United States
Department of
Agriculture

Soil
Conservation
Service

KA'U
RIVER BASIN STUDY

Hawaii County, Hawaii

February 1994

Prepared for and in cooperation with

County of Hawaii

Ka'u Soil and Water Conservation District

PREPARED BY

U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

HONOLULU, HAWAII

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EXECUTIVE SUMMARY

The purpose of this study was to provide an evaluation of the soil and water related problems and concerns in the Ka'u area. Scoping of the problems focused the study to inadequate agricultural water supply coupled with a lack of crop suitability maps. The study area was divided into seven subareas based on similar land-use. With many external influences and unknowns acting upon the area, exact formulation of alternatives was not possible. This study can be used to stimulate dialogue and further action amoung decision makers and stock holders regarding agriculture in the Ka'u area.

For the inadequate agricultural water supply problem, alternatives were formulated for each subarea. These alternatives show some infrastructure for options that could be available if sponsors were found for the project. At that time, a more detailed analysis of a given alternative would be made.

Analysis of the area for crop suitability of selected crops was accomplished using a Geographical Information System (GIS). Rainfall, temperature, pan evaporation, land use and soil parameters were analysed to produce maps showing areas of good, fair and poor suitability for coffee, Macadamia nuts, and general truck crops.

This study can be used to stimulate dialogue and further action among decision makers and stakeholders regarding agriculture in the Ka'u area.

INTRODUCTION

The County of Hawaii and the Ka'u Soil and Water Conservation District (SWCD) had requested United States Department of Agriculture's (USDA) assistance to improve domestic and agricultural water supply, and address other soil and water problems in the Ka'u area. Twenty-four items were identified from public meetings as being concerns of the sponsors and general public (Table 1). USDA participation was needed to provide comprehensive evaluation of the resource concerns and leadership in coordinating the study with other federal, state, and county agencies and private industry. The Soil Conservation Service (SCS) was the lead USDA agency and coordinated the USDA Cooperative River Basin Study.

The County of Hawaii and the Ka'u SWCD were the study sponsors. The Hawaii County Council unanimously adopted Resolution Number 45-89, on April 19, 1989, which gave their support for the Ka'u River Basin Study. The Application for Federal Assistance was filed by the County of Hawaii, in April

1989. The study was authorized by the Chief of the SCS on September 22, 1989.

The County of Hawaii's Department of Water Supply (DWS) has county-wide authority to operate and maintain public water systems on the Island of Hawaii. The County of Hawaii has the authority to levy taxes on real property, fund resource programs within its boundaries, and acquire land rights needed for program implementation.

Through the authority of Chapter 1809 Hawaiian Revised Statutes (HRS) and the Hawaiian County Grading Ordinance, the Ka'u SWCD has review authority over agricultural and construction activities that impact soil and water resources within their jurisdiction. The SWCD represents about 24 percent of the land-use cooperators in the Ka'u District.

TABLE 1 Summary of Scoping Concerns from Meetings and Response Sheets-1989/90[1]

Problem or Concern	Ranking
Flooding	High
Agricultural Water Supply	High
Wind Erosion	High
Rural Water Supply	High
Sheet & Rill Erosion	High
Streambank Erosion	Medium
Gully Erosion	Medium
Ephemeral Gully Erosion	Medium
Water Quality	Medium
Cultural Resources	Medium
Wetlands	Medium
Important Agricultural Lands	Medium
Groundwater	Medium
Municipal & Industrial Water	Medium
Visual Resources	Medium
Ocean Ecosystem	Medium
Threatened & Endangered Species	Medium
Transportation	Medium
Recreation	Medium
Wildlife Habitat	Medium
Navigation	Low
Sedimentation	Low
Noxious Plant Control	Low
Monitoring Needs	Low

[1]The concerns were ranked based on the frequency of mention, degree of institutional or public recognition, and the capability of SCS programs to evaluate and address the concern.

STUDY AREA DESCRIPTION

General Description: The Ka'u River Basin Study Area is located in the Ka'u District of the Island of Hawaii. The study area lies in Hawaii Congressional District Two and Hydrologic Unit Number 20010000. The study area consists of 297,800 acres in the southernmost portion of the Island of Hawaii.

The study area is bounded by Hawaii Volcanoes National Park and the Kapapala Forest Reserve on the east and northeast. To the west, limits of the study area include the northwestern boundaries of the Ka'u Forest Reserve, and the South Kona/Ka'u District boundary near Manuka State Park. The shore-line boundary extends from Kamoi Point on the west to Kapaoo Point on the east (See Figure 1).

Seven subareas were delineated based upon similar land-use. The boundaries of these subareas are mostly of political origin combined with some hydrologic boundaries in the upper areas. The seven subareas from northeast to southwest are:

Kapapala,
Wood Valley,
Pahala,
Naalehu,
South Point,
Kahuku, and
Manuka.

Socioeconomic: The study area includes the communities of Wood Valley, Pahala, Naalehu, Waiohinu, Punaluu, and Hawaiian Ocean View Estates. Access to the area is by Hawaii State Highway 11 that crosses through the study area and connects to Hilo on the east and Kona on the west. There are no commercial airports or harbors in the Ka'u District.

The 1990 population of the Ka'u District was approximately 4,440 with 970 persons in Hawaiian Ocean View, 1,030 persons in Naalehu, 1,520 persons in Pahala and 40 persons in part of Volcano. There has only been an increase of about 1,000 people in the last 20 years.[2] However, the average percentage change in population was nine percent in the 1970's while it increased sharply to twenty percent in the 1980's. By the year 2010, the population is expected to grow to about 7,100[3]

According to the 1990 Census of Population, there are 51 percent males and 49 percent females in the Ka'u District. The median age is 35.5 years. The labor force (ages 18 to 60) accounts for 46 percent of the population in the district, with six percent of the unemployment rate in 1990. Table 2 shows the ethnic breakdown of the Ka'u district.

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[2]Source: Hawaii County Water Use and Development Plan, Review Draft February, 1992.

[3]Source: The State of Hawaii Data Book, 1992.

There are about 1,960 housing units in the district with a twelve percent vacancy rate. The median value of the housing unit is $73,700, which is 35 percent and 70 percent lower than that of Hawaii County (at $113,000) and the State (at $245,300), respectively. The average persons in each household is 2.87 while the state average is 3.01.

Personal income data are available on the County basis. Per capita personal income for the County of Hawaii was $10,800 in 1989 (1982 dollars), while the State had an average of $13,300.

While tourism and its related businesses are the largest economic contributors for the island of Hawaii, agriculture is still the predominant source of income in the Ka'u area. Sugar cane, Macadamia nut, citrus crops, and cattle are the primary agricultural commodities produced. Other economic activities include tourism at Punaluu and Volcanoes National Park, and recreation including golf, fishing and other ocean-based activities.

Punaluu is a small-scaled resort community with an 18-hole golf course and tennis facilities. Expansion of this resort was being planned by the developer, but is currently on hold.

TABLE 2 Resident Population by Race[4]

Race	Population	Percent
White	1,621	36.5
Black	19	0.4
American Indian, Eskimo & Aleut	39	0.9
Chinese	77	1.7
Filipino	1,084	24.4
Japanese	521	11.7
Korean	1	<0.1
Vietnamese	0	0
Hawaiian	968	21.8
Samoan	19	0.4
Guamian	3	<0.1
Micronesian	20	0.4
Other & unspecified Asian & Pacific Islanders	25	0.6
Other Races	41	0.9
Total	4,438	100

[4]Source: County of Hawaii Department of Research & Development Data Book, 1991.

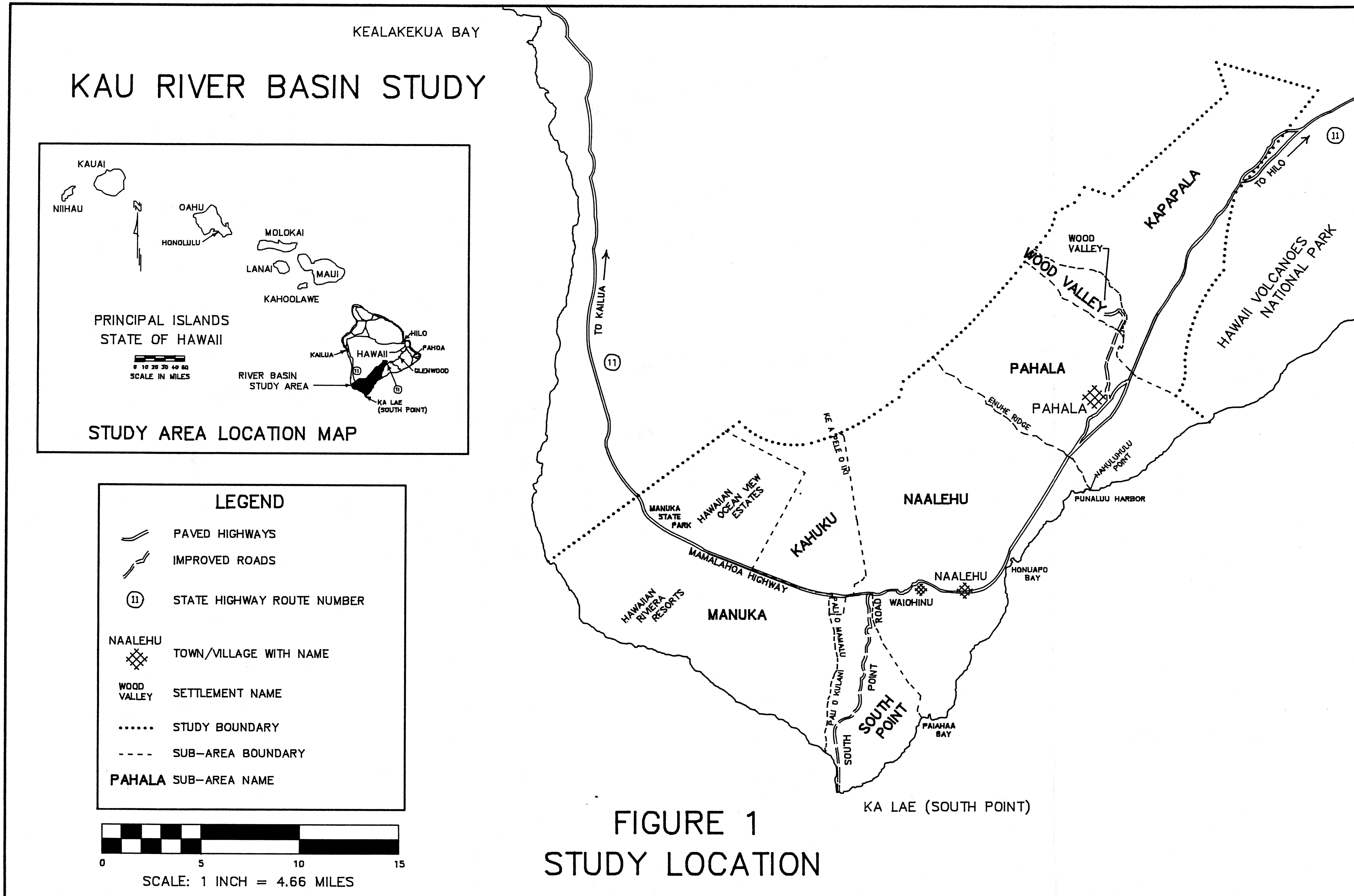


FIGURE 1
STUDY LOCATION

Construction of a large resort development called the Hawaiian Riviera Resort along the shoreline west of South Point, is proposed, but currently on hold.

Development of a commercial space launch facility is being planned for the Palima Point area to the southeast of Pahala. Lockheed Missile and Space Company withdrew from the project on October 27, 1993. The Environmental Impact Statement was in the comment review stage until November 22, 1993.

Diary operations from neighboring islands are looking into the feasibility of relocating to the Ka'u area.

The Department of Hawaiian Home Lands (DHHL) is in the process of initiating long-term development of its 11,000 acres of land holdings in the South Point area. The department plans to initially develop 76 agricultural lots ranging from 2 to 25 acres in size. Infrastructure and homestead site development is expected to begin in 1993.

Land Ownership: The major landowners in the study area are the State of Hawaii, Department of Hawaiian Home Lands, C. Brewer Co., Bernice P. Bishop Estate, and Samuel M. Damon Estate (Figure 2).

Land-use: Approximately two-thirds of the study area is classified as agricultural land by the State Land-Use Commission (Figure D-4). The other one-third is in

TABLE 3 Land-use-Ka'u District

Land-use	Acres	Percent[5]
Grazing Land[6]	83,600	28.1
Sugar cane	18,800	6.3
Macadamia Nuts	5,300	1.8
Rural	25,600	8.6
Urban/Resort	500	0.2
Forest Reserve	75,100	25.2
Naturalized Vegetation[7]	80,900	27.2
Other[8]	7,900	2.6
Federal	1	<0.1
Total	297,700	

[5]Source: USDA-Soil Conservation Service, Natural Resources Planning Staff, Honolulu, HI

[6]Includes Rangeland and Pastureland

[7]Naturalized vegetation is vegetation that has been introduced from other parts of the world that now acts as native plants.

[8]Citrus. Persimmon, Biomass, Coffee, Avocado, Banana, Wind Farm

conservation land, while pockets of urban land exist at the towns of Pahala, Naalehu, and Waiohinu. The majority of the agricultural land is used for grazing with sugar cane being second. Orchard crops include Macadamia nuts, citrus, avocado, banana, coffee, persimmon and biomass. Another major industry is cattle ranching including one dairy operation.

Geology: The study area is situated on the south and southwest slope of Mauna Loa, which is the second highest mountain in the state at 13,680 feet mean sea level (m.s.l.). Elevation of the study area ranges from sea level to approximately 6,600 feet m.s.l.

The landform of the area is geologically young because of the two active volcanoes, Mauna Loa and Kilauea, located to the north and northeast. The percent of the area covered by lava flows since 1800 range from none to greater than 25 percent. During the last 750 years, the area covered by lava flows ranged from near zero to greater than 65 percent.

TABLE 4 Subareas on Volcanoes

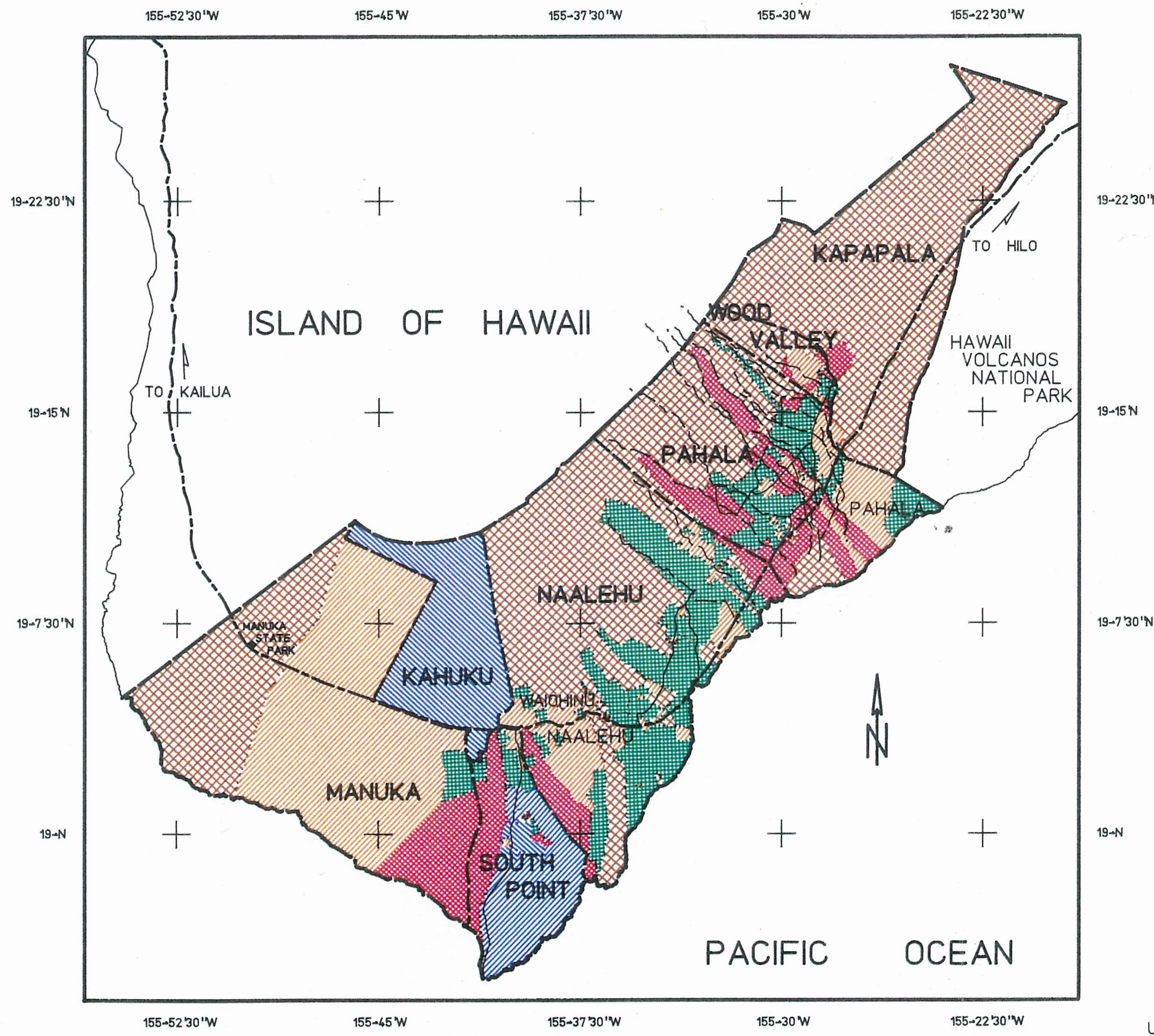
Mauna Loa	Kilauea
Kapapala	Kapapala
Wood Valley	Pahala
Pahala	
Naalehu	
South Point	
Kahuku	
Manuka	

On its east rift zone Kilauea has been in a singular eruptive phase since 1983. Kilauea erupts infrequently from its southwest rift zone, only five times in the last 200 years. The last being in 1974. The southwest rift zone affects the study area in a strip along Highway 11 from the summit to Pahala and then south of the highway to Ninole.

Mauna Loa erupts less frequently than Kilauea but produces a greater volume of lava in a shorter period of time. About 20 percent of the area west of South Point has been covered by lava in historical times and five percent since 1950. Historical flows were in 1868, 1887, and 1907. Two portions of the study area are relatively safe from lava flows: near Naalehu and the slope southeast of the present summit caldera. The rest of the study area north of Highway 11 has been covered by 15 to 20 percent by lava in the last 750 years.

The oldest exposed rocks of Mauna Loa are the Ninole volcanic series (Figure 3). This series is more than 2,100 feet thick. The upper layer of the Ninole series is a dominantly massive,

KAU RIVER BASIN STUDY



STUDY AREA

FIGURE 2
LAND OWNERSHIP (1992)

LEGEND

- STATE OF HAWAII
- DEPT. HAWAIIAN HOMELANDS
- C. BREWER CO.
- BISHOP ESTATE
- S. M. DAMON ESTATE
- OTHER PRIVATE

- STUDY AREA BOUNDARY
- SUB-AREA BOUNDARY
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS

AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID

-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

LAND OWNERSHIP FROM TAX MAP KEY MAPS, STATE OF HAWAII, DEPARTMENT OF TAXATION

NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT NATURAL RESOURCES PLANNING STAFF, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE

5 0 5 10 MILES

PREPARED BY USDA, SOIL CONSERVATION SERVICE, HAWAII STATE OFFICE NATURAL RESOURCES PLANNING STAFF HONOLULU, HAWAII SEPTEMBER 1993

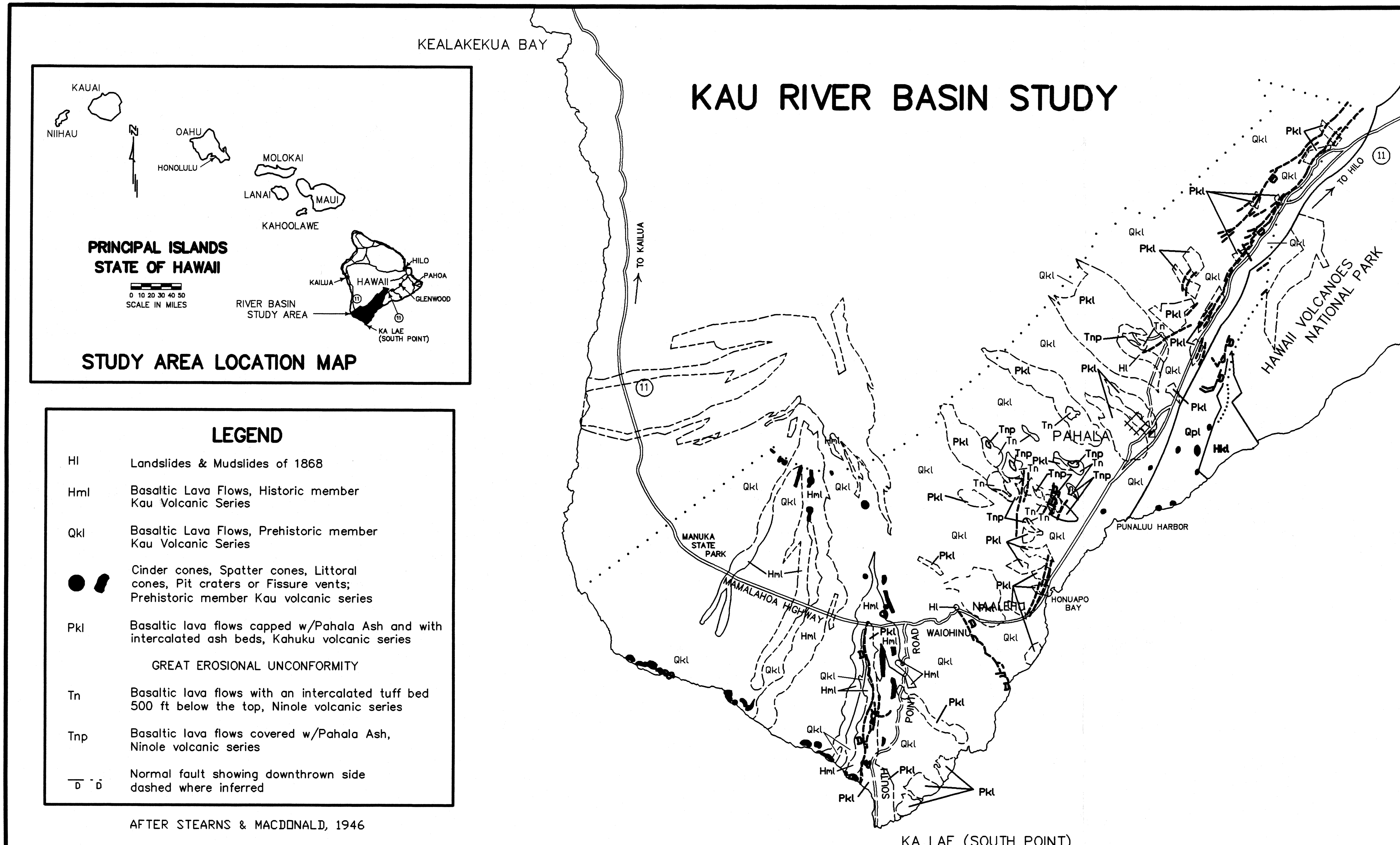


FIGURE 3
GENERAL GEOLOGY

gray, slightly weathered pa'hoe'hoe with interbedded a'a lava from 10 to 75 feet thick of the late Pleistocene epoch (0.1-0.5 million years (m.y.) before present (BP.). A reddish-brown tuff is sometimes found between the volcanic layers. This volcanic series crops out as prominent steep hills between Waiohinu and Wood Valley.

Overlying the Ninole volcanic series is the Kahuku volcanic series. This series is separated in time from the Ninole series by a long period of erosion which allowed the canyons to be formed. The Kahuku volcanic series consists of basalt flows and interbedded ash beds that were laid down before the deposition of the Pahala Ash. The a'a and pa'hoe'hoe lava flows average 15 feet thick for a total of about 1,000 feet and originated from Mauna Loa. This is capped by the Pahala Ash which is red to yellow and 12 to 50 feet thick. These deposits are of the Pleistocene epoch (0.01 to 1.6 m.y. BP) and are characterized by the Kahuku Pali north of South Point.

The Kau volcanic series comprises a'a and pa'hoe'hoe lava from late Pleistocene to Recent times (0 to 1.6-m.y. BP) originating from Mauna Loa. It is further subdivided into prehistoric and historic (after 1832) lava flows.[9] This series is what covers most of Mauna Loa.

The volcanics from Kilauea volcano occur in the southeastern portion of the study area downslope of Highway 11. The oldest is the Hilina volcanic series which comprises lava flows averaging 10 feet thick prior to the deposition of Pahala Ash. The series is represented by Hilina Pali on the south slope of Kilauea.

The Puna volcanic series comprises all a'a and pa'hoe'hoe flows from Kilauea after the Pahala Ash. Like the Kau volcanic series, it is divided into Prehistoric and Historic (after 1750) flows. This series is what covers most of Kilauea.

Geological Hazards: Associated with volcanic eruptions are earthquakes. Most of these are small and can not be felt but occasionally larger ones occur. Figure 4 shows the location of historic earthquake epicenters[10] that occurred within 200 kilometers of the center of the Big Island and were greater than Richter magnitude 4.0. The following table gives the probable recurrence interval for earthquakes of various magnitudes.

[9] The historic period is the period when there was a written record for that area.

[10] An epicenter is the point on the earth's surface directly above the focus of an earthquake.

TABLE 5 Earthquake Magnitude and Recurrence Interval for the Island of Hawaii	
Earthquake Magnitude (M)[11]	Recurrence Interval (Years)[12]
3.8	0.7
4.0	0.7
4.3	1.4
4.9	3.1
5.0	3.5
5.6	4.8
5.8	5.8
6.0	6.5
6.2	11.3
6.8	24.1
6.9	33.8
7.0	42.3
7.2	84.5
7.9	169.0

Soils: There are 52 different soil types (phases) in the Ka'u area. Soil descriptions and-acreages of each soil type in each subarea is found in Appendix C.

Soil Suitability for Crops: The soil suitability by crops is found in Appendix D.

Climate: Mean annual precipitation ranges from less than 20-inches per year at Ka Lae, near sea level, to 125-inches per year at the 3,000-foot elevation in the Ka'u Forest Reserve. Most of the annual rainfall occurs during the months from October to March. Humidity averages 60- to 70 percent.

The annual mean temperature along the coast is about 72-degrees and decreases with elevation to about 55-degrees at about 5,500-foot elevation. Temperatures vary about 15-degrees throughout the year with only a five degree variation for the average monthly minimum or maximum temperature.

Northeasterly trade winds prevail much of the time in Hawaii. Although these winds are fairly constant, when they encounter the island they combine with local winds on the mountain slopes and lowlands and are thus distorted as they transverse the island to form complex wind patterns. During the cooler

[11] M is the Richter magnitude, a measurement of the force of the earthquake.

[12] The recurrence interval can also be considered the probability of an earthquake occurring of a particular magnitude as being once in so many years. The reciprocal will give one the percent chance of the earthquake occurring within a year, for example a magnitude 5.6 quake has a 20 percent chance of occurring within a year.

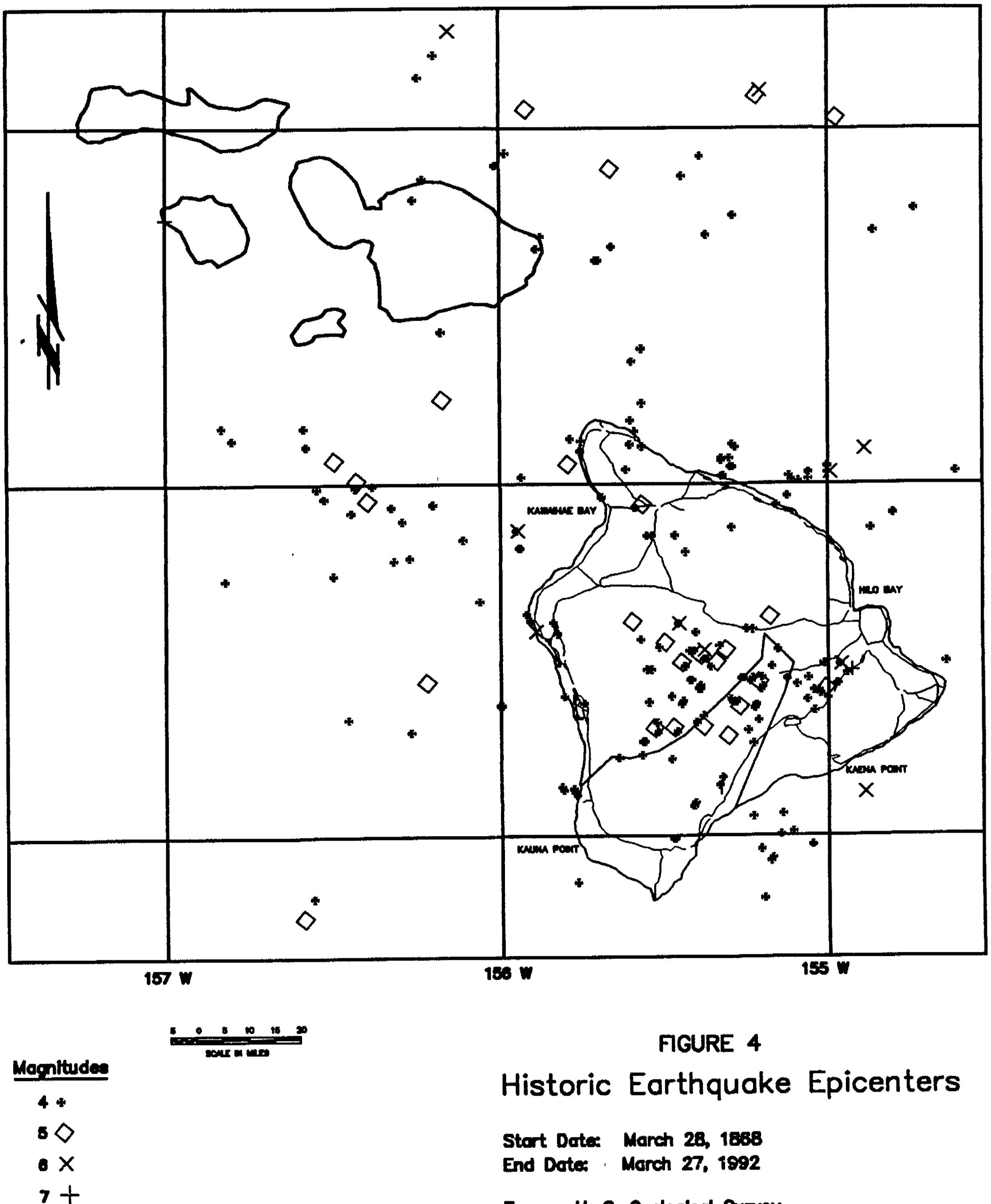


FIGURE 4

Historic Earthquake Epicenters

Start Date: March 28, 1868
End Date: March 27, 1992

From: U. S. Geological Survey
National Earthquake Information Center

winter months, the trade winds are replaced by other general winds, primarily southerlies. During the summer, wind velocity is the highest exceeding 12-miles per hour 50 percent of the time. During the winter this drops to about 40 percent of the time.

Hydrology: The area has no perennial streams or fresh water lakes because most of the volcanic series are extremely permeable. The historic members of the volcanic series (after 1832 for Mauna Loa and after 1750 for Kilauea) are extremely permeable but carry no water except near the coast where it is brackish. The prehistoric members of the volcanic series are also extremely permeable.

In the wet upland areas, the relatively impermeable Pahala Ash creates pockets of high elevation groundwater. This perched water creates high level springs and bodies of perched water, some of which have been tapped by tunnels. For the Ninole volcanic series, the basalt member is highly permeable and carries fresh water at sea level and perched water above the ash layer. The Hilina volcanic series is highly permeable but carries only brackish water along the coast.

Lateral movement of fresh water along the upper surface of the basal lens creates numerous fresh and brackish seeps and springs along the coastline. High drilling costs and thinness of the fresh water basal lens due to high permeability have prevented widespread use of basal water wells.

All water sources in the study area have little storage capability and are highly responsive to fluctuations in rainfall. Poor soil conditions, frequent seismic activity, and steep slopes have precluded, for the most part, the construction of large storage facilities in the study area. Most of the existing water storage facilities are owned and operated by Ka'u Agronomics Company for plant operation purposes. Agricultural water storage, at one time consisted of 10 small, dugout type or above ground, structures totaling 20.2-Mgal (million gallons). Currently only three reservoirs are used totaling 15.3-Mgal. The largest reservoir is the Keaiwa, with a total storage of 13.9-Mgal, which collects water from the Noguchi No. 2 tunnel with an average flow 0.23-Mgd (million gallons per day). It is concrete lined, but due to age and seismic activity, it has major cracks that produce a leakage rate of about 27 percent of the water that enters the reservoir under average conditions. The Meyer Reservoir has a capacity of 1.1-Mgal and the Pahala Factory Reservoir has a capacity of 0.3-Mgal.

Most springs and perched sources have greatly diminished output during the dry season. Nevertheless, they supply 94 percent of the current water use in the study area. Ninole springs, the second largest basal spring on the island, was estimated to have a discharge of 20- to 25-Mgd in 1943.

Kawa'a Springs was estimated to have a discharge of 10-Mgd. Neither has been exploited in modern times as a water source. In the South Point area, the basal water is brackish due to the extreme permeability of the young lavas allowing sea water to move inland through cracks and crevices.

In the Pahala and Na'alehu regions, perched sources in the Ka'u area include about forty tunnels that were dug into the hillsides to develop perched water as of 1943 (See Appendix A and Figure 5). The tunnels usually are about four-foot high and three-foot wide. They were dug at the contact of the ash and lava and follow the ash layer surface. Water usually occurs in lava filled gullies in the ash layer. New Mountain House tunnel is 7,048 feet long. These perched water sources have been successfully developed in the past and used for fluming sugar cane to the mill. Many of these sources were abandoned when trucking of sugar cane to the mill was begun.

In eastern Ka'u (Kapapala subarea), there is no prospect of developing perched water due to low rainfall and the coarseness of the ash beds. In central Ka'u (Wood Valley, Pahala and Na'alehu subareas), water tunnels were developed to flume sugar cane to the mills. Noguchi No. 2 tunnel averages 238,000-gpd (gallons per day) and New Mountain House tunnel yields 1,286,000-gpd. Most of the other tunnels produce less than this. Pahala Factory shaft is being pumped at the rate of 4.5-Mgd and has a maximum capacity of 7.2-Mgd. Unfavorable geology and low recharge greatly diminish the chances of developing high elevation water in western Ka'u (Kahuka Ranch, South Point, and Manuka subareas).

Sources of water for the domestic systems include catchment systems, wells, tunnels or springs, or delivered water. See Appendix A for a listing of all drilled water wells in the area as of 1991. The County operated municipal system for Pahala relies on the Alili Tunnel and supplements from the Pahala well during dry weather. Average usage in 1991 was 0.3-Mgd. The County operated Waiohinu-Na'alehu municipal system uses the New Mountain House Tunnel, a well and Ha'ao Spring. This water is piped to Waiohinu and also distributed to Na'alehu and South Point. Average winter usage was 0.36-Mgd in 1991. Wood Valley and Kapapala use the private agricultural distribution system from Noguchi 2 and Makakupu tunnels.

Punaluu Resort uses two wells with 0.9-Mgd of their 1.2-Mgd usage going to irrigate the golf course. Effluent from the resorts wastewater treatment plant is sometimes blended with the irrigation water. The South Point area uses the Naalehu/Waiohinu community system. A deep well with an initial capacity of 1,000-gpm was drilled in 1990, but is not operational due to high salinity. Hawaiian Ocean View Estates and Ranchos, (west of Ka Lawe and south of the highway from

Hawaiian Ocean View Estates, uses individual catchments supplemented with delivered water.

Stock water comes from springs, wells, catchments, seeps, and water tunnels. Water in the coastal area from the basal aquifer tend to be brackish. Rain sheds are used in the higher elevations to catch and store rainwater. A rain shed consists of a pitched, usually corrugated iron, roof that directs any water falling on it to a collection system that leads to a storage tank. Water flowing from the storage tank flows to stock water troughs is usually controlled by a type of float valve.

