Instream Flow Standard Assessment Report

Island of Maui
Hydrologic Unit 6055
Waiokamilo

March 2008 ***PUBLIC REVIEW DRAFT***

State of Hawaii
Department of Land and Natural Resources
Commission on Water Resource Management

COVER
Waiokamilo Stream meets the Pacific Ocean in the terminal Waiokilo Falls in the lower section of the photo. The hydrologic unit spans from Pauwalu Point (top center), with Mokumana Islet just offshore, to the midway point between Waiokilo Falls and the mouth of Wailuanui Stream (not shown) [Google Earth, 2008].

Note: This report is intended for both print and electronic dissemination and does not include diacritical marks in spelling of Hawaiian words, names, and place names due to problems associated with its use electronically. However, Commission staff has made attempts to include diacritical marks in direct quotations to preserve accuracy.

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Acronyms and Abbreviations

A&B	Alexander & Baldwin
AG	agricultural
ALISH	Agricultural Lands of Importance to the State of Hawaii
ALUM	agricultural land use maps [prepared by HDOA]
BFQ	base flow statistics
BLNR	Board of Land and Natural Resources (State of Hawaii)
C-CAP	Coastal Change Analysis Program
cfs	cubic feet per second
Code	State Water Code (State of Hawaii)
COM	commercial
Commission	Commission on Water Resource Management (DLNR)
CRAMP	Coral Reef Assessment & Monitoring Program
CWA	Clean Water Act (EPA)
CWRM	Commission on Water Resource Management
DBEDT	Department of Business, Economic Development & Tourism (State of Hawaii)
DLNR	Department of Land and Natural Resources (State of Hawaii)
DOH	Department of Health (State of Hawaii)
DWS	Department of Water Supply (County of Maui)
EMI	East Maui Irrigation Company
EMWP	East Maui Watershed Partnership
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency (Department of Homeland Security)
FILEREF	File Reference [in the Commission's records of registered diversions]
ft	feet
gad	gallons per acre per day
GIS	Geographic Information Systems
G.L.	Government Lease
GOV	government
gpm	gallons per minute
Gr.	Grant
HAR	Hawaii Administrative Rules
HC&S	Hawaiian Commercial and Sugar Company
HDOA	State Department of Agriculture (State of Hawaii)
HI-GAP	Hawaii Gap Analysis Program
HOT	hotel
HRS	Hawaii Revised Statutes
HSA	Hawaii Stream Assessment
IFS	instream flow standard
IFSAR	Instream Flow Standard Assessment Report
IND	industry
LCA	Land Commission Award
LCL	lower confidence level
LUC	Land Use Commission (State of Hawaii)
MECO	Maui Electric Company
MF	multi-family residential
mgd	million gallons per day
mi	mile
MLP	Maui Land and Pineapple Company, Inc.
MOU	Memorandum of Understanding
na	not available
NAWQA	National Water Quality Assessment (USGS)
NPV	Net Present Value

NVCS	National Vegetation Classification System
REL	religious
SCS	Soil Conservation Service (United States Department of Agriculture) Note: The SCS is now called the Natural Resources Conservation Service (NRCS)
SF	single family residential
SPI	Standardized Precipitation Index
sq mi	square miles
TFQ	total flow statistics
TFQ_{50}	50 percent exceedence probability (flow that is equaled or exceeded 50 percent of the time)
TFQ_{90}	90 percent exceedence probability
TMK	Tax Map Key
UCL	upper confidence level
UHERO	University of Hawaii's Economic Research Organization
USFWS	United States Fish and Wildlife Service (Department of the Interior)
USGS	United States Geological Survey (Department of the Interior)
WQS	Water Quality Standards
WRPP	Water Resource Protection Plan (Commission on Water Resource Management)
WTF	water treatment facility

1.0 Introduction

General Overview

The hydrologic unit of Waiokamilo is located on the northeast slope of the East Maui Volcano (Haleakala), which forms the eastern part of the Hawaiian island of Maui (Figure 1-3). It covers an area of 2.45 square miles from the slopes of Haleakala at 4,891 feet elevation to the sea. The topography is gently sloping except for the steep sides of the Keanae Valley walls that are nearly 1,000 feet high (Gingerich, 2005). Waiokamilo Stream is 4.4 miles in length, traversing in a northeasterly direction from its headwaters originating in the Koolau Forest Reserve to Waiokilo Falls before entering the ocean. Tributary to the Waiokamilo Stream is Kualani Stream, which is 2.1 miles in length. Most of the hydrologic unit is made up of forest reserves that cover slopes down to about 700 feet. The lower elevations are occupied by grasses and shrubs with very few cultivated lands. There is no major village within the unit, making population relatively small – about 181 people (Coral Reef Assessment and Monitoring Program, 2007).

Current Instream Flow Standard

The current interim instream flow standard (IFS) for Waiokamilo Stream was established by way of Hawaii Administrative Rules (HAR) §13-169-44, which, in pertinent part, reads as follows:

> Interim instream flow standard for East Maui. The Interim Instream Flow Standard for all streams on East Maui, as adopted by the commission on water resource management on June 15, 1988, shall be that amount of water flowing in each stream on the effective date of this standard, and as that flow may naturally vary throughout the year and from year to year without further amounts of water being diverted offstream through new or expanded diversions, and under the stream conditions existing on the effective date of the standard.

The current interim IFS became effective on October 8, 1988. Streamflow was not measured on that date; therefore, the current interim IFS is not a measurable value.

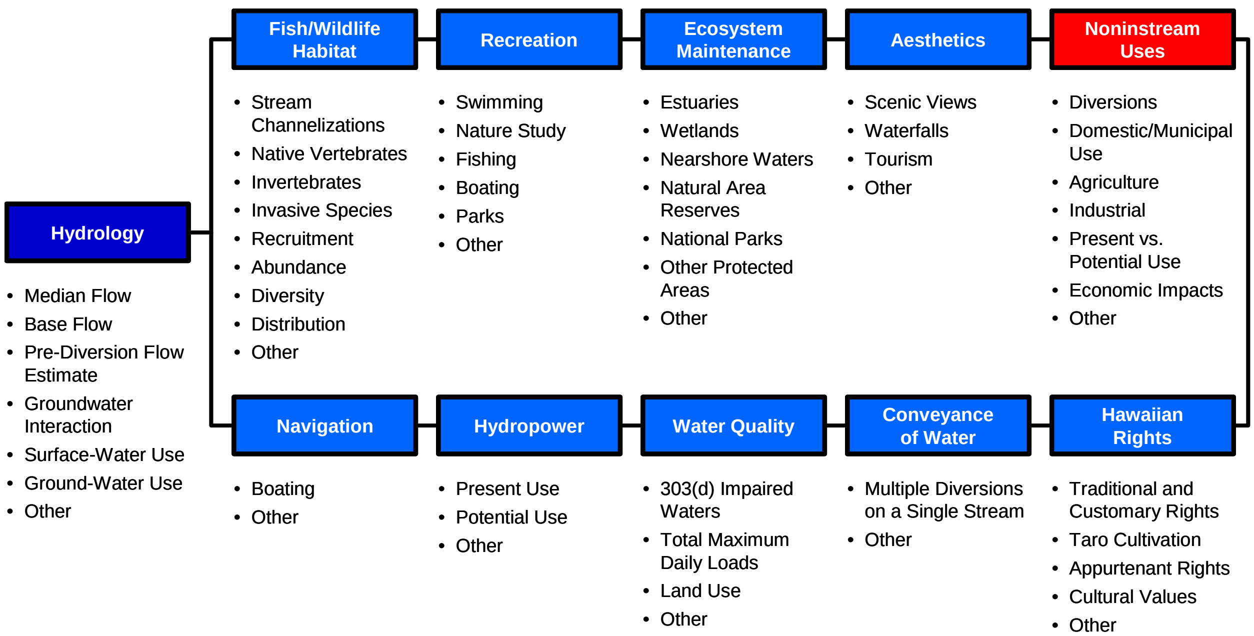
Instream Flow Standards

Under the State Water Code (Code), Chapter 174C, Hawaii Revised Statutes (HRS), the Commission on Water Resource Management (Commission) has the responsibility of establishing IFS on a stream-by-stream basis whenever necessary to protect the public interest in the waters of the State. Early in its history, the Commission recognized the complexity of establishing IFS for the State's estimated 376 perennial streams and instead set interim IFS at "status quo" levels. These interim IFS were defined as the amount of water flowing in each stream (with consideration for the natural variability in stream flow and conditions) at the time the administrative rules governing them were adopted in 1988 and 1989.

The Hawaii Supreme Court, upon reviewing the Waiahole Ditch Contested Case Decision and Order, held that such "status quo" interim IFS were not adequate to protect streams and required the Commission to take immediate steps to assess stream flow characteristics and develop quantitative interim IFS for affected windward Oahu streams, as well as other streams statewide. The Hawaii Supreme Court also emphasized that "instream flow standards serve as the primary mechanism by which the Commission is to discharge its duty to protect and promote the entire range of public trust purposes dependent upon instream flows."

To the casual observer, IFS may appear relatively simple to establish upon a basic review of the Code provisions. However, the complex nature of IFS becomes apparent upon further review of the individual components that comprise surface water hydrology, instream uses, noninstream uses, and their interrelationships. The Commission has the distinct responsibility of weighing competing uses for a limited resource in a legal realm that is continuing to evolve. The following illustration (Figure 1-1) was developed to illustrate the wide range of information, in relation to hydrology, instream uses, and noninstream uses that should be addressed in conducting a comprehensive IFS assessment.

Figure 1-1. Information to consider in setting measurable instream flow standards.

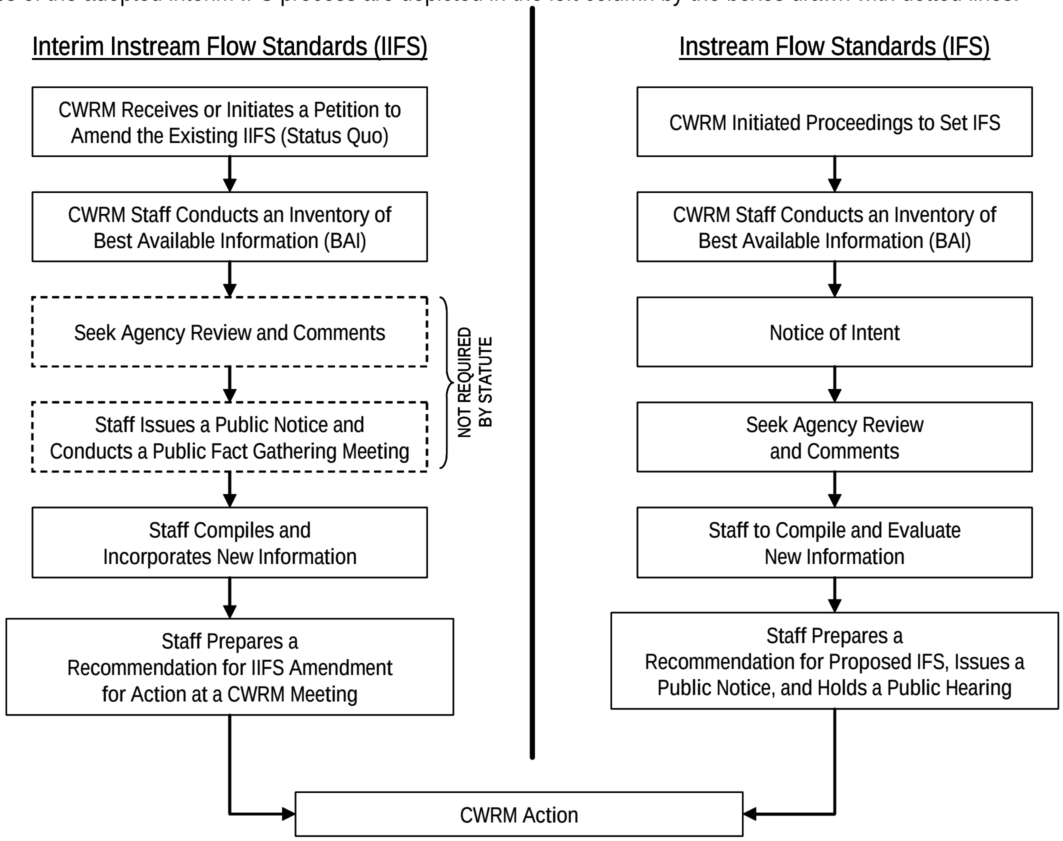


Interim Instream Flow Standard Process

The Code provides for a process to amend an interim IFS in order to protect the public interest pending the establishment of a permanent IFS. The Code, at §174C-71(2), describes this process including the role of the Commission to "weigh the importance of the present or potential instream values with the importance of the present or potential uses of water for noninstream purposes, including the economic impact of restricting such uses."

Recognizing the complexity of establishing measurable IFS, while cognizant of the Hawaii Supreme Court's mandate to designate interim IFS based on best available information under the Waiahole Combined Contested Case, the Commission at its December 13, 2006 meeting authorized staff to initiate and conduct public fact gathering. Under this adopted process (reflected in the left column of Figure 1-2), the Commission staff will conduct a preliminary inventory of best available information upon receipt of a petition to amend an existing interim IFS. The Commission staff shall then seek agency review and comments on the compiled information (compiled in an Instream Flow Standard Assessment Report) in conjunction with issuing a public notice for a public fact gathering meeting. Shortly thereafter (generally within 30 days), the Commission staff will conduct a public fact gathering meeting in, or near, the hydrologic unit of interest.

Figure 1-2. Simplified representation of the interim instream flow standard and permanent instream flow standard processes. Keys steps of the adopted interim IFS process are depicted in the left column by the boxes drawn with dotted lines.



Instream Flow Standard Assessment Report

The Instream Flow Standard Assessment Report (IFSAR) is a compilation of the hydrology, instream uses, and noninstream uses related to a specific stream and its respective surface water hydrologic unit. The report is organized in much the same way as the elements of IFS are depicted in Figure 1-1. The purpose of the IFSAR is to present the best available information for a given hydrologic unit, and to provide IFS recommendations. The IFSAR is intended to act as a living document that should be updated and revised as necessary, thus also serving as a stand-alone document in the event that the Commission receives a subsequent petition solely for the respective hydrologic unit.

Each report begins with an introduction of the subject hydrologic unit and the current IFS status. Section 2.0 is comprised of the various hydrologic unit characteristics that, both directly and indirectly, impact surface water resources. Section 3.0 contains a summary of available hydrologic information, while Sections 4.0 through 12.0 summarize the best available information for the nine instream uses as defined by the Code. Noninstream uses are summarized in Section 13.0. Maps are provided at the end of each section to help illustrate information presented within the section's text or tables. Finally, Section 14.0 provides a comprehensive listing of cited references and is intended to offer readers the opportunity to review IFSAR references in further detail.

Following the preparation of the IFSAR and initial agency and public review, information may be added to the IFSAR at any time. Dates of revision will be reflected as such. Future review of the IFSAR, by agencies and the public, will only be sought when a new petition to amend the interim (or permanent) instream flow standard is pending. Recommendations for IFS amendments shall be prepared separately as another stand-alone document. Thus, the IFSAR acts solely as a compendium of best available information and may be revised further without the need for subsequent public review following its initial preparation.

Surface Water Hydrologic Units

Early efforts to update the Commission's Water Resource Protection Plan (WRPP) highlighted the need for surface water hydrologic units to delineate and codify Hawaii's surface water resources. Surface water hydrologic units served as an important first-step towards improving the organization and management of surface water information that the Commission collects and maintains, including diversions, stream channel alterations, and water use.

In developing the surface water hydrologic units, the Commission staff reviewed various reports to arrive at a coding system that could meet the requirements for organizing and managing surface water information in a database environment, and could be easily understood by the general public and other agencies. For all intents and purposes, surface water hydrologic units are synonymous with watershed areas. Though Commission staff recognized that while instream uses may generally fall within a true surface drainage area, noninstream uses tend to be land-based and therefore may not always fall within the same drainage area.

In June 2005, the Commission adopted the report on surface water hydrologic units and authorized staff to implement its use in the development of information databases in support of establishing IFS (Commission on Water Resource Management, 2005a). The result is a surface water hydrologic unit code that is a unique combination of four digits. This code appears on the cover of each IFSAR above the hydrologic unit name.

Surface Water Definitions

Listed below are the most commonly referenced surface water terms as defined by the Code.

Agricultural use. The use of water for the growing, processing, and treating of crops, livestock, aquatic plants and animals, and ornamental flowers and similar foliage.

Channel alteration. (1) To obstruct, diminish, destroy, modify, or relocate a stream channel; (2) To change the direction of flow of water in a stream channel; (3) To place any material or structures in a stream channel; and (4) To remove any material or structures from a stream channel.

Continuous flowing water. A sufficient flow of water that could provide for migration and movement of fish, and includes those reaches of streams which, in their natural state, normally go dry seasonally at the location of the proposed alteration.

Domestic use. Any use of water for individual personal needs and for household purposes such as drinking, bathing, heating, cooking, noncommercial gardening, and sanitation.

Ground water. Any water found beneath the surface of the earth, whether in perched supply, dike-confined, flowing, or percolating in underground channels or streams, under artesian pressure or not, or otherwise.

Hydrologic unit. A surface drainage area or a ground water basin or a combination of the two.

Impoundment. Any lake, reservoir, pond, or other containment of surface water occupying a bed or depression in the earth's surface and having a discernible shoreline.

Instream Flow Standard. A quantity of flow of water or depth of water which is required to be present at a specific location in a stream system at certain specified times of the year to protect fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses.

Instream use. Beneficial uses of stream water for significant purposes which are located in the stream and which are achieved by leaving the water in the stream. Instream uses include, but are not limited to:

(1) Maintenance of fish and wildlife habitats;
(2) Outdoor recreational activities;
(3) Maintenance of ecosystems such as estuaries, wetlands, and stream vegetation;
(4) Aesthetic values such as waterfalls and scenic waterways;
(5) Navigation;
(6) Instream hydropower generation;
(7) Maintenance of water quality;
(8) The conveyance of irrigation and domestic water supplies to downstream points of diversion; and
(9) The protection of traditional and customary Hawaiian rights.

Interim instream flow standard. A temporary instream flow standard of immediate applicability, adopted by the Commission without the necessity of a public hearing, and terminating upon the establishment of an instream flow standard.

Municipal use. The domestic, industrial, and commercial use of water through public services available to persons of a county for the promotion and protection of their health, comfort, and safety, for the protection of property from fire, and for the purposes listed under the term "domestic use"

Noninstream use. The use of stream water that is diverted or removed from its stream channel and includes the use of stream water outside of the channel for domestic, agricultural, and industrial purposes.

Reasonable-beneficial use. The use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is both reasonable and consistent with the state and county land use plans and the public interest.

Stream. Any river, creek, slough, or natural watercourse in which water usually flows in a defined bed or channel. It is not essential that the flowing be uniform or uninterrupted. The fact that some parts of the bed or channel have been dredged or improved does not prevent the watercourse from being a stream.

Stream channel. A natural or artificial watercourse with a definite bed and banks which periodically or continuously contains flowing water. The channel referred to is that which exists at the present time, regardless of where the channel may have been located at any time in the past.

Stream diversion. The act of removing water from a stream into a channel, pipeline, or other conduit.

Stream reach. A segment of a stream channel having a defined upstream and downstream point.

Stream system. The aggregate of water features comprising or associated with a stream, including the stream itself and its tributaries, headwaters, ponds, wetlands, and estuary.

Surface water. Both contained surface water--that is, water upon the surface of the earth in bounds created naturally or artificially including, but not limited to, streams, other watercourses, lakes, reservoirs, and coastal waters subject to state jurisdiction--and diffused surface water--that is, water occurring upon the surface of the ground other than in contained water bodies. Water from natural springs is surface water when it exits from the spring onto the earth's surface.

Sustainable yield. The maximum rate at which water may be withdrawn from a water source without impairing the utility or quality of the water source as determined by the Commission.

Time of withdrawal or diversion. In view of the nature, manner, and purposes of a reasonable and beneficial use of water, the most accurate method of describing the time when the water is withdrawn or diverted, including description in terms of hours, days, weeks, months, or physical, operational, or other conditions.

Watercourse. A stream and any canal, ditch, or other artificial watercourse in which water usually flows in a defined bed or channel. It is not essential that the flowing be uniform or uninterrupted.

Figure 1-3. Topographic map of the Waiokamilo hydrologic unit in east Maui, Hawaii (Source: U.S. Geological Survey, 1996).

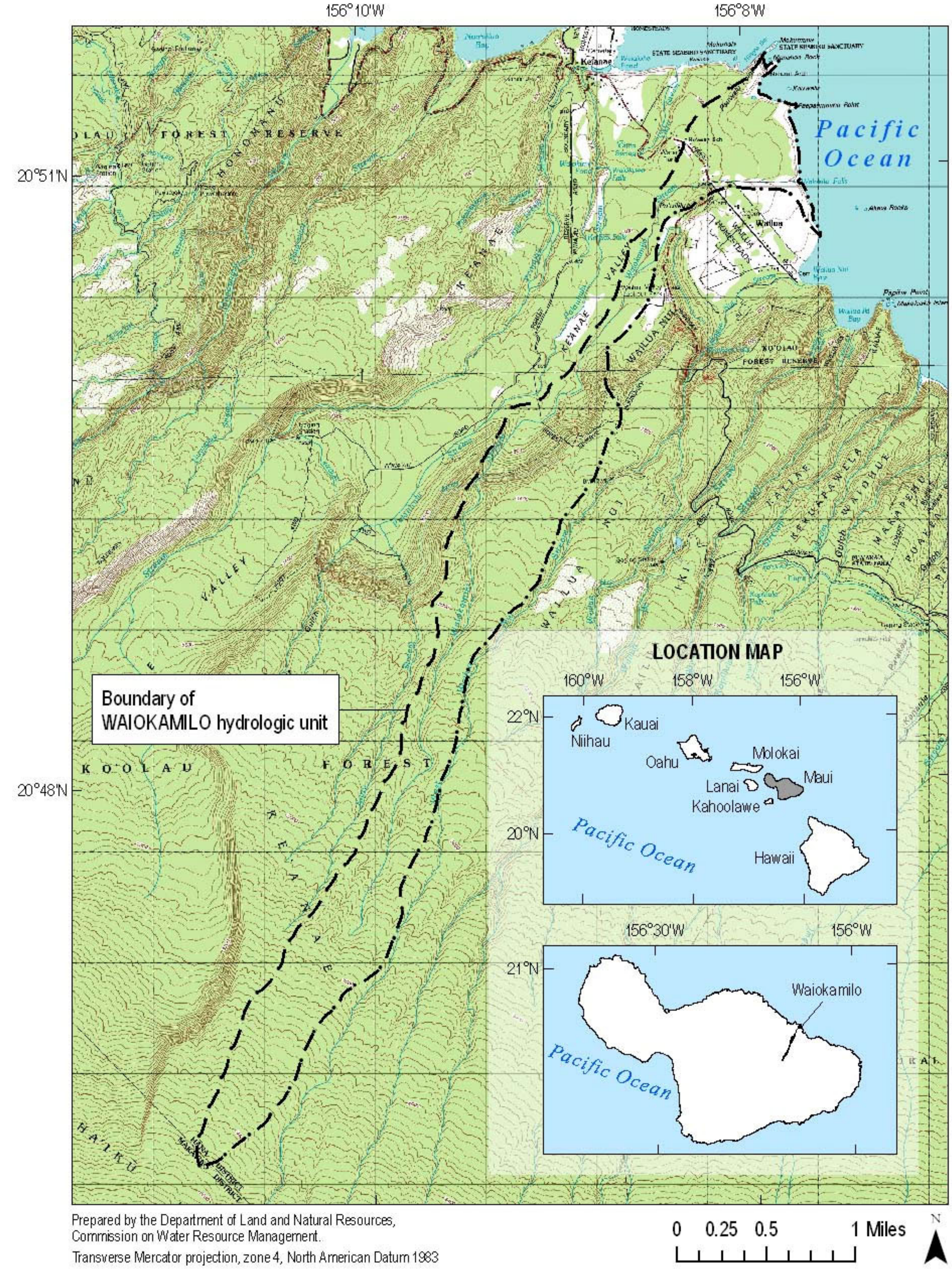


Figure 1-4. Elevation range and the location of Waiokamilo hydrologic unit. (Source: State of Hawaii, Office of Planning, 1983).

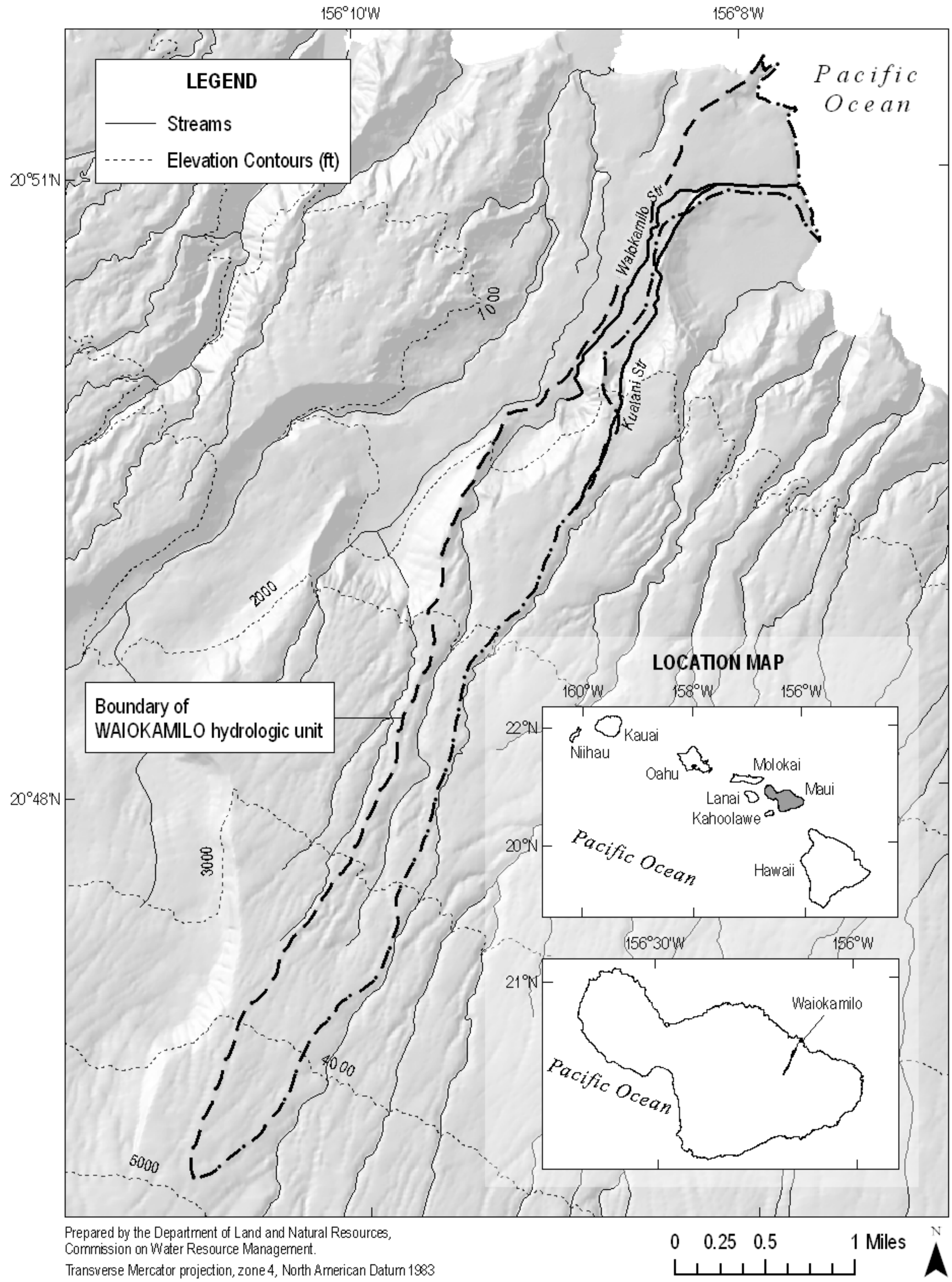


Figure 1-5. Major and minor roads and Tax Map Key (TMK) parcel boundaries for Waiokamilo hydrologic unit (Source: County of Maui, 2006; County of Maui, Geographic Information Systems [GIS] Division, Department of Management, 2006).

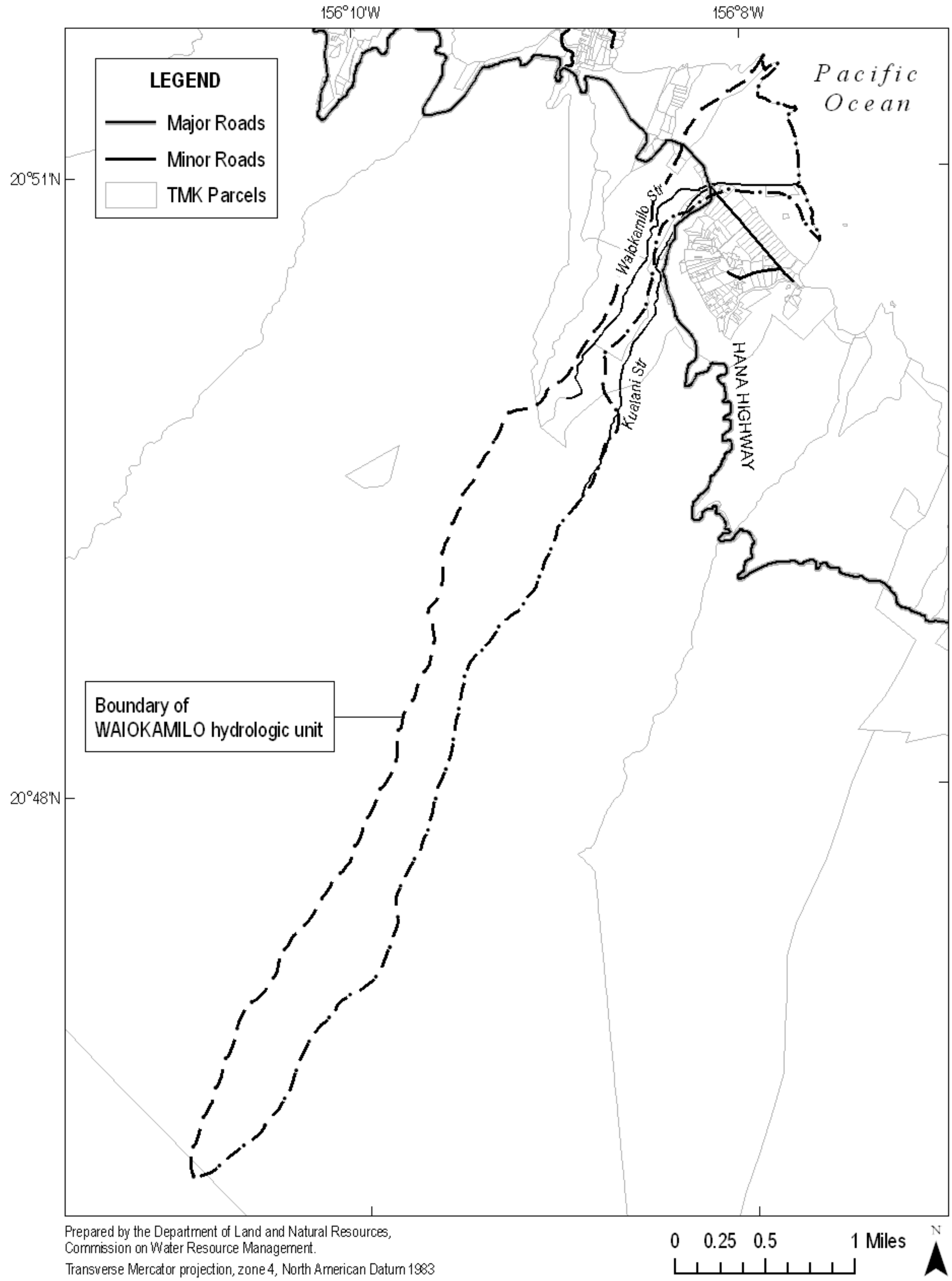
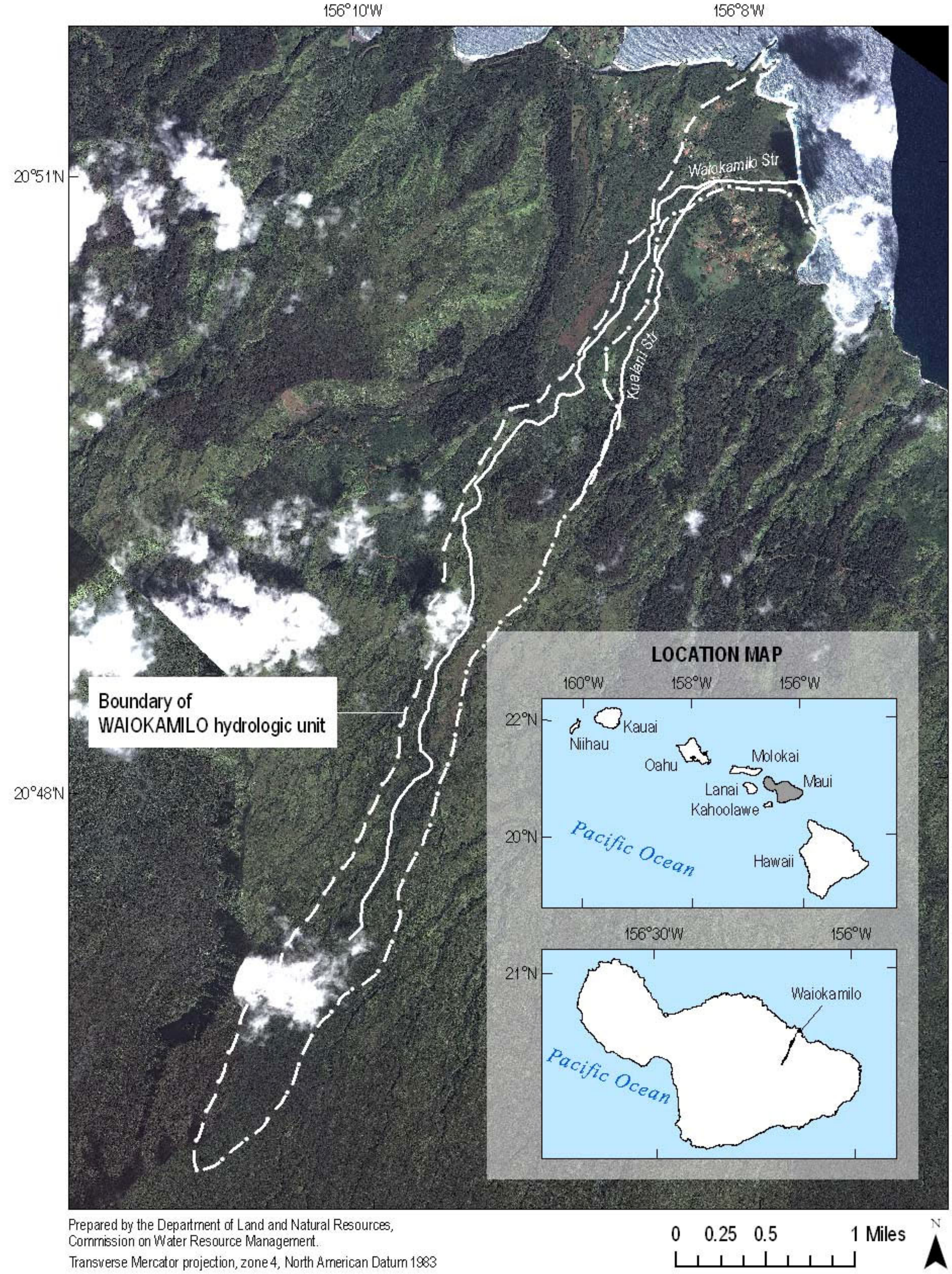


Figure 1-6. Quickbird satellite imagery of Waiokamilo hydrologic unit (Source: County of Maui, Planning Department, 2004).



