Instream Flow Standard Assessment Report

Island of Maui
Hydrologic Unit 6047
Waikamoi

September 2009 *PUBLIC REVIEW DRAFT*

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

COVER
Waikamoi and Wahinepee streams flow into the deep waters of the Pacific Ocean over terminal waterfalls [Google Earth, 2009].

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)
CPRC	Compilation of Public Review Comments (PR-2008-07, CWRM)
CWA	Clean Water Act (EPA)
CWRM	Commission on Water Resource Management (State of Hawaii)
DAR	Division of Aquatic Resources (State of Hawaii)
DBEDT	Department of Business, Economic Development and Tourism (State of Hawaii)
DHHL	Department of Hawaiian Home Lands (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)
EA	Environmental Assessment
EIS	Environmental Impact Statement
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
IRR	irrigation requirements
IWREDSS	Irrigation Water Requirement Estimation Decision Support System
LCA	Land Commission Award
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)
NHLC	Native Hawaiian Legal Corporation
NIR	net irrigation requirements
NPDES	National Pollutant Discharge Elimination System
NPV	Net Present Value
NRCS	Natural Resource Conservation Service (USDA)
NVCS	National Vegetation Classification System
OED	Office of Economic Development (County of Maui)
Park	Kula Agricultural Park
por.	Portion
REL	religious
RMT	R.M. Towill Corporation
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
TFQ_{90}	90 percent exceedence probability
TMDL	Total Maximum Daily Load
TMK	Tax Map Key
UHERO	University of Hawaii's Economic Research Organization
USDA	United States Department of Agriculture
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

1.1 General Overview

Waikamoi means water [of] the moi taro in the Hawaiian language (Pukui et al., 1974). The hydrologic unit of Waikamoi is located north 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 5.3 square miles[1] from the upper slopes of Haleakala at 9,300 feet elevation[2] to the sea (Figure 1-4). Waikamoi Stream is 8.5 miles[3] in length, traversing north from the headwaters of its tributaries near Hosmer Grove Spring at the 6,560 feet altitude to the ocean. The stream rises from sea level to 600 feet altitude 0.8 miles from the coast, contributing to a slope gradient of 790 feet per mile (Gingerich, 1999b). A major tributary to Waikamoi Stream is Alo Stream, which branches east at about 840 feet altitude. East of Waikamoi Stream within the same hydrologic unit is Wahinepee Stream. It is less than a mile in length with headwaters beginning at about the 800 feet elevation. Most of the hydrologic unit is made up of forest reserves and wetlands that cover slopes up to 7,000 feet, beyond which is part of the Haleakala National Park (Figure 1-6). Population in the hydrologic unit is about 517, with over 70 percent of the people living near Wahinepee Stream (Coral Reef Assessment and Monitoring Program, 2007).

1.2 Current Instream Flow Standard

The current interim instream flow standard (IFS) for Waikamoi Stream was established by way of Hawaii Administrative Rules (HAR) §13-169-44, which, in pertinent part, read 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.

1.3 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.

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[1] Area of the hydrologic unit is derived from the surface water hydrologic unit GIS data file (State of Hawaii, Commission on Water Resource Management, 2005c).

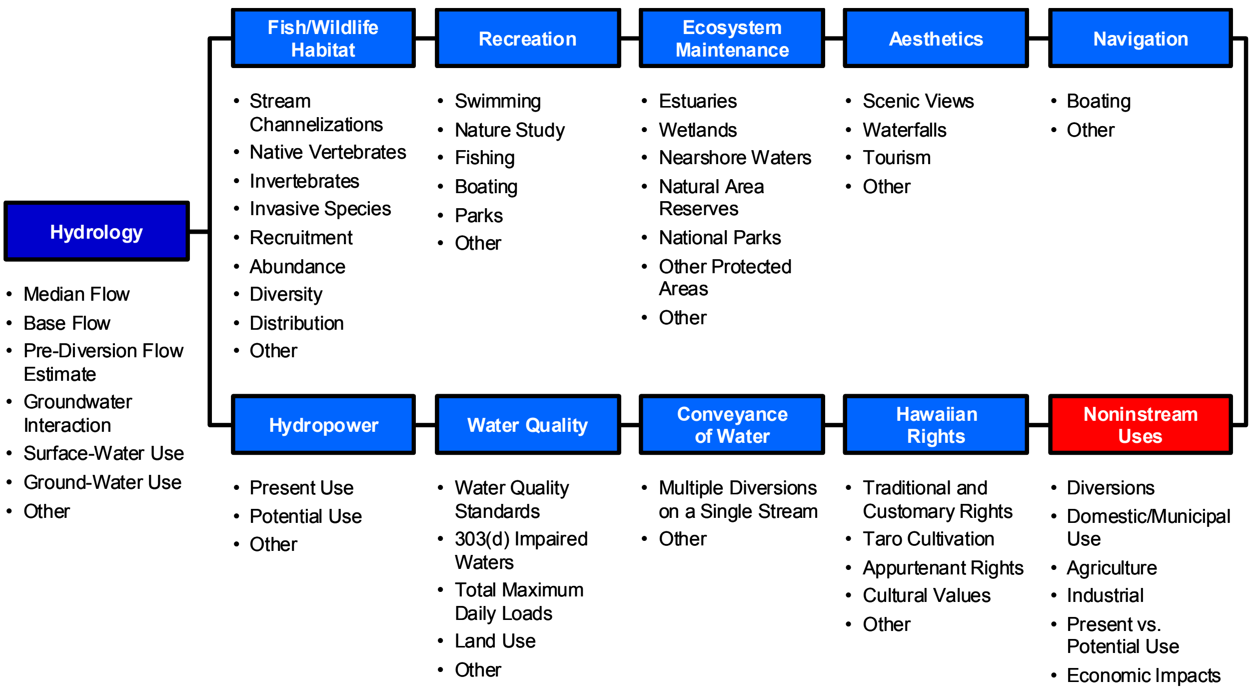
[2] Elevation data is derived from the 100 foot contours GIS data file (State of Hawaii, Office of Planning, 1997) unless otherwise noted.

[3] Length of the stream is derived from the National Hydrography Dataset (U.S. Geological Survey, 2001b).

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.

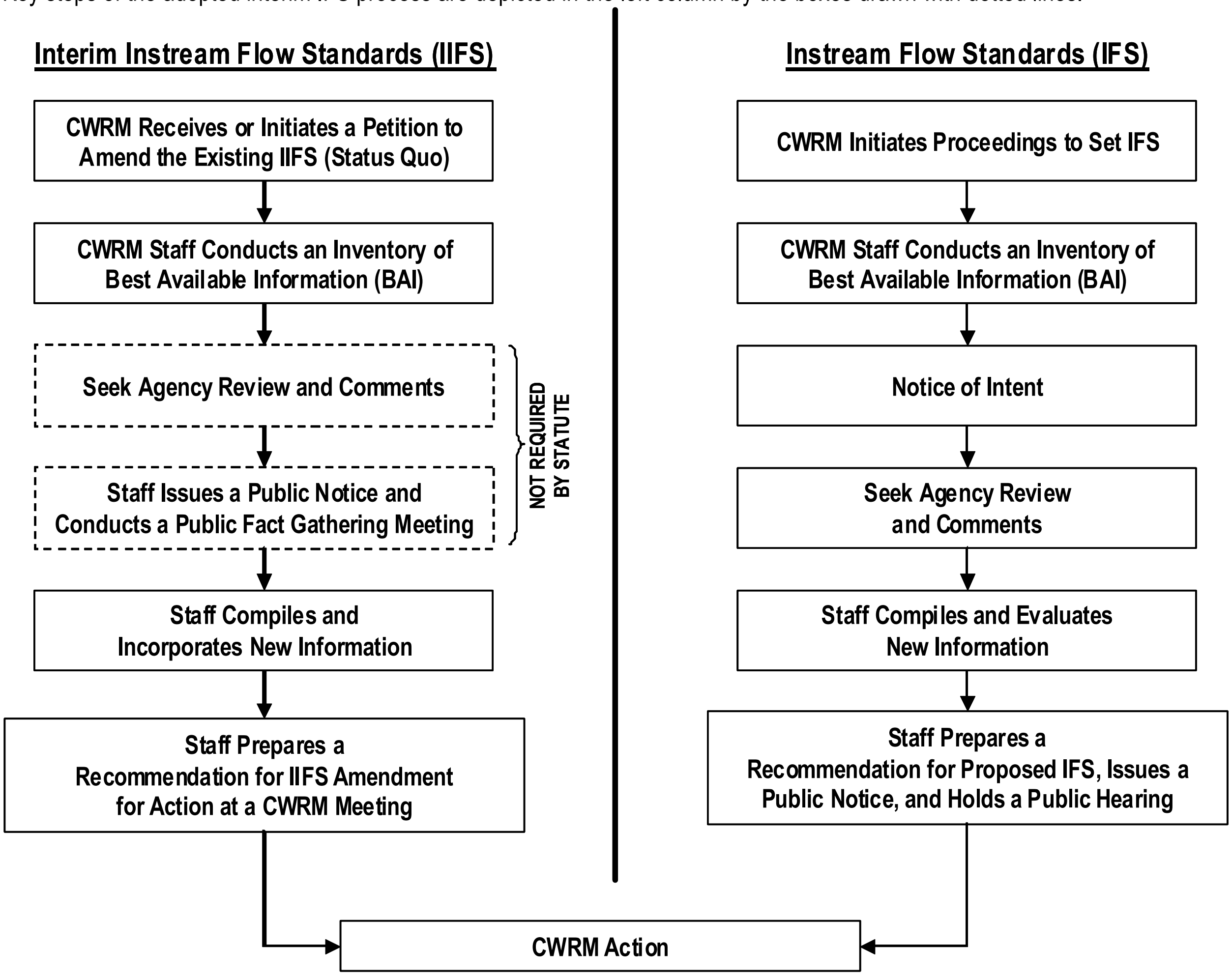


1.4 Interim Instream Flow Standard Process

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. Key steps of the adopted interim IFS process are depicted in the left column by the boxes drawn with dotted lines.



1.5 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. This information is used to determine the interim IFS recommendations, which is compiled as a separate report. 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 are prepared separately as a 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.

1.6 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 (State of Hawaii, 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.

1.7 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 Waikamoi hydrologic unit in east Maui, Hawaii (Source: USGS, 1996).

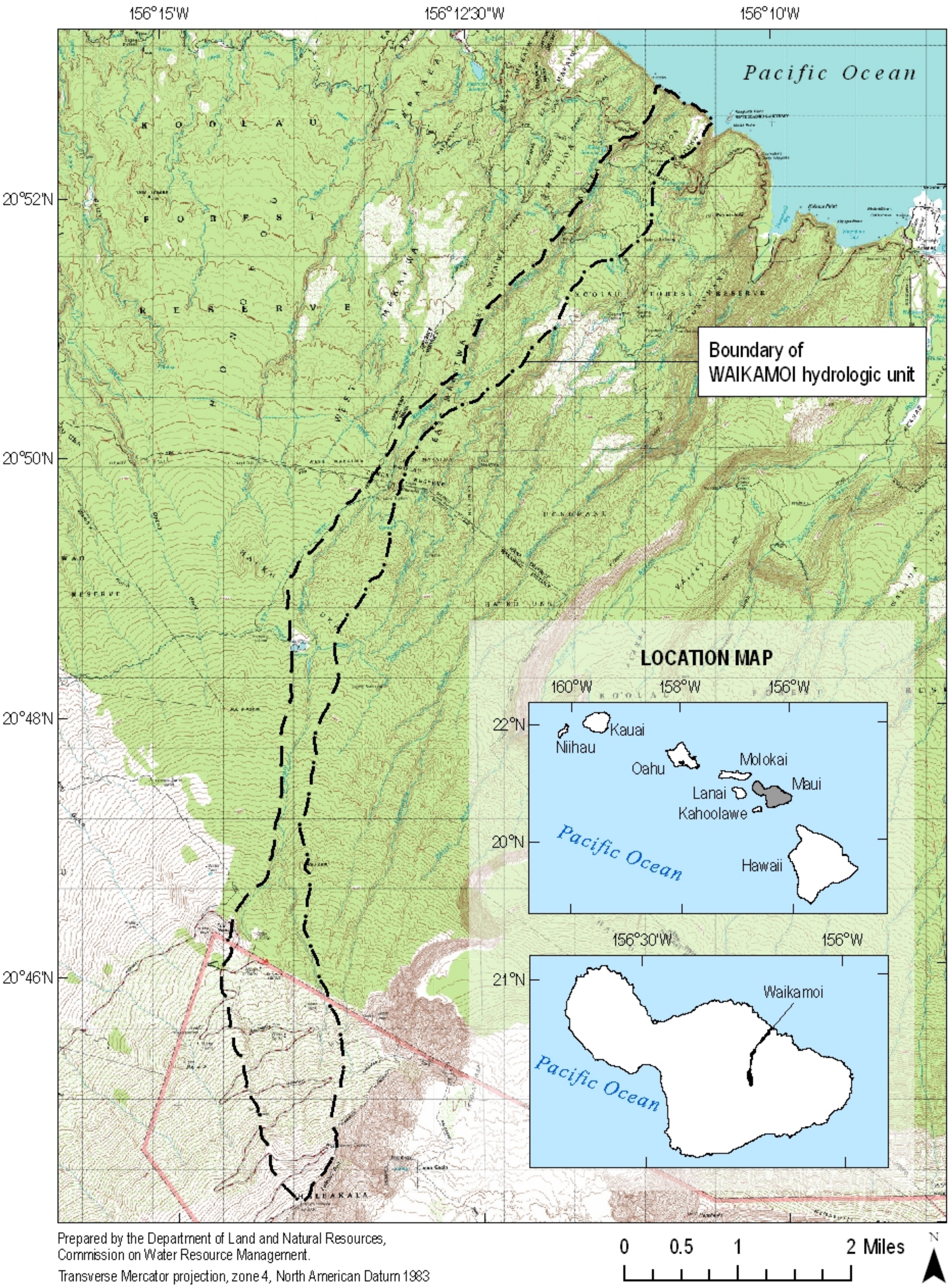


Figure 1-4. Elevation range and the location of Waikamoi hydrologic unit. (Source: State of Hawaii, Office of Planning, 1983; USGS, 2001b).

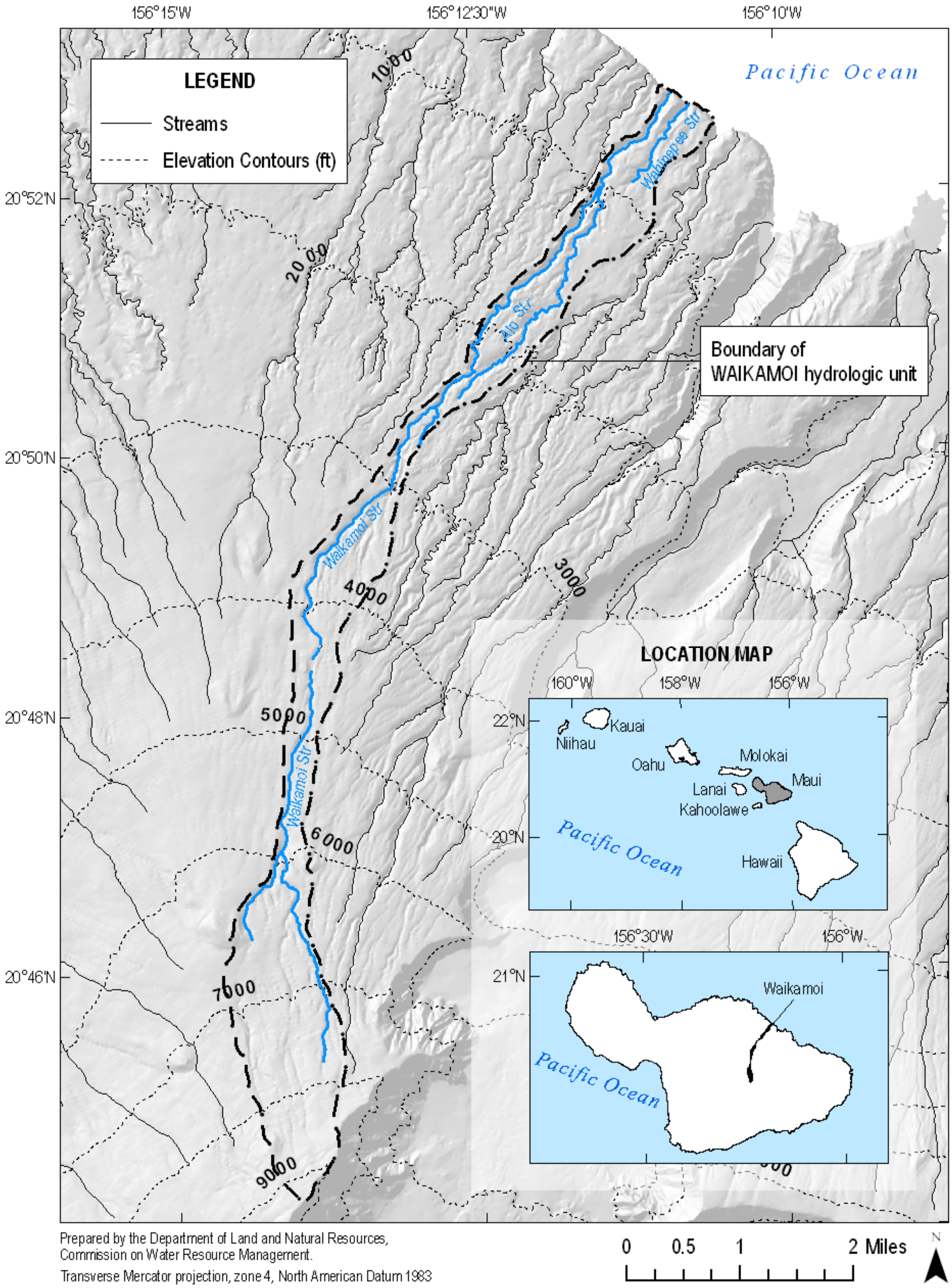


Figure 1-5. Major and minor roads and Tax Map Key (TMK) parcel boundaries for Waikamoi hydrologic unit (Source: County of Maui, 2006; County of Maui, Geographic Information Systems [GIS] Division, Department of Management, 2006; USGS, 2001b).

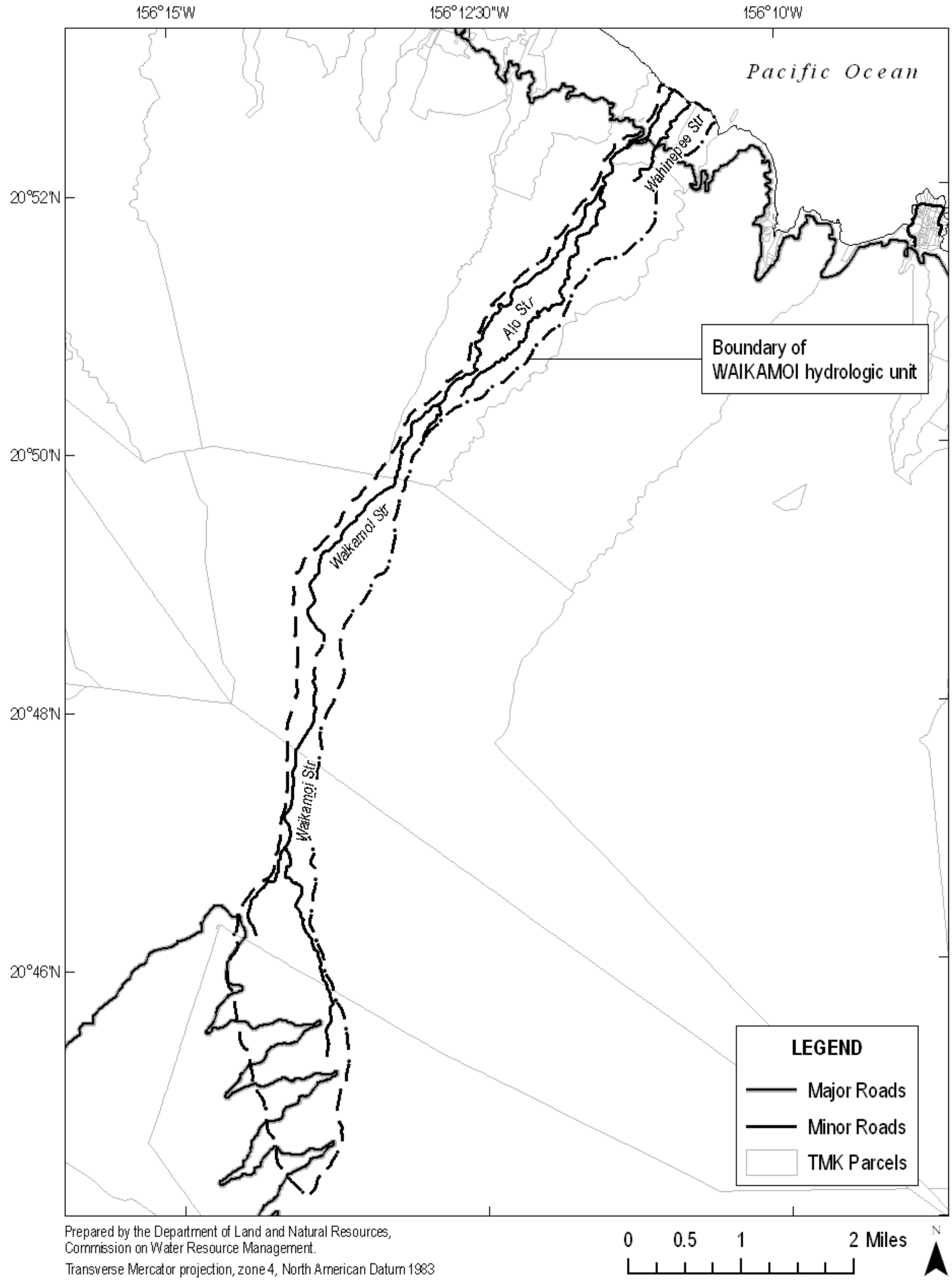
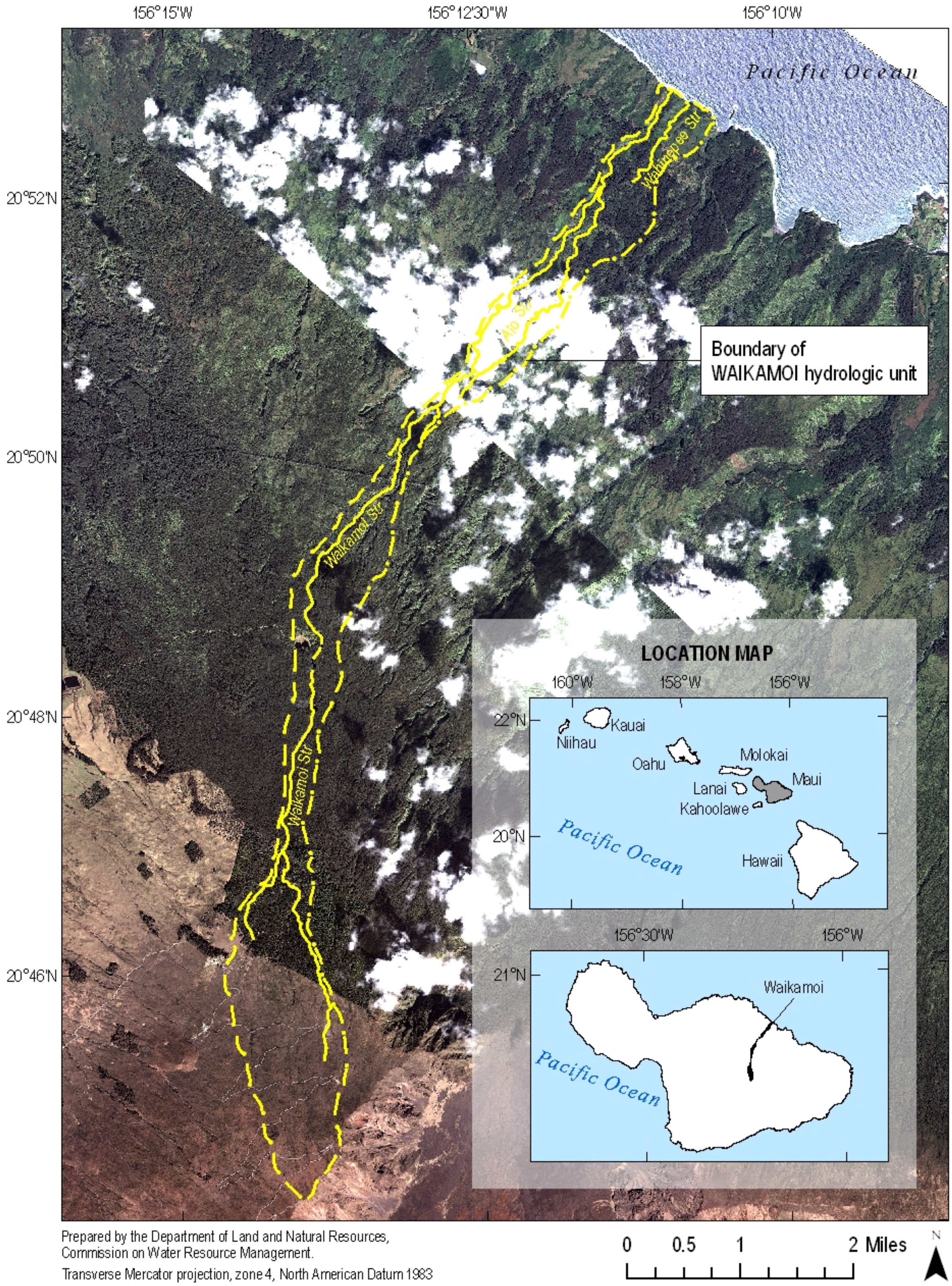


Figure 1-6. Quickbird satellite imagery of Waikamoi hydrologic unit (Source: County of Maui, Planning Department, 2004; USGS, 2001b).



2.0 Unit Characteristics

2.1 Geology

Waikamoi hydrologic unit has a land area of about 5.3 square miles that extends for about 10 miles from the coast to the summit crater of Haleakala Volcano at elevation of more than 2,800 feet above mean sea level. This hydrologic unit includes several volcanic cones on the east Maui north rift zone that formed during the post-shield volcanism stages. Moderate to high degree of drainage integration and entrenched stream channels in Waikamoi suggest a relatively mature landscape. Sections along channel walls and cliff sections reveal lava successions belonging to Honomanu Basalt, Kula Volcanics and Hana Volcanics.

The Honomanu Basalt is the oldest volcanic formation exposed on the walls of deeply eroded gulches and coastal cliffs on the north flank of Haleakala Volcano. This succession of thin-bedded lava flow deposits (Stearns, 1985) was part of the late shield-building stage on east Maui (Stearns and MacDonald, 1942), but most likely erupted about 1.1 to 0.97 Ma[4] (Chen and others, 1991). It consists mainly of pahoehoe[5] lavas (Sherrod and others, 2007), although aa[6] members may also be found within the formation. Compositionally, Honomanu Basalt displays characteristic transition from tholeiitic to alkalic lavas, suggesting that shield-building volcanic episode was gradually followed by post-shield magmatic activities that commenced with the emplacement of Kula volcanics.

About 1 percent of Waikamoi is directly underlain by Honomanu Basalt, which may be found mostly in the coastal cliff sections and at the coastal opening of the stream valley. With the predominance of poorly permeable pahoehoe lavas, Honomanu Basalt most likely traps the percolating ground water to the basal aquifer, and thus contributes to the development of high-level water[7] resources in east Maui.

The production of lavas with a higher total alkali content marked the onset of post-shield volcanic stage of the Haleakala Volcano, commencing with the eruption of Kula Volcanics from the southwest and east rift zones from 0.95 to 0.15 Ma (Sherrod and others, 2003). Kula volcanics form a thick mantle of mostly aa lavas flow deposits and are widely distributed on the north flank of Haleakala, where it piled up to 1 kilometer thick near the summit area (Sherrod and others, 2007). Kula Volcanics were also generated from cinder cones that clustered along the north rift zone (Stearns and Macdonald, 1942). Thus, lava sequences maybe found occasionally interstratified with ash and intimately associated with cinder cones. Long reposes and depositional intervals promote weathering and leads to the development of soil horizons within Kula sequence.

By far, Kula Volcanics dominates the Waikamoi hydrologic unit. Being generally composed of aa lavas, Kula Volcanics probably have extensive permeable zones that allow storage and transmission of ground water to down-gradient regions, as well as across the hydrologic unit towards adjoining areas. In areas where Kula lavas are underlain by poorly permeable layer of Honomanu Basalt, thick ash unit and soil horizon, storage for high-level ground water most likely form and become storage of high-level water with significant contribution to base-flow. About 98 percent of Waikamoi is directly underlain by thick Kula Volcanics' lava flow deposits. Areas covered with ash and cinder deposits are localized near eruptive vents.

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[4] Million years ago.
[5] Type of lava flow deposit characterized by typically smooth billowy surface and ropy textures.
[6] Type of lava flow deposit distinguished by its craggy surface and abundant jagged blocks.
[7] High-level water is water confined at higher elevation above a less permeable layer.

Less than 1 percent of the hydrologic unit encompasses the area that is directly underlain by Hana Basalt. Hana Basalt, which is characterized by high alkali content, was mainly composed of aa lava flow deposits that were erupted from the southwest and east rift zones on summit areas and from cinder cones along the north rift zone of Haleakala Volcano. Newly established radiocarbon and K-Ar[8] dates placed the age range for Hana Volcanics from 140 Ka[9] to A.D. 1633 (Sherrod and others, 2003; Sherrod and others, 2006). The extended range of eruptions of Hana lavas, which culminated to near historic activities, and its coeval relationship with the period of deep erosion of Haleakala slopes led to earlier belief that it was part of the rejuvenated volcanic stage. However, the short hiatus in radiometric dates and the large overlap in geochemical characteristics between Kula and Hana lavas support strongly for Hana eruptive episodes to belong to the waning phase of the post-shield volcanism at Haleakala (Sherrod and others, 2007).

The generalized geology of the Waikamoi hydrologic unit is described in Table 2-1 and depicted in Figure 2-2.

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

Symbol	Name	Rock Type	Lithology	Area (mi^2)	Percent of Unit
Qkul	Kula Volcanics	Lava flows	Aa and pahoehoe	5.06	96.3
Qkuv	Kula Volcanics	Cinder and spatter	Coarse near-vent fallout deposits	0.11	2.0
Qmnl	Honomanu Basalt	Lava flows	Pahoehoe and aa	0.05	0.9
Qhnv0	Hana Volcanics	Cinder and spatter	Coarse near-vent fallout	0.04	0.8

2.2 Soils

Waikamoi consists largely of soils that are fairly permeable, except for parts of the intermediate slopes where the soils are poorly drained, meaning that water does not move quickly through the soil and the soil remains wet for long periods. Along the stream course, the soils are soft and permeable. Near the coast of the hydrologic unit are well-drained soils; thus allowing rainwater to feed both streams and ground water.