The State of Hawaii has developed an aquifer classification system as part of the Water Resources Protection Plan (Figure 6). This plan estimated sustainable yields. The sustainable yield does not take into account whether the water resource is feasible to develop. Table 6 shows the named aquifer systems and sustainable yields for portions of the Southeast Mauna Loa and Kilauea aquifer sectors.

TABLE 6 Sustainable Yield for Aquifer Systems[13]

Aquifer System Name	Aquifer System Code	Sustainable Yield (Mgd)
Ka Lae	80504	31
Na'alehu	80503	117
Kapapala	80502	19
Keaiwa	80804	17

Currently, the present water uses in the Ka'u district are:[14]

TABLE 7 Present Water Uses In Ka'u District

Use	Water Usage	Percent
Municipal	0.95-Mgd	8%
Agricultural	3.74-Mgd	30%
Private DCI[15]	1.41-Mgd	11%
Others[16]	6.34-Mgd	51%

[13]Source: Hawaii County Water Use and Development Plan, Review Draft February, 1992.

[14]Ibidem.

[15]Domestic, Commercial and Industrial

[16]Industrial cooling and wash water

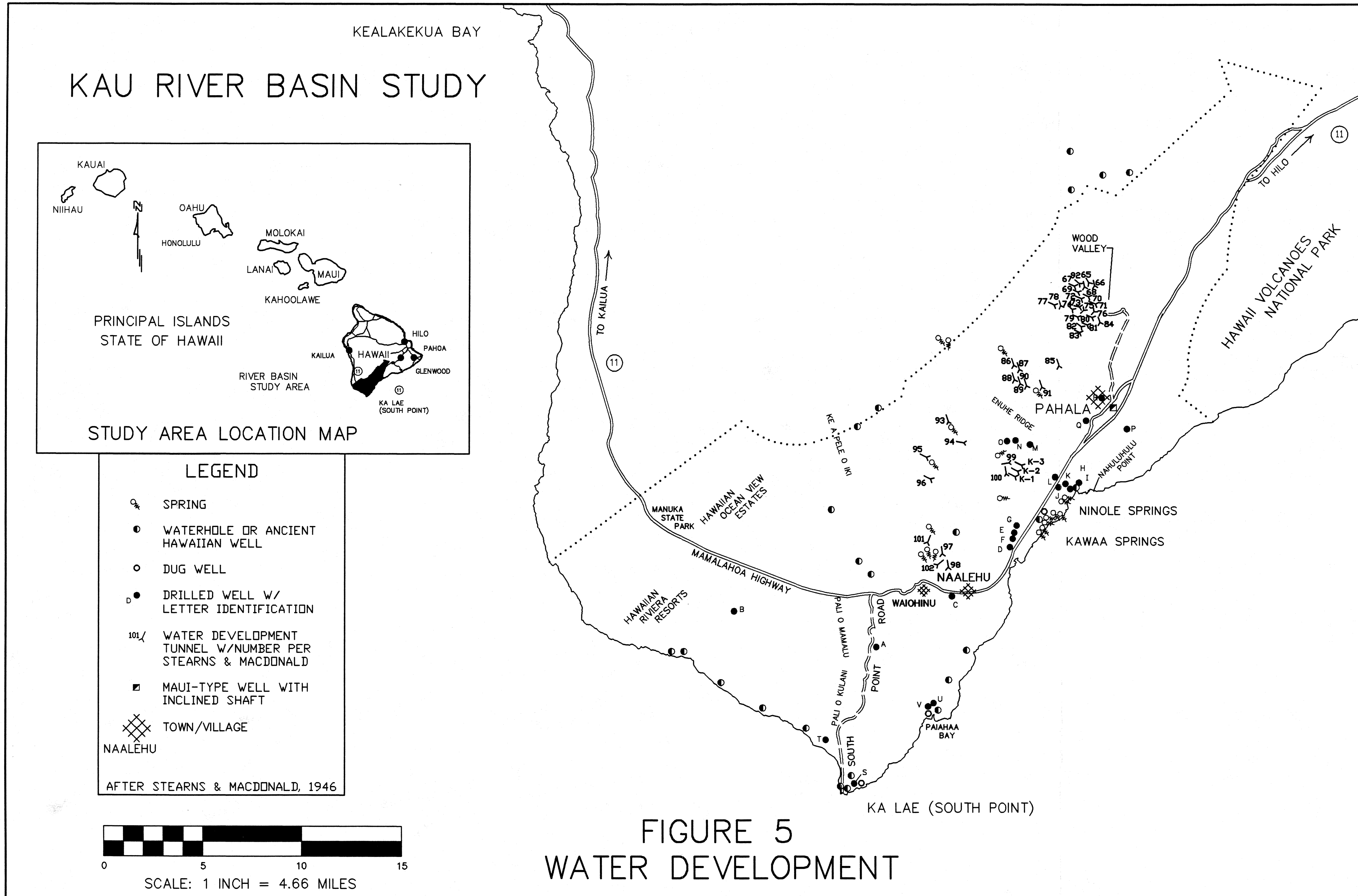


FIGURE 5
WATER DEVELOPMENT

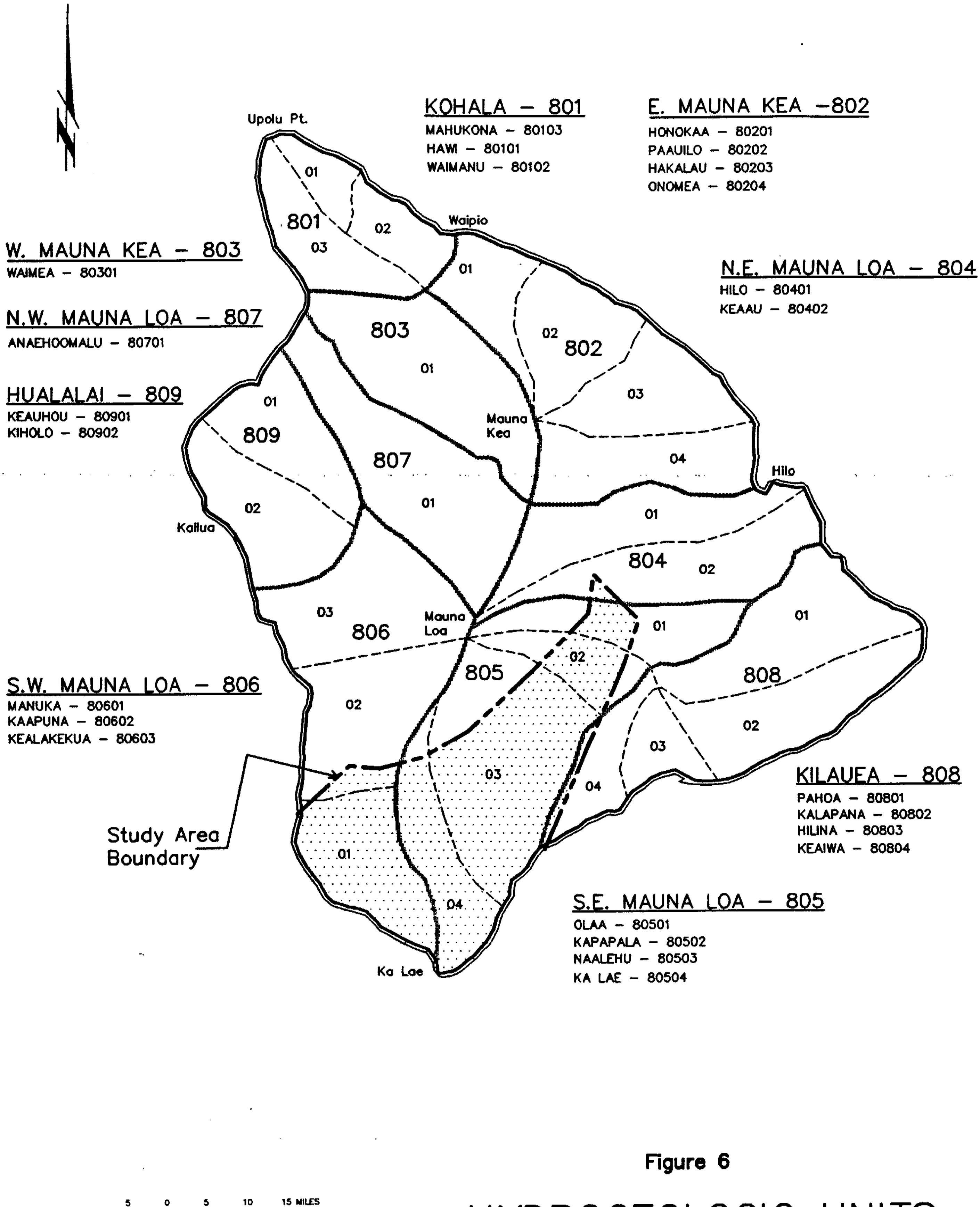


Figure 6

HYDROGEOLOGIC UNITS

Island of Hawaii

REFERENCE: Megumi Kon, Inc., 1989.

Ninety-four percent of the 12.44-Mgd is supplied by ground water sources with the remaining six percent by surface water.

Water Quality: Surface water on the Island of Hawaii is characterized by low concentrations of dissolved solids, average 64 parts per million (ppm), and minimal hardness as calcium carbonate ($CaCO_3$), average 29-ppm. Ground water however has higher concentrations of dissolved solids, average 125-ppm and hardness, average 112-ppm. Hardness is caused by calcium and magnesium compounds with some sulfate. A high silica content is derived from the lava.

Public water supplies from both surface and ground water supplies contain chemical substances in amounts generally well below the recommended limits. However, basal ground water sources along the coastal areas are susceptible to high chloride levels caused by salt water intrusion.

The Federal Safe Drinking Water Act Amendments of 1991 pertains to all public water systems whether publicly or privately operated with over 15-connections or serving 25 or more persons. Under this regulation, all public water systems must meet stringent monitoring requirements to test for lead, microbiological, radiological and disinfection by-products. In addition, they must monitor for the presence of a large number of chemicals and a list of non-regulated contaminants.

Water systems that use springs, surface water, and tunnels as water sources maybe required to be treated before distribution. The State Department of Health will determine which tunnel and spring systems are subject to the surface water rule of the Federal Safe Drinking Water Act by June 29, 1994, for community systems, and June 29, 1997, for noncommunity systems. These requirements must be met 18 months after the determination is made. Compliance with these regulations can be a major cost item with a high cost per customer for those systems with a small number of users.

The County of Hawaii is anticipating a problem bringing spring and surface water sources into compliance with Federal safe drinking water regulations and water quality standards. In addition, older systems require upgrading not only to meet future needs but to minimize losses through leakage.

Hawaii Administrative Rules Title 11, Department of Health, Chapter 54, Water Quality Standards establishes the water quality goals for water bodies in the State of Hawaii. This document identifies the following areas in the Ka'u study area as being classified as State Waters and thus having a zero degradation policy in effect:[17]

a. All lava rock shorelines not in Class I water areas;
b. All marine pools and protected coves on the Island of Hawaii [Class I]; and
c. The following wave exposed reef communities [Class I]:
   1823 Lava Flow (Punaluu)
   1868 Lava Flow (South Point)
   1887 Lava Flow (South Point).

NATURAL RESOURCES

Forestland: The Ka'u Forest Reserve is located on the southern slope of Mauna Loa. It is approximately 20-miles long and five-miles wide, covering approximately 75,100 acres. The land is generally rough consisting of old, weathered a'a and pa'hoe'hoe flows with numerous large gulches and valleys. The reserve ranges from 2,100 to 6,600 feet in elevation with slopes of 0 to 26 percent. It consists of native vegetation and ohia with a prominent tree fern undercover. Some koa is present. About 154 acres of eucalyptus and silk oak were planted primarily in the Kapapala and Wood Valley subareas. In the northwest portion of the reserve alpine plants like pukiawe, 'a'ali'i, ohelo, and kukaenene are abundant. Timber harvesting is remotely possible. There is a small amount of marketable ohia and koa.

Rangeland: Cattle grazing has reduced the native vegetation to low levels and minimal diversity. Koa haole (Leucaena glauca) was introduced to fatten cattle and to feed cattle during periods of little rainfall. The above conditions combined with low management result in an Animal Unit Month[18] (AUM) being 10 acres or more. The AUM's will drop to 2-3 acres with intensive management. Buffel grass, yellow foxtail, Natal redtop, kikuyugrass, pangolagrass, green panic, tinaroo glycine, siratro, and guineagrass are introduced species. Lantana (Lantana camara) is encroaching on areas.

Naturalized Vegetation: Naturalized vegetation[19] occurs in kipukas or is coming back in areas that are not grazed anymore. Vegetation ranges from lichen, moss, ohia, 'ama'uma'u fern, mamani, naio, Kentucky bluegrass, Christmas berry, guava, noni and sweet vernal on lava flows depending on elevation and side of island. Lantana, Natal redtop, yellow foxtail, Japanese tea, buffelgrass, and kiawe are predominant at South Point.

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[17] Source: Hawaii's Assessment of Nonpoint Source Pollution Water Quality Problems, State Dept. of Health, November, 1990.

[18] An animal Unit Month is the amount of dry weight feed that a 1,000 pound cow with or without a calf will consume in one month or the equivalent-acreage based on management practice.

[19] Naturalized vegetation is vegetation that has been introduced from other parts of the world that now acts as native plants.

Wetlands: Figure 7 indicates the general location of wetlands in the study area. The wetland types identified in the study area include several marine areas along the shoreline, an estuarine area near Ka Lae, several palustrine areas close to shore and further inland, and several intermittent riverine wetland areas. This map is for general purposes only and is not meant to identify the exact location or all of the different types of wetlands.

Wildlife: Feral pigs are abundant. The pigs cause extensive damage to the native vegetation and are hunted for sport and sustenance. Introduced pheasants, quail and chukar are also found at higher elevations. Mongoose were introduced to control the rat population but have become a pest and continue to threaten the bird population. There is some discussion to improve the fencing along the forest reserve boundaries to protect the reserves from impacts due to ranching activities and feral animals. Specifically, the Mouflon sheep is expanding its range and is feeding on the Silversword, a threatened and endangered listed plant species found in the area. Silversword is fenced on the Kahuku Ranch. The U.S. Fish and Wildlife Service has not mapped for wildlife habitat. The Department of Land and Natural Resources provided a map delineating the public hunting areas (Figure 8).

Threatened and Endangered Species (T & E): The State of Hawaii, since statehood, has been in a dynamic phase of social and economic development with some interruptions caused by periodic national economic recessions. The rapid increases in urban, rural and agricultural development, tourism, recreation and social requirements for open spaces cause direct or indirect impacts to threatened and endangered wildlife, plants, and invertebrates and their habitats.

The unique and sensitive nature of native flora and fauna of Hawaii is thoroughly documented. The state of Hawaii has approximately 80 endangered species, this is 25 percent of all rare and endangered plants and animals found in the United States. About 75 percent of all extinctions in the United States have occurred in the State of Hawaii.[20]

Of approximately 2,400 different kinds of native plants, half have been proposed as threatened or endangered and 273 are probably extinct. Of the 70 birds and one land mammal species native to Hawaii, 24 bird species have become extinct and 30 bird and one mammal species are now threatened or endangered with extinction. Table 8 depicts endangered and threatened species in the Ka'u River Basin. The plant species survey is approximately 30 percent completed. Land-use changes and exotic plants and animals continue to cause the major problems effecting native species.

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[20]Source: State Land-use District Boundary Review-Hawaii, Office of State Planning, 1992.

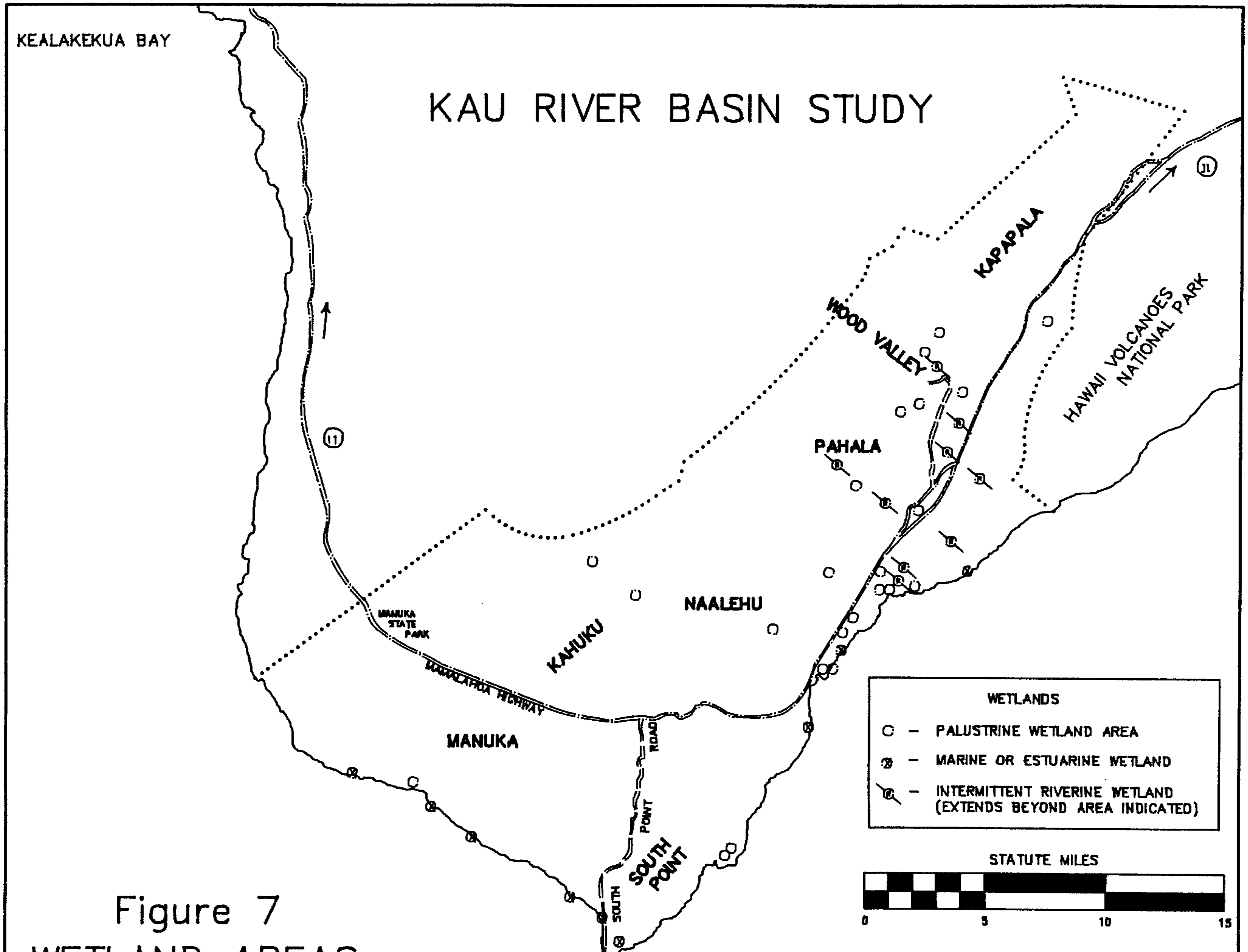

Figure 7
WETLAND AREAS

SOURCE: MAPS PRODUCED FOR THE U.S. FISH AND WILDLIFE SERVICE BY THE NATIONAL WETLANDS INVENTORY ESTABLISHED 1979.

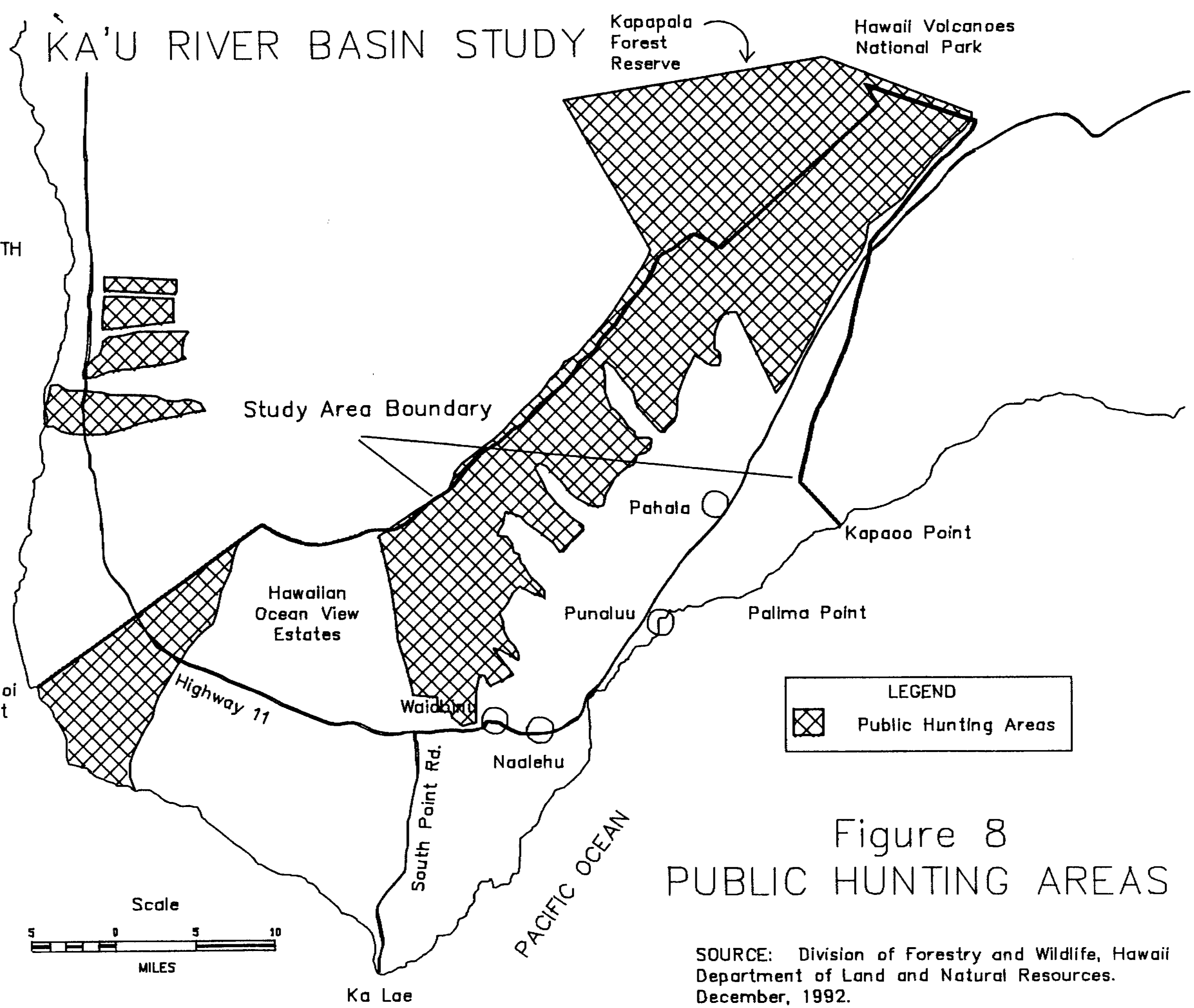

Figure 8
PUBLIC HUNTING AREAS

SOURCE: Division of Forestry and Wildlife, Hawaii Department of Land and Natural Resources. December, 1992.

Tables 9 and 10 contain State listed plant species. This list is updated as of May 18, 1993. Table 8 shows Listed and Proposed Federally Threatened and Endangered Species in the Ka'u River Basin Study area. Figure 9 shows a map of the concentration of Threatened and Endangered Plant Species. Note that there has been no formalized plant survey completed by the Department of Natural Resources for the entire area. The map (Figure 9) shows data collected by individuals on a voluntary basis. Figure 10 delineates Native Bird Habitat Boundaries for forest birds, nene, and water birds.

The U.S. Fish and Wildlife Service does not yet have designated official critical habitats for native bird species with the exception of the Palila, Loxioides bailleui.

In Hawaii, the problem of protecting native species is complex because native species generally lack strong natural defense mechanisms. Due to geographical isolation, few species reached the islands and those that did flourished with minimal competition. Most native plants are easily damaged by feral animals and do not compete well with introduced, aggressive plants. Because of their limited range, the native flora and fauna are particularly sensitive to human disturbances and to alteration of specialized habitat niches in the environment.

The main threat to the study areas surviving native species and natural communities is the destructive effect of non-native species introduced by people. With the advent of sugar cultivation and development of the cattle industry in the area, native flora and fauna were adversely impacted. Some species continue to survive in isolated non-rangeland high elevation areas and habitat niches between cultivated lands. Protection of the threatened and endangered species is a multi-level governmental function. In the State of Hawaii, the Division of Forestry and Wildlife is directly responsible for resource management on state-owned forest reserves, surrendered lands, wildlife sanctuaries, private and military lands under cooperative agreement, and public hunting areas. Where species occur on areas beyond their immediate responsibility, the Division will provide technical assistance to the land owner and seek cooperative efforts for T & E preservation and restoration on their lands.

TABLE 8 Federal Threatened and Endangered Species Listed and Proposed		
	FLORA	
Scientific Name	**Common Name**	**Status**[21]
Clermontia lindseyana	haha	PE
Clermontia pyrularia	haha	PE
Ischaemum byrone	Hilo ischaemum	PE
Mariscus fauriei	no common name	PE
Portulaca sclerocarpa	'ihi	PE
Silene hawaiiensis	no common name	PE
Diellia erecta	no common name	C1, in PE process
Flueggea neonwawraea	mehameheme	C1, in PE process
Plantago hawaiiensis	laukahi kuahiwi	C1, in PE process
Sesbania tomentosa	no common name	E
	FAUNA	
Scientific Name	**Common Name**	**Status**[16]
Forest Birds		
Loxops coccineus coccineus	Akepa, Hawaii	E
Hemignathus munroi	Akiapolaau	E
Buteo solitarius	Hawaiian Hawk	E
Psittirostra psittacea		Ou E
Corvus hawaiiensis	Hawaiian Crow alala	E
Nesichen sandvicensis	Hawaiian Goose nene	E
Oreomystis Nana (Loxops maculata mana)	Creeper, Hawaiian	E
Sea Birds		
Oceanodroma castro cryptoleucura	Band-rumped storm petrel	C2
Pterodroma phaeopygia sandwichensis	Hawaiian dark-rumped petrel	E
Puffinus auricularis newelli	Newell's shearwater	E
Mammals		
Lasiurus cinereus semotus	Hawaiian hoary bat	E
Sea Turtles		
Chelonia mydas	Green sea turtle	T
Eretmochelys imbricata		Hawksbill turtle E

[21]Status: **E** = Endangered, **PE** = Proposed Endangered, will be listed within 1 year, **C1** = Candidate for immediate listing, **C2** = Potential candidate for listing, **T** = Threatened.

TABLE 9 State Proposed Endangered Plant List for the Big Island, HI [May 1993]

Scientific Name	Common Name	Eff. Date	Critical Habitat Designated
Clermontia lidseyana Rock	'Oha wai	12/17/92	No
Clermontia peleana Rock	'Oha wai	12/17/92	No
Clermontia pyrularia Hillebr.	'Oha wai	12/17/92	No
Colubrina oppositifolia Brongn. ex H. Mann	Kauila	12/17/92	No
Cyanea hamatiflora Rock var. carlsonii (Rock) Lammers	Haha	12/17/92	No
Cyanea shipmanii Rock	Haha	12/17/92	No
Cyanea stictophylla Rock	Haha	12/17/92	No
Cyrtandra giffardii Rock	Ha'iwale	12/17/92	No
Cyrtandra tintinnabula Rock	Ha'iwale	12/17/92	No
Gouania vitifolia A. Gray	--	12/14/92	No
Mariscus fauriei (Kukenth.) T. Koyama	--	12/17/92	No
Portulaca sclerocarpa	Po'e	12/17/92	No
Pritchardia affinis Becc.	Loulu	12/17/92	No
Silene hawaiiensis Sherff	--	12/17/92	No
Tetramolopium arenarium (A. Gray) Hillebr.	--	12/17/92	No

TABLE 10 State Endangered Plant List for the Big Island, HI [May 1993]

Scientific Name	Common Name	Eff. Date	Critical Habitat Designated
Abutilon menziesii Seem.	Ko'oloa'ula	10/27/85	None
Argyroxiphium kauense (Rock & M. Neal) Degener & I. Degener	Ka'u silversword	5/7/93	None
Argyroxiphium sandwicense DC ssp. sandwicense	'Ahinahina Mauna Kea silversword	4/21/86	None
Caesalpinia kavaiensis H. Mann	Uhiuhi, kea kalamona	8/7/85	None
Gardenia brighamii Mann	Nanu, nau	9/20/85	None
Huperzia mannii	Wawae'iole	6/15/92	None
Isodendrion hosakae St. John	Aupaka	2/13/91	None
Kokia drynarioides (Seem.) Lewt.	Hau-hele'ula koki'o, Hawaiian tree cotton	1/3/85	Yes
Stenogyne angustifolia Gray var. angustifolia	--	12/29/79	None
Vicia menziesii Spreng	--	5/27/78	None

KA'U RIVER BASIN STUDY

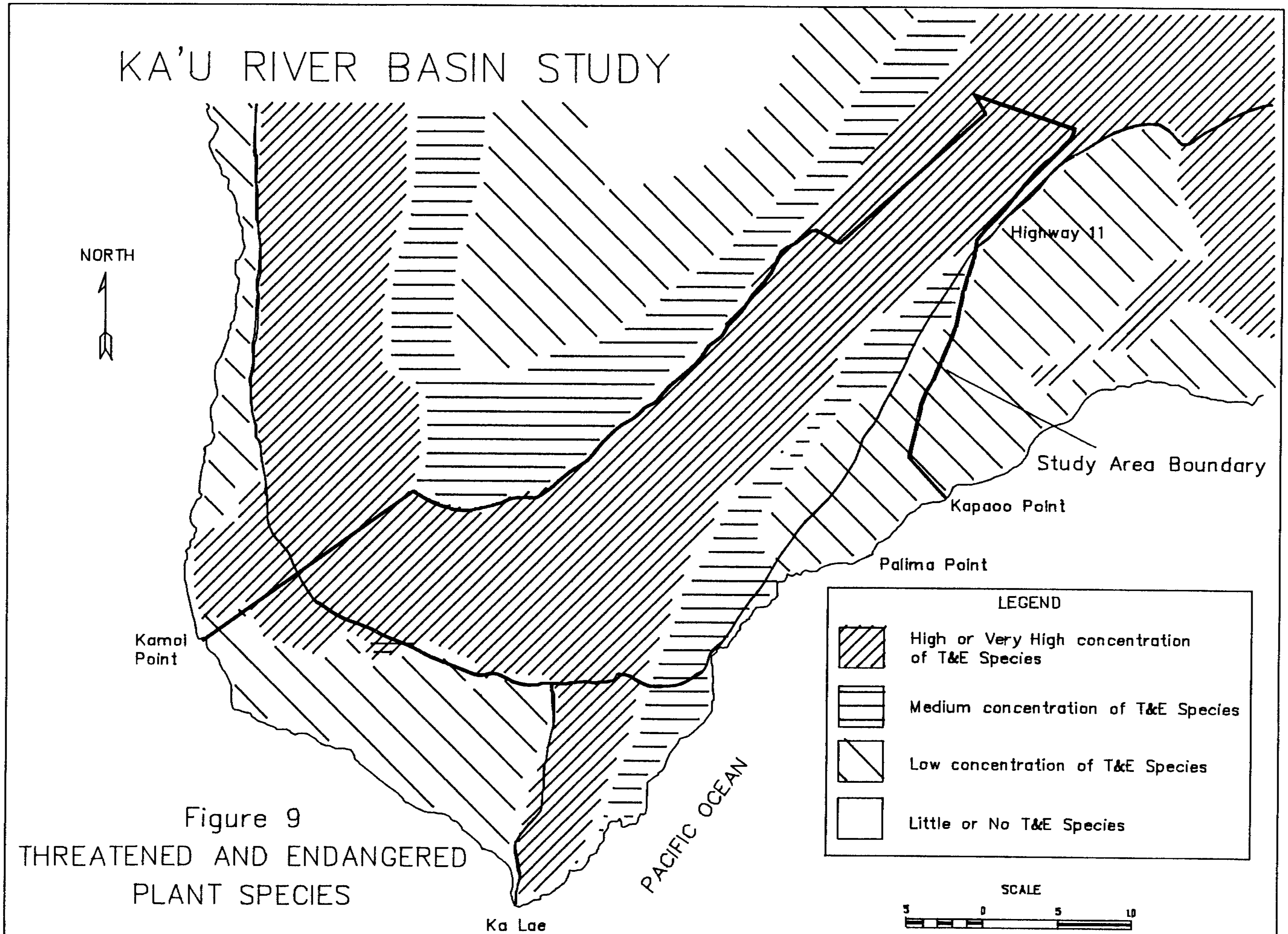

Figure 9
THREATENED AND ENDANGERED PLANT SPECIES

Hawaiian Heritage Study, Hawaii Chapter, The Nature Conservancy. December, 1992.
NOTE: Threatened and endangered species information shown on this map should be used only as a guideline based upon limited information and further refinement. It illustrates the concentrations of 98 endemic plant taxa which are listed or under review for endangered or threatened status for the ISLAND OF HAWAII. It is based mainly upon historical collections with some recent observations. (Note: Individual rare species sometimes grow only within areas that may have an overall low species concentration rating.)

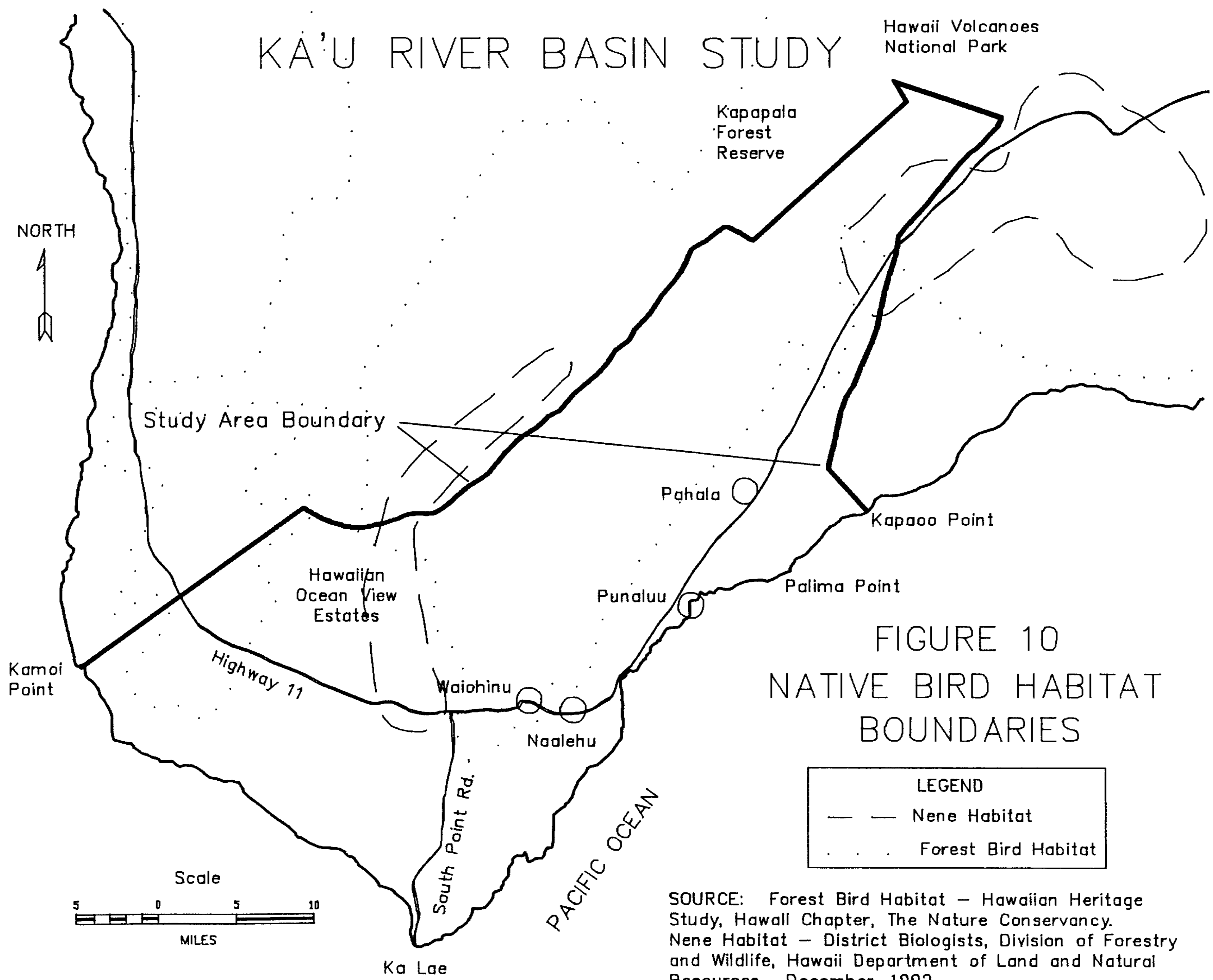

FIGURE 10
NATIVE BIRD HABITAT
BOUNDARIES

SOURCE: Forest Bird Habitat – Hawaiian Heritage Study, Hawaii Chapter, The Nature Conservancy.
Nene Habitat – District Biologists, Division of Forestry and Wildlife, Hawaii Department of Land and Natural Resources. December, 1992.