2.0 Unit Characteristics

Geology

Most of the Waiokamilo hydrologic unit's surface geology consists of fairly permeable[1] to very permeable basalts, meaning that water moves easily through the rock. Thus, once rainwater penetrates the groundcover and passes through the soil into the rock below, it will flow quickly into streams and into the ground water aquifer. The older, Kula volcanics are fairly permeable and may contain perched[2] water if there are layers that the water cannot penetrate. Nearly 42 percent of the surface geology of the hydrologic unit consists of Kula volcanics. A small area of the hydrologic unit – just under 5 percent – is made up of exposed Honomanu basalt. The Honomanu volcanic series, which predates the Kula volcanics, is believed to form the basement of the entire Haleakala mountain to an unknown depth below sea level. The Honomanu volcanics are predominantly pahoehoe (lava characterized by a smooth or ropy surface with variable interior, including lava tubes and other voids), in flows ranging from 10 to 75 feet think and are very vesicular. The Honomanu basalts are extremely permeable and yield water freely. Almost half the hydrologic unit consists of Hana volcanics. Younger than the other basalts, the Hana volcanics are so permeable that most of the rain that sinks into them continues downward to the older rocks below. The lowlands section of the hydrologic unit includes younger flows of the Hana volcanic series; most of these are highly permeable as well, and springs may issue from them. There are some alluvial deposits (soil, gravel, etc.), particularly along streams and at the coastal part of the hydrologic unit. These make up 4.5 percent of the hydrologic unit. The more seaward of these is not highly permeable. The generalized geology of the Waiokamilo hydrologic unit is depicted in Figure 2-3.

Table 2-1. Area and percentage of surface geologic features for Waiokamilo hydrologic unit.

Symbol	Name	Rock Type	Lithology	Area (mi^2)	Percent of Unit
Qa	Alluvium	Sand and gravel	Cobble to sand, moderately sorted	0.02	1.0
Qbd	Beach deposits	Sand and gravel		0.00	0.1
Qhn0	Hana Volcanics	Lava flows	Aa	0.23	9.3
Qhn1	Hana Volcanics	Lava flows	Aa	0.37	15.2
Qhn6	Hana Volcanics	Lava flows	Aa	0.59	24
Qmnl	Honomanu Basalt	Lava flows	Pahoehoe and aa	0.12	4.9
Qkul	Kula Volcanics	Lava flows	Aa and pahoehoe	0.01	0.4
Qkul	Kula Volcanics	Lava flows	Aa and pahoehoe	1.01	41.4
QTao	Older alluvium	Sand and gravel, lithified		0.08	3.4

Soils

The soils of the Waiokamilo hydrologic unit are generally good for water supply as they are mostly well-drained, permeable soils. The uplands of the hydrologic unit consist of soils developed in volcanic ash and material weathered from cinders and basic igneous rock. They absorb water and transmit it rapidly. These soils are not good for engineering or agricultural uses.

Soils in the central section of the hydrologic unit consist of silty clay and rock land, and are fairly steep and well-drained (i.e. water drains through it easily). Permeability is moderately rapid, runoff is slow, and the erosion hazard is slight.

[1] Permeability is the ease with which water passes through material. It is a factor in determining whether precipitation runs off on the surface or descends into the ground.
[2] Perched water is water confined by an impermeable or slowly permeable barrier.

Much of the lowlands of the hydrologic unit consist of stones, boulders, and soil deposited by streams along the bottoms of gulches and on alluvial fans (fan-shaped deposits of sediment at the mouth of a valley). There are small areas of a well-drained clay with moderately rapid permeability, slow to medium runoff, and a slight to moderate erosion hazard. There is a small area of poorly drained soils (i.e. soil that is wet for long periods) that are periodically flooded by irrigation in order to grow crops that thrive in water (e.g. taro and rice).

The U.S. Department of Agriculture's Natural Resources Conservation Service (formerly known as the Soil Conservation Service) divides soils into hydrologic soil groups (A, B, C, and D) according to the rate at which infiltration (intake of water) occurs when the soil is wet. The higher the infiltration rate, the faster the water is absorbed into the ground and the less there is to flow as surface runoff. Group A soils have the highest infiltration rates; group D soils have the lowest. In the Waiokamilo hydrologic unit, 32.1 percent of soils are group A; 51.1 percent group B; and 15.7 percent group D. This means that more than ¾ of the hydrologic unit's soils have moderate or high infiltration rates.

During the field investigation for a study published by Gingerich (USGS) in 2005, the reach, or section of Waiokamilo Stream below the Koolau Ditch was dry until just below the Akeke spring. The spring then feeds the stream, but much of the remainder of the stream downhill from there is a "losing" stream, that is, losing water by seepage into the ground. The study did not determine if the stream uphill of the ditch is "gaining" (the flow increases from seepage from ground water or springs in or alongside the channel) or losing. The losing reaches are mostly in an area where the soil is classified as group A, i.e. having a high infiltration rate (Figure 2-4). Waiokamilo Stream's hydrology is discussed in detail in Section 3.0, Hydrology.

Table 2-2. Area and percentage of soil types for the Waiokamilo hydrologic unit.

Map Unit	Description	Area (mi^2)	Percent of Unit
HwC	Honolua silty clay, 7 to 15 percent slopes	0.04	1.5
KBID	Kailua silty clay, 3 to 25 percent slopes	0.03	1.4
TR	Tropaquepts	0.03	1.3
rHOD	Honomanu silty clay, 5 to 25 percent slopes	0.28	11.6
rHT	Hydrandepts-Tropaquods association	1.21	49.6
rRT	Rough mountainous land	0.35	14.4
rSM	Stony alluvial land	0.47	19.1

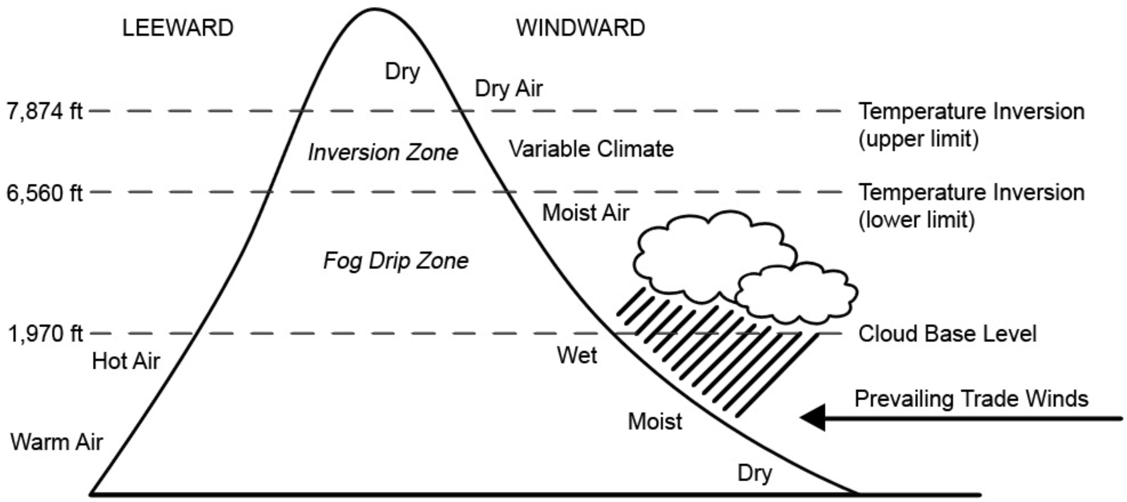
Rainfall

Rainfall distribution in Waiokamilo is governed by the orographic[3] effect (Figure 2-1). Orographic precipitation occurs when the prevailing northeasterly trade winds lift warm air up the windward side of the mountains into higher elevations where cooler temperatures persist. As a result, frequent and heavy rainfall is observed at the windward mountain slopes. Once the moist air reaches the fog drip zone, cloud height is restricted by the temperature inversion, where temperature increases with elevation, thus favoring fog drip over rain-drop formation (Shade, 1999). Fog drip is a result of cloud-water droplets impacting vegetation (Scholl et al., 2002) and it can contribute significantly to ground water recharge. The fog drip zone on the windward side of East Maui Volcano (Haleakala) extends from the cloud base level at 1,970 feet to the lower limit of the most frequent temperature inversion base height at 6,560 feet (Giambelluca and Nullet, 1991).

A majority of the mountains in Hawaii peak in the fog drip zone. In such cases, air passes over the mountains, warming and drying while descending the leeward mountain slopes. When the mountains are at elevations higher than 6,000 feet (e.g. Haleakala), climate is affected by the presence and movement of the inversion. The temperature inversion zone typically extends from 6,560 feet to 7,874 feet. This region is influenced by a layer of moist air below and dry air above, making climate extremely variable (Giambelluca and Nullet, 1991). Above the inversion zone, the air is dry and sky is frequently clear (absence of clouds) with high solar radiation, creating an arid atmosphere with little rainfall.

[3] Orographic refers to influences of mountains and mountain ranges on airflow, but also used to describe effects on other meteorological quantities such as temperature, humidity, or precipitation distribution.

Figure 2-1. Orographic precipitation in the presence of mountains higher than 6,000 feet.



The hydrologic unit of Waiokamilo is situated on the windward flank of the East Maui Volcano. The hydrologic unit receives near-daily orographic rainfall ranging from 118 inches per year at the coast to 280 inches per year near the center of the hydrologic unit. This rainfall drops down to 130-150 inches per year in the upper slopes where fog contribution to total rainfall may exceed rain-drop formation (Giambelluca et al, 1986). The high spatial variability in rainfall is evident where the mean annual rainfall decreases by about 34 inches with an average 500 feet drop in elevation in the lower half of the hydrologic unit. Rainfall is highest during the months of March, April, November and December where the mean monthly rainfall across the hydrologic unit is approximately 21-24 inches. In March, rainfall can reach as high as 35 inches in the mountains. For the rest of the year, the mean monthly rainfall ranges from 12 inches to 19 inches. The driest months are May, June and September in which only 4-6 inches of rain fall at the coast.

Currently, fog drip data for east Maui are very limited. Shade (1999) used the monthly fog drip to rainfall ratios for the windward slopes of Mauna Loa on the island of Hawaii (Table 2-3) to calculate fog drip contribution to the water-budget in windward east Maui. The fog drip to rainfall ratios were estimated using 1) the fog drip zone boundaries for east Maui (Giambelluca and Nullet, 1991), and 2) an illustration that shows the relationship between fog drip and rainfall for the windward slopes of Mauna Loa, island of Hawaii (Juvik and Nullet, 1995). The contribution of fog drip in Waiokamilo is calculated by multiplying the ratios with the monthly rainfall values (Giambelluca et al., 1986). Approximately 47 percent of Waiokamilo lies in the fog drip zone (Figure 2-5) with an estimated average annual fog drip rate of 76 inches per year.

Table 2-3. Fog drip to rainfall ratios for the windward slopes of Mauna Loa on the island of Hawaii.

Month	Ratio (%)
January-March	13
April-June	27
July-September	67
October-November	40
December	27

Solar Radiation

Solar radiation is the sun's energy that arrives at the Earth's surface after considerable amounts have been absorbed by water vapor and gases in the Earth's atmosphere. The amount of solar radiation to reach the surface in a given area is dependent upon latitude and the sun's declination angle (angle from the sun to the equator), which is a function of the time of year. Hawaii's trade winds and the temperature inversion layer greatly affect solar radiation levels, the primary heat source for evaporation. High mountain ranges block moist trade-wind air flow and keep moisture beneath the inversion layer (Lau and Mink, 2006). As a result, windward slopes tend to be shaded by clouds and protected from solar radiation, while dry leeward areas receive a greater amount of solar radiation and thus have the higher levels of evaporation.

In the Waiokamilo hydrologic unit, estimated daily solar radiation ranges from 0 to 300 calories per square centimeter per day. Solar radiation decreases from the coast toward the mountains, where there is a zone with very low solar radiation and high rainfall. Upslope of that zone, solar radiation increases (and rainfall decreases) with elevation (Figure 2-5).

Evaporation

Evaporation is the loss of water to the atmosphere from soil surfaces and open water bodies (e.g. streams and lakes). Evaporation from plant surfaces (e.g. leaves, stems, flowers) is termed transpiration. Together, these two processes are commonly referred to as evapotranspiration, and it can significantly affect water yield because it determines the amount of rainfall that becomes streamflow. On a global scale, the amount of water that evaporates is about the same as the amount of water that falls on Earth as precipitation. However, more water evaporates from the ocean whereas on land, rainfall often exceeds evaporation. The rate of evaporation is dependent on many climatic factors including solar radiation, albedo[4], rainfall, humidity, wind speed, surface temperature, and sensible heat advection[5]. Higher evaporation rates are generally associated with greater net radiation, high wind speed and surface temperature, and lower humidity.

A common approach to estimating evaporation is to employ a relationship between potential evaporation and the available water in the watershed. Potential evaporation is the maximum rate of evaporation if water is not a limiting factor, and it is often measured with evaporation pans. In Hawaii, pan evaporation measurements were generally made in the lower elevations of the drier leeward slopes where sugarcane was grown. These data have been compiled and mapped by Ekern and Chang (1985). Unfortunately, pan evaporation data are available only for the lower slopes of west and central Maui. This makes estimating the evaporative demand on the watersheds in windward east Maui challenging.

Most of the drainage basins in Hawaii are characterized by a relatively large portion of the rainfall leaving the basin as evaporation and the rest as streamflow (Ekern and Chang, 1985). Based on the available pan evaporation data for Hawaii, evaporation generally decreases with increasing elevation below the temperature inversion[6] and the cloud layer (Figure 2-1). At low elevations near the coast, pan evaporation rates are influenced by sensible heat advection from the ocean (Nullet, 1987). Pan evaporation rates are enhanced in the winter by positive heat advection from the ocean, and the opposite occurs in the summer when pan evaporation rates are diminished by negative heat advection (Giambelluca and Nullet, 1992). With increasing distance from the windward coasts, positive heat advection from dry land surfaces becomes an important factor in determining the evaporative demand at the slopes (Nullet, 1987). Within the cloud layer, evaporation rates are particularly low due to the low radiation and high humidity caused

[4] Albedo is the proportion of solar radiation that is reflected from the Earth, clouds, and atmosphere without heating the receiving surface.
[5] Sensible heat advection refers to the transfer of heat energy that causes the rise and fall in the air temperature.
[6] Temperature inversion is when temperature increases with elevation.

by fog drip. Near the average height of the temperature inversion, evaporation rates are highly variable as they are mainly influenced by the movement of dry air from the above and moist air from below (Nullet and Giambelluca, 1990). Above the inversion, the clear sky and high solar radiation at the summits cause increased evaporation. Ekern and Chang (1985) reported evaporation increased to 50 percent more than surface oceanic rates near the Mauna Kea crest on the island of Hawaii.

Land Use

The Hawaii Land Use Commission (LUC) was established under the State Land Use Law (Chapter 205, Hawaii Revised Statutes) enacted in 1961. Prior to the LUC, the development of scattered subdivisions resulted in the loss of prime agricultural land that was being converted for residential use, while creating problems for public services trying to meet the demands of dispersed communities. The purpose of the law and the LUC is to preserve and protect Hawaii's lands while ensuring that lands are used for the purposes they are best suited. Land use is classified into four broad categories: 1) agricultural; 2) conservation; 3) rural; and 4) urban.

Land use classification is an important component of examining the benefits of protecting instream uses and the appropriateness of surface water use for noninstream uses. While some may argue that land use, in general, should be based upon the availability of surface and ground water resources, land use classification continues to serve as a valuable tool for long-range planning purposes.

As of 2006, the LUC designated 79.1 percent of the land in Waiokamilo as conservation district and 20.9 percent as agricultural district (State of Hawaii, Office of Planning, 2006d). No lands were designated as rural or urban districts. The conservation district is located in the upper part of the hydrologic unit and along the coast, whereas the agricultural district lies is in the lower part of the hydrologic unit (Figure 2-6).

Land Cover

Land cover for the hydrologic unit of Waiokamilo is represented by two separate 30-meter Landsat satellite images. One of the datasets, developed by the Coastal Change Analysis Program (C-CAP), provides a general overview of the land cover types in Waiokamilo, e.g. forest, shrub land, grassland, developed areas, cultivated areas, and bare land (Table 2-4, Figure 2-7). The second is developed by the Hawaii Gap Analysis Program (HI-GAP), which mapped the National Vegetation Classification System (NVCS) associations for each type of vegetation, creating a more comprehensive land cover dataset (Table 2-5, Figure 2-8).

Based on the two land cover classification systems, the land cover of Waiokamilo consists mainly of forested areas. A majority of the hydrologic unit is made up of native Ohia forests that spread throughout the upper slopes as part of the Koolau Forest Reserve (Figure 2-8). Alien forests with a mixture of alien grasslands can be found at intermediate and lower elevations with very little urban or industrial developments.

Table 2-4. C-CAP land cover classes and area distribution in Waiokamilo hydrologic unit (Source: National Oceanographic and Atmospheric Agency, 2000).

Land Cover	Description	Area (mi²)	Percent of Unit
Evergreen Forest	Areas where more than 67 percent of the trees remain green throughout the year	1.80	73.5
Scrub/Shrub	Areas dominated by woody vegetation less than 6 meters in height	0.45	18.6
Grassland	Natural and managed herbaceous cover	0.16	6.7
Bare Land	Bare soil, gravel, or other earthen material with little or no vegetation	0.01	0.5
Water	Open water	0.01	0.37
Low Intensity Developed	Constructed surface with substantial amounts of vegetated surface	0.01	0.2
Unconsolidated Shoreline	Material such as silt, sand, or gravel that is subject to inundation and redistribution by water	< 0.01	0.1

Table 2-5. HI-GAP land cover classes and area distribution in Waiokamilo hydrologic unit (Source: HI-GAP, 2005).

Land Cover	Area (mi²)	Percent of Unit
Open Ohia Forest (uluhe)	0.84	34.2
Closed Ohia Forest (native shrubs)	0.64	26.0
Alien Forest	0.59	23.9
Uncharacterized Open-Sparse Vegetation	0.12	5.0
Uncharacterized Shrubland	0.09	3.5
Closed Ohia Forest (uluhe)	0.06	2.6
Alien Grassland	0.05	2.1
Very Sparse Vegetation to Unvegetated	0.04	1.5
Open Ohia Forest (native shrubs)	0.01	0.3
Uluhe Shrubland	0.01	0.2
Low Intensity Developed	< 0.01	0.2
Native Wet Cliff Vegetation	< 0.01	0.2
Uncharacterized Forest	< 0.01	0.1
Undefined	< 0.01	0.1

Flood Hazard

Floods usually occur following prolonged or heavy rainfall associated with tropical storms or hurricanes. The magnitude of the flood depends on topography, ground cover, and soil conditions. Rain falling on areas with steep slopes and soil saturated from previous rainfall events tends to produce severe floods in the low-lying areas. Four types of floods exist in Hawaii. Stream or river flooding occurs when the water level in a stream rises into the flood plain. A 100-year flood refers to the probability of the flood happening once in a hundred years, or 1 percent chance of happening in a given year. Flash floods occur within a few hours after a rainfall event, or they can be caused by breaching of flood safety structures such as a dam. Flash flooding is common in Hawaii because the small drainage basins often have a short response time, typically less than an hour, from peak rainfall to peak streamflow. They are powerful and dangerous in that they can develop quickly and carry rocks, mud, and all the debris in their path down to the coast, causing water quality problems in the near-shore waters. Some floods can even trigger massive landslides, blocking off an entire stream channel. One of the major historic flash flooding events occurred on December 5-6, 1988, when rainfall was at the average annual maximum, causing significant flash flooding in many parts of Maui (Fletcher III et al., 2002). Sheet flooding occurs when runoff builds up on previously saturated ground, flowing from the high mountain slopes to the sea in a shallow sheet

(Pacific Disaster Center, 2007). Coastal flooding is the inundation of coastal land areas from excessive sea level rise associated with strong winds or a tsunami.

The Federal Emergency Management Agency (FEMA) developed maps that identify the flood-risk areas in an effort to mitigate life and property losses associated with flooding events. Based on these maps, FEMA did not identify any flood-risk zones in the hydrologic unit of Waiokamilo.

Drought

Drought is generally defined as a shortage of water supply that usually results from lower than normal rainfall over an extended period of time, though it can also result from human activities that increase water demand (Giambelluca et al., 1991). The National Drought Mitigation Center (State of Hawaii, Commission on Water Resource Management, 2005b) uses two types of drought definitions — conceptual and operational. Conceptual definitions help people understand the general concept of drought. Operational definitions describe the onset and severity of a drought, and they are helpful in planning for drought mitigation efforts. The four operational definitions of drought are meteorological drought, agricultural drought, hydrological drought, and socioeconomic drought. Meteorological drought describes the departure of rainfall from normal based on meteorological measurements and understanding of the regional climatology. Agricultural drought occurs when not enough water is available to meet the water demands of a crop. Hydrological drought refers to declining surface and ground water levels. Lastly, socioeconomic drought occurs when water shortage affects the general public.

Impacts of drought are complex and can be categorized into three sectors: water supply; agriculture and commerce; and environment, public health, and safety sectors (State of Hawaii, Commission on Water Resource Management, 2005b). The water supply sector encompasses urban and rural drinking water systems that are affected when a drought depletes ground water supplies due to reduced recharge from rainfall. The agriculture and commerce sector includes the reduction of crop yield and livestock sizes due to insufficient water supply for crop irrigation and maintenance of ground cover for grazing. The environmental, public health, and safety sector focuses on wildfires that are both detrimental to the forest ecosystem as well as hazardous to the public. It also includes the impact of desiccating streams, such as the reduction of instream habitats for native species.

Droughts have affected the islands throughout Hawaii's recorded history. The most severe events of the past 15 years are associated with the El Niño phenomenon. In January 1998, the National Weather Service's network of 73 rain gauges throughout the State did not record a single above-normal rainfall, with 36 rain gauges recoding less than 25 percent of normal rainfall (State of Hawaii, Commission on Water Resource Management, 2005b). The most recent drought occurred in 2000-2002, affecting all islands, especially the southeastern end of the State. During that period, east Maui streams were at record low levels and cattle losses projected at 9 million dollars (State of Hawaii, Commission on Water Resource Management, 2005b).

With Hawaii's limited water resources and growing water demands, droughts will continue to adversely affect the environment, economy, and the citizens of the State. Aggressive planning is necessary to make wise decisions regarding the allocation of water at the present time, and conserving water resources for generations to come. The Hawaii Drought Plan was established in 2000 in an effort to mitigate the long-term effects of drought. One of the projects that supplemented the plan was a drought risk and vulnerability assessment of the State, conducted by researchers at the University of Hawaii (2003). In this project, drought risk areas were determined based on rainfall variation in relation to water source, irrigated area, ground water yield, stream density, land form, drainage condition, and land use. Fifteen years of historical rainfall data were used. The Standardized Precipitation Index (SPI) was used as the drought index because of its ability to assess a range of rainfall conditions in Hawaii. It quantifies rainfall deficit for different time periods, i.e. 3 months and 12 months. Results of the study for Maui are summarized in Table 2-6. Based on the 12-month SPI, the Kula region has the greatest risk to drought impact of the Maui regions because of its dependence on surface water sources, which is limited by low rainfall. The growing population in the already densely populated area further stresses the water supply.

Table 2-6. Drought risk areas for Maui (Source: University of Hawaii, 2003).

[Drought classifications of moderate, severe, and extreme have SPI values -1.00 to -1.49, -1.50 to -1.99, and -2.00 or less, respectively]

Sector	Drought Classification (based on 12-month SPI)		
	Moderate	Severe	Extreme
Water Supply	Kula, Kahului, Wailuku, Hana, Lahaina	Kula, Hana	Kula
Agriculture and Commerce	--	--	--
Environment, Public Health and Safety	Kula	Kula	Kula

Ground Water

Ground water is an important component of streamflow as it constitutes the base flow[7] of Hawaiian streams. When ground water is withdrawn from a well, the water level in the surrounding area is lowered. Nearby wetlands or ponds may shrink or even dry up if the pumping rate is sufficiently high (Gingerich and Oki, 2000). The long-term effects of ground water withdrawal include the reduction of streamflow, which may cause a decrease in stream habitats for native species and a reduction in the amount of water available for irrigation. The interaction between surface water and ground water warrants a close look at the ground water recharge and demand within the state as well as the individual hydrologic units.

In Hawaii, ground water is replenished by recharge from rainfall, fog drip, and irrigation water that percolate through the plant root zone to the subsurface rock. Recharge can be captured in three major fresh ground water systems: 1) fresh water-lens system; 2) dike-impounded system; and 3) perched system. The fresh water-lens system provides the most important sources of ground water. It includes a lens-shaped layer of fresh water, an intermediate transition zone of brackish water, and underlying salt water. In northeast Maui, a vertically extensive fresh water-lens system can extend several hundreds or even thousands of feet below mean sea level. A dike-impounded system is found in rift zones and caldera of a volcano where low-permeability dikes compartmentalize areas of permeable volcanic rocks, forming high-level water bodies. In Maui, dikes impound water to as high as 3,300 feet above mean sea level. A perched system is found in areas where low-permeability rocks impede the downward movement of percolated water sufficiently to allow a water body to form in the unsaturated zone above the lowest water table (Gingerich and Oki, 2000).

The hydrologic unit of Waiokamilo lies within the Keanae aquifer system that has an area of 55.6 square miles. A general overview of the ground water occurrence and movement in this area is described in Gingerich (1999) and illustrated in Figure 2-2. The fresh water-lens system is vertically extensive, in which the saturated zone extends from the Honomanu Basalt at sea level through the Kula Volcanics and into the Hana Volcanics. Streams that intersect the water table continue to gain water as they descend to sea level. Wells open to any part of the aquifer will reduce streamflow and discharge to sea. One of the two production wells (well numbers 5108-01 and 5108-02) located at the boundary of Waiokamilo and Wailuanui taps into the aquifer for municipal use (Figure 2-9). Detailed information for each well is specified in Table 2-7. As of July 2005, the ground water demand of the Keanae aquifer system is only

[7] Base flow is the water that enters a stream from persistent, slowly varying sources (such as the seepage of ground water), and maintains stream flow between water-input events (i.e., it is the flow that remains in a stream in times of little or no rainfall).

0.162 million gallons per day, which is well below the aquifer's current sustainable yield of 96 million gallons per day (State of Hawaii, Commission on Water Resource Management, 2007). Estimated total ground water recharge without accounting for fog drip contribution is 171 million gallons per day, which represents 37 percent of total rainfall (Shade, 1999).

Ground water use information is only available by island. Among the major Hawaiian islands, Maui has the second highest number of production wells following Oahu. Of the 450 productions wells in Maui, 259 are low-capacity wells with a pumping rate of less than 25 gallons per minute. Assuming all the low-capacity production wells in Maui are pumping at 1,700 gallons per day, the island-wide withdrawal rate would be 0.44 million gallons per day. The cumulative impacts of small, domestic wells become particularly important when assessing areas where municipal water is unavailable (State of Hawaii, Commission on Water Resource Management, 2007). A majority of the reported ground water use in Maui is for agriculture (54 percent) and irrigation (34 percent) (Table 2-8).

Figure 2-2. Diagram illustrating the ground water system west of Keanae Valley, northeast Maui, Hawaii. Arrows indicate general direction of ground water flow (Source: Gingerich, 1999).

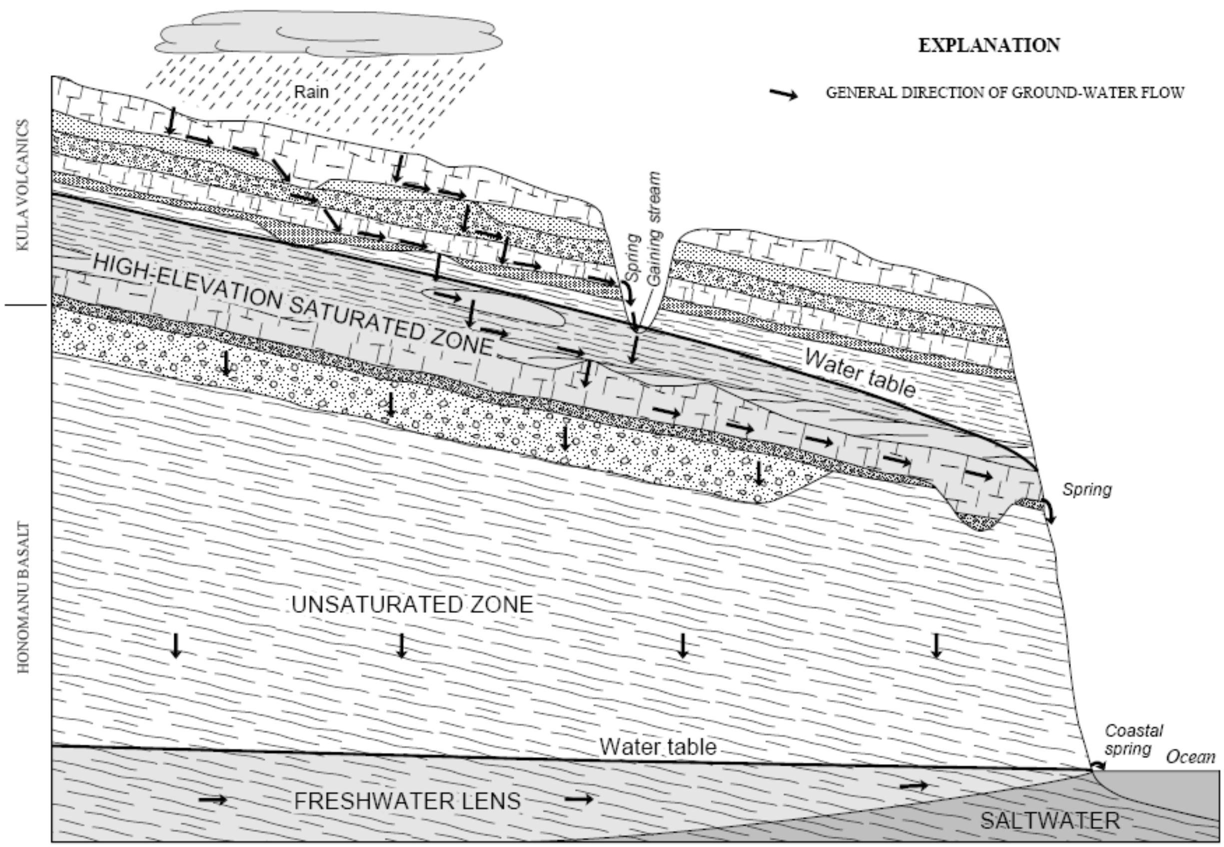


Table 2-7. Information of wells located in Waiokamilo hydrologic unit (Source: State of Hawaii, 2008).

[Negative elevation values indicate feet below mean sea level; positive elevation values indicate feet above mean sea level. Pump rate measured in gallons per minute (gpm); -- indicates value is unknown.]

Well number	Well Name	Year drilled	Use	Ground elevation (feet)	Well depth (feet)	Pump elevation (feet)	Pump depth (feet)	Pump rate (gpm)
5108-01	Keanae	1984	Municipal	214	330	--	--	100
5108-02	Keanae 2	2000	Unused	215	330	None	None	0

Table 2-8. Summary of ground water use reporting in the island of Maui (Source: State of Hawaii, Commission on Water Resource Management, 2007).

[Agriculture category includes water use for crops, livestock, and nursery plants; irrigation category includes water use for golf courses, landscape features, and other infrastructures. Mgd equals million gallons per day.]

Use Category	Use Rate (mgd)	Percent of Total (%)
Agriculture	48.134	53.7
Domestic	0.001	0
Industrial	1.683	1.9
Irrigation	9.611	10.7
Military	0	0
Municipal	30.172	33.7
Total	89.601	100

Figure 2-3. Generalized geology of Waiokamilo hydrologic unit (Source: Sherrod et al., 2007; State of Hawaii, Commission on Water Resource Management, 2004).

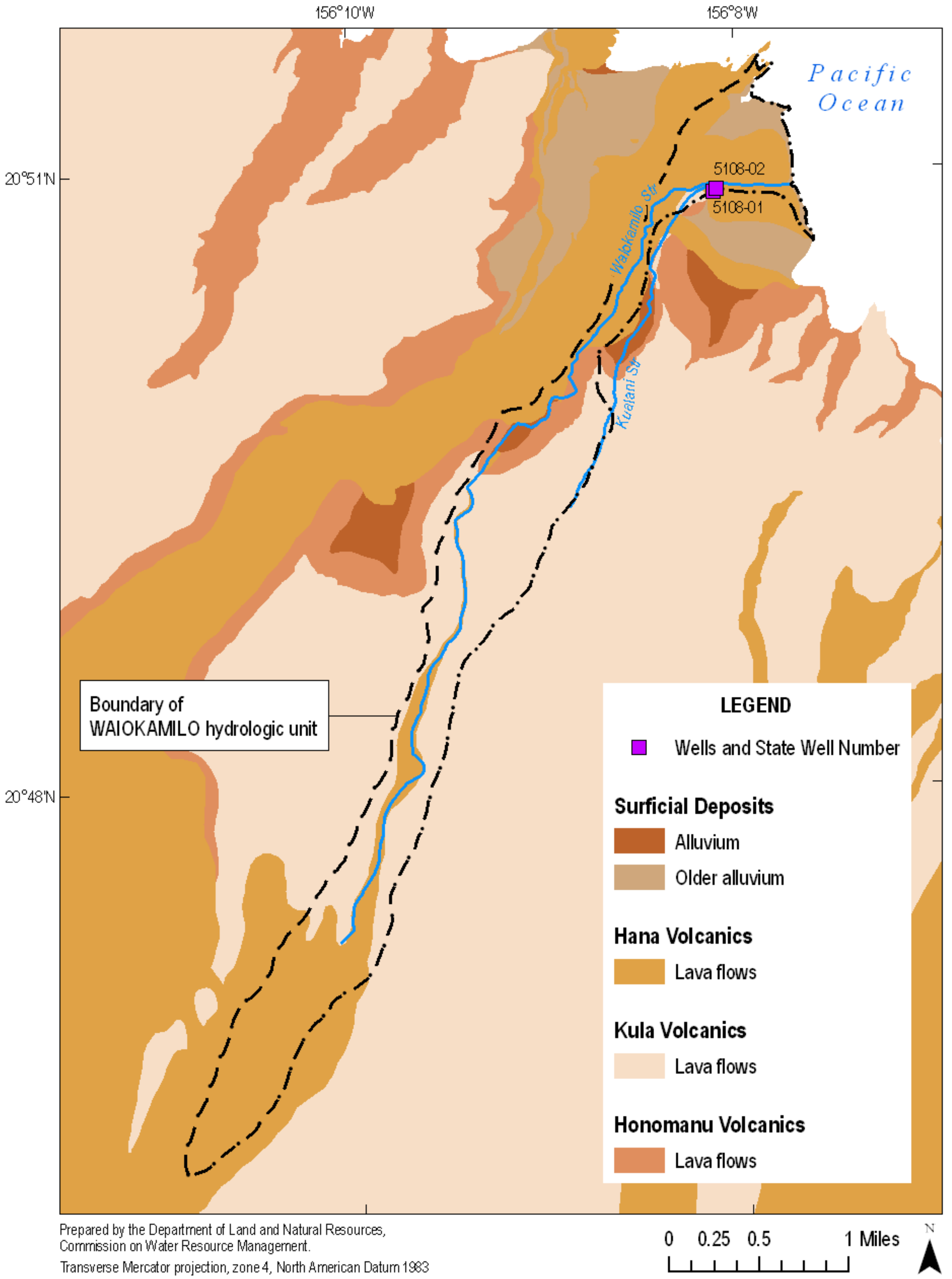


Figure 2-4. Soil classification in Waiokamilo hydrologic unit (Source: State of Hawaii, Office of Planning, 2007c).