The mauka section of the hydrologic unit consists of young aa lava that has a thin covering of volcanic ash. This soil is very stony, and can extend to a depth of 20 inches in localized areas. In the intermediate elevations surrounding the streambed, the substratum is soft, weathered basic igneous rock capped by a horizontal ironstone sheet up to 1 inch thick. Permeability is restricted by the ironstone sheet, which is impermeable except for cracks, meaning rain water will infiltrate the top of the soil then move laterally until it either seeps out as springs or base flow[10] in streams; or reaches a more permeable soil type. The lower elevations are made of Honomanu-Amalu association. About 60 percent of the association are well-drained soils, occurring on the steeper slopes. The other 40 percent are poorly drained, occurring on the less sloping tops of ridges and interfluves (regions of higher land between valleys in the same hydrologic unit). Near the coast lies the Kailua silty clay soils, which are well-drained and strongly acidic soils. The soils along the course of Waikamoi Stream and Wahinepee Stream continue as rough mountainous land from the headwaters to the coast. This type of soil is relatively soft and permeable to water in most places, while those on narrow ridgetops are less permeable (U.S. Department of Agriculture, Soil Conservation Service, 1972).

[8] Potassium-Argon dating.
[9] Thousand years ago.
[10] Base flow is the flow of water into a stream from the ground from persistent, varying sources and maintains stream flow between water-input events (i.e. during periods of no rainfall).

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 and group D soils have the lowest. In Waikamoi, a majority of the soils belong to groups C and D, indicating that the soils have low infiltration rates and are more prone to surface runoff. The streambed lie mostly on group D soils except the headwaters which consist of both groups B and C soils. Only 11 percent of the soils in the hydrologic unit are group B and these soils are located in the upper slopes near Hosmer Grove Spring (U. S. Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, 1986).

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

Map Unit	Description	Hydrologic Group	Area (mi^2)	Percent of Unit
rVS	Very stony land	C	1.30	24.7
rRT	Rough mountainous land	D	1.10	20.9
rAMD	Amalu peaty silty clay, 3 to 20 percent slopes	D	1.09	20.7
rHR	Honomanu-Amalu association	C	0.67	12.8
KDIE	Kaipoioi loam, 7 to 40 percent slopes	B	0.27	5.1
KBID	Kailua silty clay, 3 to 25 percent slopes	C	0.26	5.0
rRK	Rock land	D	0.24	4.6
KDVE	Kaipoioi very rocky loam, 7 to 40 percent slopes	B	0.13	2.5
LNE	Laumaia extremely stony loam, 7 to 40 percent slopes	B	0.12	2.3
LMF	Laumaia loam, 40 to 70 percent slopes	B	0.03	0.5
ONE	Olinda loam, 20 to 40 percent slopes	B	0.03	0.5
PfD	Pauwela clay, 15 to 25 percent slopes	B	0.02	0.3
rRO	Rock outcrop	D	< 0.01	0.1

2.3 Rainfall

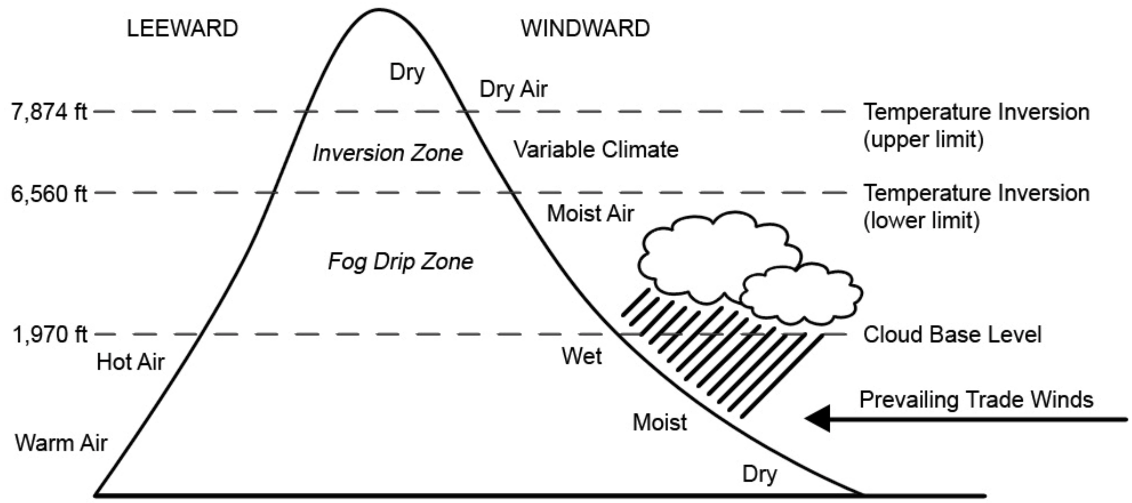
Rainfall distribution in Waikamoi is governed by the orographic[11] effect (Figure 2-1). Orographic precipitation occurs when the prevailing northeasterly trade winds lift warm air up the windward side of the mountains into higher elevations where cooler temperatures persist. As a result, frequent and 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, 1992).

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

[11] 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.

(Giambelluca and Nullet, 1992). 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.

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



The hydrologic unit of Waikamoi is situated on the windward flank of the East Maui Volcano. Waikamoi receives near-daily orographic rainfall of 118 inches per year at the coast to 240 inches per year in the intermediate slopes. This rainfall drops down to 60-70 inches per year above the temperature inversion zone in the upper slopes (Giambelluca et al., 1986). The high spatial variability in rainfall is evident where the mean annual rainfall decreases by about 40 inches with an average 800-foot drop in elevation in the lower slopes. Rainfall is highest during the months of March, April, and December where the mean monthly rainfall across the hydrologic unit is approximately 14 inches. In April, rainfall can reach as high as 20 inches in the mountains. For the rest of the year, the mean monthly rainfall ranges from 8 inches to 11 inches. The driest months are May and June, during which only 2-3 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, 1992), 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). This method was used to determine the contribution of fog drip in Waikamoi, which was calculated by multiplying the ratios with the monthly rainfall values (Giambelluca et al., 1986). Calculations show that approximately 40 percent of Waikamoi lies in the fog drip zone (Figure 2-4) with an estimated average annual fog drip rate of 69 inches per year. Since a relatively large portion of Waikamoi lies in the fog drip zone, the contribution of fog to total rainfall is significant.

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

2.4 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 land surface in a given area is dependent in part 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 higher levels of evaporation. In Waikamoi, estimated daily solar radiation is about 300 calories per square centimeter near the coast and decreases toward the uplands, where there are more clouds. Above the temperature inversion zone, solar radiation rises to about 500 calories per centimenter per day (Figure 2-4).

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[12], rainfall, humidity, wind speed, surface temperature, and sensible heat advection[13]. 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[14] 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). Shade (1999, Fig. 9) estimated pan evaporation rates of 30 inches per year below 2,000 feet elevation to 80 inches per year near the coast. Within the cloud layer, evaporation rates are particularly low due to the low solar radiation (i.e, from high cloud cover) and high humidity caused

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

by fog drip. Pan evaporation rates drop below 30 inches per year in this area as reported in Shade (1999, Fig. 9). 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 above and moist air from below (Nullet and Giambelluca, 1990). Above the inversion, clear sky and high solar radiation at the summits cause increased evaporation, with pan evaporation rates of about 50 to 70 inches per year (Shade, 1999, Fig. 9). 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.

2.6 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 95 percent of the land in Waikamoi as conservation district and the rest 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 2-5).

2.7 Land Cover

Land cover for the hydrologic unit of Waikamoi 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 Waikamoi, e.g. forest, shrub land, grassland, developed areas, cultivated areas, and bare land (Table 2-4, Figure 2-6). 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 2-7).

Based on the two land cover classification systems, the land cover of Waikamoi consists mainly of evergreen forests and shrub lands. A majority of the hydrologic unit is made up of native communities of uluhe shrub lands and Ohia forests that spread throughout the intermediate and upper slopes as part of the Koolau Forest Reserve and Waikamoi Preserve, respectively. The headwaters of Waikamoi Stream are part of the Haleakala National Park characterized by native shrublands with sparse Ohia forests. The lower slopes are mostly alien forests.

The land cover maps (Figures 2-6 and 2-7) provide a general representation of the land cover types in Waikamoi. Given that the scale of the maps is relatively large, they may not capture the smaller cultivated lands or other vegetation occupying smaller parcels of land. Land cover types may also have changed slightly since the year when the maps were published.

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

Land Cover	Description	Area (mi^2)	Percent of Unit
Evergreen Forest	Areas where more than 67 percent of the trees remain green throughout the year	3.31	63.0
Scrub/Shrub	Areas dominated by woody vegetation less than 6 meters in height	1.53	29.1
Grassland	Natural and managed herbaceous cover	0.25	4.8
Bare Land	Bare soil, gravel, or other earthen material with little or no vegetation	0.15	2.8
Water	Areas of open water with less than 30 percent of trees, shrubs, persistent emergent plants, or other land cover	0.01	0.1
Low Intensity Developed	Constructed surface with substantial amounts of vegetated surface	< 0.01	< 0.1
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 Waikamoi (Source: HI-GAP, 2005).

Land Cover	Area (mi^2)	Percent of Unit
Native Shrubland / Sparse Ohia (native shrubs)	1.35	25.7
Closed Ohia Forest (native shrubs)	1.17	22.3
Open Ohia Forest (uluhe)	1.10	20.9
Alien Forest	0.71	13.5
Closed Ohia Forest (uluhe)	0.38	7.3
Uncharacterized Open-Sparse Vegetation	0.24	4.5
Very Sparse Vegetation to Unvegetated	0.07	1.3
Alien Grassland	0.06	1.0
Closed Koa-Ohia Forest (native shrubs)	0.05	1.0
Uncharacterized Forest	0.04	0.8
Uluhe Shrubland	0.03	0.6
Closed Koa-Ohia Forest (uluhe)	0.02	0.4
Open Kiawe Forest and Shrubland (alien grasses)	0.02	0.3
Deschampsia Grassland	0.01	0.1
Kikuyu Grass Grassland / Pasture	0.01	0.1
Closed Kiawe - Koa Haole Forest and Shrubland	< 0.01	0.1
Open Ohia Forest (native shrubs)	< 0.01	< 0.1

2.8 Flood

Floods usually occur following prolonged or heavy rainfall associated with tropical storms or hurricanes. The magnitude of a 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 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 a flood safety structure 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 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 sections of a 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 Waikamoi.

2.9 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, agricultural, hydrological, and socioeconomic. 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 and 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 recording less than 25 percent of normal rainfall (State of Hawaii, Commission on Water Resource Management, 2005b). One of the more 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). According to the National Drought Mitigation Center (2009), the State of Hawaii has been in a severe drought condition since June 2008. The percentage of area categorized as severe drought increased from 3 percent in June to almost 55 percent in December of 2008. Drought conditions worsened in the last three months of 2008 that about 12 percent of the State was categorized as extreme drought. Currently, 23 percent of the State is in severe drought.

With Hawaii's limited water resources and growing water demands, droughts will continue to adversely affect the environment, economy, and the residents 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

Figure 2-2. Generalized geology of Waikamoi hydrologic unit (Source: Sherrod et al., 2007; State of Hawaii, Office of Planning, 2006a, and State of Hawaii, Commission on Water Resource Management, 2008d; USGS, 2001b).

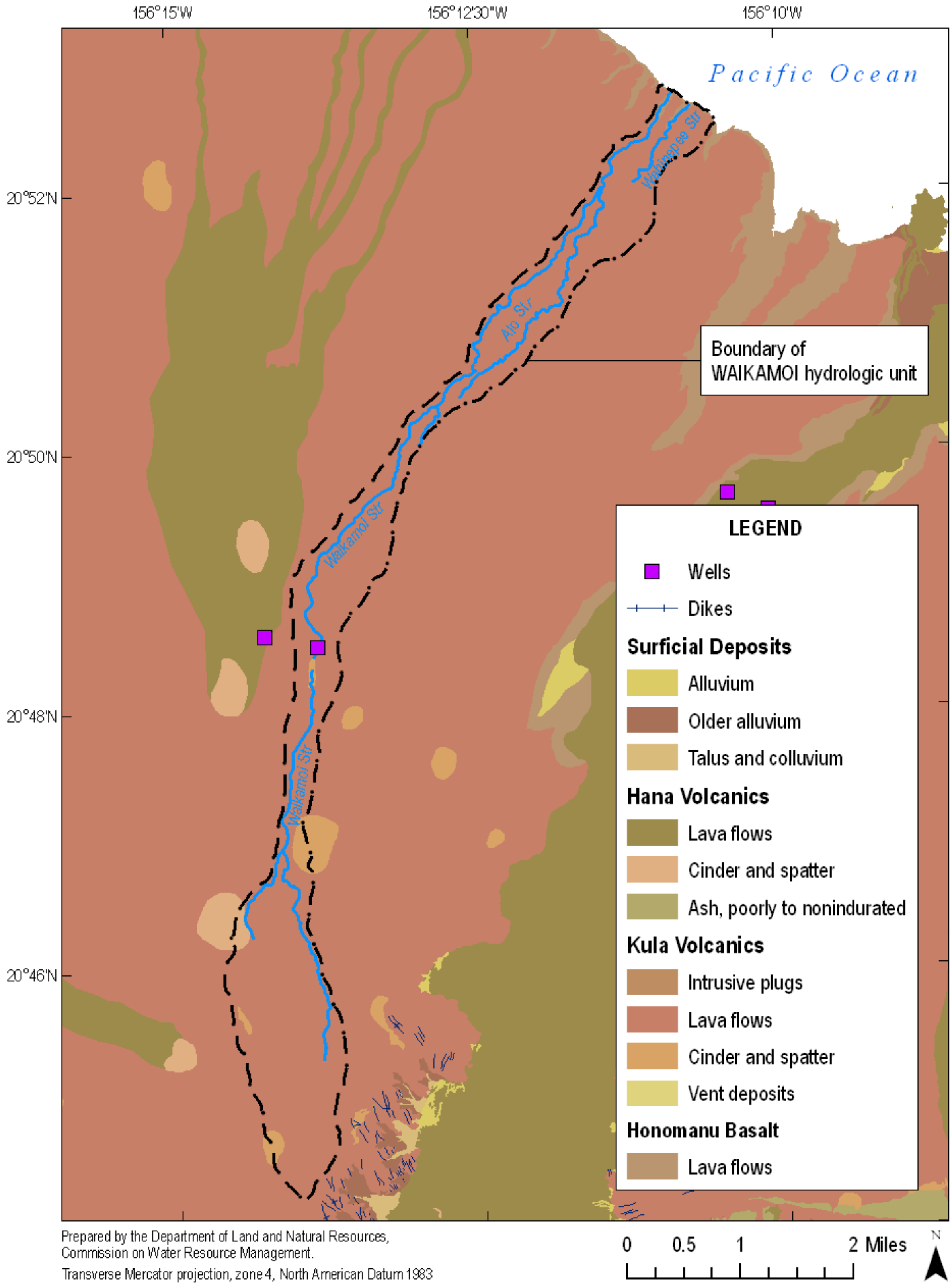


Figure 2-3. Soil classification in Waikamoi hydrologic unit (Source: State of Hawaii, Office of Planning, 2007c; USGS, 2001b).

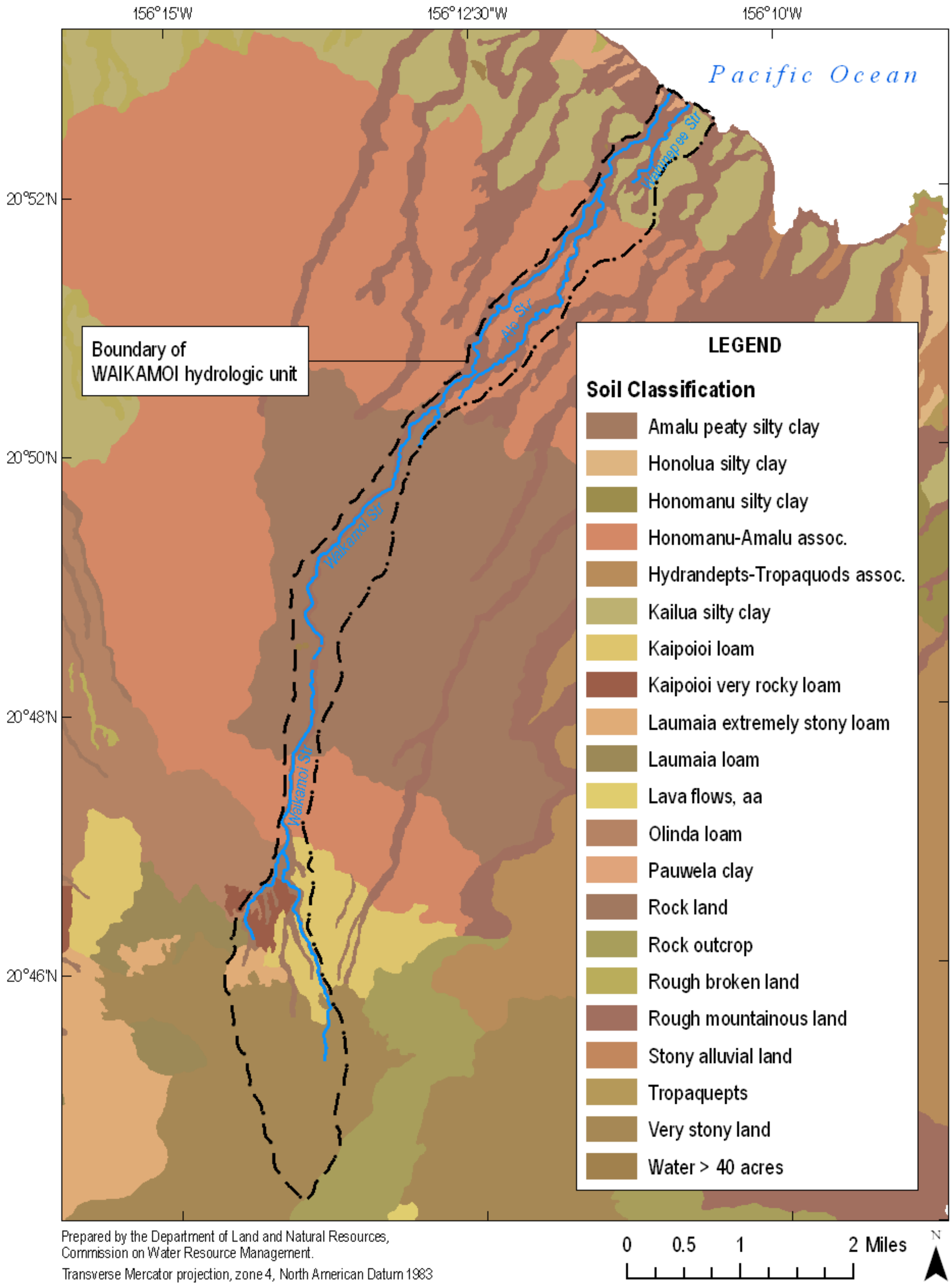


Figure 2-4. Mean annual rainfall and fog area in Waikamoi; and solar radiation for Waikamoi and the island of Maui, Hawaii (Source: Giambelluca et al., 1986; State of Hawaii, Office of Planning, 2006b; 2006c; USGS, 2001b).

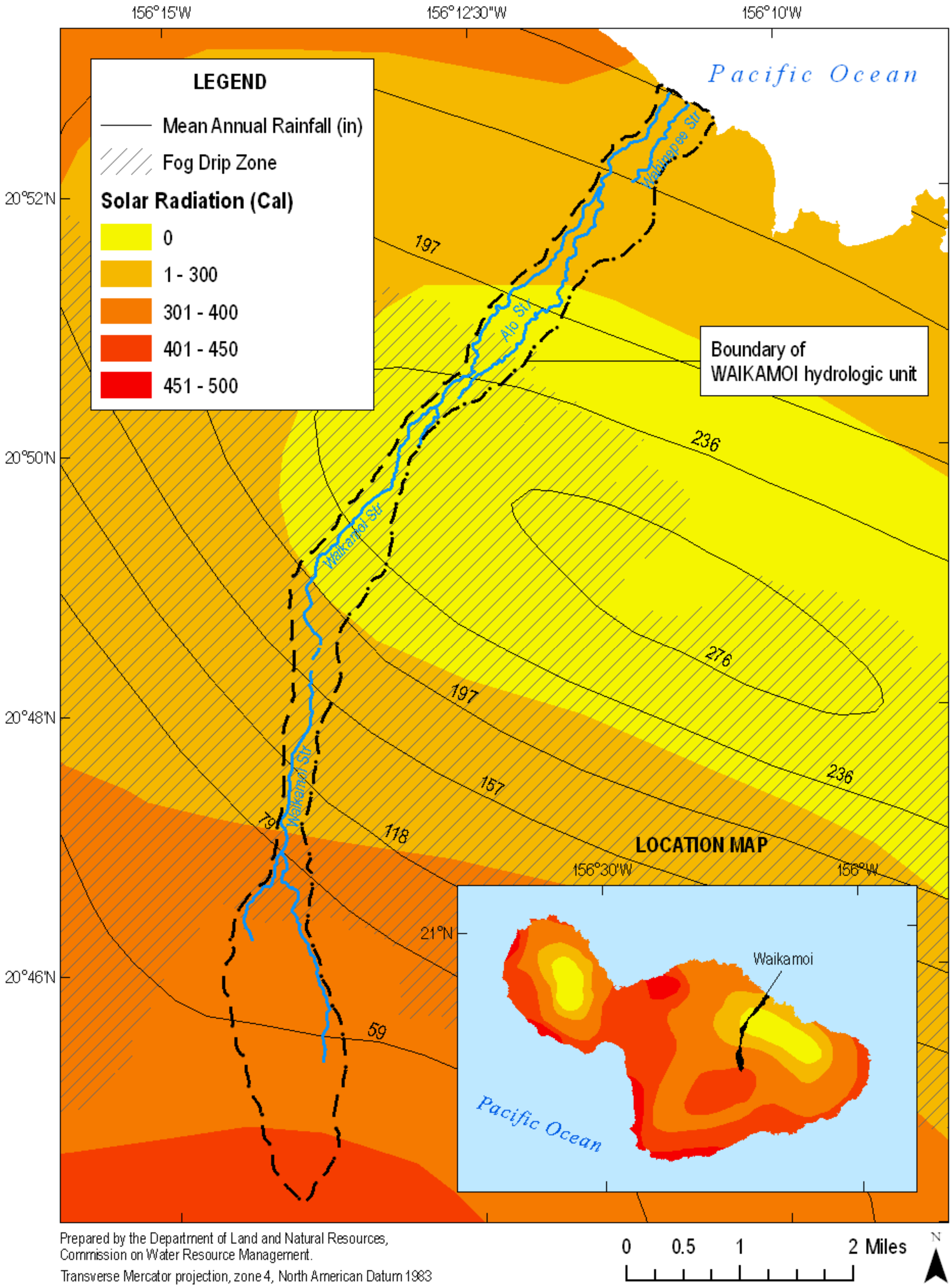


Figure 2-5. State land use district boundaries in Waikamoi hydrologic unit (Source: State of Hawaii, Office of Planning, 2006d; USGS, 2001b).

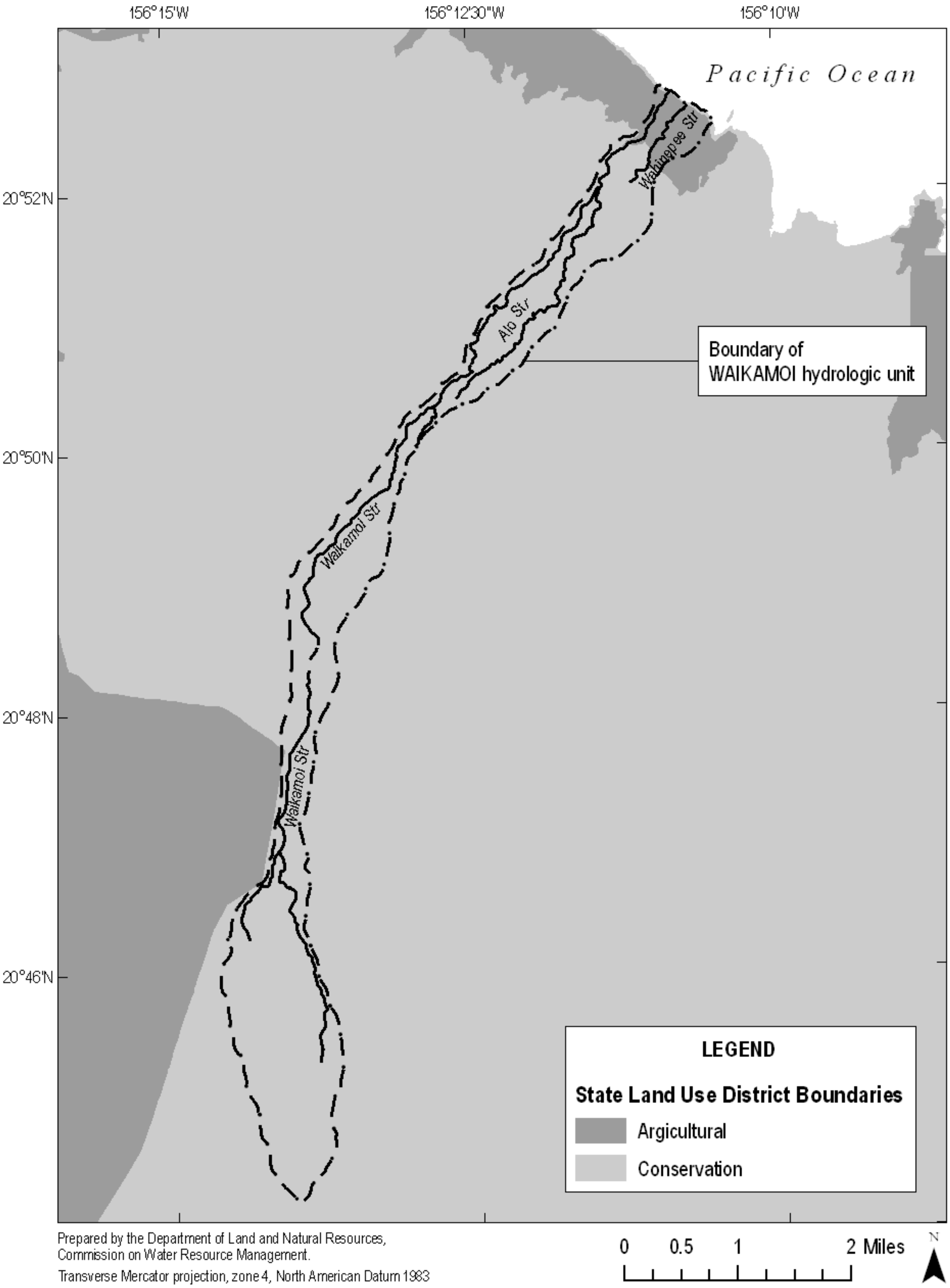


Figure 2-6. C-CAP land cover in Waikamoi hydrologic unit (Source: National Oceanic and Atmospheric Administration, Coastal Services Center, 2000; USGS, 2001b).

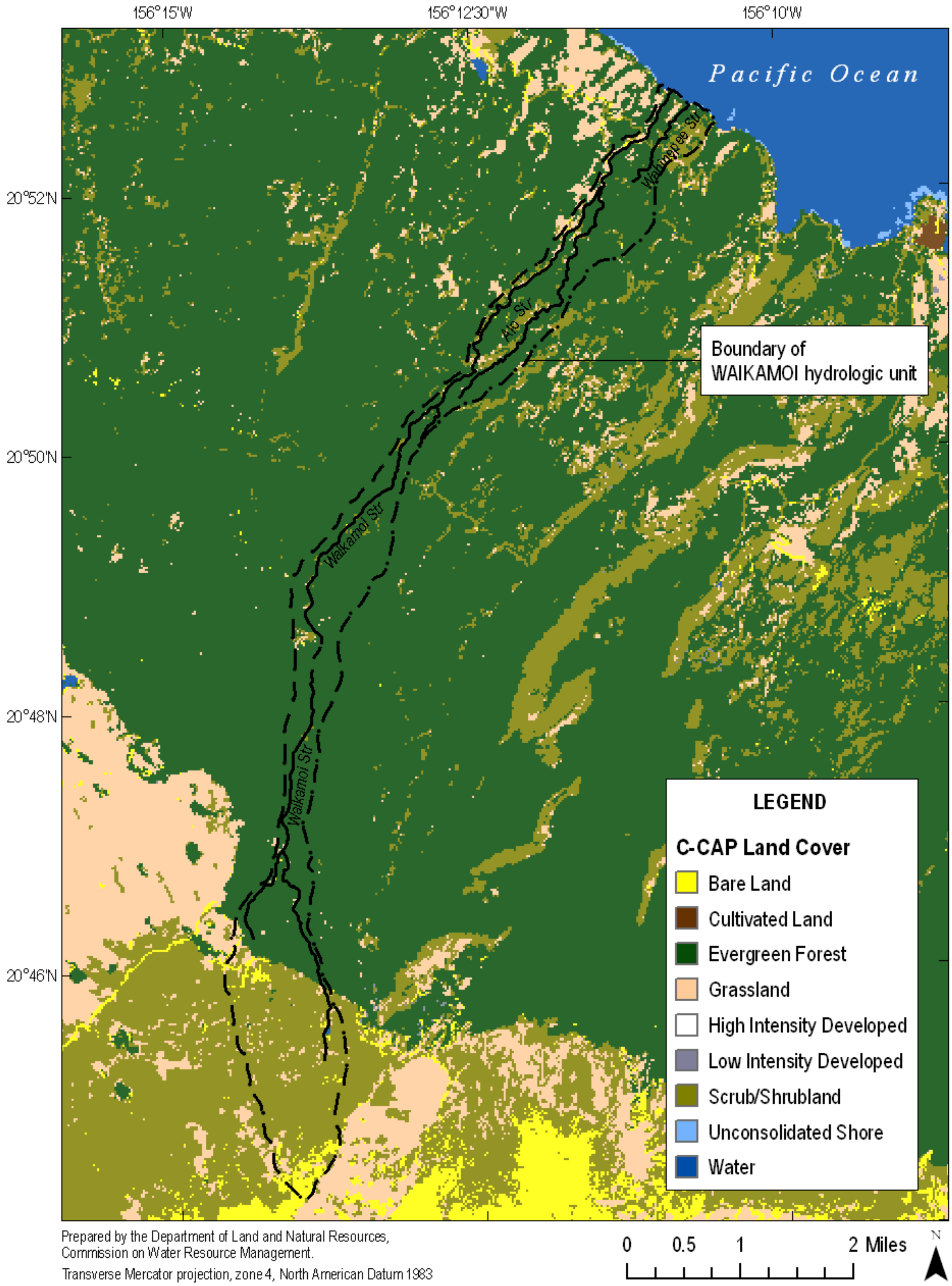
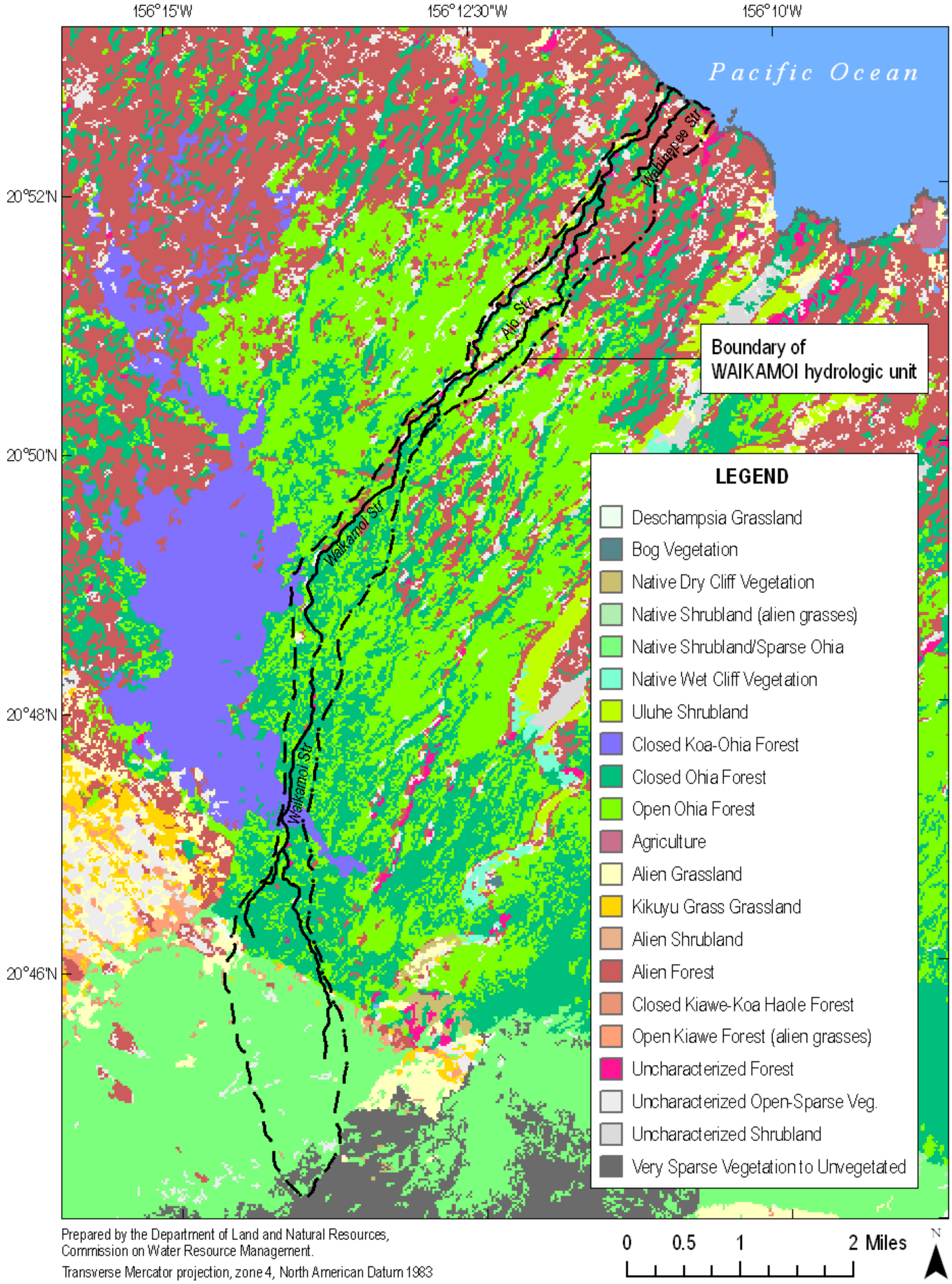


Figure 2-7. Hawaii GAP land cover classes in Waikamoi hydrologic unit (Source: Hawaii GAP Analysis Program, 2005; USGS, 2001b).