The United States Department of Interior, National Park Service operates Hawaii Volcanoes National Park just outside of the Ka'u study area. The park is designated an International Biosphere Reserve. Resource management and reasearch are on-going in the areas of nene recovery, ugulate and weed control, fire management, turtle nest protection and cultural resource protectioon. They are willing to share any information or techniques that they have found.

The Akiapolauu and Hawaii creeper occupy forests in the 3,000-7,000-foot elevation range. The Akepa is found in old lava fields at the same elevations where Ahakea flowers are present. The Alala is found in endemic forests greater than 3,000 feet in elevation. The Io is found in woody vegetated areas less than 8,500 feet in elevation. The Nene likes old a'a lava flows in the 5,000 to 8,000 foot elevation range. The 'Au'u nests in old lava at the 7,200 to 9,600 foot elevation range.

Keauhou is a former ranch inholding within Hawaiian Volcanoes Observatory which contains regenerating ohia woodland. The native rain forests of Kilauea-Keauhou, Kapapala and the lands below the forest reserve are known or believed to provide habitat for endangered forest birds. Kilauea-Keauhou is a potential national wildlife refuge. Ocean View Estates, though heavily subdivided, still manages to have small patches of vegetation containing apapane.[22]

Anchialine pools and native pockets of coastal-strand vegetation are scattered along the south Ka'u coast.

The proposed spaceport may impact species and other natural resources within the Ka'u River Basin study area.

Cultural Resources: Numerous known archaeology sites exist in the study area. Many historic areas also warrant recognition as valuable cultural resources. An example of such an historic resource are the water tunnels in the Pahala area developed in the early 20th century.

The Ka'u District presented the Hawaiians with different problems in their adaptation to and modification of the natural environment from that of other districts. A part of the district is so arid and overrun by fresh lava flow as to deserve the name desert. In contrast, a small area centering around Waiohinu was evidently one of the most desirable areas on Hawaii in which to live.

The Ka'u River Basin contains a variety of archaeological features, including petroglyphs[23], enclosures, platforms,

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[22] Source: State Land-use District Boundary Review-Hawaii, Office of State Planning, 1992.

[23] A prehistoric rock carving.

terraces, ahu[24], shelters, auwai systems[25], Heiau[26], a historic railroad bed, and walls.

The remains of the Hawaiian occupation of Ka'u have generally not been disturbed until the 1970's because of the lava flows, the aridness of the nearshore coastal lands, the lack of suitable harbors and remoteness from Hilo and Kailua. Since that decade, the level of development and historical site disturbance have tapered off considerably. Therefore, it is still possible to construct, through archaeological and historical research, a well-rounded picture of Ka'u's past.

The Ka Lae or South Point area has been viewed as one of the most important and significant regions in the Hawaiian Archipelago. This is due not only to the richness of the cultural resources present, but also to the landmark studies conducted during the 1950's. This provided a significant impetus towards the development and intensification of archaeological research in Hawai'i. Excavation data from this area have provided the basis for seriation and the relative chronology of fishhook types, which in turn have affected theories on the origin and migration of the Polynesians who settled Hawai'i. The South Point region has subsequently been the focus of archaeological research and specifically in Kama'oa-Pu'u'eo ahupua'a with work concentrating in the coastal area. This work has shown that the coastal zone of the Ka'u River Basin was, in general, densely settled by the native Hawaiians prior to the late 1800's and exploited over an extended period of time.

The vegetation in the coastal region is predominantly dominated by buffel grass on the pastures and guineagrass on the plains, with dense thickets of lantana and koa haole interspersed. The a'a flows are generally barren toward the sea coast and sparsely covered with grasses and lantana above the 250 foot elevation. The intermediate 50 to 250 foot elevation on the a'a is densely covered with koa haole. The coastal zone has little vegetation other than beach vitex, naupaka, beach heliotrope, and several trailing vines in sparsely scattered areas. Exceptions to the general trend are noted in the site description sections.

Table 11 lists the Significant Historical Sites in the Ka'u River Basin Study Area and the approximate location is shown in Figure 11.

To date, relatively few historic sites, accompanied by interpretation for the public, have been preserved in the Ka'u area. The National Historic Landmark at South Point includes two permanent village clusters on the shore, a fishing heiau,

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[24]A boundary marker usually consisting of a rock pile.

[25]An irrigation system.

[26]A temple.

TABLE 11 Significant Historical Sites in the Ka'u Area
October 1992

Cultural Resource	Quadrangle	Location	Remarks
Petroglyphs	Naliikakani	Kapapala	Kuee Village, HV 121, HV 122, HV 124 to HV 128
Ka'u Inland Trail		Kamooalii	Heiau, 3665, HV 210
Petroglyphs	Wood Valley	Kailiula	Kapapala Cave, B3-1
Petroglyphs	Pahala	Piikea	Turtle Cave, cluster-varied, 3500, B5-1
Archaeological sites		Paauau	Cluster, varied
Archaeological sites		Pueo	Cluster, varied
Petroglyphs	Punaluu	Moalua Gulch	3505 (B7-1)
Petroglyphs	Pahala	West of Kamehameha Hill	3506,(B7-2)
Archaeological sites		Kamaehameha Hill	Cluster, varied
Winding coastal trail		Keoneeleele Flat	3508, (B7-9)
Petroglyphs		Nahuluhulu Point	3509, (B7-10)
Petroglyphs		Mohokea	Cluster 3510, (B7-11)
Archaeological site	Punaluu	Punaluu	Heiau of Kaneeleele, heiau of luakini class, 3511, (B8-1)
Stepping Stone Trail			Also a cist burial, 3514-15 (B8-4 and 5)
Archaeological Site			Heiau of Lanipao, 3512 (B8-2)
Petroglyphs			Located along shore between Ninole and Punaluu 3513 (B8-3)
Archaeological Sites		Ninole	Ninole pond 3517 (B9-2)
			Heiau named Mokini, 3518 (B9-3)
			Cluster 3519-24 (B9-4 to 9)
			Heiau of Kaieie, 3516 (B9-1)
			Complex of sites, including fishing shrine 3525-27 (B910 to 12)
			Two ancient trails 3528-29 (B9-13 and 14)
Archaeological Sites		Hilea Iki	Trail, partially paved with water-worn stones 3545 (B10-17)
			Cluster of sites, 3546-50, (B10-18 to 22)
			A north-south trail 3551 (B10-11)
Archaeological Site	Naalehu	Kuhua Bay	Cluster of sites, 3539-44 (B10-11 to 16)
Archaeological Sites		Kawa Bay	Heiau Keeku, a major heiau of human sacrifice, 3530 (B10-1)
			Complex of house site and a burial, 3531-36 (B10-2 to 7)

TABLE 12 Significant Historical Sites in the Ka'u Area continued
October 1992

Cultural Resource	Quadrangle	Location	Remarks
Petroglyphs	Naalehu		3537 (B10-8)
			Extensive complex of sites, major settlement near spring 3552 (B11-1 to 97)
Archaeological Site		Hokukano	Cluster of sites, 3553-58 (B12-1 to 6)
Archaeological Site		Puhiopaheepahee	Cluster of sites, 3559-3563 (B12-7 to 11)
Archaeological Site		Hiona	Cluster of sites, 3564-3580 (B12-12 to 28)
Archaeological Sites		Honuapo	Cluster of site, 3581 (B13-1 to 10)
			Heiau Auolele, a human sacrifice heiau 3587 (B16-6 to 8)
			Heiau Kamalai, 3583 (B13-12)
Archaeological Site		Kaunamano	Shelter cave with complex of sites, 3584 (B14-1 to 24)
Archaeological Site		Kalainakekua	Heiau Makamakaole, 3585 (B14-25)
Archaeological Site		Waikapuna	Complex of sites, 3586 (B16-1 to 5)
		Kahilipali Nui	
Archaeological Sites		Waikapuna	Complex of sites 3587, (B16-6 to 8)
			Poninau Heiau, 3591 (B16-23)
			Complex of sites, 3588 (B16-9 to 20)
Archaeological Site		Kahilipali Point	Petroglyphs, on coarse pahoehoe lava, 3589 (B16-21)
Archaeological Site		Luanunu	Luanunu cave, important lava tube cave 3599 (B17-8)
Petroglyphs	Ka Lae	Kii	National Historic Site 3598 (B17-7)
Petroglyphs		Keoneokahuku	3597 (B17-6)
Petroglyphs		Kamilo	3596 (B17-5)
Archaeological Site	Kahuku Ranch	Kiolakaa	Heiau Alaipamona 3601 (B18-1)
Archaeological Site	Ka lae	Kamaoa Puueo	House sites, 3903 to 3907 located along the coast
Archaeological Site		Kaulana Bay	Ancient village complex of houses and shelters, 3911
Archaeological Site		Lua Makalei	Lava tube cave complex, 3606 (B20-2)
Archaeological Site		Lua O	Large brackish water source, 3610 (B20-7)
			Palahemo
Archaeological Sites		Pinao Bay Puu Alii	Complex of House sites, 3609, 3808 (B20-6, B20-15)
Archaeological Sites		Puu Alii Sand Dune	Ancient Fishermen's establishment
			Extensive burial site 3605 (20-1)

TABLE 12 Significant Historical Sites in the Ka'u Area continued
October 1992

Cultural Resource	Quadrangle	Location	Remarks
Archaeological Sites	Ka Lae	West of Puu Ali	Part of Pinao Bay Complex of sites 3909, 3910,
Archaeological Sites			80 mooring-holes drilled in the west ledges 3608, B20-5
			Heiau Kalalea, fisherman's heiau, 3607 (B20-8)
			Buried midden site 3902 (b20-8)
			Large house site 3901 (B20-4)
			National Historic Site
Archaeological Sites		Kahukupoko	dwelling site with midden deposits 3900 (B20-3)
		Kaalo	Midden site 3912 (B20-19)
Archaeological Sites		Waiahukini	Extensive complex of sites, Heiau Molilele (B21-1) (B21-2 to 19), (B22-14 to 24)
		Kailikii	Complex of sites (B22 1-3, 7-8)
		Hawea	Petroglyphs, human figures (B22-10)
Archaeological Sites	Puu Hou	Kaliipaa	Two U-shaped shelters 3916-7 (B22-12)
		Kahio	Petroglyphs 3918 (B22-12)
			Complex of house sites, shelter, and canoe shed 3920-27 (B22-25 to 32)
		Waialu	A water hole and shelter cave 3919 (B22-13)
		Kahio Point	Complex of house sites 3928-38 (B22-33)
		Kalipoa	Complex of platform house sites and several cairns 3939-3944 (B22-44 to 49)
		Puu Waimanalo	Shelter cave 3945 (B22-50)
		Hopelua	Shelter cave 3646 (B23-35)
Archaeological Sites	Pohue Bay	Hopelua	Complex of Shelter caves 3640-45, (B23-29)
		Kahakahakea	Petroglyphs, 3648 (B23-410
			Complex of Shelter caves 3635, (B23-24), 3636 (B23-25), 3637, (B23-26)
			Shrine 3638 (B23-28)
		Pohue Bay	Extensive petroglyph field, several hundred figures 3647 (B23-40)
			Shelter cave 3639 (B23-27)
			Complex of house sites, burial platforms, and pens 3612-27 (B23-1 to 16)
			Shelter cave 3654 (B23-47)
			Walled structures indicating camp site
		Kahuku	Heiau of Malino 3657 (B23-50)
		Humuhumu Point	Cluster of "Ahu" 3697-99 (B23-57)

TABLE 12 Significant Historical Sites in the Ka'u Area continued
October 1992

Cultural Resource	Quadrangle	Location	Remarks
	Pohue Bay	Keawaiki	Complex of house site, shelter and trail 3670-73 (B24-12)
		Kaheawai	Petroglyphs 3669 (B24-11)
		Manuka State Park	Burial cave 3679 (B24-27)
		Kipuka	Lava tube shelter cave 3688 (B24-18)
		Kaupuaa	Large corral 3690 (B24-25, 26)
		Manuka-Mawai Trail	Six sided house site 3667 (B24-9)
Archaeological Sites	Manuka Bay	Kauna Point	Shrine 3663 (24-7)
		Kaiakekua	Complex of House sites 3666 (B24-8), 3668 (B24-10), 3664 (24-6), 3662 (B24-3)
		Kipuka	Single petroglyph 3676 (B24-22), Enclosure with shrine 3676 (B24-22)
		Malua	Small shelter cave 3677 (B24-23)
		Manuka Bay	Extensive complex of sites including house platforms, kuleana, trail, heiau, and holua slide. 3675 (B24-20), 3681 (B24-29), 3682 (24-39) 3683 (B24-31), 3661 (B24-2), 3660 (B24-1) Petroglyphs 3674 (B24-19)

and some very early temporary fishing sites; work is being done for better interpretation. Sites are also being preserved at Punalu'u (a small heiau, stepping stone trail and petroglyphs), and there are plans to expand the preservation to include permanent habitation and the large heiau of Punalu'u nui. As yet, no upland concerns in Ka'u fields or sites have been preserved. In general, historic interpretation and preservation efforts are just starting in Ka'u and the study area.

RESOURCE CONCERNS

Water Quantity: The major natural resource concern in the study area is insufficient supply of agricultural and rural water during drought periods.

Presently, rural and agricultural water is supplied from two wells, one spring development and two tunnel sources. Insufficient water supply is caused by the seasonally fluctuating water sources, inadequate storage facilities, and increased demand caused by a population increase. Development of additional water sources and increased storage capacity is needed to alleviate the water shortage problem.

Limited development of the water supply in the Ka'u area restricts the potential for farms and residential developments in the area. Due to limited rainfall in most of the Ka'u area rain catchments are generally not practical, thus, limiting development to the vicinity of water sources or distribution lines. There is a need to improve the water distribution system and provide additional storage to expand service.

Recently, Ka'u Agribusiness has reduced its sugar-acreage from a maximum of 13,000 acres to slightly less than 12,500 acres[1] and has investigated cultivation of alternative crops, such as citrus, mangos and Macadamia nuts. Development of irrigation water is needed to effectively utilize the former sugar cane land for other crops.

Projected resort and industrial development in the study area will require additional water supply development. Some proposed developments, such as the Hawaiian Riviera, offer to develop private water sources.

Water Quality: Deterioration of water quality is another concern. The use of shallow well basal water and shore line spring water in the future will require the protection of groundwater resources. Controls over the use of household cesspools, animal waste systems, and disposal of industrial waste, including sugar mill effluent, will be required.

[1]Source: State Land-use District Boundary Review-Hawaii, Office of State Planning, 1992.

KAU RIVER BASIN STUDY

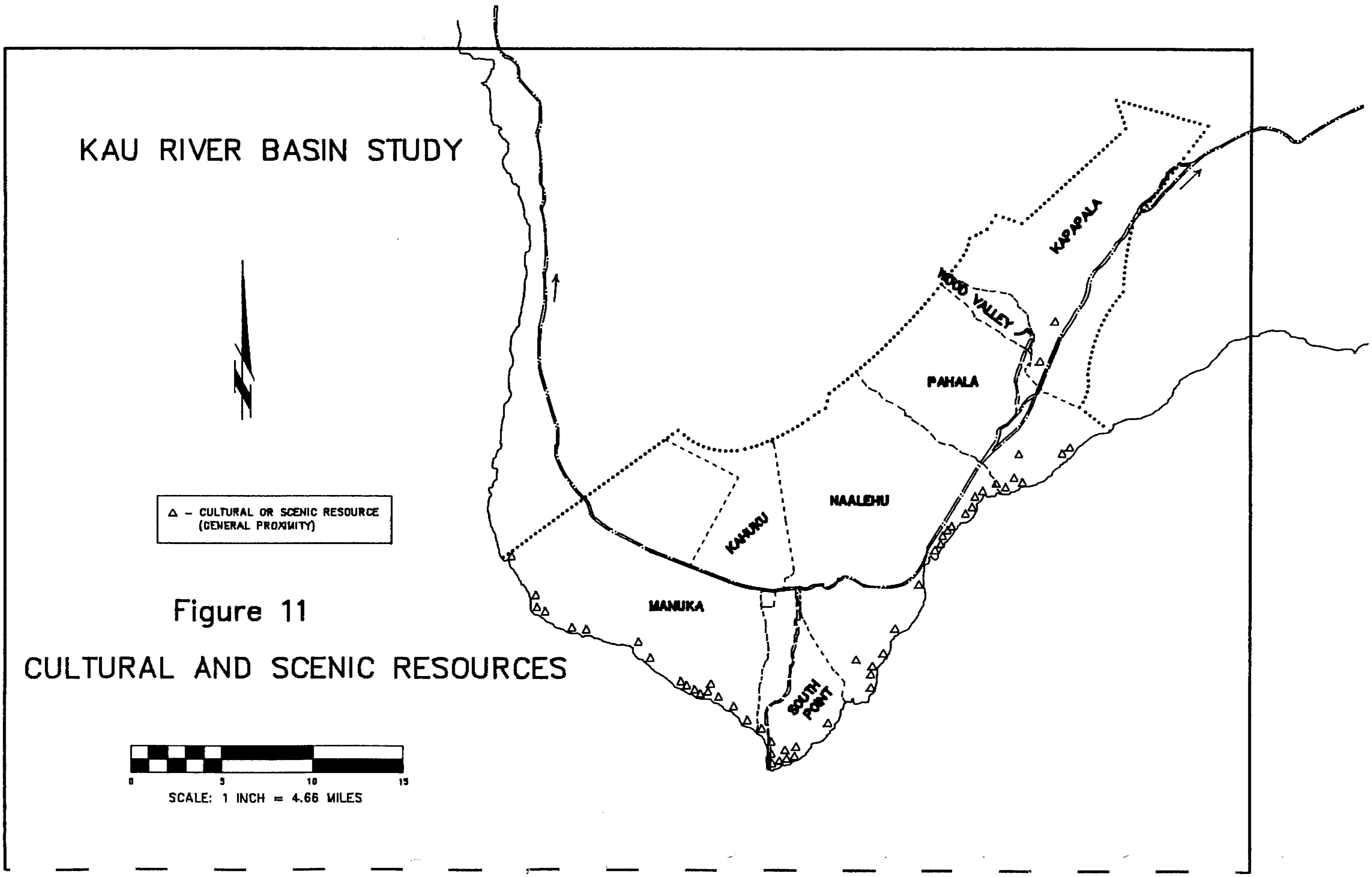

Figure 11

CULTURAL AND SCENIC RESOURCES

Ka'u Agribusiness transports its sugar mill effluent through settling basins to deposit soil and organic matter washed off of the sugar cane before processing. This effluent is not discharged into the ocean.

Identified non-point pollution sources are livestock and landfills near Na'alehu.[1] An irrigation source near Na'alehu has shown 0.14-ppb (parts per billion) Atrazine.[2] The drinking water standard is 3.0-ppb. Atrazine is a selective pre-emergent and post-emergent herbicide and plant growth regulator used for weed control on corn, sorghum, coffee, sugar cane, pineapple, citrus fruits and bananas.

Erosion/Sedimentation: Soil erosion on farmland is another resource concern. Erosion is the group of processes whereby earthy or rock material is loosened or dissolved and removed from any part of the earth's surface. There are two general classes of erosion: geologic and accelerated. Geologic erosion is the naturally occurring erosion. Accelerated erosion is erosion occurring at rates greater than geologic erosion, usually caused by human activities.

Accelerated erosion includes sheet, rill, ephemeral gully, gully and streambank erosion. Sheet erosion is the uniform movement of soil on a slope by sheets of running water as distinct from streams. Rill erosion is the erosional action of water that forms small (less than one foot deep), steep-sided channels called rills. Left unchecked, rills progress through ephemeral gullies to gullies. Ephemeral gullies are small gullies that appear in the same place every year which the landowner plows shut. The area affected is the area of lessened productivity due to the loss of topsoil caused by the closing of the gully each year. Land treatment or conservation practices only affect accelerated erosion.

Sheet, rill and ephemeral gully erosion in Macadamia nut and citrus orchards is a problem usually due to the lack of ground cover beneath the canopy of mature trees. Bare ground under the trees is desireable for harvesting or to induce conditions for crop development. Sheet and rill erosion on mature Macadamia orchards without ground cover is approximately eight tons per-acre per year. Younger orchards with ground cover and terraces are lower depending on soil type, slope, etc.

Sheet and rill erosion on a new field of sugar cane ranges from 2 to 20 tons per-acre per year and for an established field about 2 to 10 tons per-acre per year depending upon soil type and slope. Steep fields are susceptible to ephemeral

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[1] Source: Hawaii's Assessment of Nonpoint Source Pollution Water Quality Problems, State Dept. of Health, November, 1990.

[2] Source: Hawaii Groundwater Quality Protection Strategy, State Dept. of Health, March, 1990.

gully and gully erosion particularly following sugar cane harvest.

Another problem to the soil resource is erosion caused by harvesting. In Macadamia nut orchards, mechanical sweepers induce wind erosion on dry soil. In sugar cane harvesting, soil attached to the cane is removed from the field. The soil loss can be excessive in wet soils where little crop residue is left. Ka'u Agribusiness minimizes this erosion by leaving crop residue during harvesting. No research has been done in this area to quantify this problem.

Due to windiness and fragile soils, excessive wind erosion rates are expected if land in the vicinity of South Point is cultivated.

Sediment causes problems by plugging culverts and necessitating cleanup of roads. Sediment is solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, or ice, and has come to rest on the earth's surface either above or below sea level.

Storm runoff erodes streambanks and causes headcutting along stream channels. Most of the streams in the area have a stream bottom of basalt bedrock. With the increased energy of storm events, the stream can not easily erode down through the basalt, so it meanders back and forth eroding more of the channel banks. In areas of the stream channel where a headcut occurs, turbulent action of the water erodes clinker layers out from underneath the overhanging basalt flow until large pieces of the lava break off into the stream channel. These basalt boulders are reduced in size during large storm events by the abrasion caused by them rolling along the stream bottom and banging into each other. Eroded sediments are deposited in flatter areas, culverts and bridges resulting in diminished flow capacities. The former wetland and pond site at Ninole Cove has been filled in by coarse sediment. The apparent source of this sediment is the increased erosion and flushing of within-channel sediment caused by large frequency storm events.

Flooding: Flooding across the state highway between-mile posts 49 and 57 is common. This stretch of highway includes Punaluu Gulch, Moaula Gulch, Hionamoa Gulch, Paauau Gulch, Keiawa Gulch, Piikea Gulch, Hilea Gulch, Ninole Gulch, or Kaalaala Gulch. A low water crossing known locally as "The Ford" is identified by red painted reflector posts. Traffic is not to enter the low spot if water is in the red area. The flooding stops vehicular traffic for several hours two to three times each year. This traffic stoppage has caused aggravation to local residents who can not get home or have to drive around the island to get home. The flooding has also resulted in lost work days for workers and professionals, including teachers and physicians. Flood waters also damage road surfaces, shoulders, and bridges.

The major cause of the flooding appears to be inadequate capacity at the bridge crossings. When the bridges were built in the 1930s, poor sizing of the bridges they did not anticipate the changes in land-use during the last 60 years, placement of the bridge in relation to the stream channel geometry, and trying to siphon the stream under the bridge. All of these tend to cause storm waters to backup and overtop the road now.

Severe storms have caused residential flooding. The incidence of such flooding may increase if properties in flood plains are developed. Inadequate storm water conveyance also contributes to the problem.

Land Conversion: The maintenance of agricultural land in agricultural use is another concern. The tenuous financial position of the Hawaiian sugar industry and state-wide resort/industrial expansion along with possible spaceport development may create pressures to convert agricultural land to non-agricultural use. The viability of agricultural production in Ka'u is dependent on factors such as water, transportation, and market conditions.

Biodiversity: The loss of habitat of native flora and fauna continues to affect the biodiversity of the Ka'u District. Losses due to agricultural and residential development continue to adversely impact the area. Feral animals and introduced plants also impact the native plant and animal populations.

OPPORTUNITIES

Recreation: The Ka'u area has an abundance of minimally disrupted land and shoreline which provide wildlife habitat, contain archaeological and historic sites, and provide recreational opportunities to residents and nonresidents.

Recreational activities, such as hunting, fishing, camping, and hiking, require maintenance of the natural resources of the area. Park facilities can be expanded. Recreational facilities should be maintained and improved in some areas. Sediment discharges into reef environments should be reduced. Visual resources should be preserved.

Wildlife Habitat: Opportunities to maintain or enhance unique wildlife habitats and ecologic communities exists, an example being the marshes and springs along the coastline. Nesting areas for the protected nene and green sea turtle exist in or adjacent to the study area. An opportunity to check the invasion of noxious alien plant species, such as "cat's claw", also exists.

STUDY MANAGEMENT

The study was overseen by a Steering Committee. The Steering Committee is supposed to be make up of members that represent all aspects of the study. This committee was comprised of members from the Ka'u Soil and Water Conservation District, Ka'u Agribusiness, Hawaii County Department, and local ranchers, farmers, and others. Several meetings were held with the committee to obtain information, guidance on the course of the study, and review of the results from various study steps.

RELATIONSHIP TO OTHER STUDIES

The master plan and EIS for the proposed spaceport was scheduled for completion in 1993. The State of Hawaii was planning to begin construction in 1995. In October, 1993 Lockheed, a major partner, withdrew from the project. This put the fate of the spaceport in question. Construction of a launch facility and influx of workers and appurtenant services will dramatically alter the agrarian character of the Ka'u district.

Resort expansion will also require large amounts of water. Low quality water sources may be developed for landscaping needs by the larger developments. However, worker communities and tourist-based commercial areas will require water supplies beyond the needs projected by the resort developments.

Domestic and industrial demand for water will increase and may be in competition for water resources needed by agriculture and rural water supply.

PUBLIC PARTICIPATION PROCEDURES

An advisory committee was formed to guide and insure public participation throughout the course of the study. The advisory committee was composed of representatives from public agencies, private industry, and concerned citizen groups. Meetings, mailings, and other contacts were made at select study phases to gauge public reaction to the study.

FORMULATION OF ALTERNATIVES

The scoping process identified twenty-four natural resource and related issues. Preliminary field work and analysis along with inter-agency coordination has led to a refinement of the original scope of the study. The following concerns have been singled out for further study and recommended alternatives:

Agricultural Water Supply: There was a need to evaluate current and future supply and demand for agricultural water. Shortages were addressed by improving existing sources and/or developing other potential sources. Preliminary cost estimates for reservoir or well development were determined. Methods, alignment and costs for distribution systems were also considered.

Rural Water Supply: This need was addressed in the same manner as agricultural water supply.

Erosion: Soils information, along with other related data has been input into a geographical information system. Areas susceptible to high wind erosion were identified and it is recommended that such areas remain undisturbed.

Flooding: Initial investigations have led to the conclusion that current flooding problems are primarily impacting roads and bridges. An evaluation was made that this project would not help alleviate this problem.

Streambank and Gully Erosion: It was determined that streambank and gully erosion did not need an accelerated start. These problems could be handled through the current on-going conservation program administered by the SCS Hilo Field Office.

Cultural Resources: A preliminary assessment was made of the effects of all proposed actions on environmental resources including archaeological and cultural resources. The alternatives were designed to impact as little as possible known cultural resources.

ASSUMED CONDITIONS

The general assumptions of the future condition of the resources for the various alternatives are discussed below. More detailed discussions are under the subarea partitions.

Scenario 1 (**Future Without Project**, FWOP) conditions will be the same as the Present Conditions for the study area.

Scenario 2 (**Future With Project**, FWP) assumes that all sugar cane land will be out of production by the end of the study period. Also, all suitable prior sugar cane land below the 1,500 foot elevation will be planted with Macadamia nuts. The remaining lands will revert to rangeland or naturalized vegetation.

The impact of the spaceport to current sugar cane and Macadamia nut orchards is minimal. The spaceport will be placed on mostly range or naturalized vegetation land. Water will have to be developed for the spaceport as there is none available. For these reasons, no aspects of the spaceport will be addressed by this report.

The "State Land-use District Boundary Review" states that there is enough urban land in the Ka'u area to meet population and economic growth through the year 2000. However, the lack of infrastructure of highways, sewerage, water systems and public services will constrain this growth. The Ka'u River Basin Study will address only agricultural water supply and not the water needed by urban development.

Scenario 3(**Future With Project**, FWP) assumes that all sugar cane land will be out of production by the end of the study period. Also, all suitable prior sugar cane land below the 1,500 foot elevation will be planted in Macadamia nuts. Above 1,500 foot, all suitable prior sugar cane lands will be planted for biomass or plywood production using eucalyptus, except for Wood Valley. In Wood Valley, suitable land will be planted in ornamentals, truck crops, coffee trees, Macadamia nuts or citrus trees. The remaining lands will revert to rangeland or naturalized vegetation.

Rural water supply or agricultural water sources will be assessed for the subareas of South Point, Wood Valley, Kahuku and Manuka.

SUBAREA ALTERNATIVES

Alternatives for this study were proposed for only five of the six identified subwatersheds. The five subwatersheds included Wood Valley, Pahala, Naalehu, South Point, and Manuka/Kahuku. Naalehu and South Point subwatersheds were combined into one since both could be serviced by one central storage reservoir.

There were a total of ten alternatives developed for the four subwatersheds, two for Wood Valley, three for Pahala, three for Naalehu/South Point and two for Manuka/Kahuku. Alternatives for each subwatershed had the same collection elements with varying sizes of reservoirs, transmission and distribution pipelines depending on the level of water demand.

Alternatives were formulated for each subwatershed separately or in combination to provide a tool for the sponsors to use in long-range agricultural and rural water supply planning. Each alternative could be implemented to stand alone by itself. The study area being so vast would not lend itself to one alternative that would service the whole area because of economics. Therefore the study area was subdivided such that smaller projects could possibly be implemented. The alternatives addressed the agricultural and rural water shortage in the area.

Each alternative had a collection, transmission, storage, rural water treatment, and distribution elements. Collections elements utilized only the tunnels and springs that were operational tunnels and springs as sources of water. It was decided not to investigate the use of groundwater because of the high cost of development and pumping. Furthermore, the Department of Water Supply has indicated that they are converting from the tunnel and spring sources to groundwater for the domestic water source because of the Safe Drinking Water Act requirement of mandatory treatment of surface water. The tunnel and springs are considered as groundwater under the influence of the surface and therefore would have to be treated as surface water.

Transmission pipeline elements were located along either existing roads, pipelines or known right-of-ways as much as possible to facilitate construction and access.

Reservoirs were located as high as possible in fairly moderate sloping land to take advantage of gravity and reduce embankment heights.

The distribution pipeline elements for agricultural water were formulated to deliver peak demand to either existing crop areas or new areas as identified as good or fair in the crop suitability analysis. Location of these pipelines were to general locations only, requiring further planning of laterals to service specific areas.

TABLE 12 Alternative Cost Summary

Alternative	Total Cost ($)
WV1	3,000,000
WV2	4,300,000
P1	75,100,000
P2	41,600,000
P3	93,100,000
N1	42,600,000
N2	51,100,000
N3	87,900,000
M1	7,900,000
M2	12,9000,000

KAPAPALA SUBAREA

The **Kapapala** subarea totaling 52,910 acres is bordered by Hawaii Volcanoes National Park on the northeast and southeast, Kapapala Forest Reserve on the northwest and Wood Valley on the southwest. Ranching is the major economic activity.

TABLE 13 Land-use-Kapapala Subarea

Land-use	Acres	Percent[3]
Rangeland	39,500	74.7
Sugar cane	2,800	5.3
Macadamia Nuts	300	0.6
Federal	10	<0.1
Forest Reserve	10,300	19.4
TOTAL	52,910	

Alternatives

Future Without Project, FWOP:

Scenario 1: No major changes will take place in this subarea without the project. The current water use for 1,700-head of cattle is 0.02-Mgd.

TABLE 14 Agricultural Water Use

Kapapala Subarea--FWOP & FWP
Scenario 1, 2, & 3

User	Use	Quantity	Units	Average Water Use (Mgd)
Kapapala Ranch	Livestock	1,700	Hd	0.02
	TOTAL			0.02

Future With Project, FWP:

Scenario 2: The acres of sugar cane land will be converted to Macadamia nuts where suitable. There is no change in the stock water usage rate.

[3]Source: USDA-Soil Conservation Service, Natural Resources Planning Staff, Honolulu, HI

Scenario 3: The acres of sugar cane land will be converted to Macadamia nuts or biomass where suitable. Any remaining land will revert to naturalized vegetation. There is no change in the stock water usage rate.

Because of the uncertainty of the land tenure in this subwatershed, alternatives were not developed for this subwatershed.

WOOD VALLEY SUBAREA

The **Wood Valley** subarea is bordered on the northeast and southeast by the Kapapala subarea, on the northwest by the Ka'u Forest Reserve boundary, and on the southwest by the Pahala subarea. The subarea essentially consists of the Waiakaloa, Makakupu and Peleliilii Gulch drainage areas above the Makakupu and Piikea Gulch junction. The subarea consists of 5,150 acres. Agricultural production dominated by sugar cane is the major economic activity. The community of Wood Valley along with about 150 acres of truck crops, are included in the subarea.

There are 12-small farms, totalling 670 acres, that are located in Wood Valley, a farming area north of Pahala. These farms produce a variety of diversified crops including carnations, roses, zucchini, guava, beans, corn, broccoli, persimmons and coffee. There are even two "hobby" aquaculture ponds producing Golden Tilapia.

TABLE 15 Land-use Wood Valley Subarea

Land-use	Acres	Percent
Sugar cane	550	10.0
Forest Reserve	3,300	61.2
Truck Cropping	150	2.7
Rural	900	16.5
Other[4]	250	4.8
TOTAL	5,150	

Alternatives

Future Without Project, FWOP:

Scenario 1: No major changes will take place in this subarea without the project. Present water usage

[4] Coffee, Forestland-non-reserve

is 0.02-Mgd for crops and 0.01-Mgd for domestic water supply.

TABLE 16 Agricultural and Domestic Water Use

Wood Valley--FWOP

User	Use	Quantity	Units	Average Water Use (Mgd)
Jeff McCall	Ornamental	6	Acs	0.01
Gerry Magnusen	Coffee	42	Acs	0
	Truck Crops	1	Acs	0
Ray Mizuno	Guava	7	Acs	0
Stan Mizuno	Carnation	2	Acs	0.01
Masa Kai	Carnation	0.4	Acs	0
	Macadamia	6	Acs	0
Goldberg	Coffee/Macnut	12	Acs	0
Temple	Coffee	10	Acs	0
	Orchard	10	Acs	0
	Nursery	0.25	Acs	0
	TOTAL	97		0.02
Households (4 people/house w/400 gpd/house)		25	Homes	0.01
	TOTAL	25	Homes	0.01

Scenario 2: The sugar cane land will revert to naturalized vegetation because the elevation is too high for Macadamia nuts. Domestic water supply usage will double to 0.02-Mgd.

Collection Element: This element uses the Noguchi No. 2 tunnel at approximately 3,400 foot elevation as its primary source of water. The present wooden collection box would be replaced by a new concrete box that would divide the flow equally to both Wood Valley and Pahala.

Transmission Element: Water would be transported from the collection box to the storage reservoir via a 4,500 feet long, 8-inch diameter High Density Polyethylene (HDPE) pipeline. The capacity of this pipeline is 400-gallons per minute (gpm).

In the steep portions of the valley, excavation would be difficult, therefore, the pipeline would be secured with concrete thrust blocks at grade changes and at regular intervals to prevent damage from hydrostatic forces. In the lower, flatter slopes, the pipeline would be buried to prevent vandalism and physical damage to the pipeline. Pressure regulators will be installed along the pipeline to keep the hydrostatic pressure within allowable limits.