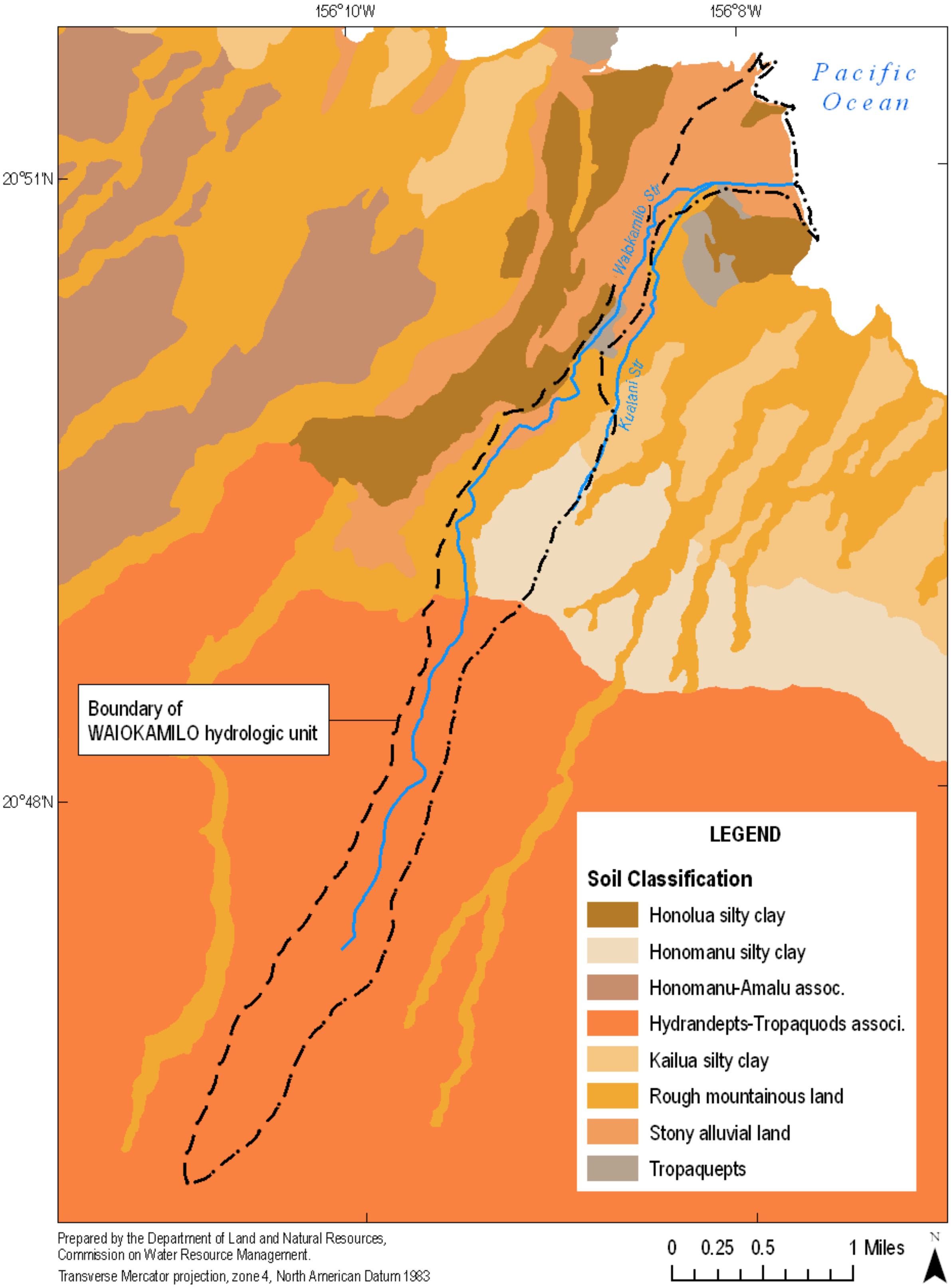


Figure 2-5. Mean annual rainfall and fog area in Waiokamilo; and solar radiation for Waiokamilo and the island of Maui, Hawaii (Source: Giambelluca et al., 1986; State of Hawaii, Office of Planning, 2006b; 2006c).

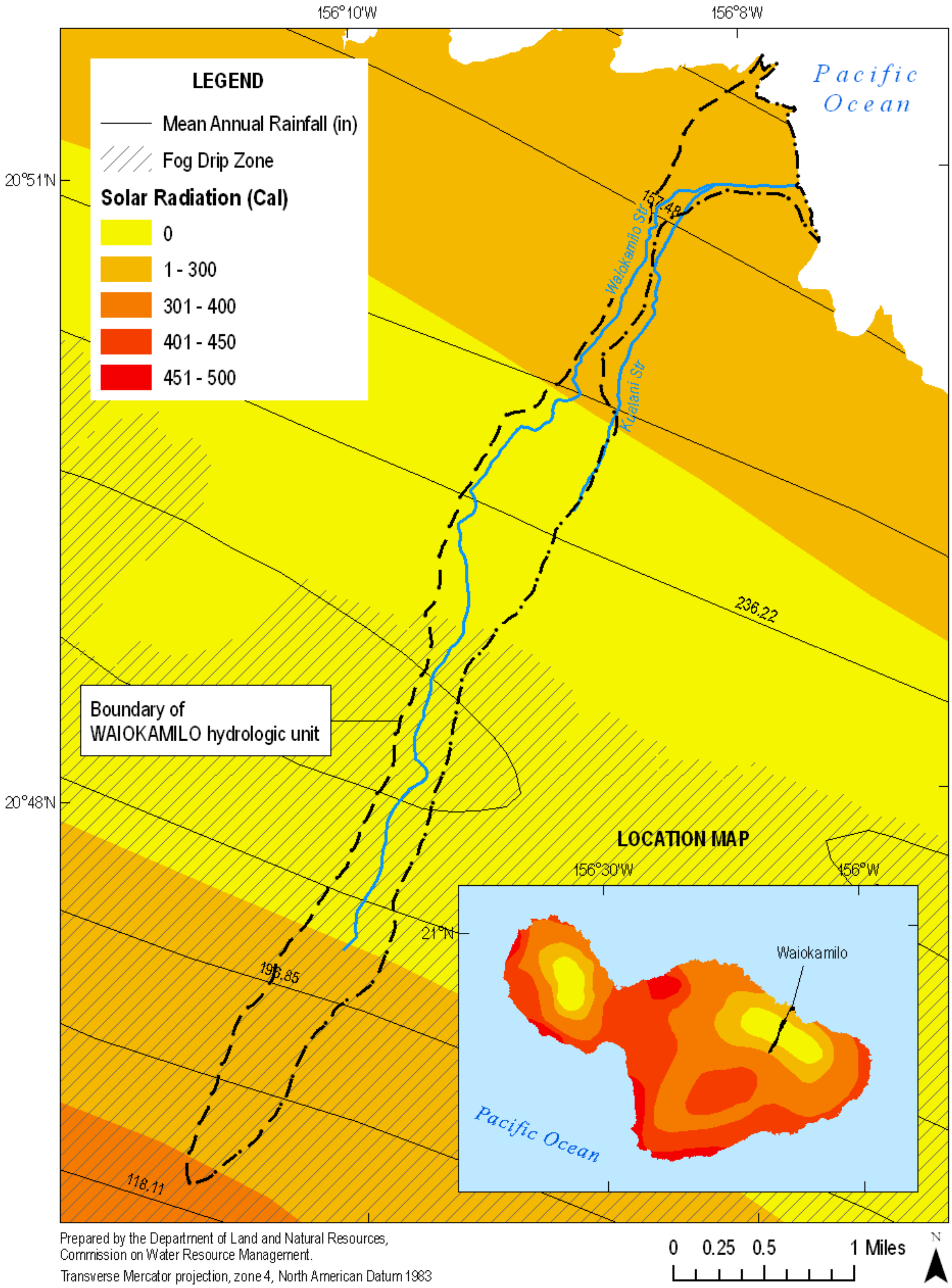


Figure 2-6. State land use district boundaries in Waiokamilo hydrologic unit (Source: State of Hawaii, Office of Planning, 2006d).

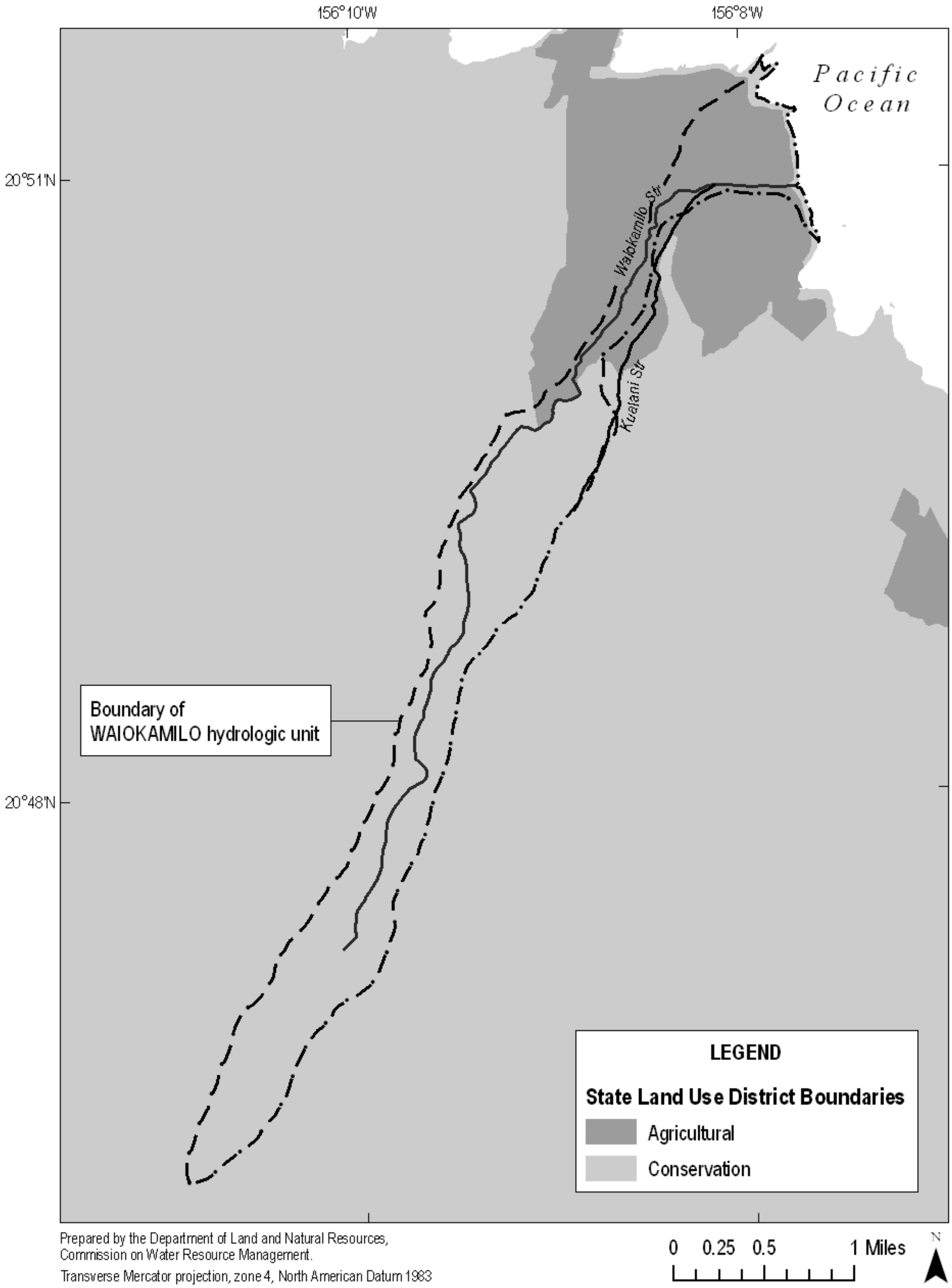


Figure 2-7. C-CAP land cover in Waiokamilo hydrologic unit (Source: National Oceanic and Atmospheric Administration, Coastal Services Center, 2000).

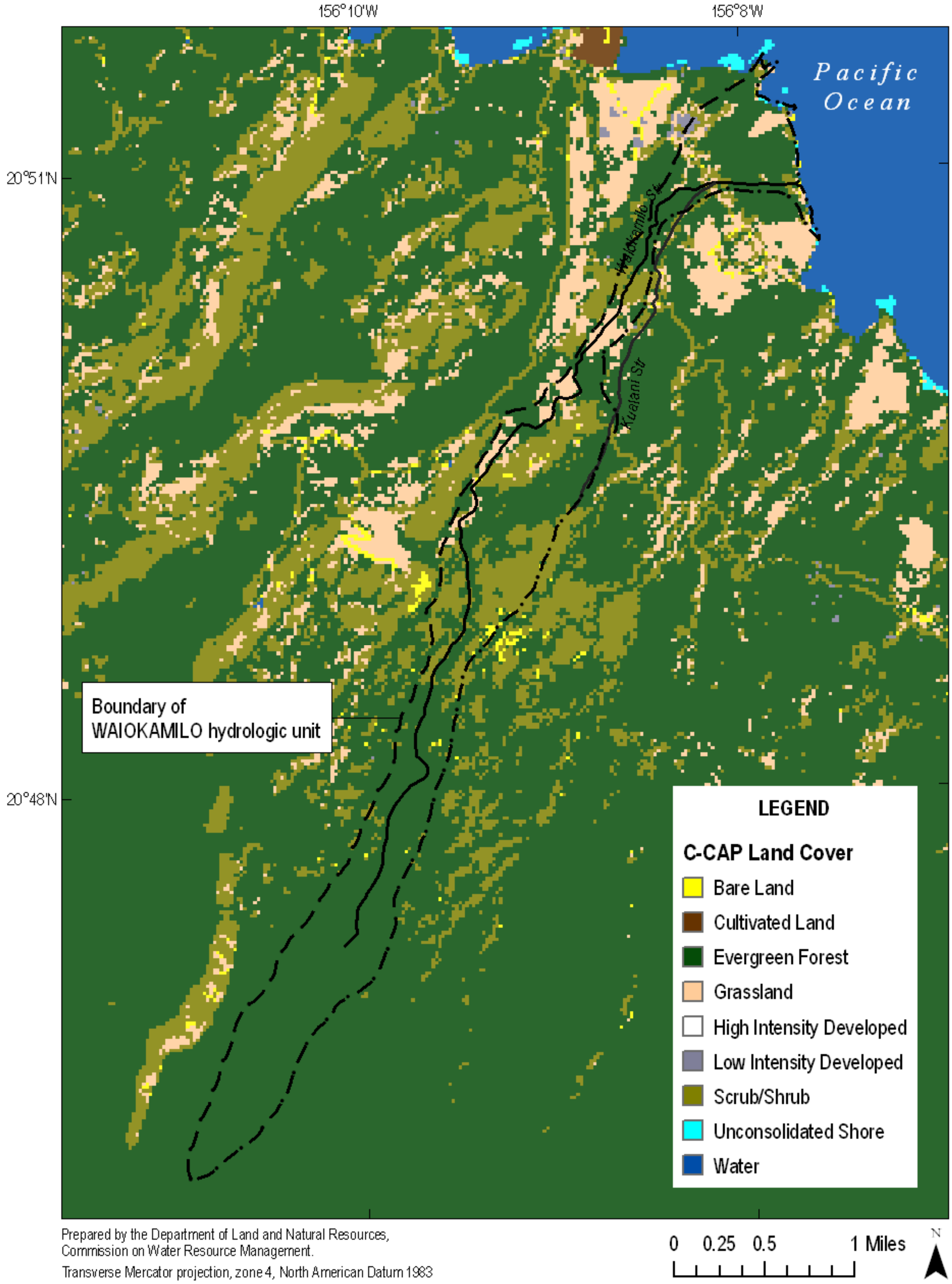


Figure 2-8. Hawaii GAP land cover classes in Waiokamilo hydrologic unit (Source: Hawaii GAP Analysis Program, 2005).

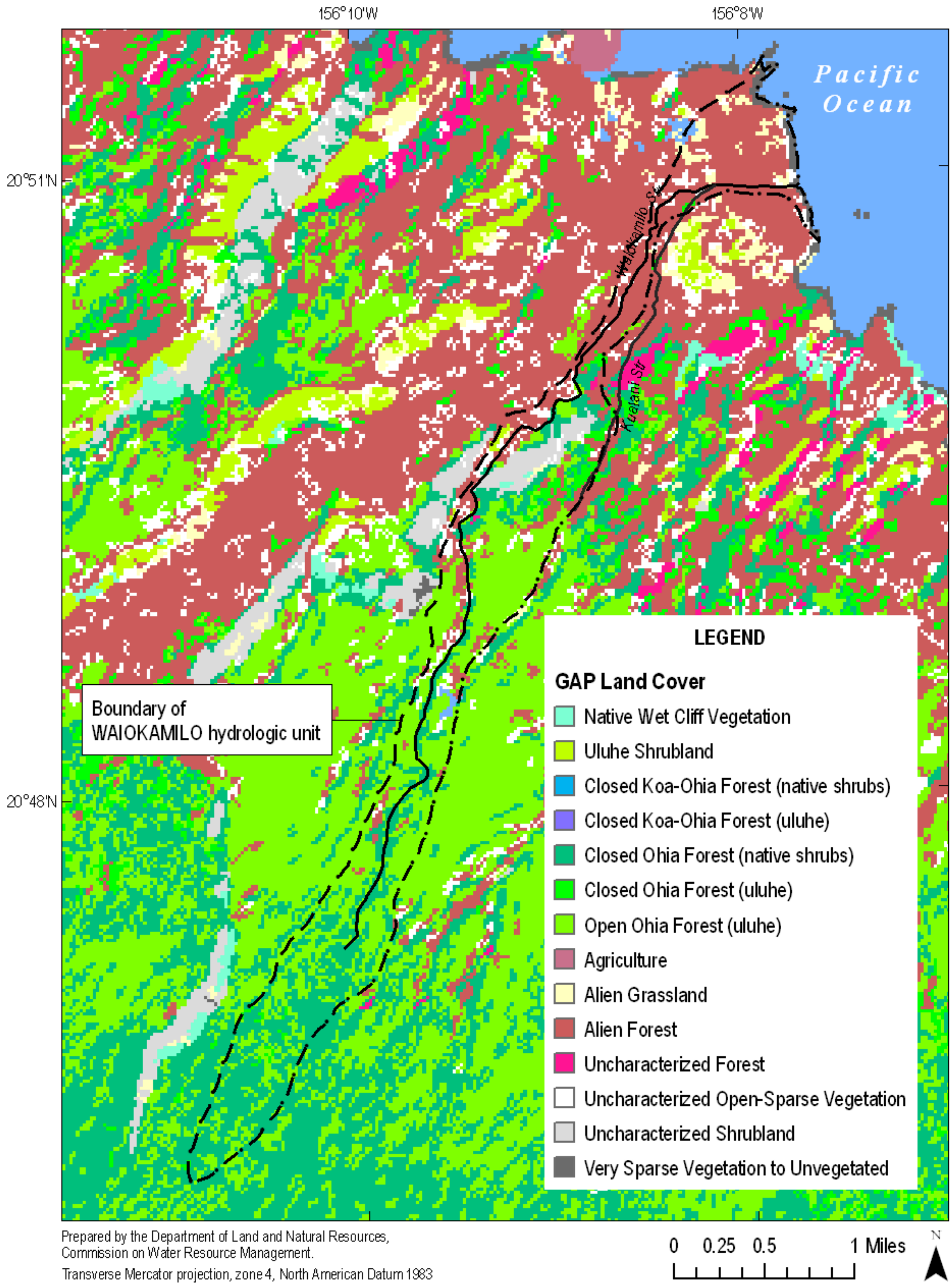
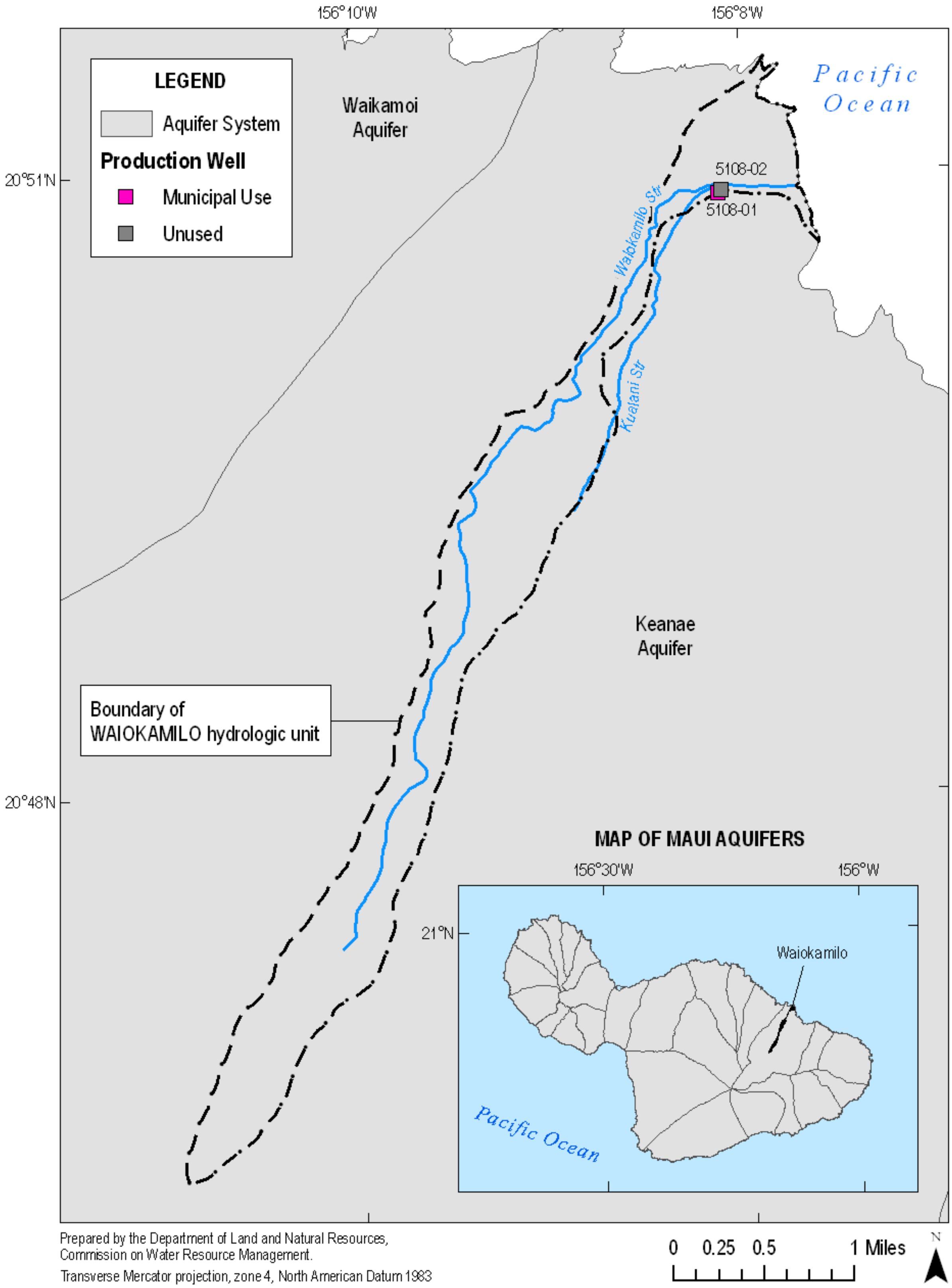


Figure 2-9. Aquifer system area and well locations in Waiokamilo hydrologic unit (Source: State of Hawaii, Office of Planning, 2006a; State of Hawaii, Commission on Water Resource Management, 2004).



3.0 Hydrology

The Commission, under the State Water Code, is tasked with establishing instream flow standards by weighing "the importance of the present or potential instream values with the importance of the present or potential uses of water for noninstream purposes, including the economic impact of restricting such uses." While the Code outlines the instream and offstream uses to be weighed, it assumes that hydrological conditions will also be weighed as part of this equation. The complexity lies in the variability of local surface water conditions that are dependent upon a wide range of factors, including rainfall, geology, and human impacts, as well as the availability of such information. The following is a summary of general hydrology and specific hydrologic characteristics for Waiokamilo Stream .

Components of streamflow. Streamflow consists of: 1) direct surface runoff in the form of overland flow and subsurface flow that rapidly returns infiltrated water to the stream; 2) ground water discharge in the form of base flow; 3) water returned from streambank storage; 4) rain that falls directly on streams; and 5) additional water, including excess irrigation water discharged into streams by humans (Oki, 2003). The amount of runoff and ground water that contribute to total streamflow is dependent on the different components of the hydrologic cycle, as well as man-made structures such as diversions and other stream channel alterations (e.g. channelizations and dams).

Surface water and ground water interaction. Streams in Hawaii can either gain or lose water at different locations depending on the geohydrologic conditions. A stream gains water when the ground water table is above the streambed. When the water table is below the streambed, the stream can lose water. Where the streambed is lined with concrete or other low-permeability or impermeable material, interaction between surface water and ground water is unlikely. Figure 3-1 presents the stream reach characteristics of Waiokamilo Stream taken from Gingerich (2005). Streamflow measurements made on May 11, 1999 show that the 0.4 mile reach immediately downstream from the Koolau Ditch to Akeke Spring was dry from water being diverted at the ditch. The stream gained about 3.8 million gallons per day from the spring, which discharges from the Honomanu Basalt (Gingerich, 1999). Downstream from the spring to the coast, Waiokamilo Stream loses flow to ground water and to various diversions. The upper reaches were unclassified probably due to inaccessibility of the stream.

Streamflow Characteristic. One of the most common statistics used to characterize streamflow is the median value of flow in a particular time period. This statistic is also referred to as the flow at 50 percent exceedence probability, or the flow that is equaled or exceeded 50 percent of the time (TFQ_{50}). The longer the time period that is used to determine the median flow value, the more representative the value is of the average flow conditions in the stream. Median flow is typically lower than the mean or average flow because of the bias in higher flows, especially during floods, present when calculating the mean flow. The flow at the 90 percent exceedence probability (TFQ_{90}) is commonly used to characterize low flows in a stream. In Hawaii, the base flow is usually exceeded less than 90 percent of the time, and in many cases less than 70 percent of the time (Oki, 2003).

In cooperation with the Commission on Water Resource Management, the USGS conducted a study (Gingerich, 2005) to assist in determining reasonable and beneficial offstream and instream uses of water in northeast Maui. The purpose of the study was to develop methods of estimating median streamflow, total flow statistics (TFQ), and base flow statistics (BFQ) at ungaged sites where observed data is unavailable. Basin characteristics and hydrologic data for northeast Maui were collected and analyzed. One of the products of the study is a set of regression equations that can be used to estimate natural (undiverted) TFQ_{50}, BFQ_{50}, TFQ_{95}, and BFQ_{95} at gaged and ungaged sites. The subscripts indicated the percentage of time the flow, either total or base flow, is equaled or exceeded.

Since there is no USGS continuous-record stream gaging station in Waiokamilo, streamflow statistics were estimated at selected ungaged sites using the regression equations developed from the study. Three sites were selected along Waiokamilo Stream: 1) station WoL is located at about 24 feet elevation in the lower reach; 2) station WoM is at 506 feet in the middle reach; and 3) station WoU is at 1,375 feet in the upper reach (Figure 3-1). The estimated streamflow statistics at each ungaged site are presented in Table 3-1. Based on the estimates, the median total flows (TFQ_{50}) at stations WoL, WoM, and WoU are 14, 10, and 7 cubic feet per second, respectively. Even though Waiokamilo is a losing stream, the flows are gradually increasing from the upper site to the coast. The flow increase between the upper and the middle site can be attributed to flow gains from Akeke Spring. At the lower site, the tributary stream Kualani may be contributing to the flow although no measurements were made to confirm the assumption.

Table 3-1. Stream flow statistics estimated using regression equations, lower and upper confidence intervals, standard errors, measured flow, and relative errors for ungaged sites in Waiokamilo (Source: Gingerich, 2005).

[Flows are in cubic feet per second (cfs); 90% LCL and 90% UCL is 90-percent lower and upper confidence level; Standard error is in percent; Relative error is the percent difference between the measured statistic and the estimated statistic; Measured flows in ***bold italic*** fall within the lower and upper 90-percent confidence interval; East Maui Irrigation Co., Ltd (EMI) 1928 measurements from March 16-20 when index station had a Q_{90} flow (reported in Gingerich, 1999)]

Stream location	Statistic	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}	Source of measured flow estimates
Waiokamilo lower (WoL)	Estimated flow	14	8.7	2.8	2.4	**TFQ_{95}**: 1999 USGS low-flow measurement (Gingerich, 1999)
	90% LCL	12	6.8	2.2	1.8	
	90% UCL	17	11	3.6	3.2	
	Standard error	9.8	14.4	14.2	15.9	
	Measured flow	--	--	5.7	--	
	Relative error	--	--	-51	--	
Waiokamilo middle (WoM)	Estimated flow	10	6.1	2.2	1.8	**TFQ_{95}**: Average of EMI 1928 measurement and 1999 USGS low-flow measurement (Gingerich, 1999)
	90% LCL	9.0	5.0	1.8	1.4	
	90% UCL	12	7.4	2.6	2.3	
	Standard error	7.3	10.7	11.4	12.8	
	Measured flow	--	--	4.9	--	
	Relative error	--	--	-55	--	
Waiokamilo upper (WoU)	Estimated flow	7.0	3.9	1.3	1.1	No data available
	90% LCL	6.1	3.3	1.1	0.90	
	90% UCL	7.8	4.7	1.6	1.3	
	Standard error	6.9	10.2	9.1	10.1	
	Measured flow	--	--	--	--	
	Relative error	--	--	--	--	

The TFQ_{95} and BFQ_{95} at the middle and lower sites were adjusted based on low-flow measurements made by USGS and measurements made by the EMI in 1928. Table 3-2 shows the adjusted flow statistics. The middle site TFQ_{95} estimate is a combination of the measured net gains of about 4.1 cubic feet per second (Gingerich, 1999), probably from the spring, and the upper site estimate from regression equation. At the lower site, additional gains of 0.12 cubic feet per second and a tributary inflow of 1.3 cubic feet per second increase the undiverted flow estimate to 6.8 cubic feet per second (Gingerich, 2005).

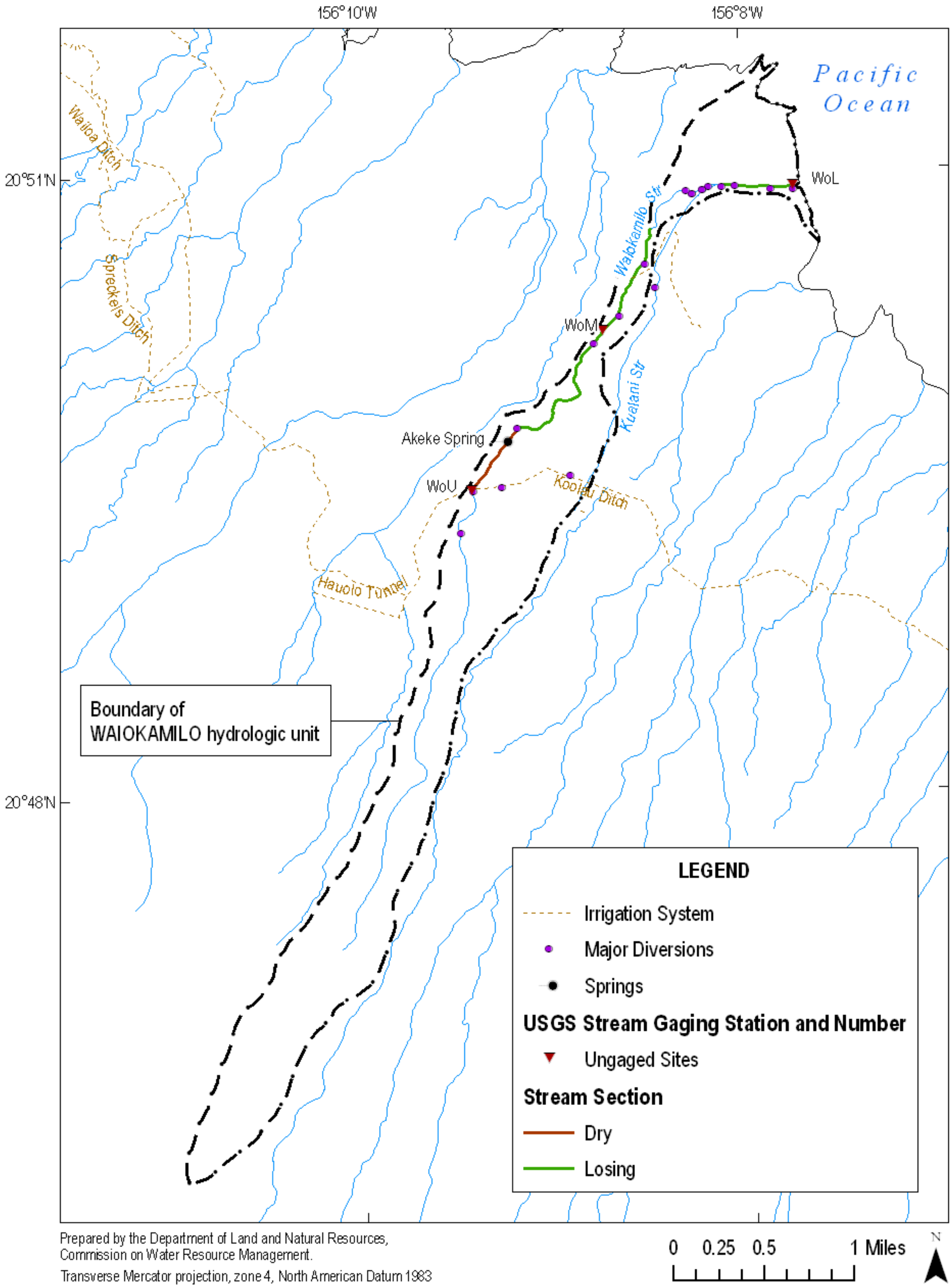
Table 3-2. Estimates of natural (undiverted) streamflow statistics for ungaged sites in Waiokamilo (Source: Gingerich, 2005).

[Flows are in cubic feet per second (cfs); Numbers in ***bold italic*** are considered maximums at sites downstream of unquantified but known losing reaches]

Stream location	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}	Source of estimate
Waiokamilo lower (WoL)	14	8.7	6.8	6.8	Regression equation; **TFQ_{95}**: measurement plus upper site estimate
Waiokamilo middle (WoM)	10	6.1	5.4	5.4	Regression equation; **TFQ_{95}**: measurement plus upper site estimate
Waiokamilo upper (WoU)	7.0	3.9	1.3	1.1	Regression equation

Effects of diversions can be assessed by comparing the flow statistics under natural conditions (Table 3-2) and those under diverted conditions. A number of diversions are located along Waiokamilo Stream, with three being taro diversions and one private diversion. Flow at the middle site (WoM) is affected by one diversion that is taking water at a known constant volume of 0.40 cubic feet per second. Median base flow (BFQ_{50}) decreased 61 percent from 6.1 to 3.7 cubic feet per second (Gingerich, 2005). Flow at the lower site is reduced by three diversions, one at 440 feet elevation diverting at least 3.7 cubic feet per second and oftentimes all low flows (Gingerich, 1999), the second at 220 feet elevation diverting 1.1 cubic feet per second, and the third private diversion at 250 feet elevation diverting an unknown amount of water (Gingerich, 2005). Median base flow (BFQ_{50}) decreased 30 percent from 8.7 to 2.6 cubic feet per second (Gingerich, 2005).

Figure 3-1. Location of diversions, irrigation systems, and selected ungaged sites in Waiokamilo hydrologic unit (Source: Gingerich, 2005; State of Hawaii, Office of Planning, n.d.; 2004c; 2005).



4.0 Maintenance of Fish and Wildlife Habitat

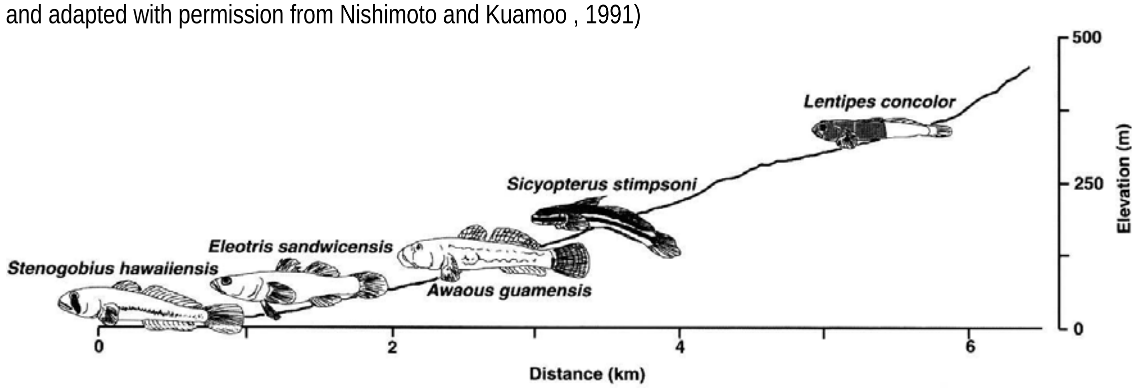
When people in Hawaii consider the protection of instream flows for the maintenance of fish habitat, their thoughts generally focus on just a handful of native species including five native fishes (four gobies and one eleotrid), two snails, one shrimp, and one prawn. Table 4-1 below identifies commonly mentioned native stream animals of Hawaii.

Table 4-1. List of commonly mentioned native stream organisms. (Source: State of Hawaii, Division of Aquatic Resources, 1993).