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 Waikamoi Stream.

3.1 Streams in Hawaii

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 different components of the hydrologic cycle[15], as well as man-made structures such as diversions and other stream channel alterations (e.g. channelizations and dams).

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. Whether a stream is gaining or losing flow can be determined by taking flow measurements at the endpoints of a channel reach. Another way that ground water influences streamflow is through springs. A spring is formed when a geologic structure (e.g., fault or fracture) or a topographic feature (e.g., side of a hill or a valley) intersects ground water either at or below the water table. It can discharge ground water onto the land surface, directly into the stream, or into the ocean. Figure 3-1 illustrates a valley that has been incised into a high-level water table, resulting in ground water discharges that contribute directly to streamflow and springs. At places where erosion has removed the caprock, ground water discharges either as springs or into the ocean as seepage.

3.2 Ground Water

Ground water is an important component of streamflow as it constitutes the base flow[16] of Hawaiian streams. When ground water is withdrawn from a well, the water level in the surrounding area is lowered. Pumping wells near streams commonly cause stream water to flow into the underlying ground water body, affecting the quality of ground water (LaBaugh and Rosenberry, 2008). 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 can include the reduction of streamflow, which may cause a

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[15] Hydrologic cycle (i.e. water cycle) represents the processes and pathways involved in the circulation of water between the atmosphere and land either on a global scale or within a hydrologic unit. The components of the hydrologic cycle include the following main processes: evaporation, precipitation, interception, transpiration, infiltration, and runoff.

[16] 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).

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. On 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 Waikamoi lies within the Waikamoi aquifer system that has an area of 26 square miles. A general overview of the ground water occurrence and movement in this area is described in Gingerich (1999b) and illustrated in Figure 3-1. Waikamoi and Wahinepee Stream lie on lava flows of the Kula Volcanics for most of its length, with the exception of 3,000 feet of Honomanu Basalt near the coast (Gingerich, 1999b). Alo Stream, tributary of Waikamoi Stream, lies on lava flows of Kula Volcanic for its entire length. Ground water for the hydrologic unit is found at high elevations in the Kula Volcanics as well as a fresh water-lens system in the underlying Honomanu Basalt. Near the 6,560 feet and 3,200 feet altitudes, the valley has been incised into the high-elevation water table, causing ground water to discharge at Hosmer Grove Spring and Waikamoi Spring, repectively. A thick layer of unsaturated zone separates the high-elevation water body and the fresh water lens. The high-elevation saturated zone is not present near the coast when erosion has removed the low-permeability layers formed by the Kula Volcanics. Withdrawal from wells at or below sea level should not affect the high-elevation water table because the thick unsaturated zone will prevent any significant changes in the vertical flow gradient. However, wells that remove water from the high-elevation water body can reduce streamflow and recharge into the fresh water lens. A test hole (well number 4813-01) of 1-inch diameter casing was drilled in 1940 for ground water investigation purposes (Figure 3-2). This test hole is not actively withdrawing water from the Waikamoi aquifer. As of June 2008, the sustainable yield of the Waikamoi aquifer system is 40 million gallons per day with no existing ground water demand (State of Hawaii, Commission on Water Resource Management, 2008c). Estimated total ground water recharge without accounting for fog drip contribution is 85 million gallons per day, which represents 35 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, 191 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 0.32 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, 2008c). A majority of the reported ground water use in Maui is for agricultural (54 percent) and municipal (34 percent) uses (Table 3-1).

Figure 3-1. Diagram illustrating the ground water system west of Keanae Valley, northeast Maui, Hawaii. Arrows indicate general direction of ground water flow (Source: Gingerich, 1999b).

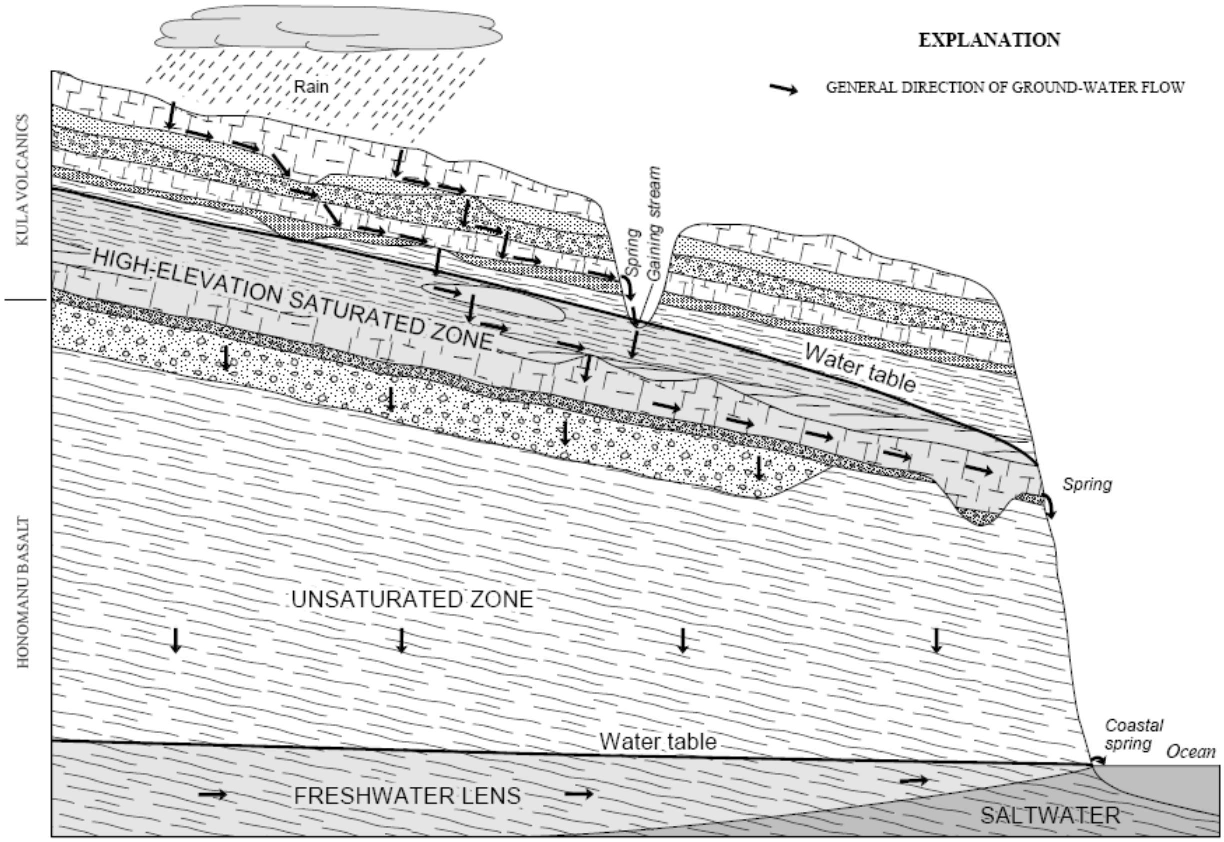


Table 3-1. Summary of ground water use reporting in the island of Maui (Source: State of Hawaii, Commission on Water Resource Management, 2008c).

[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 is 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

3.3 Streamflow Characteristics

Waikamoi Stream, its tributary Alo Stream, and Wahinepee Stream are located in the hydrologic unit of Waikamoi. Waikamoi Stream is 8.5 miles in length, traversing north from the headwaters of its tributaries near Hosmer Grove Spring at the 6,560 feet altitude to the ocean. The stream rises from sea level to 600 feet altitude 0.8 miles from the coast, contributing to a slope gradient of 790 feet per mile (Gingerich, 1999b). A major tributary to Waikamoi Stream is Alo Stream, which branches east at about 840 feet altitude. East of Waikamoi Stream within the same hydrologic unit is Wahinepee Stream. It is less than a mile in length with headwaters beginning at about the 800 feet altitude.

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 normal 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 average 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).

Eight inactive USGS continuous-record stream gaging stations were located in the hydrologic unit of Waikamoi, seven of which were located on Waikamoi Stream and one was located on tributary Alo Stream. No stream gaging stations are located on Wahinepee Stream. Refer to Table 3-2 for information on the location and status of each gaging station. Average annual streamflow, lowest daily streamflow, and average annual base flow were calculated based on data from the years with complete streamflow record, and the statistics are presented in Table 3-3. Tables 3-4 through 3-9 contain information on the location and flow-duration characteristics of the gaging stations in Waikamoi, excepting station 16553000 downstream from the Upper Kula Pipeline.

Table 3-2. Information on the location of USGS continuous-record stream gaging stations in the hydrologic unit of Waikamoi (Source: Gingerich, 1999b).

[Gaging-station number is preceded by 16 and ends in 00]

Station number	Station location	Station altitude (feet)	General location description	Status
5526	Waikamoi Stream	5,750	Below headwater tributaries	Inactive
5528	Waikamoi Stream	4,487	Upstream from Upper Kula Pipeline	Inactive
5530	Waikamoi Stream	4,250	Downstream from Upper Kula Pipeline	Inactive
5545	East Branch Waikamoi Stream	3,020	East tributary of Waikamoi Stream	Inactive
5540	Waikamoi Stream	3,000	Near the Lower Kula Pipeline	Inactive
5550	Waikamoi Stream	1,294	Upstream from Wailoa (Koolau) Ditch	Inactive
5560	Waikamoi Stream	1,150	Downstream from Wailoa (Koolau) Ditch	Inactive
5570	Alo Stream	1,248	Downstream from Wailoa (Koolau) Ditch	Inactive

Table 3-3. Average annual and lowest daily streamflow, and average annual base flow at USGS surface water gaging stations in the hydrologic unit of Waikamoi (Source: Gingerich, 1999b).

[Mgal/d, million gallons per day; --, not determined; gaging-station number is preceded by 16 and ends in 00]

Station number	Station location	Period of record	Years of complete record	Average annual streamflow (Mgal/d)	Lowest daily streamflow (Mgal/d)	Average annual base flow (Mgal/d)
5526	Waikamoi Stream	1949–66	15	0.36	0	0
5528	Waikamoi Stream	1953–68	15	1.33	0	0.05
5530	Waikamoi Stream	1945-49	0	--	0	--
5545	East Branch Waikamoi Stream	1918–28	9	2.72	0.07	0.65
		1932–33				
5540	Waikamoi Stream	1918	10	7.9	0.1	1.05
		1919–28				
		1932–34				
5550	Waikamoi Stream	1922–57	35	16.37	0.1	3.02
5560	Waikamoi Stream	1910–22	10	18.24	0.2	3.78
5570	Alo Stream	1910–57	46	4.78	0.19	1.29

Flow in Waikamoi Stream is captured by five surface water diversion systems, 1) Upper Kula Pipeline at 4,240 feet elevation; 2) Lower Kula Pipeline at about 2,961 to 2,985 feet elevation; 3) Wailoa (Koolau) Ditch at 1,300 feet elevation; 4) Spreckels Ditch at 1,200 feet elevation; and 5) Manuel Luis Ditch at 700 feet elevation (Gingerich, 1999b). The following is a summary of the flow conditions on Waikamoi and Wahinepee Stream, categorized by the approximate location of the stream reaches (i.e., upper, middle, and lower). Based on the available streamflow data, Waikamoi Stream appears to be 1) dry above the Kula Pipeline diversion system; 2) flowing year round between the 3,000 feet and 500 feet (near Manuel Luis Ditch) altitudes; and 3) losing water below the Manuel Luis Ditch near the 700 feet elevation.

Waikamoi Stream, upper reach. The upper reach is from the headwaters to the Upper Kula Pipeline diversion system, where according to Gingerich (2005), the stream is mostly dry. The upstream-most station (station 16552600) is mostly dry (Table 3-4), and the median flow (TFQ_{50}) at the station upstream from the Upper Kula Pipeline (station 16552800) is 0.12 cubic feet per second based on 15 years of complete record (Table 3-5). Streamflow measurements made on October 17, 1994 during low-flow conditions show that the tributary headwater streams above the 6,000 feet elevation were dry (Gingerich, 1999b).

Waikamoi Stream, middle reach. Downstream from the Upper Kula Pipeline to Manuel Luis Ditch, Waikamoi Stream is gaining ground water flow. Median streamflow is 2.2 cubic feet per second at station 16554000 (near the Lower Kula Pipeline) and increases to 9.3 cubic feet per second at station 16556000 downstream from Wailoa (Koolau) Ditch (Table 3-6 to 3-9). Low-flow measurements made on October 18, 1994 show that the cumulative flow, without the effects of diversion, increase from the 0.82 million gallons per day below the Kula Pipeline diversion system to 1.54 million gallons per day upstream of the Manuel Luis Ditch. Base flow estimate upstream from stations 16554000 and 16554500 is 1.7 million gallons per day and increases to 3.02 million gallons per day at the 1,300 feet altitude near station 16555000, resulting in an average ground water gain of 1.3 million gallons per day (Gingerich, 1999b). This gain in streamflow could be attributed to flow gains from the east tributary of Waikamoi Stream, which has a median streamflow of 1.4 cubic feet per second, and flow gains from Waikamoi Spring at the 3,200 feet elevation. Alo Stream, a major tributary of Waikamoi Stream, is a gaining stream and it also gains an average of about 1.3 million gallons per day upstream of the 1,248 feet altitude (near station 16557000).

Waikamoi Stream, lower reach. According to Gingerich (2005), Waikamoi Stream is losing flow to ground water downstream from the Manuel Luis Ditch. Low-flow measurements were conducted in 2002 to 2003 but not reported in the study.

Wahinepee Stream. Wahinepee Stream is a gaining stream from its headwaters to the 500 feet altitude (Gingerich, 2005). The stream is only diverted by the Manuel Luis Ditch at 900 feet elevation.

Table 3-4. General information and flow-duration characteristics of USGS stream gaging station below the headwater tributaries of Waikamoi Stream, Maui (station 16552600).

Station number:	16552600		
Station name:	WAIKAMOI STREAM AT PUU LUAU NR OLINDA, MAUI, HI		
Flow diverted or regulated?:	N	Altitude (feet):	5,750
Latitude (decimal degrees):	20.78374306	Altitude accuracy (feet):	not available
Longitude (decimal degrees):	-156.23496797	Basin area (square miles):	2.1
Latitude/Longitude accuracy:	unknown	Period of record:	1950-1967
Horizontal datum:	nad83	Complete water years:	1951-1958,1960-1966
Minimum daily mean discharge during period of record:		**Maximum daily mean discharge during period of record:**	
Discharge, cubic feet per second:	0	Discharge, cubic feet per second:	404
Number of occurrences:	5,742	Number of occurrences:	1
Most recent occurrence:	11/30/1966	Most recent occurrence:	12/10/1954

Flow-duration characteristics based on complete water years during period of record (15 complete years)

Percentage of time discharge equaled or exceeded	Mean	50	55	60	65	70	75	80	85	90	95	99
Discharge, in cubic feet per second	0.55	0	0	0	0	0	0	0	0	0	0	0

Table 3-5. General information and flow-duration characteristics of USGS stream gaging station on Waikamoi Stream above Upper Kula Pipeline, Maui (station 16552800).

Station number:	16552800		
Station name:	WAIKAMOI STR AB RES AT KULA PL INTAKE NR OLINDA		
Flow diverted or regulated?:	Y	Altitude (feet):	4,487
Latitude (decimal degrees):	20.80457474	Altitude accuracy (feet):	not available
Longitude (decimal degrees):	-156.23107892	Basin area (square miles):	2.5
Latitude/Longitude accuracy:	unknown	Period of record:	1953-1968
Horizontal datum:	nad83	Complete water years:	1954-1968
Minimum daily mean discharge during period of record:		**Maximum daily mean discharge during period of record:**	
Discharge, cubic feet per second:	0	Discharge, cubic feet per second:	473
Number of occurrences:	52	Number of occurrences:	1
Most recent occurrence:	11/22/1962	Most recent occurrence:	12/10/1954

Flow-duration characteristics based on complete water years during period of record (15 complete years)

Percentage of time discharge equaled or exceeded	Mean	50	55	60	65	70	75	80	85	90	95	99
Discharge, in cubic feet per second	2.1	0.12	0.11	0.08	0.08	0.06	0.06	0.05	0.04	0.03	0.02	0.01

Table 3-6. General information and flow-duration characteristics of USGS stream gaging station on Waikamoi Stream near the Lower Kula Pipeline, Maui (station 16554000).

Station number:	16554000		
Station name:	WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI, MAUI		
Flow diverted or regulated?:	Y	Altitude (feet):	3,000
Latitude (decimal degrees):	20.82873940	Altitude accuracy (feet):	not available
Longitude (decimal degrees):	-156.21996786	Basin area (square miles):	3.46
Latitude/Longitude accuracy:	unknown	Period of record:	1918,1920-1928,1932-1935
Horizontal datum:	nad83	Complete water years:	1920-1927,1933-1934

Minimum daily mean discharge during period of record:		**Maximum daily mean discharge during period of record:**	
Discharge, cubic feet per second:	0.15	Discharge, cubic feet per second:	500
Number of occurrences:	21	Number of occurrences:	1
Most recent occurrence:	11/24/1933	Most recent occurrence:	11/22/1921

Flow-duration characteristics based on complete water years during period of record (10 complete years)

Percentage of time discharge equaled or exceeded	Mean	50	55	60	65	70	75	80	85	90	95	99
Discharge, in cubic feet per second	12	2.2	1.9	1.7	1.4	1.2	1.1	0.93	0.77	0.62	0.46	0.31

Table 3-7. General information and flow-duration characteristics of USGS stream gaging station on the east tributary of Waikamoi Stream above the Lower Kula Pipeline, Maui (station 16554500).

Station number:	16554500		
Station name:	E BR WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI		
Flow diverted or regulated?:	Y	Altitude (feet):	3,020
Latitude (decimal degrees):	20.82790614	Altitude accuracy (feet):	Not available
Longitude (decimal degrees):	-156.21996788	Basin area (square miles):	0.07
Latitude/Longitude accuracy:	unknown	Period of record:	1918-1928,1932-1933
Horizontal datum:	nad83	Complete water years:	1919-1927

Minimum daily mean discharge during period of record:		**Maximum daily mean discharge during period of record:**	
Discharge, cubic feet per second:	0.31	Discharge, cubic feet per second:	104
Number of occurrences:	107	Number of occurrences:	1
Most recent occurrence:	11/23/1932	Most recent occurrence:	11/22/1921

Flow-duration characteristics based on complete water years during period of record (9 complete years)

Percentage of time discharge equaled or exceeded	Mean	50	55	60	65	70	75	80	85	90	95	99
Discharge, in cubic feet per second	4.2	1.4	1.2	1.1	0.93	0.93	0.77	0.62	0.62	0.46	0.46	0.31

Table 3-8. General information and flow-duration characteristics of USGS stream gaging station on the east tributary of Waikamoi Stream above the Wailoa (Koolau) Ditch, Maui (station 16555000).

Station number:	16555000		
Station name:	WAIKAMOI STR AB WAILOA DITCH NR HUELO, MAUI,HI		
Flow diverted or regulated?:	Y	Altitude (feet):	1,293.59
Latitude (decimal degrees):	20.85845835	Altitude accuracy (feet):	Not available
Longitude (decimal degrees):	-156.19691262	Basin area (square miles):	3.93
Latitude/Longitude accuracy:	unknown	Period of record:	1922-1958
Horizontal datum:	nad83	Complete water years:	1923-1957

Minimum daily mean discharge during period of record:		**Maximum daily mean discharge during period of record:**	
Discharge, cubic feet per second:	0.20	Discharge, cubic feet per second:	2,460
Number of occurrences:	1	Number of occurrences:	1
Most recent occurrence:	10/10/1953	Most recent occurrence:	01/26/1948

Flow-duration characteristics based on complete water years during period of record (35 complete years)

Percentage of time discharge equaled or exceeded	Mean	50	55	60	65	70	75	80	85	90	95	99
Discharge, in cubic feet per second	25	7.9	7.0	6.0	5.3	4.5	3.8	3.1	2.5	1.9	1.3	0.57

Table 3-9. General information and flow-duration characteristics of USGS stream gaging station on Waikamoi Stream below the Wailoa (Koolau) Ditch, Maui (station 16556000).

Station number:	16556000		
Station name:	WAIKAMOI STREAM NEAR HUELO, MAUI, HI		
Flow diverted or regulated?:	Y	Altitude (feet):	1,150
Latitude (decimal degrees):	20.86123575	Altitude accuracy (feet):	Not available
Longitude (decimal degrees):	-156.19552373	Basin area (square miles):	3.98
Latitude/Longitude accuracy:	unknown	Period of record:	1911-1922
Horizontal datum:	nad83	Complete water years:	1912-1921
Minimum daily mean discharge during period of record:		**Maximum daily mean discharge during period of record:**	
Discharge, cubic feet per second:	0.31	Discharge, cubic feet per second:	1,300
Number of occurrences:	15	Number of occurrences:	1
Most recent occurrence:	07/14/1920	Most recent occurrence:	05/01/1916

Flow-duration characteristics based on complete water years during period of record (10 complete years)

Percentage of time discharge equaled or exceeded	Mean	50	55	60	65	70	75	80	85	90	95	99
Discharge, in cubic feet per second	28	9.3	7.7	6.7	5.9	4.9	4.0	3.6	2.8	2.2	1.4	0.61

Table 3-10. General information and flow-duration characteristics of USGS stream gaging station on Alo Stream below the Wailoa (Koolau) Ditch, Maui (station 16557000).

Station number:	16557000		
Station name:	ALO STREAM NEAR HUELO, MAUI, HI		
Flow diverted or regulated?:	N	Altitude (feet):	1,248.38
Latitude (decimal degrees):	20.85956921	Altitude accuracy (feet):	Not available
Longitude (decimal degrees):	-156.19413494	Basin area (square miles):	0.47
Latitude/Longitude accuracy:	unknown	Period of record:	1911-1958
Horizontal datum:	nad83	Complete water years:	1912-1957
Minimum daily mean discharge during period of record:		**Maximum daily mean discharge during period of record:**	
Discharge, cubic feet per second:	0.11	Discharge, cubic feet per second:	248
Number of occurrences:	1	Number of occurrences:	1
Most recent occurrence:	11/04/1911	Most recent occurrence:	01/03/1927

Flow-duration characteristics based on complete water years during period of record (46 complete years)

Percentage of time discharge equaled or exceeded	Mean	50	55	60	65	70	75	80	85	90	95	99
Discharge, in cubic feet per second	7.4	3.1	2.6	2.3	2.0	1.7	1.5	1.3	1.1	0.93	0.74	0.49

In cooperation with the Commission on Water Resource Management, the USGS conducted a study (Gingerich, 2005) to assist in determining reasonable and beneficial noninstream and instream uses of surface water in northeast Maui. The purpose of the study was to develop methods of estimating natural (undiverted) median streamflow, total flow statistics (TFQ), and base flow statistics (BFQ) at ungaged sites where observed data are unavailable. The study area lies between the drainage basins of Kolea Stream to the west and Makapipi Stream to the east. Basin characteristics and hydrologic data for the study area 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 indicate the percentage of time the flow, either total or base flow, is equaled or exceeded.

Streamflow statistics at continuous-record gaging stations were estimated using the regression equations, and then compared to the measured flow to assess the accuracy of the regression method by computing the relative error. Relative error is the percent difference between the measured flow and the estimated statistic. The flow statistics and associated statistical comparisons are presented in Table 3-12. Note that the measured flows are different from the TFQ_{50} values in Tables 3-4 through 3-10 for the corresponding stations. That is because the measured flows in the study were adjusted to a common base period for comparison so that the differences in flow among stations reflect spatial differences in climate and basin characteristics, as well as temporal differences in rainfall (Gingerich, 2005). The adjusted flows are listed in Table 3-11.

Table 3-11. Selected estimated median and low-flow characteristics for continuous-record sites in the Waikamoi hydrologic unit (Gingerich, 2005, Table 2).

[Qxx is the xx percent flow duration of streamflow; ft^3/s, cubic feet per second; base period is 1914-17, 1921-2001; gaging-station number is preceded by 16 and ends in 00; active stations are shown in ***bold italics***; +, combined with record from indicated station; index station is station 5180; --, no adjustment; NA, not applicable]

Gaging-station number	Length of concurrent record (years)	TFQ_{50}		BFQ_{50}		TFQ_{95}		BFQ_{95}	
		during concurrent period (ft3/s)	adjusted to index station (ft3/s)	during concurrent period (ft3/s)	adjusted to index station (ft3/s)	during concurrent period (ft3/s)	adjusted to index station (ft3/s)	during concurrent period (ft3/s)	adjusted to index station (ft3/s)
5528	15	0.12	0.14	0.05	0.06	0.02	0.02	0.02	0.01
5540	7	2.5	2.5	1.3	1.2	0.62	0.69	0.32	0.46
5545	8	1.5	1.3	0.8	0.72	0.46	0.47	0.37	0.43
5550	35	7.9	7	3.8	3.5	1.3	1.1	0.89	0.8
5560	4	15	7.1	5.1	3.6	2	1.5	1.6	1
5570	39	3.1	2.7	1.6	1.4	0.77	0.7	0.62	0.58

The regression equations performed better in predicting the higher flow statistics (TFQ_{50} and BFQ_{50}) than the lower flow statistics (TFQ_{95} and BFQ_{95}) for all continuous-record gaging stations, excepting station 16552800. For all stations excluding station 16552800, relative errors between the measured and estimated TFQ_{50} and BFQ_{50} are under 20 percent. A majority of the measured TFQ_{50} and BFQ_{50} fall within the 90 percent confidence interval of the corresponding estimated statistics, indicating that the regression equations are relatively accurate in their predictions. For station 16552800, the relative errors between measured and estimated statistics are not necessarily meaningful because the stream goes dry during low-flow conditions (Gingerich, 1999b).

When comparing the lower flow statistics, one must be cautious in using the relative error value to compare the difference between the measured and estimated statistics because the flow values are small. From a mathematical standpoint, a small difference between two decimal numbers can project to a large relative difference. For example, the difference between a flow of 0.01 million gallons per day and 0.02 million gallons per day is insignificant compared to the difference between a flow of 2 million gallons per day and 4 million gallons per day. However, both exhibit a 50 percent relative difference. The relative error between the measured and estimated TFQ_{95} for station 16555000 is 27 percent; however, the measured flow is within the 90 percent confidence interval of the estimated statistic. In other words, the regression equations are relatively accurate in predicting the BFQ_{95} for station 16555000 even though the relative error is large. The accuracy of the regression equations in predicting flow for Wahinepee Stream cannot be assessed because there are no available measured streamflow data.

Table 3-12. Stream flow statistics estimated using regression equations, lower and upper confidence intervals, standard errors, measured flows, and relative errors for continuous-record sites in Waikamoi (Gingerich, 2005, Table 9).

[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]

Gaging Station	Statistic	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}
16552800	Estimated flow	1.2	0.55	0.33	0.22
	90% LCL	0.98	0.39	0.21	0.13
	90% UCL	1.5	0.78	0.53	0.37
	Standard error	13.2	19.5	26.8	30.1
	Measured flow	0.14	0.06	0.02	0.01
	Relative error	760	820	1600	2100
16554000	Estimated flow	2.9	1.4	0.76	0.55
	90% LCL	2.5	1.1	0.57	0.4
	90% UCL	3.3	1.7	1	0.76
	Standard error	8	11.9	16.4	18.4
	Measured flow	***2.5***	***1.2***	***0.69***	***0.46***
	Relative error	16	17	10	20
16555000	Estimated flow	6.6	3.5	1.4	1.1
	90% LCL	6	3.1	1.1	0.83
	90% UCL	7.3	4.1	1.7	1.4
	Standard error	5.6	8.3	12.6	14
	Measured flow	***7***	***3.5***	***1.1***	0.8
	Relative error	-6	0	27	38
16556000	Estimated flow	6.7	3.6	1.4	1.1
	90% LCL	6.1	3.1	1.1	0.84
	90% UCL	7.4	4.2	1.7	1.4
	Standard error	5.6	8.3	12.5	14
	Measured flow	7.1	***3.6***	***1.5***	***1***
	Relative error	-6	0	-13	10
16557000	Estimated flow	2.7	1.7	1.1	0.96
	90% LCL	2.3	1.3	0.76	0.65
	90% UCL	3.2	2.2	1.5	1.4
	Standard error	9.3	13.7	19.9	22.3
	Measured flow	***2.7***	***1.4***	0.7	0.58
	Relative error	0	13	57	66

The regression equations were also applied to a selected ungaged site WiL near the mouth of Waikamoi Stream, and two low-flow stations, WiML and WiMU in the lower and upper middle reaches of Waikamoi Stream, respectively (Figure 3-3). Low-flow measurements were made at the ungaged site and compared to the estimated flows. Results are presented in Table 3-13. Again, the regression equations performed better in predicting the higher flow statistics than the lower flow statistics for all three sites. Flow estimates at the low-flow stations were generally underestimated because the regresson equations may not account for flow gains from ground water sources at those stations. Since the ungaged site WiL is in a losing section of Waikamoi Stream, the regression equations may not account for losses of water, resulting in an overestimate of flow.