Storage Element: Storage will be provided for the agricultural water system by a 0.5-million gallon (Mgal) HDPE lined reservoir at elevation 2,360 feet. The reservoir will be referred to hereafter as the Wood Valley Reservoir. This reservoir will supply water for agricultural purposes and will also serve as a source of water for the rural water system whenever there is a water shortage.

Rural water will be stored in a 10,000-gallon concrete tank at elevation 2,570 feet. Water would be supplied to this tank from the 8-inch diameter HDPE transmission pipeline and also would be supplemented by water pumped up from the 0.5-Mgal storage reservoir via a 40-gpm pump.

Rural Water Treatment Element: In order to comply with the Safe Drinking Water Act, the rural water supply must be treated. A 20-gpm surface water treatment plant would be installed close to the 10,000-gallon concrete tank. Treated water from this plant must meet the water quality standards set in the Hawaii Administrative Rules , Title 11, Department of Health (DOH) - Chapter 20, "Rules Relating to Potable Water Systems". Additionally, the plant must be operated by a qualified water treatment plant operator as certified by the DOH.

Distribution Element: Improvements to this element will include the installation of two separate pipelines to serve the agricultural and rural water needs.

The agricultural pipeline is a buried 4,500 feet long, 4-inch diameter HDPE along Center Street extending southerly from the 0.5-Mgal reservoir to the terminus of Center Street and down to the temple on Wood Valley Road. The capacity of this pipe would be 100-gpm.

The rural water pipeline is a 1- to 1/2-inch diameter ductile iron pipe (DIP) extending from the 10,000-gallon concrete tank along the same alignment as the agricultural water pipeline.

Installation Cost: The installation cost of this alternative including engineering, administrative, and land rights cost is approximately $3,000,000. Land rights requirement is estimated at 3 acres.

Scenario 3: The acres of sugar cane land will be converted to 40 acres of onamentals, 100 acres of coffee, 60 acres of truck crops, and 100 acres of citrus trees. Domestic water supply will remain the same as Alternative 2.

A rural water development system will be planned capable of supporting 50 homes with an average of four persons per home. This system will use 0.02-Mgd. A water treatment facility must be included with this system as required by the Clean Water Act. The system would include a storage reservoir, water treatment plant, chlorinator, and storage tank along with distribution pipelines.

The storage reservoir would be on the upper slope of Wood Valley and have enough storage capacity to hold domestic and agricultural water. Two pipelines would exit the reservoir, for irrigation and the other to the water treatment facility.

A modular water treatment plant that would remove turbidity, color, taste and odor, iron and manganese from the surface water by combining chemical coagulation, mechanical flocculation, filtration and tube settler sedimentation would be installed. A treatment plant capable of handling 20 gallons per minute should be sufficient for the needs of the valley. A chlorination plant to disinfect the water would be installed after the treatment plant. From this point on, the water storage and distribution system must be closed so that the domestic water supply does not become contaminated.

The storage tank will not be open to the air.

In addition to installation costs, an operator, and operation and maintenance costs must be allowed for. The Clean Water Act and Department of Health regulations require frequent testing of the water supply for various substances to ensure proper operation of the plant. It also ensures that there has been no contamination of the water supply.

TABLE 17 Agricultural and Domestic Water Use Wood Valley--FWP Scenario 2 & 3				
User	Use	Quantity	Units	Average Water Use (Mgd)
Diversified Farmers	Ornamental	90	Acs	0.02
	Coffee	100	Acs	0.02
	Truck Crops	110	Acs	0.02
	Citrus	100	Acs	0.02
	TOTAL	400	Acs	0.08
Households		50	Homes	0.02[5]
	TOTAL	50	Homes	0.02

Alternatives for this subwatershed will provide agricultural water to the farmers and ranchers in the Wood Valley area and rural water to households in the subwatershed. Two alternatives were developed for this subwatershed. The first would service only the existing cropland and households. The second would service a twofold increase in demand for both agriculture and rural water.

Alternative WV1: This alternative would provide agricultural and rural water to only the existing farmers and households in the subwatershed. The various elements will have the capacity to supply water to 150 acres of cropland at a peak demand of 100-gpm and 25-households at 10-gpm. (Figure E-4)

Alternative WV2
This alternative would provide agricultural and rural water to the future without project condition. The various elements will have the capacity to supply water to 400 acres of cropland at a peak demand of 300-gpm and 50 households at 20-gpm. (Figure E-5)

Collection Element: As in Alternative WV1, this alternative will use Noguchi 2-tunnel as its primary source of water. In addition, the Weda Tunnel (elevation 3,600 feet) will also be tapped. A new concrete collection box will be installed at the mouth of the tunnel.

Transmission Element: This element includes the installation of 6,500 feet of 8-inch diameter HDPE pipe

[5] Assumes 4 people/house w/400 gpd/house usage

that will transport the water from Noguchi 2 Tunnel to the proposed HDPE lined 3.5-Mgal Wood Valley Reservoir. A 6,000 feet long, 8-inch HDPE pipeline would transport water from Weda Tunnel to the Wood Valley Reservoir. Both pipelines would be anchored at critical grade changes in the steep slopes and buried in the flatter slopes. Pressure reducing and/or release valves will be installed at critical points.

Storage Element: Storage will be provided for the agricultural water system by a 3.5-million gallon (Mgal) HDPE lined reservoir at elevation 2,360 feet. This reservoir will supply water for agricultural purposes and will also serve as a source of water for the rural water system whenever there is a water shortage.

Rural water will be stored in a 20,000-gallon concrete tank at elevation 2,570 feet. Water would be supplied to this tank from the 8-inch diameter HDPE transmission pipelines from both the Weda and Noguchi 2-tunnels and also would be supplemented by water pumped up from the 3.5-Mgal storage reservoir via a 40-gpm pump.

Rural Water Treatment Element: This element is the same as Alternative WV2 except the treatment plant capacity will be doubled to handle 20-gpm.

Distribution Element: The distribution element for this alternative is on the same alignment as Alternative WV1 except that both the agricultural rural water pipelines will have a spur to the south to service the new agricultural area. This spur will extend southerly from the southerly terminus of Center Road to the Wood Valley Road.

The agricultural pipeline is a buried 4,000 foot long, 8-inch diameter HDPE pipeline along Center Street extending southerly from the 3.5-Mgal line reservoir to the terminus of Center Street. The pipeline reduces to a 3,500 feet long, 5-inch diameter HDPE from here to the temple on Wood Valley Road. The agricultural water spur is also a buried 3,500 foot long, 5-inch diameter HDPE pipeline that extends southerly from the terminus of Center Street to Wood Valley Road.

The rural water pipeline is a buried 5,800 foot long, 2-inch diameter DIP extending southerly from the 20,000-gallon concrete tank to the terminus of Center Street. The line reduces to a 3,000 foot long, 1- to 1/2-inch diameter DIP from the terminus to the temple on Wood Valley Road. The 1-to 1/2-inch diameter spur extends 3,000 feet from the terminus to Wood Valley Road.

Installation Cost: The installation cost for this alternative, including engineering, administrative and land rights cost is approximately $4,300,000. Required land rights is estimated at 7 acres.

PAHALA SUBAREA

The **Pahala** subarea has a northeastern boundary from Kapaoo Point to the southwestern side of Wood Valley subarea. The southwestern boundary is from the Ka'u Forest Reserve to Nahuluhulu Point (along Enuhe Ridge and Na Puu Kulua) including the Punaluu Gulch watershed. The major agricultural activities are sugar cane, Macadamia nuts and ranching. The subarea consists of 47,250 acres and includes the town of Pahala.

TABLE 18 Land-use-Pahala Subarea

Land-use	Acres	Percent[6]
Rangeland	11,500	24.3
Pastureland	200	0.4
Sugar cane	7,600	16.1
Macadamia Nuts	4,800	10.2
Rural	350	0.7
Forest Reserve	17,500	37.1
Naturalized Vegetation	1,500	3.2
Other[7]	3,800	8.0
TOTAL	47,250	100.0

Alternatives

Future Without Project, FWOP:

Scenario 1: No major changes will take place in this subarea without the project. Current average water use is 4.0-Mgd.

[6]Source: USDA-Soil Conservation Service, Natural Resources Planning Staff, Honolulu, HI

[7]Forestland-non-reserve, Other nonagricultural use

TABLE 19 Agricultural Water Use Pahala Subarea--FWOP				
Agricultural Water Use Pahala Subarea--FWOP				
User	Use	Quantity	Units	Average Water Use (Mgd)
Kau Agribusiness	Macadamia	3,500	Acs	1.3
Kau Sugar	Sugar	6,000	Acs	2.7
	TOTAL	9,500		4.0

Future With Project, FWP:

Scenario 2: The acres of sugar cane land will be converted to Macadamia nuts where suitable. Average water use will be 2.2-Mgd.

TABLE 20 Agricultural Water Use Pahala Subarea--FWP Scenario 2				
User	Use	Quantity	Units	Average Water Use (Mgd)
Kau Agribusiness	Macadamia	5,500[8]	Acs	2.0
Kau Sugar	Sugar	0	Acs	0
Undefined	Range	4,000	Acs	0
	TOTAL	9,500		2.0

Scenario 3: The acres of sugar cane land will be converted to Macadamia nuts or biomass where suitable. Any remaining land will revert to naturalized vegetation. Average water use will be 2.33-Mgd.

[8] Includes existing 3,500 acres

TABLE 21 Agricultural Water Use Pahala Subarea--FWP Scenario 3				
User	Use	Quantity	Units	Average Water Use (Mgd)
Kau Agribusiness	Macadamia	5,500	Acs	2.0
Kau Sugar	Sugar	0	Acs	0
Undefined	Eucalyptus	2,000	Acs	0.05
Undefined	Range	2,000	Acs	0
	TOTAL	9,500		2.05

Alternatives for this subwatershed will provide agricultural water to Kau Agribusiness for their macadamia nut operations. Three alternatives were formulated to service the existing and proposed cropland areas. There are approximately 3,500 acres presently in macadamia nuts up to elevation 1,500 feet that is serviced by the Sisal and Palima wells. No water would be provided to the milling operation that is primarily supplied from the Pahala Shaft.

Scenario 1: This alternative would provide agricultural water to the existing 3,500 acres that Kau Agribusiness is presently irrigating from the Palima and Sisal wells. It would have the capacity to provide a peak demand of 9.0-Mgd. (Figure E-6)

Collection Element: The sources of water for this alternative are the Alili, Kaumaikeohu and 50 percent of the Noguchi No. 2 tunnels. New concrete collection boxes will be installed at all three sites (Alili - 2,900 feet elevation, Kaumaikeohu - 2,900 feet elevation, and Noguchi 2 - 3,400 feet elevation).

Either suspension or fixed pier supports will be provided at all major stream crossings to support the weight of the pipe and water. Pressure reducing and/or release valves will be provided to prevent damage to the pipe from excessive hydrostatic pressures. Anchor blocks will be provided at major grade changes.

Transmission Element: This element includes the installation of the following pipelines from the three sources to the proposed reservoir 6,000 feet long, 12-inch diameter HDPE (Alili Tunnel), 7,000 feet long, 10-inch diameter HDPE (Kaumaikeohu Tunnel), and 2,400 feet long, 8-inch diameter HDPE (Noguchi 2).

Storage Element: Storage will be provided by 400-Mgal HDPE lined reservoir at about elevation 2,750 feet west of Hionamoa Gulch. The reservoir will be referred to as the Pahala Reservoir.

Distribution Element: Improvements for this element include the installation of 18,000 feet of 24-inch diameter Polyvinyl Chloride (PVC) pipe from the Pahala Reservoir to the existing Kau Agribusiness macadamia nut irrigation system. This pipeline would have a capacity of 4,000-gpm.

Installation Cost: Installation cost of this alternative including engineering, administrative, and land rights cost is estimated at $75,100,000. Land rights requirements is about 23 acres.

Scenario 2: This alternative would provide water to 2,000 new acres of Macadamia nuts that are generally located between Puu Enuhe and Keaiwa Gulch and up to elevation 1,800 feet. It would have the capacity to provide a peak demand of 3.0-Mgd. (Figure E-7) This existing system will still service the 3,500 acres of exisint Macadamia nuts.

Collection Element: This element would involve the same improvements as Alternative P1.

Transmission Element: This element would involve the same improvements as Alternative P1.

Storage Element: Storage will be provided by a 200-Mgal HDPE lined Pahala Reservoir at the same location as the reservoir site for Alternative P2.

Distribution Element: This element includes the installation of 18,000 feet long, 10-inch diameter PVC and 10,000 feet long, 16-inch diameter (PVC). This element would extend southerly from the Pahala Reservoir down to the Kau Sugar field road along the 1,600 feet elevation, then easterly to Keaiwa Camp and westerly to the Middle Mouala Camp Site. The capacity of the pipeline is 2,200-gpm.

Installation Cost: Installation cost of this alternative including engineering, administrative, and land rights cost is approximately $41,600,000. Land rights requirements is about 24 acres.

Scenario 3: This alternative would provide agricultural water to the existing 3,500 Kau Agribusiness Macadamia nut and also for 2,000 additional new acres of Macadamia nuts specified in Alternative P2. It would have the capacity to provide a peak demand of 12-Mgd. (Figure E-8)

Collection Element: This element would involve the same improvements as in Alternative P1.

Transmission Element: This element would involve the same improvements as in Alternative P1.

Storage Element: Storage will be provided by a 800-Mgal HDPE lined Pahala Reservoir at the same location as the reservoir site for Alternative P2.

Distribution Element: This element includes the installation of 18,000 feet of 10-inch diameter PVC, 8,000 feet of 24-inch diameter PVC, and 1,000 feet of 30-inch diameter PVC. This element would extend southerly from the Pahala Reservoir down to the Kau Sugar field road along the 1,600 feet elevation, then easterly to Keaiwa Camp and westerly to the Middle Moaula Camp Site to service the new 2,000 acres of Macadamia nuts. The pipeline would also continue down to the connect with the existing Kau Agribusiness irrigation pipeline at about elevation 750 feet. The maximum capacity of the pipeline is 6,200-gpm.

Installation Cost: Installation cost for this alternative, including engineering, administrative, and land rights is approximately $93,100,000. Required land rights is estimated at 86 acres.

NAALEHU SUBAREA

The **Naalehu** subarea is bordered on the northeast by the Pahala subarea, on the northwest by the 5,400 foot elevation contour line and the southwest by a line connecting Paiahaa Bay and Ke A Pele o Iki. The agricultural activities are sugar cane and ranching. The subarea consists of 77,300 acres and includes the towns of Naalehu and Waiohinu.

TABLE 22 Land-use-Naalehu Subarea		
Land-use	Acres	Percent[9]
Rangeland	7,700	10.0
Pastureland	3,700	4.8
Sugar cane	7,900	10.2
Macadamia Nuts	200	0.2
Rural	1,600	2.1
Urban/Resort	500	0.6
Forest Reserve	32,300	41.8
Naturalized Vegetation	19,900	25.8
Other[10]	3,500	4.5
TOTAL	77,300	100.0

Alternatives

Future Without Project, FWOP: No major changes will take place in this subarea without the project. Current average water use is 2.8-Mgd for agricultural and stock water.

TABLE 23 Agricultural Water Use

Naalehu Subarea--FWOP

User	Use	Quantity	Units	Average Water Use (Mgd)
Kau Agribusiness	Macadamia	0	Acs	0
Kau Sugar	Sugar	6,500	Acs	2.7
Undefined	Range			
Kawaihae Ranch	Livestock	3,000	Hd	0.03
S&S Diary	Dairy	1,100	Hd	0.07
	TOTAL			2.8

Future With Project, FWP: Truck Crops

Scenario 2: The sugar cane land will be converted to 1,000 acres of Macadamia nuts and where suitable. Average water use will be 4.0-Mgd for agricultural and stock water.

[9]Source: USDA-Soil Conservation Service, Natural Resources Planning Staff, Honolulu, HI

[10]Citrus, Biomass, Forestland-non-reserve, Other nonagricultural use

TABLE 24 Agricultural Water Use Naalehu Subarea--FWP Scenario 2				
User	Use	Quantity	Units	Average Water Use (Mgd)
Kau Agribusiness	Macadamia	2,100	Acs	2.2
Kau Sugar	Sugar	0	Acs	0
Undefined	Truck Crop	1,000	Acs	1.7
Undefined	Range	4,400	Acs	0
Kawaihae Ranch	Livestock	3,000	Hd	0.03
S&S Diary	Dairy	1,100	Hd	0.07
	TOTAL			4.0

Alternatives for this subwatershed will provide agricultural water to the farmers and ranchers in the Naalehu and South Point area. Domestic water supply will be assumed to be furnished by the Department of Water Supply. Three alternatives were formulated for this subwatershed varying the level of crop demand with a constant stockwater demand for 5,800 head of cattle.

Alternative N1: This alternative would provide agricultural water to the approximately 1,000 acres of truck crops and citrus in the South Point area and Hilea. Also stockwater would be provided for 5,800-head of cattle at Kahuku Ranch, DALEICO RANCH in South Point and Kawaihae Ranch and S&S Dairy in the Naalehu area. The various elements will have the capacity to deliver 1,850-gpm at peak demand. (Figure E-9)

Collection Element: The sources of water for this alternative included the Hilea and Ninole streams. Low head concrete diversion structures would be installed at elevation 2,120 feet on Hilea Stream and at elevation 2,180 feet on Ninole Stream to divert water to the storage reservoir. These structures would divert water during the high flows to be stored in a reservoir. The structures would have to be armor plated on the bottom to prevent damage from rolling boulders and the inlets will be grated to prevent debris from getting to the reservoir.

Transmission Element: Water would be transported from the diversion structures on Hilea Stream to the storage reservoir by a 4,800 feet of buried 36-inch diameter PVC pipe. This pipe would have a capacity of 18-Mgd. A 8,300 feet buried 18-inch diameter PVC with a capacity of

3.9-Mgd would transport water from Ninole Stream to the reservoir

Storage Element: Storage would be provided for this alternative by a 80-Mgal reservoir in a depressional area between Puu Iki and Kaiholena at about elevation 1,800 feet. This reservoir will be referred to as the Hilea Reservoir. The reservoir will be lined with HDPE lining. A sediment basin must be installed to trap any debris that is transported from the diversion structures.

Distribution Element: Water would be transported from the reservoir to the service areas by varying sizes of PVC pipes. From the reservoir to Waiohinu the pipe sizes would range from 12,000 feet of 18-inch diameter, to 32,000 feet of 16-inch diameter PVC. The maximum capacity in this section is 1,850-gpm. From Waiohinu along Kamaoa Road to the South Point Road, the pipe would be 20,000 feet of 16-inch diameter PVC. The maximum capacity in this section is 750-gpm.

Pressure regulators and or release valves will installed to reduce hydrostatic pressure.

A 0.5-Mgal concrete tank would be installed at the intersection of South Point Road and Kamaoa Road (elevation 1,430 feet) to provide temporary agricultural water storage for the ranchers, DHHL homesteaders, and citrus operations along South Point Road. This should be an automatic regulating tank.

From this storage tank water would flow by gravity along South Point Road via a 14,000 feet long, 6-inch diameter HDPE and 14,000 feet long, 4-inch diameter HDPE pipeline to terminate at about elevation 600 feet. The maximum capacity of the pipeline is 250-gpm.

Water would be pumped up from the storage tank to service the citrus operations by a 4000 feet long, 10-inch diameter HDPE pipeline with a maximum capacity of 500-gpm. Two 60 HP pumps would need to be installed at the tank site to accomplish this, one pump would be operational while the other would used as a standby.

Installation Cost: The installation cost of this alternative including engineering, administrative, and land rights costs is approximately $42,600,000.

Scenario 3: The sugar cane land will be converted to 3,000 or 4,000 acres Macadamia nuts, Truck crops, or biomass where suitable. Any remaining land will revert to naturalized vegetation. Average water use will be 0.9-Mgd for agricultural and livestock water.

TABLE 25 Agricultural Water Use Naalehu Subarea--FWP Scenario 3				
User	Use	Quantity	Units	Average Water Use (Mgd)
Kau Agribusiness	Macadamia	2,100	Acs	2.2
Kau Sugar	Sugar	0	Acs	0
Undefined	Truck Crops	3,000	Acs	5.1
Undefined	Eucalyptus	2,100	Acs	0.05
Undefined	Range	2,300	Acs	0
Kawaihae Ranch	Livestock	3,000	Hd	0.03
S&S Diary	Dairy	1,100	Hd	0.07
	TOTAL			7.45

Alternative N2: This alternative would provide agricultural water to the approximately 3,000 acres of truck crops and citrus in the South Point area and Hilea. Also stockwater would be provided for 5,800 head of cattle at Kahuku Ranch, DALEICO RANCH in South Point and Kawaihae Ranch and S&S Dairy in the Naalehu area. The various elements will have the capacity to deliver 5,600-gpm at peak demand. (Figure E-10)

Collection Element: This element would involve the same improvements as in alternative N1.

Transmission Element: This element would involve the same improvement as in Alternative N1.

Storage Element: All improvements in this element are the same as in Alternative N1 except the Hilea Reservoir will have a capacity of 120-Mgal.

Distribution Element: Water would be transported from the reservoir to the service areas by varying sizes of PVC pipes. From the reservoir to Waiohinu the pipe sizes would range from 12,000 feet of 30-inch diameter, to 32,000 feet of 20-inch diameter PVC. The maximum capacity in this section is 5,600-gpm. From Waiohinu along Kamaoa Road to the South Point Road the pipe would be 20,000 feet of 18-inch diameter PVC. The maximum capacity in this section is 750-gpm.

Pressure regulators and or release valves will installed to reduce hydrostatic pressure.

All other parts of this element are the same as Alternative N1.

Installation Cost: Installation cost of this alternative including engineering, administrative, and land rights cost is approximately $51,100,000. Land rights requirement is about 31 acres.

Alternative N3: This alternative would provide agricultural water to the approximately 4,000 acres of truck crops, Macadamia nut, eucalyptus, and citrus in the South Point area and Hilea. Also stockwater would be provided for 5,800 head of cattle at Kahuku Ranch, DALEICO RANCH in South Point and Kawaihae Ranch and S&S Dairy in the Naalehu area. The various elements will have the capacity to deliver 7,400-gpm at peak demand. (Figure E-11)

Collection Element: This element would involve the same improvements as in alternative N1.

Transmission Element: This element would involve the same improvement as in Alternative N1.

Storage Element: All improvements in this element are the same as in Alternative N1 except the Hilea Reservoir will have a capacity of 450-Mgal.

Collection Element: This element would involve the same improvements as in alternative N1.

Transmission Element: This element would involve the same improvement as in Alternative N1.

Storage Element: All improvements in this element are the same as in Alternative N1 except the Hilea Reservoir will have a capacity of 120-Mgal.

Distribution Element: Water would be transported from the reservoir to the service areas by varying sizes of PVC pipes. From the reservoir to Waiohinu the pipe sizes would range from 12,000 feet of 36-inch diameter, to 32,000 feet of 24-inch diameter PVC. The maximum capacity in this section is 7,400-gpm. From Waiohinu along Kamaoa Road to the South Point Road the pipe would be 20,000 feet of 18-inch diameter PVC. The maximum capacity in this section is 750-gpm.

Pressure regulators and or release valves will installed to reduce hydrostatic pressure.

All other parts of this element are the same as Alternative N1.

Installation Cost: Installation cost of this alternative including engineering, administrative, and land rights cost is approximately $87,900,000. Land rights requirement is about 58 acres.

SOUTH POINT SUBAREA

The **South Point** subarea is bordered on the east by the Naalehu subarea, on the north by the Kahuku subarea, and on the west by the Manuka subarea. South Point, also known as Ka Lae, is the southernmost point in both the state and the United States. The subarea, 19,940 acres, consists of individual home sites and pastoral lots.

The State Department of Hawaiian Home Lands (DHHL) has awarded about 1,750 acres of agriculture/pasture lots in the South Point area to native Hawaiians. Water supply must be provided before the land can be occupied and made productive. The DLNR has drilled a well with a possible capacity of 36,000 to 180,000-Mgd for potable water or 140,000 to 430,000-Mgd for irrigation water. This variation is due to the undetermined safe pumping rate for the well. Tests during well construction failed to pinpoint a pumping level at which the chloride level stabilized. No distribution system has been installed yet.

TABLE 26 Land-use-South Point Subarea

Land-use	Acres	Percent[11]
Grazing land[12]	19,700	98.8
Other[13]	240	1.2
TOTAL	19,940	100.0

Alternatives

Future Without Project, FWOP: No major changes will take place in this subarea without the project. Average current water use is 2.7-Mgd for agricultural and livestock water.

[11] Source: USDA-Soil Conservation Service, Natural Resources Planning Staff, Honolulu, HI

[12] Grazing land includes rangeland, pastureland and naturalized vegetation.

[13] Citrus, Wind Farm

TABLE 27 Agricultural Water Use South Point--FWOP				
User	Use	Quantity	Units	Average Water Use (Mgd)
Morton Bassan	Citrus	150	Acs	2.7
Kahuku Ranch	Livestock	1,400	Hd	0.01
DALEICO RANCH	Livestock	1,400	Hd	0.01
Other	Various		Hd	0
	TOTAL			2.72

Future With Project, FWP:

Scenario 2: There is no sugar cane grown in this subarea. There will be no change in water usage.

Scenario 3: The rangeland will be improved by the addition of an agricultural water supply. Average water usage will be 5.6-Mgd for agricultural, livestock and domestic water supply.

TABLE 28 Agricultural and Domestic Water Use South Point--FWP Scenario 3				
User	Use	Quantity	Units	Average Water Use (Mgd)
Morton Bassan	Citrus	150	Acs	2.7
Kahuku Ranch	Livestock	1,400	Hd	0.01
DALEICO RANCH	Livestock	1,400	Hd	0.01
Other	Various		Hd	0
DHHL				
Ag Lots				
Dwelling	Rural	50	Homes	0.03
Agriculture	Various	100	Acs	0.4
Pastoral Lots				
Dwelling	Units	25	Homes	0.01
Agriculture	Various	625	Acs	2.5
	TOTAL			5.66

KAHUKU SUBAREA

The **Kahuku** subarea is bordered on the northeast by the Naalehu subarea, on the south by the South Point and Manuka subareas, on the east by the Manuka subarea and Ka'u SWCD boundary, and on the north by the 5,400 foot elevation contour line. The subarea is 74,800 acres and is mostly ranches.

TABLE 29 Land-use-Kahuku Subarea

Land-use	Acres	Percent[14]
Grazing land[15]	40,300	53.9
Forest Reserve	11,700	15.6
Rural	22,800	30.4
Recreational	2	<0.1
TOTAL	74,802	100.0

Alternatives

Future Without Project, FWOP: No major changes will take place in this subarea without the project. Average current water usage is 0.44-Mgd for domestic and livestock water. The domestic water is from catchments.

Scenario 2: There is no sugar cane grown in this subarea. There is no change in the water usage from Scenario 1.

TABLE 30 Agricultural and Domestic Water Use

Manuka & Kahuku-FWOP

User	Use	Quantity	Units	Average Water Use (Mgd)
HOVE (catch)	Rural	1,000	Homes	0.4[16]
Ranchos (catch)	Rural	60	Homes	0.02[17]
Kahuku Ranch	Livestock	1,400	Hd	0.01[18]
	TOTAL			0.44

[14]Source: USDA-Soil Conservation Service, Natural Resources Planning Staff, Honolulu, HI

[15]Grazing land includes rangeland, pastureland and naturalized vegetation.

[16]400 gpd per lot

[17]400 gpd per lot

[18]10 gpd per animal

Scenario 3: The rangeland will be improved by the addition of an agricultural water supply. Domestic water will increase to 0.85-Mgd without catchments and livestock water will remain the same as Alternative 1 (0.1-Mgd).

TABLE 31 Agricultural and Domestic Water Use

Manuka & Kahuku-FWP Scenario 3

User	Use	Quantity	Units	Average Water Use (Mgd)
HOVE	Rural	2,000	Homes	0.8[19]
Ranchos	Rural	120	Homes	0.05[20]
Kahuku Ranch	Livestock	1,400	Hd	0.01[21]
	TOTAL			0.86

MANUKA SUBAREA

The **Manuka** subarea is bordered on the east by the Kahuku and South Point Subareas. This boundary consists of a line proceeding north from the ocean along Pali O Kulani and Pali O Mamalu to Highway 11, west along Highway 11 to the northeastern and southeastern boundary of Hawaiian Ocean View Estates. The Ka'u SWCD boundary forms the northwestern and southern edges of this subarea. The subarea is 20,120 acres and is mostly individual home sites and light industrial.

TABLE 32 Land-use-Manuka Subarea

Land-use	Acres	Percent[22]
Rural	20	<0.1
Grazing land[23]	20,103	99.9
TOTAL	20,123	100.0

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[19] 400 gpd per lot

[20] 400 gpd per lot

[21] 10 gpd per animal

[22] Source: USDA-Soil Conservation Service, Natural Resources Planning Staff, Honolulu, HI

[23] Grazing land includes rangeland, pastureland and naturalized vegetation.

Alternatives

Future Without Project, FWOP: No major changes will take place in this subarea without the project. Current average water usage is 0.44-Mgd for domestic and livestock water. The domestic water is from catchments.

Future With Project, FWP:

Scenario 2: There is no sugar cane grown in this subarea. There will be no change from Scenario 1 for water usage.

Scenario 3: The subarea will be improved by the addition of an rural water supply. This water supply would benefit the home owners by providing another source of water for fire protection. Domestic water will increase 0.85-Mgd without catchments. Livestock usage will remain at 0.1-Mgd. A breakdown for this alternative is included in the tables for the Kahuka Subarea alternatives.

Alternatives for this subwatershed will provide rural water to the Hawaiian Ocean View Estates and the Hawaiian Ranchos subdivisions and stockwater to Kahuku Ranch in Kahuku. The first alternative will service the existing conditions and the second will service additional residences.

It is assumed that with the DWS going to groundwater sources that the Mt. House Tunnel and Haao Springs would become available for other uses and therefore could be used for rural water supply in the Manuka area.

Alternative M1: This alternative would provide rural water to the existing 1,060-residences in the Hawaiian Ocean View (1,000) and Hawaiian Ranchos (60) subdivision. It will also supply stockwater to approximately 1,400 head of cattle at Kahuku Ranch. The elements of this alternative will provide a maximum of 500-gpm. (Figure E-12)

Both alternatives only have temporary storage tanks with only a one day supply.

Collection Element: The sources of water for this alternative are the Mt. House Tunnel and Haao Springs. New concrete collection boxes will be installed at both sites (Mt. House - elevation 3,400 feet, Haao Springs - elevation 2,300 feet).

Transmission Element: The existing collection pipeline 12-inch diameter DIP from Mt. House to Haao Springs is fairly new and will not have to be replaced. However, the piping, fittings, and valves at Haao Springs will have to be redesigned and replaced.

Storage Element: A 25,000-gallon concrete tank would be installed at Haao Springs to provide temporary storage. This tank would also serve as a regulating storage tank for the variation in elevation for the two sources.

Distribution Element: Water would be transported from the 25,000-gallon concrete reservoir at Haao Springs to a 0.5-Mgal concrete tank at HOVE (elevation 2,000 feet) by 48,000 feet of 8-inch diameter DIP that generally follows Highway 11. A booster pump will be required at about elevation 1,800 feet along Highway 11 to get water to the 0.5-Mgal tank at HOVE. Residences of the Hawaiian Ranchos Kahuku Ranch could be serviced by gravity from this tank. However, pumping facilities must be provided at the 0.5-Mgal tank to pump water up to residences at or above elevation 5,000 feet.

Rural Water Treatment Element: A water treatment plant will be installed at the 0.5-Mgal tank that would have the capacity to treat 400-gpm. Operation of this plant will require the services of a certified operator and monitoring will also be required.

Installation Cost: Installation cost of this alternative including engineering, administrative, and land rights cost is estimate at $7,900,000. This does not include the cost of improvements to pump water up to HOVE residences at or above elevation 5,000 feet.

Alternative M2: This alternative would provide rural water to the existing 1,600 residences in the Hawaiian Ocean View (1,000) and Hawaiian Ranchos (60) subdivision. It will also supply stockwater to approximately 1,400 head of cattle of Kahuku Ranch. The elements of this alternative will provide a maximum of 700-gpm. (Figure E-13)

Both alternatives only have temporary storage tanks with only a one day supply.

Collection Element: This element would involve the same improvements as Alternative M1.

Transmission Element: This element would involve the same improvements as Alternative M1.

Storage Element: A 25,000-gallon concrete tank would be installed at Haao Springs to provide temporary storage. This tank would also serve as a regulating storage tank for the variation in elevation for the two sources.

Distribution Element: Water would be transported from the 25,000-gallon concrete reservoir at Haao Springs to a 1.0-Mgal concrete tank at HOVE (elevation 2,000 feet) by

48,000 feet of 8-inch diameter DIP that generally follows Highway 11. A booster pump will be required at about elevation 1,800 feet along Highway 11 to get water to the 1.0-Mgal tank at HOVE. Residences of the Hawaiian Ranchos Kahuku Ranch could be serviced by gravity from this tank. However, pumping facilities must be provided at the 1.0-Mgal tank to pump water up to residences at or above elevation 5,000 feet.

Rural Water Treatment Element: A water treatment plant will be installed at the 1.0-Mgal tank that would have the capacity to treat 700-gpm. Operation of this plant will require the services of a certified operator and monitoring will also be required.

Installation Cost: Installation cost of this alternative including engineering, administrative, and land rights cost is estimate at $12,900,000. This does not include the cost of improvements to pump water up to HOVE residences at or above elevation 5,000 feet.

SUMMARY

The purpose of this study was to identify and assess significant natural resource problems in the Ka'u study area. The scoping process identified five major concerns: Flooding, Agricultural Water Supply, Wind Erosion, Rural Water Supply, and Sheet and Rill Erosion. Concerns noted also included water quality, biodiversity, cultural resources, wetlands and potential loss of agricultural land.

Field investigation of flooding problems on the highways and roads identified inadequate bridge sizing. Residential flooding is the result of ineffective strom water and flood plain management. Solutions to these problems were deemed to be within the purview and capabilities of the County of Hawaii. There is no apparent need for major works of improvement such as flood water retarding structures or channel modifications.

It was determined during the study that critical erosion areas which were currently under cultivation are generally and adequately addressed under the mandates of the Food Security Act Conservation Provision. Agricultural activity, especially South Point , would necessitate measures for protection against wind erosion. Technical assistance for planning and implementing these measures is available from the Soil Conservation Service. Financial assistance may be available from the USDA's Agricultural Stabilizatin and Conservation Service (ASCS). Land designated as Highly Erodible Land (HEL) which was identified during the planning for the Food Security Act is for the most part being farmed with acceptable conservation measures, such as residue management. There are opportunities to go beyond the Food Security Act requirements with a Resource Management System. Technical assistance is available from SCS in planning and designing such a system. Achievement of this level of resource protection is often constrained by economics and uncertainty about future operations on the part of the farmers. Federal cost-sharing programs do not generally provide sufficient incentive because of annual caps to motivate land users to install comprehensive conservation measures. The study provides soils data which will be useful to decision makers in making crop selection and management choices.

Coarse sediment depositing in the stream channels after large flow events is the result of natural stream erosion. Debris basins upstream will capture this sediment before it is deposited in the areas of concern. However, this will not stop the cause of the problem.

Water supply presents a challenge to decision makers. The study presents some opportunities for collecting, storing, and transporting water. Being a scarce resource, decisions will need to be made about allocation of water between competing users. Through the Small Watershed Program, SCS can currently provide technical and financial assistance for the construction of agricultuaral water projects. This program requires sponsorship by a unit of state or local government, which has the capability to acquire land rights for installation of any works of improvement, as well as any necessary permits. In addition, a sponsor would be obligated to pay at least fifty percent (50%) of the construction costs, and operate and maintain the project once construction is complete.

Information presented on cultural resources and biodiversity is intended to underscore the importance of invoking a logistic, decision-making paradigm.

The sustainability and viability of Ka'u's future will be determined by prudent use of the area's natural resources. This study was carried out to provide information which would be useful togovernment officials, business and community leaders, and others. Decisions must be made with an appreciation of the interconnectedness of human activities and the natural environment.

