Scylla serrata |
| Tahitian prawn | Macrobrachium lar |

Native

| | |
|---|---|
| crooked-walking shrimp | Macrobrachium grandimanus |
| spineless shrimp | Atya bisulcata |

Fish

Exotic

| | |
|---|---|
| bluegill | Lepomis macrochirus |
| Chinese catfish | Clarias fuscus |
| dojo | Misgurnus anguillicaudatus |
| Java tilapia | Tilapia mosambica |
| largemouth bass | Micropterus salmoides |
| swordtail | Xiphophorus helleri |
| wild guppy | Poecilia reticulata |
| summer mullet | Cholon spp. |

Native

| | |
|---|---|
| aholehole | Kuhlia sandvicensis |
| mullet | Mugil cephalus |
| 'o'opu 'akupa | Eleotris sandwicensis |
| 'o'opu nakea | Awaous stamineus |
| 'o'opu naniha | Awaous genivittatus |

Mollusks

Native

| | |
|---|---|
| hapawai or wi | Theodoxus vespertinus |
| hihiwai | Neritina granosa |

U.S. Fish and Wildlife Service personnel made limited field observations and recorded the following information: The estuary and terminal segment were sampled on several occasions between 1975 and 1979. Water in the estuarine basin is usually rather turbid with silt runoff and plankton. The area has been influenced by the town dump that was active until about 1976.

The depth of the estuary at the head end is 7 meters, with strong salinity stratification being common in the summer.

Schools of mullet fry, juvenile papio, kaku, nehu and the shrimp 'opae-'oeha'a, occur in the terminal end. Large mullet have been seen in the head end.7/

The lower reaches of Kilauea Stream open into a large estuarine area, although flow to the ocean is partially restricted by an extensive sandbar. Ironwood forest separates the main body of the estuary from the beach below. The lower stream is lined for much of its length with a thin fringe of bulrushes, backed by flat grasslands that are probably flooded during periods of high stream flow. Extensive growth of hau trees reaches the edge of the stream at several points along its length. The water along the shore at the first major bend in the stream is 4 feet or more in depth at the bulrush edge. The bottom is soft mud at this point, turning to a firm sand bottom closer to the estuary mouth. The thin fringe of bulrushes attests to the relatively steep edge of the estuary for much of its length.

Fish observed in the lower estuarine portion of the stream course include tilapia, aholehole, and mullet. Presumably 'o'opu and other fishes that regularly move between saltwater and freshwater are regular occupants of the estuarine portion of this site.

Two tributaries discharge into the estuary; Wailapa Stream, which is heavily overgrown in the terminal section, and Kaluamakua Stream, which has an abundance of Macrobrachium lar and poeciliids. The head of the estuary and the adjacent terminal reach of Kilauea Stream exhibit the environmental separation or preferences of Neritina granosa and Theodoxus vespertinus. The terminal reach of the stream is dominated by Tahitian prawns with some largemouth bass and a few 'o'opu nakea present.

In many respects, the Kilauea estuary is similar to Lumahai Stream valley to the west. Yet the latter site appears to support a far greater number of water birds, particularly coots. Water in the Kilauea estuary appears to be flowing at a fairly rapid rate, perhaps explaining the lack of submergent and floating vegetation. Deeper water at the shoreline results in less food available for water birds, particularly the surface feeding or shallow-diving forms. Bulrush habitat is limited to a narrow growth along the shore at Kilauea estuary, and even this habitat has been infringed upon by cattle and horses in the area. The estuarine portion of Kilauea Stream is relatively undisturbed by surrounding development or land use, but Kilauea is subjected to frequent visitation by fishermen and other beach users. The proximity of a parking area to the best bulrush habitat may inhibit use by native water birds. The shores of the stream mouth provide potential shore bird (and stilt) feeding habitat at low tide. This estuary is close to a large sea bird nesting area at Kilauea Point. It is not known if sea birds play a significant role in the ecology of the estuary.

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7/ Heacock, p. F-13.

Waipake Stream

The stream was described to have moderate to low water quality and natural values (U.S. Fish and Wildlife Service, 1978). It is used for water related recreational activities and flows to the ocean continuously year-round. Three diversions and six road crossings were noted. No biological sampling was reported.