Scientific Name	Hawaiian Name	Type
Awaous guamensis	‘O‘opu nakea	Goby
Lentipes concolor	‘O‘opu hi‘ukole (alamo‘o)	Goby
Sicyopterus stimpsoni	‘O‘opu nopili	Goby
Stenogobius hawaiiensis	‘O‘opu naniha	Goby
Eleotris sandwicensis	‘O‘opu akupa (okuhe)	Eleotrid
Atyoida bisulcata	‘Opae kala‘ole	Shrimp
Macrobrachium grandimanus	‘Opae ‘oeha‘a	Prawn
Neritina granosa	Hihiwai	Snail
Neritina vespertina	Hapawai	Snail

Hawaii’s native stream animals have amphidromous life cycles (Ego, 1956) meaning that they spend their larval stages in the ocean (salt water), then return to fresh water streams to spend their adult stage and reproduce. Newly hatched fish larvae are carried downstream to the ocean where they become part of the planktonic pool in the open ocean. The larvae remain at sea from a few weeks to a few months, eventually migrating back into a fresh water stream as juvenile *hinana*, or postlarvae (Radtke, R.L. et al., 1988). Once back in the stream the distribution of the five native fish species are largely dictated by their climbing ability (Nishimoto & Kuamoo, 1991) along the stream’s longitudinal gradient. This ability to climb is made possible by a fused pelvic fin which forms a suction disk. *Eleotris sandwicensis* lacks fused pelvic fins and is mostly found in lower stream reaches. *Stenogobius hawaiiensis* has fused pelvic fins, but lacks the musculature necessary for climbing (Nishimoto and Kuamoo, 1997). *Awaous guamensis* and *Sicyopterus stimpsoni* are able to ascend moderately high waterfalls (less than ~20 meters) (Fitzsimons and Nishimoto, 1990), while *Lentipes concolor* has the greatest climbing ability and has been observed at elevations higher than 3,000 feet (Fitzsimons and Nishimoto, 1990) and above waterfalls more than 900 feet in vertical height (Englund and Filbert, 1997). Figure 4-1 illustrates the elevational profile of these native fresh water fishes.

Figure 4-1. Elevational profile of a terminal-estuary stream on the Big Island of Hawaii (Hakalau Stream). (Source: McRae, 2007, and adapted with permission from Nishimoto and Kuamoo , 1991)



The maintenance, or restoration, of stream habitat requires an understanding of and the relationships between the various components that impact fish and wildlife habitat, and ultimately, the overall viability of a desired set of species. These components include, but are not limited to, species distribution and diversity, species abundance, predation and competition among native species, similar impacts by alien species, obstacles to migration, water quality, and streamflow. The Commission does not intend to delve into the biological complexities of Hawaiian streams, but rather to present basic evidence that conveys the general health of the subject stream. The biological aspects of Hawaii's streams have an extensive history, and there is a wealth of knowledge which continues to grow and improve.

One of the earliest statewide stream assessments was undertaken by the Commission in cooperation with the National Park Service's Hawaii Cooperative Park Service Unit. The 1990 Hawaii Stream Assessment (HSA) brought together a wide range of stakeholders to research and evaluate numerous stream-related attributes (e.g., hydrology, diversions, gaging, channelizations, hydroelectric uses, special areas, etc.). The HSA specifically focused on the inventory and assessment of four resource categories: 1) aquatic; 2) riparian; 3) cultural; and 4) recreational. Though no fieldwork was conducted in its preparation, the HSA involved considerable research and analysis of existing studies and reports. The data were evaluated according to predefined criteria and each stream received one of five ranks (outstanding, substantial, moderate, limited, and unknown). Based on the stream rankings, the HSA offered six different approaches to identifying candidate streams for protection.

Due to the broad scope of the HSA inventory and assessment, it continues to provide a valuable information base for the Commission's Stream Protection and Management Program and will continue to be referred to in various sections throughout this report. Unfortunately, the aquatic resources of Waiokamilo Stream were classified as "unknown." The HSA classification was based on two surveys, with the last one conducted in 1963.

Surface water diversion systems can have profound effects on the availability of instream habitats for native stream fauna (fish, shrimp, and snails). The major diversion systems in northeast Maui are operated by East Maui Irrigation Co, Ltd. With a few exceptions, the diversions capture all base flow and an unknown amount of total streamflow in each stream, decreasing flow downstream of the diversion and sometimes causing streams to go dry (Gingerich and Wolf, 2005). Changes in flow volume may influence the physical and chemical characteristics of stream water and flow (e.g. temperature, pH, velocity), hence altering the stream ecosystem.

In cooperation with the Commission on Water Resource Management, the USGS conducted a study to assess the effects of surface water diversion systems on habitat availability for native stream species in northeast Maui, Hawaii. The goal was to determine a relationship between streamflow and habitat availability using a habitat selection model. By incorporating hydrology, stream morphology, and habitat characteristics, the model simulated habitat and streamflow relations for various species and life stages (Gingerich and Wolf, 2005). The end product of the study was a set of equations that estimates the area of usable streambed habitat over a range of streamflow under natural or diverted conditions.

The study focused on certain native fish, snail and shrimp species found in Hawaiian streams. Three fish species of the Gobiidae family, also known as gobies, were considered: 1) alamoo (*Lentipes concolor* (Gill)); 2) nopili (*Sicyopterus stimpsoni* (Gill)); and 3) goby nakea (*Awaous guamensis* (Valenciennes)). In addition, one of the freshwater snail species, *Neritina granosa* (Sowerby), commonly referred to as hihiwai, and the mountain shrimp, *Atyoida bisulcata* (Randall), also known as opae kalaole or mountain opae, were also considered in the study. All the species are amphidromous, in which individuals migrate between a fresh water stream and the saltwater ocean, and then return to the freshwater environment once in their lifetime. The gobies of interest have a fused pelvic fin, allowing them to climb upstream.

Stream morphology data were collected at five streams (excluding Waiokamilo) in northeast Maui at three locations along the stream: 1) directly upstream of the diversions at about 1,400-1,700 feet elevation (upper site); 2) midway to the coast at about 500-600 feet (middle site); and 3) near the coast at 10-40 feet elevation (lower site). Estimated natural and diverted median total and base flows were compiled from Gingerich (2005). Habitat availability and species abundance were quantified using snorkel surveys made during daylight hours. The lower sites were evaluated for adult and juvenile nopili, adult nakea, and hihiwai. Since the adult and juvenile alamoo, and opae do not typically live in the lower reaches, they were evaluated only in the middle and upper sites. Hydrologic data were entered into the habitat selection model to develop a set of equations that estimate the area of usable streambed habitat over a range of streamflow values.

These equations were applied to two sites in Waiokamilo Stream, middle (WoM) and lower (WoL), to estimate the amount of available habitats under diverted and natural conditions. Results were plotted against those of the five studied streams as represented by the green band in Figure 4-2. The general relation shows that as streamflow increases, the area of estimated usable streambed habitat for all interested species also increases. Since the lower site is downstream from multiple diversions, only 59-70 percent of the expected habitat for the gobies and hihiwai, and 73-77 percent of the expected habitat for the opae are available if 30 percent of the median base flow is present under diverted conditions (Table 4-2). When median base flow is at 61 percent of the natural conditions (middle site), 83-93 percent of the expected habitat for the gobies and hihiwai, and 90-93 percent of the expected habitat for the opae are available. Thus, the addition of even a small amount of water to a relatively dry stream can have a significant effect on the amount of habitat available (Gingerich and Wolf, 2005). Estimates of expected habitat availability are not representative of stream reaches within close proximity to large waterfalls since they generally prevent all species of interest, except for the opae and alamoo, to migrate upstream.

Figure 4-2. Relative habitat available for given relative base flow at studied streams. Relative change is the difference between natural and diverted conditions divided by natural conditions (Gingerich and Wolff, 2005).

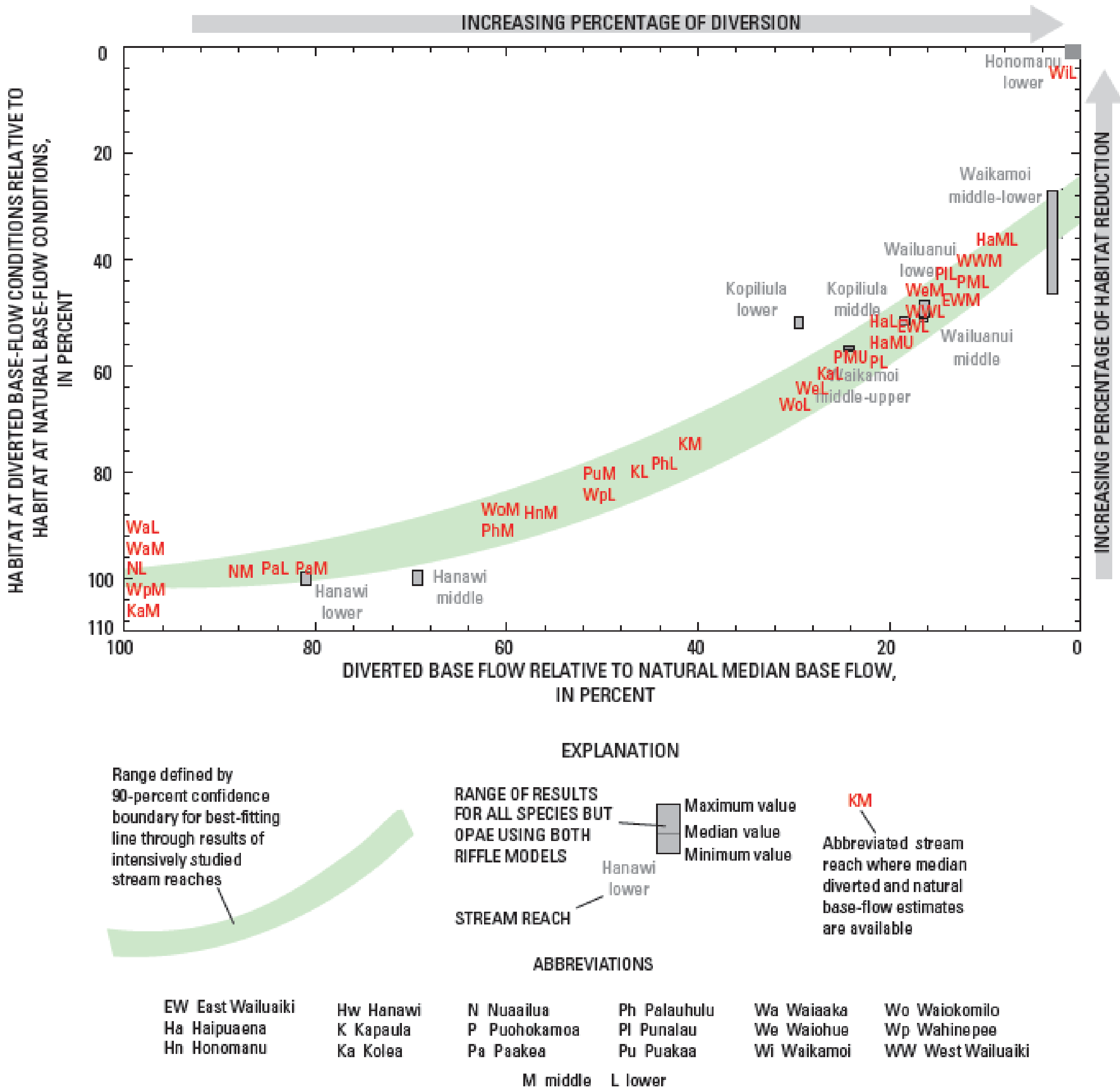


Table 4-2. Summary of relative base flow and available habitat in Waiokamilo Stream (Source: Gingerich and Wolff, 2005).

[ft³/s is cubic foot per second; Numbers in ***bold italic*** are considered maximums at sites downstream of unquantified but known losing reaches]

Stream site	Median base flow remaining in stream (ft³/s)		Median base flow at diverted conditions relative to median base flow at natural conditions (% of natural conditions)	Habitat available at diverted conditions (excluding opae) relative to habitat available at natural conditions (% of natural conditions)	Habitat available for opae at diverted conditions relative to habitat available at natural conditions (% of natural conditions)
	Diverted	Natural			
lower (WoL)	2.6	8.7	30	70 - 59	77 - 73
middle (WoM)	***3.7***	6.1	61	93 - 83	93 - 90

NOTE: The Commission is currently awaiting updated stream survey data for Waiokamilo Stream from the State of Hawaii Division of Aquatic Resources. Figure 4-4 provides an indication of the range of survey information available as of 2006.

Another important consideration of fish and wildlife habitat is the presence of critical habitat. Under the Endangered Species Act, the U.S. Fish and Wildlife Service is responsible for designating critical habitat for threatened and endangered species. Though there are very few threatened or endangered Hawaiian species that are directly impacted by streamflow (e.g., Newcomb's snail), the availability of surface water may still have indirect consequences for other species. Based upon current designations, there are no known critical habitat areas for fish and wildlife associated with Waiokamilo Stream.

In addition to critical habitat, the presence of native bird habitat should not be overlooked. Bird habitat ranges from urban environments and grasslands, to wetlands and native rainforests. Within these habitat ranges, streams provide an important source of food and water for native birds. Springs flow into loi and fishponds where native waterbirds, such as the *aukuu* (black-crowned night-heron) and the *koloa* (Hawaiian duck), search for food and locations to build a nest for their young. Streams are also valuable indicators of forest health. Since the headwaters of streams typically originate from forested areas, a forest with dense vegetation, especially along the stream bank would help prevent erosion, thus yielding cleaner fresh water for fish and wildlife as well as water demands in the lowland areas.

A diversity of native birds can be found in east Maui. Some of the notable species found in Haleakala National Park include the Hawaii (Dark-rumped) Petrel, *Nene* (Hawaiian Goose), and Common *Amakihi* (Pratt, 1993). Within Waikamoi Preserve and the northeast slope of Haleakala above 4,000 feet, the species found are the Maui Parrotbill, Maui Creeper, and *Akohekohe* (Crested Honeycreeper). The *Iiwi*, Red-billed Leiothrix, and *Apapane* are more common in Waikamoi Preserve. The U.S. Fish and Wildlife Service (n.d.) estimated the habitat ranges for native Hawaiian forest birds based on vegetation boundaries. In Waiokamilo, the native forest bird habitat spans 0.4 square miles across the upper slopes of the hydrologic unit where there is an abundance of forested wetlands (Figure 4-5).

Figure 4-3. Relative habitat available for given relative base flow at studied streams. Relative change is the difference between natural and diverted conditions divided by natural conditions (Source: Gingerich and Wolff, 2005).

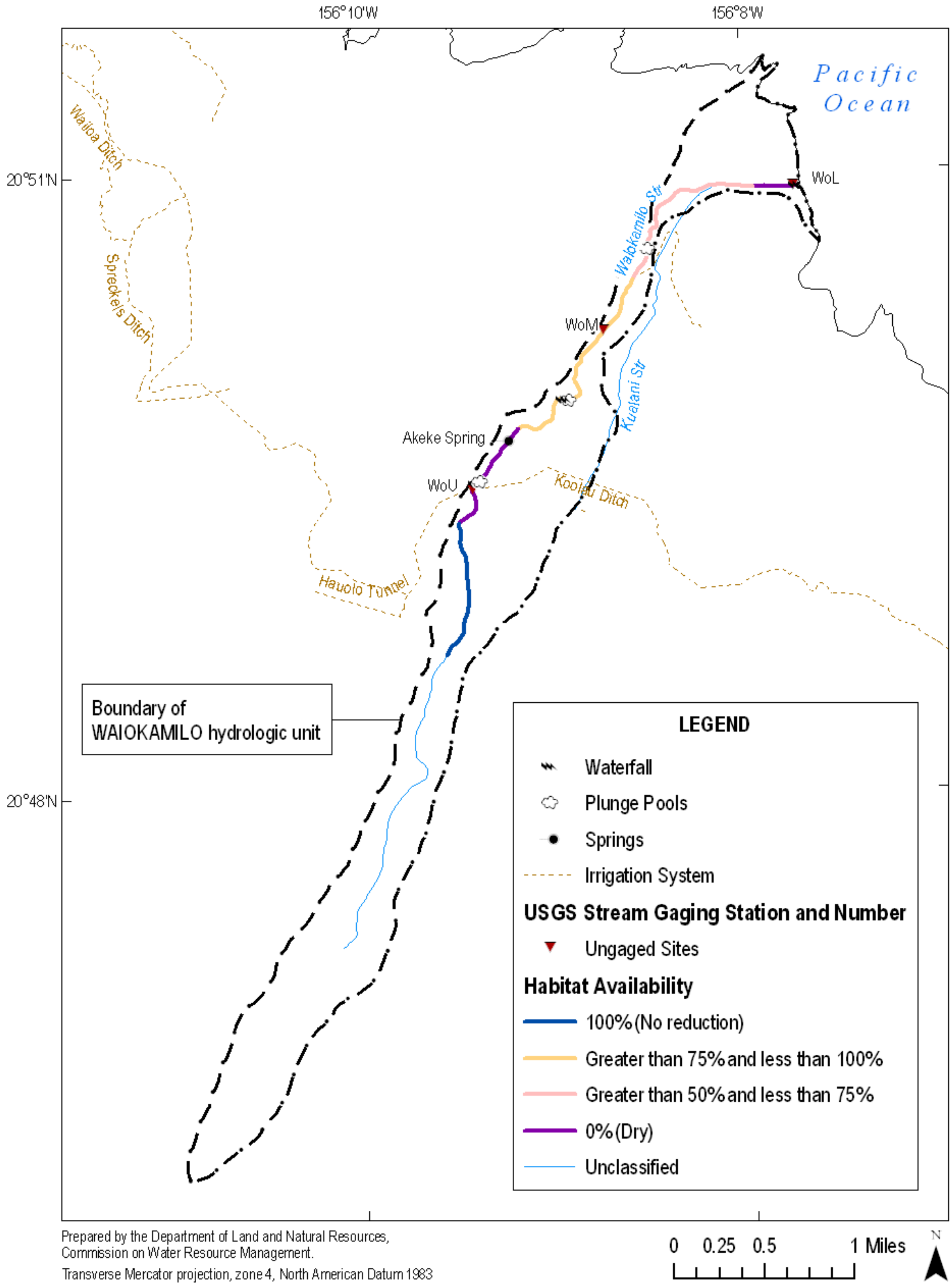


Figure 4-4. State Division of Aquatic Resources stream survey points for Waiokamilo hydrologic unit.

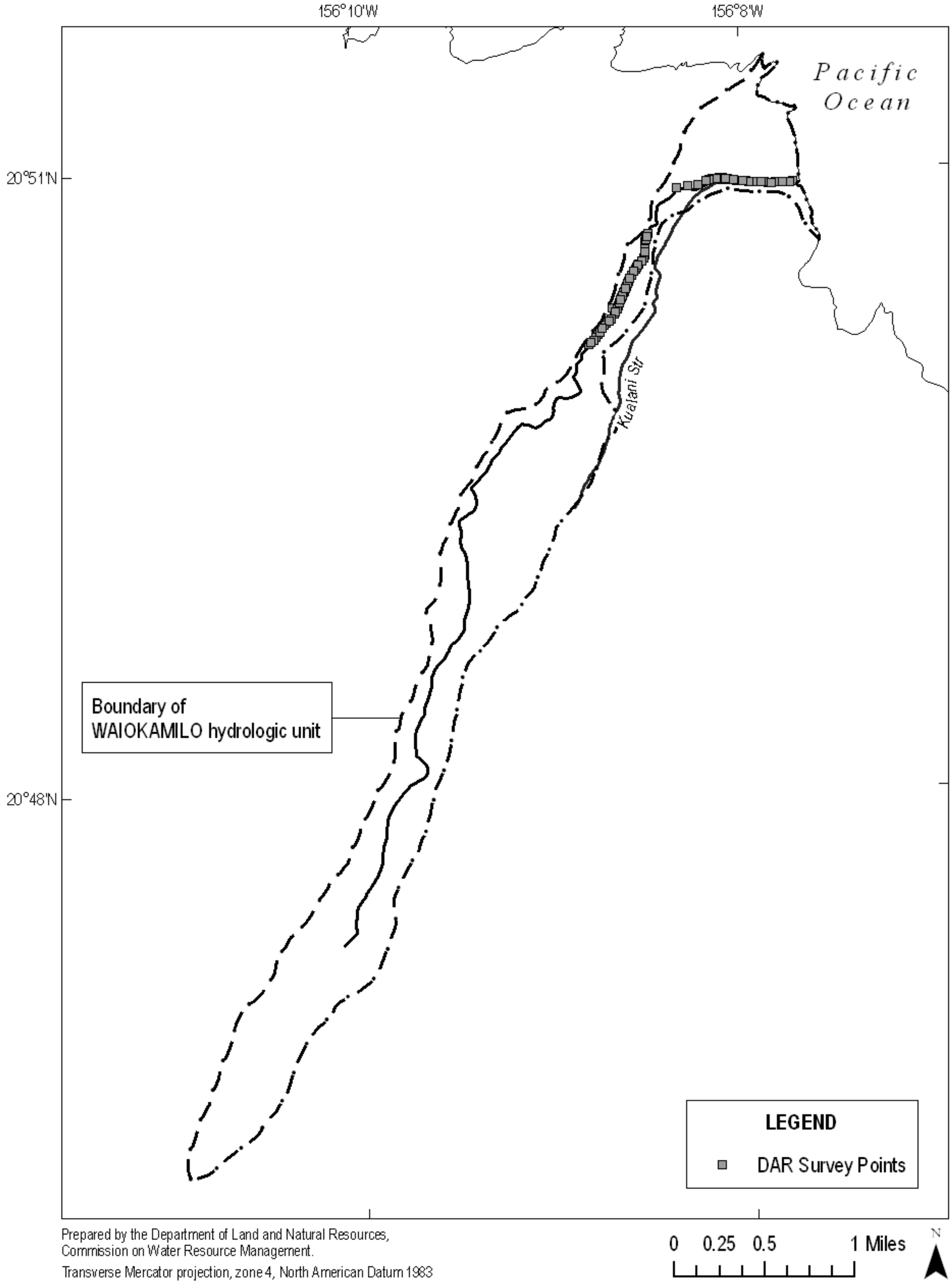
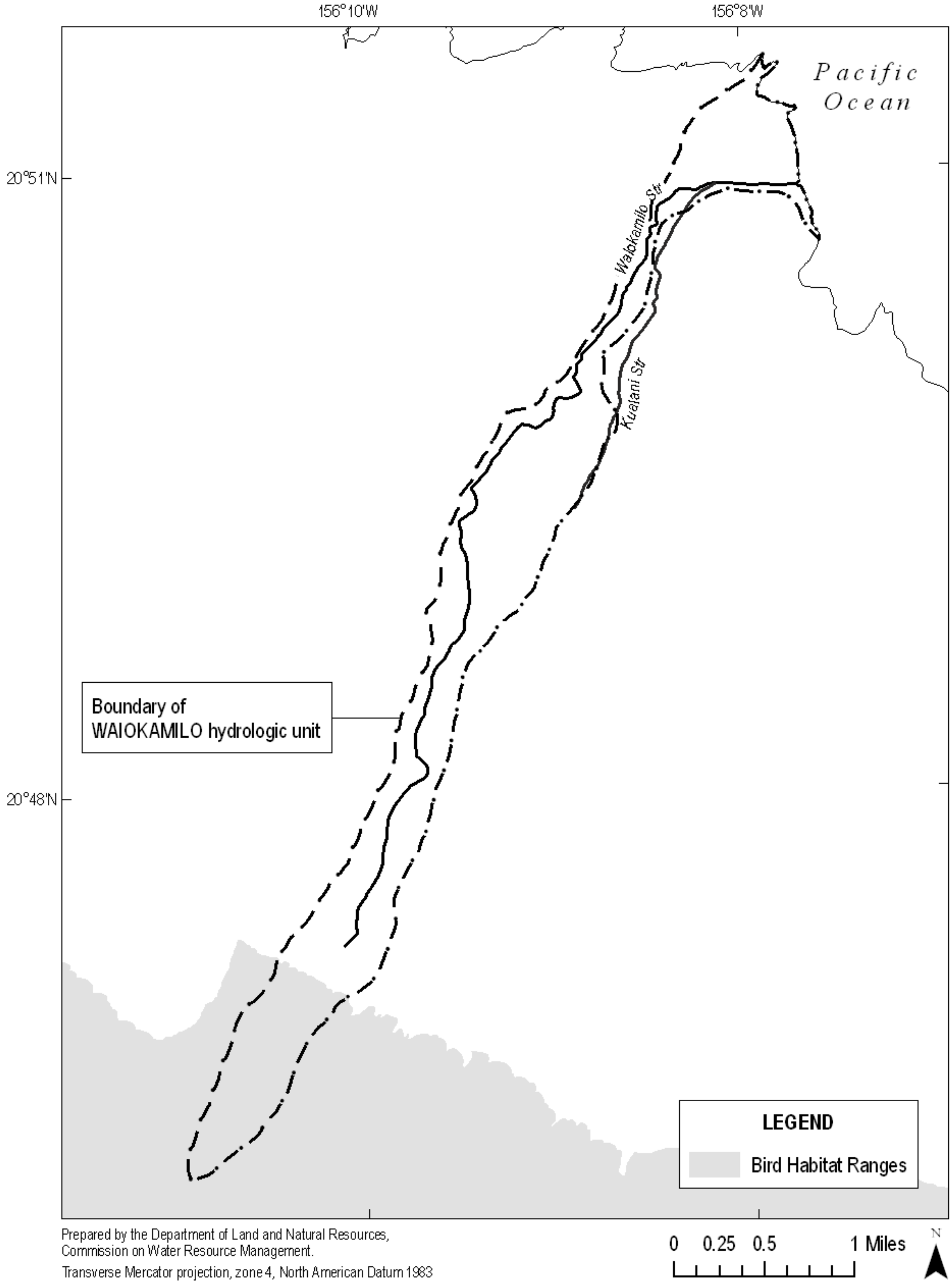


Figure 4-5. Bird habitat ranges, critical habitats, and density distribution of threatened and endangered plant species in the Waiokamilo hydrologic unit (Source: Jacobi, 1989; Scott et al., 1986; State of Hawaii, Office of Planning, 1992, 2004).



5.0 Outdoor Recreational Activities

Water-related recreation is an integral part of life in Hawaii. Though beaches may attract more users, the value of maintaining streamflow is important to sustaining recreational opportunities for residents and tourists alike. Streams are often utilized for water-based activities, such as boating, fishing, and swimming, while offering added value to land-based activities such as camping, hiking, and hunting. Growing attention to environmental issues worldwide has increased awareness of stream and watershed protection and expanded opportunities for the study of nature; however, this must be weighed in conjunction with the growth of the eco-tourism industry and the burdens that are placed on Hawaii's natural resources.

The recreational resources of Waiokamilo Stream were classified as "outstanding" by the HSA's regional recreation committee; however, it was not ranked as one of the outstanding streams statewide. The HSA identified opportunities for fishing, hunting, swimming, and scenic views related to Waiokamilo. Of a total of nine experiences (opportunities categorized by a recreational opportunity spectrum), three were defined as high quality experiences (Table 5-1).

Table 5-1. Hawaii Stream Assessment survey of recreational opportunities by type of experience.

	Urban		Country		Semi-Natural		Natural	
	Norm	High	Norm	High	Norm	High	Norm	High
Camping								
Hiking								
Fishing			■		■		■	
Hunting						■		
Swimming			■		■		■	
Boating								
Parks								
	Trail		Road		Ocean		Air	
Scenic Views						■		■
	Educational		Botanical					
Nature Study								

According to public hunting data, Hunting Unit B on the island of Maui consists of portions of the Koolau Forest Reserve. The portion of the hunting area unit within the Waiokamilo hydrologic unit is approximately 1.83 square miles or 74.7 percent of the hydrologic unit (Figure 5-1). A permit is required for the hunting of wild pigs and goats, using rifles, shotguns, bows and arrows, and dogs. Bag limits are two pigs and two goats of either sex per day, while the hunting season is open year-round on Saturdays, Sundays, and State holidays. Handguns are allowed for the hunting of pigs with or without dogs.

Since changes to streamflow and stream configurations have raised concerns regarding their impact to on-shore and near-shore activities, the Commission attempted to identify these various activities in relation to Waiokamilo Stream. A 1981 Maui Resource Atlas, prepared by the State of Hawaii Department of Transportation's Harbors Division, inventoried coral reefs and coastal recreational activities. Looking at available GIS data, the Commission identified the following activities that were known to occur or observed at or near Waiokamilo: pole and line fishing, trolling/bottom fishing, and some specialized fisheries. There are no opportunities for beach swimming related to Waiokamilo since the stream enters the ocean at a terminal waterfall known as Waiokilo Falls (Figure 5-2).

Another facet of recreation is the unique educational opportunities that streams provide for nature study. One way to approach this is to identify established study sites or nature centers that offer structured learning programs. In lieu of that, the Commission considered available GIS data to identify schools in proximity to Waiokamilo Stream that may utilize the stream as part of its curriculum. Keanae Elementary School, established in 1915, is the only public education facility in the area and is less than a 0.25 miles from Waiokamilo Stream. However, Keanae Elementary was closed in 2005, for the time being, due to a lack of students. Local area students must now attend Hana High and Elementary (San Nichols, C. 2005).

Figure 5-1. Public hunting areas for game mammals in Waiokamilo hydrologic unit (Source: State of Hawaii, Office of Planning, 2002b).

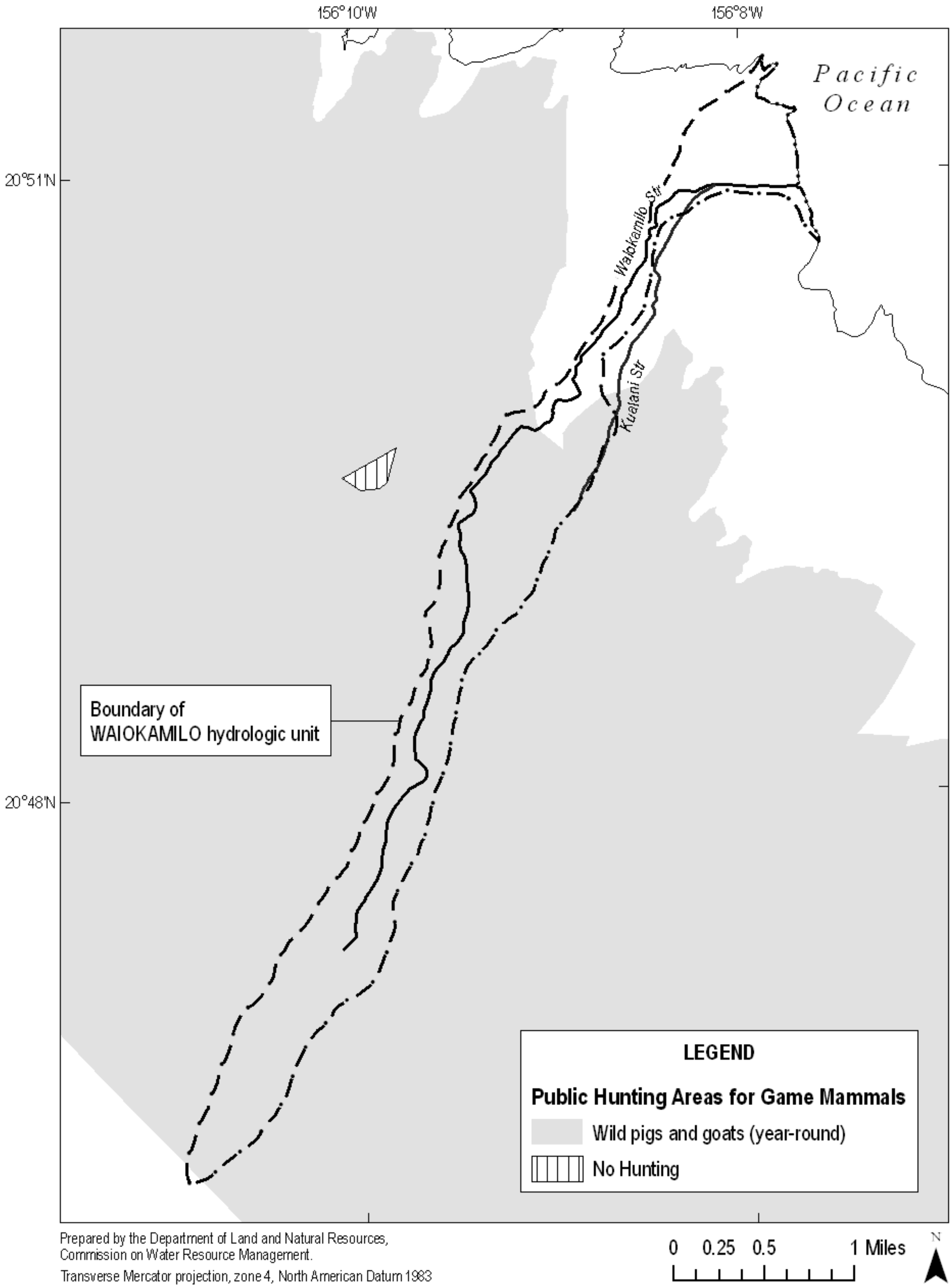
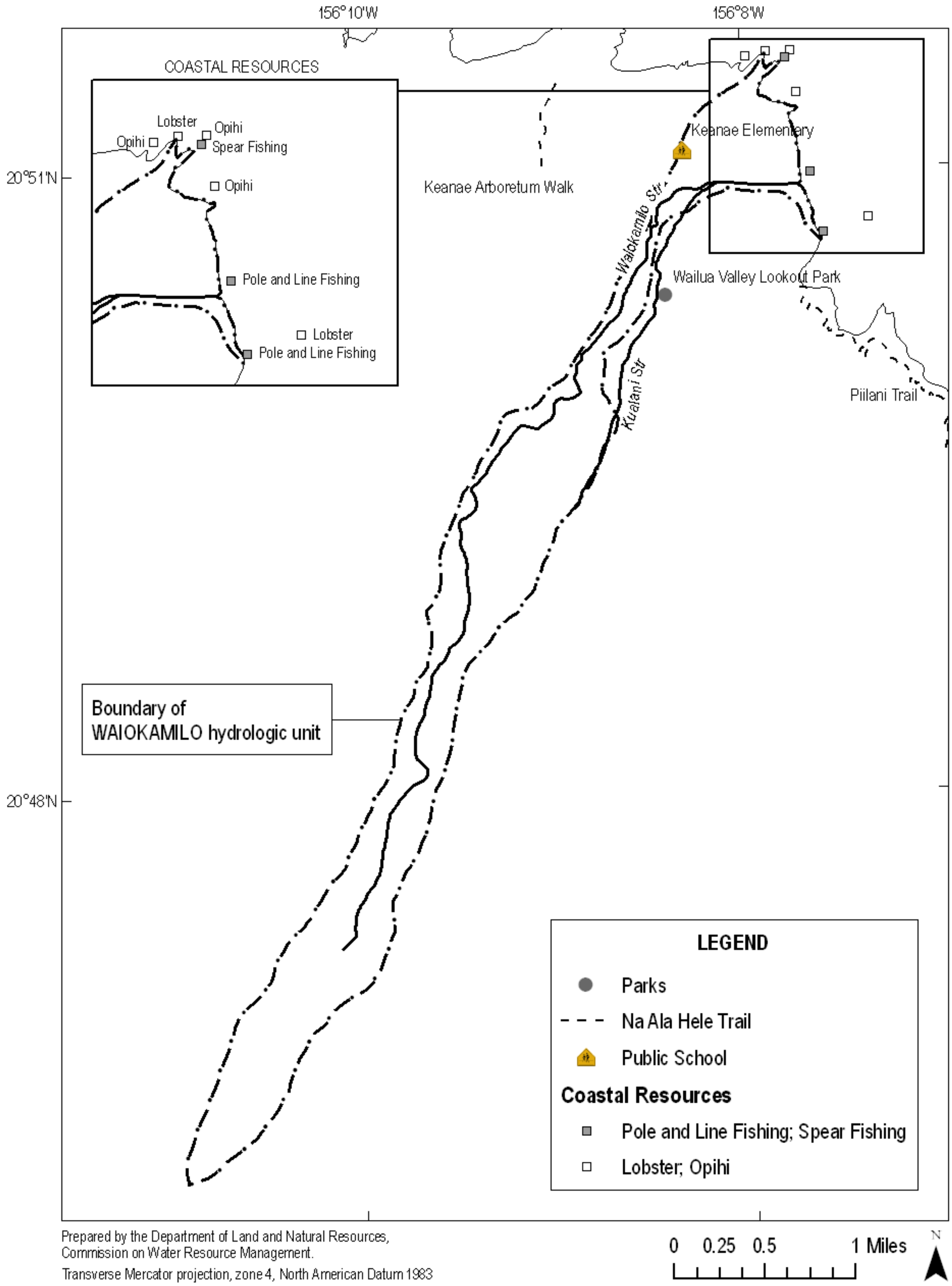


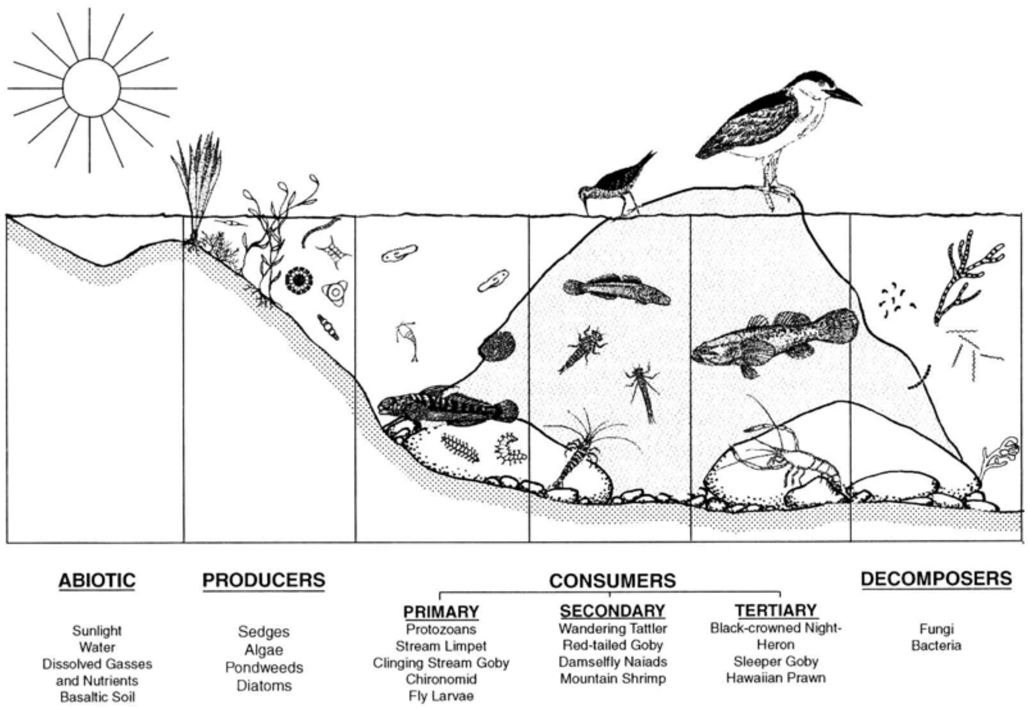
Figure 5-2. Recreational points of interest for Waiokamilo hydrologic unit (Source: State of Hawaii, Office of Planning, 1999, 2002a; 2002c; 2002d; 2004a).