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APPENDIX A

WATER TUNNELS AND WELLS IN THE KA'U AREA

TABLE A-1 Water Development Tunnels in the Ka'u Area[A1]

No.[A2]	Owner	Name or Location	Approx. Altitude (feet)	Approx. Length (feet)	Yield (gpd)	Geologic Structure and Perching Formation
65	Hawaiian Agricultural Co.	Makakupu (13)[A3][1729-02]	3,700	5,798	505,000	Kahuku lava on 6+- feet of Pahala Ash
A66	do.	---[1729-01]	3,600	---	---	Kahuku lava on ash bed
A67	do.	Mauka of Ranch(18)[1730-03]	4,300	98	0[A4]	do.
A68	do.	Weda 2 (9) [1730-02]	3,750	198	---	do.
A69	do.	Weda 1 (8) [1630-01]	3,700	344	---	do.
A70	do.	Weda (7) [1630-02]	3,600	1,627	149,000	do.
A71	do.	Weda 3 (10) 1630-10]	3,400	599	90,000	do.
A72	do.	Helo (5) [1630-03]	3,600	1,799	214,000	do.
A73	do.	Fault (6) [1630-04]	3,500	138	0[A5]	do.
74	do.	Noguchi mauka (4) [1630-09]	3,600	1,128	86,000	Ninole lava on ash bed
75	do.	Noguchi 2 (19) [1630-05]	3,450	2,480	236,000	do.
A76	do.	Noguchi 1 [1629-01]	3,400	---	689,000	do.
A77	do.	--- [1630-06]	4,150	---	---	Kahuku lava on ash bed
A78	do.	--- [1630-07]	3,900	---	---	do.
A79	do.	Double Arch (11) [1530-01]	3,700	1,479	595,000	do.
A80	do.	Mudflow (Clark) (2) [1630-08]	3,500	2,611	444,000	do.
A81	do.	Mudflow 3 (3) [1530-02]	3,500	333	---	do.
A82	do.	--- [1530-03]	3,400	---	---	do.
A83	do.	--- [1530-04]	3,250	---	---	do.
A84	do.	Ipuu Ridge (14) [1529-01]	2,600	435	---	Ninole lava on ash bed
85	do.	Alili (15) [1331-01]	2,900	3,839	713,000	Kau lava on Pahala Ash
A86	do.	Shirakura (20) [1333-04]	3,700	1,750	297,000	Kahuku lava on ash bed

A1 Source: Stearns, HT and MacDonald, GA, 1946, Geology and Water resources of the Island of Hawaii, HI Div Hydrography Bull. 9, p299-301.
A2 An "A" indicates that the tunnel was abandoned prior to the Ka'u Water Study by D. Carpenter (1983)
A3 Numbers in parenthesis are owners numbers. Numbers in brackets are DLNR-DWRM ID numbers.
A4 Abandoned
A5 Ibidem

TABLE A-1 Water Development Tunnels in the Ka'u Area (continued)[A6]

No.	Owner	Name or Location	Approx. Altitude (feet)	Approx. Length (feet)	Yield (gpd)	Geologic Structure and Perching Formation
A87	do.	Moaula Gulch (17) [1333-01]	3,500	1,716	247,000	do.
A88	do.	--- [1333.02]	3,100	---	---	Kau lava on 20+- feet of Pahala Ash
A89	do.	Fukuda (12) [1333-03]	3,000	1,844	203,000	Kau lava on 18+- feet of Pahala Ash
A90	do.	Kaumaikeohu (1) [1332-01]	2,900	2,093	210,000	Ninole lava on ash bed
91	do.	Domestic Supply (16) [1232-01]	2,750	2,574	345,000	do.
A92	do.	Horita [1730-01]	4,150	1,500	29,000[A7]	Kahuku lava on ash bed
A93	Hutchinson Sugar Plantation Co.	Plantation Spring	3,650	3,097	199,000	Ninole lava on ash bed
A94	do.	Vischer [1035-01]	2,150	---	0	None[A8]
95	do.	New Mountain House [0936-01]	3,400	7,048	1,175,000	Kahuku lava and talus on ash
A96	do.	Old Mountain House [0836-01]	3,070	---	---	Kahuku lava on ash bed
A97	do.	Kahilipali [0536-01]	2,250	359	279,000[A9]	do.
98	do.	Kapuna [1136-01]	1,900	---	---	do.
99	do.	Makanau 1	1,750	---	---	Ninole lava on ash bed
100	do.	Makanau 2 [0933-01]	1,500	---	---	do.
101	do.	Hano [0537-01]	2,300	---	25,000[A10]	Early Kau porphyritic olivine basalt overlying 6 feet of red vitric ash
A102	do.	Tanaka [0436-02]	2,100	715	1,000[A11]	Kahuku lava on ash bed

[A6]Source: Stearns, HT and MacDonald, GA, 1946, Geology and Water resources of the Island of Hawaii, HI Div Hydrography Bull. 9, p299-301.
[A7]Low water yield in 1931.
[A8]Driven in Kau basalt by a Mr. Vischer, the site determined with a "doodle bug."
[A9]Average combined discharge of tunnels 97 & 102 during 1924 was 279,700 daily
[A10]Estimated flow on December 2, 1939. Tunnel dug prior to 1920. The basalt is either early Kau or late Kahuku lava.
[A11]Reported to go dry a month after rains cease. Six to eight feet of transported soil overlying the aquifer; hence, the basalt is either late Kahuku or early Kau lava. Average combined discharge of tunnels 97 & 102 during 1924 was 279,700 daily

TABLE A-2 Drilled Water Wells in the Ka'u Area as of 1991[A12]

Map ID	DLNR-DWRM ID Number	User	Date Completed	Depth (ft)	Avg. Pumpage (Mgd)
A	0139-01	State DOWRM	1990	1,325	--.-
B	0246-01	Hawaii Kau Rch	----	1,095	--.-
C	0335-01	Hawaii DWS	1971	896	0.54
D	0533-01	Kau Sugar	1946	34	--.-
E	0533-02	Kau Sugar	1965	132	1.64
F	0533-03	Kau Sugar	1965	125	1.66
G	0632-01	Kau Sugar	1965	140	1.66
H	0830-01	Hawaiiana Inv	1972	24	2.16
I	0830-02	C Brewer	1971	172	--.-
J	0831-01	Hawaiiana Inv	1968	174	--.-
K	0831-02	Hawaiiana Inv	1971	172	2.16
L	0831-03	C. Brewer	1971	172	--.--
M	1032-01	Kau Sugar	1969	941	--.--
N	1033-01	Kau Sugar	1969	877	--.--
O	1033-02	Kau Sugar	1968	859	--.--
P	1128-02	Hawn Ranch	1970	375	--.--
Q	1129-01	Brewer Orchard	1974	820	--.--
R	1229-01	Hawaii DWS	1930	2,900	0.48
S	8540-01	US Army	1941	64	--.--
T	8741-01	----	1967	----	--.--
U	8836-01	C. Brewer	1966	----	--.--
V	8837-01	C. Brewer	1966	----	--.--

[A12] Source: DLNR Div of Water Resource Management 4/92

APPENDIX B

CONSERVATION PRACTICES

Conservation Practices: The Food Security Act of 1990 (FSA) requires that a conservation plan be developed and implemented for any piece of land or owner that receives payments from the U. S. Department of Agriculture (USDA) for commodity crops. In the Ka'u area the commodity crops are coffee, sugar, honey, milk and cattle.

Several different conservation practices in various combinations are currently incorporated into conservation plans developed by various land owners in the study area. The former Pahala Field Office and the Hilo Field Office of the USDA Soil Conservation Service have assisted land owners in developing their conservation plans. These plans vary for each owner, crop and resource area. Table B-1 shows various practices used by the land owners in the area for each crop.

TABLE B-1 SCS Conservation Practices By Crop	
Crop	**Practice**
Sugar Cane	
	Cross-slope planting
	Crop Residue Management
	Precision Tillage
	Scheduled harvesting
	Grassed Waterways
	Diversions
	Volunteer Ground Cover
	Sediment Debris Basins
Macadamia Nuts	
	Ground cover for younger orchards
	Cross slope planting
	Wind Breaks
	Terraces with diversions
	Grassed Waterways
	Sediment Control Basins
	Drip irrigation for younger orchards
	Star sprinklers for older orchards
Non-irrigated Pasture	
	Grassed Waterways
	Diversions
	Brush Management
	Windbreaks
	Water distribution systems
	Grazing management w/electric fencing
	Improved pasture planting
Dairy	
	Pasture improvement
	Brush control
	Grazing management
	Sewage lagoon
Rangeland	
	Water distribution system
Citrus	
	Windbreaks Ground cover
	Irrigation system
Truck crops	
	Cross slope planting
	Terraces
	Ground cover
	Wind breaks
	Contour strip cropping
	Crop rotation

TABLE B-2 Acres of Land Treated with Conservation Practice(s) thru 1992		
Land-use	Treated[1] acres	Percent
Cropland	21,500	67.0
Grazingland	14,600	8.9
Woodland	10	
Wildlife Land	2,580	
Other	2,580	
TOTAL	41,260	13.9

These practices are used to prevent soil from being removed from its original location or to conserve water.

TABLE B-3 Tons of Soil Saved with Conservation Practice(s) FY1988-FY1992	
Land-use	Tons Saved[2]
Cropland	270,090
Farm Bill Related(FY92)	80,200
Grazingland	67,990
Woodland	0
Wildlife Land	0
Other	0
TOTAL	418,280 tons

The primary conservation measures applied by the Hilo Field Office in the Ka'u Watershed are described below. All are included in SCS National Handbook of Conservation Practices and the Hilo Field Office Field Office Technical Guide Section IV. The numerals in parenthesis is the SCS Practice Code. Each conservation practice has an associated Standard which includes Definition, Scope, Purpose, Conditions where Practice Applies, and Design Criteria.
Each practice also has associated Specifications covering materials and installation of the practice.

[1] Source: USDA-Soil Conservation Service-FSA Reports

[2] Source: USDA-Soil Conservation Service-FSA Reports

Waste Management System (312)

A planned system in which all necessary components are installed for managing liquid and solid waste, including runoff from concentrated waste areas in a manner that does not degrade air, soil, or water resources. Its purpose is to manage waste in rural areas in a manner that prevents or minimizes degradation of air, soil, and water resources protects public health and safety. Such systems are planned to preclude discharge of pollutants to surface or ground water and to recycle waste through soil and plants to the fullest extent possible.

Brush Management (314)

Managing and manipulating stands of brush on rangeland, pastureland, and recreation and wildlife areas by mechanical, chemical or biological means or by prescribed burning. Its purpose is to improve or restore a quality plant cover to (1) reduce sediment and improve water quality, (2) increase quality and production of desirable plants for livestock and wildlife, (3) maintain or increase wildlife habitat values, (4) enhance esthetic and recreation qualities, (5) maintain open land, and (6) protect life and property.

Chiseling and Subsoiling (324)

To improve water and root penetration and aeration by loosening the soil, without inverting and with a minimum of mixing of the surface soil, to shatter restrictive layers below normal plow depth that inhibit water movement or root development.

Conservation Cover (327)

To reduce soil erosion and sedimentation, improve water quality, and create or enhance wildlife habitat by establishing and maintaining perennial vegetative cover to protect soil and water resources on land retired from agricultural production.

Conservation Cropping Sequence (328)

Conservation cropping sequence is an adapted sequence of crops designed to provide adequate organic residue for maintenance or improvement of soil tilth. The purpose is to improve or maintain good physical, chemical, and biological conditions of the soil; help reduce erosion; improve water use efficiency and water quality; improve wildlife habitat; or break reproduction cycles of plant pests.

Conservation Tillage (329)

Conservation tillage is any tillage and planting system in which at least 30 percent of the soil surface is covered by plant residue after planting to reduce soil erosion by water; or, where soil erosion by wind is the primary concern, at least 1,000 pounds per-acre of flat small grain residue-equivalent are on the surface during the critical erosion period. Its purpose is to reduce soil erosion; help maintain or develop good soil tilth, efficient moisture use, and water quality; and provide food and cover for wildlife.

Contour Farming (330)

To reduce erosion and control water by farming sloping land in such a way that preparing land, planting and cultivating are done on the contour. (This includes following established grades of terraces and diversions.)

Cover and Green Manure Crop (340)

Cover and green manure crop is a crop of close-growing grasses legumes, or small grain grown primarily for seasonal protection and soil improvement. It usually is grown for one year or less, except where there is permanent cover as in orchards. The purpose is to control erosion during periods when the major crops do not furnish adequate cover; add organic material to the soil; and improve infiltration, aeration, and tilth.

Crop Residue Use (344)

Crop residue use features the use of plant residues to protect cultivated fields during critical erosion periods. Its purpose is to conserve soil moisture, increase soil infiltration, reduce soil loss, and improve soil tilth.

Sediment Basin (350)

A basin constructed to collect and store debris or sediment. Its purpose is to preserve the capacity of reservoirs, ditches, canals, diversions, waterways and streams; to prevent undesirable deposition on bottom lands and developed areas; to trap sediment originating from construction sites; and to reduce or abate pollution by providing basins for deposition and storage of silt, sand, gravel, stone, agricultural wastes, and other detritus.

Diversion (362)

A diversion is a channel constructed across the slope with a supporting ridge on the lower side to divert water from areas to sites where it can be used or disposed of safely.

Field Windbreak (392)

Field windbreak is a strip or belt of trees or shrubs established in or adjacent to a field to reduce soil erosion; conserve moisture; protect crops, orchards, livestock, and wildfire; or increase the natural beauty of an area.

Filter Strip (393) (draft)

A filter strip is a strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff and wastewater.

Grassed Waterway or Outlet (412)

A grassed waterway is a natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff. The purpose is to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding and to improve water quality.

Hillside Ditch (423)

A hillside ditch is a channel that has a supporting ridge on the lower side constructed across the slope at definite vertical intervals and gradient, with or without a vegetative barrier. The purpose is to control the flow of water in sloping areas by diverting runoff water to a protected outlet, thus minimizing erosion and runoff.

Irrigation System, Drip (441)

To efficiently apply irrigation water directly to the plant root zone to maintain soil moisture within the range for good plant growth without excessive water loss, erosion, reduction in water quality or salt accumulation. This is a planned irrigation system in which water applicators (orifices, emitters, porous tubing, perforated pipe) operate efficiently under low pressure. The applicators can be placed on or below the surface of the ground.

Irrigation System, Sprinkler (442)

A planned irrigation system in which all necessary facilities are installed for efficiently applying water by means of perforated pipes or nozzles operated under pressure. Its purpose is to efficiently and uniformly apply irrigation water to maintain adequate soil moisture for optimum plant growth without causing excessive water loss, erosion, or reduced water quality.

Irrigation Water Management (449)

To effectively use available irrigation water supply in managing and controlling the moisture environment of crops to promote the desired crop response; to minimize soil erosion and loss of plant nutrients; to control undesirable water loss; and to protect water quality. This is accomplished by determining and controlling the rate, amount and timing of irrigation water in a planned and efficient manner.

Mulching (484)

Mulching is applying plant residues or other suitable materials to the soil surface to conserve moisture; prevent surface compaction or crusting; reduce runoff and erosion; and help establish plant cover.

Pasture and Hayland Management (510)

Proper treatment and use of pastureland or hayland to prolong the life of desirable forage species, to maintain or improve the quality and quantity of forage, and to protect the soil and reduce water loss.

Grazing Land Mechanical Treatment (548)

Renovating, contour furrowing, pitting, or chiseling native grazing land by mechanical means to improve plant cover and water quality by aerating the soil, increasing insoak and available moisture, reducing erosion, and protecting low lying land or structures from siltation.

Terrace (600)

Terraces consist of an earth embankment, a channel or a combination ridge and channel constructed across the slope. Terraces are constructed to (1) reduce slope length, (2) reduce erosion, (3) reduce sediment content in runoff water, (4) intercept and conduct surface runoff at nonerosive velocity to a stable outlet, (5) retain runoff for moisture conservation, (6) prevent gully development , (7) reform the land surface, (8) improve farmability, (9) reduce flooding, or (10) improve water quality.

APPENDIX C

SOIL-ACREAGE BY SUBAREA

TABLE C-1 Acres of Soil in Subarea Kapapala

Soil Symbol	Acres	Percent
AFD	14	<0.1
HCD	675	1.2
HDP	1,148	2.1
KBC	4	<0.1
KLC	1,075	1.9
KMD	1,813	3.3
MoD	26	<0.1
MoE	137	0.2
NaD	33	0.1
PKB	43	0.1
PTC	181	0.3
RB	917	1.7
WAC	85	0.2
WAD	12	<0.1
rCL	10	<0.1
rHP	6,567	11.8
rKAD	3,898	7.0
rKHD	18,567	33.4
rKUC	875	1.6
rKXD	2,651	4.8
rKVD	83	0.1
rLV	1,665	3.0
rLW	9,482	17.1
rMWD	613	1.1
rPYD	2,485	4.5
rRO	247	0.5
rVS	198	0.4
	------	---.-
TOTAL	55,519	100.0

TABLE C-2 Acres of Soil in Subarea Wood Valley

Soil Symbol	Acres	Percent
ASD	1	<0.2
AlD	55	1.1
AlE	179	3.5
ApD	55	1.1
HlC	59	1.2
KLC	12	0.2
KLD	24	0.5
KMD	8	0.2
MoD	176	3.5
NaC	185	3.6
PTC	124	2.4
RB	638	12.5
rHP	2,290	45.0
rKAD	181	3.6
rKFD	8	0.2
rKXD	234	4.6
rKYD	118	2.3
rPYD	118	4.6
MoC	601	11.8
	------	---.-
TOTAL	5,086	100.0

TABLE C-3 Acres of Soil in Subarea Naalehu

Soil Symbol	Acres	Percent
AlC	1,793	2.3
AlD	458	0.6
AlE	178	0.2
ApD	1,431	1.9
HlC	1,020	1.3
KBC	346	0.5
KJC	4	<0.1
KKC	1	<0.1
MoD	566	0.7
MoE	750	1.0
NaC	703	0.9
NaD	716	0.9
NaE	806	1.1
NhD	1,340	1.7
PKB	496	0.6
PSC	280	0.4
RB	2,505	3.3
WAC	29	<0.1
WKD	54	0.1
rHP	20,986	27.4
rKAD	754	1.0
rKED	1,066	1.4
rKFD	21	<0.1
rKGD	1,099	1.4
rKXD	6,893	9.0
rKYD	4,398	5.7
rLLD	854	1.1
rLV	6,274	8.2
rLW	6,498	8.5
rPXE	2,174	2.8
rPYD	7,427	9.7
rRO	3,098	4.0
rVS	512	0.7
	------	---.-
TOTAL	76,701	100.0

TABLE C-4 Acres of Soil in Subarea Southpoint

Soil Symbol	Acres	Percent
KBC	4,256	22.1
KIC	855	4.4
KJC	1,237	6.4
KKC	357	1.9
PKB	6,160	32.0
RB	238	1.2
rKED	1,019	5.3
rKYD	179	0.9
rLV	2,230	11.6
rLW	2	<0.1
rPXE	163	0.9
rPYD	385	2.0
rRO	865	4.6
rVS	1,296	6.7
	------	---.-
TOTAL	19,242	100.0

TABLE C-5 Acres of Soil in Subarea Manuka

Soil Symbol	Acres	Percent
KIC	117	0.2
KJC	14	<0.1
PKB	15	<0.1
RB	417	0.6
rCL	614	0.8
rKYD	637	0.9
rLV	54,769	74.0
rLW	11,892	16.1
rMWD	40	0.1
rPXE	4,549	6.1
rRO	596	0.8
rVS	328	0.4
	------	---.-
TOTAL	73,988	100.0

TABLE C-6 Acres of Soil in Subarea Pahala

Soil Symbol	Acres	Percent
AlC	419	0.9
AlD	1,401	3.0
AlE	684	1.4
ApD	711	1.5
FL	508	1.1
HlC	882	1.8
MoD	1,691	3.6
MoE	527	1.1
NaC	1,202	2.
NaD	1,143	2.
PSC	74	0.
PTC	282	0.
RB	1,353	2.
WAC	1,352	2.
WAD	1,120	2.4
WKD	880	1.9
rCL	24	0.1
rHP	16,457	34.7
rKAD	467	1.0
rKED	41	0.1
rKXD	889	1.9
rKYD	313	0.7
rLLD	1,126	2.4
rLV	2,419	5.1
rLW	6,530	13.8
rPXE	465	1.0
rPY	2,751	5.8
rVS	41	0.1
W	3	<0.1
MoC	828	1.
	------	---.-
TOTAL	47,425	100.0

TABLE C-7 Acres of Soil in Subarea Kahuku

Soil Symbol	Acres	Percent
ApD	880	4.1
HCD	603	2.8
HIC	107	0.5
KIC	208	1.0
KJC	344	1.6
KKC	69	0.3
PND	286	1.3
PSC	78	0.4
RB	38	0.2
rCL	643	3.0
rHP	369	1.7
rKED	71	0.3
rKHD	1,008	4.6
rKXD	2,545	11.7
rKYD	1,399	6.4
rLLD	319	1.5
rLV	8,378	38.6
rLW	1,574	7.3
rMWD	899	4.1
rPXE	1,109	5.1
rRO	151	0.
rVS	603	2.8
TOTAL	21,681	100.0

AFD APAKUIE VERY FINE SANDY LOAM, 12 TO 20 PERCENT SLOPES: This deep, well-drained soil occurs on moderately steep uplands. It formed in volcanic ash, sand, and cinders. The soil reaction is neutral throughout the profile. Included in mapping are small areas where considerable soil blowing has occurred and the vegetation is sparse. Small stony areas are also included. Permeability is rapid, and runoff is slow. The hazard of soil blowing is moderate.

ASD APAKUIE VERY STONY VERY FINE SANDY LOAM, 12 TO 20 PERCENT SLOPES: This deep, well-drained soil occurs on moderately steep uplands. It formed in volcanic ash, sand, and cinders. The soil reaction is neutral throughout the profile. Included in mapping are small areas where considerable soil blowing has occurred and the vegetation is sparse. Loose stones occupy about 3 percent of the surface. Permeability is rapid, and runoff is slow. The hazard of soil blowing is moderate.

AlC ALAPAI SILTY CLAY LOAM, 0 TO 10 PERCENT SLOPES: This deep, well-drained soil occurs on nearly level to moderately sloping uplands. It formed in volcanic ash. The surface layer is very strongly acid, and the subsoil is slightly acid to neutral. It is extremely stony in places. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

AlD ALAPAI SILTY CLAY LOAM, 10 TO 20 PERCENT SLOPES: This deep, well-drained soil occurs on moderately sloping to moderately steep uplands. It formed in volcanic ash. The surface layer is very strongly acid, and the subsoil is slightly acid to neutral. It is extremely stony in places. Permeability is rapid, runoff is medium, and the erosion hazard is moderate.

AlE ALAPAI SILTY CLAY LOAM, 20 TO 35 PERCENT SLOPES: This deep, well-drained soil occurs on steep uplands. It formed in volcanic ash. The surface layer is very strongly acid, and the subsoil is slightly acid to neutral. It is extremely stony in places. In many places the surface layer and part of the subsoil have been removed as a result of plowing and water erosion. Permeability is rapid, runoff is medium, and the erosion hazard is severe.

ApD ALAPAI EXTREMELY STONY SILTY CLAY LOAM, 10 TO 20 PERCENT SLOPES: This deep, well-drained soil occurs on moderately sloping moderately steep uplands. It formed in volcanic ash. The surface layer is very strongly acid, and the subsoil is slightly acid to neutral. This soil is 20 to 30 inches deep over aa lava. Stones cover 3 to 15 percent of the surface. There are small areas of soil less than 20 inches deep over aa or pahoehoe lava.

These inclusions occupy less than 10 percent of this unit. Permeability is rapid, runoff is medium, and the erosion hazard is moderate.

FL FILL LAND: This land type consists of areas filled with bagasse and soil from sugarcane mill wash and alluvium from floodwaters. This soil is deep and well drained. Slope is 0 to 6 percent. Permeability is moderate, runoff is medium, and the erosion hazard is slight.

HCD HANIPOE VERY STONY LOAM, 12 TO 20 PERCENT SLOPES: This deep, well-drained soil occurs on moderately steep uplands. It formed in volcanic ash. The surface layer is slightly acid; the subsoil is neutral. The soil is very stony and fragmental aa lava occurs at depths of 20 to 30 inches. This soil is very rocky in places. Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

HDD HANIPOE SILT LOAM, 12 TO 20 PERCENT SLOPES: This deep, well drained soil occurs on moderately steep uplands. It formed in volcanic ash. The surface layer is slightly acid; the subsoil is neutral. Permeability is moderately rapid, runoff is medium, and the erosion hazard is moderate.

HFD HANIPOE VERY ROCKY SILT LOAM, 6 TO 20 PERCENT SLOPES: This moderately deep, well drained soil occurs on moderately sloping to moderately steep uplands. It formed in volcanic ash. The surface layer is slightly acid; the subsoil is neutral. Permeability is moderately rapid, runoff is medium, and the erosion hazard is moderate.

HHC HEAKE VERY ROCKY SANDY LOAM, 6 TO 12 PERCENT SLOPES: This shallow, well-drained soil occurs on moderately sloping uplands. It formed in recent volcanic ash and pumice. The upper part of the surface layer is medium acid. The rest of the profile is neutral. Permeability is rapid, runoff is medium, and the erosion hazard is moderate.

HKC HEAKE EXTREMELY ROCKY SANDY LOAM, 0 TO 10 PERCENT SLOPES: This shallow, well-drained soil occurs on nearly level to moderately sloping uplands. It formed in recent volcanic ash and pumice. The upper part of the surface layer is medium acid. The rest of the profile is neutral. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

HlC HILEA SILTY CLAY LOAM, 6 TO 12 PERCENT SLOPES: This shallow, well-drained soil occurs on moderately steep uplands. It formed in volcanic ash. The surface layer is very strongly acid, and the subsoil is strongly acid.

Permeability is rapid, runoff is medium, and the erosion hazard is slight.

KIC KAMAOA LOAM, 6 TO 12 PERCENT SLOPES: This deep, well-drained soil occurs on moderately sloping uplands. It formed in volcanic ash. The soil is medium acid in the surface layer, and neutral in the subsoil. The surface is extremely stony in places. Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

KJC KAMAOA LOAM, MODERATELY SHALLOW, 6 TO 12 PERCENT SLOPES: This deep, well-drained soil occurs on moderately sloping uplands. It formed in volcanic ash. The surface layer is medium acid, and the subsoil is neutral. The surface is extremely stony in places. The depth to bedrock ranges from 20 to 30 inches. There are small areas of soils less than 20 inches deep over bedrock. Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

KKC KAMAOA EXTREMELY STONY LOAM, 6 TO 12 PERCENT SLOPES: This deep, well-drained soil occurs on moderately sloping uplands. It formed in volcanic ash. The surface layer is medium acid, and the subsoil is neutral. Stones occupy 3 to 15 percent of the surface. Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

KLC KAPAPALA LOAM, 0 TO 10 PERCENT SLOPES: This deep, well-drained soil occurs on nearly level to moderately sloping uplands. It formed in recent volcanic ash. Below the surface layer are banded layers of very dark grayish-brown and dark-brown soil ranging from loam to fine sand. The surface layer is slightly acid, and the subsoil is mildly alkaline to neutral. Soil is only 20 to 36 inches deep over bedrock. Permeability is moderately rapid, runoff is slow and the erosion hazard is slight.

KLD KAPAPALA LOAM, 10 TO 20 PERCENT SLOPES: This deep, well-drained soil occurs on moderately sloping to moderately steep uplands. It formed in recent volcanic ash. Pahoehoe lava is at a depth of about 48 inches. The surface layer is slightly acid, and the subsoil is mildly alkaline to neutral. Permeability is moderately rapid, runoff is medium and the erosion hazard is moderate.

KMD KAPAPALA VERY ROCKY LOAM, 6 TO 20 PERCENT SLOPES: This moderately deep, well-drained soil occurs on gently sloping to moderately steep uplands. It formed in recent volcanic ash. The surface layer is slightly acid, and the subsoil is mildly alkaline to neutral. The soil is 20 to 30 inches deep over bedrock. Rock outcrops and stones occupy 10 to 25 percent of the surface of this soil. Permeability is moderately rapid, runoff is slow and the erosion hazard is slight.

MND MANAHAA EXTREMELY STONY SILT LOAM, 6 TO 20 PERCENT SLOPES: This well-drained soil occurs on moderately sloping to moderately steep uplands. It formed in volcanic ash and is moderately deep to pahoehoe lava bedrock. The soil is slightly acid throughout the profile. Stones cover 3 to 15 percent of the surface layer. Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

MoC MOAULA SILTY CLAY LOAM, 0 TO 10 PERCENT SLOPES: This very deep, well-drained soil occurs on gently sloping to moderately sloping uplands. It formed in volcanic ash. Depth to bedrock is more than 5 feet. The soil is strongly acid in the surface layer and slightly acid to neutral in the subsoil. Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

MoD MOAULA SILTY CLAY LOAM, 10 TO 20 PERCENT SLOPES: This very deep, well-drained soil occurs on moderately steep uplands. It formed in volcanic ash. Depth to bedrock is more than 5 feet. The soil is strongly acid in the surface layer and slightly acid to neutral in the subsoil. Permeability is moderately rapid, runoff is medium, and the erosion hazard is severe.

MoE MOAULA SILTY CLAY LOAM, 20 TO 35 PERCENT SLOPES: This very deep, well-drained soil occurs on steep uplands. It formed in volcanic ash. Depth to bedrock is more than 5 feet. The soil is strongly acid in the surface layer and is slightly acid to neutral in the subsoil. Permeability is moderately rapid, runoff is medium the erosion hazard is severe.

NaC NAALEHU SILTY CLAY LOAM, 0 TO 10 PERCENT SLOPES: This very deep, well-drained silty clay loam soil occurs on nearly level to moderately sloping uplands. It formed in volcanic ash. The soil grades from slightly acid in the surface layer to neutral in the subsoil. Permeability is moderately rapid, runoff is slow and the erosion hazard is slight.

NaD NAALEHU SILTY CLAY LOAM, 10 TO 20 PERCENT SLOPES: This very deep, well-drained soil occurs on moderately sloping to moderately steep uplands. It formed in volcanic ash. The surface layer is slightly acid, and the subsoil is neutral. Permeability is moderately rapid, runoff is medium and the erosion hazard is moderate.

NaE NAALEHU SILTY CLAY LOAM, 20 TO 35 PERCENT SLOPES: This deep, well-drained soil occurs on steep uplands. It formed in volcanic ash. The surface layer is slightly acid, and the subsoil is neutral. Permeability is moderately rapid, runoff is medium and the erosion hazard is severe.

NhD NAALEHU VERY ROCKY SILTY CLAY LOAM, 6 TO 20 PERCENT SLOPES: This well-drained soil occurs on moderately sloping to moderately steep uplands. It formed in volcanic ash. The soil is moderately deep, 20 to 36 inches to bedrock. Rock outcrops occupy 5 to 15 percent of the surface area. The soil grades from slightly acid in the surface layer to neutral in the subsoil. Included are small areas where the soil is less than 20 inches deep over bedrock. Permeability is moderately rapid, runoff is slow to medium and the erosion hazard is slight to moderate.

PKB PAKINI VERY FINE SANDY LOAM, 2 TO 6 PERCENT SLOPES: This deep, well-drained soil occurs on gently sloping uplands. It formed in volcanic ash. The surface layer is neutral, and the subsoil is mildly alkaline. Permeability is rapid, runoff is slow, and the hazard of soil blowing is moderate.

PND PIIHONUA SILTY CLAY LOAM, 6 TO 20 PERCENT SLOPES: This deep, well-drained soil occurs on moderately sloping to moderately steep uplands. It formed in volcanic ash. A weakly cemented layer of volcanic ash occurs at a depth of 17 to 25 inches. The soil is very strongly acid to extremely acid throughout the profile. Included are small areas where the surface layer is extremely stony. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

PPC PUAULU SILT LOAM, 0 TO 10 PERCENT SLOPES: This very deep, well-drained soil occurs on nearly level to moderately sloping uplands. It formed in volcanic ash. The surface layer is a silt loam and the underlying layers are stratified with volcanic ash, cinders, and pumice. The soil is very strongly acid in the surface layer and neutral to medium acid in the underlying layers. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

PSC PUUKALA EXTREMELY STONY SILT LOAM, 6 TO 12 PERCENT SLOPES: This is a shallow, well-drained, extremely stony soil on moderately sloping uplands. It formed in recent volcanic ash and is 10 to 20 inches deep over pahoehoe lava bedrock. Aa lava fragments make up 10 to 50 percent of the soil mass. This soil is strongly acid in the surface layer and medium acid in the subsoil. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

PTC PUUKALA VERY ROCKY SILT LOAM, 6 TO 12 PERCENT SLOPES: This is a shallow, well-drained, extremely stony soil on moderately sloping uplands. It formed in recent volcanic ash and is typically about 15 inches deep over pahoehoe lava bedrock. Pahoehoe lava outcrops occupy about 10 percent of the surface area. This soil is strongly acid in the surface layer and medium acid in the subsoil. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

RB ROUGH BROKEN LAND: This land type consists of very steep, precipitous land broken by many intermittent drainage channels. It occurs primarily in gulches, and the slope is dominantly 35 to 70 percent. The soil material ranges from very shallow to deep. Stones and rock outcrops are common in some areas.

WAC WAIAHA SILT LOAM, 0 TO 10 PERCENT SLOPES: This shallow, well-drained soil occurs on nearly level to moderately sloping uplands. It formed in volcanic ash. The soil is underlain with pahoehoe bedrock at depths of 15 to 20 inches. The soil is slightly acid in the surface layer and neutral to mildly alkaline in the subsoil. Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

WAD WAIAHA SILT LOAM, 10 TO 20 PERCENT SLOPES: This shallow, well-drained soil occurs on moderately sloping to moderately steep uplands. It formed in volcanic ash. The soil is underlain with pahoehoe bedrock at depths of 15 to 20 inches. The soil is slightly acid in the surface layer and neutral to mildly alkaline in the subsoil. Permeability is moderately rapid, runoff is medium, and the erosion hazard is moderate.