For Wahinepee Stream, the regression equations were applied at two ungaged sites, site WpM in the middle reach and site WpL near the mouth of the stream. The estimated TFQ_{50} and BFQ_{50} for ungaged sites WpM and WpL are 1.3 and 1.4 cubic feet per second, respectively. These statistics also represent flows under the natural (undiverted) condition (Table 3-14) because measured flow data is not available to assess the actual diverted flow.

Table 3-13. Stream flow statistics estimated using regression equations, lower and upper confidence intervals, standard errors, measured flow, and relative errors for ungaged sites and low-flow stations in Waikamoi (Gingerich, 2005, Table 10).

[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]

Stream location	Statistic	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}	Source of measured flow estimates
Waikamoi lower (WiL)	Estimated flow	10	5.7	2	1.6	Flow statistics from 5550 and 5570 upstream plus Waikamoi middle upper and middle, lower sites; effects of natural flow addition are unknown because stream is losing; stream goes dry at low flow
	90% LCL	9	4.8	1.6	1.2	
	90% UCL	12	6.9	2.6	2.1	
	Standard error	7.1	10.4	13.2	14.8	
	Measured flow	< 11	< 5.9	< 2.8	< 2.4	
	Relative error	> -9	> -3	> -29	> -33	
Waikamoi middle lower (WiML)	Estimated flow	9.6	5.4	2	1.6	Flow statistics from 5550 and 5570 upstream plus Waikamoi middle upper plus average of 9 USGS low-flow measurements in 2002-03
	90% LCL	8.6	4.5	1.6	1.2	
	90% UCL	11	6.4	2.5	2	
	Standard error	6.6	9.6	13.1	14.7	
	Measured flow	***> 11***	***> 5.9***	2.8	2.4	
	Relative error	-13	-8	-29	-33	
Waikamoi middle upper (WiMU)	Estimated flow	9.2	5.2	2	1.6	Flow statistics from 5550 and 5570 upstream plus average of 10 USGS low-flow measurements in 2002-03
	90% LCL	8.3	4.4	1.6	1.2	
	90% UCL	10	6.1	2.5	2	
	Standard error	6.2	9.2	13.1	14.6	
	Measured flow	> 10.5	***> 5.7***	2.6	> 2.2	
	Relative error	< -16	< -9	-23	< -27	
Wahinepee lower (WeL)	Estimated flow	2.4	1.8	1.6	1.6	TFQ95: EMI 1928 measurement; unknown amount of upstream diversion at Wailoa Ditch; effects of natural flow addition are unknown because stream may be gaining or losing
	90% LCL	1.8	1.1	0.88	0.83	
	90% UCL	3.2	2.7	2.8	3	
	Standard error	16.6	24.6	33.9	38.1	
	Measured flow	--	--	> 0.46	--	
	Relative error	--	--	< 250	--	
Wahinepee middle (WeM)	Estimated flow	1.3	0.89	0.97	0.94	TFQ95: EMI 1928 measurement; unknown amount of upstream diversion at Wailoa Ditch; effects of natural flow addition are unknown because stream may be gaining or losing
	90% LCL	0.92	0.54	0.56	0.5	
	90% UCL	1.8	1.4	1.7	1.7	
	Standard error	19.2	28.5	32.4	36.5	
	Measured flow	--	--	0.46	--	
	Relative error	--	--	110	--	

A summary of the natural (undiverted) streamflow statistics is presented in Table 3-14. The flow estimates at the ungaged site (WiL) and the two low-flow stations (WiML and WiMU) on Waikamoi Stream are a combination of low-flow measurements and regression estimates. The flow statistics for Waikamoi Stream are consistent with the nature of a gaining stream in which the stream is gaining flow from the station 16555000 upstream from Wailoa (Koolau) Ditch to low-flow station WiML downstream from Manuel Luis Ditch. The TFQ_{50} for the ungaged site WiL is the same as that for low-flow station WiML because the regression equations did not account for the losses of water between these two sites. Estimates for station 16557000 are presented to show the addition of flow from the east tributary of Waikamoi Stream to the main stream.

Table 3-14. Estimates of natural (undiverted) streamflow statistics for gaged and ungaged sites, and low-flow stations in Waikamoi (Source: Gingerich, 2005, Table 11).

[TFQxx is the xx percent flow duration of total streamflow; BFQxx is the xx percent flow duration of base flow; all flows are in cubic feet per second; numbers in ***bold italic*** are considered maximums at sites downstream of unquantified but known losing reaches; g.s., gaging station; adj., adjustment]

Stream location	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}	Source of estimate
Waikamoi Stream					
lower (WiL)	13	7	***2.8***	***2***	Middle-lower site estimate plus equation adj.; TFQ95, BFQ95: Middle-lower site estimate plus low-flow measurements
middle lower (WiML)	13	6.7	***2.8***	***1.9***	Middle-upper site estimate plus equation adj.; TFQ95: Middle-upper site estimate plus low-flow measurements
middle upper (WiMU)	12	6.6	2.6	1.9	Upper sites estimates plus low-flow measurements
upper (5550)	7	3.5	1.1	0.8	Continuous record gaging station
upper (5570)	2.7	1.5	0.7	0.6	Continuous record gaging station
Wahinepee Stream					
lower (WpL)	2.4	1.8	1.1	1.1	Middle site estimate plus equation adj.
middle (WpM)	1.3	0.9	0.5	0.5	Regression equation; TFQ95, BFQ95: low-flow measurement

Effects of diversions can be assessed by comparing the flow statistics under natural conditions (Table 3-14) with those under diverted conditions (Table 3-15). Diversion at the Wailoa (Koolau) Ditch could potentially reduce median total flow at low-flow station WiMU by 81 percent. At low-flow station WiML and ungaged site WiL, the Manuel Luis Ditch could potentially reduce total flow by over 90 percent by capturing all the base flow. During low-flow conditions, the stream could go dry in the lower reaches of Waikamoi Stream. Wahinepee Stream is only diverted by the Manual Luis Ditch, which could potentially reduce median total flow by 54 percent and low flows by 83 percent.

Table 3-15. Estimates of diverted stream flow statistics and percent flow reduction for gaged and ungaged sites in Waikamoi (Source: Gingerich, 2005, Table 12).

[TFQxx is the xx percent flow duration of total streamflow; BFQxx is the xx percent flow duration of base flow; percent reduction is relative to undiverted flow at the same location; all flows are in cubic feet per second; 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}		Comments
	Estimate	Percent reduction	Estimate	Percent reduction	Estimate	Percent reduction	Estimate	Percent reduction	
Waikamoi Stream									
lower (WiL)	0.8	94	0.5	93	***0.2***	93	***0***	100	Diverted at Manuel Luis Ditch
middle lower (WiML)	0.4	97	0.2	97	***0.2***	93	***0***	100	Diverted at Manuel Luis Ditch
middle upper (WiMU)	2.3	81	1.6	77	0.8	69	0.5	74	Diverted at Wailoa Ditch
upper (5550)	7	0	3.5	0	1.1	0	0.8	0	Minor upstream diversion
upper (5570)	2.7	0	1.5	0	0.7	0	0.6	0	Not diverted
Wahinepee Stream									
lower (WpL)	1.1	54	0.9	50	0.6	83	0.6	83	Diverted at Manuel Luis Ditch
middle (WpM)	1.3	0	0.9	0	0.5	0	0.5	0	

Mathematical models and equations are commonly used to represent hydrologic occurrences in the real world; however, they are typically based on a set of assumptions that oftentimes render their estimates questionable in terms of accuracy and precision. This does not mean the public should entirely discount the estimates produced by these mathematical tools because they do provide quantitative and qualitative relative comparisons that are useful when making management decisions. Objections have been raised by several agencies in regards to the use of regression equations to estimate flow statistics. While the estimated statistics are presented to fulfill the purpose of compiling the best available information that will be considered in determining the interim IFS recommendations, the Commission staff does not intend to rely exclusively on the regression equations to make such important management decisions. The limitations and potential errors of the regression equations must also be considered.

One of the limitations of the regression equations is that they do not account for variable subsurface geology, such as those of intermittent streams and where springs discharge high flow to streams. The equations may overestimate flow statistics in intermittent streams as they do not account for losing reaches. On the other hand, the equations may underestimate the additional streamflow gained from springs. Furthermore, the equations may produce poor results when applied to sites that have basin characteristics outside the range of values used to develop the equations. The regression equations tend to predict more accurately the higher flow statistics, TFQ_{50} and BFQ_{50}, rather than the lower flow statistics, TFQ_{95} and BFQ_{95}. According to Gingerich (2005), the most reliable estimates of natural and diverted streamflow duration statistics at gaged and ungaged sites in the study area were made using a combination of continuous-record gaging station data, low-flow measurements, and values determined from the regression equations. The study found that the average reduction in the low flow of streams due to diversions ranges from 69 to 100 percent.

3.4 Long-Term Trends in Streamflow

In a different study, the USGS examined the long-term trends and variations in streamflow on the islands of Hawaii, Maui, Molokai, Oahu, and Kauai, where long-term stream gaging stations exist (Oki, 2004). The study analyzed both total flow and estimated base flow at 16 long-term gaging stations. For the 90-year period 1913-2002, monthly mean base flows generally followed an increasing trend above the long-term average from 1913 to early 1940s, and a decreasing trend after the early 1940s to 2002 (Figure 3-4). Monthly mean total flows follow a similar pattern with the exception that the monthly mean total flow increased from mid-1980s to mid-1990s, and decreased from mid-1990s to 2002. Downward trends in the annual total low flow percentiles, TFQ_{75} and TFQ_{90}, were statistically significant at the 5 percent level of significance. This is consistent with the annual base flow percentiles (Oki, 2004). In summary, the available long-term streamflow data suggest that streamflow is generally decreasing.

Figure 3-2. Aquifer system area and well locations in Waikamoi hydrologic unit (Source: State of Hawaii, Office of Planning, 2006b; State of Hawaii, Commission on Water Resource Management, 2008d; USGS, 2001b).

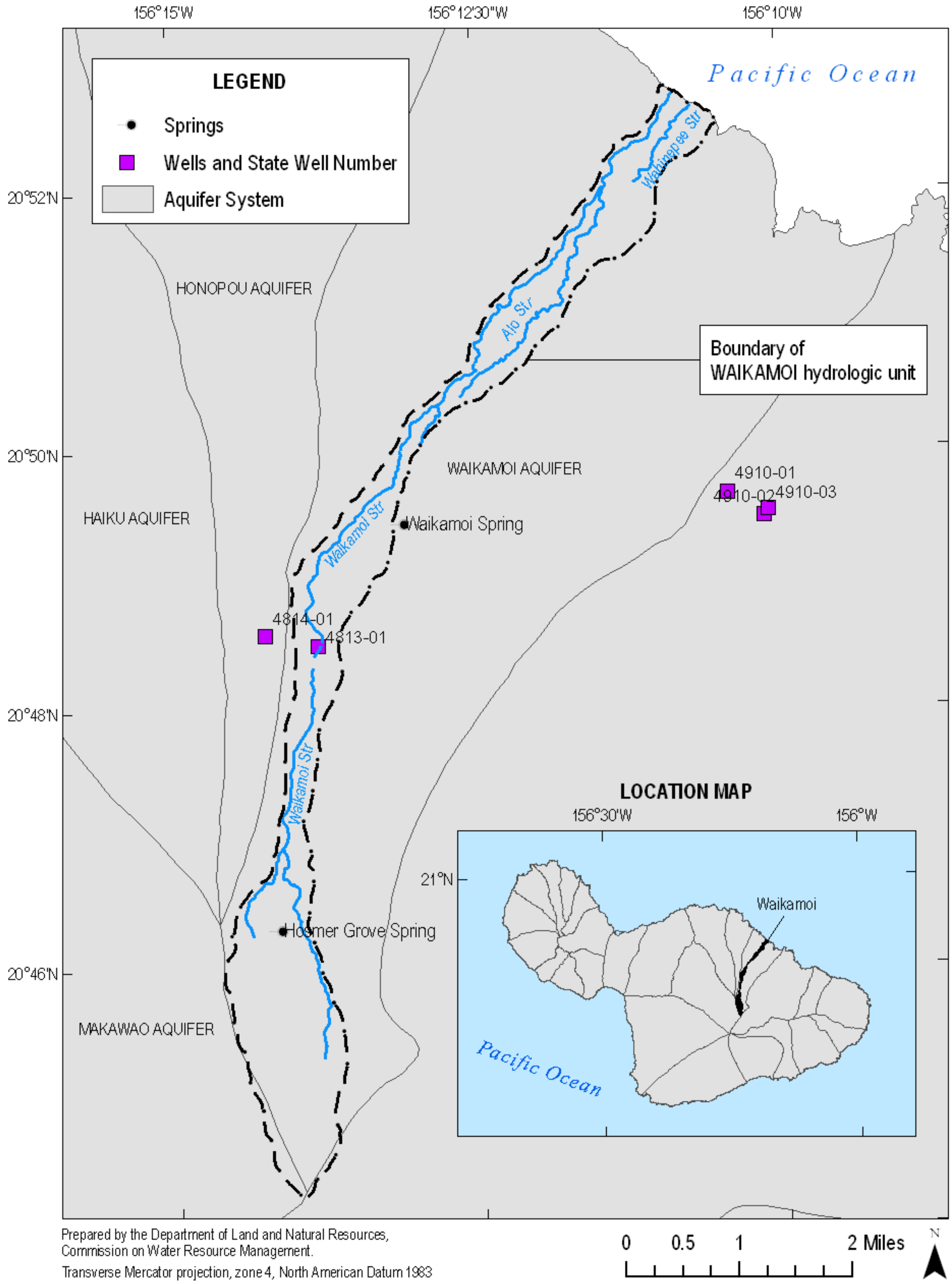


Figure 3-3. Location of diversions, irrigation systems, USGS gaging stations, and selected ungaged sites in Waikamoi hydrologic unit (Source: State of Hawaii, Office of Planning, n.d.; 1996, 2004c; 2005; USGS, 2001b).

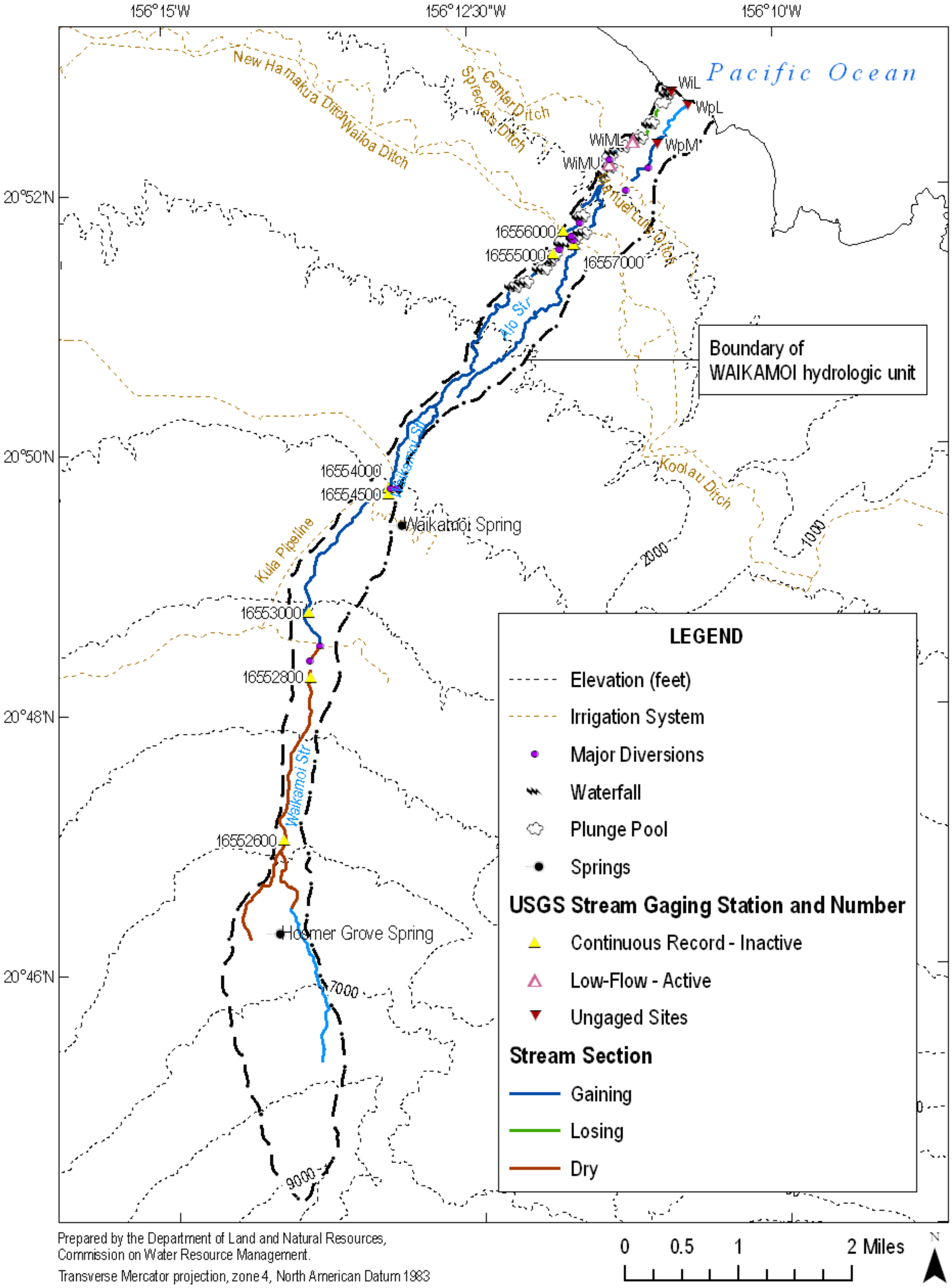
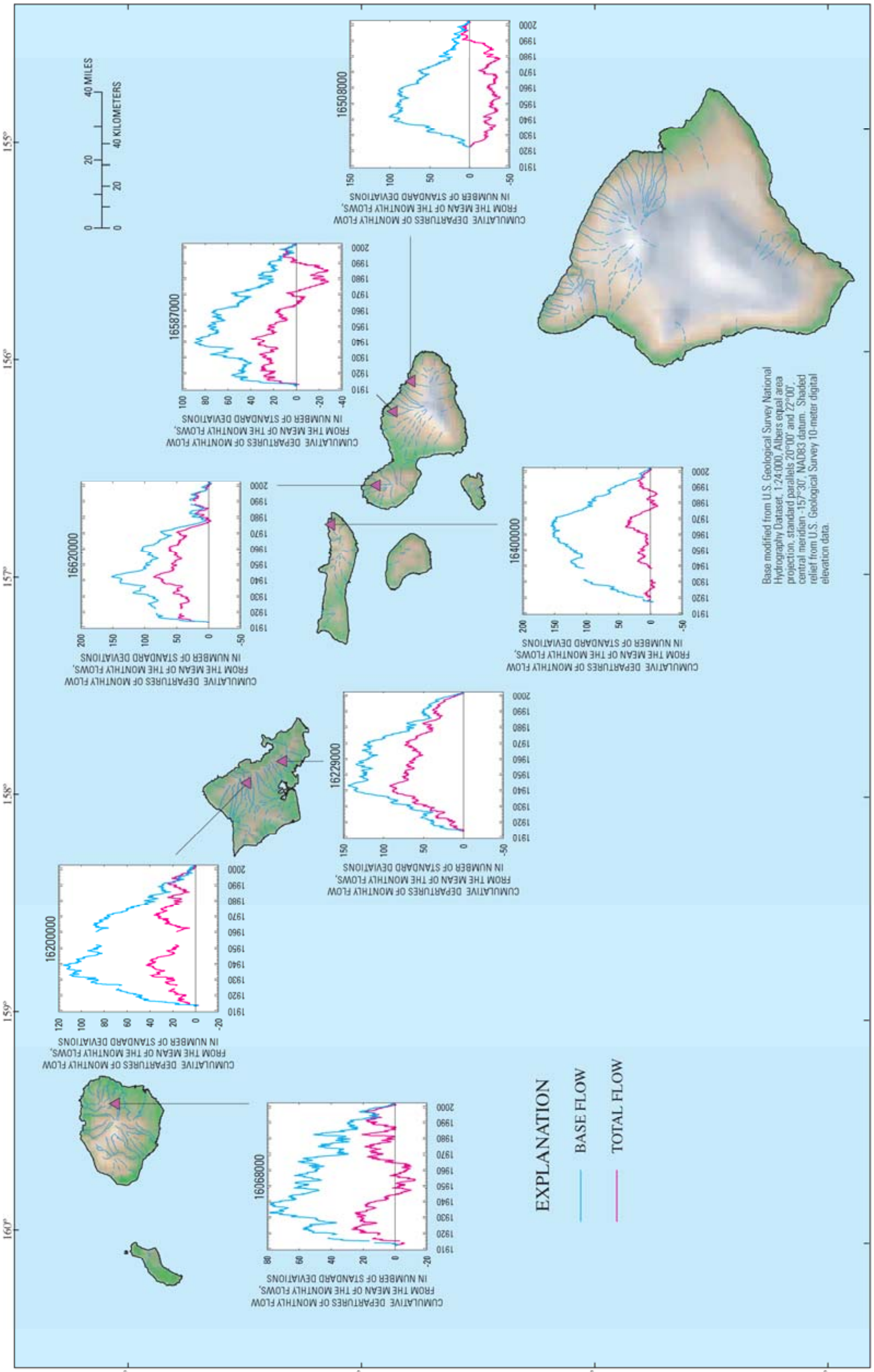


Figure 3-4. Cumulative departures of monthly mean flow from the mean of the monthly flows, Hawaii. This data is based on complete water years from 1913 through 2002. (Oki, 2004, Figure 4).



4.0 Maintenance of Fish and Wildlife Habitat

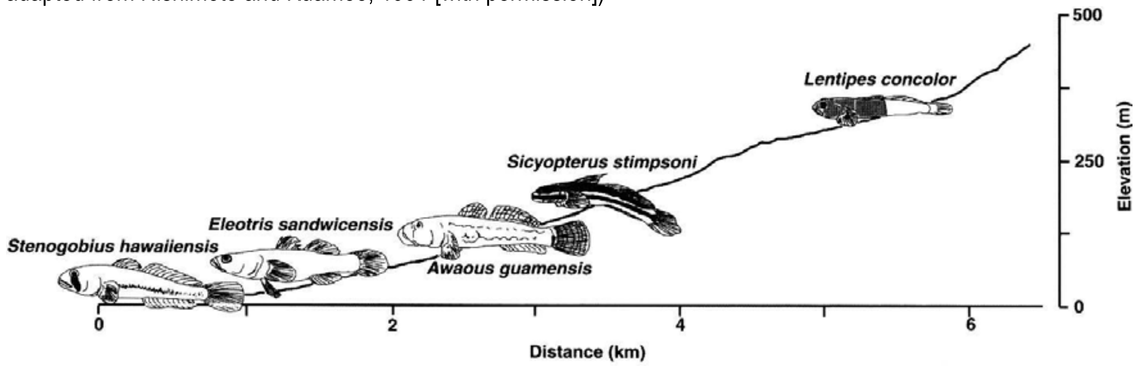
When people in Hawaii consider the protection of streamflows for maintaining fish habitat, their thoughts generally focus on a handful of native species, including five native fishes (four gobies and one eleotrid), two snails, one shrimp, and a prawn (Table 4-1). Four of the fish species - *Stenogobius hawaiiensis* (Goby), *Sicyopterus stimpsoni* (Goby), *Eleotris sandwicensis* (Eleotrid), and *Lentipes concolor* (Goby) - are endemic (found only in Hawaii), and the *Awaous guamensis* is an indigenous (native to Hawaii and elsewhere) goby. Only the *Lentipes concolor* was considered a "category 1 candidate for listing in the National Register for Endangered Species…but has since been reclassified as a Species of Concern" (as cited in Gingerich and Wolff, 2005). The crustaceans (*Macrobrachium grandimanus* (prawn) and *Atyoida bisulcata* (shrimp)), and mollusks (*Neritina vespertina* and *Neritina granosa* (snail)) are both endemic to Hawaii.

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 et al., 1988). Once back in the stream, the distribution of the five native fish species are largely dictated by their climbing ability (Nishimoto and 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 the lower stream reaches. *Stenogobius hawaiiensis* is also found in the lower reaches because while it has fused pelvic fins, it 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 in height, 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.

Table 4-1. List of commonly mentioned native stream organisms and their generalized distribution within natural undiverted streams. (Source: State of Hawaii, Division of Aquatic Resources, 1993; Ford et al., 2009).

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

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



Amphidromy has many advantages, the most important being "the potential for repopulating a stream with a full compliment of its formerly predominant vertebrate and invertebrate species" (as cited in Ford et al., 2009). Streams in Hawaii experience many natural disturbances in the stream ecosystem, including floods, landslides, hurricanes, and drought. Post-larvae oceanic recruitment (amphidromy) "allows rapid recolonization of streams after catastrophic events...and prevents genetic isolation of populations". In addition, the periodic drying of lower stream reaches and the flashy nature of Hawaii's streams with the sudden peak flows that allow for flushing of debris from the streambed, encourage "migration and spawning by aquatic organisms." There has also been evidence that the timing of reproduction and recruitment is strongly influcened by freshets and periods of heavy rain.

4.1 Impacts on Native Species Distribution

Gingerich and Wolff (2005) discussed "bottlenecks" as dry reaches in the stream that prevent upstream migration of native species. While surface water diversions are not considered as "bottlenecks", the dry reaches that are often found immediately downstream from the diversions can function as "bottlenecks" that inhibit species migration. With a few exceptions, the diversions capture almost 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. This prevents the upstream migration of native stream animals, restricts surviving adult animals to the disconnected deep pools, and causes postlarvae recruits to be stranded at the stream mouth. 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. While Ford et al. (2009) suggested that the presence of amphidromous species upstream of diversions is an indication of restored continuity in streamflow from periodic freshets, continued dewaterment of streams by diversions, especially during low flow conditions, could possibly result in longer stream reaches with prolonged dry periods, limiting overall habitat for native species.

Large waterfalls are obvious "bottlenecks" in the stream ecosystem that restrict the upstream migration of most native aquatic species, except the alamoo and opae. These species have fused pelvic fins and the musculature for climbing high vertical walls and inhabiting the upper stream reaches. Therefore, streams with terminal waterfalls may habor a lower diversity of native aquatic species than those without. On the other hand, terminal estuaries and pools downstream of waterfalls are known to carry a diversity of native species and are ideal spots for traditional gathering.

Irrigation ditches serve as lateral conduits between watersheds, which may contribute to the spread of both native and alien species. The Commission does not condone the release of ditch flows as the correct means of flow restoration, but rather have streamflow bypass the diversion structure and continue to flow downstream. However, streams may be used to convey diverted flow from one ditch to another, introducing alien species from one stream to another. Furthermore, overflow in the ditch could also introduce invasive species into the stream. The potential for introducing species from invasive-dominated terminal reaches to native-dominated mid- and headwater reaches is not a major problem in east Maui due to the presence of large waterfalls. Ford et. al. (2009) discussed how ditches may also be "sinks" where "larvae cannot reach the sea and/or where recruits may not survive to reproduce." This is especially the case when native amphidromous species inhabit waters upstream of the ditches. The location and types of diversion structure also affect the ability of ability of amphidromous species to migrate upstream.

Diversions have significantly reduced baseflows in the stream, limiting overall habitat for native species. While restoration of streamflow and increased connectivity could lead to the development of a richer and more native-dominated community in the stream, many other factors must also be considered in balancing the benefits of flow restoration to overall stream life versus providing water for agricultural and domestic uses. In addition to dewaterment, predation by native and non-native animals is also an important negative impact on the distribution on the native aquatic species. Some of the potentially harmful non-native species in east Maui include guppies, mosquitofish, swardtails, carp, oriental weatherfish (dojo), goldfish, Louisiana crayfish, apply snails (harmful to taro), and Asian clam (Ford et. al., 2009). In addition, the "aholehole are known to attack nests of goby eggs and may also consume returning post-larval gobies" (as cited in Ford et. al., 2009). Irrigation ditches may contribute to the spread of alien species; on the other hand, they aid in dispersing the native aquatic species, strengthing the overall population and continued survival of the native freshwater species.

As stated in Ford et. al. (2009), the "synergistic effects of human alterations have led to a decline in the populations of native freshwater species statewide." Steamflow has also decreased over the past decade (see Section 3.4) and this has resulted, as generally believed, in less native stream species. While traditional gathering continues in east Maui, area residents are limited to certain areas with adequate streamflow to gather these resources (multiple residents in east Maui, personal communication, October 2008). Streams in east Maui are recognized as important habitats for native Hawaiian stream animals (Gingerich and Wolff, 2005). The maintenance, or restoration, of stream habitat requires an understanding of and the relationships among 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.

4.2 Brief Overview of Literature

The biological aspects of Hawaii's streams have an extensive history, and there is a wealth of knowledge that continues to grow and improve. Ford et al. (2009) provided a general summary of the existing literature on native stream ecology since 1960. The earlier studies focused on the life histories and population biology of native amphidromous species. During the period of 1970s to 1980s, "the *Awaous guamensis* and *Sicyopterus stimpsoni* were listed along with *Lentipes concolor* by both the American Fisheries Society and the IUCN Red List of Threatened and Endangered Species" based on limited distribution and data availability. In 1996, "the USFWS delisted *Lentipes concolor* as candidate endangered species in response to statewide stream surveys" that indicated healthy and stable populations of the species. More recent studies focused on biological organization at the community and ecosystem levels, reproductive ecology (as cited in Ford et al., 2009), and habitat availability (Gingerich and Wolff, 2005).

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).

Due to the broad scope of the HSA's 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 of this report. For Waikamoi Stream, the aquatic resources were classified as "without", meaning no native species were present. No species from Native Species Group One and Introduced Species Groups were identified. The HSA classification was based on five surveys, with the last one conducted in 1990.

Table 4-2. Hawaii Stream Assessment categorization of aquatic resources in Waikamoi Stream.