6.0 Maintenance of Ecosystems

An ecosystem can be generally defined as the complex interrelationships of living (biotic) organisms and nonliving (abiotic) environmental components functioning as a particular ecological unit. Depending upon consideration of scale, there may be a number of ecosystem types that occur along a given stream such as estuaries, wetlands, and stream vegetation, according to the State Water Code. Figure 6-1 provides a simplified ecosystem represented in a Hawaiian stream. The entire hydrologic unit, as it relates to hydrologic functions of the stream, could also be considered an ecosystem in a very broad context.

Figure 6-1. Simplified ecosystem illustrated in a Hawaiian stream. (Source: Ziegler, 2002, illustration by Keith Kruger)



The Hawaiian resource-use concept of ahupuaa is closely related to the Western concepts of ecosystem maintenance. Native Hawaiians were only allowed to grow crops, hunt, fish, and gather materials within the limits of their ahupuaa, so there was substantial incentive for them to manage and conserve the resources within their living unit. Likewise, watershed resources must be properly managed and conserved to sustain the health of the stream and the instream uses that are dependent upon it.

The riparian resources of Waiokamilo Stream were not classified by the HSA. The HSA ranked the streams according to a scoring system using six of the seven variables presented in Table 6-1. Detrimental organisms were not considered in the final ranking; however, their presence and abundance are considerable ecosystem variables.

Table 6-1. Hawaii Stream Assessment indicators of riparian resources for Waiokamilo Stream.

Category	Value
Listed threatened and endangered species: These species are generally dependent upon undisturbed habitat. Their presence is, therefore an indication of the integrity of the native vegetation. The presence of these species along a stream course was considered to be a positive attribute; with the more types of threatened and endangered species associated with a stream the higher the value of the resource. Only federally listed threatened or endangered forest or water birds that have been extensively documented within the last 15 years were included.	None
Recovery habitat: Recovery habitat consists of those areas identified by the USFWS and DLNR as essential habitat for the recovery of threatened and endangered species. Streams that have recovery habitat anywhere along their length were included.	None
Other rare organisms and communities: Many species that are candidates for endangered or threatened status have not been processed through all of the requirements of the Endangered Species Act. Also a number of plant communities associated with streams have become extremely rare. These rare organisms and communities were considered to be as indicative of natural Hawaiian biological processes as are listed threatened and endangered species.	None
Protected areas: The riparian resources of streams that pass through natural area reserves, refuges and other protected areas are accorded special protection from degradation. Protected areas were so designated because of features other than their riparian resources. The presence of these areas along a stream, however, indicates that native processes are promoted and alien influences controlled.	None
Wetlands: Wetlands are important riparian resources. They provide habitat for many species and are often important nursery areas. Because they are often extensive areas of flat land generally with deep soil, many have been drained and converted to agricultural or urban uses. Those that remain are, therefore, invaluable as well as being indicators of lack of disturbance.	None
Native forest: The proportion of a stream course flowing through native forest provides an indication of the potential "naturalness" of the quality of a stream's watershed; the greater the percentage of a stream flowing through native forest most of which is protected in forest reserves the more significant the resource. Only the length of the main course of a stream (to the nearest 10 percent) that passes through native forest was recorded.	40%
Detrimental organisms: Some animals and plants have a negative influence on streams. Wild animals (e.g., pigs, goats, deer) destroy vegetation, open forests, accelerate soil erosion, and contaminate the water with fecal material. Weedy plants can dramatically alter the nature of a stream generally by impeding water flow. Three species, California grass, hau, and red mangrove, are considered to have the greatest influence. The presence of any of these animals or plants along a stream course was considered a potentially negative factor, while the degree of detriment is dependent on the number of species present.	2 (Hau, Pigs)

For the purpose of this section, management areas are those locales that have been identified by federal, state, county, or private entities as having natural or cultural resources of particular value. The result of various government programs and privately-funded initiatives has been a wide assortment of management areas with often common goals. Such designated areas include forest reserves, private preserves, natural area reserves, wildlife sanctuaries, national parks, historic landmarks, and so on. In Waiokamilo, nearly 75 percent of the hydrologic unit falls within the Koolau Forest Reserve (Table 6-2).

Table 6-2. Management areas located within Waiokamilo hydrologic unit.

Management Area	Managed by	Area (mi^2)	Percent of Unit
Koolau Forest Reserve	State Division of Forestry and Wildlife	1.83	74.7
The Koolau Forest Reserve, consisting of over 31,000 acres (48.45 sq. mi.) is one of eight reserves on the Island of Maui that are managed by DLNR's Division of Forestry and Wildlife. These reserves are established as multi-use land areas that incorporate various, and often competing, public uses and benefits. The management goals of the Forest Reserve System include: 1) Protect and manage forested watersheds for production of fresh water supply for public uses now and into the future; 2) Maintain biological integrity of native ecosystems; 3) Provide public recreational opportunities; and 4) Strengthen the economy by assisting in the production of high quality forest products in support of a sustainable forest industry.			
Pauwalu Point Wildlife Sanctuary	State Division of Forestry and Wildlife	0.01	0.5
The Pauwalu Point Wildlife Sanctuary, managed by DLNR's Division of Forestry and Wildlife, encompasses nearly 11 acres (0.02 sq. mi.) and includes Pauwalu Point and the offshore islets of Mokuhala, Mokumana, and Manahoa (Rock). This sanctuary has been identified by the USFWS as an area for waterbird recovery			

In addition to the individual management areas outlined above, Watershed Partnerships are another valuable component of ecosystem maintenance. Watershed Partnerships are voluntary alliances between public and private landowners who are committed to responsible management, protection, and enhancement of their forested watershed lands. There are currently nine partnerships established statewide, three of which are on Maui. Table 6-3 provides a summary of the partnership area, partners, and management goals of the East Maui Watershed Partnership.

Table 6-3. Watershed partnerships associated with Waiokamilo hydrologic unit.

Management Area	Year Established	Total Area (mi^2)	Area (mi^2)	Percent of Unit
East Maui Watershed Partnership	1991	186.73	1.88	76.7
The East Maui Watershed Partnership (EMWP) is comprised of the County of Maui, State Department of Land and Natural Resources, East Maui Irrigation Co. Ltd., Haleakala National Park, Haleakala Ranch Company, Keola Hana Maui, Inc. (Hana Ranch Company), and The Nature Conservancy. The management priorities of the EMWP include: 1) Watershed resource monitoring; 2) Animal control; 3) Weed control; 4) Management infrastructure; and 5) Public education and awareness programs. The EMWP has conducted various projects including the construction of over seven miles of fence construction and on-going fence maintenance, the survey and removal of invasive plant species, eradication of animal species through an expanded hunting program, implementation of runoff and stream protection measures, water quality monitoring, and extensive public education and outreach campaigns.				

In 1974, the U.S. Fish and Wildlife Service (USFWS) initiated a new National Wetlands Inventory that was considerably broader in scope than an earlier 1954 inventory that had focused solely on valuable waterfowl habitat. The inventory for Hawaii was completed in 1978 and utilized a hierarchical structure in the classification of various lands. The USFWS defines wetlands as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water" (Cowardin, L.M. et al., 1979). Nearly 46 percent of Waiokamilo is classified as seasonal, non-tidal palustrine wetlands occurring in the headwaters of the hydrologic unit (Table 6-4 and Figure 6-2). Palustrine wetlands are nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, or wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 percent.

Table 6-4. Wetland classifications for Waiokamilo hydrologic unit (Source: U.S. Fish and Wildlife Service, 1978).

System Type	Class	Regime	Area (mi^2)	Percent of Unit
Palustrine	Emergent, persistent	Seasonal non-tidal	< 0.01	0.1
Palustrine	Forested, broad-leaved evergreen	Seasonal non-tidal	0.78	31.7
Palustrine	Scrub/shrub, broad-leaved evergreen	Seasonal non-tidal	0.34	14.1

A series of vegetation maps describing upland plant communities was prepared as part of a USFWS survey in 1976 to 1981 to determine the current status of native forest birds and their associated habitats. Table 6-5 and Figure 6-3 present the portion of the hydrologic unit (~1000 feet above mean sea level) that was surveyed and the degree of disturbance of native forest. Nearly two-thirds of the unit above 1,500 feet is predominantly native species with little or no alien species.

Table 6-5. Distribution of native and alien plant species for Waiokamilo hydrologic unit. (Source: Jacobi, 1989).

Canopy Type	Area (mi^2)	Percent of Unit
Communities totally dominated by native species of plants	1.55	63.2
Communities dominated by introduced species but contain remnant populations of native species; no native community structure remaining	0.02	1.0

The density of threatened and endangered plant species is low at elevations below 1,600 feet, while the majority of the hydrologic unit, roughly 62 percent, has a high concentration of threatened and endangered plant species at higher elevations (Table 6-6 and Figure 6-4).

Table 6-6. Density of threatened and endangered plants for Waiokamilo hydrologic unit.

Density	Area (mi^2)	Percent of Unit
High concentration of threatened and endangered species	1.51	61.5
Low concentration of threatened and endangered species	0.94	38.5

A current working paper is being developed by the University of Hawaii's Economic Research Organization (UHERO), entitled *Environmental Valuation and the Hawaiian Economy*, which discusses the use of existing measures of economic performance and alternative statistical devices to provide an economic valuation of threatened environmental resources. The paper focuses on the Koolau, Oahu watershed and illustrates three categories of positive natural capital (forest resources, shoreline resources, and water resources) against a fourth category (alien species) that degrades natural capital. In the case of the Koolau forests, a benchmark level of degradation is first defined for comparison against the current value of the Koolau system. The Koolau case study considers a hypothetical major disturbance caused by a substantial increased population of pigs with a major forest conversion from native trees to the non-indigenous Miconia (*Miconia calvescens*), along with the continued "creep" of urban areas into the upper watershed (Kaiser, B. et al., n.d.).

Recognizing that in the United States, the incorporation of environmental and natural resource considerations into economic measures is still very limited, the paper provides the estimated Net Present Value (NPV) for "Koolau Forest Amenities." These values are presented in Table 6-7.

Table 6-7. Estimated Net Present Value (NPV) for Koolau Forest Amenities (Source: Kaiser, B. et al., n.d.).

Amenity	Estimated Net Present Value (NPV)	Important limitations
Ground water quantity	$4.57 to $8.52 billion NPV	Optimal extraction assumed.
Water quality	$83.7 to $394 million NPV	Using averted dredging cost estimates.
In-stream uses	$82.4 to $242.4 million NPV	Contingent valuation estimate for a single small fish species.
Species habitat	$487 to $1,434 million NPV	Contingent valuation estimate for a single small bird species.
Biodiversity	$660,000 to $5.5 million NPV	Average cost of listing 11 species in Koolaus.
Subsistence	$34.7 to $131 million NPV	Based on replacement value of pigs hunted.
Hunting	$62.8 to $237 million NPV	Based on fraction of hunting expenditures in state. Does not include damages from pigs to the other amenities.
Aesthetic values	$1.04 to $3.07 million NPV	Contingent valuation; Households value open space for aesthetic reasons.
Commercial harvests	$600,000 to $2.4 million NPV	Based on small sustainable extraction of koa.
Ecotourism	$1.0 to $2.98 billion NPV	Based on fraction of direct revenues to ecotourism activities.
Climate control	$82.2 million	Based on replacement costs of contribution of all tropical forests to carbon sequestration.
Estimated value of joint services:	**$7.444 to $14.032 billion**	

Following upon the results of the Koolau case study, the paper provides a brief comparison with the east Maui forests, noting the particular importance of the east Maui watershed as the single largest source of surface water in the state, home to some of the most intact and extensive native forests left in Hawaii, along with having the State's largest concentration of endangered forest birds. In both cases, the Koolaus and east Maui, the most valuable aspects of the forested areas are believed to be ecotourism, aesthetic pleasure, species habitat, water quality, and water quantity. Both regions are roughly the same size; however, the east Maui forests may have greater value due to greater species diversity and native habitat, and the County of Maui's dependence upon surface water as a drinking water source (water quality) (Kaiser, B. et al., n.d.).

Figure 6-2. Reserves and wetlands for the Waiokamilo hydrologic unit (Source: State of Hawaii, Office of Planning, 2003; 2007b).

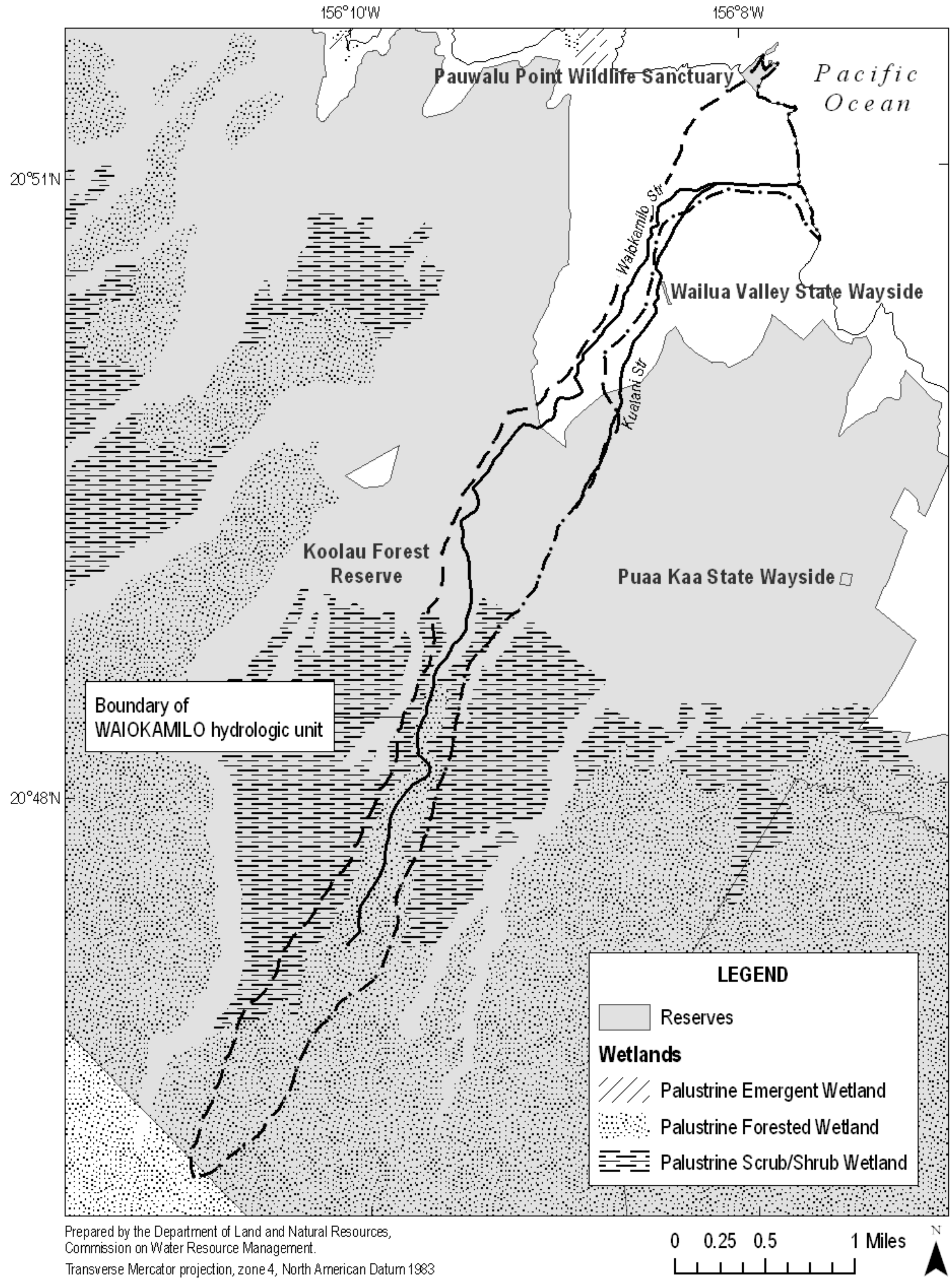


Figure 6-3. Distribution of native and alien plant species for Waiokamilo hydrologic unit (Source: Jacobi, 1989; Scott et al., 1986; State of Hawaii, Office of Planning, 1992, 2004b; 2004d).

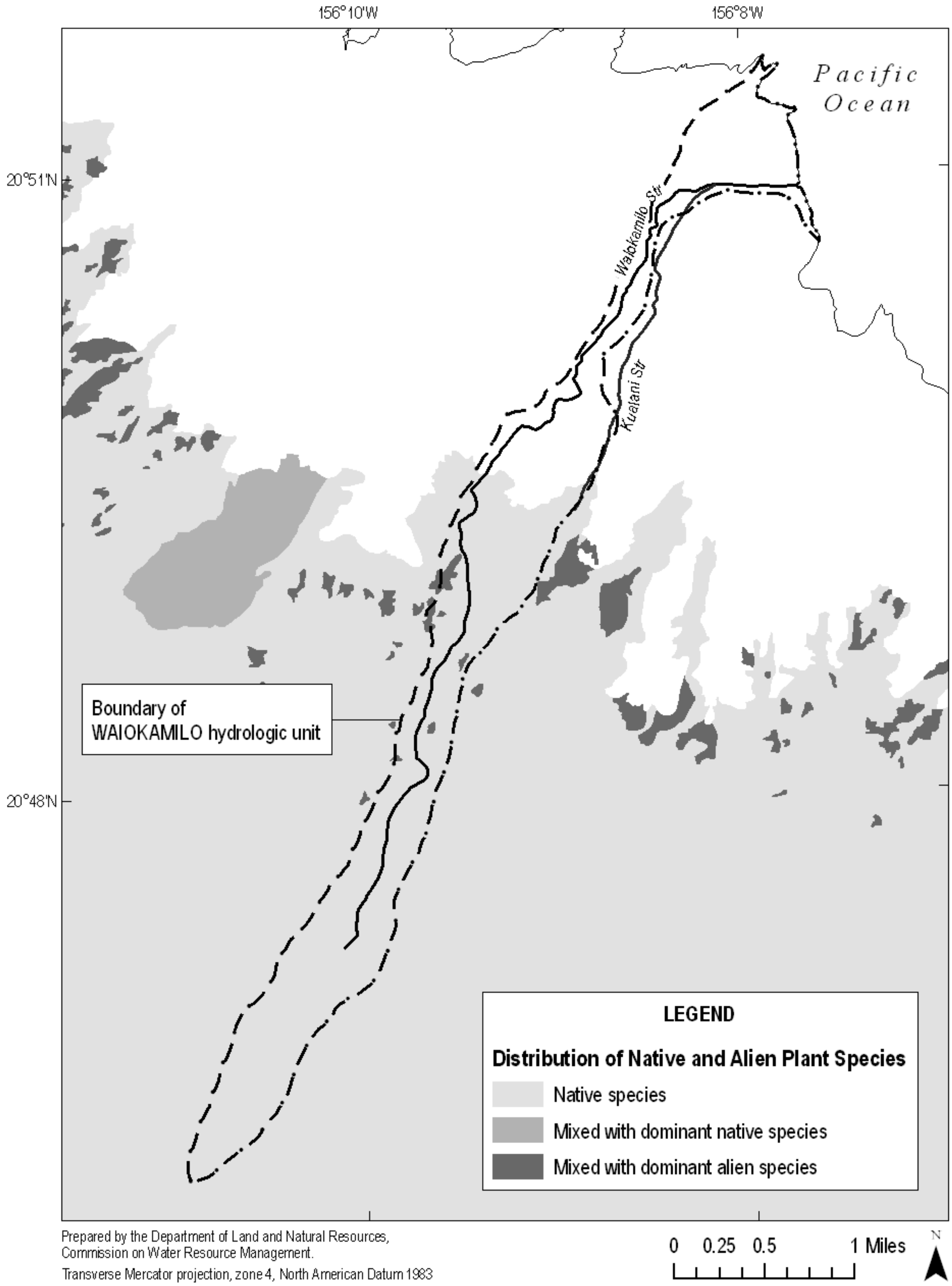
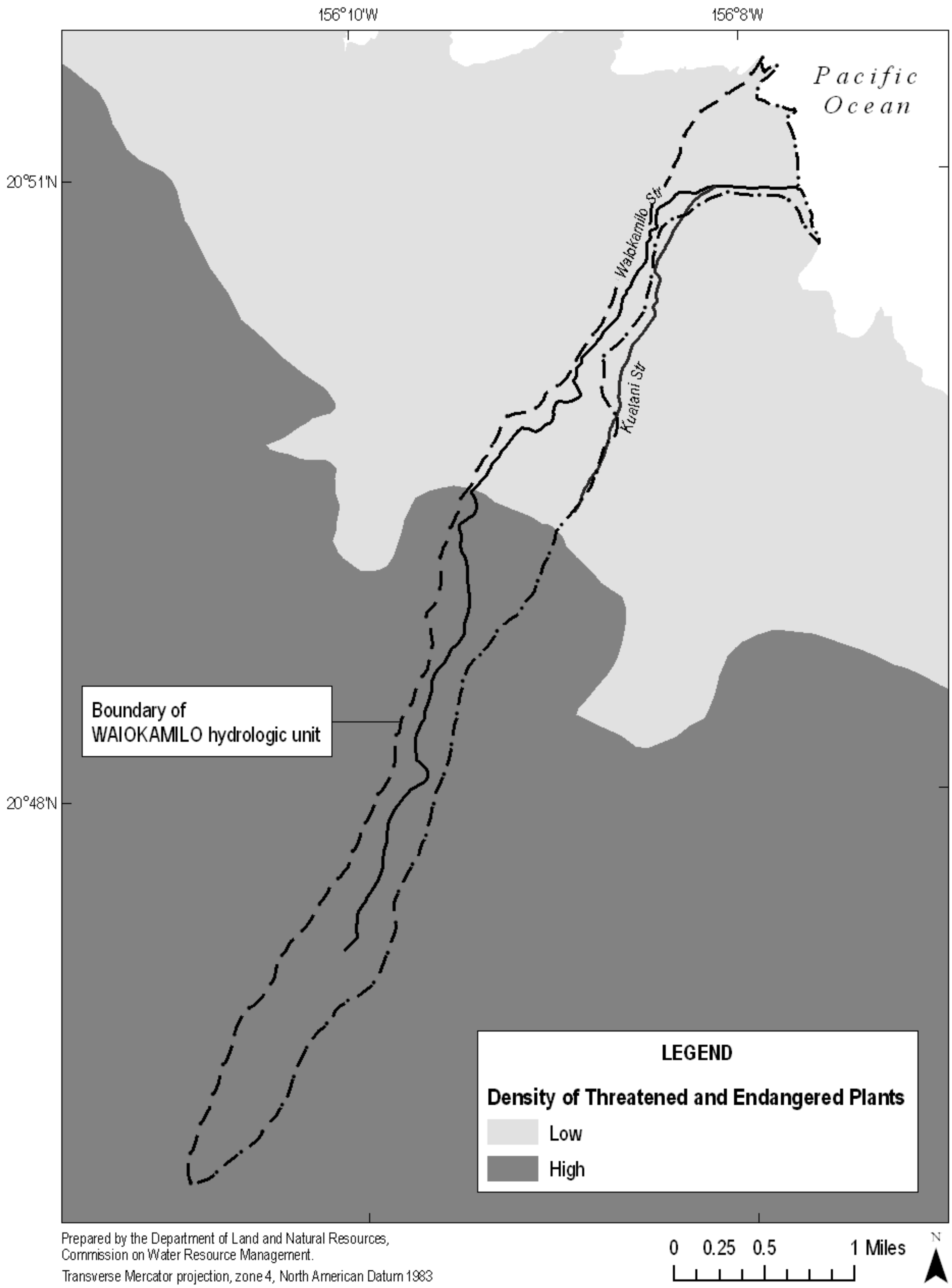


Figure 6-4. Density of threatened and endangered plant species for Waiokamilo hydrologic unit (Source: Jacobi, 1989; Scott et al., 1986; State of Hawaii, Office of Planning, 1992; 2004b; 2004d).



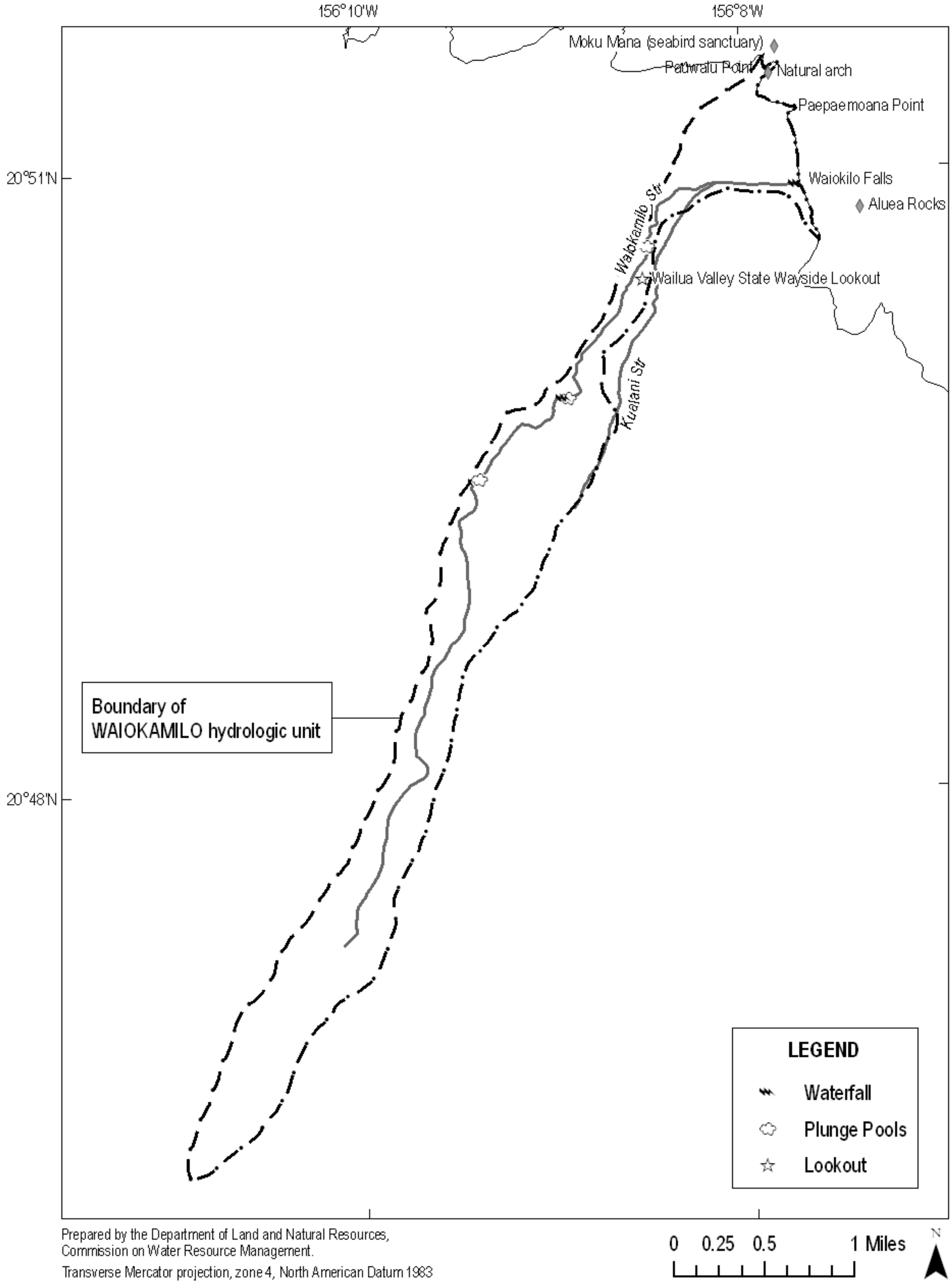
7.0 Aesthetic Values

Aesthetics is a multi-sensory experience related to an individual's perception of beauty. Since aesthetics by definition is a subjective observation, a stream's aesthetic value cannot be determined quantitatively (Wilson Okamoto & Associates, Inc., 1983). However, there are certain elements, either within or surrounding a stream, which appeal to an observer's visual and audio senses, such as waterfalls and cascading plunge pools. Several assumptions were made in identifying the elements that give Waiokamilo Stream a particular aesthetic quality.

The headwaters of Waiokamilo Stream originate in the lush tropical forests of the Koolau Forest Reserve. Along with its tributary Kualani Stream, they flow northeasterly through the evergreen forests that cover a majority of the drainage basin. Of the two waterfalls along Waiokamilo Stream, Waiokilo Falls is located near the coast. Wailua Valley State Wayside Lookout is located at about 430 ft elevation and provides a picturesque view of the upper basin as well as the lower basin where the stream empties into the ocean. (Figure 7-1).

In a 2007 Hawaii State Parks Survey, released by the Hawaii Tourism Authority, scenic views accounted for 21 percent of the park visits statewide, though that was a decrease from 25 percent in a 2003 survey. Other aesthetic-related motivations include viewing famous landmarks (9 percent), hiking trails and walks (7 percent), guided tour stops (6 percent), and viewing of flora and fauna (2 percent). On the island of Maui, visitors' preference to visit state parks for scenic views (26 percent) was second only to uses for outings with family and friends (29 percent). In comparison, residents primarily used state parks for ocean/water activities (30 percent), followed by outings with friends and family (28 percent), and then scenic views (9 percent). Overall, Maui residents were very satisfied with scenic views giving a score of 9.7 (on a scale of 1 to 10, with 10 being outstanding), with out-of-state visitors giving a score of 9.3. Though there are no state parks located in the hydrologic unit, it is assumed that where Waiokamilo Stream crosses Hana Highway there may be opportunities for scenic enjoyment.

Figure 7-1. Aesthetic points of interest for the Waiokamilo hydrologic unit (Source: Gingerich and Wolff, 2005, Plate 1; U.S. Geological Survey, 1996).



8.0 Navigation

The State Water Code, Chapter 174C, HRS, includes navigation as one of nine identified instream uses; however, it fails to further define navigation. Navigational water use is largely defined as water utilized for commercial, and sometimes recreational, transportation. In the continental United States, this includes water used to lift a vessel in a lock or to maintain a navigable channel level. Under the provisions of the Clean Water Act, navigable waters also include wetlands (Nevada Division of Water Resources, n.d.).

Hawaii streams are generally too short and steep to support navigable uses. If recreational boating (primarily kayaks and small boats) is included under the definition of navigation, then there are only a handful of streams statewide that actually support recreational boating and even fewer that support commercial boating operations. Kauai's Wailua River is the only fresh water waterway where large boat commercial operations exist, and no streams are believed to serve as a means for the commercial transportation of goods.

The hydrologic unit of Waiokamilo is not known to support any instream uses of navigation.

9.0 Instream Hydropower Generation

The generation of hydropower is typically accomplished through instream dams and power generators; however, the relatively short lengths and flashy nature of Hawaii’s streams often require water to be diverted to offstream power generators. In these “run-of-river” (i.e., utilizes water flow without dams or reservoirs) designs, water is diverted through a series of ditches, pipes, and penstocks to the powerplant, and then returned to the stream. Some designs call for the powerplant to be situated such that the drop of water level (head) exiting the plant can be sent to fields for crop irrigation instead.

Considering the definition of instream hydropower generation, there are no known true instream hydropower systems located on Waiokamilo Stream, nor has the potential for hydropower generation been identified in previous reports (W.A. Hirai & Associates, Inc., 1981).

While the following information should perhaps be a part of Section 13.0, Noninstream uses, it has been included here for further consideration. Carol Wilcox, in her book *Sugar Water: Hawaii’s Plantation Ditches*, described the use of surface water for generating hydroelectricity by Hawaiian Commercial and Sugar Company as follows:

> On Maui, Hawaiian Commercial and Sugar Company (HC&S) had three hydroelectric plants, all utilizing water collected by the East Maui Irrigation Company (EMI) irrigation system. The earliest, Paia Hydro, was built by Maui Agricultural Company in 1912 with an 800-kilowatt capacity. In 1923, the penstock was extended to a higher elevation, thus increasing the capacity to 1000 kilowatts. HC&S built a 4000-kilowatt hydroplant at Kaheka in 1924. In 1982, a 500-kilowatt hydroelectric powerplant was installed at the Hamakua Ditch above Paia. Located only 50 feet below the Wailoa Forebay, this “low-head” hydroplant takes water through a 36-inch pipe and discharges it into the Hamakua Ditch.
>
> Besides these three hydros, HC&S has a bagasse-powered steam powerplant at the Paia factory, and the Central Powerplant, built in 1918, located at Kahului. In 1921, electric lighting was brought to the camp houses. By the 1930s this was the largest plantation power system in Hawaii, with a 12,000-kilowatt capacity. The largest consumer was the water pumps (6000 kilowatts), then the factory (1500 kilowatts), and general uses such as lighting, feed mill, dairy, carpentry shop, refrigerator plants, machine shops, and “talkie movie houses” (400 kilowatts). Surplus power (900 kilowatts) was sold to Kahului Railroad Company and to Maui Electric Company. The Central Powerplant supplied power for all of central Maui until after World War II. In 1984, the combined total capacity of all HC&S power-generating systems was rated at 37,300 kilowatts.

The hydrologic unit of Waiokamilo is not known to support any instream or noninstream generation of hydroelectricity.

10.0 Maintenance of Water Quality

The maintenance of water quality is important due to its direct impact upon the maintenance of other instream uses such as fish and wildlife habitat, outdoor recreation, ecosystems, aesthetics, and taro cultivation (traditional and customary Hawaiian rights). Water quantity may directly impact water quality, as reduction of stream flows often results in increased water temperatures, and higher flows can aid in quickly diluting stream contamination events. Surface water temperatures may fluctuate widely in response to seasonal and diurnal variations, water column depth, channel substrate, presence of riparian vegetation, and ground water influx. Surface water also differs considerably from ground water, generally exhibiting lower concentrations of total dissolved solids, chlorides, and other major ions, along with higher concentrations of suspended solids, turbidity, microorganisms, and organic forms of nutrients (Lau and Mink, 2006). Findings of a 2004 USGS National Water Quality Assessment (NAWQA) Program report identified land use, storm-related runoff, and ground water inflow as major contributors of surface water contaminants (Anthony, S.S. et al., 2004).

The State of Hawaii Department of Health (DOH), Environmental Planning Office maintains State Water Quality Standards (WQS), a requirement under the Federal Clean Water Act (CWA) of the Environmental Protection Agency (EPA). The CWA aims to keep waters safe for plants and animals to live and people to wade, swim, and fish. Water Quality Standards are the measures that states use to evaluate the physical, chemical, and biological health of their waters.

State WQS define: 1) the classification system for State surface waters, which assigns different protected uses to different water classes; 2) the specific numeric or narrative water quality criteria needed to achieve that use; and 3) a general antidegradation policy, which maintains and protects water quality for the uses defined for a class. Quantitative and qualitative data are utilized. Numeric water quality criteria have specific numeric concentrations (levels of pollutants) that must be met. Narrative water quality criteria are statements that must be met, such as "all waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants (State of Hawaii, Department of Health, 2004)." Conventional pollutants include nutrients and sediments. Toxic pollutants include pesticides and heavy metals. Indicator bacteria are utilized to assess bacterial levels. Biological assessments of aquatic communities are also included in the data collected.