WKD WAIAHA VERY ROCKY SILT LOAM, 10 TO 20 PERCENT SLOPES: This is a shallow, well-drained, extremely stony soil on moderately sloping to moderately steep uplands. It formed in volcanic ash. Rock outcrops occupy 10 to 25 percent of the surface area. The soil is underlain with pahoehoe bedrock at depths of 15 to 20 inches. The soil is slightly acid in the surface layer and neutral to mildly alkaline in the subsoil. Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

rHP HYDRANDEPT-TROPOFOLIST ASSOCIATION: This unit consists of Hydrandepts and Tropofolists that are mapped together because of limited use. Hydrandepts make up 50 to 70 percent of the association. They are well to moderately well drained, have smeary consistence, and are more than 20 inches deep. Permeability is rapid, runoff is slow, and the erosion hazard is moderate. Tropofolists are thin, organic soils on lava flows. They have 4 to 12 inches of organic material over fragmental aa or pahoehoe lava. Permeability and runoff of Tropofolists is variable, and the erosion hazard is slight.

rKAD KAHALUU EXTREMELY ROCKY MUCK, 6 TO 20 PERCENT SLOPES: This very shallow, well-drained, organic soil overlies pahoehoe lava bedrock on moderately sloping to moderately steep uplands. This soil is very strongly acid. Although the organic soil is rapidly permeable, the underlying pahoehoe lava is very slowly permeable, except where water moves rapidly through cracks. Runoff is rapid. There is little or no erosion hazard.

rKED KAIMU EXTREMELY STONY PEAT, 7 TO 25 PERCENT SLOPES: This is a well-drained, extremely stony organic soil that is shallow to fragmental aa lava, but deep to underlying bedrock. It occurs on moderately sloping to moderately steep uplands. The soil is neutral in reaction. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

rKFD KEAUKAHA EXTREMELY ROCKY MUCK, 6 TO 20 PERCENT SLOPES: This is a very shallow, well-drained, organic soil overlying pahoehoe lava bedrock. The soil occurs on the undulating to rolling topography of the pahoehoe lava flow. This soil is strongly acid. Rock outcrops occupy about 25 percent of the surface area. Although the organic soil is rapidly permeable, the underlying pahoehoe lava is very slowly permeable, except where water moves rapidly through cracks. Runoff is medium, and the erosion hazard is slight.

rKGD KEEI EXTREMELY ROCKY MUCK, 6 TO 20 PERCENT SLOPES: This is a very shallow, well-drained, organic soil overlying pahoehoe lava bedrock. It occurs on moderately sloping to moderately steep uplands. This soil is strongly acid. Although the organic soil is rapidly permeable, the underlying pahoehoe lava is very slowly permeable, except where water moves rapidly through cracks. Runoff is medium and the erosion hazard is slight.

rKHD KEKAKE EXTREMELY ROCKY MUCK, 6 TO 20 PERCENT SLOPES: This is a very shallow, well-drained, organic soil overlying pahoehoe lava bedrock. It occurs on moderately sloping to moderately steep uplands. The soil is strongly acid. Rock outcrops occupy 25 to 50 percent of the surface area. Although the organic soil is rapidly permeable, the underlying pahoehoe lava is very slowly permeable, except where water moves rapidly through cracks. Runoff is medium, and the erosion hazard is slight.

rKUC KILAUEA EXTREMELY GRAVELLY SAND, 6 TO 12 PERCENT SLOPES: This deep, somewhat excessively drained gravelly sand occurs on moderately sloping uplands. It formed in volcanic ash, pumice, and cinders. The surface layer is neutral. The underlying material is moderately alkaline. Permeability is rapid. Runoff is slow. The hazard of soil blowing is moderate.

rKXD KILOA EXTREMELY STONY MUCK, 6 TO 20 PERCENT SLOPES: This is a well-drained, extremely stony organic soil that is shallow to fragmental aa lava, but deep to underlying bedrock. It occurs on moderately sloping to moderately steep uplands. Slightly weathered ash and cinders are in the voids of the lava. The soil is strongly acid. Permeability is rapid, runoff is very slow, and the erosion hazard is slight.

rKYD KONA EXTREMELY ROCKY MUCK, 6 TO 20 PERCENT SLOPES: This is a well-drained, very shallow, organic soil overlying pahoehoe lava bedrock. It occurs on moderately sloping to moderately steep uplands. The surface layer is slightly acid. Although the organic soil is rapidly permeable, the underlying pahoehoe lava is very slowly permeable, except where water moves rapidly through cracks. Runoff is medium, and the erosion hazard is slight.

rLLD LALAAU EXTREMELY STONY MUCK, 6 TO 20 PERCENT SLOPES: This is a well-drained, extremely stony organic soil that is shallow to fragmental aa lava, but deep to underlying bedrock. It occurs on moderately sloping to moderately steep uplands. The surface layer is very strongly acid. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

rLV LAVA FLOWS, AA: This land type consists of aa lava with little or no soil material. The lava is rough and broken. It is a mass of clinkery, hard, glassy, sharp pieces of lava on a rough undulating to steep topography. The land is bare of vegetation, except for mosses, lichens, and few shrubs and trees.

rLW LAVA FLOWS, PAHOEHOE: This land type consists of pahoehoe lava with little or no soil material. The lava has a billowy, glassy surface that is relatively smooth. In some areas, however, the surface is rough and broken, and there are hummocks and pressure domes. The land is typically bare of vegetation, except for mosses and lichens. In higher rainfall areas, shrubs have gained a foothold in cracks and crevices.

rMUB MANU SILT LOAM, 2 TO 6 PERCENT SLOPES: This well-drained soil occurs on gently sloping uplands. It formed in volcanic ash, cinders, and pumice. The soil is moderately deep, about 36 inches to pahoehoe lava bedrock. The soil grades from medium acid in the surface layer to neutral in the lower part of the subsoil. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

rMWD MAWAE EXTREMELY STONY MUCK, 6 TO 20 PERCENT SLOPES: This is a well-drained, extremely stony organic soil that is shallow to fragmental aa lava, but deep to underlying bedrock. Slopes are undulating to rolling. The surface layer is medium acid. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

rPHB PUHIMAU SILT LOAM, 2 TO 6 PERCENT SLOPES: This is a shallow, well-drained soil on nearly level to moderately sloping uplands. It formed in volcanic ash and pumice, and overlies pahoehoe lava bedrock at depths of 10 to 16 inches. It is medium acid in the surface layer and slightly acid in the subsoil. Rock outcrops occupy about 10 to 20 percent of the surface area. Permeability is rapid, runoff is slow, and the erosion hazard is moderate.

rPXE PUNA EXTREMELY STONY MUCK, 3 TO 25 PERCENT SLOPES: This is a well-drained, extremely stony organic soil that is shallow to fragmental aa lava, but deep to underlying bedrock. It occurs on gently sloping to moderately steep uplands. Rock outcrops occupy 10 to 20 percent of the surface area. This soil reaction is neutral in reaction. Permeability is rapid, runoff is slow, and the erosion hazard is slight.

rPYD PUNALUU EXTREMELY ROCKY PEAT, 6 TO 20 PERCENT SLOPES: This very shallow, well-drained organic soil overlies pahoehoe lava bedrock. It occurs on gently sloping to moderately steep uplands. Rock outcrops occupy about 30 percent of the surface area. This soil is medium acid. Although the organic soil is rapidly permeable, the underlying pahoehoe lava is very slowly permeable, except where water moves rapidly through cracks. Runoff is slow, and the erosion hazard is slight.

rRO ROCK LAND: This land type consists of pahoehoe lava bedrock covered by a thin layer of soil. The average depth of the soil material is between 6 and 8 inches, although in some places the material extends into the cracks of the lava. The dominant slope is between 10 and 15 percent. Pahoehoe outcrops occupy 50 to 90 percent of the surface area. The water erosion hazard is slight.

rVS VERY STONY LAND: This land type consists of very shallow volcanic ash and a high proportion of aa lava outcrops. Dominant slope is between 10 and 15 percent. Between the lava outcrops and in the cracks of the lava, the soil material extends to a depth of 5 to 20 inches. The erosion hazard is slight.

APPENDIX D

SOIL SUITABILITY FOR SELECTED CROPS

Median Annual Rainfall and Mean Annual Pan Evaporation: The median annual rainfall values were used in this study to obtain, in conjunction with the mean annual pan evaporation, a general idea of the sufficiency of rainfall to satisfy crop needs. This information was <u>not</u> included in the criteria for rating the land for crop production as it was assumed that irrigation could be made available. By looking at both rainfall and PAN maps (Figures D-1 and D-2), one can see in general where the areas of sufficient rainfall occur. PAN data can be used to estimate evapotransporation (e.g. PAN = ET for a mature sugar cane crop). See referenced sources for further details. A more reliable approach in determining rainfall sufficiency, of course, would be to calculate a water budget on a daily basis. Of less accuracy, but perhaps sufficient for field planning would be to use monthly precipitation and PAN data which is readily available. One should also consider microtopographic features as they affect solar radiation and wind velocities. Data sources used were: DLNR Report R74 and DLNR Circular C88.

General Wind Protection: This map was generated using annual wind power data from DLNR-DOWALD sources. These average values do not indicate the power of wind gusts which are really the most important to crop damage. Figure D-3, however, does serve to indicate zones of generally lesser or greater wind velocity. Some local expertise was then obtained to arrive at where, in general, wind breaks are required vs. recommended for most crops.

Current Land-use (1992) and Current Agriculture (1992): The sources of land-use (Figure D-4) and current agriculture (Figure D-5) data for these maps were obtained from SCS personnel located on the Big Island. Areas smaller that about 40 acres are not shown.

Crop Suitability: An attempt was made to provide a general indication for selected areas as to the suitability for the production of coffee (Figure D-6), Macadamia nuts (Figure D-7), and truck crops (Figure D-8). Factors considered were slope as it affects trafficability and erosivity; soil erodability factor (K) used in the Universal Soil Loss Equation; gravel, cobble and stone content as it affects land preparation and trafficability; soil drainage class; soil depth to impervious material and annual temperature. Not considered here were moisture, wind, aspect, economics and infrastructure. Areas less that 10 acres downslope and 100 acres upslope were not shown. Also, temperature was not included in the ratings for truck crops as critical temperatures vary for different truck crops. Critical temperatures for selected truck crops are shown in Table D-1.

TABLE D-1 Temperature Ranges (°F) for Selected Truck Crops

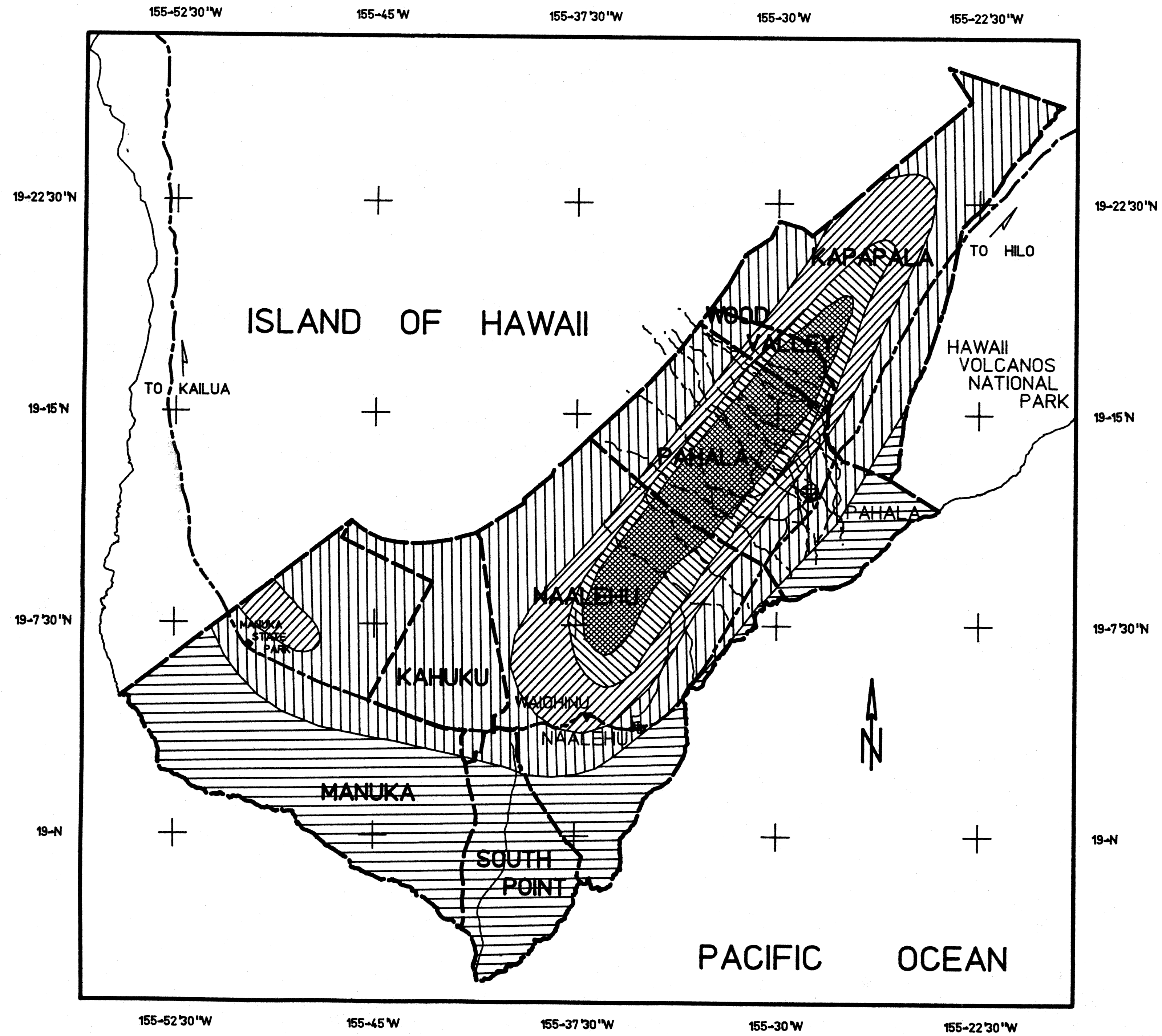
Crop	Good	Ratings Fair	Poor
Lettuce	57-68	50-56, 69-85	<50,> 86
Cabbage	59-68	50-58, 69-76	<50,> 77
Tomatoes	59-82	50-58, 83-89	<50,> 90
Eggplant	70-86	59-69, 87-103	<59,>104
Squash	63-86	54-62, 87-94	<54,> 95
Corn	64-86	54-63, 87-103	<54,>104

These temperatures generally correspond to the following elevations. One must also consider topography and aspect for specific sites.

TABLE D-2 Temperature (°F) at Elevations

Elevation (Feet)	Temperature (°F)
0	75
500	74.5
1,000	73
1,500	71
2,000	70
2,500	68
3,000	67
5,000	61
10,000	28

KAU RIVER BASIN STUDY



STUDY AREA

FIGURE D-1
MEDIAN ANNUAL RAINFALL

LEGEND

- UNDER 40 INCHES
- 40 TO 60 INCHES
- 60 TO 80 INCHES
- 80 TO 100 INCHES
- OVER 100 INCHES

- STUDY AREA BOUNDARY
- SUB-AREA BOUNDARY
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS

AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID

-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RAINFALL ZONES INTERPOLATED FROM CIRCULAR C88, STATE OF HAWAII, DLNR, DOWALD

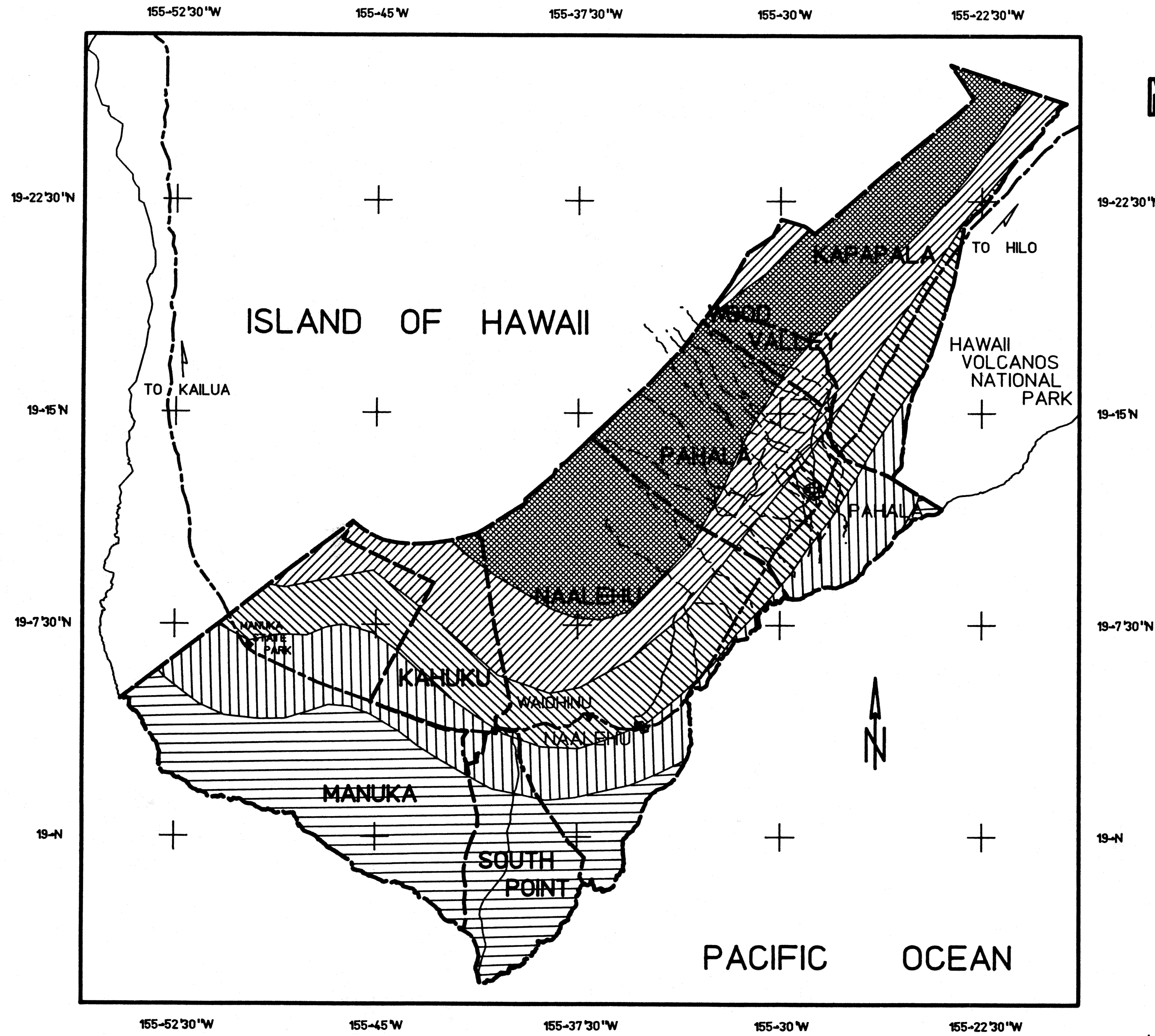
NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT NATURAL RESOURCES PLANNING STAFF, SCS HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE
5 0 5 10 MILES

PREPARED BY USDA, SOIL CONSERVATION SERVICE, HAWAII STATE OFFICE NATURAL RESOURCES PLANNING STAFF HONOLULU, HAWAII SEPTEMBER 1993

KAU RIVER BASIN STUDY



STUDY AREA

FIGURE D-2
MEAN ANNUAL PAN EVAPORATION

LEGEND

- OVER 80 INCHES
- 70 TO 80 INCHES
- 60 TO 70 INCHES
- 50 TO 60 INCHES
- UNDER 50 INCHES

- STUDY AREA BOUNDARY
- SUB-AREA BOUNDARY
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS

AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID

-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

PAN EVAPORATION ZONES FROM REPORT R74, STATE OF HAWAII, DLNR, DOWALD

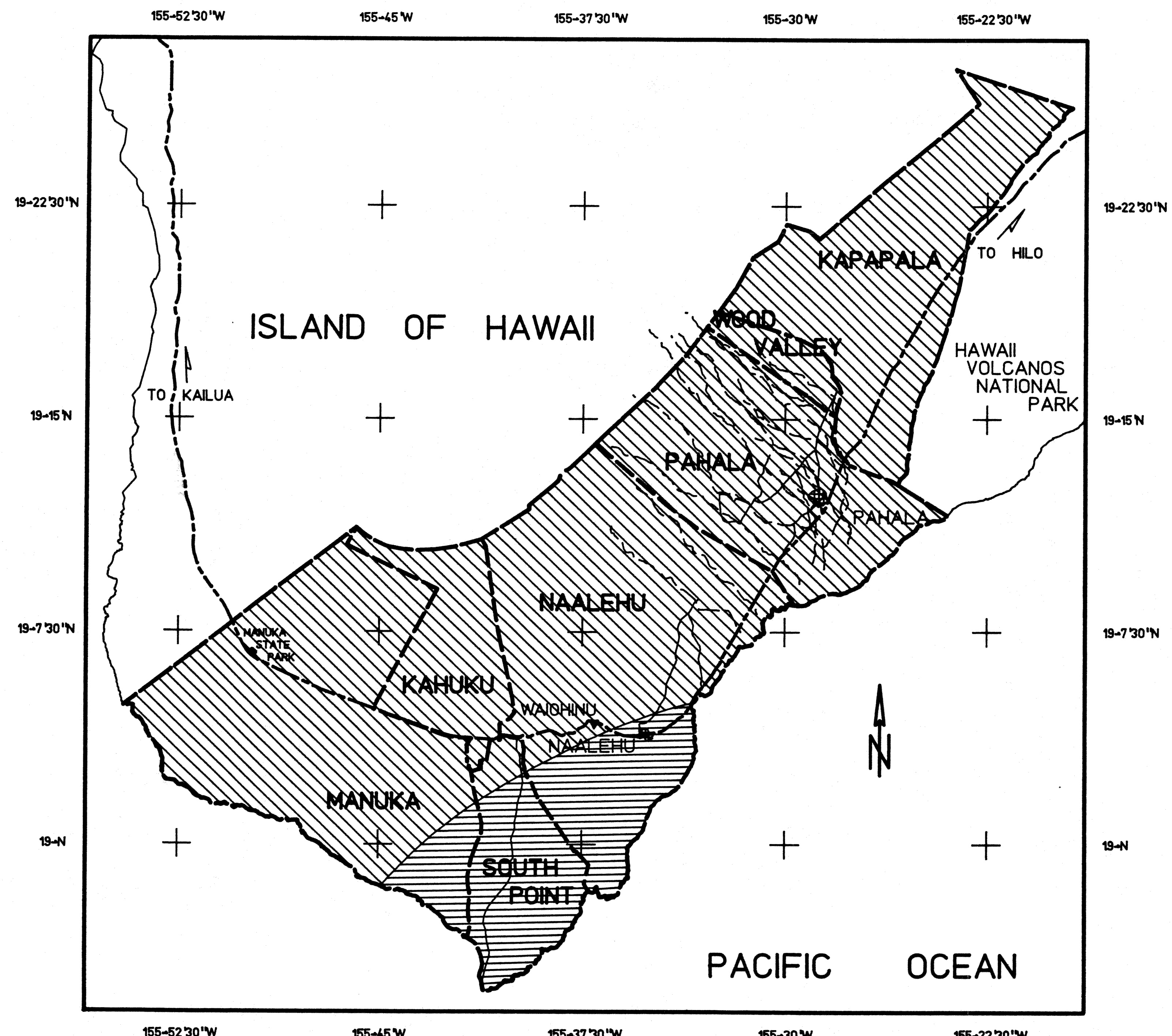
NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT NATURAL RESOURCES PLANNING STAFF, SCS HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE
5 0 5 10 MILES

PREPARED BY USDA, SOIL CONSERVATION SERVICE, HAWAII STATE OFFICE NATURAL RESOURCES PLANNING STAFF HONOLULU, HAWAII SEPTEMBER 1993

KAU RIVER BASIN STUDY



STUDY AREA

FIGURE D-3
GENERAL WIND PROTECTION

LEGEND

- WIND PROTECTION NEEDED
- WIND PROTECTION RECOMMENDED
- STUDY AREA BOUNDARY
- SUB-AREA BOUNDARY
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS
- AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID

-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

WIND ZONES DETERMINED FROM WIND ATLAS, STATE OF HAWAII, DLNR, DOWALD

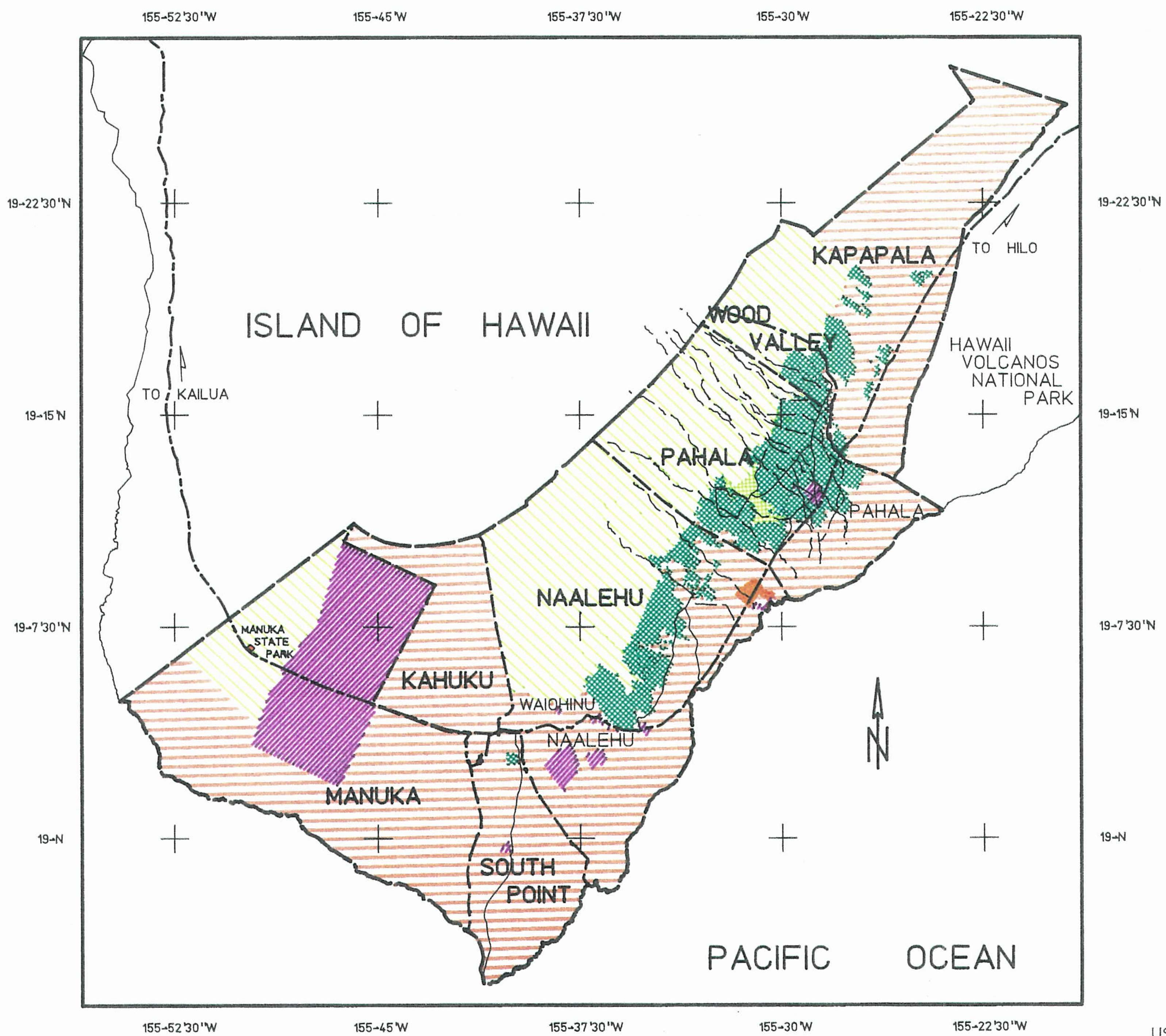
NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT NATURAL RESOURCES PLANNING STAFF, SCS HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE
5 0 5 10 MILES

PREPARED BY USDA, SOIL CONSERVATION SERVICE, HAWAII STATE OFFICE NATURAL RESOURCES PLANNING STAFF HONOLULU, HAWAII SEPTEMBER 1993

KAU RIVER BASIN STUDY



STUDY AREA

FIGURE D-4
CURRENT LANDUSE (1992)

LEGEND

- FOREST/CONSERVATION LAND
- NATURALIZED VEGETATION
- RECREATION AREAS
- OTHER NON-AGRICULTURAL
- GRAZING LAND
- CROP PRODUCTION

- STUDY AREA BOUNDARY
- SUB-AREA BOUNDARY
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS

AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID

-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

CURRENT LANDUSES DETERMINED BY SCS, HILO FIELD OFFICE PERSONNEL

NOTE:

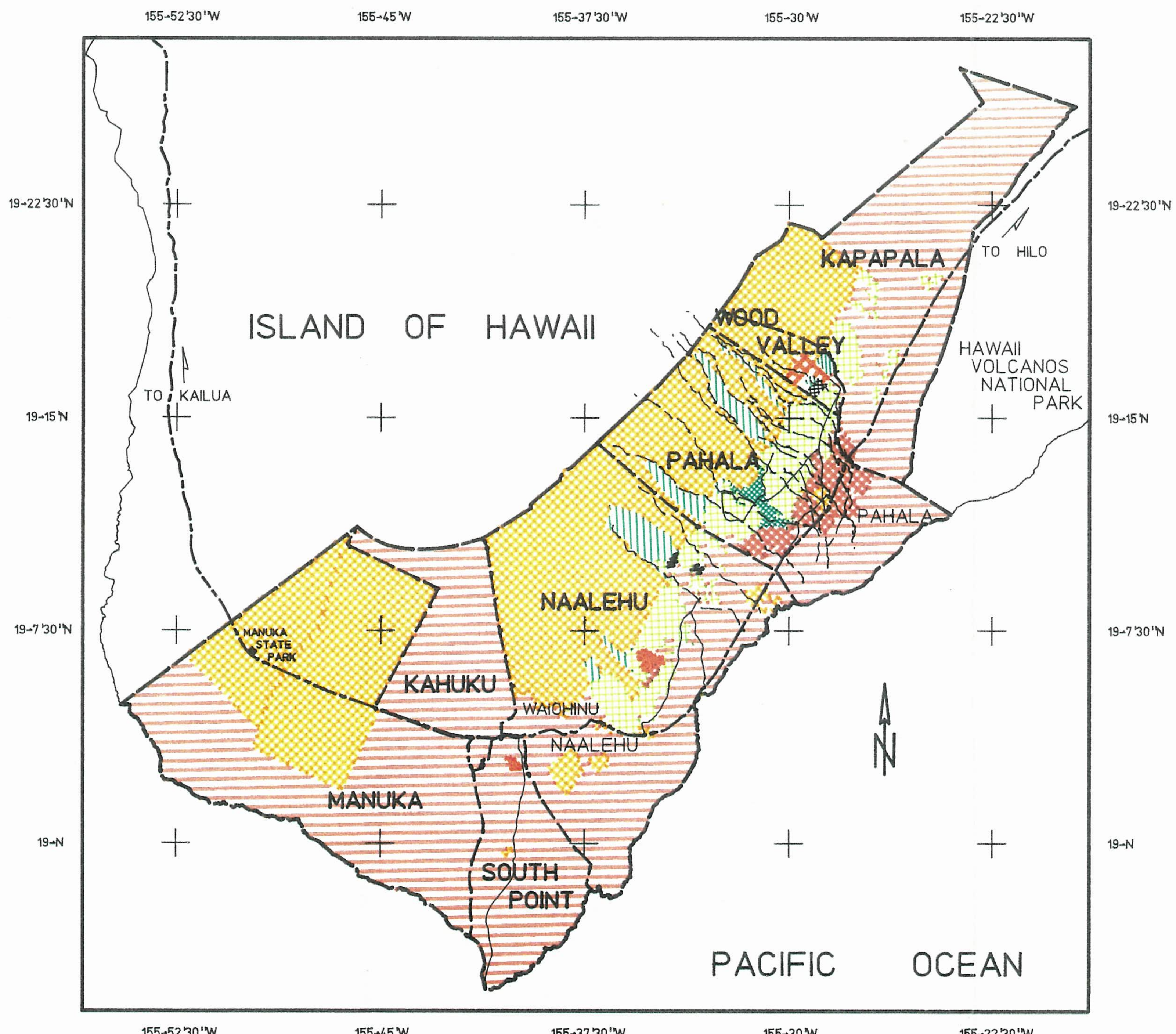
USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT NATURAL RESOURCES PLANNING STAFF, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE
5 0 5 10 MILES

PREPARED BY USDA, SOIL CONSERVATION SERVICE, HAWAII STATE OFFICE NATURAL RESOURCES PLANNING STAFF HONOLULU, HAWAII SEPTEMBER 1993

KAU RIVER BASIN STUDY

FIGURE D-5
CURRENT AGRICULTURE (1992)



STUDY AREA

LEGEND

- SUGAR CANE
- MACADAMIA NUTS
- CITRUS
- ROW CROPS
- COFFEE
- BIOMASS PRODUCTION
- DIVERSIFIED AGRICULTURE
- FOREST
- GRAZING LAND
- NATURALIZED VEGETATION
- NON-AGRICULTURAL
- STUDY AREA BOUNDARY
- SUB-AREA BOUNDARY
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS

AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID

-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

AGRICULTURAL LANDUSES DETERMINED BY SCS, HILO FIELD OFFICE PERSONNEL

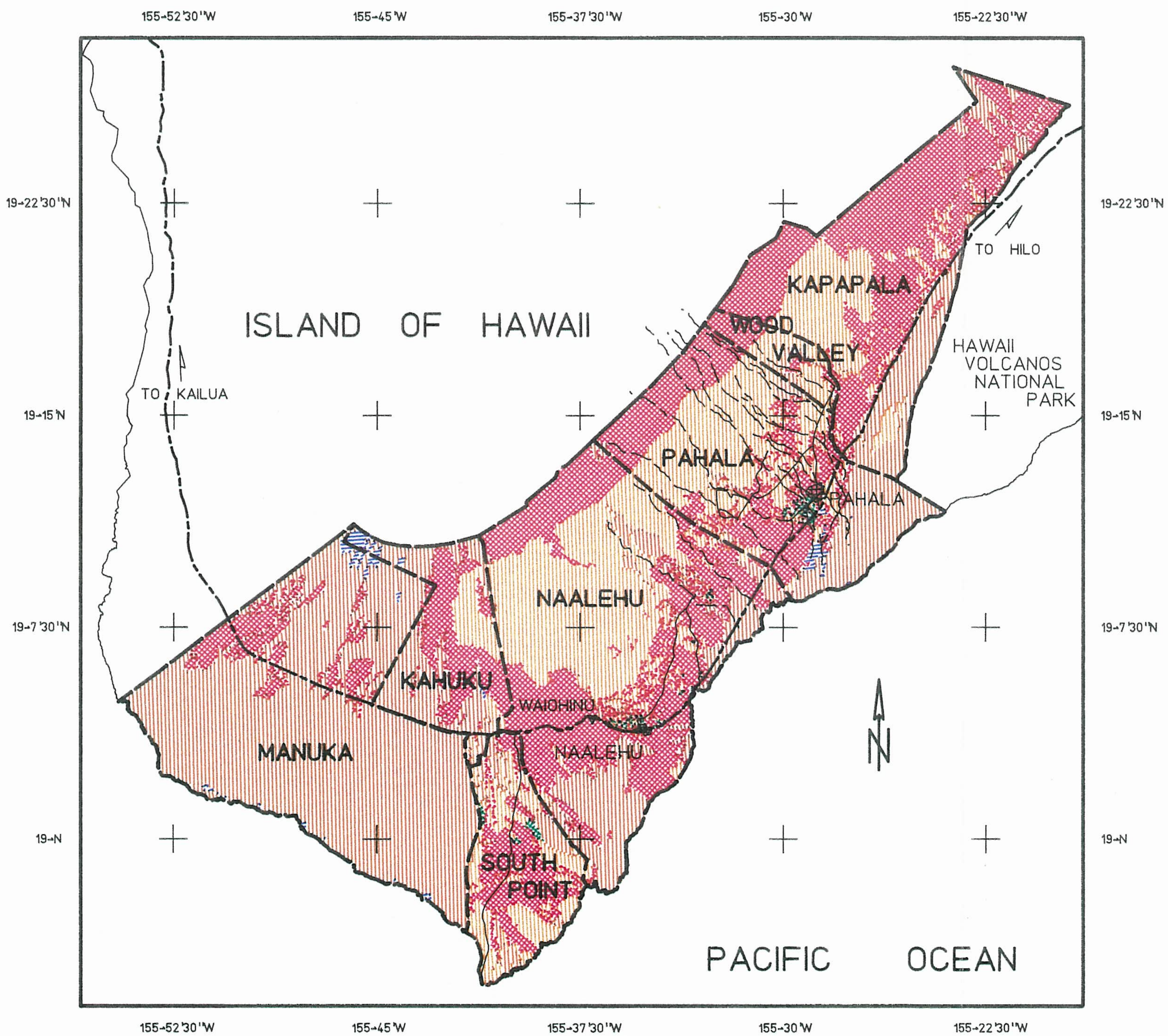
NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT NATURAL RESOURCES PLANNING STAFF, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE
5 0 5 10 MILES

PREPARED BY USDA, SOIL CONSERVATION SERVICE, HAWAII STATE OFFICE NATURAL RESOURCES PLANNING STAFF HONOLULU, HAWAII SEPTEMBER 1993

KAU RIVER BASIN STUDY



STUDY AREA

FIGURE D-6
GENERAL SUITABILITY: COFFEE

LEGEND

- GOOD SUITABILITY
- FAIR SUITABILITY
- POOR SUITABILITY
- DETERMINE ON-SITE
- LAVA/ROUGH-BROKEN AREAS

- STUDY AREA BOUNDARY
- SUB-AREA BOUNDARY
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS

AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

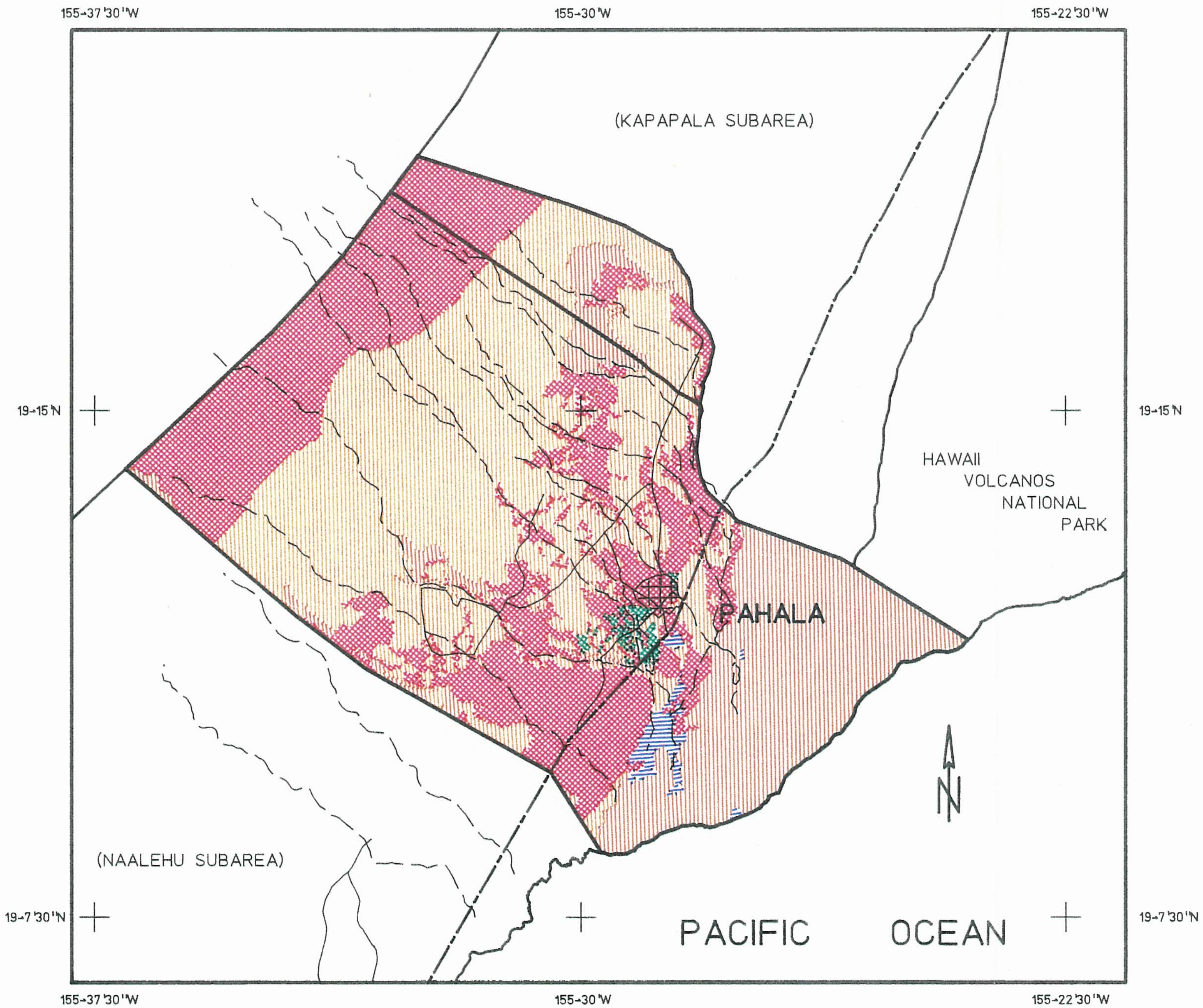
USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE
5 0 5 10 MILES

PREPARED BY USDA, SOIL CONSERVATION SERVICE, HAWAII STATE OFFICE NATURAL RESOURCES PLANNING STAFF HONOLULU, HAWAII SEPTEMBER 1993

KAU RIVER BASIN STUDY

FIGURE D-7
GENERAL SUITABILITY: COFFEE



WOOD VALLEY/PAHALA SUB-AREAS

LEGEND

- GOOD SUITABILITY
- FAIR SUITABILITY
- POOR SUITABILITY
- DETERMINE ON-SITE
- LAVA/ROUGH-BROKEN AREAS
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS
- AREA IN BOX APPROXIMATES 500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE

5 0 5 MILES

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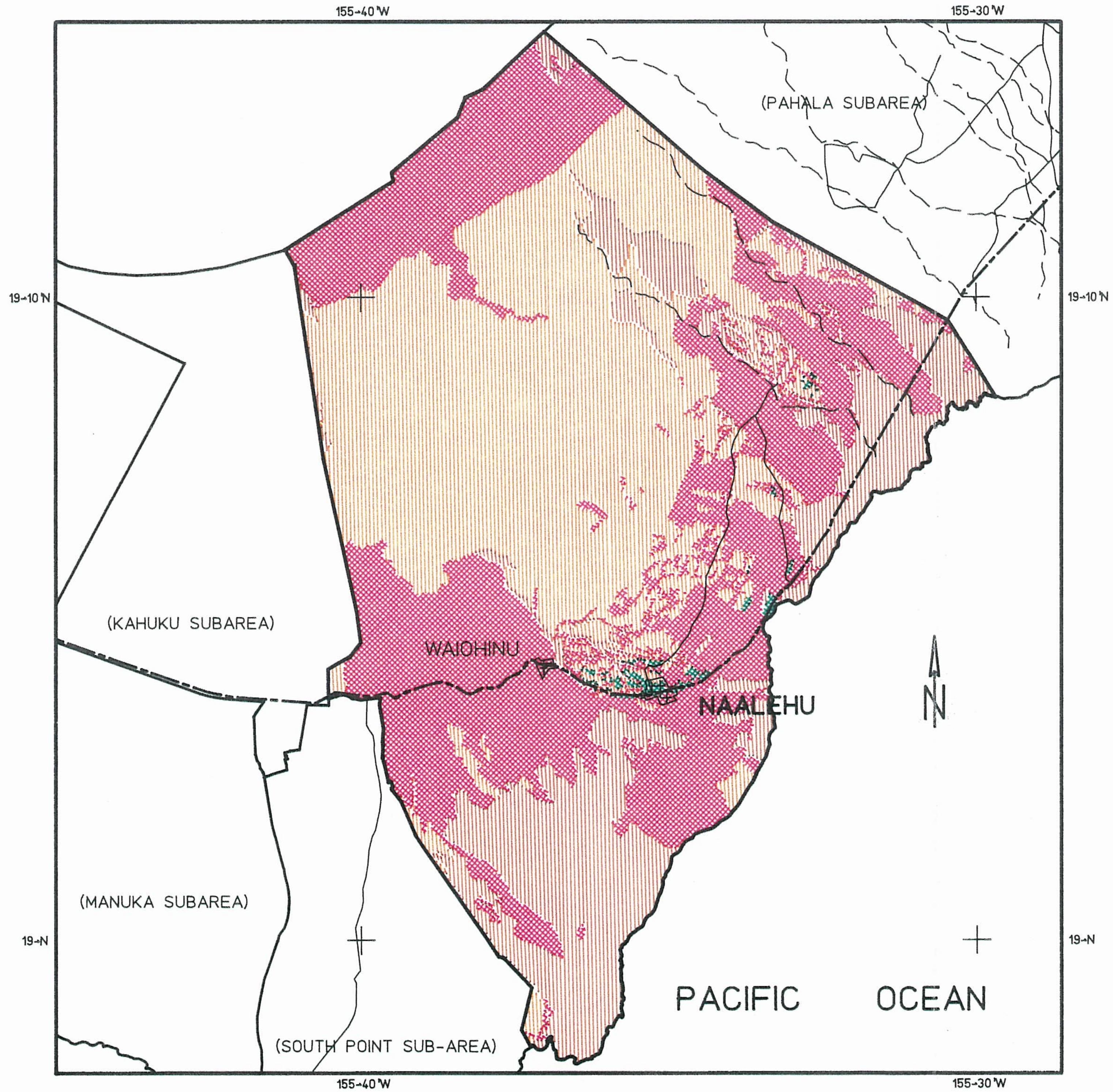
KAU RIVER BASIN STUDY



NAALEHU SUB-AREA

FIGURE D-8 GENERAL SUITABILITY: COFFEE

LEGEND

- GOOD SUITABILITY
- FAIR SUITABILITY
- POOR SUITABILITY
- LAVA/ROUGH-BROKEN AREAS
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS
- AREA IN BOX APPROXIMATES 500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE

5 0 5 MILES

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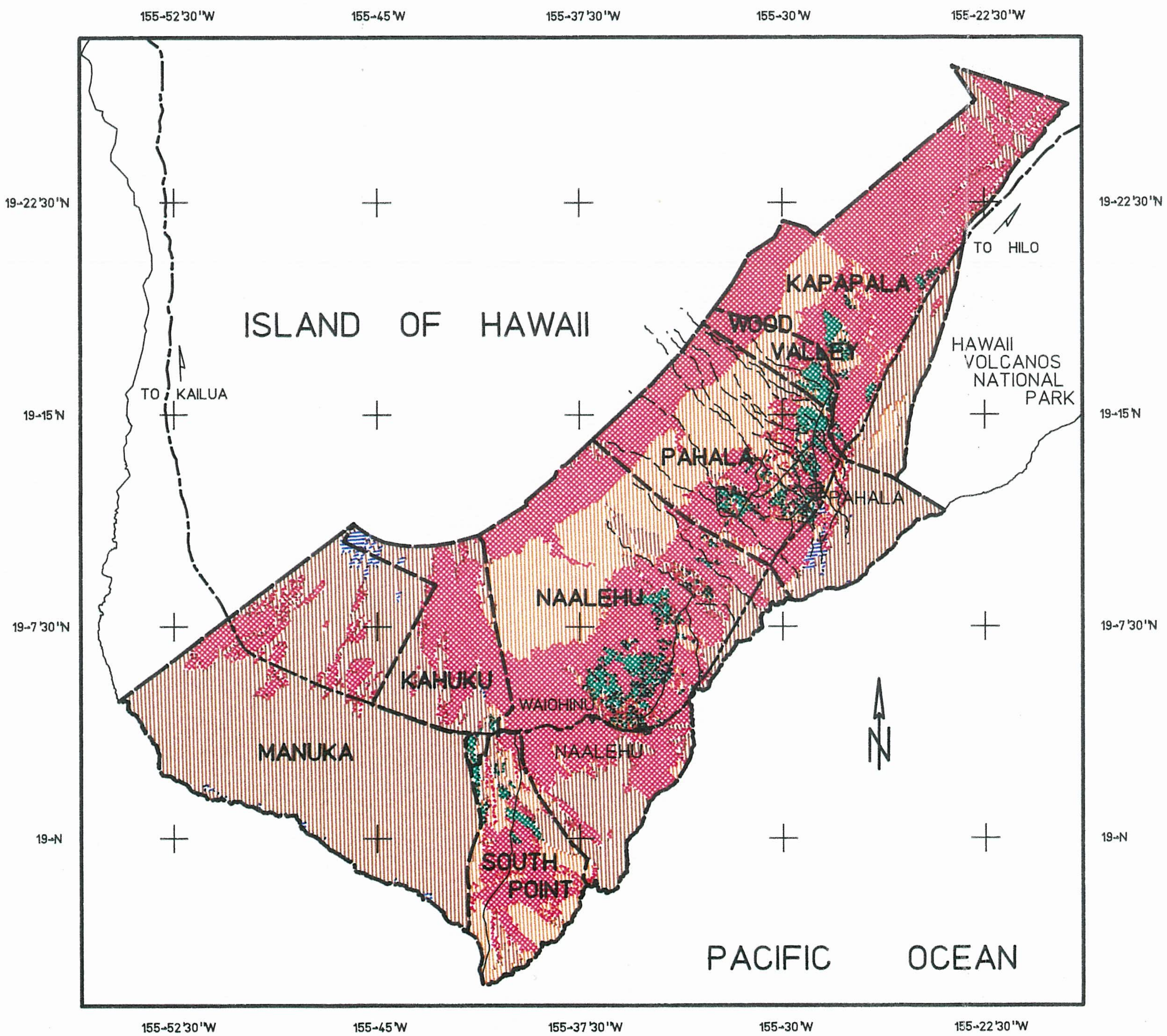
KAU RIVER BASIN STUDY

FIGURE D-9
GENERAL SUITABILITY: MACADAMIA NUTS



STUDY AREA

LEGEND

GOOD SUITABILITY	STUDY AREA BOUNDARY
FAIR SUITABILITY	SUB-AREA BOUNDARY
POOR SUITABILITY	PRINCIPLE STREAMS
DETERMINE ON-SITE	STATE HIGHWAY NO. 11
LAVA/ROUGH-BROKEN AREAS	SECONDARY ROADS

AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE
5 0 5 10 MILES

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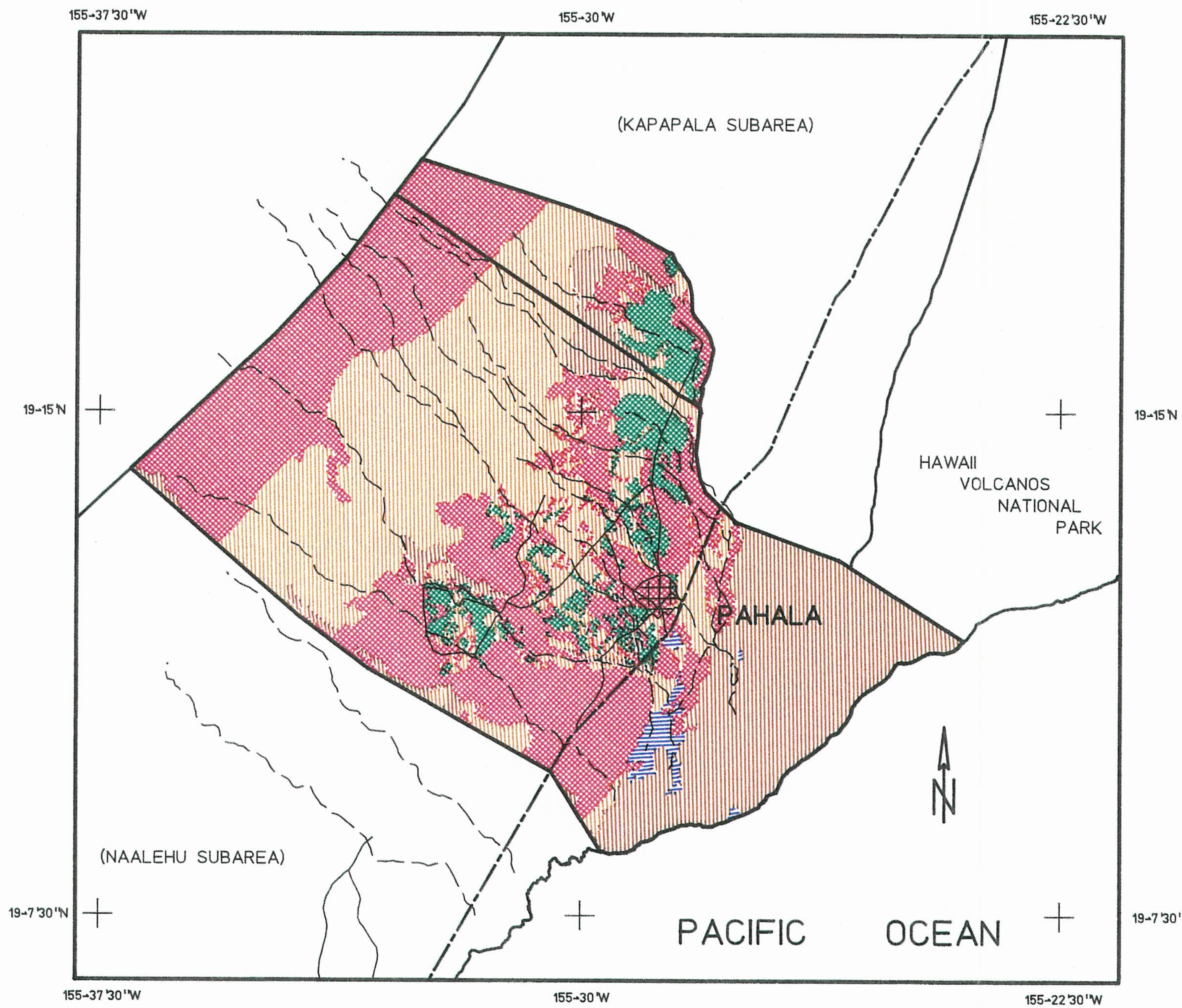
KAU RIVER BASIN STUDY

FIGURE D-10
GENERAL SUITABILITY: MACADAMIA NUTS



WOOD VALLEY/PAHALA SUB-AREAS

LEGEND

- GOOD SUITABILITY
- FAIR SUITABILITY
- POOR SUITABILITY
- DETERMINE ON-SITE
- LAVA/ROUGH-BROKEN AREAS
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS
- AREA IN BOX APPROXIMATES 500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE

5 0 5 MILES

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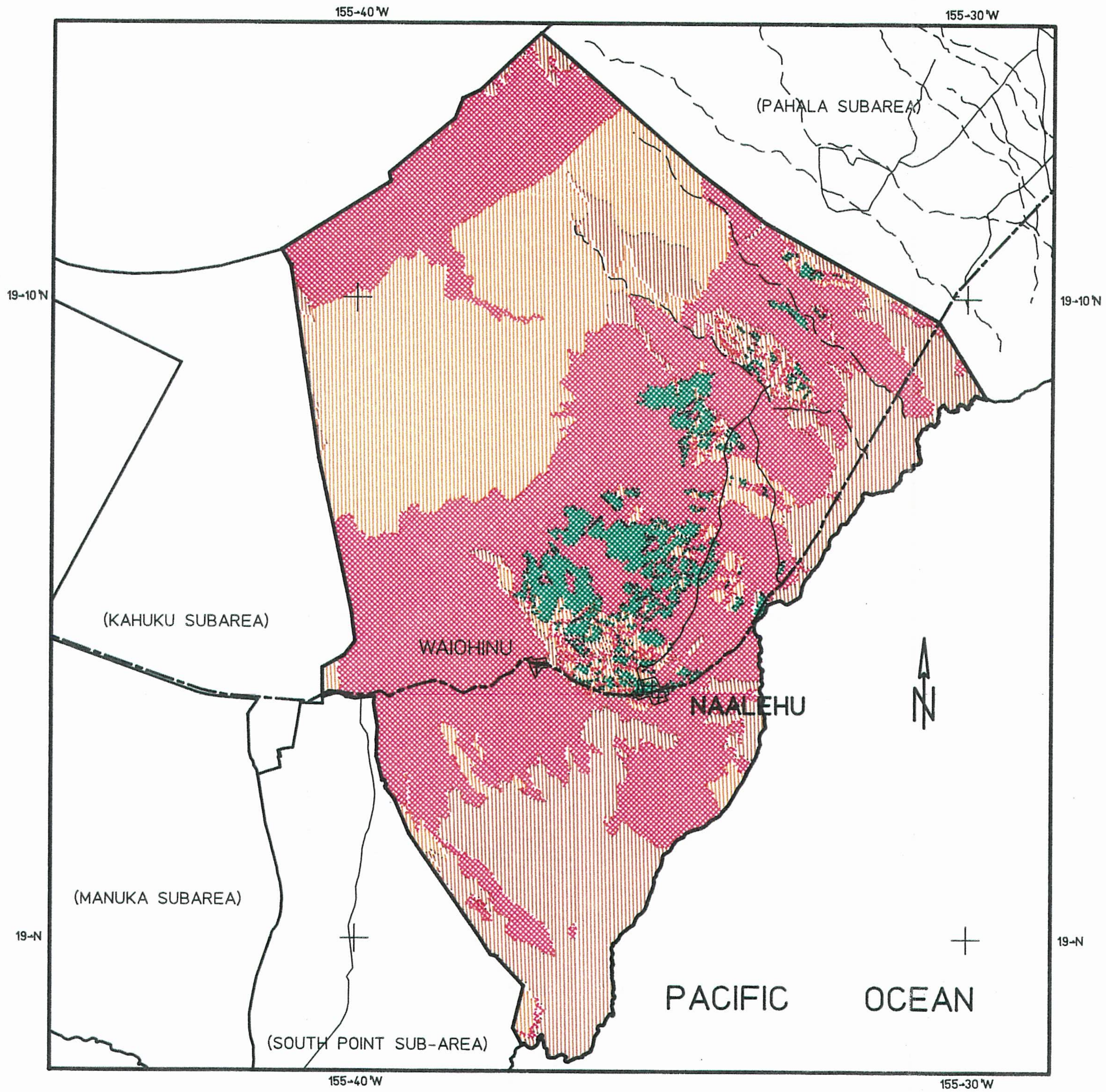
KAU RIVER BASIN STUDY



NAALEHU SUB-AREA

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FIGURE D-11
GENERAL SUITABILITY: MACADAMIA NUTS

LEGEND

- GOOD SUITABILITY
- FAIR SUITABILITY
- POOR SUITABILITY
- LAVA/ROUGH-BROKEN AREAS
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS
- AREA IN BOX APPROXIMATES 500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

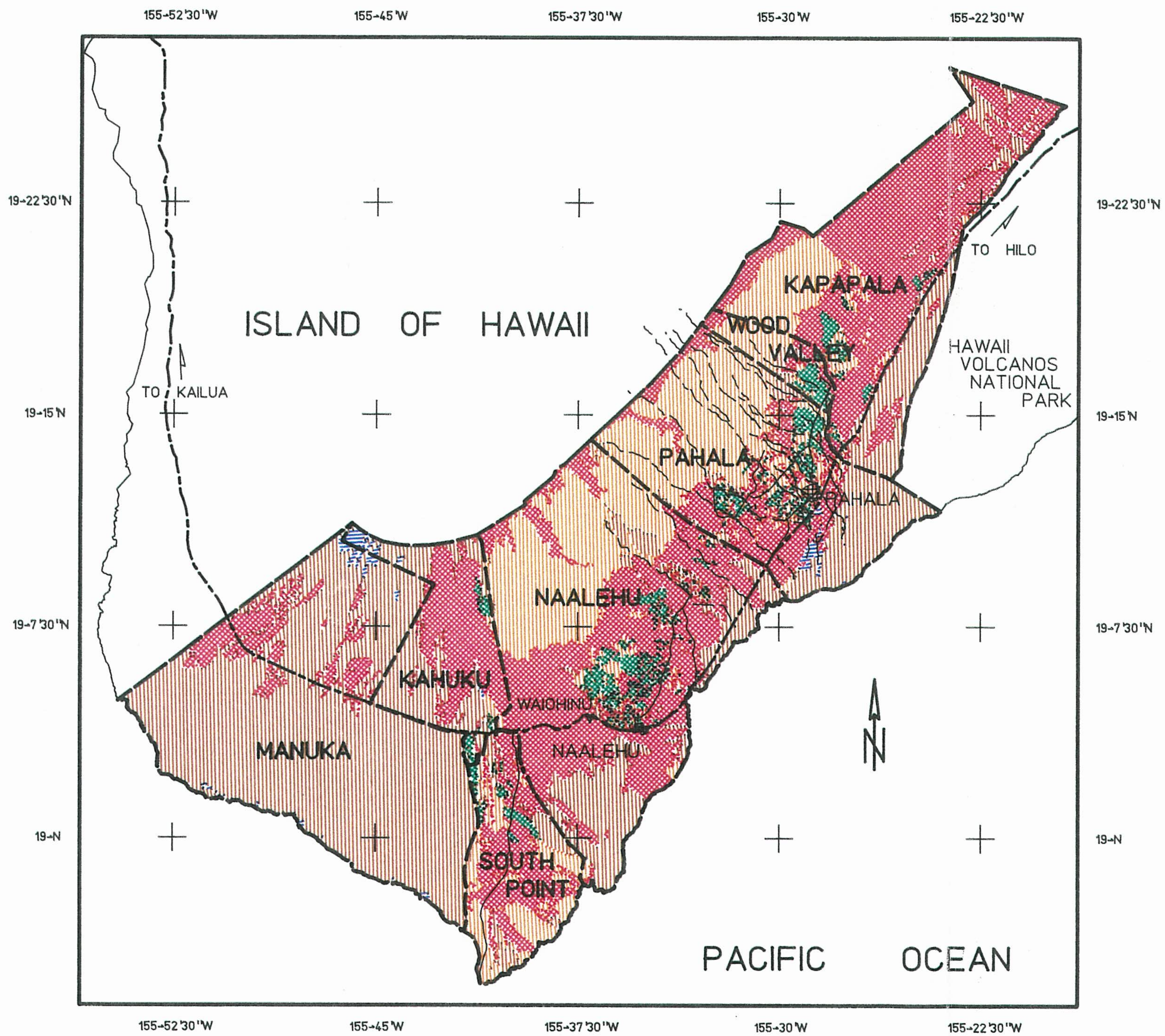
USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE

5 0 5 MILES

KAU RIVER BASIN STUDY

FIGURE D-12
GENERAL SUITABILITY:
GENERAL TRUCK CROPS



STUDY AREA

LEGEND

- GOOD SUITABILITY
- FAIR SUITABILITY
- POOR SUITABILITY
- DETERMINE ON-SITE
- LAVA/ROUGH-BROKEN AREAS

- STUDY AREA BOUNDARY
- SUB-AREA BOUNDARY
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS

AREA IN BOX APPROXIMATES 2,500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE

5 0 5 10 MILES

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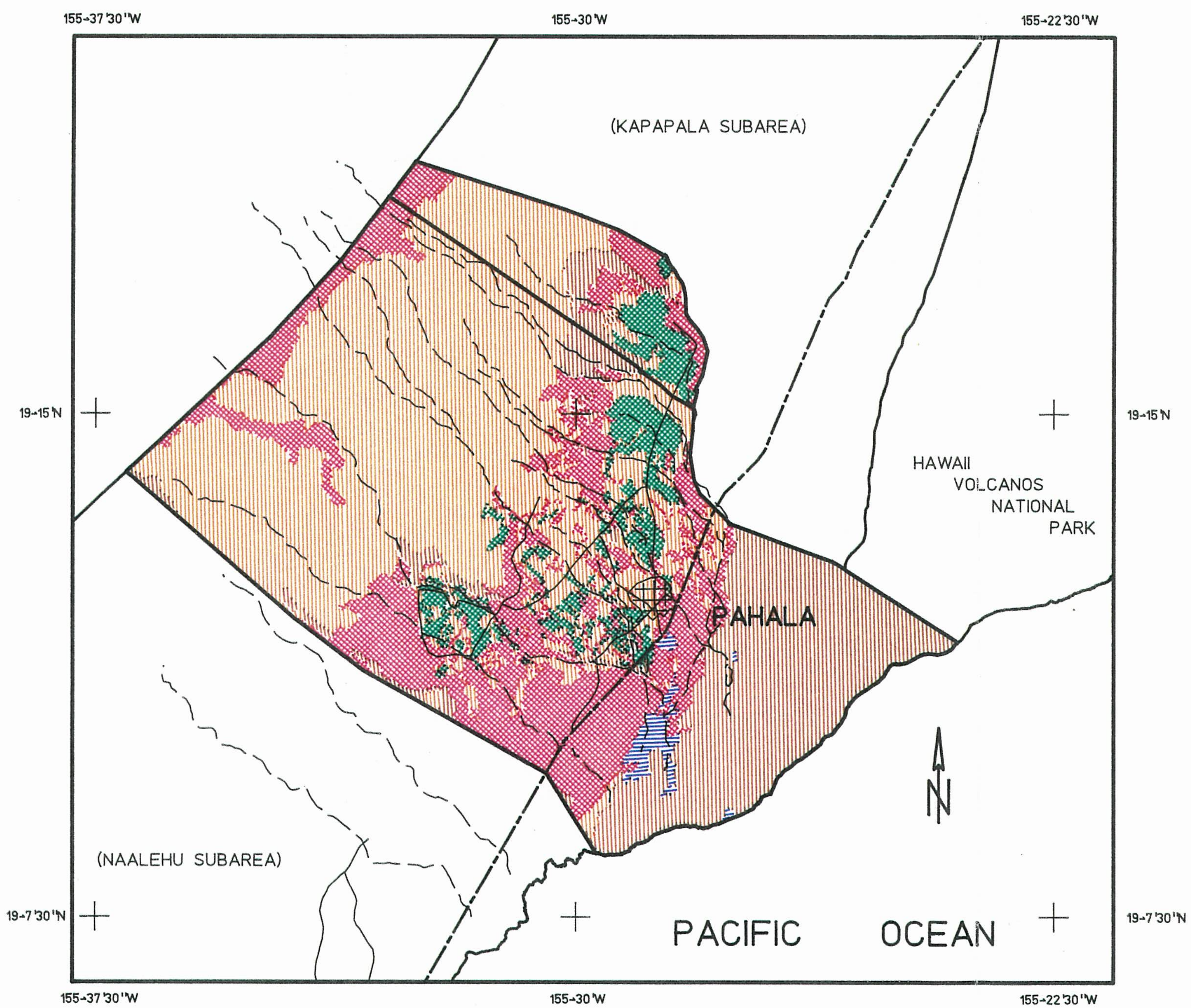
KAU RIVER BASIN STUDY

FIGURE D-13
GENERAL SUITABILITY: GENERAL TRUCK CROPS



WOOD VALLEY/PAHALA SUB-AREAS

LEGEND

- GOOD SUITABILITY
- FAIR SUITABILITY
- POOR SUITABILITY
- DETERMINE ON-SITE
- LAVA/ROUGH-BROKEN AREAS
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS
- AREA IN BOX APPROXIMATES 500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE

5 0 5 MILES

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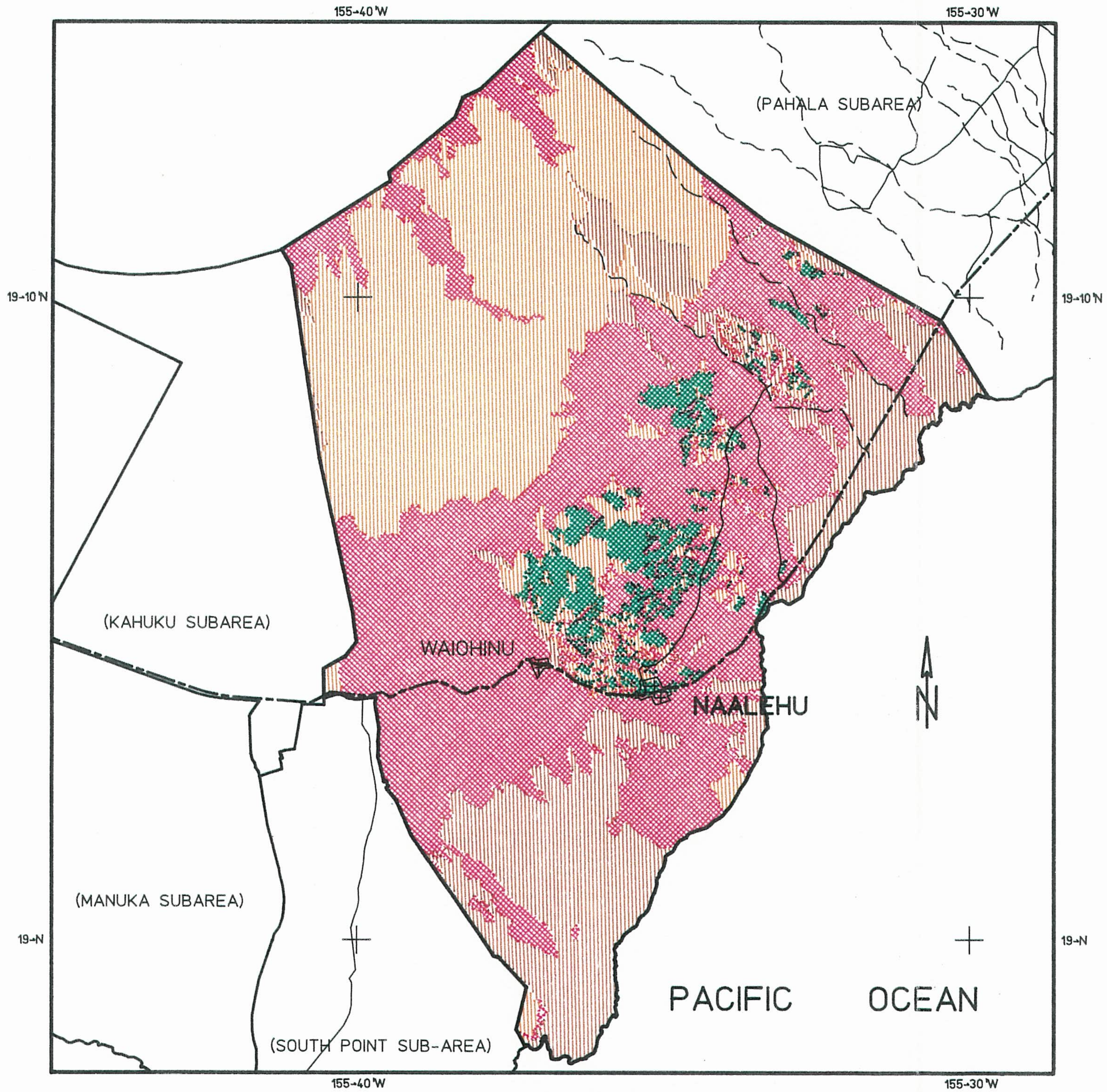
KAU RIVER BASIN STUDY



NAALEHU SUB-AREA

FIGURE D-14
GENERAL SUITABILITY: TRUCK CROPS

LEGEND

- GOOD SUITABILITY
- FAIR SUITABILITY
- POOR SUITABILITY
- LAVA/ROUGH-BROKEN AREAS
- PRINCIPLE STREAMS
- STATE HIGHWAY NO. 11
- SECONDARY ROADS
- AREA IN BOX APPROXIMATES 500 ACRES AT MAP SCALE

BASE SOURCES:

-SHORELINE AND SOILS-
USDA, SCS GEF QUADRANGLE DIGITAL SOILS DATA, 1:24,000, CLARK 1866 SPHEROID
-STUDY BOUNDARY, PRINCIPLE STREAMS AND ROADS-
USGS QUADRANGLE 1:24,000 HARDCOPY, CLARK 1866 SPHEROID, TRANSV. MERC. PROJ.

THEMATIC SOURCES:

RATED SUITABILITIES DETERMINED BY SCS, HAWAII STATE OFFICE, SOIL SCIENCE STAFF

NOTE:

USE MAP FOR GENERAL PLANNING PURPOSES ONLY. CONSULT STATE SOIL SCIENTIST, SCS, HAWAII STATE OFFICE, HONOLULU, HAWAII FOR FURTHER INFORMATION.