Category	Value	Rank
Native Species Group 1 (NG1) Four native freshwater species were classified as "indicator species" and comprised the Native Species Group One (NG1). The committee considered these species, ʻoʻopu alamoʻo (*Lentipes concolor*), ʻo ʻopu nakea (*Awaous stamineus*), ʻoʻopu nopili (*Sicyopterus stimpsoni),* and hihiwai (Neritina granosa), as representatives of potentially high quality stream ecosystems.	0	Poor
Native Species Group 1 (NG2) The other seven native species considered more common comprised Native Species Group Two (NG2). These included two ʻoʻopu akupa (*Eleotris sandwicensis*), ʻoʻopu naniha (*Stenogobius genivittatus*), aholehole (*Kuhlia sandvicensis*), ʻamaʻama (*Mugil cephalus*), ʻoʻpae kalaʻole (*Atyoida bisulcata*), ʻoʻpae ʻoehaʻa (*Macrobrachium grandimanus*), and hapawai (*Theodoxus vespertinus*). Presence of these species was considered to be typical of a healthy native stream ecosystem.	1	Good
Introduced Species Group One (IG1) This group included noxious, non-native stream animals that may prey upon and/or out-compete with native species. *Macrobrachium lar.* (Tahitian prawn), was not included in this group even though it may pose a threat to native stream animals because it is believed to be present in almost all Hawaiian streams.	0	
Introduced Species Group Two (IG2) This consists of the non-native species considered to be innocuous to Hawaiian streams.	0	

4.3 Analysis of Habitat Availability

In cooperation with the Commission on Water Resource Management and others, the USGS conducted a study to assess the effects of surface water diversion systems on habitat availability for native stream species in northeast Maui. The goal was to determine a relationship between streamflow and habitat availability using a habitat selection model. Five out of 21 streams in the study area were selected for intensive study because they represented a range of hydrologic conditions (i.e., geograhic location, drainage area, terminal waterfall, estuary, human impacts, data availability, and access) present in the study area. By incorporating hydrology, stream morphology, and habitat characteristics, the model simulated habitat and streamflow relations for various species and life stages (Gingerich, 2005) in the 5 representative streams. Results of this habitat model, along with additional data from field reconnaissance surveys, aerial images, and GIS analyses, were extrapolated to estimate habitat availability in the remaining 16 streams. The outcome of the study was ultimately a map (Gingerich and

Wolff, 2005, Plate 1) describing the habitat availability for native stream fauna in 21 streams in northeast Maui.

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) nakea (*Awaous guamensis* (Valenciennes)). The gobies of interest have a fused pelvic fin, allowing them to climb upstream. One of the fresh water 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. Since opae and alamoo (adult and juvenile) do not typically live in the lower reaches, they were evaluated only in the middle and upper sites. The lower sites were evaluated for adult and juvenile nopili, adult nakea, and hihiwai.

Waikamoi was one of the five intensely studied streams used to develop the streamflow-habitat relationship. Flow and stream morphology data were collected during base flow conditions when most of the flow was diverted at the Wailoa and New Hamakua Ditch (about 1,300-1,200 feet elevation). Estimated natural and diverted median total and base flows were compiled from Gingerich (2005). Since streamflow measured during the habitat surveys was lower than estimated median total and base flow under diverted conditions, it can be assumed that habitat measurements were made during the driest conditions. Habitat availability and species abundance were quantified using snorkel surveys made during the day. Hydrologic data were entered into the habitat simulation model to estimate the area of usable streambed habitat over a range of streamflow values.

Results of the habitat simulation model can be summarized in Figure 4-2. The plot shows the relationship between diverted base flow (x-axis) and habitat availability (y-axis). The colored band indicates the range of values as defined by the 90 percent confidence level. If results from a particular site lie within this colored band, then there is only a 10 percent chance that the results will not be as predicted by the plot. In general, the plot shows that as base flow increases, the area of estimated usable streambed habitat for all interested species also increases. It also shows that “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.” For instance, when 20 percent of the natural base flow is returned to a dry reach, natural habitat availability increases to 60 percent. 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, from migrating upstream.

Of the 70 miles of stream length within the study area, 36 miles have retained 75 to 100 percent of the natural habitat availability, 8 miles with 25 to 50 percent of the natural habitat, and 11 miles with no habitat at all because the stream reaches were dry (Table 4-3). Of the 36 miles with more than 75 percent natural habitat, 20 miles of the stream length were upstream from major diversion ditches. Figure 4-3 describes the habitat availability for Waikamoi Stream and specific data are included in Tables 4-4 and 4-5. Upstream of Wailoa Ditch where there are no diversions, the stream has no reduction in flow and thus, retains 100 percent of the natural habitat. Between Wailoa and Center Ditch where both Waikamoi and tributary Alo streams were diverted, enough base flow is maintained by ground water contribution to provide about 56-57 percent of the expected natural habitat for all species and about 70 percent of the natural opae habitat. Downstream from Center Ditch, the stream is dry (no available habitat) until more ground water is gained to provide 27-46 percent of the expected natural habitat for all species and at least 40 percent of the natural opae habitat. A base flow of 0.61 cubic feet per second is needed to maintain at least 50 percent of the natural opae habitat below the Center Ditch. Near the coast, the stream loses water and becomes dry, providing no habitat. When flow is abundant, Waikamoi Stream terminates as a waterfall where only the opae and alamoo could migrate upstream. Overall, greater than 50 percent of the natural habitat for all species in Waikamoi Stream was already maintained below Wailoa and New Hamakua Ditch under diverted conditions.

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).

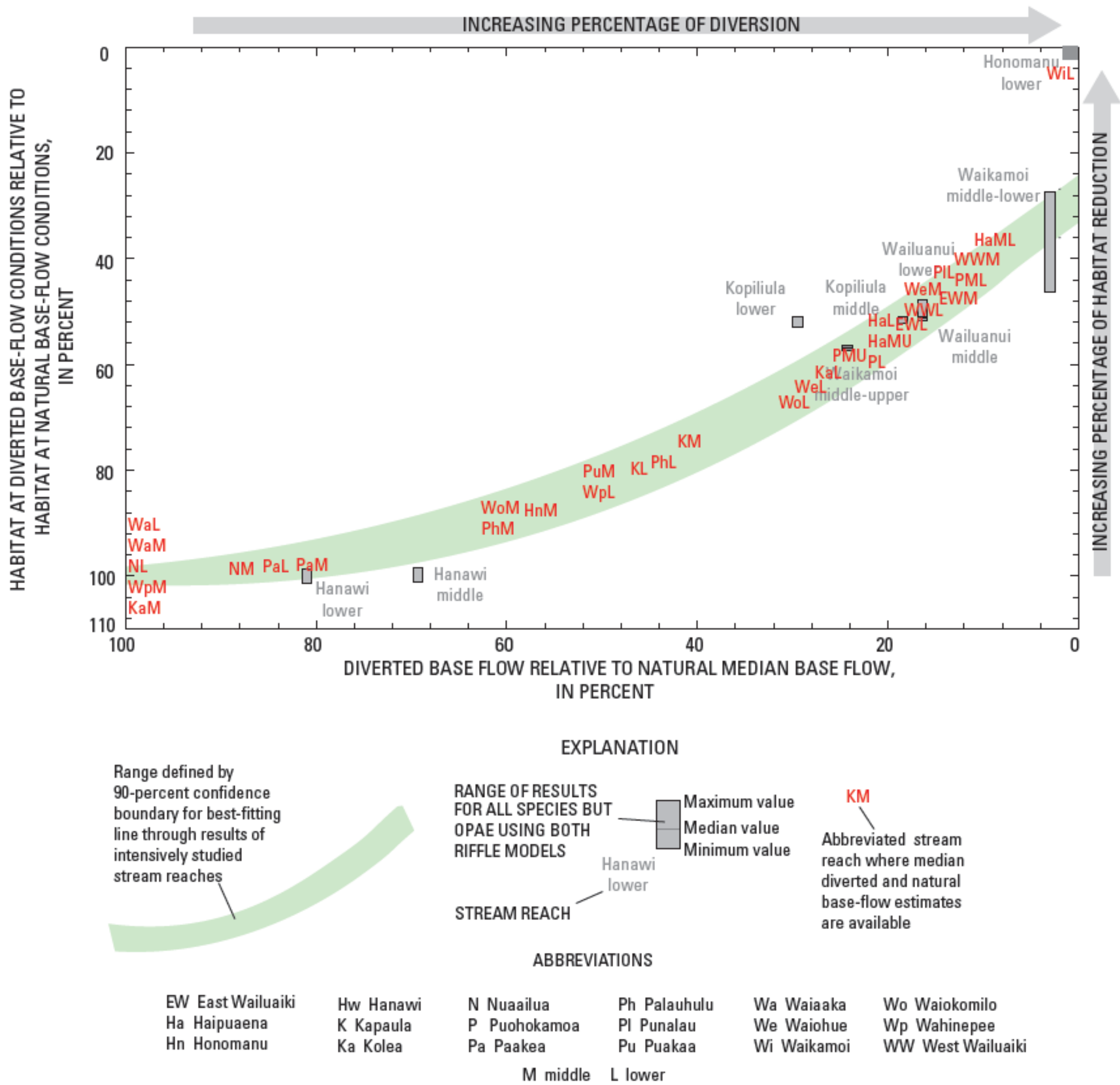


Table 4-3. Summary of estimated aquatic habitat distribution at diverted base flow relative to natural conditions, calculated using GIS (Source: Gingerich and Wolff, 2005).

Habitat Availability	Stream Length (miles)
100 percent (no reduction)	26
75 to 100 percent	10
50 to 100 percent	10
25 to 50 percent	8
0 percent (dry)	11
Insufficient Information	5
Total *	70

* The total linear miles of stream length differs from that presented in Ford et al. (2009) probably due to differences in digitization of the stream reaches from Gingerich and Wolff (2005), Plate 1.

Table 4-4. Summary of modeled habitat for Waikamoi Stream (Source: Gingerich and Wolff, 2005, Table 8).

[ft^3/s is cubic foot per second]

Stream site	Median base flow remaining in stream (ft^3/s)		Habitat available at diverted median base flow conditions relative to habitat available at natural median base flow condition (% of natural habitat)	Flow needed to produce habitat relative to habitat available at natural median base-flow conditions (ft^3/s)		Amount of habitat relative to habitat available at natural median base-flow conditions with flow at percentage of natural base flow	
	Diverted	Natural		50% of natural habitat	90% of natural habitat	50% of natural base flow	90% of natural base flow
middle-lower	.20	6.7	27 – 46	.13 – 1.1	4.9 – 5.1	78 – 82	96
middle-upper	1.6	6.6	56 – 57	1.2	3.8 – 4.1	81 – 84	99

Table 4-5. Summary of modeled opae habitat for Waikamoi Stream (Source: Gingerich and Wolff, 2005, Table 9).

[ft^3/s is cubic foot per second; NA, not applicable]

Stream site	Median base flow remaining in stream (ft^3/s)		Habitat available at diverted median base flow conditions relative to habitat available at natural median base flow condition (% of natural habitat)	Flow needed to produce habitat relative to habitat available at natural median base-flow conditions (ft^3/s)		Amount of habitat relative to habitat available at natural median base-flow conditions with flow at percentage of natural base flow	
	Diverted	Natural		50% of natural habitat	90% of natural habitat	50% of natural base flow	90% of natural base flow
middle-lower	.20	6.7	40 – 64	.61	2.4 – 4.4	84 – 92	97 – 98
middle-upper	1.6	6.6	70	NA	3.7 – 3.8	86 – 87	98

Wahinepee Stream was not one of the intensively studied streams; thus, results of the habitat simulation model were extraploted to estimate the stream habitat availability (Table 4-6). Since the middle reach of Wahinepee Stream has 100 percent of the the natural base flow, there is no reduction in habitat availability. In the lower reach, maintaining 50 percent of the natural base flow could retain at least 76 percent of the expected natural habitat availability for all species.

Table 4-6. Summary of relative base flow and available habitat in Wahinepee Stream (Source: Gingerich and Wolff, 2005, Table 10).

[ft^3/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 (ft^3/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 (WpL)	.90	1.8	50	87-76	89-85
middle (WpM)	.90	.90	100	100	100

4.4 Distribution of Native Freshwater Species

The HSA inventory was general in nature, resulting in major data gaps, especially those related to the distribution and abundance of aquatic organisms – native and introduced – inhabiting the streams. The State of Hawaii Division of Aquatic Resources (DAR) has since continued to expand the knowledge of aquatic biota in Hawaiian streams. Products from their efforts include the compilation and publication of an Atlas of Hawaiian Watersheds and Their Aquatic Resources for each of five major islands in the state (Kauai, Hawaii, Oahu, Molokai, and Maui). Each atlas describes watershed and stream features, distribution and abundance of stream animals and insect species, and stream habitat use and availability. Based on these data, a watershed and biological rating is assigned to each stream to allow easy comparison with other streams on the same island and across the state. The data presented in the atlases are collected from various sources, and much of the stream biota data are from stream surveys conducted by DAR. Figure 4-4 illustrates the DAR suvey locations on Waikamoi Stream. Currently, efforts have been focused on updating the atlases with more recent stream survey data collected statewide, and developing up-to-date reports for Commission use in determining the interim IFS recommendations for east Maui. At this time, an updated draft inventory report on Waikamoi is pending and an analysis of DAR's findings will be included in the Final IFSAR. The original report submitted by DAR will be made available at that time.

The SWCA Environmental Consultants, at the request of Hawaiian Commercial and Sugar Company, conducted a study that analyzed research published by DAR, USGS, and other investigators (Ford et. al., 2009). The objective of the study was to present biological information that may help the Commission in determining reasonable and beneficial instream and offstream uses of the surface water in east Maui. The authors stressed that no data exists to suggest "any of the nine native Hawaiian amphidromous species is at risk of either endangerment and/or extinction in east maui streams or else where in the State", and that dry reaches in diverted streams are periodically wetted by freshets, allowing streamflow continuity and the upstream migration of native species. However, other investigators have reported that "hihiwai were limited to about 185 meters and 223 meters in the lower reaches of Waiohue and Waikolu Streams [Maui], respectively…and suggested this was due to the effect of dewaterment on habitat availability" (as cited in Ford et. al., 2009). It was also important to note that frequent changes in stream community structure that may result in absence of native stream animals should not be interpreted as a negative indicator of stream health.

Results of the studies analyzed by SWCA Environmental Consultants are presented in Tables 4-7 and 4-8. The consultant summarized data mainly from SWCA field studies, the USGS habitat availability study (Gingerich and Wolff, 2005), and DAR's Atlas of Hawaiian Watersheds and Their Aquatic Resources. Please note that Commission staff is awaiting updated data from DAR and will supplement the following tables with new data. Compared with the other east Maui streams, not many stream animals were observed in Waikamoi Stream and its tributary Alo Stream. Only the Tahitian prawn (alien amphidromous specie) and the opae kalaole were present in the stream and they were observed in the middle and upper reaches, mostly above diversion structures. According to Table 4-7, the opae was the most conspicuous species that was found in most of the east Maui streams except Punalau and Ohia. In Wahinepee Stream, no data is available to confirm the presence or absence of amphidromous species in the stream. The limited number of biota observed in these streams may be attributed to the terminal waterfall that inhibits upstream migration of amphidromous species, except the alamoo and opae. While Waikamoi is mostly a gaining stream (see Chapter 3), habitat measurements from USGS were conducted during the driest conditions. Therefore, the absence of alamoo in the Waikamoi Stream may be due to a combination of drought conditions and dewaterment of the stream by the EMI System and the Maui DWS Upcountry System.

Table 4-7. Known distribution of amphidromous species in east Maui streams (Ford et. al., 2009, Table 3).

[X = present; ND = no data]

East Maui Streams (T) = terminal falls	*Kuhlia spp.*	*Eleotris* sandwicensis	*Stenogobius hawaiiensis*	*Awaous guamensis*	*Sicyopterus stimpsoni*	*Lentipes concolor*	*Neritina granosa*	*Neritina vespertinus*	*Macrobrachium lar (Alien amphidromous)*	*Macrobrachium grandimanus*	*Atyoida bisulcata*
Honopou		X		X	X	X			X	X	X
Hanehoi											X
Kolea (T)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Waikamoi (T)									X		X
Wahinepe'e (T)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haipua'ena (T)						X			X		X
Puohokamoa				X		X			X		X
Punalau				X	X	X			X		
Honomanū											X
Nua'ailua				X	X	X	X	X	X		X
Palauhulu/Pi'ina'au	X	X	X	X	X	X	X	X	X	X	X
'Ohia							X				
Waiokamilo (T)				X					X		X
Wailua Nui	X	X		X		X			X		X
W. Wailua Iki	X			X		X	X		X		X
E. Wailua Iki	X	X		X		X	X		X		X
Kopiliula	X	X		X	X	X	X		X		X
Waiohue	X	X	X	X	X	X	X	X	X	X	X
Pa'akea (T)				X		X	X		X		X
Kapaula											X
Hanawī	X	X	X	X	X	X	X		X		X
Makapipi	X	X		X	X	X			X		X

Table 4-8. Distribution of amphidromous species in lower, middle, and upper reaches of east Maui streams within the USGS stydt area summarized from SWCA, USGS, and DAR sources. (Source: Ford et. al., 2009, Table 4)

STREAM	Number of Amphidromous Species Reported			Terminal Waterfall	Number of Non-Native Species Reported
	Lower	Middle*	Upper**		
Kolea	ND	ND	ND	√	ND
Waikamoi		1	2	√	5
Waikamoi – Alo***			1		
Wahinepe'e	ND	ND	ND	√	ND
Puohokamoa	4	3	2		1
Haipua`ena	1	3	1	√	4
Punalau	2	1	1		2
Honomanu	1		1		
Nua'ailua	6	5	2		2
Pi'ina'au / Palauhulu	10	6	4		9
'Ōhi'a	1				
Waiokamilo		2	2	√	8
Wailuanui	10	6	5		5
West Wailuaiki	4	4	1		7
East Wailuaiki	5	2	1		1
Kopiliula / Puaka'a	4	7	6		3
Waiohue	10	5	4		2
Pa'akea	5	2	1	√	1
Waia'aka	ND	ND	ND		
Kapā'ula			1		
Hanawi	7	7	2		2
Makapipi	4	5	2		6

Key to Table:
ND = no data
* Above diversion structures in some reaches
** Above diversion structures
*** Waikamoi and its tributary Alo are counted as one stream.

4.5 Other Critical Habitats

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 Waikamoi 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. Figure 4-5 illustrates the native forest bird habitat spans in the hydrologic unit of Waikamoi.

Figure 4-3. Estimated habitat availability in Waikamoi hydrologic unit (Source: Gingerich and Wolff, 2005; USGS, 2001b).

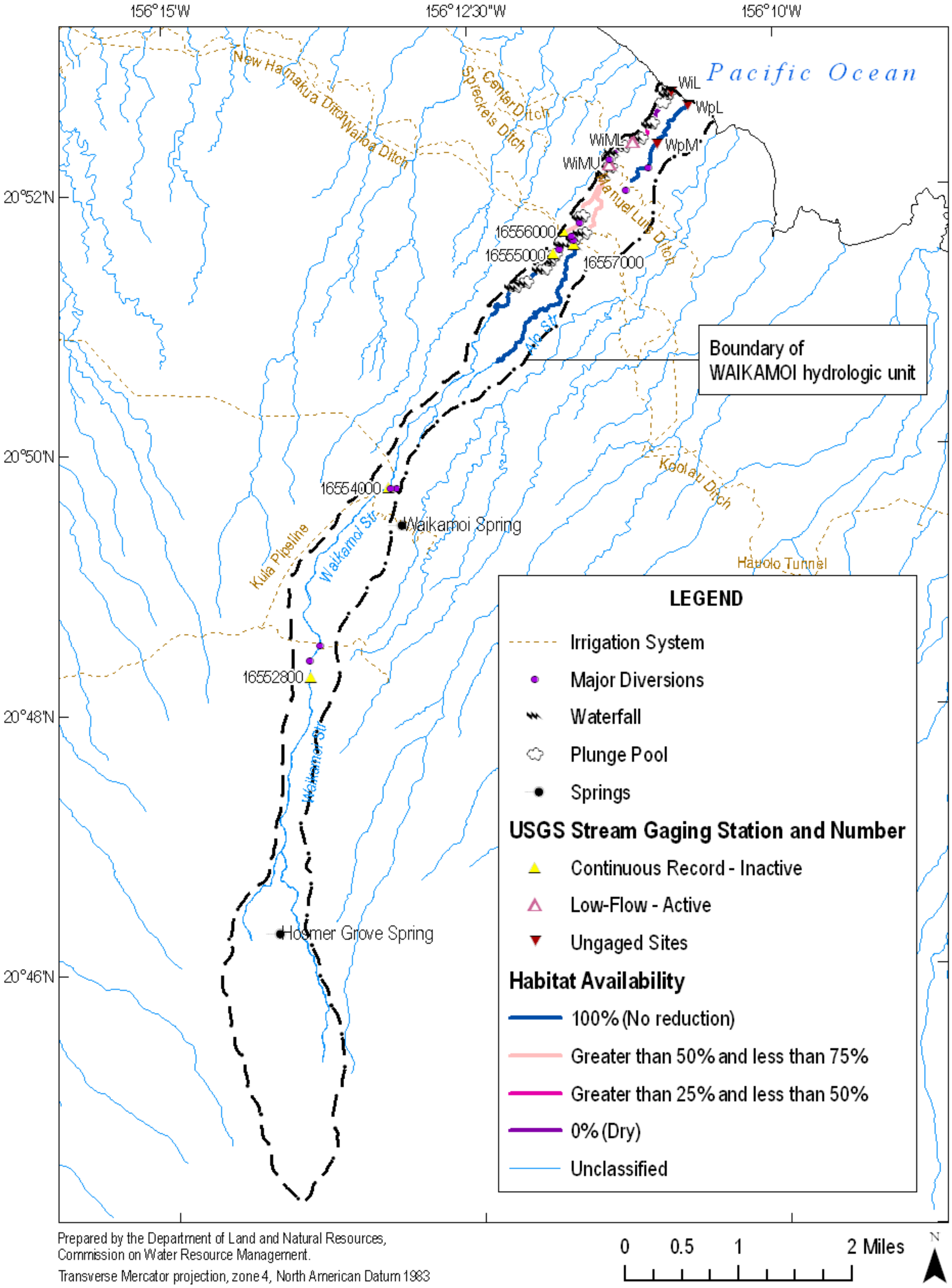


Figure 4-4. Division of Aquatic Resource survey point in Waikamoi Stream (Source: USGS, 2001b).

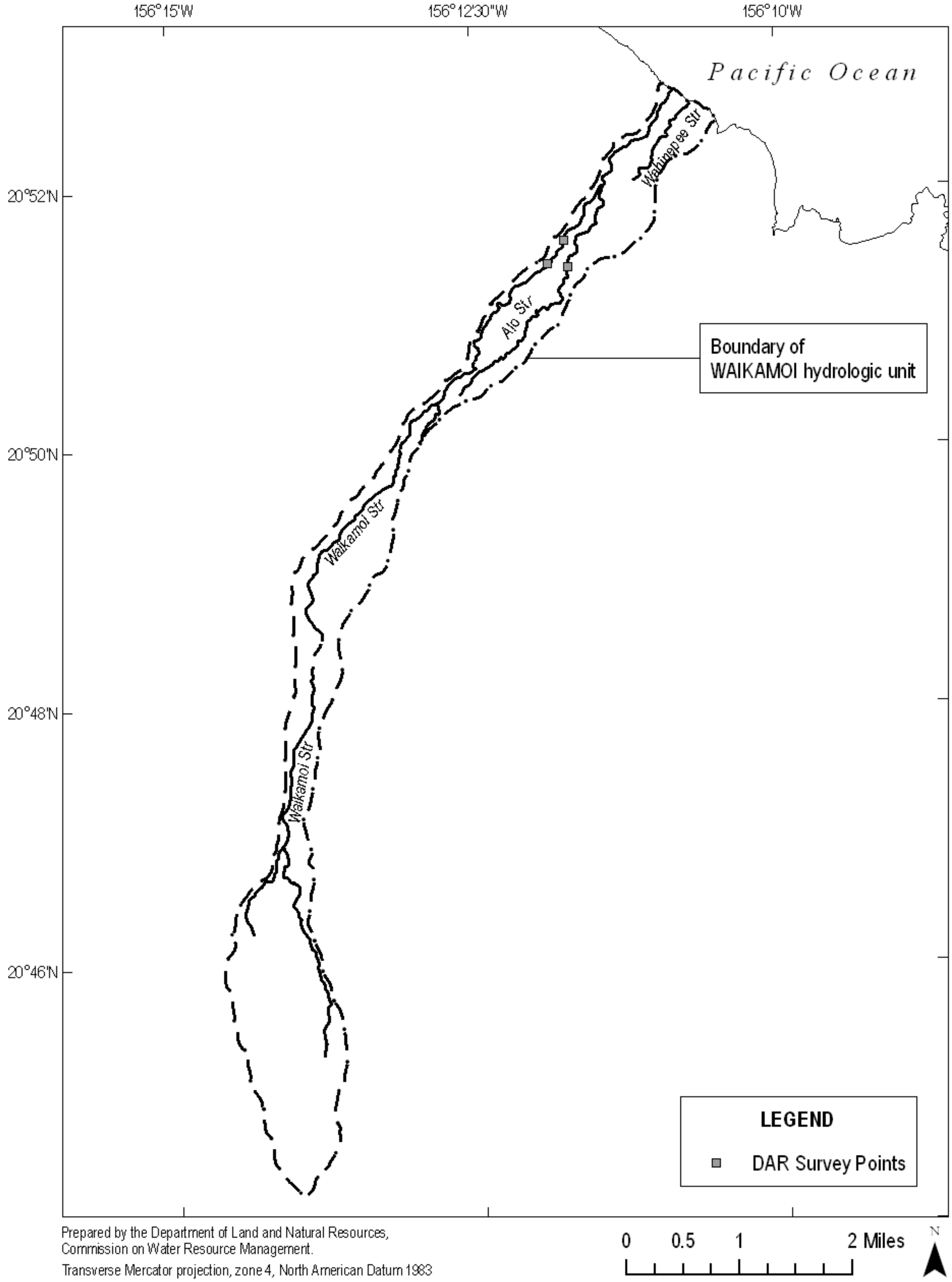
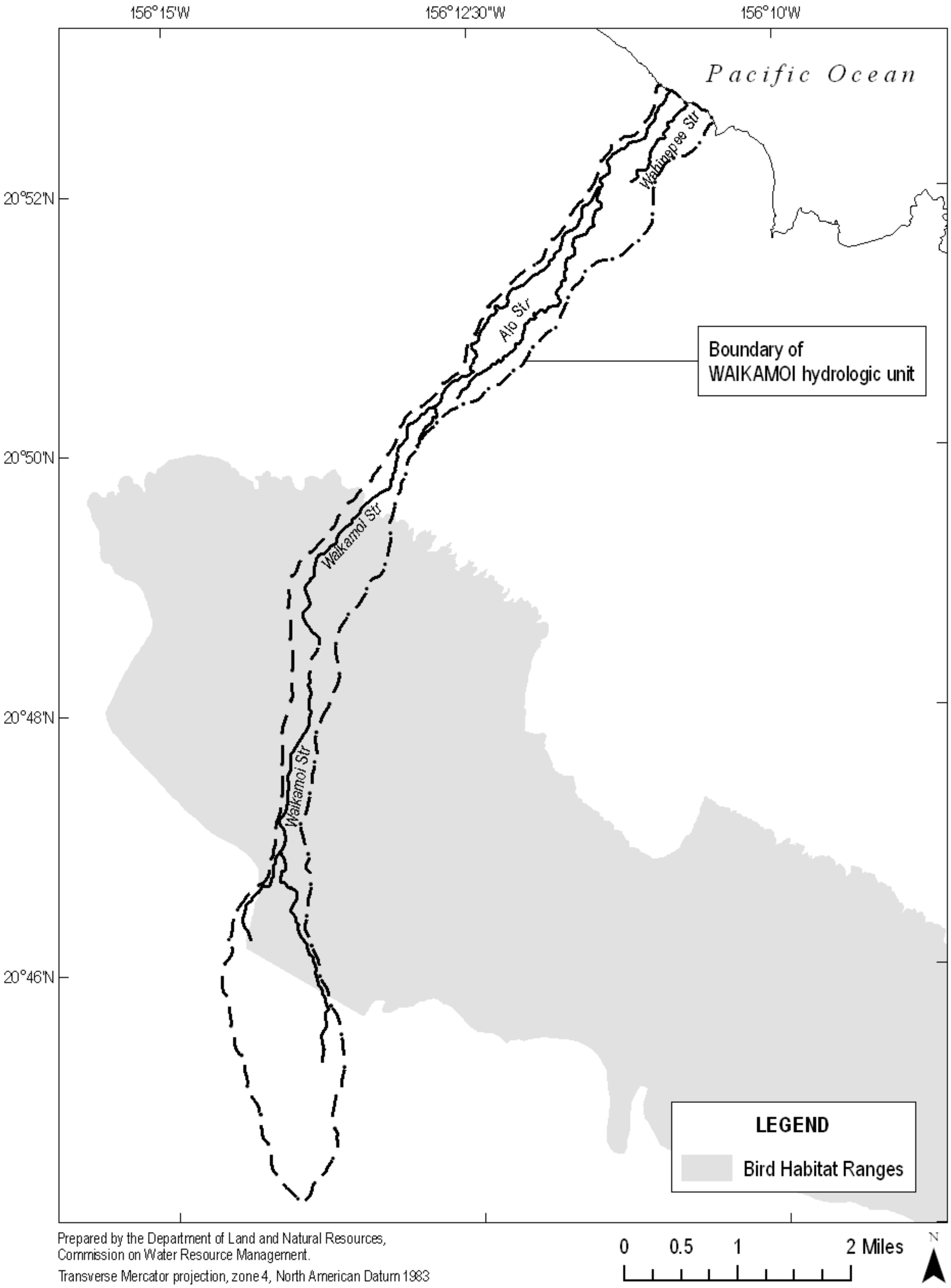


Figure 4-5. Native Hawaiian forest habitat ranges in Waikamoi hydrologic unit (Source: U.S. Fish and Wildlife Service, n.d; USGS, 2001b).



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 State of Hawaii Department of Health (DOH) maintains water quality standards (HAR 11-54) for recreational areas in inland recreational waters based on the geo-mean of *Enterococcus*, a fecal indicator: 33 colony-forming units per 100 mL of water or a single-sample maximum of 89 colonies per 100 mL. This is for full-body contact (swimming, jumping off cliffs, etc.). If *Enterococcus* exceeds those values, the water body is considered to be impaired. DOH also has a standing advisory for *Leptospirosis* in all freshwater streams. The marine recreational zone, which extends from the shoreline seaward to 1,000 feet from shore, requires an *Enterococci* geo-mean of less than 7 colony-forming units per 100 mL of water, to protect human health.

The recreational resources of Waikamoi Stream were classified as "substantial" by the HSA's regional recreation committee. The HSA identified opportunities for hunting, swimming, and scenic views related to Waikamoi (Table 5-1). None of the recreational opportunities were considered to be a high-quality experience (National Park Service, Hawaii Cooperative Park Service Unit, 1990). Wahinepee Stream was not one of the assessed streams in the HSA.

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 hunting area is approximately 1.5 square miles or 28 percent of the Waikamoi hydrologic unit, and it lies within the lower half 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 Waikamoi and Wahinepee 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 trolling/bottom fishing, and opihi picking as the only activities that were known to occur or observed at or near Waikamoi (Figure 5-2).

John Clark, in his book *The Beaches of Maui County* (1989), describes the Waikamoi area as follows:

> The shoreline from Maliko to Honomanū is characterized by high, steep sea cliffs. Within this long reach of cliffs are a number of bays that are usually little more than wide, moderately deep indentations in the shoreline, usually where streams meet the ocean. The beaches in these areas are narrow stretches of large boulders lying directly at the base of the sea cliffs. Many of these boulder beaches are not accessible at all by land, and if they are, it is only by a hazardous climb using a rope or cable to get down the cliffs. During the winter and spring months these bays are assaulted by heavy surf that sweeps completely across the boulders against the sea cliffs. There are no fringing reefs to check the advance of surf or strong currents. Over the years many fishermen have lost their lives along this dangerous coastline. These rough waters have long been excellent grounds for netting *akule* and *ʻōpelu* and for hooking *ʻūʻū*, *ʻāweoweo*, and *āhole*.
>
> There is no public access to any of these shoreline areas except from the ocean. Many of the bays are over one mile away from the Hāna Highway, and all of the land between the highway and the shoreline is private property replete with locked gates and No Trespassing signs.