A 2006 DOH report to the EPA integrates CWA section (§) 305(b) and §303(d). CWA §305(b) requires states to describe the overall water quality statewide and the extent to which water quality provides for the protection and propagation of a balanced population of shellfish, fish, and wildlife and allows recreational activities in and on the water.…The CWA §303(d) requires states to submit a list of Water-Quality Limited Segments, waters that do not meet state water quality standards, plus a priority ranking of listed waters, based on the severity of pollution and the uses of the waters.…The §303(d) list leads to action (State of Hawaii, Department of Health, 2006, Executive Summary)."

The sources for the 2006 integrated report are Hawaii's 2004 §303(d) list, plus readily-available data collected from any State water bodies over the preceding six years (State of Hawaii, Department of Health, 2006). Per §303(d), impaired waters are listed after review of "'all existing and readily available water quality-related data and information' from a broad set of data sources" (State of Hawaii, Department of Health, 2004, p.57). However, available data are not comprehensive of all the streams in the State. According to the Hawaii Administrative Rules Title 11 Chapter 54 (HAR 11-54) all State waters are subject to monitoring; however, in the most recent list published (2006), only 74 streams statewide had sufficient data for evaluation of whether exceedence of WQS occurred. Neither Waiokamilo Stream nor Kualani Stream appears on the 2006 List of Impaired Waters in Hawaii, Clean

Water Act §303(d). While some data exist for Waiokamilo Stream (and its "entire network"), there were not sufficient data for decision-making.

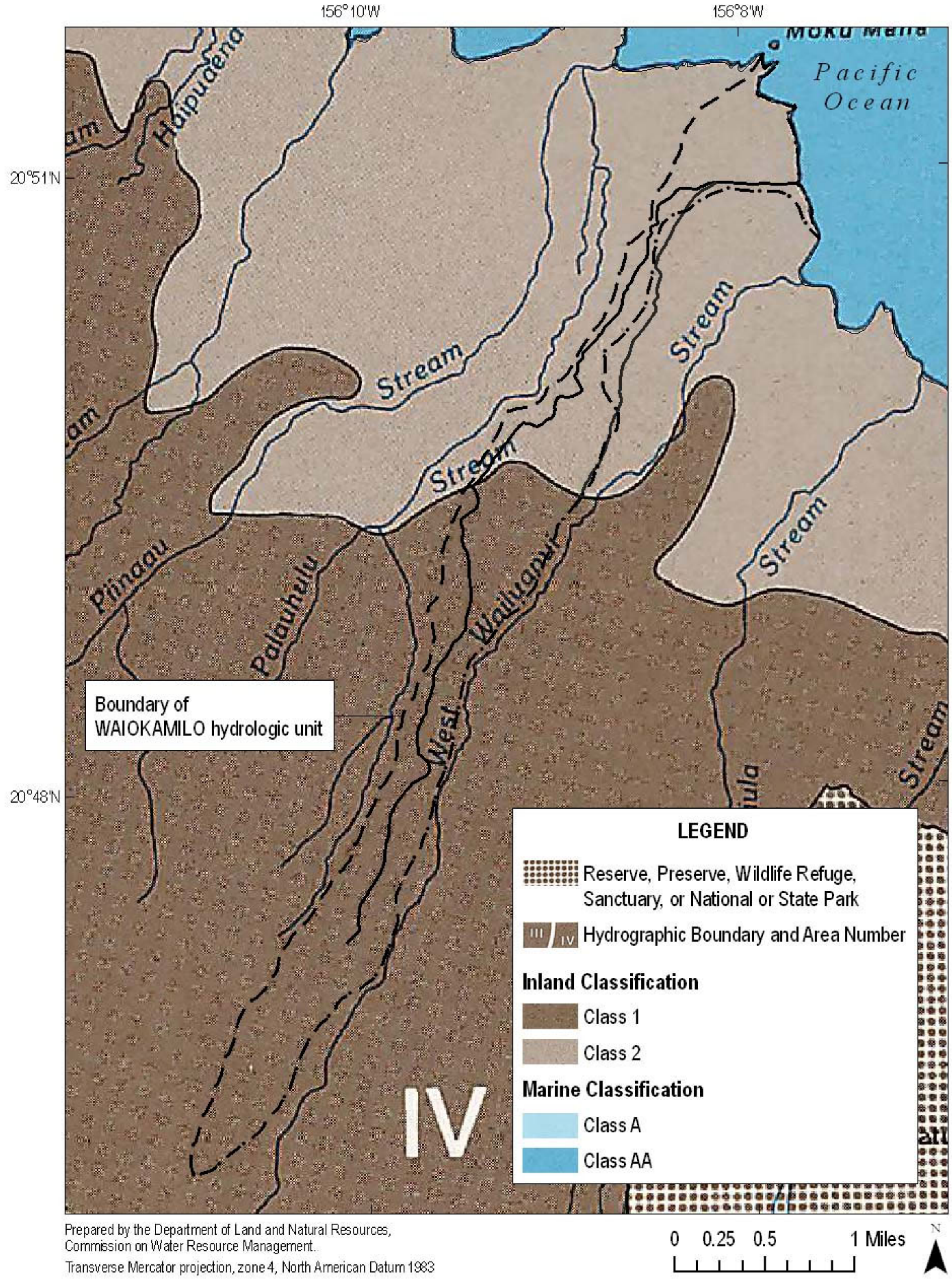
The 2006 integrated report indicates that the "current WQS require the use of enterococci as the indicator bacteria for evaluating public health risks in inland waters; however, no new data was [*sic*] available for this parameter in inland waters. [DOH Clean Water Branch] efforts have been focused on coastal areas (State of Hawaii, Department of Health, 2006, Chapter II, p.20)." The report also states: "Public health concerns may be underreported. Leptospirosis is not included as a specific water quality standard parameter. However, all freshwaters within the state are considered potential sources of Leptospirosis infection by the epidemiology section of the Hawaii State Department of Health. No direct tests have been approved or utilized to ascertain the extent of the public health threat through water sampling. Epidemiologic evidence has linked several illness outbreaks to contact with freshwater, leading authorities to issue blanket advisories for all fresh waters of the state (State of Hawaii, Department of Health, 2006, Chapter II, p.3)."

HAR 11-54 addresses WQS. It classifies inland and marine waters for purposes of applying standards and water quality parameters. Class 1 inland waters are protected to "remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source." These waters are used for a number of purposes including domestic water supply, protection of native breeding stock, and baseline references from which human-caused changes can be measured. Class 2 inland waters are protected for uses such as recreational purposes, support of aquatic life, and agricultural water supplies. Waters in natural reserves, preserves, sanctuaries, refuges, national and state parks, and state or federal fish and wildlife refuges are considered Class 1 waters.

Waiokamilo Stream is Class 2 from the coast to approximately 1,550 feet elevation. Above that elevation, it is Class 1. Kualani Stream is Class 2. It should be noted that there is no direct relationship between elevation and water quality.

HAR 11-54 classifies marine waters. The objective of Class AA waters is that they "remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions." Class A waters are protected for recreational purposes and aesthetic enjoyment; and protection of fish, shellfish, and wildlife. Discharge into these waters is permitted under regulation. The marine waters at the mouth of the entire Waiokamilo hydrologic unit are Class AA waters. Figure 10-1 shows the Waiokamilo hydrologic unit, including inland and marine (coastal) water classifications.

Figure 10-1. Water quality standards for the Waiokamilo hydrologic unit. (Source: State of Hawaii, Department of Health, 1987). The classifications are general in nature and should be used in conjunction with Hawaii Administrative Rules, Chapter 11-54, Water Quality Standards.



11.0 Conveyance of Irrigation and Domestic Water Supplies

Under the State Water Code, the conveyance of irrigation and domestic water supplies to downstream points of diversion is included as one of nine listed instream uses. The thought of the stream as a conveyance mechanism for noninstream purposes almost seems contrary to the concept of instream flow standards. However, the inclusion of this instream use is intended to ensure the availability of water to all those who may have a legally protected right to the water flowing in a stream. Of particular importance in this section is the diversion of surface water for domestic purposes. In its August 2000 decision on the Waiahole Ditch Combined Contested Case Hearing, the Hawaii Supreme Court identified domestic water use of the general public, particularly drinking water, as one of, ultimately, four trust purposes.

The Commission's records for the hydrologic unit of Waiokamilo indicate that there are a total of 19 registered diversions, of which 15 are non-East Maui Irrigation Company (EMI) diversions. Since EMI diversions transport water to locations outside of this hydrologic unit, the information is not discussed in this section; rather, it is included in Section 13.0, Noninstream uses. Of the remaining 15 diversions, 11 were declared for domestic purposes, in part, with a total of eight service connections. All 15 diversions are utilized for irrigation of various crops and livestock, including the cultivation of taro.

This information is derived from original registration documents, much of which has not been field verified and may have changed. In 2007, the Commission contracted R.M. Towill Corporation to conduct a statewide diversion verification inventory starting with priority areas across the island of Maui. The Commission is currently awaiting the results of the field verifications and plans to include this data upon further assessment of best available information. More detailed information on each registered diversion may be found in Table 13-1 in Section 13.0, Noninstream uses.

NOTE: The Commission is currently awaiting stream diversion verification data for Waiokamilo Stream from its consultants.

12.0 Protection of Traditional and Customary Hawaiian Rights

The maintenance of instream flows is important to the protection of traditional and customary Hawaiian rights, as they relate to the maintenance of stream resources (e.g., hihiwai, opae, oopu) for gathering, recreation, and the cultivation of taro. In ancient Hawaii, the islands (*moku*) were subdivided into political subdivisions, or ahupuaa, for the purposes of taxation. The term ahupuaa in fact comes from the altar (*ahu*) that marked the seaward boundary of each subdivision upon which a wooden head of a pig (*puaa*) was placed at the time of the *Makahiki* festival when harvest offerings were collected for the rain god and his earthly representative (Handy et al., 1972).

Each ahupuaa had fixed boundaries that were usually delineated by natural features of the land, such as mountain ridges, and typically ran like a wedge from the mountains to the ocean thus providing its inhabitants with access to all the natural resources necessary for sustenance. The beach, with its fishing rights, were referred to as *ipu kai* (meat bowl), while the upland areas for cultivation were called *umeke ai* (poi container hung in a net) (Handy et al., 1972). As noted earlier in Section 6.0, Western concepts of ecosystem maintenance and watersheds are similar to the Hawaiian concept of ahupuaa, and so the Commission's surface water hydrologic units often coincide with or overlap ahupuaa boundaries. The hydrologic unit of Waiokamilo encompasses the ahupuaa of Wailua Nui, Keanae, and Haiku Uka as shown in Figure 12-2.

Appurtenant rights are rights to the use of water utilized by (non-riparian) parcels of land at the time of their original conversion into fee simple lands: When land allotted during the 1848 Mahele was confirmed to the awardee by the Land Commission and/or when the Royal Patent was issued based on such award, the conveyance of the parcel of land carried with it the appurtenant right to water (State of Hawaii, Commission on Water Resource Management, 2007). These rights are provided for under the State Water Code, HRS §174C-101, as follows:

- Provisions of this chapter shall not be construed to amend or modify rights or entitlements to water as provided for by the Hawaiian Homes Commission Act, 1920, as amended, and by chapters 167 and 168, relating to the Molokai irrigation system. Decisions of the commission on water resource management relating to the planning for regulation, management, and conservation of water resources in the State shall, to the extent applicable and consistent with other legal requirements and authority, incorporate and protect adequate reserves of water for current and foreseeable development and use of Hawaiian home lands as set forth in section 221 of the Hawaiian Homes Commission Act.

- No provision of this chapter shall diminish or extinguish trust revenues derived from existing water licenses unless compensation is made.

- Traditional and customary rights of ahupuaa tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778 shall not be abridged or denied by this chapter. Such traditional and customary rights shall include, but not be limited to, the cultivation or propagation of taro on one's own kuleana and the gathering of hihiwai, opae, oopu, limu, thatch, ti leaf, aho cord, and medicinal plants for subsistence, cultural, and religious purposes.

- The appurtenant water rights of kuleana and taro lands, along with those traditional and customary rights assured by this section, shall not be diminished or extinguished by a failure to apply for or to receive a permit under this chapter. (The exercise of an appurtenant water right is still subject to the water use permit requirements of the Water Code, but there is no deadline to exercise that right without losing it, as is the case for correlative and riparian rights, which must have been exercised before designation of a water management area.)

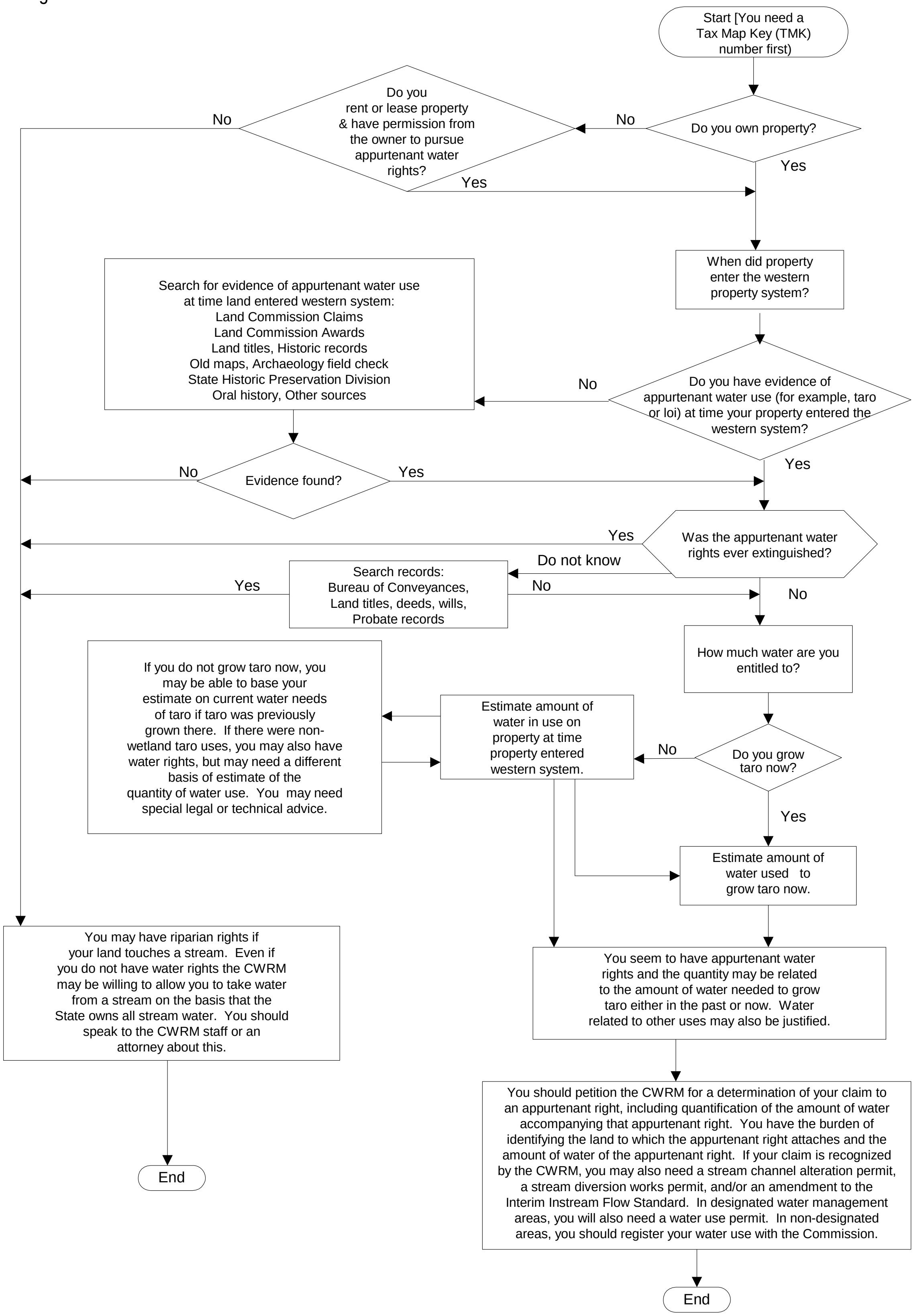
In August 2000, the Hawaii Supreme Court issued its decision in the Waiahole Ditch Combined Contested Case Hearing, upholding the exercise of Native Hawaiian and traditional and customary rights as a public trust purpose. These rights are described in the Commission's 2007 *Water Resource Protection Plan – Public Review Draft*, as follows:

> Appurtenant water rights are rights to the use of water utilized by (non-riparian) parcels of land at the time of their original conversion into fee simple lands i.e., when land allotted by the 1848 Mahele was confirmed to the awardee by the Land Commission and/or when the Royal Patent was issued based on such award, the conveyance of the parcel of land carried with it the appurtenant right to water.[1] The amount of water under an appurtenant right is the amount that was being used at the time of the Land Commission award and is established by cultivation methods that approximate the methods utilized at the time of the Mahele, for example, growing wetland taro.[2] Once established, future uses are not limited to the cultivation of traditional products approximating those utilized at the time of the Mahele[3], as long as those uses are reasonable, and if in a water management area, meets the State Water Code's test of reasonable and beneficial use ("the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is both reasonable and consistent with the State and county land use plans and the public interest"). As mentioned earlier, appurtenant rights are preserved under the State Water Code, so even in designated water management areas, an unexercised appurtenant right is not extinguished and must be issued a water use permit when applied for, as long as the water use permit requirements are met [Figure 12-1].

The Hawaii Legislative Session of 2002 clarified that the Commission is empowered to "determine appurtenant rights, including quantification of the amount of water entitled to by that right," (HRS §174C-5(15)). In those cases where a Commission decision may affect an appurtenant right, it is the claimant's duty to assert the appurtenant right and to gather the information required by the Commission to rule on the claim. The Commission is currently in the process of developing a procedural manual to aid in the understanding and assembling of information to substantiate an appurtenant rights claim.

[1] 54 Haw. 174, at 188; 504 .2d 1330, at 1339.
[2] 65 Haw. 531, at 554; 656 P.2d 57, at 72.
[3] *Peck v Bailey*, 8 Haw. 658, at 665 (1867).

Figure 12-1. Generalized process for determining appurtenant water rights. This process is generalized and may not fully explain all possible situations. It does not apply to Hawaiian Homes Lands. If you are Native Hawaiian you may have other water rights.



The Commission conducted a cursory assessment of tax map key parcels to identify their associated Land Commission Awards, in an attempt to identify the potential for future appurtenant rights claims within the hydrologic unit of Waiokamilo. In addition to original reference documents, a 2001 inventory conducted by Kumu Pono Associates, under contract by East Maui Irrigation Company, serves as a valuable reference of historical accounts of the lands of Hamakua Poko, Hamakua Loa and Koolau, Maui Hikina (east Maui). Table 12-1 presents the results of the Commission's assessment.

Table 12-1. Tax map key parcels with associated Land Commission Awards for the Waiokamilo hydrologic unit.

[LCA is Land Commission Award; Gr. is Grant; and G.L. is Government Lease.]

TMK	Landowner	LCA	Grants/Leases	Notes
(2)1-1-004:006	State Of Hawaii	none	G.L. S-4192	
(2)1-1-007:020	Ah You,Abel Jr /Etal	none	Gr. 2091:2	
(2)1-1-008:004	Acain,Lucy Ellen Akiona /Etal	3472	Gr. 3117	Gr. 3117 applies to parcels 4 and 23.
(2)1-1-008:005	State Of Hawaii	none	G.L. S-4328	
(2)1-1-008:006	Tam,Anne Vivienne W Y	none	Gr. 4866	
(2)1-1-008:007	Chong Kee Family Trust /Etal	none	Gr. 3223	
(2)1-1-008:010	Akina,Andrew /Etal	none	Gr. 1899	
(2)1-1-008:011	Algasca,Miulan /Etal	none	Gr. 2949	
(2)1-1-008:012	East Maui Irrigation Co. Ltd.	10828B:4	none	
(2)1-1-008:014	State Dept. Of Hawaiian Home Lands	none	Gr. S-15845	
(2)1-1-008:023	Sexton,Anne Lenhart /Etal	none	Gr. 3117	Gr. 3117 applies to parcels 4 and 23.
(2)2-4-016:004	East Maui Irrigation Co. Ltd.	none	Gr. 182	

In accordance with the State Water Code and the Supreme Court's decision in the Waiahole Ditch Combined Contested Case Hearing, the Commission is focused on the assertion and exercise of appurtenant rights as it largely relates to the cultivation of taro. Wetland kalo or taro (*Colocasia esculenta* (L.) Schott) is an integral part of Hawaiian culture and agricultural tradition. The preferred method of wetland taro cultivation, where terrain and access to water permitted, was the construction of loi (flooded terraces) and loi complexes. These terraces traditionally received stream water via carefully engineered open channels called auwai. The auwai carried water, sometimes great distances, from the stream to the loi via gravity flow. In a system of multiple loi, water may either be fed to individual loi through separate little ditches if possible, or in the case of steeper slopes, water would overflow and drain from one loi to the next. Outflow from the loi may eventually be returned to the stream.

The loi also served other needs including the farming of subsidiary crops such as banana, sugar cane, and ti plants that were planted on its banks, and the raising of fish such as oopu, awa, and aholehole within the waters of the loi itself. At least 85 varieties of taro were collected in 1931, each of which varied in color, locale, and growing conditions. The water needs of taro under wet conditions depend upon: 1) climate; 2) location and season (weather); 3) evaporation rate; 4) soil type; 5) ground water hydrology; 5) water temperature; and 6) agronomic conditions (crop stage; planting density and arrangement; taro variety; soil amendment and fertilization regime; loi drainage scheme; irrigation system management; and weed, pest, and disease prevalence and management).

In 2002, the State Office of Hawaiian Affairs cosponsored a "No Ka Lo‘i Conference", in the hopes bringing together taro farmers from around the state to share knowledge on the cultivation of taro. An outcome of the conference was an acknowledgement that farmers needed to better understand the water requirements of their taro crops to ensure and protect their water resource interests. The result of this effort was a 2007 USGS wetland kalo water use study, prepared in cooperation with the State Office of Hawaiian Affairs, which specifically examined flow and water temperature data in a total of 10 cultivation areas on four islands in Hawaii. Two of the loi (flooded terrace) complexes are located in east Maui (Wailua and Keanae).

The study reiterated the importance of water temperature in preventing root rot – according to a University of Hawaii study (1997, p.62) temperature should not exceed 78ºF (25.6ºC) yet not get so cold that it slows the growth of taro. The 2007 study, however, noted that, “although irrigation flows for kalo cultivation have been measured with varying degrees of scientific accuracy, there is disagreement regarding the amount of water used and needed for successful kalo cultivation, with water temperature recognized as a critical factor. Most studies have focused on the amount of water consumed rather than the amount needed to flow through the irrigation system for successful kalo cultivation.” As a result, the study was designed to measure the throughflow of water in commercially viable loi complexes, rather than measuring the consumption of water during taro growth.

Because water requirements for taro vary with the stage of maturity of the plants, all the cultivation areas selected for the study were at approximately the same stage (i.e. near harvesting, when continuous flooding is required). Temperature measurements were made every 15 minutes for approximately 2 months. Flow measurements were collected at the beginning and the end of that period. Data were collected during the dry season (June – October), when water requirements for cooling kalo are higher. Surface water temperatures generally begin to rise in April and remain elevated through September, due to increased solar heating. Water inflow temperature was measured in 17 loi complexes, and only three had inflow temperatures rising above 27ºC (the threshold temperature above which wetland kalo is more susceptible to fungi and associated rotting diseases).

The average and median inflows from all 10 cultivation areas studied are listed in Table 12-2 below. The study indicated that the “values are consistent with previously reported inflow and are significantly higher than values generally estimated for consumption during kalo cultivation.” It should also be noted that farmers were interviewed during field visits; most “believed that their supply of irrigation water was insufficient for proper kalo cultivation.”

Table 12-2. Summary of water use calculated from loi and loi complexes by island, State of Hawaii (Source: Gingerich et al., 2007, Table 10).

[gad = gallons per acre per day; na = not available]

Island	Complex				Loi			
	Number	Average water use (gad)	Average windward water use (gad)	Average leeward water use (gad)	Number	Average water use (gad)	Average windward water use (gad)	Average leeward water use (gad)
Kauai	6	120,000	97,000	260,000	2	220,000	220,000	na
Oahu	5	310,000	380,000	44,000	4	400,000	460,000	210,000
Maui	6	230,000	230,000	na	na	na	na	na
Hawaii	2	710,000	710,000	na	na	na	na	na
Average of all measurements		260,000	270,000	150,000	350,000	370,000	210,000	350,000
Median of all measurements		150,000	150,000	150,000	270,000	320,000	210,000	270,000

The windward Maui areas chosen for the study were Waihee, Wailua, and Keanae. Wailua and Keanae each have numerous individual loi and loi complexes. Three of the Wailua area complexes were available for study: 1) Lakini complex, supplied through an auwai with water diverted from Hamau Stream, which in turn receives diverted water from Waiokamilo Stream; 2) Wailua complex, supplied through an auwai with water diverted from Waiokamilo Stream; and 3) Waikani complex, supplied through an auwai with water diverted from Wailuanui Stream. The loi in Keanae were treated as a single complex supplied by the Keanae Flume, which diverts water from Palauhulu Stream.

The study results are presented below in Table 12-3 (discharge measurements) and Table 12-4 (water-temperature statistics).

Table 12-3. Summary of discharge measurements and areas for selected loi complexes, Island of Maui (Source: Gingerich et al., 2007, Table 6).

[mgd = million gallons per day; gad = gallons per acre per day; na = not applicable; average water use is determined by summing the averages of each complex or loi and dividing by the number of complexes or loi.]

Area	Complex						
	Station	Irrigation area (acre)	Date	Measurement time	Discharge (mgd)	Water use (gad)	Remarks
Waihee	Ma08A-CI	2.3	7/29/2006	1501	0.34	150,000	total flow for upper and lower complexes
			9/22/2006	1158	0.30	130,000	total flow for upper and lower complexes
	Ma08B-CIR	na	7/29/2006	1500	0.025		
	Ma08B-CIL	na			0.06		
		0.76		na	0.085	110,000	combined right and left complex inflows
	Ma08B-CIR	na	9/22/2006	1150	0.058		
	Ma08B-CIL	na		1055	0.067		
		0.76		na	0.13	160,000	combined right and left complex inflows
Wailua (Lakini)	Ma09-CIR	na	7/30/2006	1004	0.26		
	Ma09-CIL	na		947	0.30		
		0.74		na	0.56	750,000	combined right and left complex inflows
	Ma09-CIR	na	9/21/2006	1015	0.16		
	Ma09-CIL	na		1049	0.06		
	Ma09-CIM	na		1206	0.19		
		0.74		na	0.41	550,000	combined right, left, and middle complex inflows
Wailua	Ma10-CI	3.32	7/30/2006	1136	0.59	180,000	
			9/21/2006	845	0.46	140,000	
Wailua (Waikani)	Ma11-CI	2.80	7/30/2006	1236	0.54	190,000	
			9/21/2006	1608	0.26	93,000	
Keanae	Ma12-CI	10.53	7/31/2006	836	1.90	180,000	former USGS streamflow-gaging station
			9/21/2006	1415	1.60	150,000	
number		6.00				6	
minimum		0.74				93,000	
maximum		10.53				750,000	
average		3.41				230,000	

Table 12-4. Water-temperature statistics based on measurements collected at 15-minute intervals for loi complexes on the Island of Maui (Source: Gingerich et al., 2007, Table 7).

[ºC = degrees Celsius; na = not applicable]

Geographic designation	Area	Station	Period of record	Temperature (ºC) Mean	Range	Mean daily range	Temperature measurements greater that 27ºC (percent)
Windward	Waihee	Ma08A-CI	7/29/2006 - 9/22/2006	21.6	19.9 - 24.0	2.0	0.0
		Ma08B-CIL	7/29/2006 - 9/22/2006	24.9	20.3 - 34.0	7.6	25.4
		Ma08B-CO	7/29/2006 - 9/22/2006	25.5	20.0 - 35.5	5.7	27.0
Windward	Wailua (Lakini)	Ma09-CIT	7/30/2006 - 9/21/2006	20.7	18.5 - 23.4	2.3	0.0
		Ma09-CO	7/30/2006 - 9/21/2006	23.2	18.4 - 31.7	7.4	16.9
Windward	Wailua	Ma10-CI	7/30/2006 - 9/21/2006	22.5	20.5 - 25.9	1.9	0.0
Windward	Wailua (Waikani)	Ma11-CI	7/30/2006 - 9/21/2006	22.2	21.0 - 24.0	0.7	0.0
		Ma11-CO	7/30/2006 - 9/21/2006	26.1	22.1 - 31.8	3.3	29.1
Windward	Keanae	Ma12-CI	7/31/2006 - 9/21/2006	20.0	19.0 - 21.9	1.0	0.0
		Ma12-CO	equipment malfunction	na	na	na	na

According to a 1995 cultural landscape study prepared by Group 70 International, Inc. et al., for the County of Maui Planning Department, there are three complexes of taro loi in cultivation with sources attributed to Waiokamilo Stream, two of which are considered part of the larger Wailuanui loi complex. The first complex is the Lakini loi located mauka of Hana Highway. Although Lakini is considered part of the Wailua complex and occurs within the Wailuanui hydrologic unit, the source of water is from an auwai conveying water from Kualani Stream (USGS referred to this as Hamau Stream in Gingerich, S.B. *et al*, 2007). Though Kualani Stream appears to be a tributary of Waiokamilo, Gingerich et al. (2007) indicates that Kualani "receives diverted water from Waiokamilo Stream further upstream." Water is diverted from Waiokamilo Stream and flows via an auwai to feed the Lakini loi. The outflow from the Lakini complex continues in the auwai under the highway to feed the central portion of the larger Wailuanui complex. Group 70 International, Inc. et al. (1995) also noted that the ridge line at Lakini had been cut to allow for the construction of the auwai to carry water from Waiokamilo to Wailuanui, a testament to the engineering skill of the early Hawaiian planters.

The second complex, referred to as the Wailua loi complex by Gingerich et al. (2007), comprises the northwest portion of the larger Wailuanui loi complex and is primarily fed by an auwai that takes water directly from Waiokamilo Stream. The Wailua complex is approximately 3.32 acres and consists of roughly 55 individual loi. Group 70 International, Inc. et al. (1995) noted the complexity of the entire Wailuanui complex, having identified 339 individual loi from a 1982 aerial photograph and also indicated that portions of the complex had been converted to rice cultivation by the early 1900s.

The smallest of the three complexes associated with Waiokamilo Stream is located on both sides of the stream just makai of Hana Highway. Group 70 International, Inc. et al. (1995) indicated that the loi was located “a short distance behind the Harry K. Mitchell family compound,” and “is cultivated by two separate families.” A cursory examination of recent aerial imagery reveals that additional taro loi may have been opened/reopened in other areas of the Waiokamilo hydrologic unit, warranting further analysis related to potentially increased water requirements for the area.

The Commission’s records for the hydrologic unit of Waiokamilo indicate that there are a total of 19 registered diversions, of which 15 are non-EMI diversions. Of these non-EMI diversions, 11 registrants declared water use for taro cultivation with an estimated cultivable area of 514.71 acres (0.80 square miles). This estimation of taro acreage includes a collective registration by the Keanae/Wailuanui Native Hawaiian Land Association (File reference: EAST MAUI TARO) which declared water use for approximately 350 acres of taro from both Waiokamilo and Wailuanui Streams. In addition, six of the registrants claimed water use for other irrigation purposes including the watering of livestock, aquaculture, and the cultivation of fruits, vegetables, flowers, and other plants. This information is derived from original registration documents, much of which has not been field verified and may have changed. As noted earlier, the Commission is currently awaiting the results of the field verifications and plans to include this data upon further assessment of best available information. More detailed information on each registered diversion may be found in Table 13-1 in Section 13.0, Noninstream uses.

Historical uses of Waiokamilo Stream can also provide some insight into the protection of traditional and customary Hawaiian rights. Without delving into the extensive archive of literature (refer to East Maui Irrigation Company, 2001), Handy and Handy, in *Native Planters of Old Hawaii*, provide a limited regional description as follows:

> Beyond Keʻanae is a sizable bay formed by erosion where three streams flow into the ocean. Facing the bay on its west side is a pocket of land which slopes gently seaward from the base of a cliff which corresponds to that separating Keʻanae Valley from the peninsula. This cliff probably represents an old shore line during a period of subsidence. About half the gently sloping land seaward of the cliff was terraced with loʻi which were watered by Wailuanui (Big Wailua) Stream, the larger of the three that flow into the bay. The land beyond the terraced area, on the Keʻanae side toward the sea, is too high for irrigation; here sweet potatoes were planted. And on high ground, there was a war temple. A road runs down to the bay between the terraced area and the higher ground, and along this road are the houses of the people, and the Roman Catholic Church.
>
> Wailua has been notable for its continued occupancy and cultivation by Hawaiian families. This has been due, we were told, to the influence of the Catholic mission. Land titles here are very complicated, too much so to be defined correctly by an outsider.”
>
> There are several small stream between Keʻanae and Wailuanui. They flow in deep small gorges, and the terrain is very rough, but there were a few small *loʻi* developments. There are said to have been two springs of fresh water, which were opened by Kane and Kanaloa in their travels on Maui. From these springs, in a valley named ʻOhiʻa, comes the water that irrigates the *loʻi* in Wailua, so says the legend (*Ka Nupepa Kuʻokoʻa*, October 4, 1923). The Wailuanui Stream gushes down in a beautiful cascade in its gorge just before flowing into the *loʻi* area. This cascade is called Wai-o-Kane (Water of Kane).

The cultural resources of Waiokamilo Stream were not classified by the HSA, likely due to a lack of archaeological survey coverage. The HSA collected data in three general areas of: 1) archaeological; 2) historical; and 3) modern practices. Archaeological data were originally compiled by the State Historic Preservation Division and is only current to the date of the HSA (Table 12-5).

Table 12-5. Cultural resource elements evaluated as part of the Hawaii Stream Assessment for Waiokamilo Stream.

Category	Value
Survey coverage: The extent of archaeological survey coverage was analyzed and recorded as complete, partial, very limited, and none. Few valleys are completely surveyed. Many have little or no survey coverage.	None
Predictability: The ability to predict what historic sites might be in unsurveyed areas was scored as high, medium, or low predictability or unable to predict. A high score was assigned if archaeologists were able to predict likely site patterns in a valley given historic documents, extensive archaeological surveys in nearby or similar valleys, and/or partial survey coverage. A low score was assigned if archaeologists were unable to predict site patterns in a valley because of a lack of historical or archaeological information. A medium score was assigned to all other cases.	Not assessed
Number of Sites: The actual number of historic sites known in each valley is straightforward yet very time consuming to count. Instead, archaeologists used survey information to estimate the number of sites in each valley. These figures, adequate for this broad-based assessment, are only rough estimates.	Not assessed
Valley significance as a Whole District: The overall evaluation of each valley's significance was made considering each valley a district. The significance criteria of the National and Hawaii Registers of Historic Places was used. Criterion A applies if the district is significant in addressing broad patterns of prehistory or early history. Criterion B applies if the district is associated with important people (rulers) or deities. Criterion C applies if the district contains excellent examples of site types. Criterion D applies if the district is significant for information contained in its sites. Finally, Criterion E applies if the district is culturally significant for traditionally known places or events or for sites such as burials, religious structures, trails, and other culturally noteworthy sites.	Not assessed
Site Density: The density patterns of historic sites make up a variable extremely important to planners. Three ranks were assigned: low for very few sites due either to normal site patterning or extensive land alteration, moderate for scattered clusters of sites, and high for continuous sites. Valleys with moderate or high density patterns are generally considered moderate or high sensitivity areas.	Not assessed
Site Specific Significance: The site specific significance variable was developed for valleys that had low densities of sites (very few sites) due either to normal site patterning or to extensive land alteration. An example of the first type might be a valley with housing sites on the side but too narrow for taro or housing sites on the valley floor. The second type might be a valley in which there had been sugar cane cultivation but a large heiau was left. The site specific significance of these valleys was categorized as either: 1) sites significant solely for information content which can undergo archaeological data recovery; or 2) sites significant for multiple criteria and merit preservation consideration. Those categorized as meriting preservation consideration would likely include large heiau, burial sites, and excellent examples of site types.	Not assessed
Overall Sensitivity: The overall sensitivity of a valley was ranked very high, high, moderate, low, or unknown. Very high sensitivity areas have moderate or high densities of sites with little or no land alteration. They are extremely important archaeological and/or cultural areas. High sensitivity areas have moderate or high densities of sites with little or no land alteration. Moderate sensitivity areas have very few sites with the sites meriting preservation consideration due to multiple criteria or moderate densities of sites with moderate land alteration. Low sensitivity areas have very few sites due to normal site patterning or due to extensive land alteration. The sites present are significant solely for their informational content, which enable mitigation through data recovery. Those valleys where no surveying had been undertaken and the ability to predict what might be found was low were ranked unknown.	Not assessed

Table 12-5. Cultural resource elements evaluated as part of the Hawaii Stream Assessment for Waiokamilo Stream .