SCALE

5 — 0 — 5 MILES

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APPENDIX E

PLANS FOR ALTERNATIVES

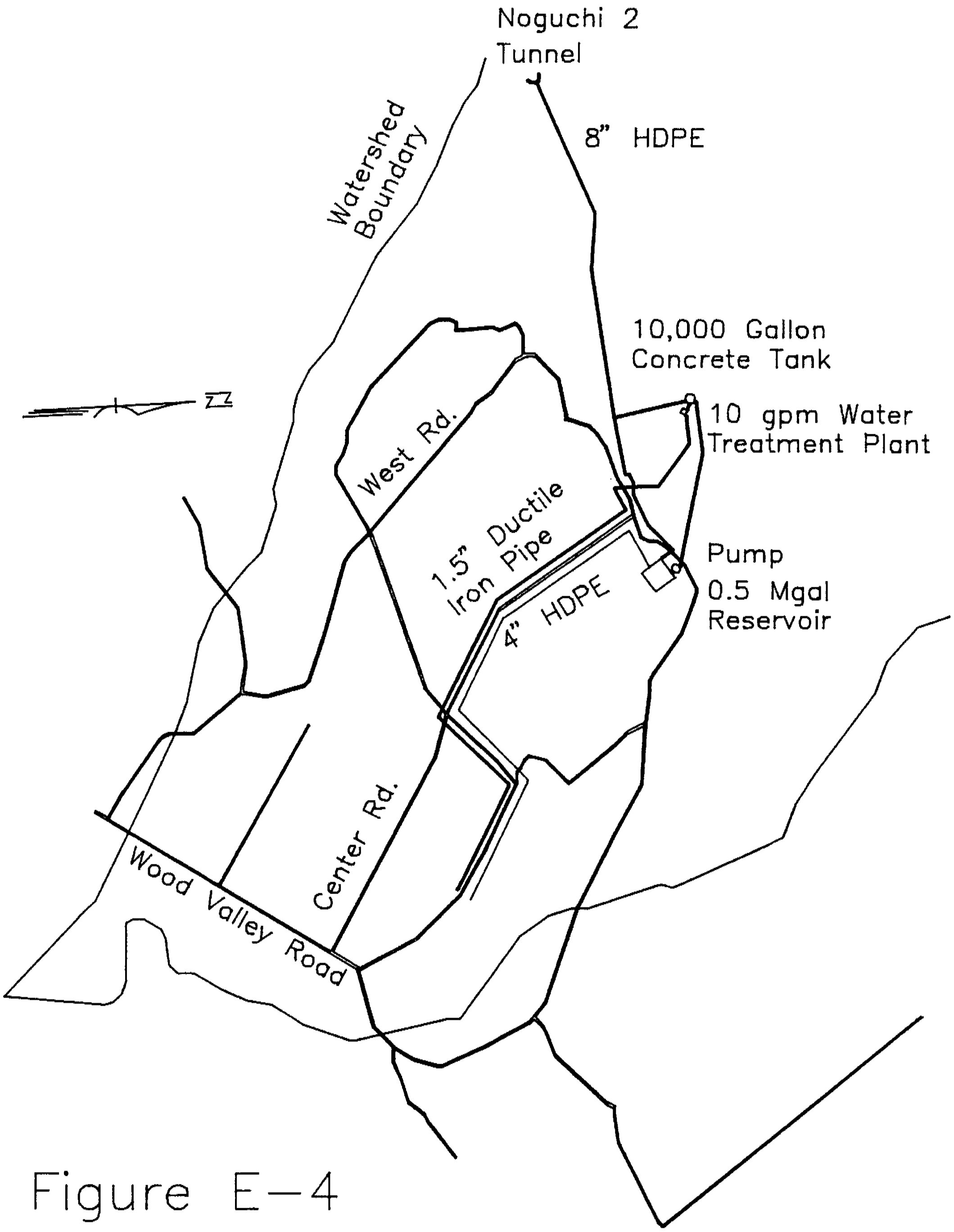


Figure E-4
Wood Valley
Alternative WV1

SCALE

1 Mile 1/2 0 1 Mile

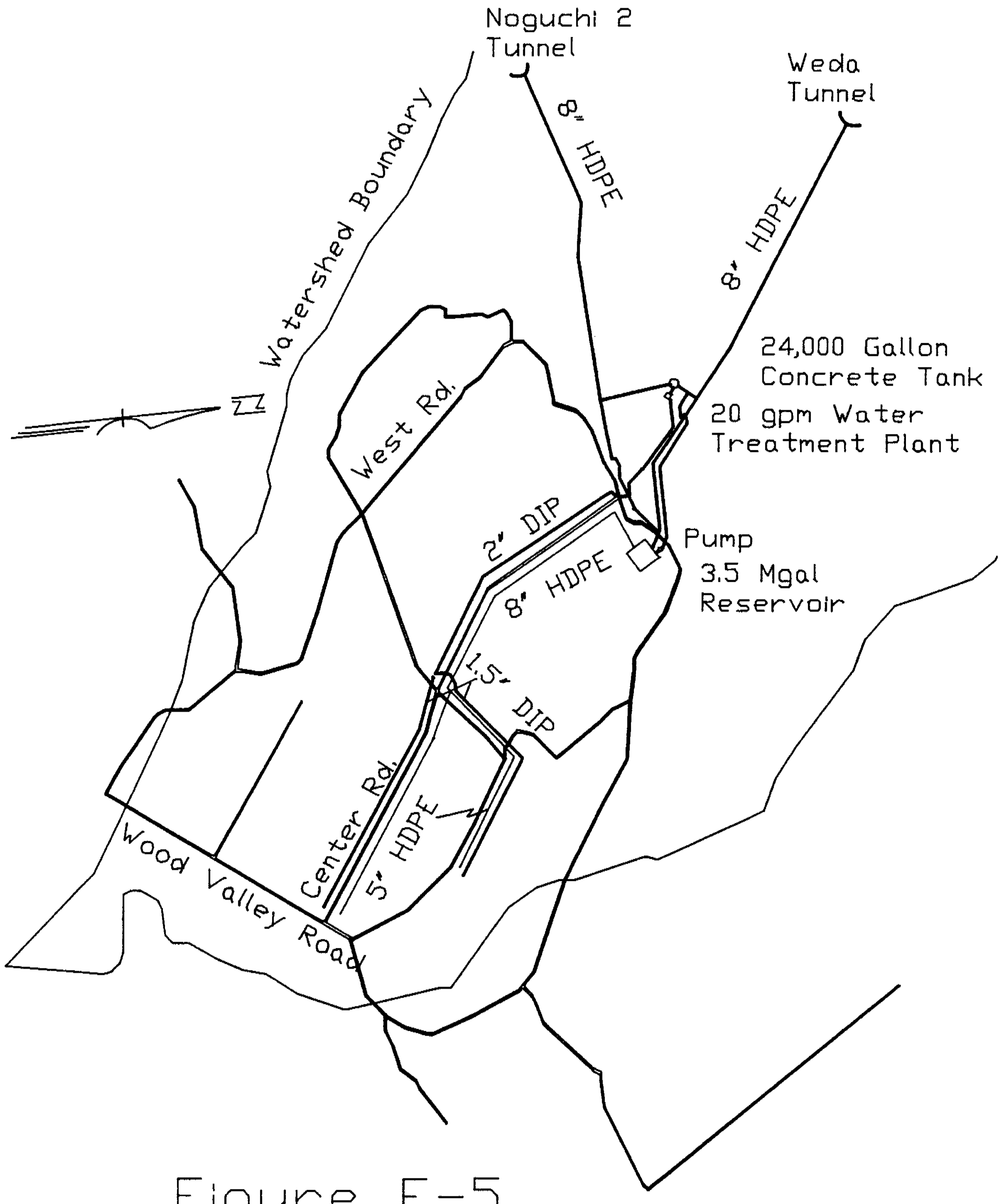
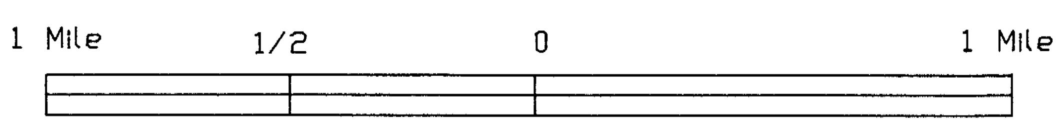


Figure E-5
Wood Valley
Alternative WV2

SCALE



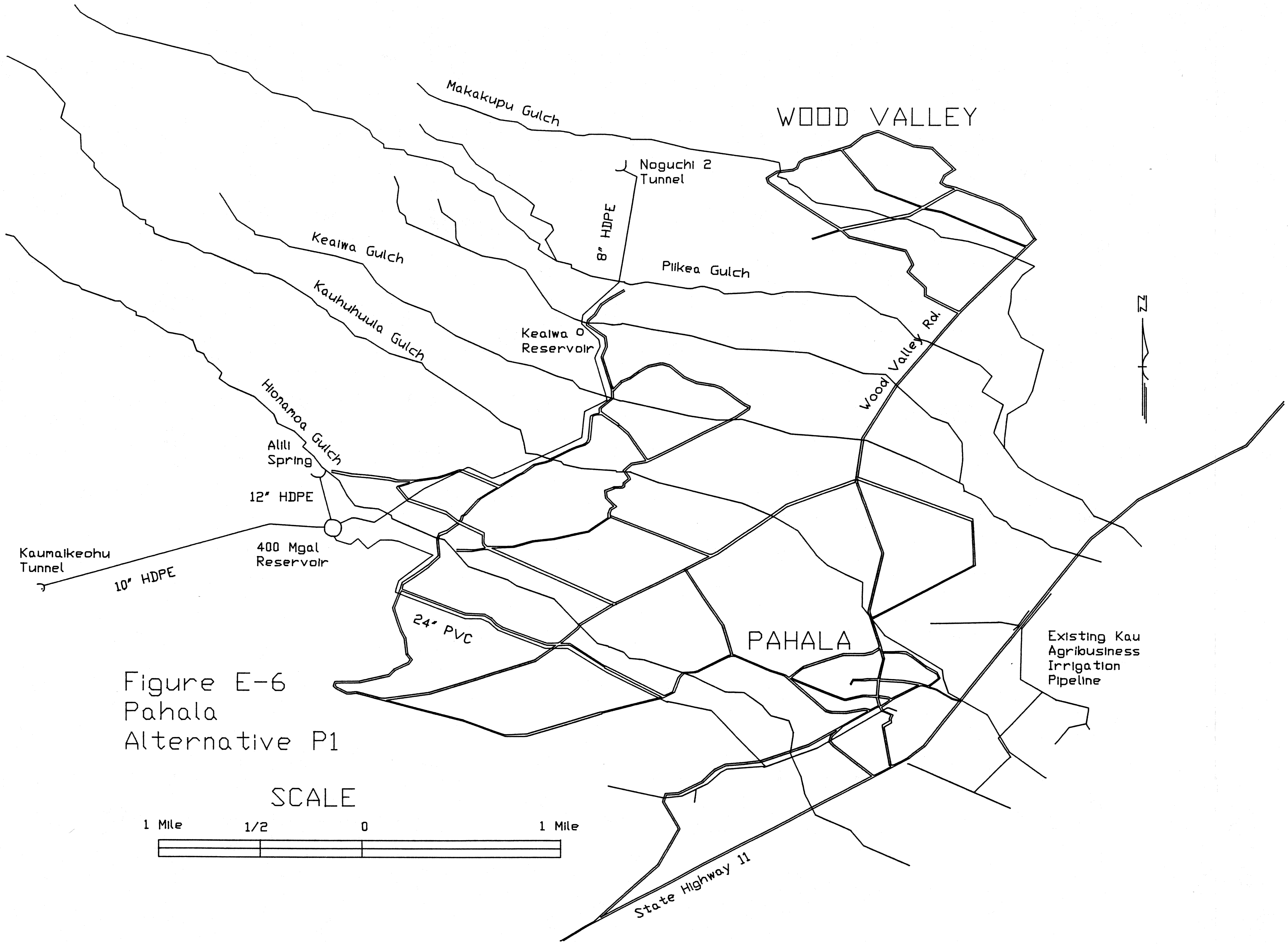


Figure E-6
Pahala
Alternative P1

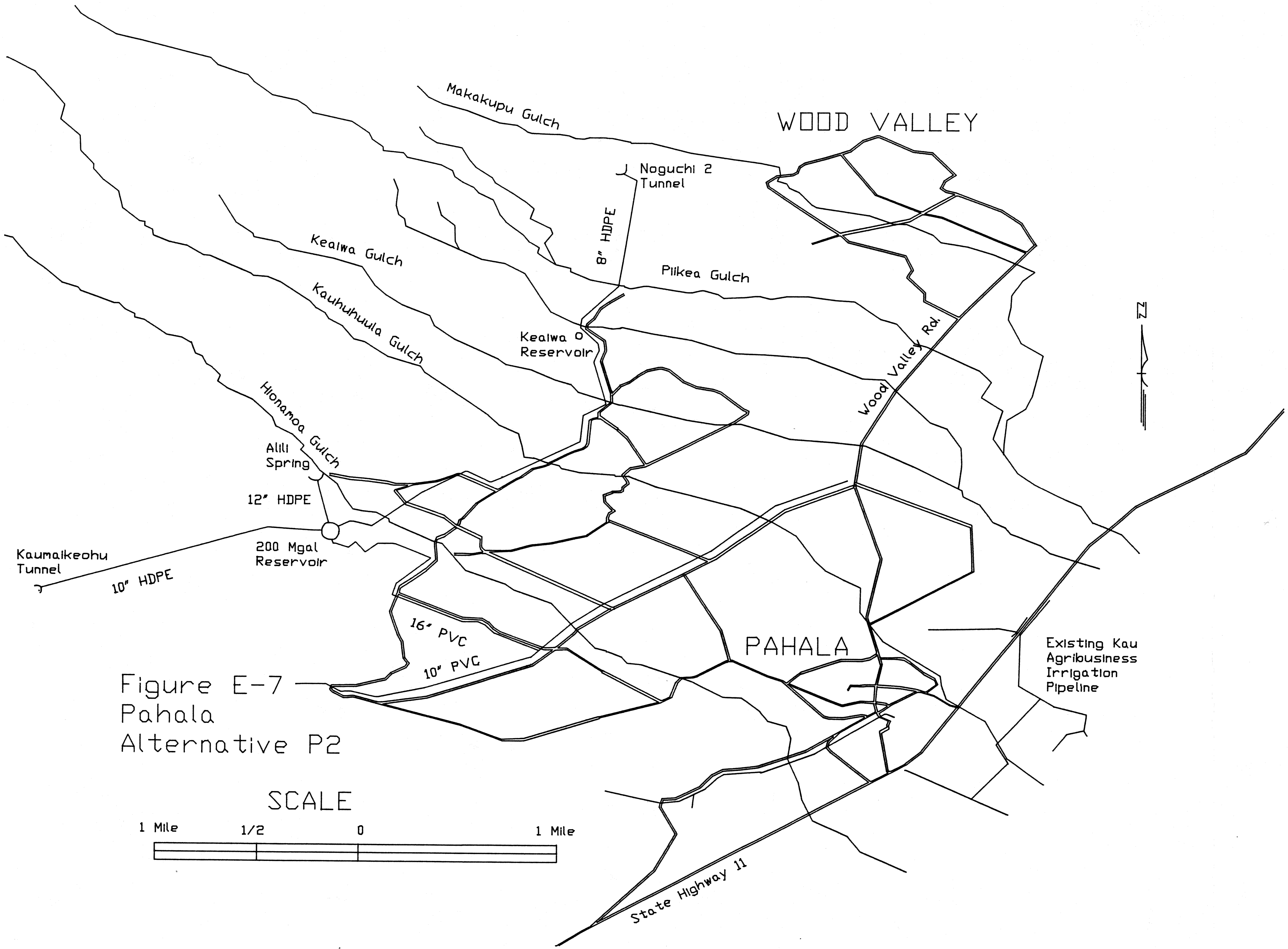


Figure E-7
Pahala
Alternative P2

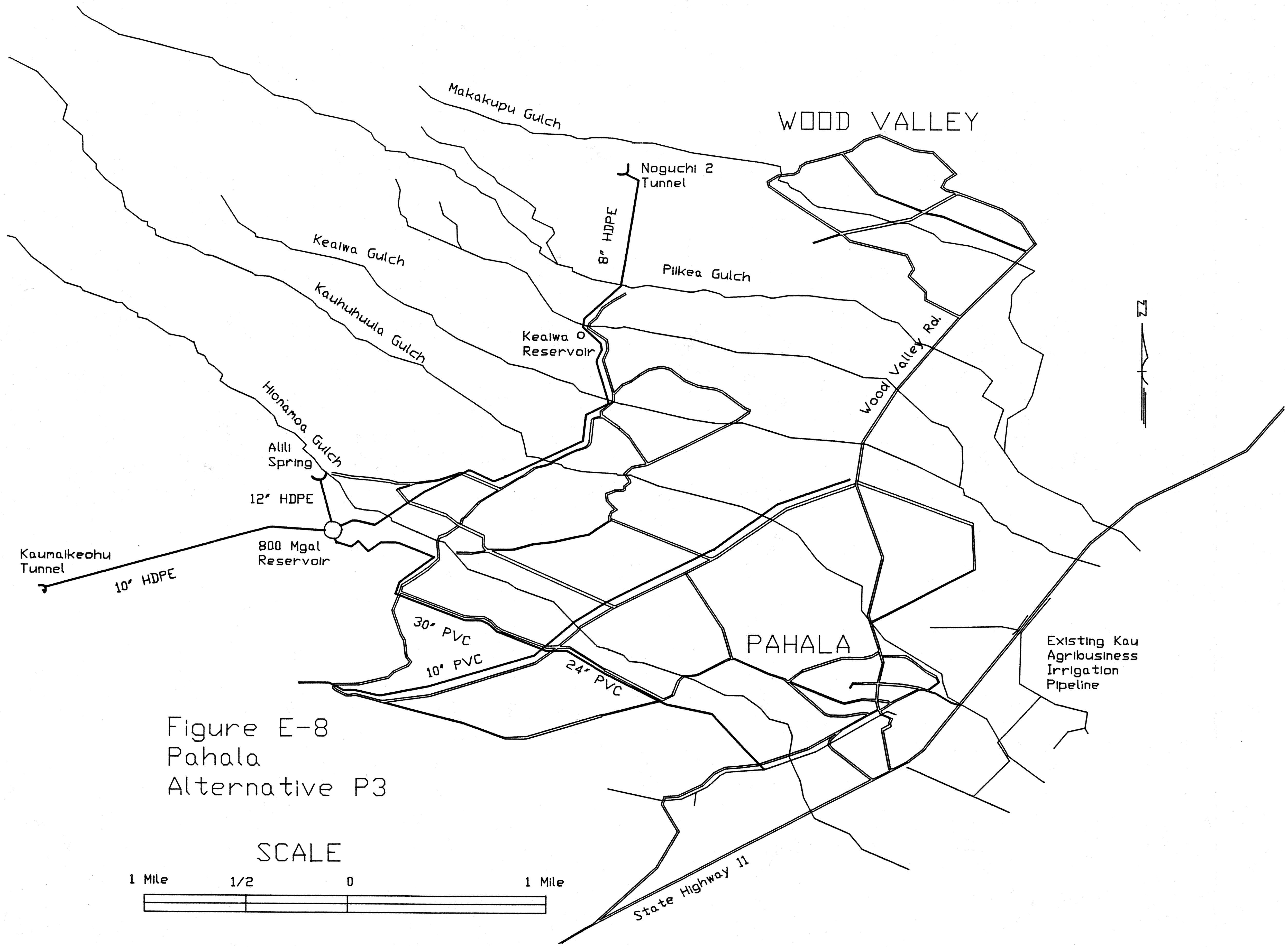


Figure E-8
Pahala
Alternative P3

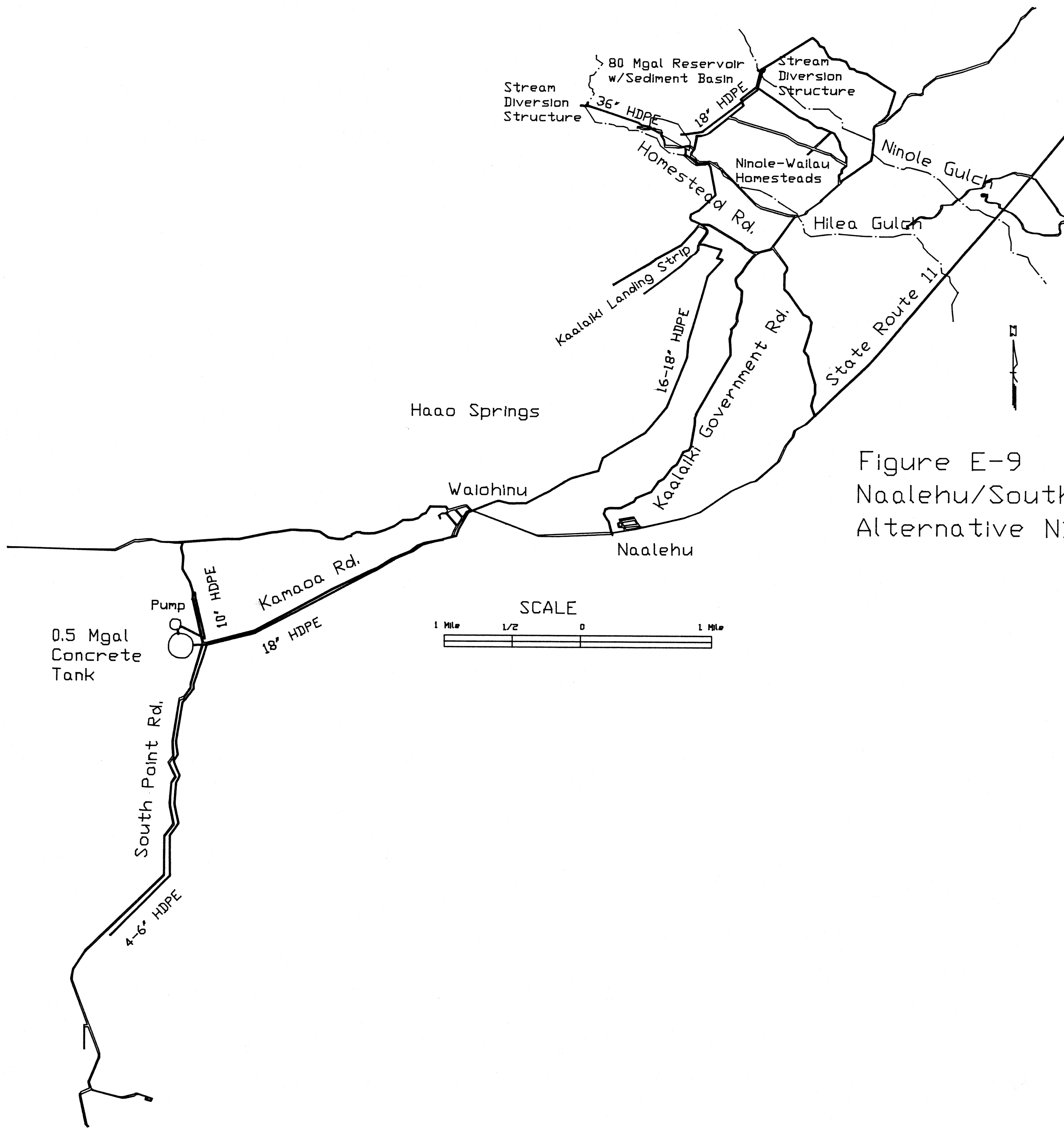


Figure E-9
Naalehu/South Point
Alternative N1

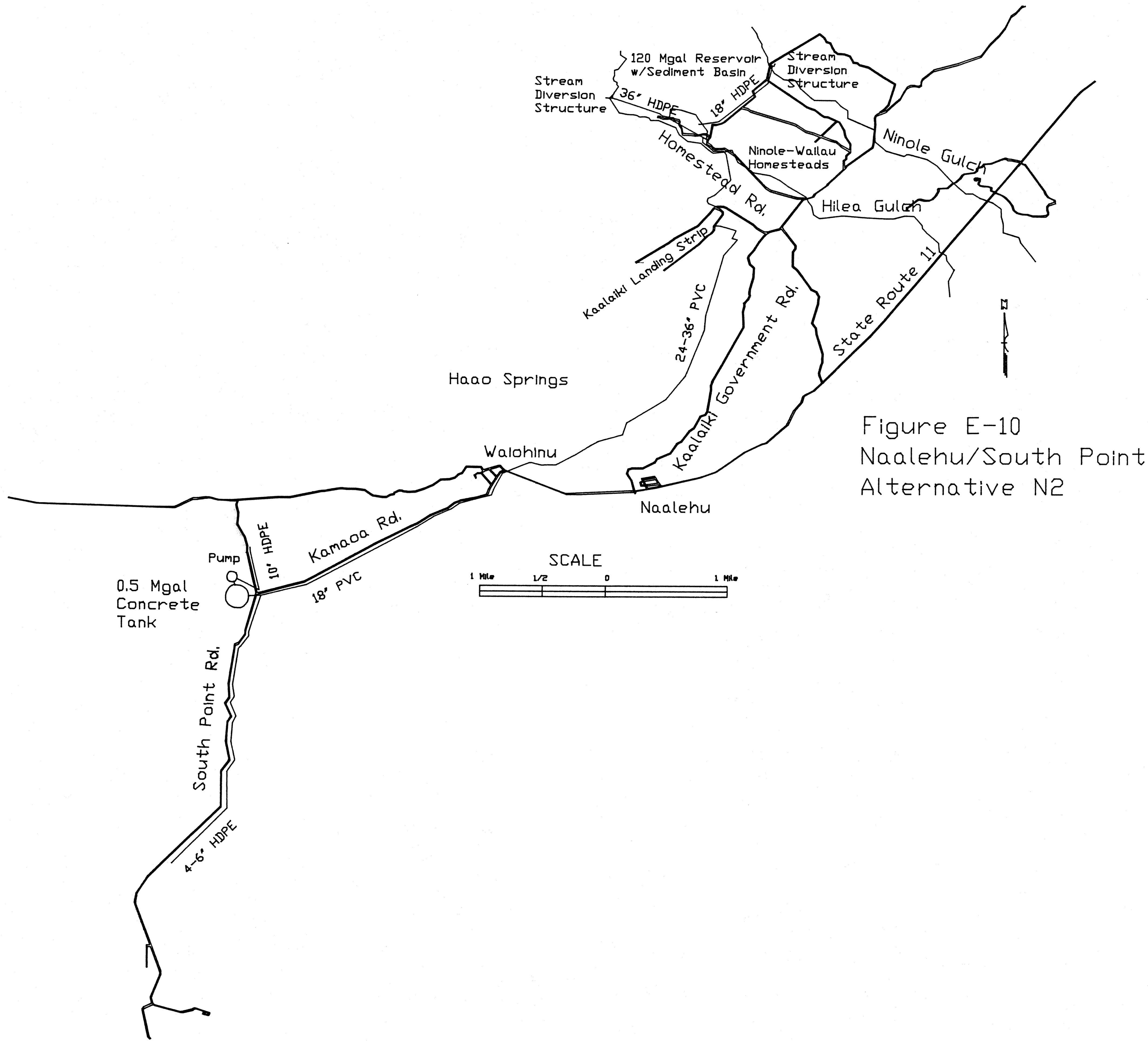


Figure E-10
Naalehu/South Point
Alternative N2

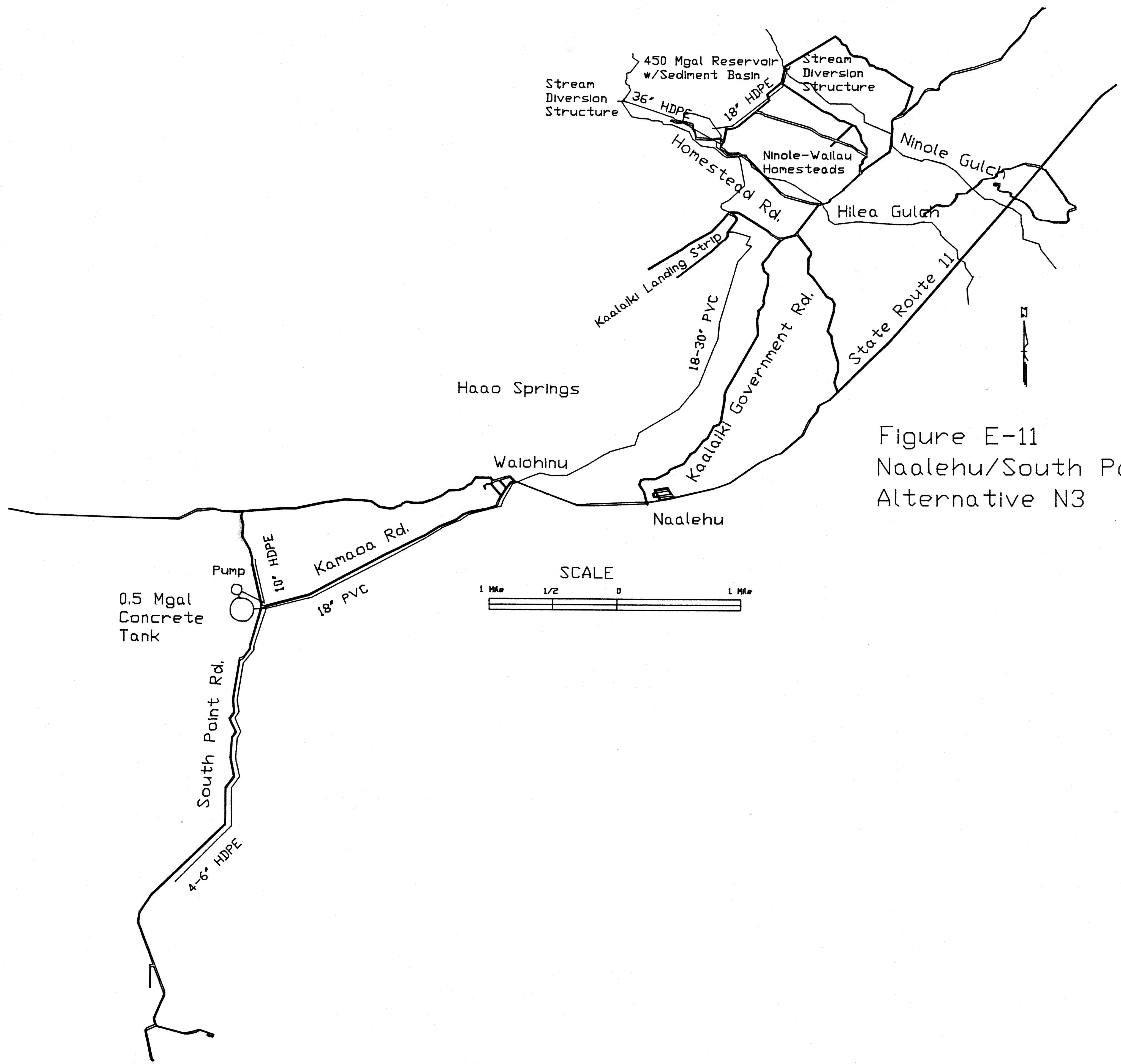


Figure E-11
Naalehu/South Point
Alternative N3

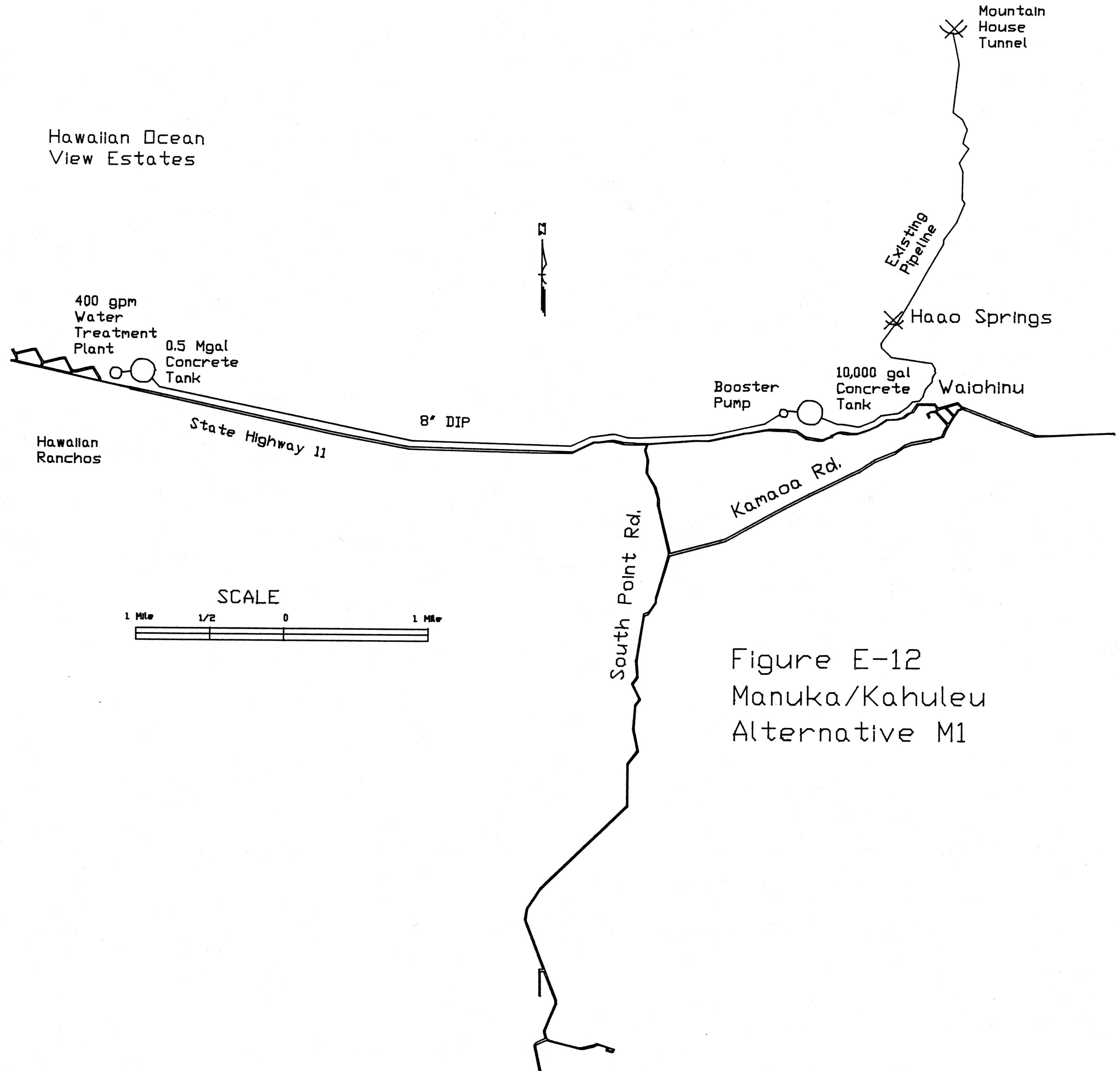


Figure E-12
Manuka/Kahuleu
Alternative M1

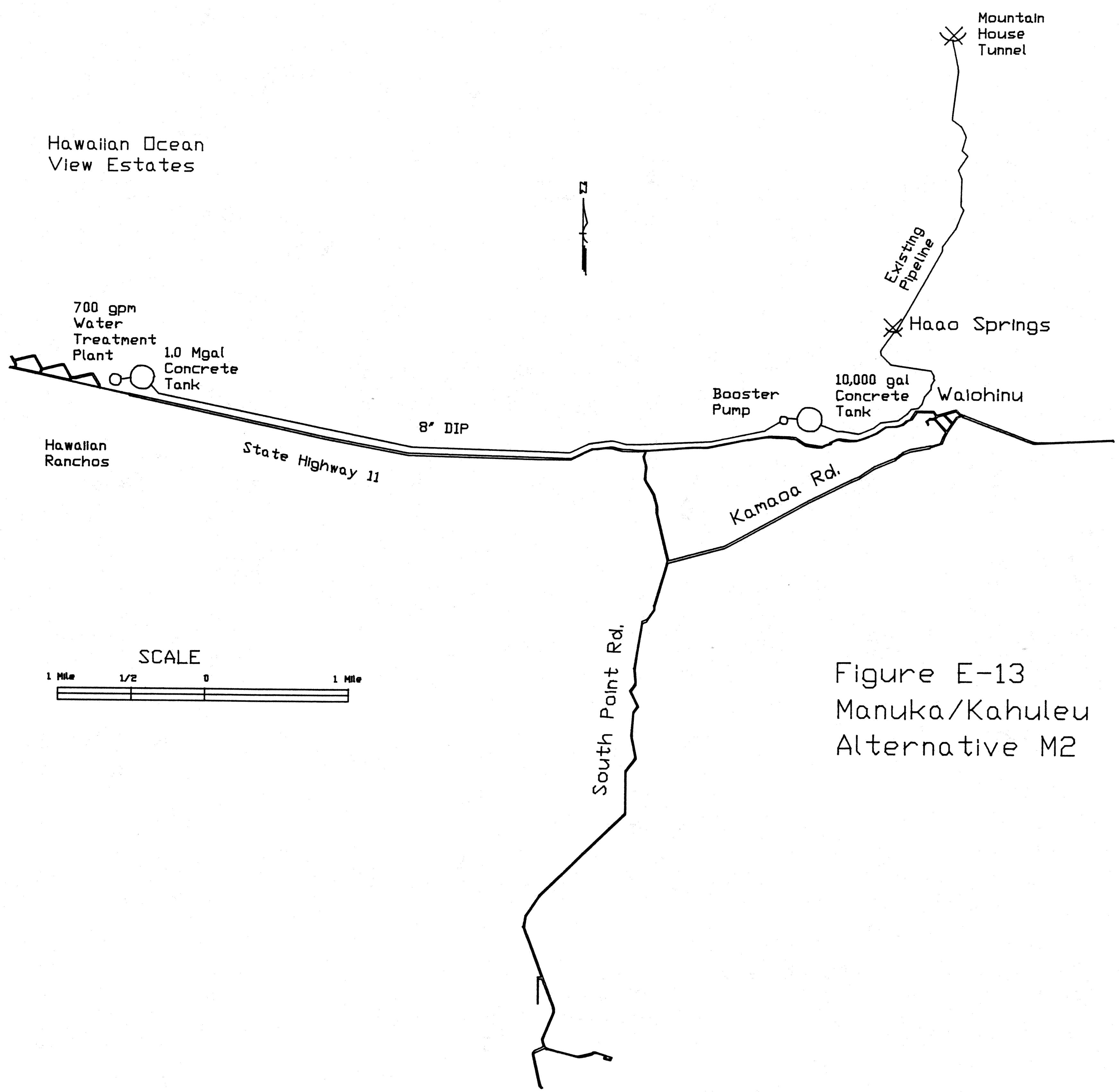


Figure E-13
Manuka/Kahuleu
Alternative M2