Another element 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 Waikamoi and Wahinepee Stream that may utilize the stream as part of its curriculum. The Commission did not identify any educational facilities in the area.

See Figure 5-2 for the locations of various recreation-related points of interest.

Figure 5-1. Public hunting areas for game mammals in Waikamoi hydrologic unit (Source: State of Hawaii, Office of Planning, 2002b; USGS, 2001b).

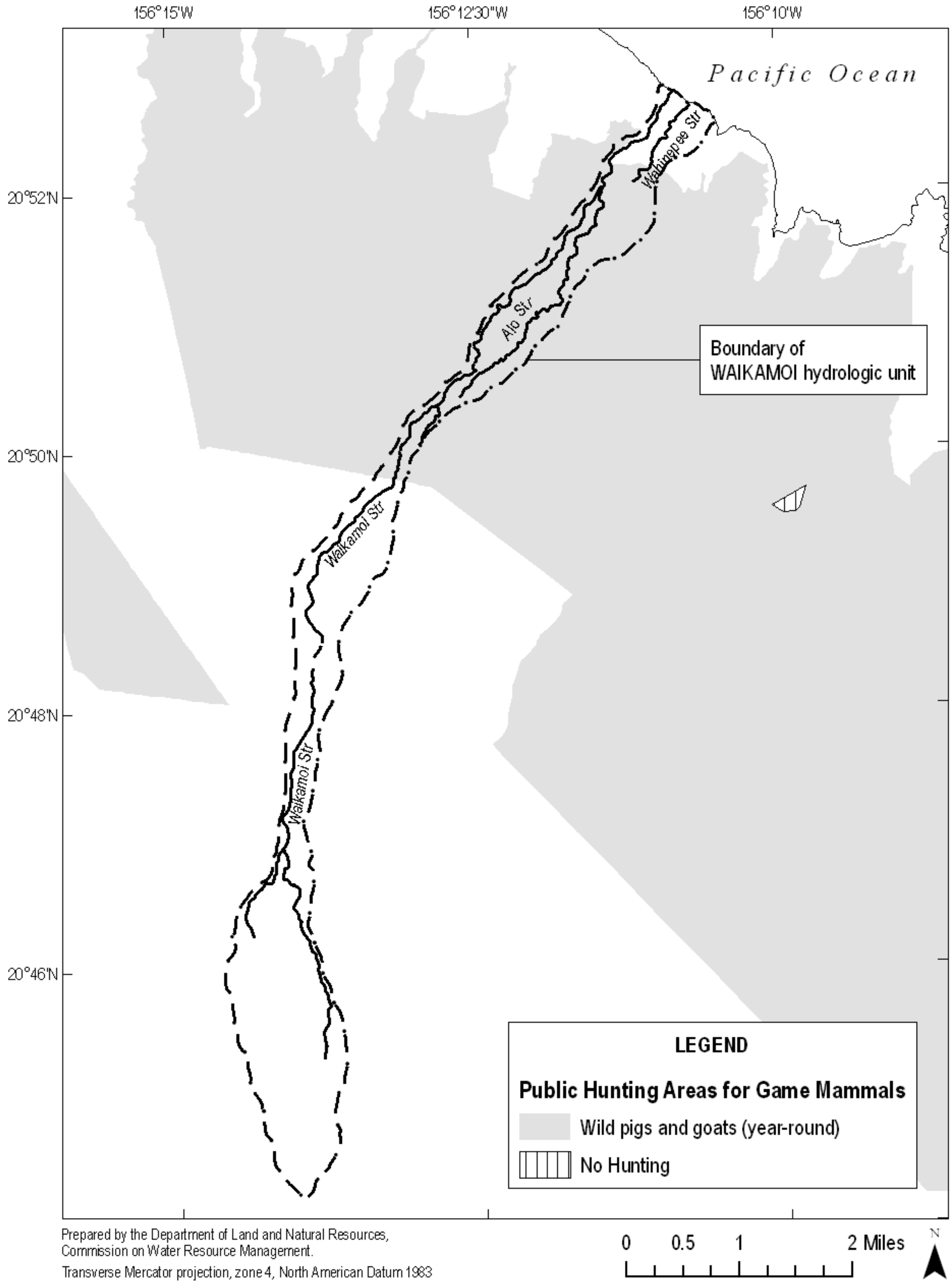
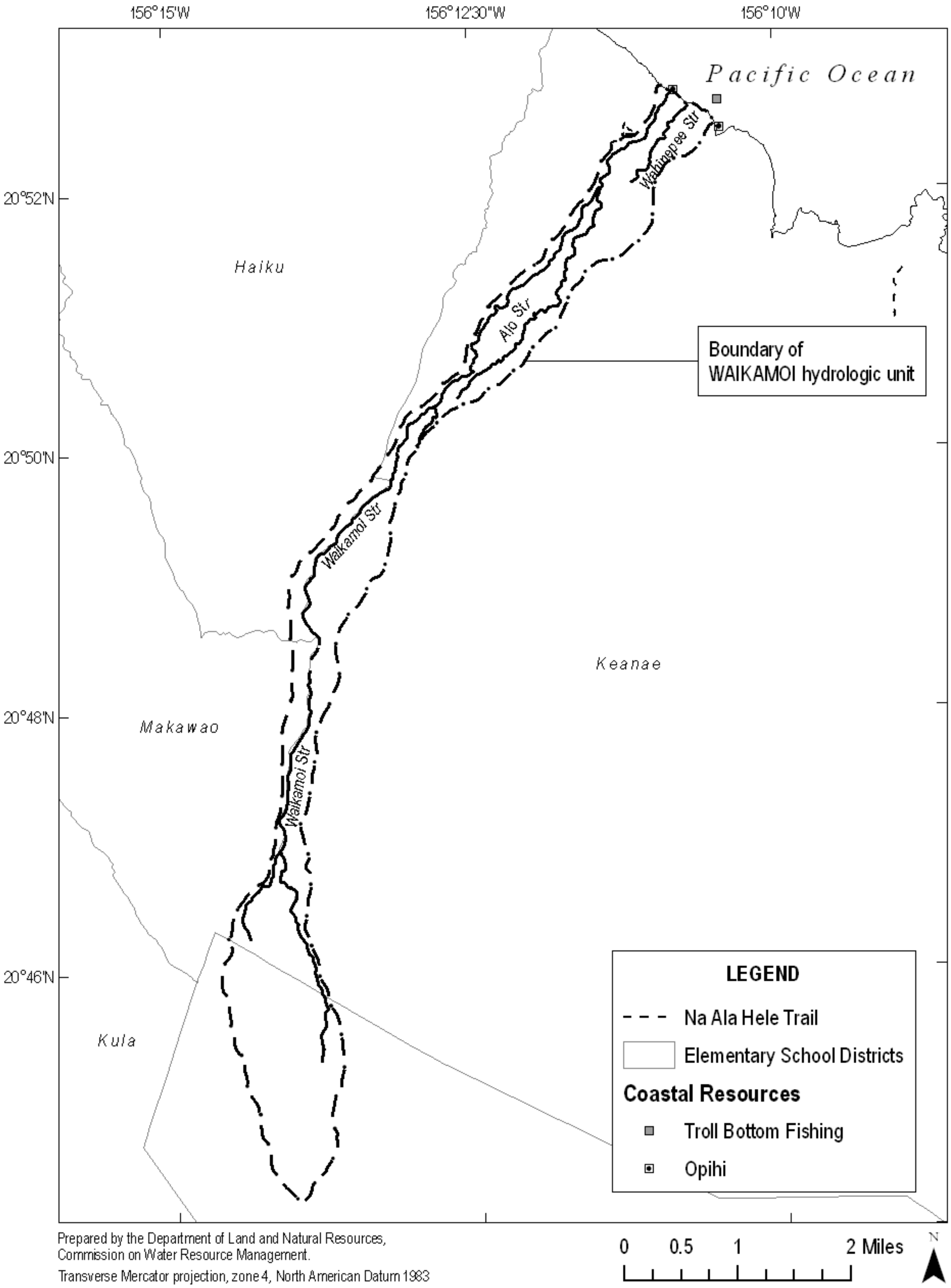


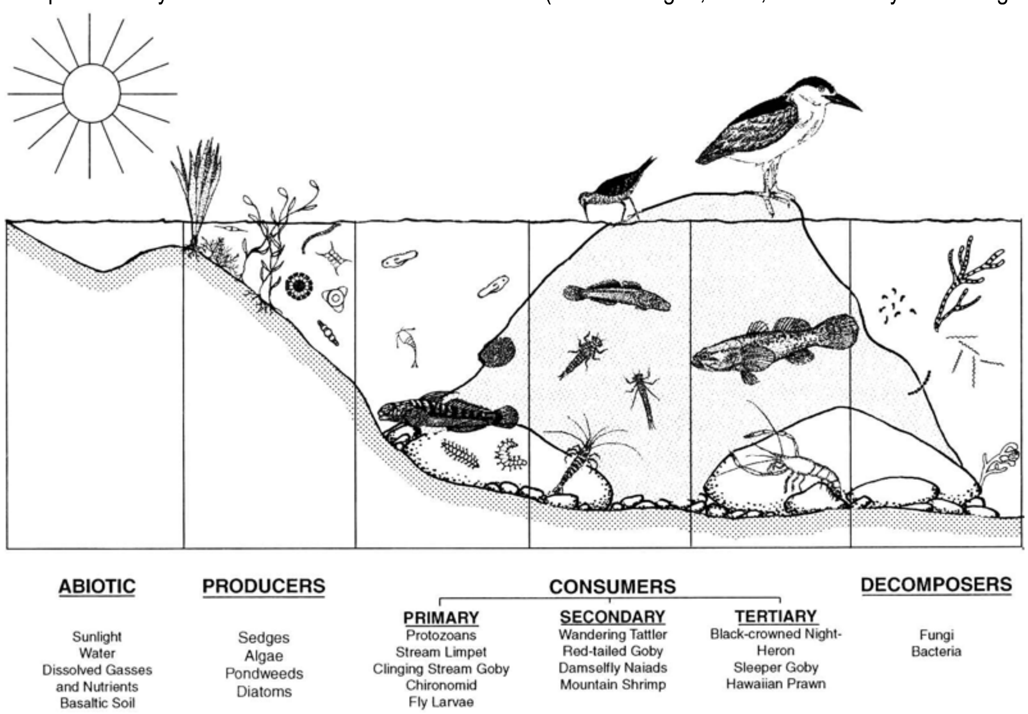
Figure 5-2. Recreational points of interest for Waikamoi hydrologic unit (Source: State of Hawaii, Office of Planning, 1999, 2002a; 2002c; 2002d; 2004a; USGS, 2001b).



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 generally utilized natural resources within the limits of their ahupuaa; therefore, it was important 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 Waikamoi Stream were classified as "substantial" by the HSA, while those of tributary Alo Stream and Wahinepee Stream were not classified (National Park Service, Hawaii Cooperative Park Service Unit, 1990). 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 Waikamoi 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.	3
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.	Partially protected
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.	Less than ½-square mi. of palustrine wetlands identified by USFWS
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.	30%
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 Waikamoi, about 29 percent of the hydrologic unit falls within the Haleakala National Park, 28 percent within the Koolau Forest Reserve, and 7 percent within the Waikamoi Preserve (Table 6-2).

Table 6-2. Management areas located within Waikamoi hydrologic unit. (Source: State of Hawaii, Division of Forestry and Wildlife, 2008a; State of Hawaii, Office of Planning, 2007b).

Area Name	Managed by	Area (mi2)	Percent of Unit
Haleakala National Park	U.S. National Park Service	1.52	28.9
The Haleakala National Park was established in 1916 and currently encompasses 30,183 acres (47.09 sq. mi.) of land, of which 24,719 acres have been designated as Wilderness Area. General management policies of the National Park System focuses on the preservation of natural, cultural, and archaeological resources, while providing for public use and recreation.			
Koolau Forest Reserve	State Division of Forestry and Wildlife	1.47	27.9
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.			
Waikamoi Preserve	The Nature Conservancy	0.36	6.9
The Waikamoi Preserve is managed by The Nature Conservancy of Hawaii (TNCH) and encompasses a total area of 5,230 acres (8.16 sq. mi.). The preserve was established in 1983 to protect the unique native biodiversity of east Maui including 63 species of rare plants and 13 species of birds (seven are endangered). The management rights of the land, owned by the Haleakala Ranch Company, were conveyed to TNCH through a permanent conservation easement. Public access is available through the National Park Service and the East Maui Watershed Partnership, and scientific research opportunities are offered through TNCH.			

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 Waikamoi hydrologic unit. (Source: State of Hawaii, Division of Forestry and Wildlife, 2008b; East Maui Watershed Partnership, 1993).

Management Area	Year Established	Total Area (mi^2)	Area (mi^2)	Percent of Unit
East Maui Watershed Partnership	1991	186.73	4.96	94.5
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 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 et al., 1979). Approximately 32 percent of Waikamoi is classified as non-tidal palustrine wetlands occurring in the upper slopes of the hydrologic unit (Figure 6-2). Palustrine wetlands are non-tidal 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 Waikamoi hydrologic unit (Source: U.S. Fish and Wildlife Service, 1978).

System Type	Class	Regime	Area (mi²)	Percent of Unit
Palustrine	Forested, broad-leaved evergreen	Semipermanent non-tidal	1.05	20.0
Palustrine	Forested, broad-leaved evergreen	Seasonal/Unknown non-tidal	0.26	4.9
Palustrine	Open Water/unknown bottom	Permanent non-tidal	0.01	0.2
Palustrine	Scrub/shrub, broad-leaved evergreen	Seasonal/Unknown non-tidal	0.35	6.7

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. Approximately 39 percent of the unit is predominately native species with little or no alien species.

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

Canopy Type	Area (mi²)	Percent of Unit
Communities totally dominated by native species of plants	2.06	39.3
Communities that have the dominant vegetation layer occupied by native species and the subdominant layer primarily occupied by exotic species	0.18	3.3
Communities dominated by introduced species but contain remnant populations of native species; no native community structure remaining	0.12	2.2
Communities that are totally dominated by introduced plants; virtually no native species remaining	0.53	10.1
Non-vegetated areas or disturbance not determined	0.14	2.6
Unknown	1.25	23.9

Based upon the current designations, the Waikamoi hydrologic unit contains critical habitat areas for ten plant species (Table 6-6).

Table 6-6. Percentage of critical habitat areas for Waikamoi hydrologic unit (Source: State of Hawaii, Office of Planning, 2004b).

Scientific Name	Common/Hawaiian Name	Description	Area (mi²)	Percent of Unit
Argyroxiphium sandwicense ssp. macrocephalum	Silversword, ʻAhinahina	Plant	0.76	14.6
Asplenium fragile var. insulare	No common name	Plant	< 0.01	< 0.1
Brighamia rockii	Pua ʻala	Plant	0.01	0.2
Cyanea copelandii ssp. haleakalaensis	Haha	Plant	0.12	2.3
Cyanea hamatiflora ssp. hamatiflora	No common name	Plant	0.87	16.7
Cyanea mceldowneyi	No common name	Plant	0.80	15.2
Diplazium molokaiense	No common name	Plant	0.21	3.9
Geranium multiflorum	Nohoanu	Plant	0.03	0.6
Phlegmariurus mannii	Wawaeʻiole	Plant	0.01	0.1
Phyllostegia mannii	No common name	Plant	0.46	8.8

The density of threatened and endangered plant species is high at elevations above 1,300 feet, while the rest of the Waikamoi hydrologic unit, roughly 15 percent, has a low concentration of threatened and endangered plant species at lower elevations (Table 6-7 and Figure 6-4).

Table 6-7. Density of threatened and endangered plants for Waikamoi hydrologic unit. (Source: State of Hawaii, Office of Planning, 1992).

Density	Area (mi^2)	Percent of Unit
High concentration of threatened and endangered species	4.44	84.6
Low concentration of threatened and endangered species	0.81	15.4

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 Oahu Koolau forests, a benchmark level of degradation is first defined for comparison against the current value of the Oahu Koolau system. The Oahu 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 [Oahu] Forest Amenities." These values are presented in Table 6-6 below.

Table 6-8. Estimated Net Present Value (NPV) for Koolau (Oahu) 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 Oahu 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 Oahu 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 Waikamoi hydrologic unit (Source: State of Hawaii, Office of Planning, 2003; 2007b; USGS, 2001b).

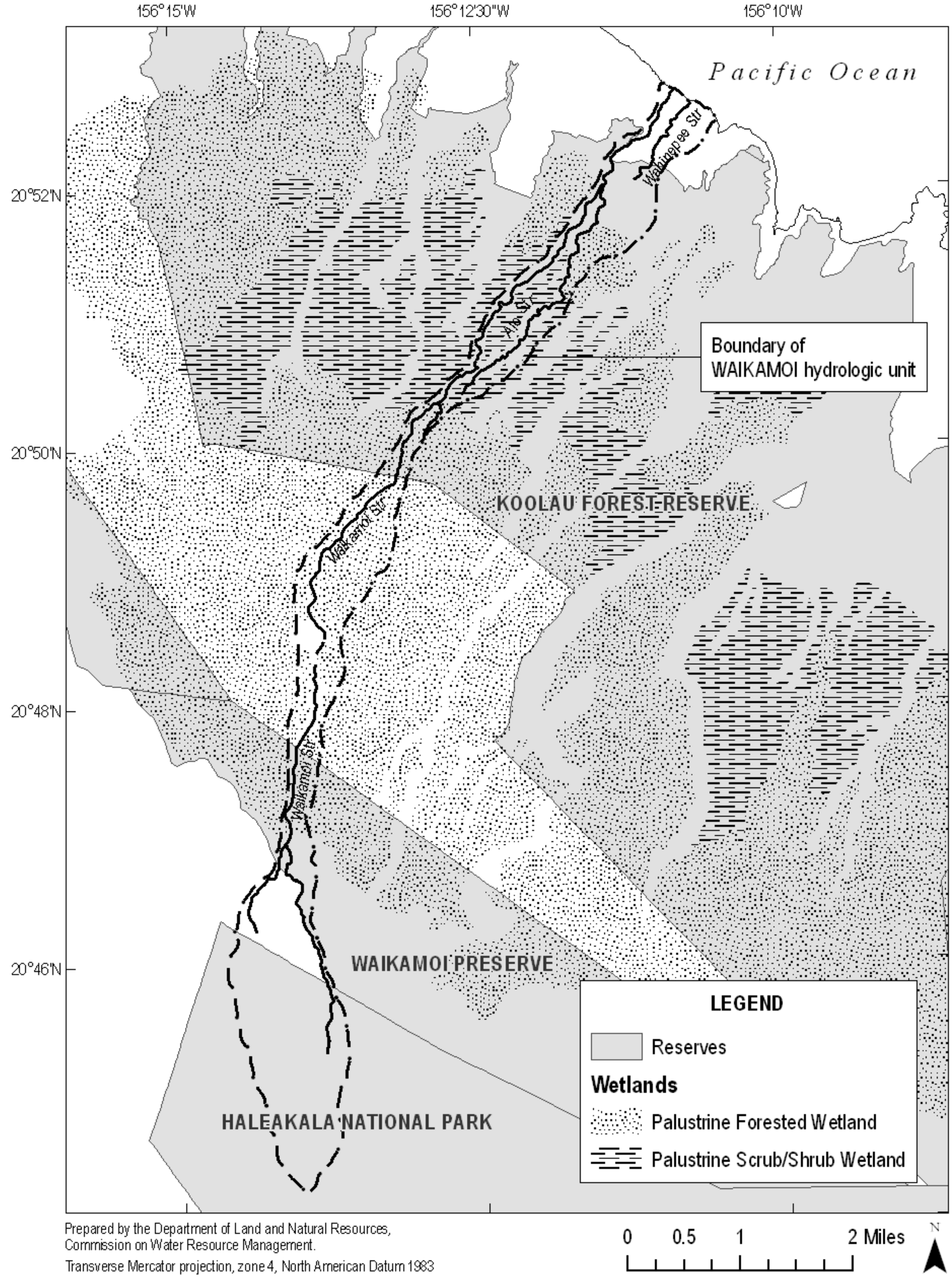


Figure 6-3. Distribution of native and alien plant species for Waikamoi hydrologic unit (Source: Jacobi, 1989; Scott et al., 1986; State of Hawaii, Office of Planning, 1992, 2004b; 2004d; USGS, 2001b).

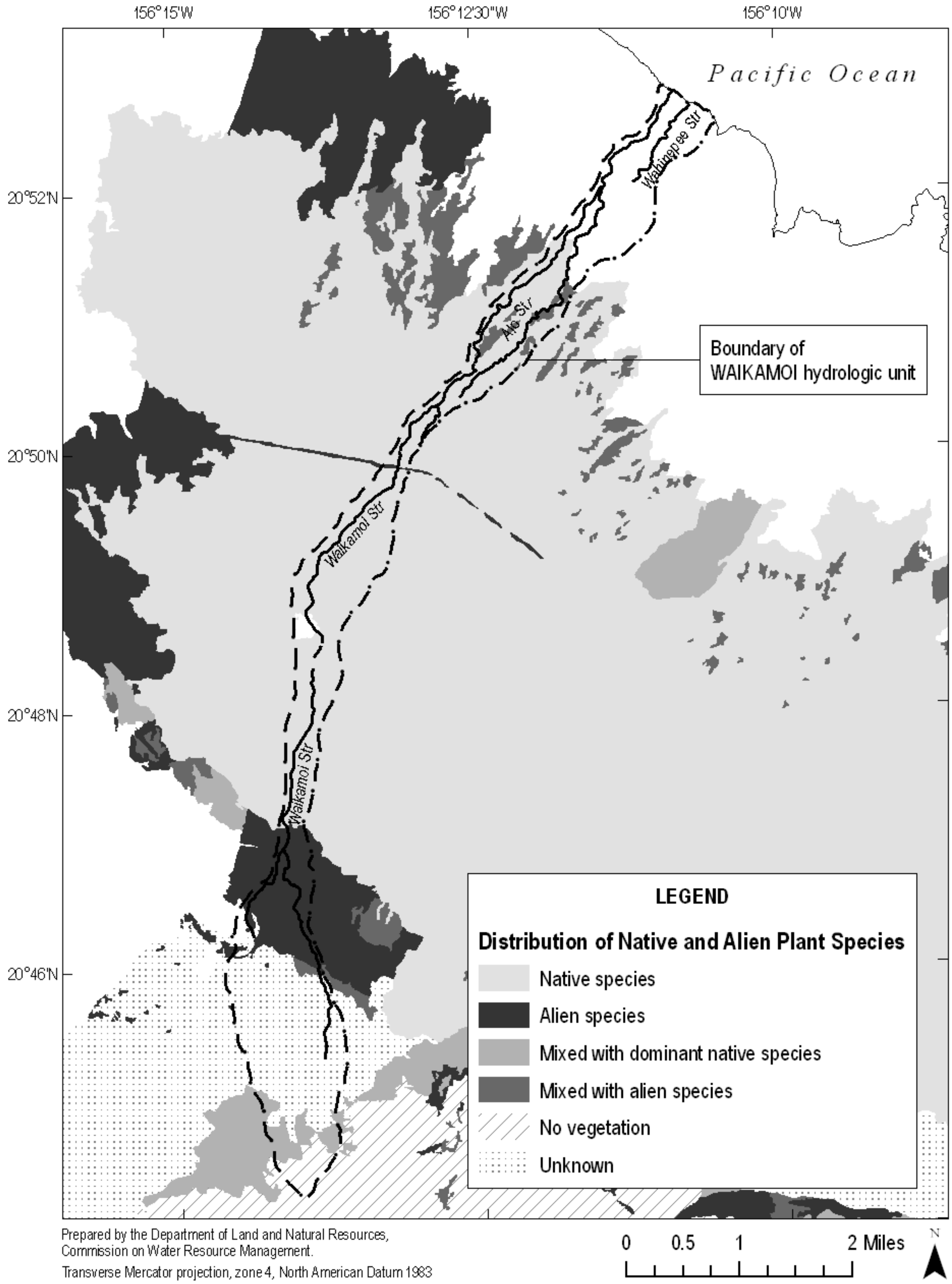
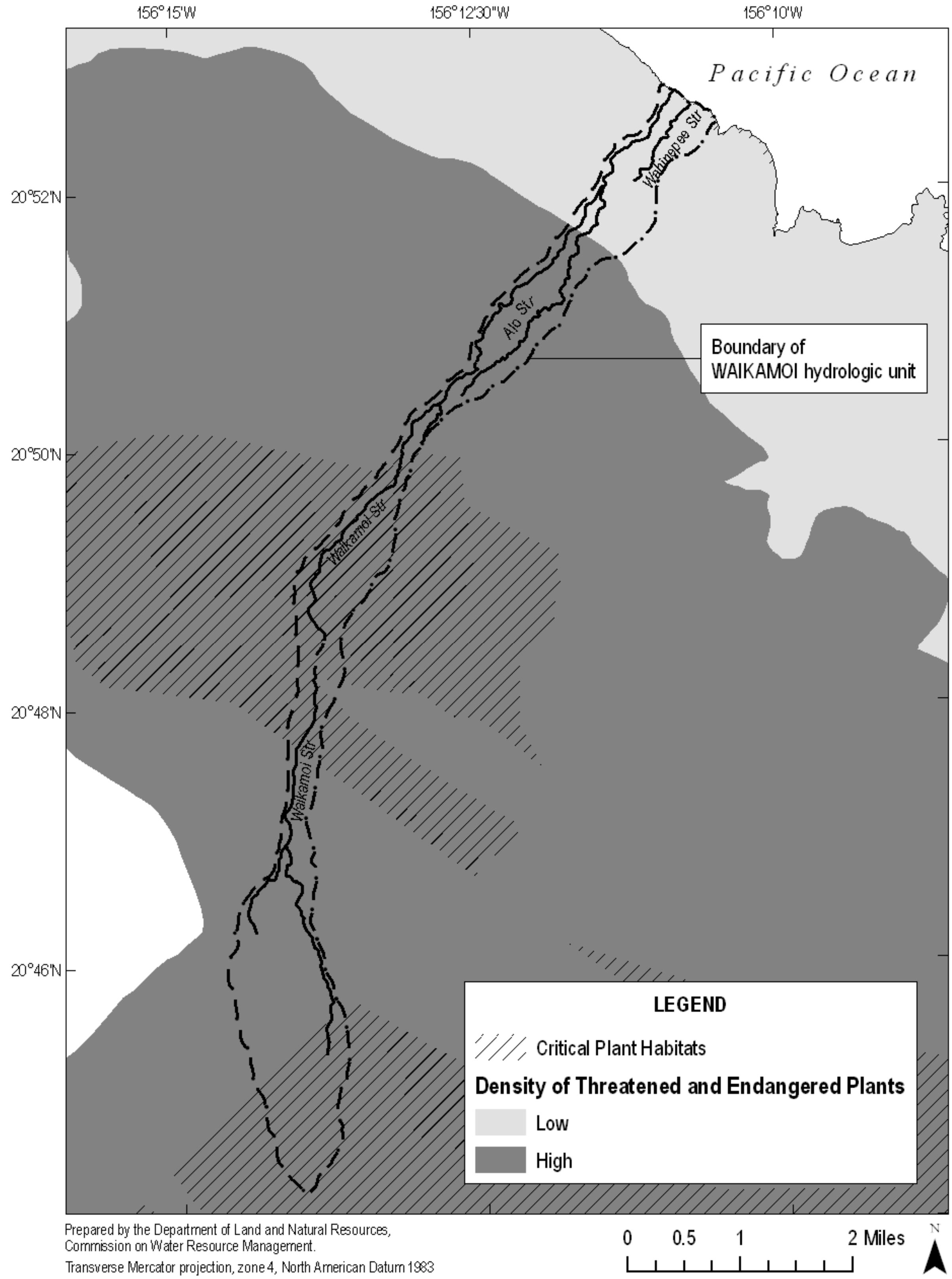


Figure 6-4. Critical plant habitats, and density of threatened and endangered plant species for Waikamoi hydrologic unit (Source: Jacobi, 1989; Scott et al., 1986; State of Hawaii, Office of Planning, 1992, 2004b; 2004d; USGS, 2001b).



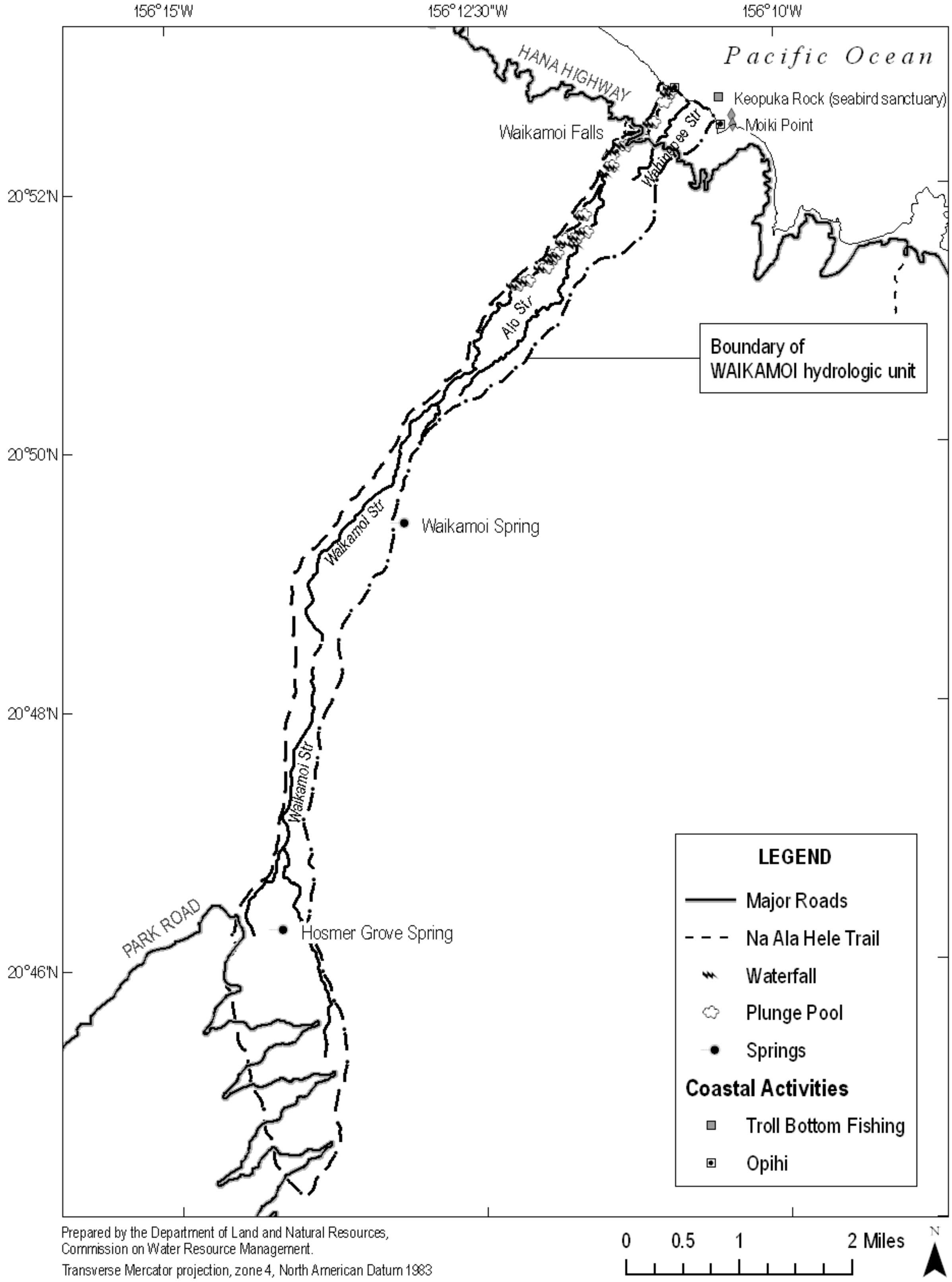
7.0 Aesthetic Values

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 auditory senses, such as waterfalls and cascading plunge pools. Several assumptions were made in identifying the elements that give Waikamoi Stream and Wahinepee Stream a particular aesthetic quality.