Field notes recorded by John Maciolek, U.S. Fish and Wildlife Service, between 1975 and 1979 indicated the presence of gobies in the terminus area of Waipake Stream. Water temperature at the mouth of the stream has been recorded at 28.5° C. Species observed in the first 10 meters above high tide included Theodoxus cariosus, isopods, amphipods, and aholehole. Post-larval Atya spp., 'o'opu 'akupa, bloodworms, and Namalycastis were observed about 100 meters upstream.

The upper reach of Waipake Stream was described as very small with only lymaeids and insects being present.

Moloaa Stream

The stream is described as having moderate to low ratings for water quality and natural values (U.S. Fish and Wildlife Service, 1978). It flows to the ocean continuously year-round. Three road crossings were noted.4/ An area of the stream, in a gulch southeast of Ka Loko Reservoir, has been described as having clear water. Water temperature was recorded on one occasion at 21° C. Aquatic species observed, in order of abundance, included swordtails, lymaeid snails, atyids, damsel fly nymphs, and tadpoles.6/

4/ USFWS, p. F-8.

6/ Maciolek, p. F-13.

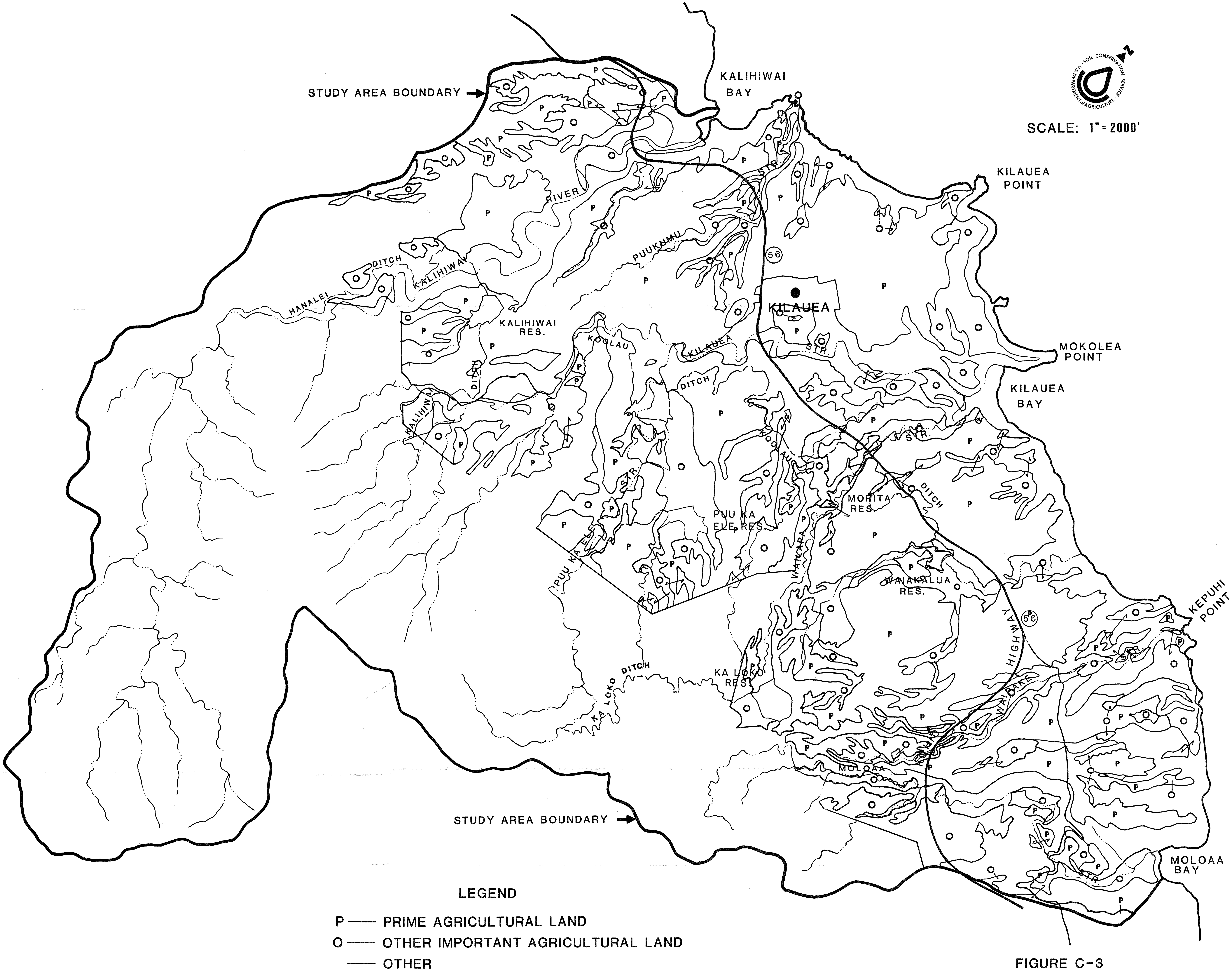
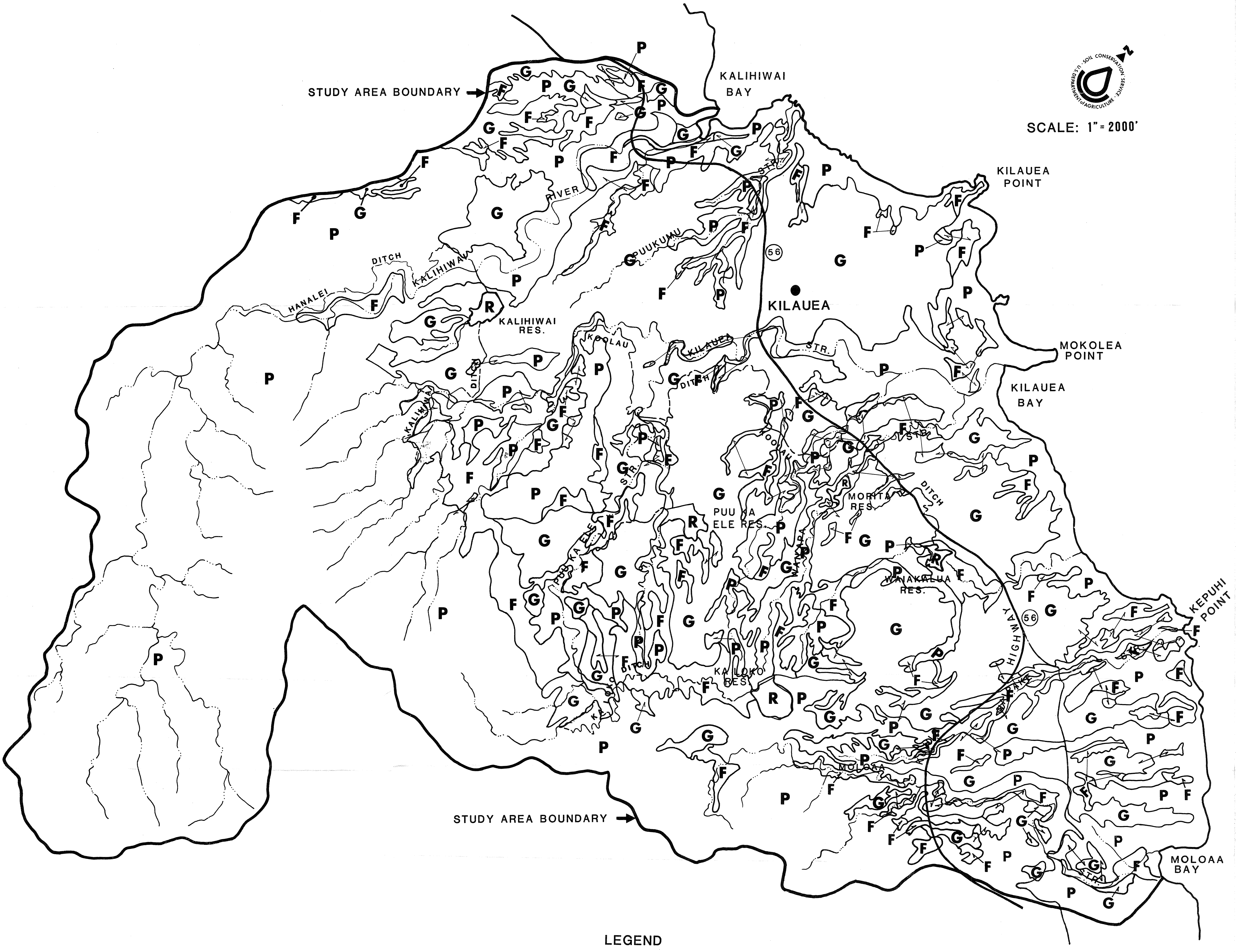