Category	Value
Historic Resources: Several types of sites were considered by inclusion in this section, particularly bridges, sugar mills and irrigation systems. Those that are listed on the State or National register were inventoried, but none of them assessed.	Waiokamilo Bridge
Taro Cultivation: Streams and stream water have been and continue to be an integral part of the Hawaiian lifestyle. The committee identified a number of factors important to current Hawaiian practices. These include current taro cultivation, the potential for taro cultivation, appurtenant rights, subsistence gathering areas, and stream-related mythology. The committee felt that a complete assessment of the cultural resources of Hawaii's streams should include these items but, due to limits of information, only the current cultivation of taro was included.	10 to 50 acres of taro

Fishponds are another integral part of traditional Hawaiian culture, which speaks volumes of Native Hawaiian skill and knowledge of aquaculture, which has also seen a resurgence of interest in recent years. Fishponds are found throughout the Hawaiian Islands and were either man-made or natural enclosures of water used for the raising and harvesting of fish and other aquatic organisms. Kikuchi (1973) identified six main types of fishponds, two of which are associated with streams (*loko wai*, *loko ia kalo*) and one type is associated with fresh water springs (*kaheka* or *hapunapuna*).

- Type III – *Loko Wai*: An inland fresh water fishpond which is usually either a natural lake or swamp, which can contain ditches connected to a river, stream, or the sea, and which can contain sluice grates. Although most frequently occurring inland, *loko wai* are also located along the coast near the outlet of a stream.
- Type IV – *Loko Ia Kalo*: A fishpond utilizing irrigated taro plots. *Loko ia kalo* are located inland along streams and on the coast in deltas and marshes.
- Type VI – *Kaheka* and *Hapunapuna*: A natural pool or holding pond. The majority, if not all of these types of ponds, are anchialine ponds with naturally occurring shrimp and mollusks.

According to a 1990 Hawaii Coastal Zone Management Program *Hawaiian Fishpond Study for the Islands of Hawaii, Maui, Lanai, and Kauai*, the Puu Polu fishpond exists towards the northern portion of the hydrologic unit near the ocean (Table 12-6 and Figure 12-2) (DHM, Inc., 1990).

Table 12-6. Inventory and classification of fishpond in the Waiokamilo hydrologic unit (Source: DHM, Inc., 1990)

The classification of the fishpond for condition and significance. The condition or integrity of the fishpond was based on the criteria of wall condition, degree of siltation, and degree of encroachment by vegetation. Significance decisions were based on the National Register of Historic Places criteria A, B, C and D. The National Register Criteria, described below, were established for use in evaluating and determining the eligibility of properties for listing on the National Register of Historic Places.

Criterion A: Specifies association with events or broad patterns important in the history of an area. As economic and political resources fishponds have played significant roles in events and patterns important to Hawaiian history.

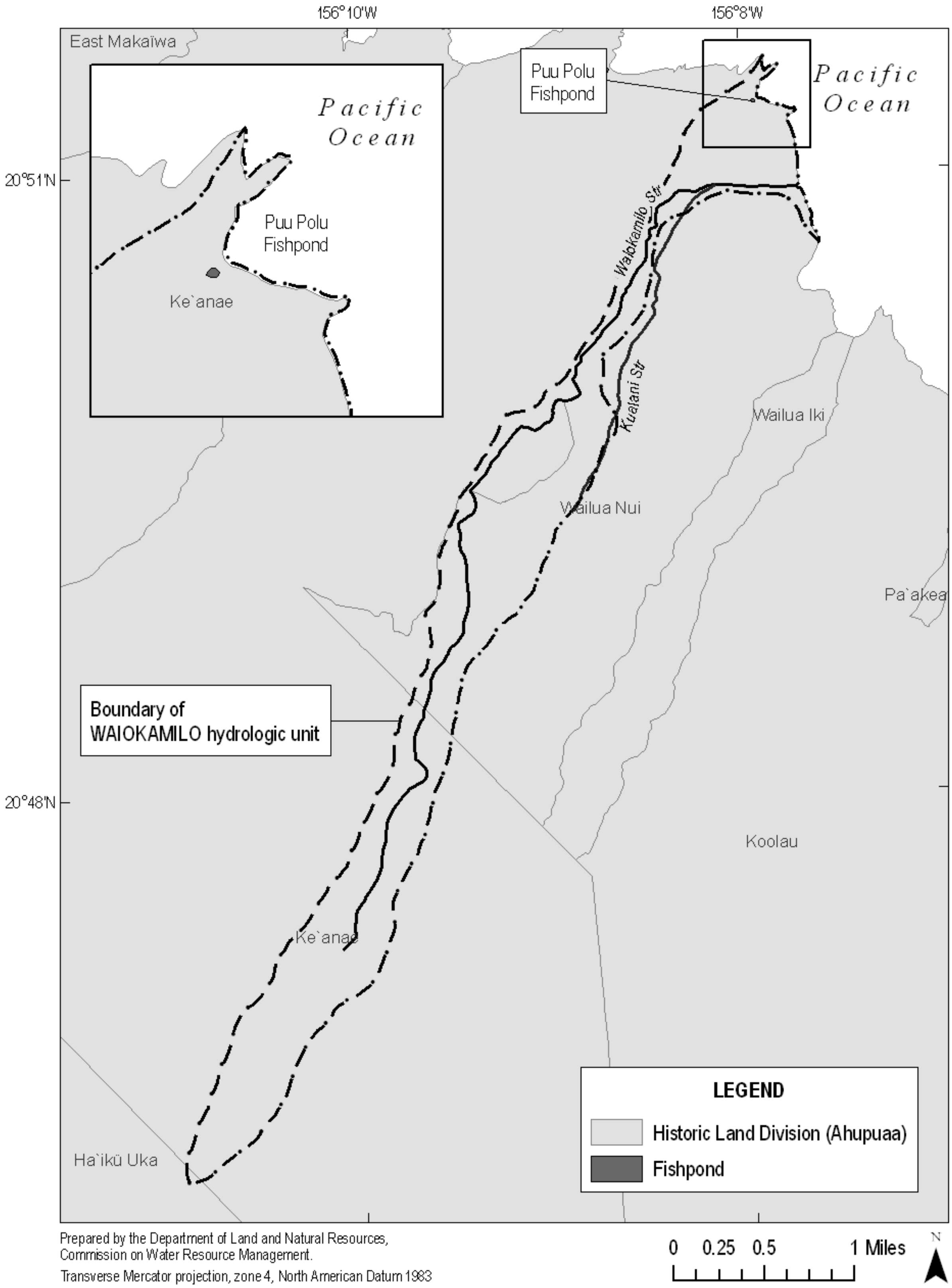
Criterion B: Specifies association with the lives or persons significant in our past. The literature search identified several fishponds which have direct associations to people significant in our past.

Criterion C: Applies to sites that represent architectural achievements. Most fishponds contain structural remains representing considerable architectural achievement by prehistoric as well as historic period engineers.

Criterion D: States that the property has yielded or has the potential to yield information significant for our understanding of traditional culture, history, prehistory, and foreign influences on traditional culture and history. All fishponds satisfy this criterion.

Fishpond Name:	Puu Polu
Ili/Ahupuaa:	Keanae
TMK Parcel:	(2) 1-1-008:011
Classification:	IIB: Wall in fair to poor condition; Heavy siltation or completely filled; Vegetation encroachment on most or all of fishpond; and Three (3) or less National Register criteria.
Pond Type:	III, Loko Wai: An inland fresh water fishpond which is usually either a natural lake or swamp, which can contain ditches connected to a river, stream, or the sea, and which can contain sluice grates. Although most frequently occurring inland, Loko Wai are also located along the coast near the outlet of a stream.
Ownership:	Private

Figure 12-2. Traditional ahupuaa boundaries in the vicinity of Waiokamilo hydrologic unit. This hydrologic unit spans three ahupuaa – Wailua Nui, Keanae, and Haiku Uka (Source: State of Hawaii, Office of Planning, 2007a).



13.0 Noninstream Uses

Under the State Water Code, noninstream uses are defined as "water that is diverted or removed from its stream channel…and includes the use of stream water outside of the channel for domestic, agricultural, and industrial purposes." In most cases, water is diverted from the stream channel via a physical diversion structure. Diversions take many forms, from small PVC pipes in the stream that remove relatively small amounts of water, to earthen auwai (ditches), hand-built rock walls, and concrete dams that remove relatively larger amounts of water. Water is most often used away from the stream channel and is not returned; however, as in the case of taro fields, water may be returned to the stream at some point downstream of its use. While the return of surface water to the stream would generally be considered a positive value, this introduces the need to consider water quality variables such as increased temperature, nutrients, and dissolved oxygen, which may impact other instream uses.

In addition to the amount of water currently (or potentially) being diverted offstream, the Commission must also consider the diversion structure and the type of use, all of which impact instream uses in different ways. The wide range of diversion structures, as noted above, is what makes regulation of surface water particularly difficult, since one standard method cannot be depended upon for monitoring and measuring flow. The ease of diverting streamflow, whether it be by gravity-flow PVC pipe, pump, or a dug channel, also plays a role in the convenience of diverting surface water and the abundance of illegal, non-permitted diversions.

Upon the enactment of the State Water Code and subsequent adoption of the Hawaii Administrative Rules, the Commission required the registration of all existing stream diversions statewide. The Commission categorized the diversions and filed registrations according to the registrant's last name or company name. While it is recognized that the ownership and/or lease of many of the properties with diversions has changed since then, the file reference (FILEREF) remains the name of the original registrant file (Table 13-1). Locations are depicted in Figure 13-8.

In 2007, the Commission initiated a contract for the purpose of conducting statewide field investigation to verify and inventory surface water uses and stream diversions, and update existing surface water information. Priority 1 Areas, under this contract, include all east Maui streams that are part of the pending Petition to Amend Interim Instream Flow Standards. Data from this study are pending. Table 13-1 primarily contains information extracted from the original registration files.

For the Waiokamilo hydrologic unit, East Maui Irrigation Co. (EMI) operates only the Koolau Ditch as part of the larger East Maui Irrigation System. Though EMI registered all of its "major" diversions (included in Table 13-1), EMI opted not to register their "minor" diversions and instead provided a map, lists and photographs. Though these minor diversions may vary widely in construction, one example consists of a small concrete basin collecting ground water seepage, which then transports the collected water via a gravity-flow PVC pipe to a larger ditch, ultimately joining one of the primary systems. The registration of these minor diversions is arguable since the contribution of these small seeps and springs to total streamflow is unknown. Information on EMI's minor diversions is listed in Table 13-2, and their locations depicted in Figure 13-8.

Since the enactment of HAR Title 13 Chapter 168, stream diversion works permits are required for the construction of new diversions or alteration of existing diversions, with the exception of routine maintenance. These permitted (as opposed to "registered") diversion works are not part of the Commission's verification effort, nor have any diversions been permitted in the Waiokamilo hydrologic unit.

Table 13-1. Registered diversions in the Waiokamilo hydrologic unit.

[* Based on preliminary diversion verification efforts.]

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.9.6	AKINA S	2-1-1-008:	unknown		No	No	No
Diversion consists of a 12-inch PVC pipe from Waiokamilo Stream. Use is for 2 acres of taro.							
REG.320.6	EAST MAUI IRR	2-1-1-002:			No	Yes	
Water is diverted from Waiokamilo Stream at Intake K-25 (Koolau Ditch intake on Waiokamilo Stream [Kikokiko Intake]) into the Koolau Ditch system. The diversion structure is concrete with a divertable capacity of 7 mgd, controlled by a wooden gate. Declarant stated that approx. 36,000 acres are irrigated from this source and all other HC&S and EMI sources. Uses include irrigation of sugar, pineapple, and a variety of other crops; cooling, manufacturing, and mill use; and hydroelectric; and livestock. Quantity of use taken at Wailoa @ Honopou gaging station (total declared Q for gage is 45943.000 MG).							
REG.326.6	EAST MAUI IRR	2-1-1-002:			No	Yes	
Water is diverted from Kualani Stream at Intake K-22 (Koolau Ditch intake on Kualani Stream) into the Koolau Ditch system. The diversion structure is concrete with a divertable capacity of 9 mgd, controlled by a 10" steel pipe. Declarant stated that approx. 36,000 acres are irrigated from this source and all other HC&S and EMI sources. Uses include irrigation of sugar, pineapple, and a variety of other crops; cooling, manufacturing, and mill use; and hydroelectric; and livestock. Quantity of use taken at Wailoa @ Honopou gaging station (total declared Q for gage is 45943.000 MG).							
REG.328.6	EAST MAUI IRR	2-1-1-002:			No	Yes	
Water is diverted from Waiokamilo Stream at Intake K-24 (Koolau Ditch intake on Waiokamilo Stream [#12 intake]) into the Koolau Ditch system. The diversion structure is concrete with a divertable capacity of 9 mgd, controlled by the size of the opening. Declarant stated that approx. 36,000 acres are irrigated from this source and all other HC&S and EMI sources. Uses include irrigation of sugar, pineapple, and a variety of other crops; cooling, manufacturing, and mill use; and hydroelectric; and livestock. Quantity of use taken at Wailoa @ Honopou gaging station (total declared Q for gage is 45943.000 MG).							
REG.329.6	EAST MAUI IRR	2-1-1-002:			No	Yes	
Water is diverted from Waiokamilo Stream at Intake K-23 (Koolau Ditch intake on Waiokamilo Stream [#11 intake]) into the Koolau Ditch system. The diversion structure is concrete with a divertable capacity of 20 mgd, controlled by the size of the opening. Declarant stated that approx. 36,000 acres are irrigated from this source and all other HC&S and EMI sources. Uses include irrigation of sugar, pineapple, and a variety of other crops; cooling, manufacturing, and mill use; and hydroelectric; and livestock. Quantity of use taken at Wailoa @ Honopou gaging station (total declared Q for gage is 45943.000 MG).							
REG.333.6	EAST MAUI TARO	2-1-1-002:	unknown		No	No	Yes
Diversion consists of a concrete basin and dam on West Wailuanui Stream. Registration of diversion was made in conjunction with Diversion (Event ID) REG.333.6 on Waiokamilo Stream. Uncertain whether or not declared use is for combined sources of water. Declared use is for ~350 or more acres of wetland taro, watercress, ornamental flowers and foliage, and livestock. Declarant claims divertable capacity is 10 or more million gallons per day.							
REG.335.6	ECHTERNACH S	2-1-1-008:007		Yes	No	Yes	No
Diversions consists of plastic pipe. Uses are domestic (one house, one service building); irrigation of vegetable garden, fruit trees, and landscaping; livestock; fish pond; and aquatic plants. Water use is approx. 500-700' downstream of diversion.							
REG.499.6	HOKOANA BK	2-1-1-008:010			No	Yes	Yes
Diversion from Waiokamilo Stream to irrigate 2.09 acres of taro. Declarant claims riparian and appurtenant rights. Three sources (Waiokamilo Stream, Palauhulu Stream, and a spring (source of Waianu Stream) serve ~3 acres in taro production and ~ 10 acres in other uses, including watercress, ti plants, flowers for sale to florists, and domestic and landscaping uses for one dwelling. Declarant also asserts gathering rights.							

Table 13-1. Registered diversions in the Waiokamilo hydrologic unit.

[* Based on preliminary diversion verification efforts.]

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.553.6	KAINOA J	2-1-1-008:011			No	Yes	No
Diversion structure is a concrete intake, 18” x 14” x 6” deep with metal trash grate; user has 1” diameter black polyethelene pipe. Diversion is from Kaleipelehua Stream, a tributary to Waiokamilo Stream. Declarant claims that average flow before diversion was 200 gpm; divertable capacity is 10gpm (measured with 5 gal container and stopwatch). Uses are domestic and irrigation of diverse fruits and landscaping. Note: declaration is in Needham file.							
REG.569.6	KANOA I	2-1-1-008:010		Yes	Yes*	Yes	Yes
Diversion structure a 4” intake pipe in stream. (Declaration indicates concrete diversion but field notes do not so indicate.) Use is one domestic service connection; aquaculture; and irrigation of 6 acres of taro, haleconia, and vegetables. Declarant claims Kuleana appurtenant rights and traditional gathering rights (oopu, opae, hihiwai, prawns). Field verification indicates that pipe transports water to a portion of TMK 1-1-007:020 where it is used for irrigation of ~6 acres of heliconia and noni. Waiokamilo Field notes also indicate declarant leases 1-1-002:007, and Waiokamilo Stream runs through property. At the time (1994), the declarant plans to use water from the stream to farm (taro, bananas, and fern shoots).							
REG.859.6	MITCHELL HO	2-1-1-008:010			No	Yes	Yes
Diversion is described as plastic pipe hose (from unmapped tributary to Waiokamilo Stream). Declared water use is 1 gal. every 5 min. Use is 6’ x 4’ fish pond. Declarant claims appurtenant, riparian, correlative (groundwater) and Hawaiian rights.							
REG.891.6	NEEDHAM E	2-1-1-008:006	0.0351	Yes*	Yes*	Yes	No
Diversion structure described as both concrete and pipe. Use is one domestic connection and irrigation of ~2,500 sq. ft. (100’ x 25’) for taro, and fire prevention. Annual water use estimated at 8,280,000 gallons; other users are “all Wailua taro farmers.”							
REG.970.6	PUU R	2-1-1-008:011			No	Yes	No
Diversion consists of concrete ditch with divertable capacity of 3 mgd. Uses are irrigation of ~2 acres for taro, and ornamentals, plus livestock. Water also used by others on TMK 1-1-04-6. Field verification indicates 3” filter with a 1 ½” PVC pipe in Waiokamilo Stream on TMK 1-1-008:006. This line transports water to a 100 gal. holding tank on declarant’s property for domestic and irrigation (taro) purposes.							
REG.1128.6	VILLALON C	2-1-1-008:011			No	Yes	Yes
Diversion consists of 8” pipe with daily use to irrigate ~3 1.2 acres of watercress, ti leaves, and haleconia / tropical plants. Declarant claims riparian rights.							
REG.1203.6	WENDER ES	2-1-1-008:011			No	Yes	Yes
Diversion is a pipe from Waiokamilo Stream. Use is 50,000gpd (100,000 gpd combined from two pipes and one pump) for domestic use; to irrigate 1511.65 acres of wetland taro, orchard, ti & other cultural plants, vegetables, etc; livestock; hydroelectric; aquaculture; recreation; and traditional gathering. Declarant claims riparian, appurtenant, and correlative water rights. . Field investigation indicates 3” filter and 1 ½” PVC pipe not in use at present time (Nov. 1994). States that intakes are on TMK 1-1-008:004.							
REG.1204.6	WENDER ES	2-1-1-008:011		Yes*	Yes*	Yes	Yes
Diversion is a pump from Waiokamilo Stream. Use is 50,000gpd (100,000 gpd combined from two pipes and one pump) for domestic use; to irrigate 1511.65 acres of wetland taro, orchard, ti & other cultural plants, vegetables, etc; livestock; hydroelectric; aquaculture; recreation; and traditional gathering. Declarant claims riparian, appurtenant, and correlative water rights.							

Table 13-1. Registered diversions in the Waiokamilo hydrologic unit.

[* Based on preliminary diversion verification efforts.]

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.1205.6	WENDER ES	2-1-1-008:010		Yes	Yes	Yes	Yes
Diversion is a pipe from Waiokamilo Stream. Use is 50,000gpd (100,000 gpd combined from two pipes and one pump) for domestic use; to irrigate 1511.65 acres of wetland taro, orchard, ti & other cultural plants, vegetables, etc; livestock; hydroelectric; aquaculture; recreation; and traditional gathering. Declarant claims riparian, appurtenant, and correlative water rights. Field investigation indicates 3” filter and 1 ½” PVC pipe are in use for domestic, irrigation (~1 acre taro, ~2 acres fruit trees and garden plants); and livestock. States that intakes are on TMK 1-1-008:004 and the second one is not in use.							
REG.1238.6	YOUNG A	2-1-1-008:006	unknown	No*	Yes	No	Yes
Diversion consists of a 3-ft. metal pipe in the stream bank on unnamed tributary to Waiokamilo Stream. Uses include one domestic service connection, irrigation for taro, guava, lilikoi, breadfruit, kukui, coconut, flowers, and landscaping, also livestock and aquaculture. Declarant claims riparian and kuleana appurtenant rights. Diversion is not believed to be active, as field verification states that no diversion was found.							
REG.1239.6	YOUNG A	2-1-1-008:006	unknown	No*	Yes	Yes	Yes
Stream diversion, kuleana open ditches from Waiokamilo Stream. Diversion structure is stone and rock. Uses include one domestic service connection, irrigation for taro, guava, bananas, lilikoi, breadfruit, kukui, coconut, flowers, and landscaping, also livestock and aquaculture. Declarant claims riparian and kuleana appurtenant rights. Diversion is not believed to be active, as field verification states that no diversion was found.							

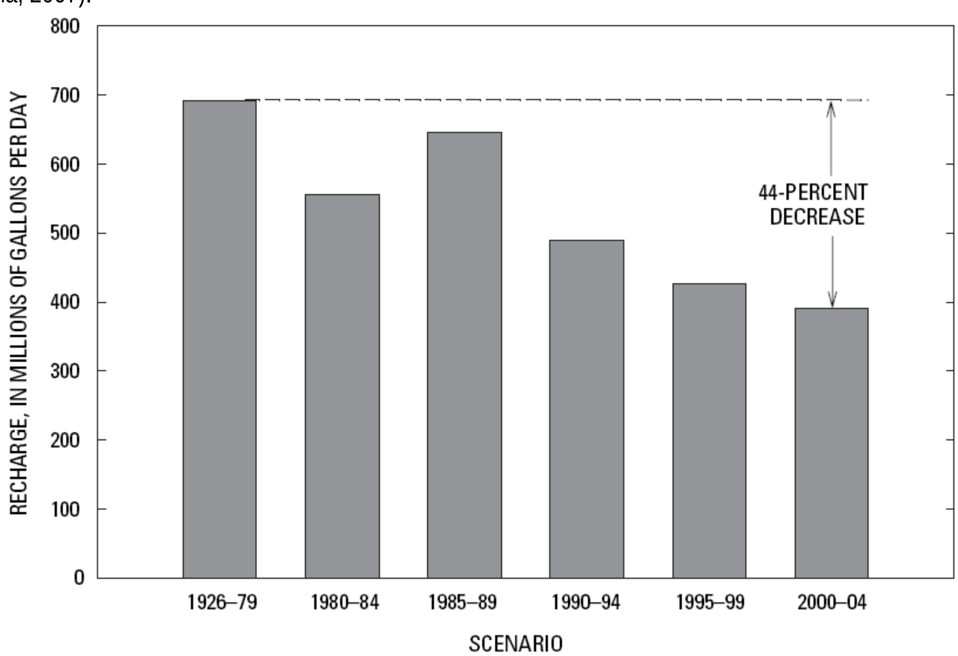
Table 13-2. Minor diversions on the EMI System in the Waiokamilo hydrologic unit.

Diversion ID	EMI Ditch System	Description
K-22a	Koolau	6" Kulani aluminum pipe intake diverted to main Kulani intake. Concrete catchment basin with pipe.
K-22b	Koolau	Koolau Ditch #10 crosscut intake #1. Concrete catchment basin with pipe.
K-22c	Koolau	Koolau Ditch #10 crosscut intake #2. Concrete catchment basin with pipe.
K-22d	Koolau	Koolau Ditch #10 crosscut intake #3. Concrete catchment basin with pipe.
K-22e	Koolau	Koolau Ditch #10 crosscut intake #4. Concrete catchment basin with pipe.
K-22f	Koolau	Koolau Ditch #10 crosscut intake #5. Concrete catchment basin with pipe.
K-22g	Koolau	Koolau Ditch #10 crosscut intake #6. Concrete catchment basin with pipe.
K-23a	Koolau	4" PVC pipe intake east of #11 intake. Concrete catchment basin with pipe.
K-24a	Koolau	Koolau Ditch #12 crosscut intake #1. Concrete catchment basin with pipe.
K-24b	Koolau	Koolau Ditch #12 crosscut intake #2. Concrete catchment basin with pipe.
K-24c	Koolau	Koolau Ditch #12 crosscut intake #3. Concrete catchment basin with pipe.
K-24d	Koolau	Koolau Ditch #12 crosscut intake #4. Concrete catchment basin with pipe.
K-24e	Koolau	Koolau Ditch #12 crosscut intake #5. Concrete catchment basin with pipe.
K-24f	Koolau	Small intake west of main #12 crosscut intake. Concrete catchment basin with pipe.
K-24g	Koolau	Small intake west of main #12 crosscut intake. Concrete catchment basin with pipe.
K-24h	Koolau	Small intake west of main #12 crosscut intake. Stream tributary captured by ditch.
K-24i	Koolau	Small intake west of main #12 crosscut intake. Concrete catchment basin with pipe.
K-24j	Koolau	Small intake west of main #12 crosscut intake.
K-25a	Koolau	East Kikokiko 2" pipe intake. Concrete catchment basin with pipe.
K-25b	Koolau	Kikokiko small intake. Concrete diversion structure with grate.
K-25c	Koolau	Kikokiko 6" pipe intake mauka of bridge. Concrete catchment basin with pipe.
K-25d	Koolau	West Kikokiko 4" pipe intake.
K-25e	Koolau	West Kikokiko 3" pipe intake. Concrete catchment basin with pipe.
K-25f	Koolau	Kikokiko 3" PVC pipe intake under bridge.

Following the establishment of instream flow standards, one of the proposed measures to increase streamflow may be to decrease the amount of water diverted from streams. Such measure has important implications to ground water recharge because it affects the amount of water available for irrigation. Decreasing the amount of water diverted at the ditches located in east Maui affects the amount of water available for the irrigation of crops in west and central Maui. Since the early 20th century, about 100 billion gallons of water (274 million gallons per day) have been diverted each year from Maui streams for irrigation in west and central Maui. More than half of this diverted water, 59 billion gallons per year (162 million gallons per day), comes from east Maui (Engott and Vana, 2007).

The effects of irrigation water on ground water recharge can be analyzed using the water budget equation[4]. Engott and Vana (2007) at the USGS conducted a study that estimated each of the water budget components for west and central Maui using data from 1926 to 2004. Components of the water budget include rainfall, fog drip, irrigation, runoff, evapotranspiration, and recharge. Results of the study were separated into six historical periods: 1926-79, 1980-84, 1985-89, 1990-94, 1995-99, and 2000-04. From 1979 to 2004, ground water recharge decreased 44 percent from 693 million gallons per day to 391 million gallons per day (Figure 13-1). The low recharge rate in 2004 coincides with the lowest irrigation and rainfall rates that were 46 percent and 11 percent lower than those in 1979, respectively. During this period, agricultural lands decreased 21 percent from 112,657 acres in 1979 to 88,847 acres in 2004. Further analysis revealed that a 20 percent decrease in irrigation rate could result in 9 percent reduction in recharge. A similar study by Izuka et al. (2005) reported that 34 percent decrease in irrigation rate constituted a 7 percent reduction in recharge in the Lihue basin in Kauai, Hawaii. Since over half of the irrigation water for west and central Maui comes from east Maui, a 20 percent decrease in the amount of water diverted from streams in the east can potentially reduce recharge in the west and central parts of Maui by 5 percent.

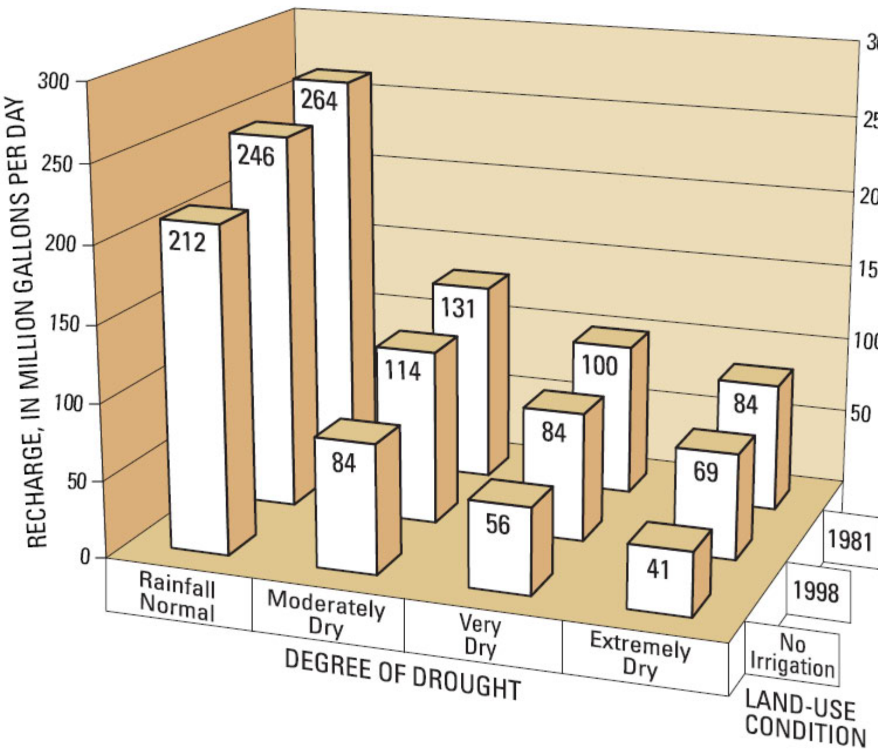
Figure 13-1. Estimated recharge for six historical periods between 1926 and 2004, central and west Maui, Hawaii (Source: Engott and Vana, 2007).



[4] Water-budget is a balance between the amount of water leaving, entering and being stored in the plant-soil system. The water budget method/equation is often used to estimate ground water recharge.

Droughts, or periods of lower than average rainfall, have been shown to drastically decrease ground water recharge (Figure 13-2). The period of drought that occurred in 1998-2002, where rainfall was at least 30 percent lower than the average annual rainfall, was estimated to reduce recharge by 27 percent in west and central Maui (Engott and Vana, 2007). For example, on the island of Kauai, the drought conditions reduced recharge in Lihue basin by 34-37 percent (Izuka et al., 2005). Even though droughts can have exacerbating effects on ground water recharge, these effects are transient and are usually mitigated by periods of higher than average rainfall (Engott and Vana, 2007). However, prolonged loss of irrigation water caused by a decrease in the amount of water diverted by irrigation ditches has greater effects on the long-term trends of ground water levels.

Figure 13-2. Summary of estimated recharge, in million gallons per day, for various land-use and rainfall conditions in the Lihue Basin, Kauai, Hawaii (Source: Engott and Vana, 2007).



The Agricultural Lands of Importance to the State of Hawaii (ALISH) were completed by the State Department of Agriculture (HDOA) in 1977, with the assistance of the Soil Conservation Service (SCS), U.S. Department of Agriculture, and the College of Tropical Agriculture, University of Hawaii. Three classes of agriculturally important lands were established for Hawaii in conjunction with an SCS effort to inventory prime agricultural lands nationwide. Hawaii's effort resulted in the classification system of lands as: 1) Prime agricultural land; 2) Unique agricultural land; and 3) Other important agricultural land. Each classification was based on specific criteria such as soil characteristics, slope, flood frequency, and water supply. ALISH was intended to serve as a long-term planning guidance for land use decisions related to important agricultural lands. HDOA is currently in the process of developing agricultural incentives based on classifications of Important Agricultural Lands. Waiokamilo does not contain any prime or unique agricultural land (Table 13-3).

Table 13-3. Agricultural Lands of Importance to the State of Hawaii and area distributions in the Waiokamilo hydrologic unit.

Density	Area (mi^2)	Percent of Unit
Other lands	0.10	4.1

From 1978 to 1980, HDOA prepared agricultural land use maps (ALUM) based on data from its Planning and Development Section and from SCS. The maps identified key commodity areas (with subclasses) consisting of: 1) Animal husbandry; 2) Field crops; 3) Orchards; 4) Pineapple; 5) Aquaculture; 6) Sugarcane; and Wetlands (Table 13-4).

Table 13-4. Agricultural land uses and area distributions in the Waiokamilo hydrologic unit.

Density	Area (mi^2)	Percent of Unit
Wetlands	< 0.01	< 0.01
Animal husbandry, grazing	0.28	11.6

Though both ALISH and ALUM datasets are considerably outdated, many of the same agricultural assumptions may still hold true. The information is presented here to provide the Commission with present or potential noninstream use information (Figure 13-9).

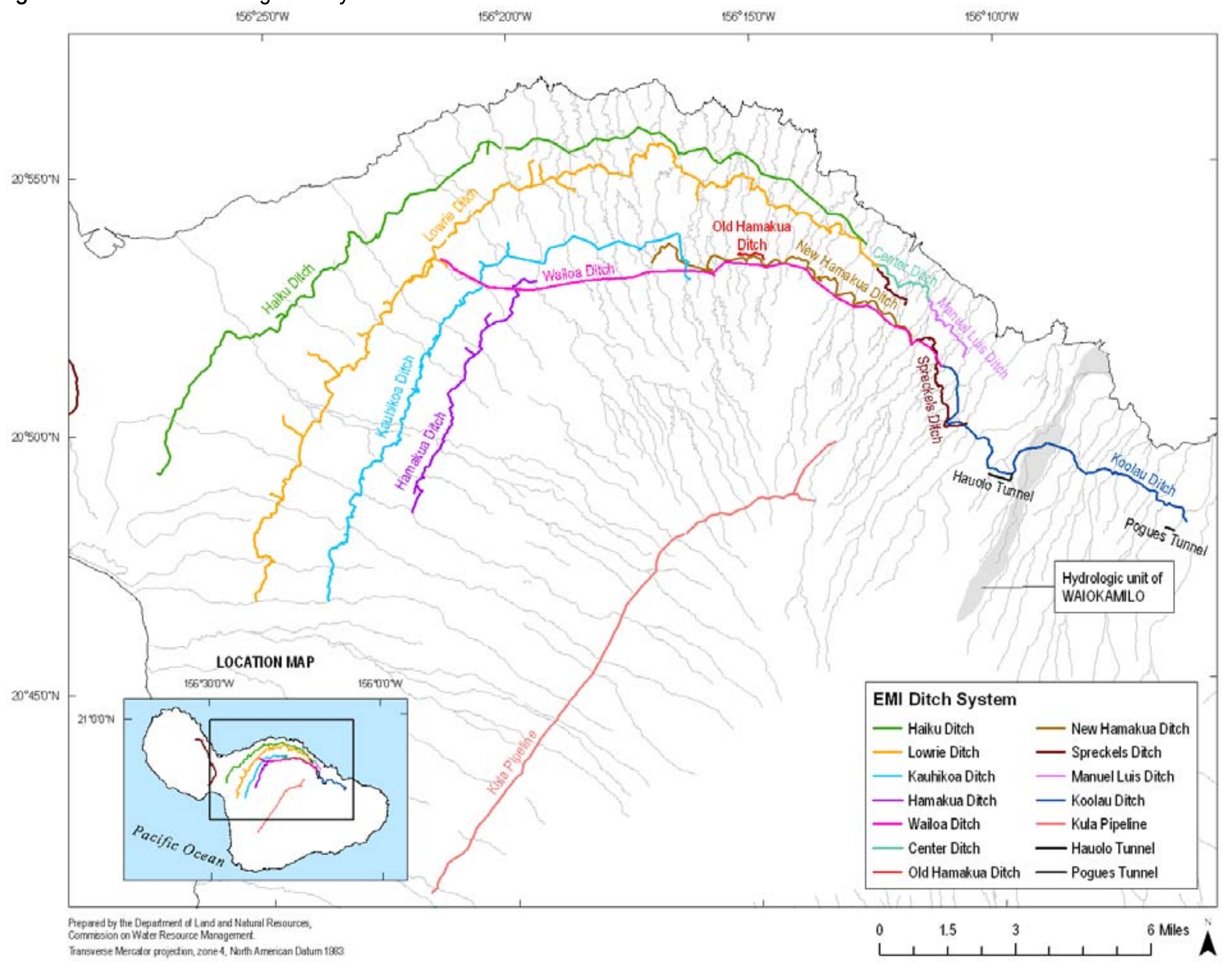
The presence of the EMI system adds considerable complexity to the Commission's role in weighing instream and noninstream uses. While this is largely due to the transfer of water from one hydrologic unit to another, the importance of the system to both agriculture and municipal water supply in Upcountry and Central Maui play a pivotal role in the consideration of economic impacts. The complexity of the EMI system is detailed in Table 13-5 and illustrated in Figure 13-3.