The headwaters of Waikamoi Stream originate in Haleakala National Park where vegetation is predominately native shrub lands with sparse alien grasses. In the intermediate slopes of the hydrologic unit, Waikamoi Stream flows through native communities of Ohia forests and Uluhe shrub lands that lie within the Waikamoi Preserve and Koolau Forest Reserve. The lower elevations are mostly alien forests of the Koolau Forest Reserve. The surrounding vegetation for Wahinepee Stream is predominately alien forests. A number of waterfalls and plunge pools are located along the lower reaches of Waikamoi Stream, which provide great scenic spots for the public. Among the many waterfalls is Waikamoi Falls that is about 70-foot high and it can be seen from Hana Highway. There are two springs in the hydrologic unit, Hosmer Grove Spring at the 6,560 feet altitude near the headwaters and Waikamoi Spring at 3,200 feet altitude. Keopuka Rock, a State seabird sanctuary, can be seen from the shoreline of the hydrologic unit (Figure 7-1).

In a 2007 Hawaii State Parks Survey, released by the Hawaii Tourism Authority (OmniTrak Group Inc., 2007), 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 Waikamoi Stream crosses Hana Highway there may be opportunities for scenic enjoyment.

Figure 7-1. Aesthetic points of interest for the Waikamoi hydrologic unit (Source: USGS, 1996; 2001b).



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 (State of Nevada, Department of Conservation and Natural Resources, 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 Waikamoi 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.

Considering the definition of instream hydropower generation, there are no known true instream hydropower systems located on Waikamoi Stream, Alo Stream and Wahinepee 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* (1996), describes 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 a 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.

HC&S continues to operate three run-of-river hydroelectric facilities on the Wailoa Ditch, which is supplied with water from several sources including Waikamoi Stream, Alo Stream and Wahinepee Stream. Power generated from these facilities is used to satisfy sugar mill power requirements first, while remaining electricity not used by the mill is sold to Maui Electric Company (MECO). According to MECO, power is sold as available, with an estimated oil savings of 16,200 barrels per year. The hydraulic turbine generators located at the Kaheka, Paia, and Hamakua facilities on the Wailoa Ditch are capable of producing 4.5 megawatts, 1.1 megawatts, and 150 kilowatts, respectively (Hew, personal communication, August 2009).

An “Amended and Restated Power Purchase Agreement” between HC&S and MECO, dated 1989, details the terms. “Force Majeure” events are listed in the agreement, releasing HC&S from their obligation to provide the agreed-upon amount of power to MECO if events beyond their control prevent them from delivering energy (Alexander and Baldwin [A&B] Hawaii and Maui Electric Company, Limited, 1989). Therefore, an order to reduce ditch flow may release HC&S and MECO from this agreement, thereby reducing the amount of power that MECO can provide to its customers.

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 traditional and customary Hawaiian rights. There are several factors that affect a stream's water quality, including physical, chemical, and biological attributes. The State of Hawaii Department of Health (DOH) is responsible for water quality management duties statewide. The DOH Environmental Health Administration oversees the collection, assessment, and reporting of numerous water quality parameters in three high-priority categories:

- Possible presence of water-borne human pathogens;
- Long-term physical, chemical and biological components of inland, coastal, and oceanic waters; and
- Watershed use-attainment assessments, identification of sources of contamination, allocation of those contributing sources, and implementation of pollution control actions.

The Environmental Health Administration is also responsible for regulating discharges into State waters, through permits and enforcement actions. Examples include federal National Pollutant Discharge Elimination System (NPDES) permits for storm water, and discharge of treated effluent from wastewater treatment plants into the ocean or injection wells.

Sediment and temperature are among the primary physical constituents of water quality evaluations. They are directly impacted by the amount of water in a stream. The reduction of streamflow often results in increased water temperatures, whereas higher flows can aid in quickly diluting stream contamination events. According to a book published by the Instream Flow Council, "[w]ater temperature is one of the most important environmental factors in flowing water, affecting all forms of aquatic life (Amear et al, 2004)." While this statement is true for continental rivers, fish in Hawaii are similar, but their main requirement is flowing water. Surface water temperatures may fluctuate in response to seasonal and diurnal variations, but only a few degrees Celsius in natural streams, mainly because streams in Hawaii are so short. However, temperatures in streams with concrete-lined channels, and dewatered streams, may fluctuate widely due to the vertical solar contact. Surface water temperatures may also fluctuate widely due to 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).

Water body types can be freshwater, marine, or brackish. They can be further delineated as inland fresh waters, estuaries, embayments, open coastal waters, and oceanic waters (HAR 11-54-5 to 11-54-6). Each water body type has its own numeric criteria for State of Hawaii Water Quality Standards (WQS).

Fresh waters are classified for regulatory purposes, according to the adjacent land's conservation zoning. There are two classes for the inland fresh waters. 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.

Class 1 waters are further separated into Classes 1a and 1b. Class 1a waters are protected for the following uses: scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other non-degrading uses which are compatible with the protection of the ecosystems associated with waters of this class. Streams that run through natural reserves, preserves, sanctuaries, refuges, national and state parks, and state or federal fish and wildlife refuges are Class 1a. Streams adjacent to the most environmentally sensitive conservation subzone, "protective" are Class 1b, and are protected for the same uses as Class 1a waters, with the addition of domestic water supplies, food processing, and the support and propagation of aquatic life (HAR 11-54-3). These classifications are used for regulatory purposes, restricting what is permitted on the land around receiving waters. For example, public access to Class 1b waters may be restricted to protect drinking water supplies.

Land use affects water quality because direct runoff (rainfall that flows overland into the stream) can transport sediment and its chemical contaminants into the stream. According to the U.S. Environmental Protection Agency (EPA), "[a] TMDL or Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. Water quality standards are set by States, Territories, and Tribes. They identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing as well as ecological health), and the scientific criteria required to support those uses. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the State has designated. The calculation must also account for seasonal variation in water quality. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs (EPA, 2008)."

The DOH, Environmental Health Administration maintains the State of Hawaii Water Quality Standards (WQS), a requirement under the Federal Clean Water Act (CWA) regulated by the 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 ensure protection of the physical, chemical, and biological health of their waters. "A water quality standard defines the water quality goals of a water body, or portion thereof, by designating the use or uses to be made of the water and by setting criteria necessary to protect the uses (CWA §131.2)." Each state specifies its own water uses to be achieved and protected ("designated uses"), but CWA §131.10 specifically protects "existing uses", which it defines as "…those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards (CWA §131.3)."[17] Although the State WQS do not specify any designated uses in terms of traditional and customary Hawaiian rights, the "protection of native breeding stock," "aesthetic enjoyment," and "compatible recreation" are among the designated uses of Class 1 inland

[17] Existing uses as defined in the CWA should not be confused with existing uses as defined in the State Water Code, although there is some overlap and linkage between the two. Under the Water Code, if there are serious threats to or disputes over water resources, the Commission may designate a "water management area." Water quality impairments, including threats to CWA existing uses, are factors that the Commission may consider in its designation decisions. Once such a management area is designated, people who are already diverting water at the time of designation may apply for water use permits for their "existing uses." The Commission then must weigh if the existing use is "reasonable and beneficial." The Water Code defines "reasonable-beneficial use" as "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." The relationships between a Commission existing use and a CWA existing use can help determine the appropriateness of the use and its consistency with the public interest.

waters, and "recreational purposes, the support and propagation of aquatic life, and agricultural and industrial water supplies" are among the designated uses of Class 2 inland waters. This means that uses tied to the exercise of traditional and customary Hawaiian rights that are protected by the State Constitution and the State Water Code (Section 12.0, Protection of Traditional and Customary Hawaiian Rights), including but not limited to gathering, recreation, healing, and religious practices are also protected under the CWA and the WQS as designated and/or existing uses. Therefore, the Commission's interim IFS recommendation may impact the attainment of designated and existing uses, water quality criteria, and the DOH antidegradation policy, which together define the WQS and are part of the joint Commission and DOH obligation to assure sufficient water quality for instream and noninstream uses.

State of Hawaii 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 protect 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 concentrations (levels of pollutants) that must be attained based on water body type, e.g. fresh water stream. Qualitative standards are general narrative statements that are applicable to all State waters, 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.

Once data are gathered and evaluated for quality and deemed to be representative of the waterbody segment, a decision is made as to whether the appropriate designated uses are being attained. This set of decisions are then tabulated into a report to the EPA that integrates two CWA sections; (§) 305(b) and §303(d). This Integrated Report is federally required every even-numbered year. CWA §305(b) requires states to describe the overall water quality statewide. They must also describe 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. Additionally, they determine whether the designated uses of a water body segment are being attained, and if not, what are the potential causes and sources of pollution. The CWA §303(d) requires states to submit a list of Water-Quality Limited Segments, which are waters that do not meet state water quality standards and those waters' associated uses. States must also provide a priority ranking of waters listed for implementation of pollution controls, which are prioritized based on the severity of pollution and the uses of the waters. In sum, the §303(d) list leads to action.

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 6 years (State of Hawaii, Department of Health, 2007). 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 (from the 2006 list that was published in 2007), only 74 streams statewide had sufficient data for evaluation of whether exceedence of WQS occurred. Waikamoi Stream appears on the 2006 List of Impaired Waters in Hawaii, Clean Water Act §303(d). While some data exist for the stream, there were not sufficient data for decision-making; therefore, no decision was made pertaining to the attainment of WQS or the applicable designated uses. Wahinepee Stream does not appear on the 2006 List of Impaired Waters in Hawaii, Clean Water Act §303(d).

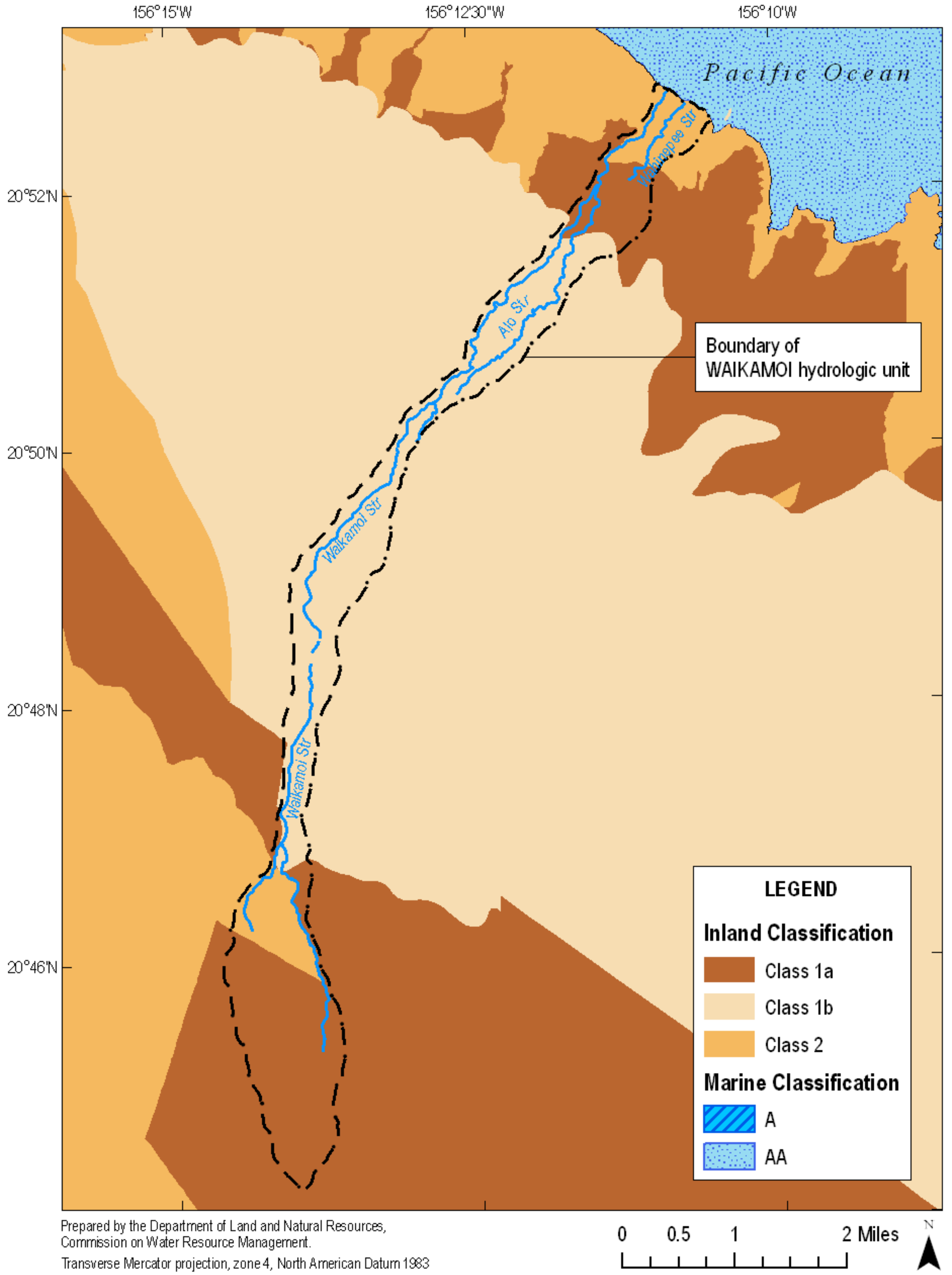
The 2006 Integrated Report indicates that the current WQS require the use of *Enterococci* as the indicator bacteria for evaluating public health risks in the waters of the State; however, no new data were available for this parameter in inland waters. As mentioned in Section 5.0, Outdoor Recreational Activities, DOH maintains WQS for inland recreational waters based on the geo-mean statistic of *Enterococci*: 33 colony-forming units per 100 mL of water or a single-sample maximum of 89 colonies per 100 mL. This is for full-body contact (swimming, jumping off cliffs into waterfall pools, etc.). If *Enterococci* count exceeds those values, the water body is considered to be impaired. DOH Clean Water Branch efforts have been focused on coastal areas (State of Hawaii, Department of Health, 2006, Chapter II, p.20). The marine recreational zone, which extends from the shoreline seaward to 1,000 feet from shore, requires an *Enterococci* geo-mean of less than 7 colony-forming units per 100 mL of water to protect human health (HAR 11-54-8).

The 2006 Integrated Report also states: "Public health concerns may be underreported. *Leptospirosis* is not included as a specific water quality standard parameter. However, all fresh waters 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 fresh water, leading authorities to issue blanket advisories for all fresh waters of the state (State of Hawaii, Department of Health, 2006, Chapter II, p.3)."

Waikamoi Stream is classified as Class 1a inland waters at its headwater tributary that lies in the Haleakala National Park, and in the lower reach that lies within the Koolau Forest Reserve. From the tributary down to approximately 6,100 feet elevation and the short section of the stream near the ocean, Waikamoi Stream is classified as Class 2 inland waters. Between the 6,100 feet and 1,300 feet altitudes, the stream is classified as Class 1b inland waters as parts of the stream lie in the Waikamoi Preserve (upper reaches) and the Koolau Forest Reserve (lower reaches). The headwaters of Wahinepee Stream is classified as Class 1a inland waters as it in the Koolau Forest Reserve, wheres a majority of the stream is classified as Class 2 inland waters. It should be noted that the conservation subzone map utilized for this interpretation is general and elevations are not exact. It should also be noted that there is no direct relationship between elevation and attainment of water quality standards.

Marine water body types are delineated by depth and coastal topography. Open coastal waters are classified for protection purposes from the shoreline at mean sea level laterally to where the depth reaches 100 fathoms (600 feet). Marine water classifications are based on marine conservation areas. 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 Waikamoi hydrologic unit are Class AA waters. Figure 10-1 shows the Waikamoi hydrologic unit, including inland and marine (coastal) water classifications.

Figure 10-1. Water quality standards for the Waikamoi hydrologic unit. (Source: State of Hawaii, Office of Planning, 2002e; 2008). 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.

Neither the State nor the County keeps a comprehensive database of households whose domestic water supply is not part of a municipal system (i.e. who use stream and / or catchment water). The County of Maui Department of Water Supply (DWS) does not have data for water users who are not on the county system and may be using catchment or surface water for domestic use (Ellen Kraftsow, personal communication, June 23, 2008). The State of Hawaii Department of Health Safe Drinking Water Branch administers Federal and State safe drinking water regulations to public water systems in the State of Hawaii to assure that the water served by these systems meets State and Federal standards. Any system which services 25 or more people for a minimum of 60 days per year or has at least 15 service connections is subject to these standards and regulations. Once a system is regulated by the Safe Drinking Water Branch, the water must undergo an approved filtration and disinfection process when it has been removed from the stream. It would also be subject to regulatory monitoring. The DOH Safe Drinking Water Branch does not currently regulate any public water systems in the Waikamoi hydrologic unit.

The Commission's records for the hydrologic unit of Waikamoi indicate that there are a total of 11 registered diversions, of which six are East Maui Irrigation Company (EMI) diversions and four were registered by both EMI and Maui DWS (Upper and Lower Kula Systems). Since EMI and Maui DWS 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. Only one diversion, registered by Puohokamoa Farm (File reference: PUOKAMOA FARM), diverts water for domestic purposes. The diversion, a 1-in. pipe, is also used for watering of livestock, aquaculture, hydroelectric power generation, and irrigation.

More information on the diversions for the Waikamoi hydrologic unit may be found in Tables 13-1 and 13-2 of Section 13.0, Noninstream Uses.

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. Article XII, Section 7 of the State Constitution addresses traditional and customary rights: "The State reaffirms and shall protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by ahupuaʻa tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778, subject to the right of the State to regulate such rights." Case notes listed in this section indicate, "Native Hawaiian rights protected by this section may extend beyond the ahupuaʻa in which a native Hawaiian resides where such rights have been customarily and traditionally exercised in this manner. 73 H.578, 837 P.2d 1247."

It is difficult to fully represent in words the depth of the cultural aspects of streamflow, including traditions handed down through the generations regarding gathering, ceremonial and religious rites, and the ties to water that are pronounced in Hawaiian legend and lore. "There is a great traditional significance of water in Hawaiian beliefs and cultural practices…The flow of water from mountain to sea is integral to the health of the land. A healthy land makes for healthy people, and healthy people have the ability to sustain themselves (Kumu Pono Associates, 2001b, p.II:8)."

Taro cultivation is addressed in this section of the report as well as the next section, 13.0 Noninstream Uses. This is because instream flow standards take into account both social and scientific information. For sociological and cultural purposes, taro cultivation can be considered an instream use as part of the "protection of traditional and customary Hawaiian rights," that is specifically listed as an instream use in the Water Code. Taro cultivation can also be considered a noninstream use since it removes water from a stream (even if water from taro loi is later returned to the stream). It could be argued that for scientific analysis, taro cultivation is an instream use since taro loi provide habitat for stream biota, but because the water is physically taken out of the stream, it is also a noninstream use. Another way to look at the approach of indentifying taro cultivation as both instream and noninstream uses is that when the Commission addresses taro cultivation as an instream use, it is generally in the context of traditional and customary Hawaiian rights; whereas when the Commission addresses taro cultivation as a noninstream use, it is approaching the issue from the aspects of agriculture and water use.

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, Maintenance of Ecosystems, 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 includes parts of the ahupuaa of East Makaiwa, Haiku Uka, and Kalialinui as shown in Figure 12-2.

An appurtenant water right is a legally recognized right to a specific amount of surface freshwater – usually from a stream – on the specific property that has that right. This right traces back to the use of water on a given parcel of land at the time of its original conversion into fee simple lands: When the 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 if water was being used on that land at or shortly before the time of the Mahele (State of Hawaii, Commission on Water Resource Management, 2007).

An appurtenant right is different from a riparian right, but they are not mutually exclusive. Riparian rights are held by owners of land adjacent to a stream. They and other riparian landowners have the right to reasonable use of the stream's waters on those lands. Unlike riparian lands, the lands to which appurtenant rights attach are not necessarily adjacent to the freshwater source (i.e., the water may be carried to the lands via auwai or ditches), but some pieces of land could have both appurtenant and riparian rights.

Appurtenant rights are provided for under the State Water Code, HRS §174C-101, Sections (c) and (d), as follows:

- Section (c). 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.

- Section (d). 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 2008 Water Resource Protection Plan – *Public Review Draft* as follows:

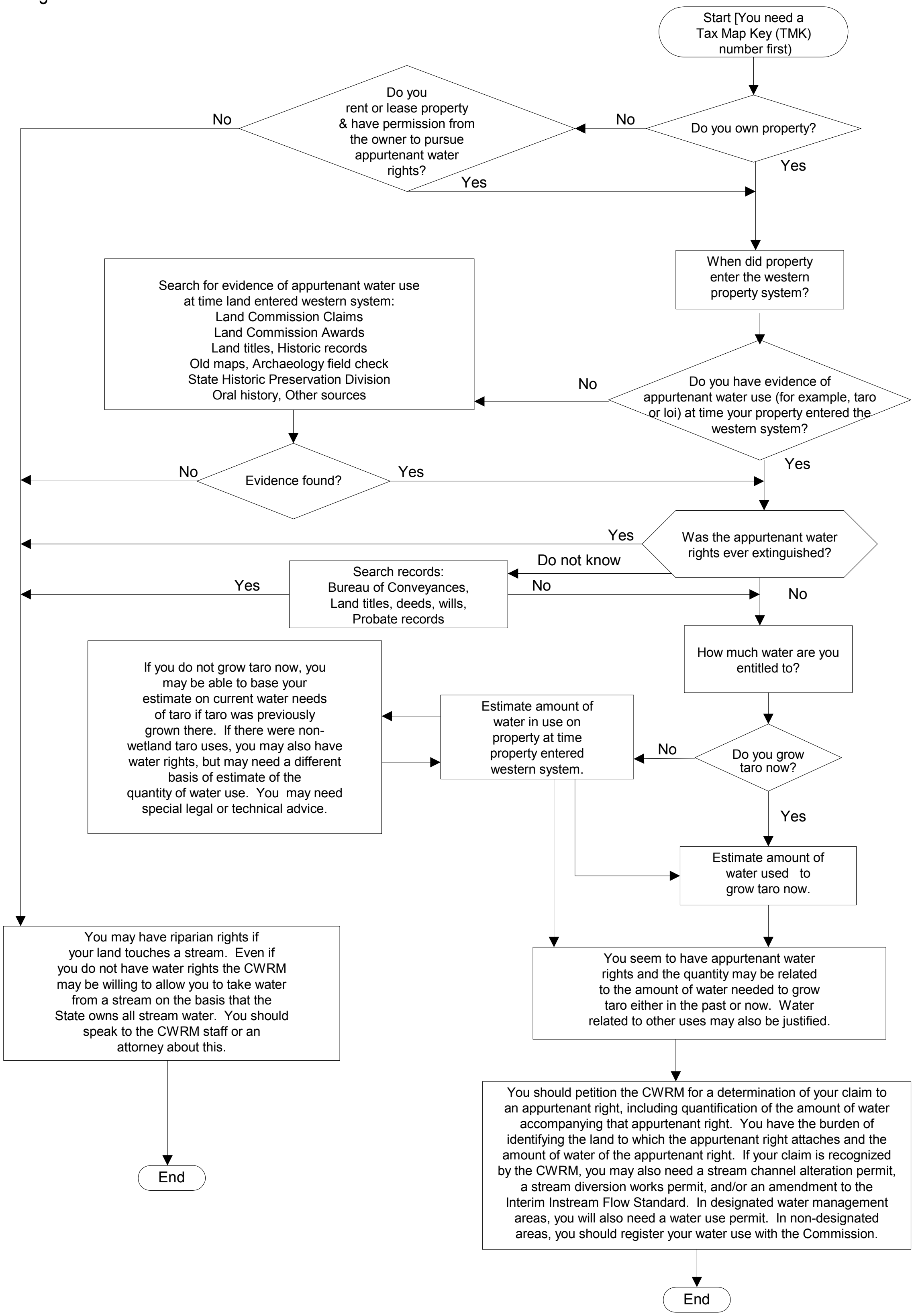
> Appurtenant water rights are rights to the use of water utilized by parcels of land at the time of their original conversion into fee simple lands i.e., when land allotted by the 1848 Mahele was confirmed to the awardee by the Land Commission and/or when the Royal Patent was issued based on such award, the conveyance of the parcel of land carried with it the appurtenant right to water.[18] 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.[19] Once established, future uses are not limited to the cultivation of traditional products approximating those utilized at the time of the Mahele[20], 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

[18] 54 Haw. 174, at 188; 504 .2d 1330, at 1339.
[19] 65 Haw. 531, at 554; 656 P.2d 57, at 72.
[20] *Peck v Bailey*, 8 Haw. 658, at 665 (1867).

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.

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 Waikamoi. In addition to the 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 Waikamoi hydrologic unit.

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

TMK	Landowner	LCA	Grants/Leases	Notes
(2)1-1-001:022	East Maui Irrigation Co. Ltd. /Etal	none	Gr. 2916	
(2)1-1-001:024	East Maui Irrigation Co. Ltd. /Etal	3715-B:2	none	
(2)1-1-001:025	East Maui Irrigation Co. Ltd. /Etal	none	Gr. 3060	Gr. 3060 applies to parcels 25 and 26.
(2)1-1-001:026	East Maui Irrigation Co. Ltd. /Etal	none	Gr. 3060	Gr. 3060 applies to parcels 25 and 26.
(2)1-1-001:028	East Maui Irrigation Co. Ltd. /Etal	none	Gr. 1395:6	
(2)1-1-001:029	East Maui Irrigation Co. Ltd. /Etal	none	Gr. 3394	
(2)1-1-001:031	State of Hawaii /Etal Alexander, Larry George /Etal	3957-B:3:I	G.L. S-3699	
(2)1-1-001:050	State of Hawaii /Etal A&B Properties, Inc /Etal	none	G.L. 3578 (por.) (Water license)	
(2)2-3-005:003	Haleakala Ranch Co.	5230	Gr. 3502 Gr. 3515 (por.)	
(2)2-3-005:004	Haleakala Ranch Co.	7124	none	
(2)2-4-016:004	East Maui Irrigation Co. Ltd. /Etal	none	Gr. 182	
(2)2-9-014:001	State of Hawaii	none	G.L. 3578 (por.) (Water license)	

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).

Among its comments during the preparation of previous IFSARs for east Maui, Native Hawaiian Legal Corporation (NHLC) submitted testimony from 2001 relating to taro cultivation and gathering practices in east Maui streams. The pre-printed forms were completed by several east Maui residents. The information relating to taro cultivation is presented in Table 12-2 (See PR-2008-07). No testimony specifically identifies the hydrologic unit of Waikamoi.

Table 12-2. Summary of the 2001 testimonies submitted by NHLC related to taro cultivation.

Declarant (CPRC Reference)	Stream Adjacent To Property	Stream Adjacent To Property Where Kalo Is Grown	Stream Source For Auwai Adjacent To Property	Stream Source For Auwai Adjacent To Property Where Kalo Is Grown	Streams Where Kalo Would Be Grown If Water Were Available
Charles L. Barclay (CPRC 29.2-3)	Wailuanui	Lakini	Lakini	Kualani, Waiokamilo (Kamilo)	Makapipi
	<u>Problem Statement (Kalo):</u> "No constant water flow. Also because of lack of water flow at Lakini we are unable to open all of our patches at Wailua-Nui."				
Awapuhi Carmichael (CPRC 29.2-55)					
Daniel Carmichael (CPRC 29.2-33)					
Puanani Holokai (CPRC 29.2-17)	(lease) Piinaau & Palahulu	(lease) Piinaau & Palahulu	(lease) Piinaau & Palahulu	(lease) Piinaau & Palahulu	
Cindy Ku'uipo Ka'auamo (CPRC 29.2-21)	Waiokamilo			Waiokamilo, Kulani, Wailuanui, Palauhulu, Piinaau	
Darlene Kaauamo (CPRC 29.2-19)	Waiokamilo			Waiokamilo, Kulani, Wailuanui, Palauhulu, Piinaau	
Frances Kaauamo (CPRC 29.2-45)			Waikani		
Hannah K. Kaauamo (CPRC 29.2-27)	Ka'amilo (Wai O'Ka Milo)	La'Kine, Wai O'Ka Milo, Kulani	Wai'Lua'Nui, Wai'O'Kamilo	La'Kine, Wai'Lua'Nui, Kulani, Wai Kani, Wai O'Ka Milo,	Wai'Lua'Nui
	<u>Problem Statement (Kalo):</u> "There is not enough water flowing through the streams, - That is one of the reason why we have a lot diseases destroying our taro - We have to depend on the rain to get more water flow - In the above streams but some of the stream have no life (note enough flow)."				

Table 12-2. Continued. Summary of the 2001 testimonies submitted by NHLC related to taro cultivation.

Declarant (CPRC Reference)	Stream Adjacent To Property	Stream Adjacent To Property Where Kalo Is Grown	Stream Source For Auwai Adjacent To Property	Stream Source For Auwai Adjacent To Property Where Kalo Is Grown	Streams Where Kalo Would Be Grown If Water Were Available
Leolani R. Kaauamo (CPRC 29.2-41)	Ka'a Hiio (?)	Laikaine-moii (?, illegible)	Wailuanui, Waiokamoii	Wailuanui, Waiokamoii, Lakai, Waiokani	Wailuanui
	Problem Statement (Kalo): "Water was constructed by the State of HI but insufficient water to feed way water has diminished since not enough water to fill 8" of pipe on a continuous flow."				
Mary Kaauamo (CPRC 29.2-43)			Wailuanui and Waiokamilo	Wailuanui and Waiokamilo	
Samuel E. Kaauamo (CPRC 29.2-25)	Lakini, Kaamilo	Lakini, Kaamilo	Lakini, Kaamilo	Lakini, Kaamilo	Lakin, Kamilo
Solomon Kaauamo Jr. (CPRC 29.2-29)	Kaamilo (Waiokamilo)	Lakini, Kulani, Waiokamilo, Wailuanui	Wailuanui, Waiokamilo	Wailuanui, Waiokamilo, Lakini, Kulani	Wailuanui
	Problem Statement (Kalo): "Water way was constructed by the State of HI, but insufficient water to feed water way. Water has diminished since. Not enough water to fill 8" of pipe, on a continuous flow."				
Gladys Kanoa (CPRC 29.2-31)	Waiokamilo, Piinaau, Palauhulu, Kulani	Waiokamilo, Piinaau, Palauhulu, Kulani	Waiokamilo, Piinaau, Palauhulu, Kulani	Lakini, Makilo, Waiokamilo, Palauhulu, Kualani	
Jerome Kekiwi, Jr. (CPRC 29.2-49)	Lakini, Kulani, Kamilo	Wai O Kamilo, Lakini, Kulani	Wai O Kamilo, Lakini, Kulani		Waikau, Wailua
	Problem Statement (Kalo): "The water is unable to reach the land because there is no access or irrigation to go to the kalo patch."				
Puaala Kekiwi (CPRC 29.2-47)			(lease) Kulani, Waiokamilo	Kulani, Waiokamilo	
Chauncey K. Kimokeo (CPRC 29.2-5)			Palahulu	Keanae Flume	
Ihe Kimokeo (CPRC 29.2-11)			Palahulu	Keanae Flume	
Lincoln A. Kimokeo (CPRC 29.2-9)			Palahulu	Palahulu	Kolea to Makapipi
	Problem Statement (Kalo): "Because of low water pressure water is unable to reach loi furthest from flume catchments and production is minimal and could be of higher quality. This prevents all kalo farmers & residents of this ahupua'a from utilizing all of the resources in this ahupua'a and making higher productivity depending on the streams."				
Pualani Kimokeo (CPRC 29.2-7)			Palahulu	Palahulu	Any property next to me
	Problem Statement (Kalo): "We need constant flowing water at all times. Patches next to the flume catch is more likely to have a better growth than the patches at the end cause the water pressure gets smaller and warmer."				
Willie K. Kimokeo (CPRC 29.2-13)	Palahulu	Keanae Flume	Keanae Flume	Keanae Flume	

Table 12-2. Continued. Summary of the 2001 testimonies submitted by NHLC related to taro cultivation.