FIGURE C-3
AGRICULTURAL LANDS OF IMPORTANCE
TO THE STATE OF HAWAII

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY




LEGEND

G — GOOD
F — FAIR
P — POOR
R — RESERVOIR

FIGURE C-4

SOIL SUITABILTY RATINGS FOR ORCHARD CROPS

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY

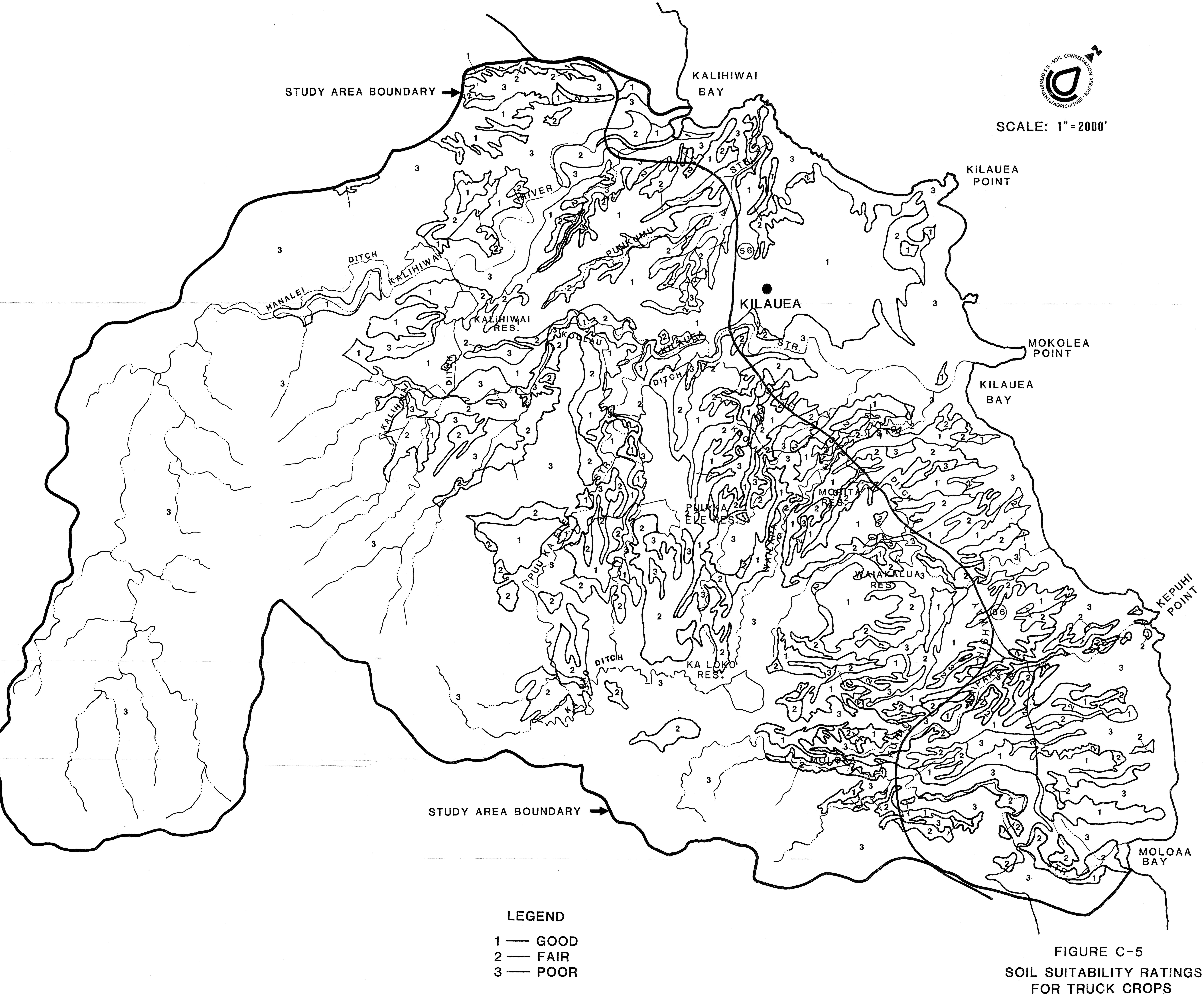



FIGURE C-5

SOIL SUITABILITY RATINGS FOR TRUCK CROPS

KILAUEA AGRICULTURAL WATER MANAGEMENT STUDY