Table 13-5. Historic Timeline of the East Maui Irrigation System (Source: Wilcox, 1996)

1869	-	Samuel Alexander and Henry Baldwin partner to purchase 11.94 acres of Bush Ranch.
1876	-	Alexander and Baldwin form the Hamakua Ditch Company on Maui.
1878	-	Construction of the Hamakua Ditch is completed (not to be confused with the Upper and Lower Hamakua Ditches on the island of Hawaii).
1894	-	Alexander & Baldwin (A&B) is established as an agency.
1898	-	A&B gain control of Hawaiian Commercial & Sugar (HC&S), then become its agent shortly thereafter.
	-	Construction of Lowrie Ditch is started about this time. The Lowrie Ditch emanates from the Kailua watershed in the Makawao District, and receives water from a reservoir in Papaaea and Kailua Stream where the diversion intercepts the source of the older Haiku Ditch.
1900	-	A&B is incorporated with accumulated assets of $1.5 million, compared with a net profit of just $2,627.20 in 1895
	-	Lowrie Ditch is completed with a capacity of 60 million gallons per day and is able to irrigate 6,000 acres. The 22-mile system is 75 percent open ditch, but also includes 74 tunnels, 19 flumes, and a total of 4760 feet of siphons.
1904	-	Construction begins on Koolau Ditch, which extends the system 10 miles toward Hana.
1905	-	Koolau Ditch is completed with a capacity of 85 million gallons per day, and consists of 7.5 miles of tunnel and 2.5 miles of open ditch and flume.
1908	-	The East Maui Irrigation Company (EMI) is formed to develop and administer the surface water for all the plantations owned, controlled, or managed by A&B.
	-	A&B gains control of Kihei Plantation.
1912	-	The old Haiku Ditch is abandoned between 1912 and 1929.
1914	-	New Haiku Ditch is completed with a capacity of 100 million gallons per day. The system is mostly tunnel, partially lined, with a length of 54,044 feet.
1915	-	Kauhikoa Ditch is completed with a capacity of 110 million gallons per day and a length of 29,910 feet.
1918	-	Construction of Wailoa Ditch is started.
1923	-	Wailoa Ditch is completed with a capacity of 160 million gallons per day. The system is mostly tunnel, completely lined, with a length of 51,256 feet. Capacity was later increased to 195 million gallons per day (date unknown).

In total, the EMI system consists of 388 separate intakes, 24 miles of ditch, 50 miles of tunnel, twelve inverted siphons, and numerous small feeders, dams, intakes, pipes, and flumes (Figure 13-3). Supporting infrastructure includes 62 miles of private roads and 15 miles of telephone lines. The system primarily captures surface water from multiple watersheds in East Maui with a combined area of approximately 56,000 acres, of which 18,000 acres are owned by EMI, and the rest by the State of Hawaii (Wilcox, 1996).

Figure 13-3. East Maui Irrigation System.



The EMI system has a delivery capacity of 450 million gallons per day, but delivers an average of 165 million gallons per day. However, the average water delivery can vary considerably due to variable climate conditions that affect surface water availability. Approximately 70 percent of the water delivered via the EMI system emanates from State lands, for which Alexander & Baldwin (A&B) and EMI have obtained water leases pursuant to four license areas (Table 13-6).

Table 13-6. Revocable permits issued to A&B/EMI.

Revocable Permit No.	License Area	Acres
S-7264	Huelo	8,752.69
S-7263	Honomanu	3,381.00
S-7265	Keanae	10,768.00
S-7266	Nahiku	10,111.22

The last water license agreement expired in 1986, after which all four agreements were extended as revocable permits that were renewed annually, alternating in issuance to EMI and A&B. In 2001, a request was made to the State Board of Land and Natural Resources (BLNR) to enter into a long-term lease rather than continue with year-to-year revocable permits. A contested case before the BLNR is currently pending; however, the existing permits continue to be renewed on a holdover basis (A&B, 2007).

There have been few changes to the EMI system since the Wailoa Ditch was completed in 1923. EMI continues to provide water to HC&S which is the largest producer of raw sugar in Hawaii, and only one of two remaining sugar plantations in the state. In 2006, HC&S produced about 81 percent of the total raw sugar in Hawaii, or approximately 173,600 tons, amounting to about 3 percent of total U.S. sugar produced (A&B, 2007). HC&S also produces molasses, a by-product of sugar production, and specialty food-grade sugars sold under their Maui Brand® trademark. Table 13-7 summarizes the harvest and production yields for HC&S from 2000 through 2006.

Table 13-7. Summary of sugar-related harvests by HC&S for 2000-2006 (Source: A&B, 2002; 2003; 2005; 2007).

[* Data were not reported]

Year	Raw sugar produced (tons)	Percent of total raw sugar produced In Hawaii	Area harvested (acres)	Yield per acre (tons)	Average cost per ton (dollars)	Molasses produced (tons)	Specialty food-grade sugar produced (tons)
2006	173,600	81.0	16,950	10.2	*	55,900	15,500
2005	192,700	76.0	16,639	11.6	*	57,100	18,900
2004	198,800	77.0	16,890	11.8	435	65,100	15,500
2003	205,700	79.0	15,660	13.1	422	72,500	12,100
2002	215,900	79.0	16,557	13.0	332	74,300	11,000
2001	191,500	70.0	15,101	12.7	371	71,200	8,848
2000	210,269	*	17,266	12.2	331	70,551	*

The HC&S sugar plantation currently consists of approximately 43,300 acres of land. Sugar is cultivated on roughly 35,100 acres, while the balance is leased to third parties, is not suitable for cultivation, or is used for plantation purposes (A&B, 2006). Approximately 30,000 acres are irrigated with water delivered by EMI, with 5,000 acres irrigated solely with EMI water, and the remaining 25,000 acres are irrigated with a mix of EMI water and supplemental ground water pumped by HC&S.

The total amount of water HC&S needs from EMI varies largely with weather and seasonal conditions, but ranges from a low of 134 million gallons per day in the winter months to a high of 268 million gallons per day during peak usage in the months of May to October (Findings of Fact, Conclusions of Law, and Decision and Order, 2007). From 2002 to 2004, HC&S received 71 percent of its water supply from EMI (surface water), while the remaining 29 percent was supplemental ground water. The EMI system was designed and constructed to take full advantage of the gravity flow of water from higher to lower elevations, thus minimizing pumping and the additional consumption of electrical power. As a result, HC&S attempts to divert the maximum possible amount of water into the EMI system at the Wailoa Ditch, which has a capacity of 195 million gallons per day.

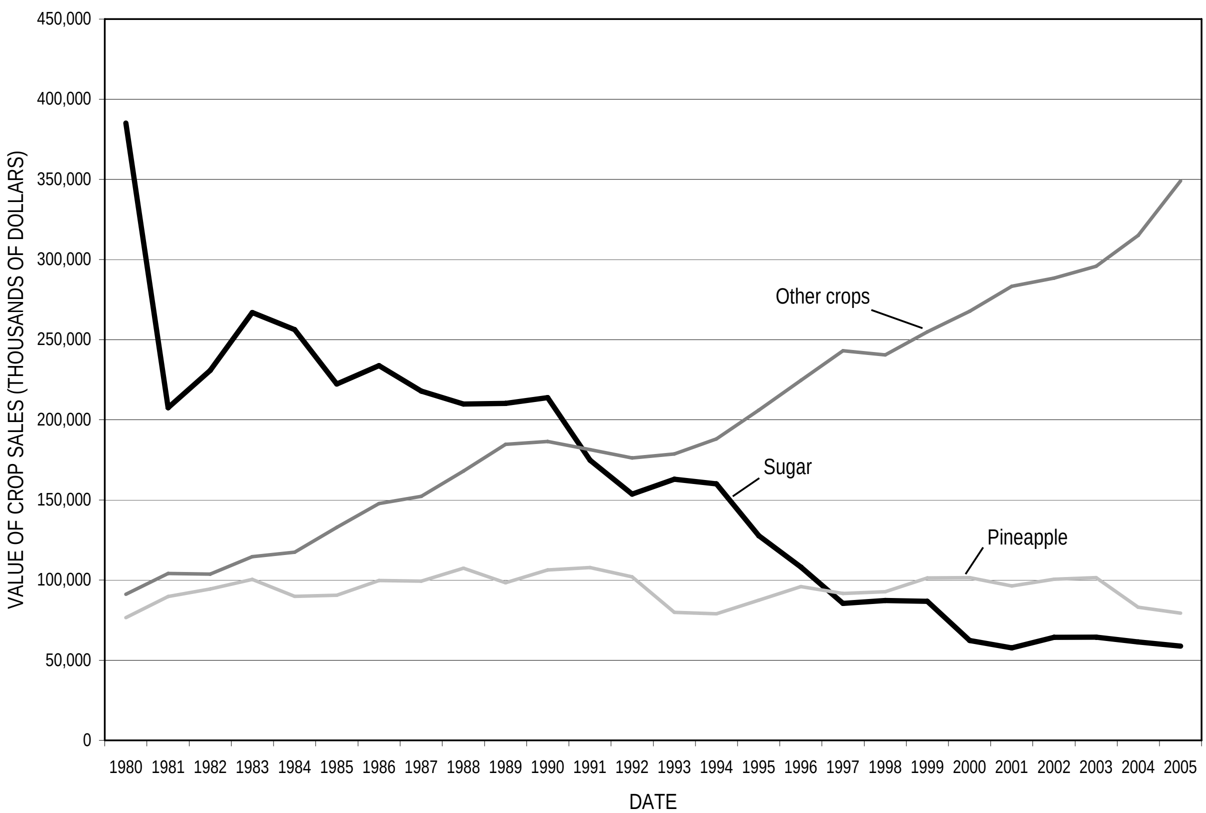
Of the estimated 1,750 agriculture-related jobs on Maui (Department of Business, Economic Development & Tourism [DBEDT], 2007), HC&S employs approximately 800 full-time workers, while EMI employs an additional 17 workers. The Agribusiness sector of HC&S saw a revenue increase of 3 percent, or $4.2 million, in 2006 over the previous year. This increase was attributed to higher revenues in repair services and trucking, higher-power sales, higher equipment rentals and soil sales, and higher specialty sugar and molasses sales. In comparison, lower revenues were reported in the bulk sugar sales (A&B, 2007). Table 13-8 provides a summary of HC&S' agribusiness revenues for 2000 to 2006.

Year	Revenue (dollars)	Operating Profit (dollars)	Operating Profit Margin (percent)
2006	$ 127,400,000	$ 6,900,000	5.4
2005	$ 123,200,000	$ 11,200,000	9.1
2004	$ 112,800,000	$ 4,800,000	4.3
2003	$ 112,900,000	$ 5,100,000	4.5
2002	$ 112,700,000	$ 13,800,000	12.2
2001	$ 105,976,000	$ 5,660,000	5.3
2000	$ 107,510,000	$ 7,522,000	7.0

Table 13-8. Summary of HC&S' agribusiness revenues for 2000 to 2006 (Source: A&B, 2002; 2005; 2007).

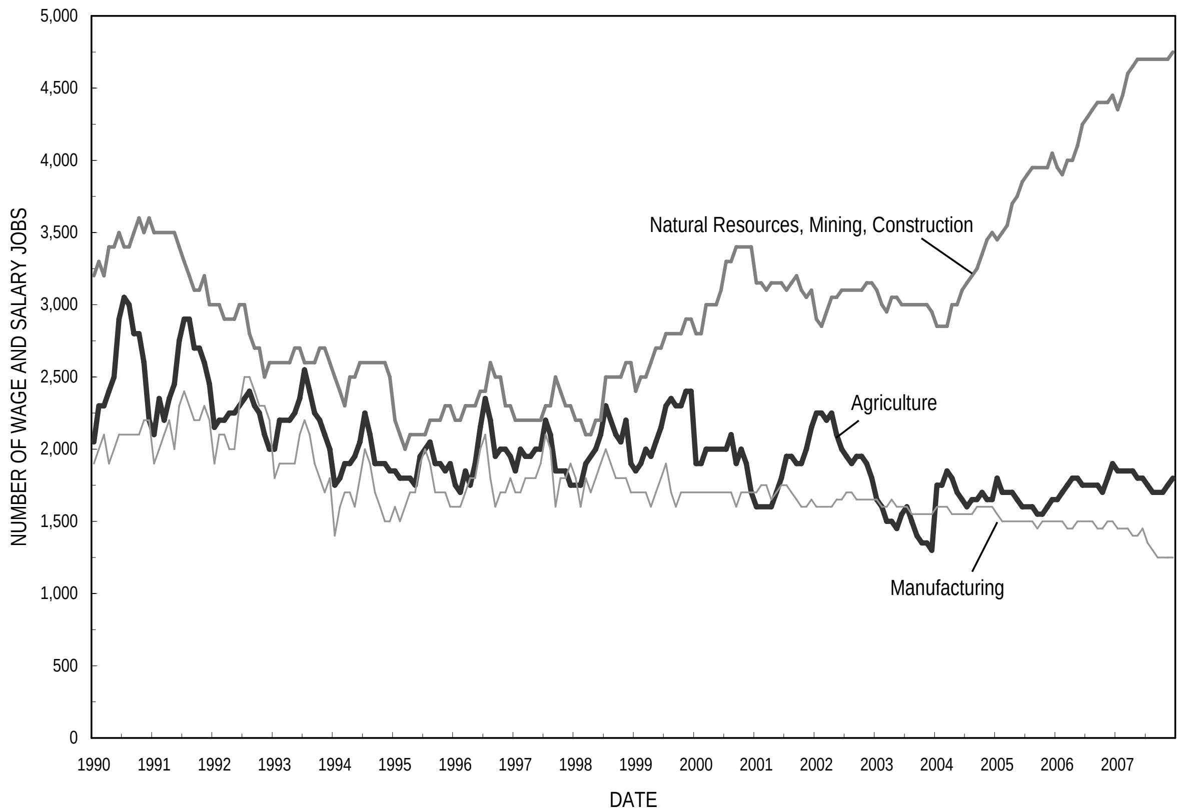
Overall, Hawaii sugar growers produce more sugar per acres than most other sugar-producing areas of the world; however, this advantage is offset by Hawaii's higher labor costs and higher transportation costs resulting from the longer distance to the U.S. mainland market. The DBEDT *State of Hawaii Data Book* shows the dramatic decline in sugar crop sales as plantations have closed over the last 25 years (DBEDT, 2006). Figure 13-4 illustrates the decline of sugar, the steady value of pineapple sales, and the increase of other crops generally considered as diversified agriculture.

Figure 13-4. Value of crop sales for sugar, pineapple and other crops from 1980 to 2005 (Source: DBEDT, 2006).



Examination of monthly economic indicators shows that, in general, agricultural jobs have slowly decreased on the island of Maui over the past 15 years. This trend is illustrated in Figure 13-5 along with trends for: 1) Natural resources, mining, and construction; and 2) Manufacturing.

Figure 13-5. Monthly number of wage and salary jobs, for three sectors including agriculture, for the island of Maui from 1990 to 2007 (Source: DBEDT, 2008).



In addition to sugar crops, HC&S receives revenue from its sale of electricity to Maui Electric Company (MECO). The HC&S Puunene Sugar Mill continues to provide a renewable energy alternative in the form of sugar cane bagasse, a fibrous byproduct of the sugar extraction process. Bagasse is the primary fuel used in boilers to generate steam, a requirement for sugar processing and for driving steam turbine generators to produce electricity. The electricity that is not used by the sugar mill is sold to MECO for distribution. HC&S is under contract with MECO to supply, at specified rates, 12 megawatts of power from 7:00 a.m. to 9:00 p.m. daily except Sunday and 8 megawatts at all other times. The contract provides for monetary penalties if these requirements are not met by HC&S. The approximate oil savings is 44,700 barrels per year (MECO, 2008).

HC&S also receives revenue from the delivery of water to the County of Maui Department of Water Supply's (DWS) Upcountry system, and to Maui Land and Pineapple Company, Inc. (MLP) for its east Maui pineapple fields. MLP cultivates roughly 6,000 acres of pineapple, over 2,800 of which are situated in east Maui and rely on the EMI system for water. While there are indications that MLP has leased, or is planning to lease, 400 additional acres in east Maui to expand their pineapple growing operations (Findings of Fact, Conclusions of Law, and Decision and Order, 2007), MLP has also expressed their intention of shifting plantings from Upcountry Maui to agricultural land in west Maui due to the susceptibility of their east Maui fields to drought conditions. MLP states that their west Maui lands are less susceptible to drought and irrigation storage capacity is being increased (MLP, 2007).

MLP estimates their water requirements from the EMI system at 4.5 million gallons per day from 2004 through 2009, and a reduction to approximately 4.4 million gallons per day from 2009 to 2016. Under a

License and Water Agreement between MLP and EMI, two “classes” of water are transported via the EMI system. The first class of water, which represents the majority of MLP’s usage, is pumped by Maui Pineapple Co., Ltd. into the Koolau Ditch from Hanawi Stream at Nahiku near the start of the EMI system. The second class of water is what MLP is contractually allowed to withdraw, for a fee, from the EMI system when flow exceeds 100 million gallons per day.

According to MLP’s Annual Reports to the U.S. Securities and Exchange Commission, the last year that MLP had an operating profit for their pineapple operations was in 1999. Table 13-9 provides a summary of revenue and operating losses from 1999 to 2006. Some of the revenue losses can be attributed to increased importation of oversees pineapple products (specifically from Thailand); though it appears that the U.S. had begun imposing antidumping duties, as canned pineapple imports had decreased in 2001. Regardless, in June 2007, MLP ceased pineapple canning operations on Maui, attributing the closure to increased imports of cheaper canned pineapple. MLP is instead choosing to focus on the production of pineapple juice and fresh fruit. The closure of Hawaii’s last canned pineapple producer resulted in the loss of 120 jobs, or 27 percent of the company’s workforce (Hao, 2007).

Table 13-9. Summary of MLP’s revenues and operating losses for 1999 to 2006 (Source: MLP, 2002; 2004; 2005; 2007).

[Numbers in parentheses indicate operating losses; numbers not in parentheses are gains.]

Year	Revenue (dollars)	Operating Loss (dollars)
2006	$ 65,200,000	$ (18,600,000)
2005	$ 74,500,000	$ (11,400,000)
2004	$ 80,000,000	$ (10,800,000)
2003	$ 105,000,000	$ (921,000)
2002	$ 92,500,000	$ (8,500,000)
2001	$ 92,000,000	$ (3,000,000)
2000	$ 85,900,000	$ (2,900,000)
1999	$ 94,400,000	$ 6,100,000

The other major user of EMI surface water, Maui DWS, receives approximately 8.2 million gallons per day, a portion of which goes directly to the Kula Agricultural Park. Under a December 31, 1973 agreement between EMI, HC&S, and the County of Maui, EMI agreed to collect and deliver to the County 12 million gallons per 24-hour period for a term of 20 years, with an option for the County to receive an additional 4 million gallons after giving one year’s written notice to EMI. Set to expire in 1993, this agreement was extended on several occasions, with the last extension expiring on April 30, 2000.

EMI currently delivers water to the County under a Memorandum of Understanding (MOU) that was executed on April 13, 2000, which provides for the County to continue to receive 12 million gallons per day from the Wailoa Ditch with an option to receive an additional 4 million gallons. However, the MOU also includes stipulations for periods of low flow, whereby the County will receive a minimum allotment of 8.2 million gallons per day while HC&S will also receive 8.2 millions gallons per day, or 9.4 million gallons per day should fire flow be required (Maui DWS, 2007b). The MOU has a term of 25 years and sets water delivery rates at $0.06 per thousand gallons. For the 2006 fiscal year, Maui DWS reported purchasing a total of 2,601 million gallons from EMI, at a cost of $156,848, which includes various other sources in addition to the Wailoa Ditch (Maui DWS, 2007a).

Of the five separate water systems operated by DWS, the Upcountry Maui (sometimes referred to as Makawao) system is the second largest system and is supported by Maui's largest surface water treatment facility (WTF), the Kamole Weir WTF. Surface water, for the most part, supplements the primary ground water sources (Haiku and Kuapakalua wells) for the region, but serves as backup in the event of pump failure or drought. The Kamole Weir WTF produces an average 3.6 million gallons per day, but is capable of producing 8 million gallons per day at maximum capacity. DWS also plans to increase capacity by 2.3 million gallons per day in 2015 (Findings of Fact, Conclusions of Law, and Decision and Order, 2007; Maui DWS, 2007e).

The Kamole Weir WTF receives water from the Wailoa Ditch and supplies water to approximately 6,571 water service connections and is capable of providing water to the entire Upcountry region (9,708 connections) if necessary (Maui DWS, 2007e). The Upcountry system includes the communities of Kula, Pukalani, Makawao, and Haiku, with an estimated population of 30,981 people (Findings of Fact, Conclusions of Law, and Decision and Order, 2007). Metered water usage in the Upcountry system has steadily climbed over the past 10 years, with the largest portion going towards potable water use (Table 13-10).

Table 13-10. Historical metered consumption for the Upcountry system, Maui (Source: Maui DWS, 2007d).

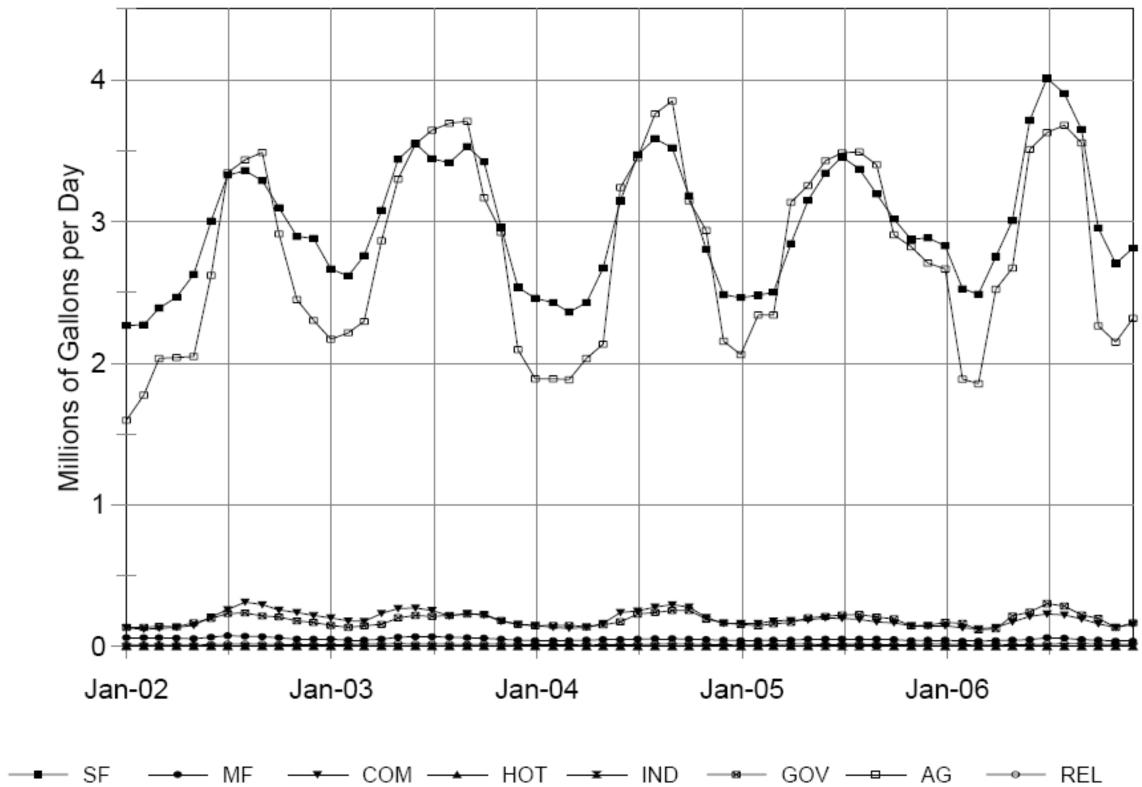
[Data reported in million gallons per day]

Year	General	Agriculture Potable	Total Potable	Agriculture Non-potable	Total
2005	4.441	2.378	6.820	0.571	7.391
2004	4.387	2.138	6.525	0.575	7.100
2003	4.778	2.320	7.098	0.582	7.680
2002	4.461	1.908	6.368	0.433	6.801
2001	4.823	2.563	7.387	0.690	8.077
2000	4.370	2.504	6.873	0.505	7.379
1999	4.146	2.474	6.620	0.555	7.175
1998	4.003	2.382	6.384	0.512	6.897
1997	3.693	1.829	5.521	0.374	5.895
1996	4.083	1.923	6.007	0.481	6.487
1995	4.382	2.300	6.682	0.634	7.317
1994	3.871	1.931	5.802	0.504	6.306

For the Makawao-Pukalani-Kula Community Plan District, water use for agriculture and single-family residences has been very similar over the past 5 years. The two uses also have strong annual patterns, with water use rising approximately 1.5 million gallons per day during summer months versus winter months (Figure 13-6). Other water uses within the district are relatively low (Maui DWS, 2007d).

Figure 13-6. Historical monthly water consumption by use class code for the Makawao-Pukalani-Kula Community Plan District, Maui (Source: Maui DWS, 2007d).

[SF is single family residential; MF is multi-family residential; COM is commercial; HOT is hotel; IND is industry; GOV is government; AG is agricultural; REL is religious)



The County of Maui, as part of its current effort to update the Maui County Water Use and Development Plan, is examining various resource options to meet the forecasted water needs and planning objectives of the Upcountry district over a 25 year planning period. Expansion of the Kamole Weir WTF is the primary long-term option affecting water delivered via the Wailoa Ditch; however, other options for the entire district include developing additional ground water sources, expanding/upgrading interconnections (booster pumps) between systems, and increasing water storage capacity (Maui DWS, 2007c). Upcountry water demands are expected to increase, as depicted in Figure 13-7, based upon five water demand projections derived from varying growth scenarios (low, medium low, base, medium high, and high) to the year 2030.

Figure 13-7. Actual and projected water demands of all metered use classes for the Upcountry District, Maui (Source: Maui DWS, 2007d).

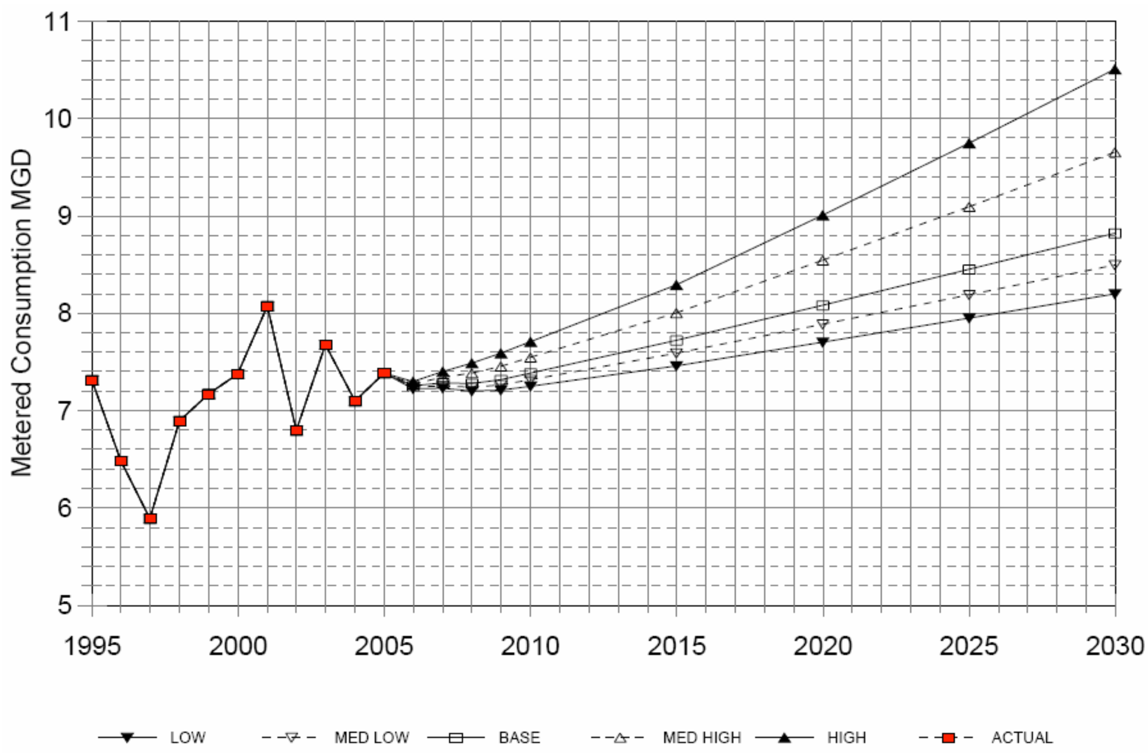


Figure 13-8. Registered and EMI minor diversions identified in the Waiokamilo hydrologic unit (Source: East Maui Irrigation Company, 1970).

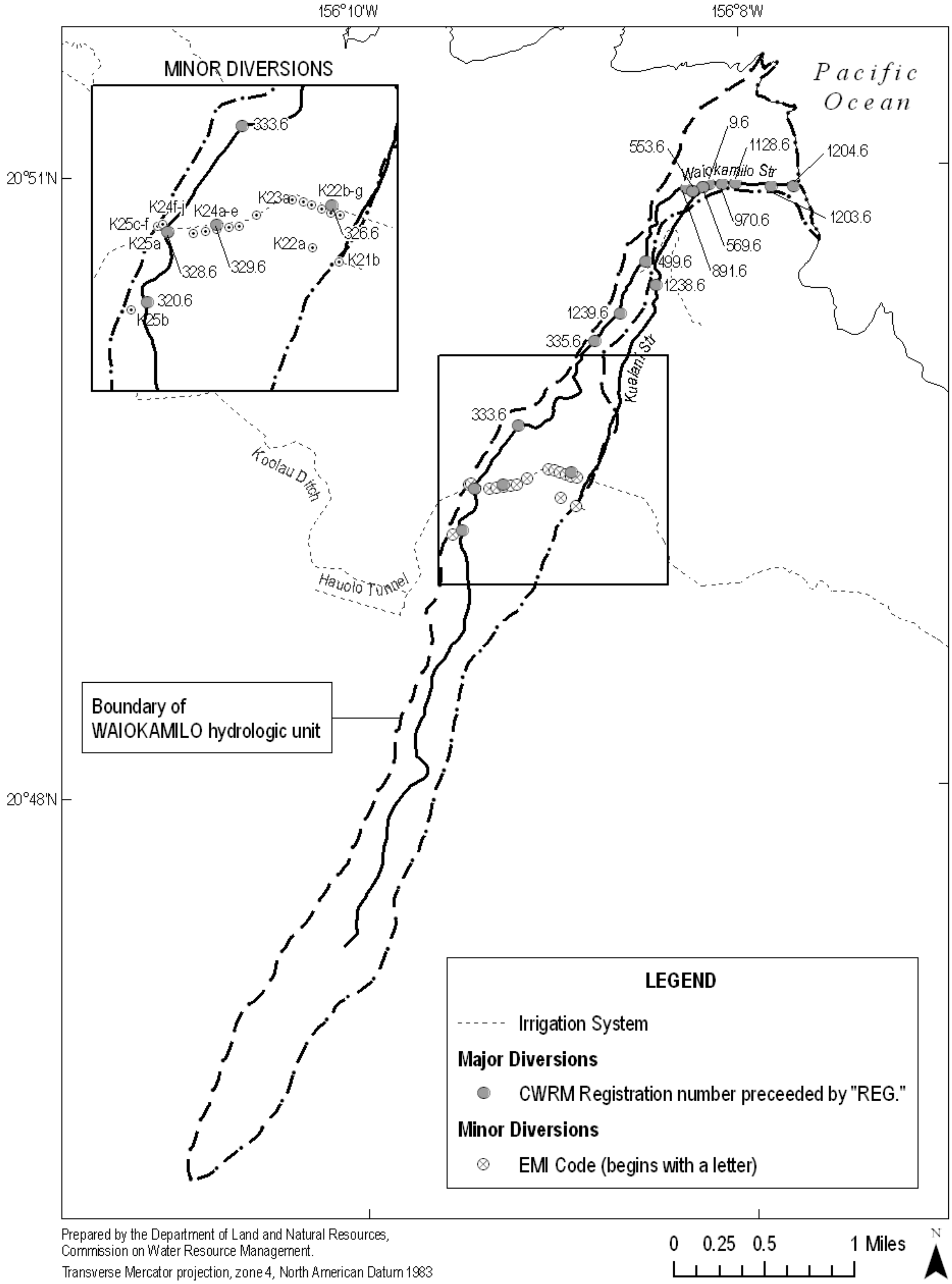
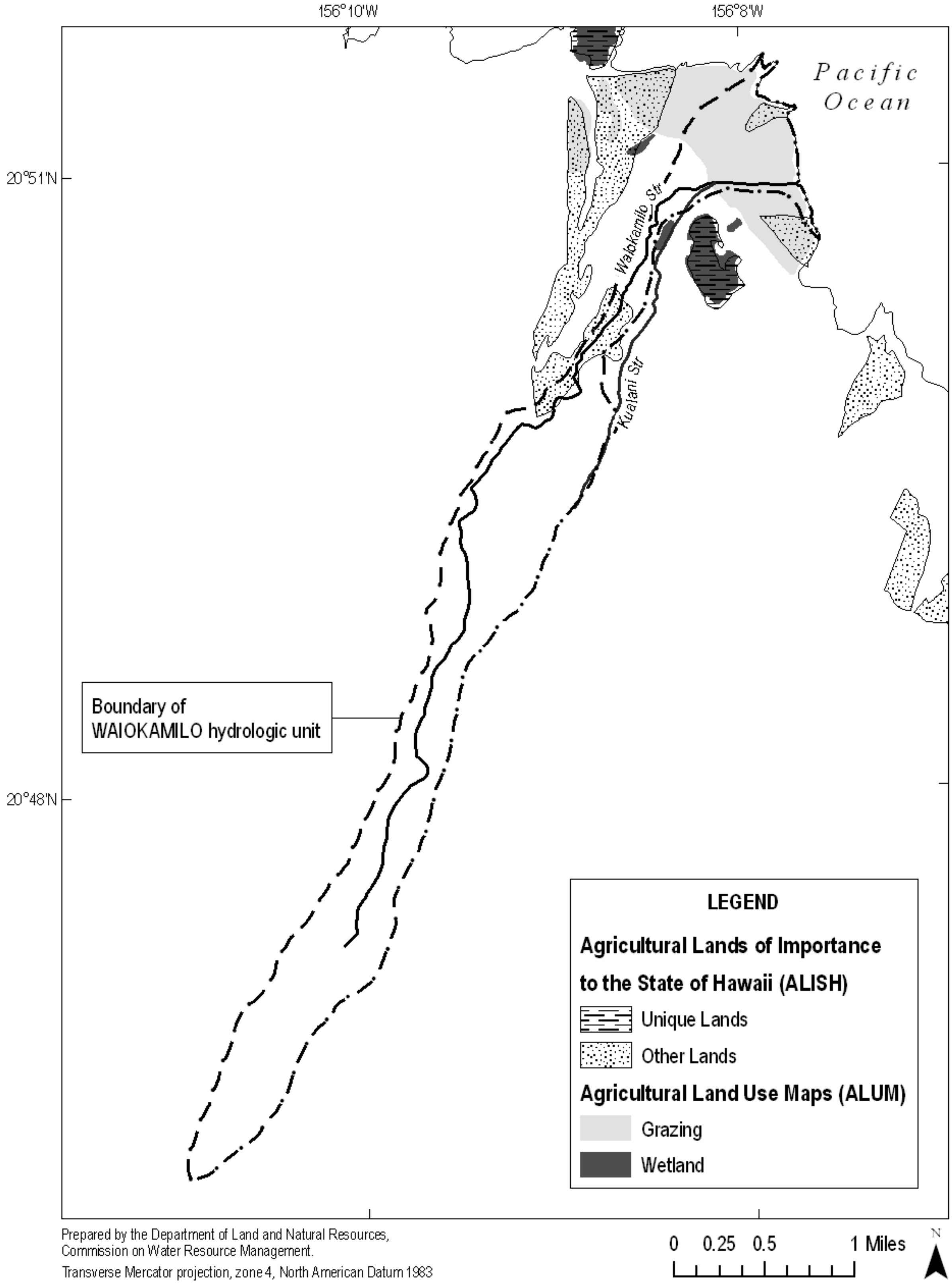


Figure 13-9. Potential agricultural land use for the Waiokamilo hydrologic unit based on the ALISH and ALUM classification systems (Source: State of Hawaii, Office of Planning, 1977; 1980).



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