Declarant (CPRC Reference)	Stream Adjacent To Property	Stream Adjacent To Property Where Kalo Is Grown	Stream Source For Auwai Adjacent To Property	Stream Source For Auwai Adjacent To Property Where Kalo Is Grown	Streams Where Kalo Would Be Grown If Water Were Available
Norman D. Martin Jr. (CPRC 29.2-15)	Waikane, Kulani, Waiokamilo	Waikane, Kulani, Waiokamilo	Waikane, Kulani, Waiokamilo	Waikane, Kulani, Waiokamilo	Waikane
	<u>Problem Statement (Kalo):</u> "Lack of water."				
B. Tau-a M. Pahukoa (CPRC 29.2-51)	Waiakamilo (sic), Piinaua (sic)	Palauhulu, Waiakamilo & Piinaua But [illegible] water from flume that comes from Palauhulu also.	Waiakamilo, Palauhulu, Piinaua & also Waipio	Waiokamilo & Piinaau	Waipio
	<u>Problem Statement (Kalo):</u> "There is lack of water to even push (?) the stream."				
Benjamin Smith Sr. (CPRC 29.2-37)	Wailua Nui		Wailua Nui, Ka Milo		
	<u>Problem Statement (Kalo):</u> "We subsist on whatever water that is not diverted. Since 1985 our streams are dry. We need more water that we are accustomed to before Hawaii became a state."				
Lucille L. Smith (CPRC 29.2-39)	Wailua Nui		Wailua Nui, Kamilo		
Edward Wendt (CPRC 29.2-53)	Lakini and Waiokamilo, Kulani	Lakini and Waiokamilo, Kulani	Lakini, Kulani, Waiokamilo	Lakini, Kulani, Waiokamilo	

In 2002, the State Office of Hawaiian Affairs cosponsored a "No Ka Lo'i Conference", in the hopes of 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. Typically, the water in the taro loi is warmer than water in the stream because of solar heating. Consequently, a taro loi needs continuous flow of water to maintain the water temperature at an optimum level. Multiple studies cited in Gingerich, et al., 2007, suggest that water temperature should not exceed 77ºF (25ºC). Low water temperatures slow taro growth, while high temperatures may result in root rot (Penn, 1997). When the flow of water in the stream is low, possibly as a result of diversions or losing reaches, the warmer water in the taro loi is not replaced with the cooler water from the stream at a quick enough rate to maintain a constant water temperature. As a result, the temperature of the water in the taro loi rises, triggering root rot.

The USGS 2007 study 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 (Gingerich, et al., 2007)." 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 12-3. 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 12-3. 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
Median of all measurements		150,000	150,000	150,000		270,000	320,000	210,000

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 12-4 (discharge measurements) and Table 12-5 (water-temperature statistics).

Table 12-4. 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 12-5. 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

The Commission's records for the hydrologic unit of Waikamoi indicate that there are a total of 11 registered diversions, 10 of which are operated by EMI or Maui DWS. The remaining diversion (File reference: PUOKAMOA FARM) was declared for domestic water use purposes, watering of livestock, aquaculture, hydroelectric pwer generation, and irrigation. Water use for taro cultivation is not known. More information on the registered diversions may be found in Table 13-1 of Section 13.0, Noninstream Uses.

Commission staff held a Public Fact Gathering Meeting on April 10, 2008 in Haiku, Maui to gather comments on previous IFSARs for east Maui. Written comments were also accepted over a 3-month period. A great deal of the oral and written testimony addressed traditional and customary rights, including taro cultivation and gathering practices. Dozens of east Maui residents testified that insufficient water in the streams to cultivate as much taro as desired; and that often the water that does flow is too warm, resulting in root rot.

Further, testimony indicated that there is insufficient native fauna for gathering, and the water is also not sufficient for recreation. Testimony before the Board of Land and Natural Resources from May 2001 was also provided, with six long-time east Maui residents all stating that the streamflow in east Maui has diminished within their lifetimes (See PR-2008-07, 29.3-1 through 29.3-12). Some of the same six residents also provided oral testimony on April 10, 2008 and/or in writing. They, and others, state that the reduction in streamflow has impacted their ability to survive off the land and to perpetuate the Hawaiian culture (See PR-2008-07).

As noted earlier, NHLC submitted comments during the preparation of previous IFSARs for east Maui. The testimony from 2001 consisted of a pre-printed form in which people identified information pertaining to taro cultivation and gathering practices in east Maui streams. The information from these forms, as it relates to gathering, is presented in Table 12-6 (See PR-2008-07, 29.2-1 through 29.2-56). No testimony specifically identifies the hydrologic unit of Waikamoi.

Table 12-6. Summary of the 2001 testimonies submitted by NHLC related to gathering practices.

Declarant (CPRC Reference)	What Is Gathered By The Family	Streams Where Gathering Is Practiced	What Would Be Gathered If Water Were Available	Streams Where Gathering Would Be Practiced If Water Were Available
Charles L. Barclay (CPRC 29.2-3)	opae, hihiwai, o'opu	Honomanu to Makapipi	opae, hihiwai, o'opu	Honomanu, Waiokamilo
	Problem Statement (Gathering): "Not enough free-flowing water to maintain the kalo, opae, hihiwai & o'opu."			
Awapuhi Carmichael (CPRC 29.2-55)	opae, hi hi wais, oopu	from Honomanu to Makapipi	opai (?)	Palauhulu, West Wailuaiki
	Problem Statement (Gathering): "As a child we had all the water we needed to gather & grow healthy taro. When Hawaii became a state, our ahupua'a is left with little or no water to grow healthy taro and gather. Our fishing areas are depleted. We need the water for this native (Kanaka maoli) ahupuaa whose people have existed here since time immemorial."			
Daniel Carmichael (CPRC 29.2-33)	opaes, hihiwais, oopu, and a variety of fishes in the ocean	Hanawi - Palauhulu, Piinaau Haepuaena - Wailuanui Stream - Waioka Milo aka Kamilo - Kapa'akea - Waiohue, Kapiliula, Wailuaiki East and West, Makapipi	a variety of species	all streams between Kolea & Kuahiwi
	Problem Statement (Gathering): "We do not have enough water in all streams from Kolea to Kuahiwi Nahiku for us to gather from mountain to ocean and from boundary in the ahupua'a of Keanae - Wailuanui within the Koolau District."			
Puanani Holokai (CPRC 29.2-17)	hihiwai, opae	Makapipi - Honomanu	opae, hihiwai	Palahulu
	Problem Statement (Gathering): "Can not gather opae in Palahulu stream because no water flow."			

Table 12-6. Continued. Summary of the 2001 testimonies submitted by NHLC related to gathering practices.

Declarant (CPRC Reference)	What Is Gathered By The Family	Streams Where Gathering Is Practiced	What Would Be Gathered If Water Were Available	Streams Where Gathering Would Be Practiced If Water Were Available
Cindy Ku'uipo Ka'auamo (CPRC 29.2-21)	opae, hi'iwai, prawns, o'opu, gold fish, haha	Makapipi to Honomanu	opae, hi'iwai	Wailuanui, Waiokamilo, Kulani, Palauhulu, Piinaau, Honomanu
	<u>Problem Statement (Gathering):</u> "Water is a source of life to land and man. It is not for man to possess, but simply for man to use. However, the right to use water depends entirely upon the use of it. The people of Keanae-Wailuanui Ahupua'a have respected the rights of water use for many generations. Our ancestors have taught us that water is of great value. Without it there is no life. "The decrease of water flow affects all life in, around and on this land. It prevents spawning of 'opae & 'o'opu, disrupting the natural process of reproduction resulting in decrease food supply. In addition, making it harder for people to gather. "Insufficient water flow decreases water temperature causing stagnation, allowing small ponds to become host of bacteria, spreading disease among striving creatures, plant life and even man. "Finally, the interruption of natural water flow affects taro. Diseases, foreign pest, decrease in production, frustration among farmers and a threat to our Hawaiian Culture as well as our way of life. "Like our ancestors, the people of Keanae-Wailuanui Ahupua'a understand the importance of water for all life. Because of this, we have inherited the rights of trusteeship over our natural resources. "Ad a trustee, I ask that you answer this question… Do you value the comfort of man or the life of man?... Think about it and do what is right. Restore our streams… Give life not death!"			
Darlene Kaauamo (CPRC 29.2-19)	opae, hihiwai, haha, prawn, gold fish, prawns	Makapipi to Honomanu	opae, hihiwai, haha, gold fish	Wailuanui, Waiokamilo, Kulani, Palauhulu, Piinaau, Honomanu
	<u>Problem Statement (Gathering):</u> "Insufficient water flow in our streams causes multiple problems. It decreases the production of food supply in our streams, causes an increase of bacteria in the water that remain in our streams causing hazard to the people & life that live in and around that area. Most importantly, it destroys the essence of out lifestyle of a taro farming community by causing damage to our taro."			
Frances Kaauamo (CPRC 29.2-45)				
	<u>Problem Statement (Gathering):</u> "Water flow in streams at times are reduced to 0 which years back the same streams would flow continuously."			
Hannah K. Kaauamo (CPRC 29.2-27)	pohole, leko, polu (?), opai, o'opu, hihiwai, HaHa	Makapipi to Kolea		
Leolani R. Kaauamo (CPRC 29.2-41)	Po-ne (sic), leko, poiup (?), ooipi (?), opoe (opae?), oopu, hihiwai, haha, pula, leko, pohole	Makapip (sic) to Kolea		in most of these streams but not enough water to sustain life
	<u>Problem Statement (Gathering):</u> "Not enough water for oopu to move downstream to spawn. Today there is no oopu."			
Mary Kaauamo (CPRC 29.2-43)			opae, oopu, hihiwai	Wailuanui and Waiokamilo

Table 12-6. Continued. Summary of the 2001 testimonies submitted by NHLC related to gathering practices.

Declarant (CPRC Reference)	What Is Gathered By The Family	Streams Where Gathering Is Practiced	What Would Be Gathered If Water Were Available	Streams Where Gathering Would Be Practiced If Water Were Available
Samuel E. Kaauamo (CPRC 29.2-25)	pupu, kalo, paholi [possibly means pohole?], haha, luau	Kuhiwa - Kolea		Kuhiwai Kolea
	Problem Statement (Gathering): "EMI is taking too much water."			
Solomon Kaauamo Jr. (CPRC 29.2-29)	opae, oopu, hihiwai, pulu, leko, pohole	Makapipi to Kolea		in most of these streams but not enough water to sustain life
	Problem Statement (Gathering): "Not enough water for oopu to move downstream to spawn. Today there is no oopu."			
Gladys Kanoa (CPRC 29.2-31)	hihiwai, opae, oopu, prawns, ahole, mullet	Honomanu to Makapipi	hihiwai, opae, oopu, prawns	Honomanu to Makapipi
	Problem Statement (Gathering): "Most years we have losses to our taro crops due to drought. Water temperatures cannot be maintained cold enough to keep taro healthy. Taro farmers shouldn't have to compete for use of limited water."			
Jerome Kekiwi, Jr. (CPRC 29.2-49)	opae, hihiwai, oopu	from Honomanu to Makapipi	opae, hihiwai, oopu	Kolea, Honomanu
	Problem Statement (Gathering): "When the rain stops, the water flow in Wailua streams drop to almost nothing. It is hard to grow kalo with no water in the patches."			
Puaala Kekiwi (CPRC 29.2-47)	opae, hihiwai, oopu	from Makapipi to Honomanu	opae	Palahulu in Keanae
	Problem Statement (Gathering): "Getting water to a few of our patches when my neighbor doesn't let any water down."			
Chauncey K. Kimokeo (CPRC 29.2-5)	opae, hihiwai, o'opu, ferns, plants	from Kolea to Makapipi		
Ihe Kimokeo (CPRC 29.2-11)	oopu, hihiwai, opae, pig hunting, prons (sic)	Kolea to Makapipi		
Lincoln A. Kimokeo (CPRC 29.2-9)	opae, hihiwai, prawns, Hawaiian herbs, ferns shoots, ti leaves, flowers, plants to make leis	all streams (Kolea to Makapipi)	Everything of use	Kolea to Makapipi
	Problem Statement (Gathering): "Regular water flow once sustained the right environment for great populations of fish and other stream life, today disturbed water flow prevents stream life to increase population."			
Pualani Kimokeo (CPRC 29.2-7)	opae, hihiwai, o'opu, Hawaiian herbs, ferns shoots, ti leaves, flowers, lei making ferns	all streams of the Koolau	Everything	All (along the Koolau Valley)
	Problem Statement (Gathering): "Our kalo growth would be massive if the water was left alone. We would not have all these sickness in our loi. Worked the loi all my life and never did see all the problems on our kalo & water till the years of late 1960 through now."			

Table 12-6. Continued. Summary of the 2001 testimonies submitted by NHLC related to gathering practices.

Declarant (CPRC Reference)	What Is Gathered By The Family	Streams Where Gathering Is Practiced	What Would Be Gathered If Water Were Available	Streams Where Gathering Would Be Practiced If Water Were Available
Willie K. Kimokeo (CPRC 29.2-13)	oopu, hihiwai, opae, water cress, mountain kalo, haha	Kolea to Makapipi	oopu, hihiwai, opae, water cress	Kolea to Makapipi
	Problem Statement (Gathering): "Lack of water."			
Norman D. Martin Jr. (CPRC 29.2-15)	oopu, hihiwai, opai, everything	Kolea to Makapipi	oopu, opai, hihiwai	Kolea to Makapipi
	Problem Statement (Gathering): "Lack of water."			
B. Tau-a M. Pahukoa (CPRC 29.2-51)	opae, hihiwai	from Kolea to Makapipi		from Makapipi to Kolea & Waipio, Honomanu, Wailuaiki & Waialohe which is the muluwai of Palauhulu & Piinaau
	Problem Statement (Gathering): "The problem is not all of the water in the streams meet the sea."			
Benjamin Smith Sr. (CPRC 29.2-37)	opai, hihiwai, oopu	Hanawi, Kapaula, Kopiliula, Kapa'akea, East and West Wailua Iki , Honomanu, Makapipi	opai, hihiwai, oopu	all streams between Kolea & Kuahiwa
Lucille L. Smith (CPRC 29.2-39)	opai, hihiwai & oopu	Hanawi, Makapipi, Kopiliula, Kapa'akea, East and West Wailua Iki , Kapahula, Waiohue, Honomanu	opai, hihiwai, oopu	streams between Kolea & Kuahiwa
Edward Wendt (CPRC 29.2-53)	opae, hihiwai, oopu		opai, hihiwai, oopu	Waiokamilo - Wailua Stream
	Problem Statement (Gathering): "Cause not enough free flowing to enhance aquatic life and to assist in good taro growth."			

Historical uses of Waikamoi 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 Kumu Pono Associates, 2001a), Handy et al., in *Native Planters of Old Hawaii* (1972), provide a limited regional description as follows:

> The northeast coast of East Maui has precipitous shores eroded by the waves which the trade winds sweep against its cliffs, islets, and inlets. Here the flank of Haleakala is steep, and as the trade winds blow up across their forested slopes they are cooled and release their moisture, making this the wettest coastal region in all the islands.
>
> O'opuola Gulch marked the boundary between Hamakua and Ko'olau. Its stream watered small *lo'i* areas, as did likewise Waikamoi, Puohokmaoa, and Haipuaena Streams.
>
> Throughout wet Ko'olau, the wild taro growing along the streams and in the pockets high on the canyonlike walls of the gulches bespeaks former planting of stream taro along the watercourses,

> on the side of the gulches, and in the forest above. The same is true of the wild taros seen here and there in the present forest above the road and in protected spots on what was formerly low forest land, now used as pasture.

The cultural resources of Waikamoi Stream were not classified by the HSA, likely due to a lack of archaeological survey coverage. Data were collected in 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 are only current to 1990, the date of the HSA (Table 12-7).

Table 12-7. Cultural resource elements evaluated as part of the Hawaii Stream Assessment for Waikamoi 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.	None
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

Table 12-7. Continued. Cultural resource elements evaluated as part of the Hawaii Stream Assessment for Waikamoi Stream.

Category	Value
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
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.	Waikamoi Stream 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.	None

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*, there are no fishponds present in the Waikamoi hydrologic unit (DHM, Inc., 1990).

Another component in the assessment of traditional and customary Hawaiian rights is the presence of Department of Hawaiian Home Lands (DHHL) parcels within the surface water hydrologic unit. The mission of DHHL is to effectively manage the Hawaiian Home Lands trust and to develop and deliver land to native Hawaiians (PBR Hawaii, 2004). In September 2004, DHHL published the Maui Island Plan which served to examine infrastructure needs, provide development cost estimates, and identify priority areas for homestead development. Of the more than 31,000 acres of DHHL land on the island of Maui, no parcels occur within the Waikamoi hydrologic unit (Figure 12-3).

Figure 12-2. Traditional ahupuaa boundaries in the vicinity of Waikamoi hydrologic unit. This hydrologic unit spans three ahupuaa — East Makaiwa, Haiku Uka, and Kalialinui (Source: State of Hawaii, Office of Planning, 2007a; USGS, 2001b).

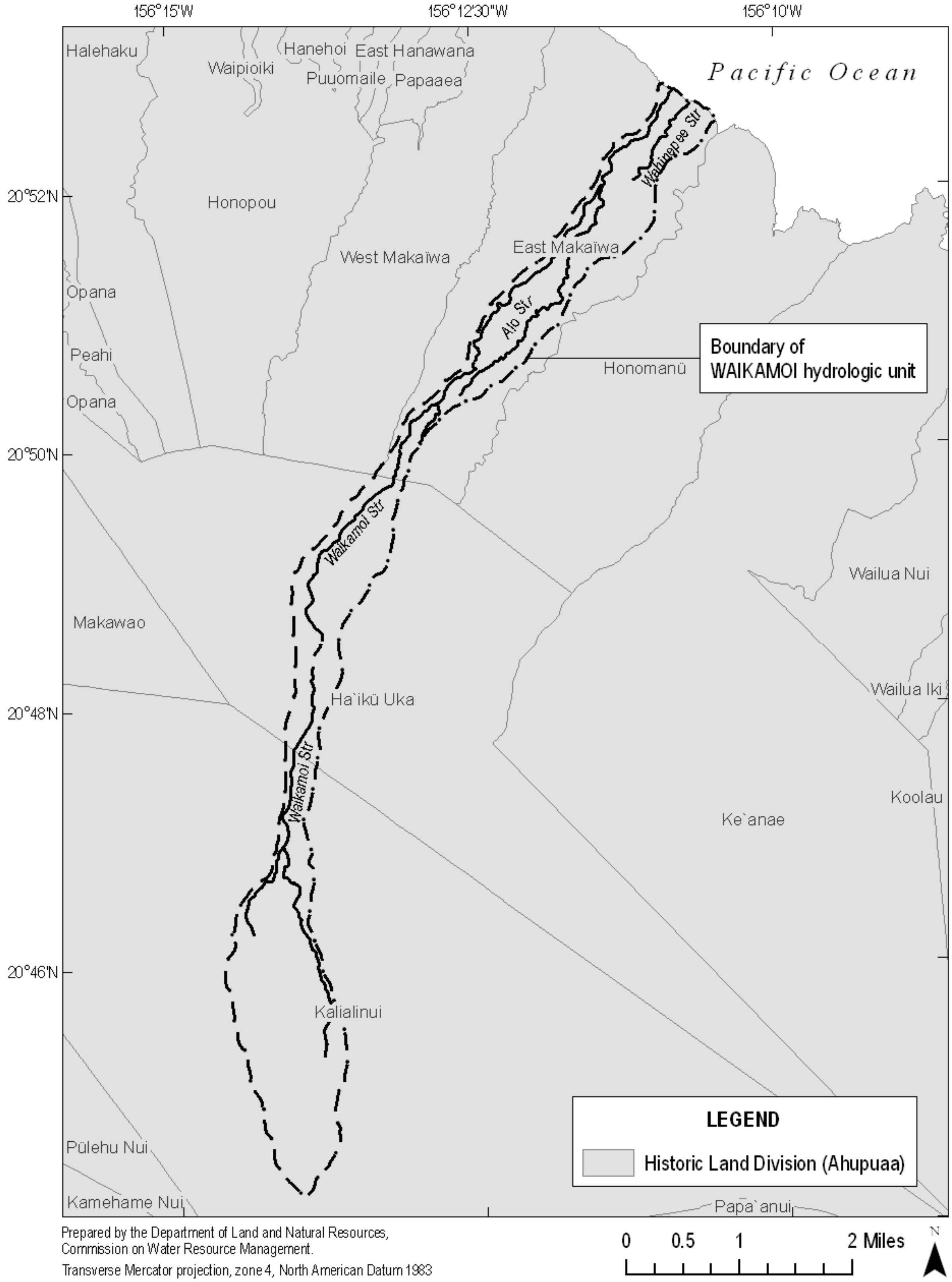
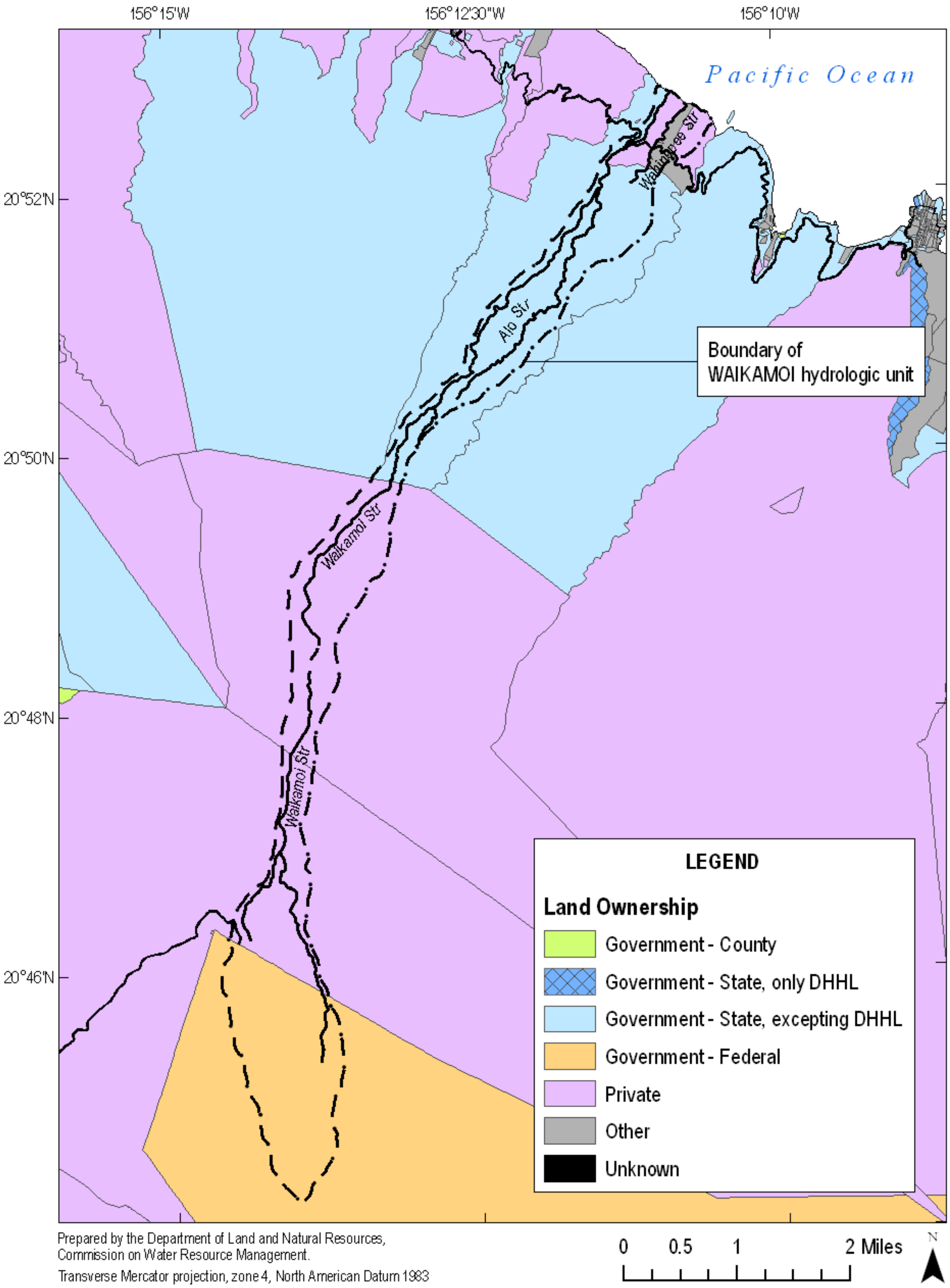


Figure 12-3. Land ownership in Waikamoi hydrologic unit (Source: County of Maui, 2006; USGS, 2001b).



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." Article XI, Section 3 of the State Constitution states: "The State shall conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally sustainable lands." Water is crucial to agriculture and agricultural sustainability. Article XI, Section 3 also states, "Lands identified by the State as important agricultural lands needed to fulfill the purposes above shall not be reclassified by the State or rezoned by its political subdivisions without meeting the standards and criteria established by the legislature and approved by a two-thirds vote of the body responsible for the reclassification or rezoning action. [Add Const Con 1978 and election Nov 7, 1978]." It is the availability of water that allows for the designation of Important Agricultural Lands.

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 from the stream. Water is most often used away from the stream and it is not returned; however, as in the case of taro fields and some hydroelectric plants, water may be returned to the stream at a point downstream of its use. While the return of 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. Additionally, discharge of water from a ditch system into a stream may introduce invasive species.

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. 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 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.

13.1 Stream 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 (i.e., FILEREF) remains the name of the original registrant file (Table 13-1). Locations are depicted in Figure 13-14.

In Waikamoi, East Maui Irrigation Company (EMI) operates three ditch systems, running from east to west, as part of the larger East Maui Irrigation System. Though EMI registered all of its "major" diversions (included in Table 13-1), the Commission did not require EMI to register what the company calls "minor" diversions and instead were provided with maps, lists, and photographs. 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 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 13-14.

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

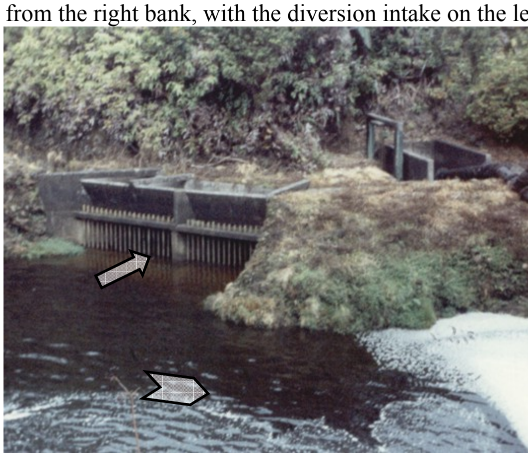
[Source of photos are denoted at the end of each description; CWRM, Commission on Water Resource Management; DAR, Division of Aquatic Resources; EMI, East Maui Irrigation Company, Inc.; RMT, R.M. Towill Corporation (R.M. Towill conducted field verifications on the island of Maui under contract with the Commission on Water Resource Management in late 2007); Arrows (⇨) indicate general direction of water flow to, into, and through noninstream diversions; Chevrons (⋗) indicate general direction of natural surface water flow]

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.149.6	EAST MAUI IRR MAUI DWS	2-4-016:		Yes	No	Yes	No

Water is diverted from Waikamoi Stream at Intake UF-3 into the Upper Kula Water System. Registrant identified water use is municipal. The diversion structure is concrete and has a divertible capacity of 6 mgd. At this point, Waikamoi stream is impounded behind a concrete dam to create an instream reservoir with an estimated capacity of 1 million gallons. Measurement of total flow of the Upper Kula Water System, including this and other intakes, is available from Maui DWS Olinda Water Treatment Facility.

Photos. a) View from atop dam structure in Waikamoi Stream with diversion intake on the left bank, where it passes through a debris gate and is then piped to the Waikamoi Reservoirs (EMI, 05/1989); b) Downstream view from atop the dam structure, looking towards the left bank (CWRM, 04/2009); c) Upstream view from left bank, with water from the flume entering the reservoir on the opposite bank (left) and inflow of Waikamoi stream (right) (CWRM, 04/2009); d) Downstream view from the right bank, with the diversion intake on the left bank (left) and the dam structure (right) (CWRM, 04/2009).

a)



b)

c)

d)

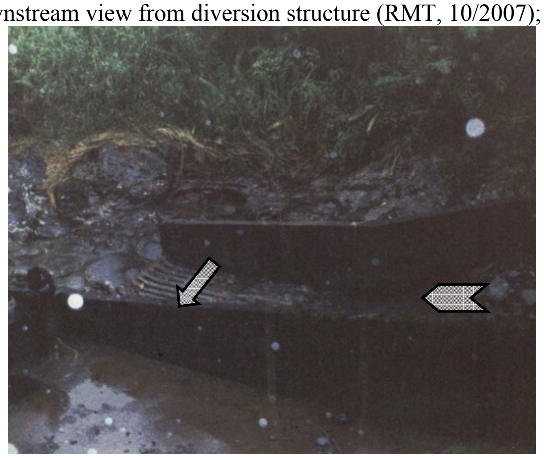
Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.160.6	EAST MAUI IRR	1-1-001:		Yes	No	Yes	No

Water is diverted from Alo Stream at Intake W-1 into the Wailoa Ditch. Registrant identified water use is for municipal (County of Maui), irrigation of approximately 36,000 acres of sugar, pineapple, and a variety of other crops, industrial cooling, manufacturing, and milling, hydroelectric, and livestock. The diversion structure is concrete and has a divertible capacity of 40 mgd. Measurement of total flow of Wailoa Ditch, including this and other intakes, is available from USGS gaging station 16588000 (Wailoa Ditch at Honopou near Huelo).

Photos. a) View of diversion structure from left bank of stream, with Wailoa Ditch running below intake grate perpendicular to streamflow (EMI, 05/1989); b) Downstream view of intake grate from right bank (RMT, 10/2007); c) Downstream view from diversion structure (RMT, 10/2007); d) Upstream view from diversion structure (RMT, 10/2007).

a)



b)

c)

d)

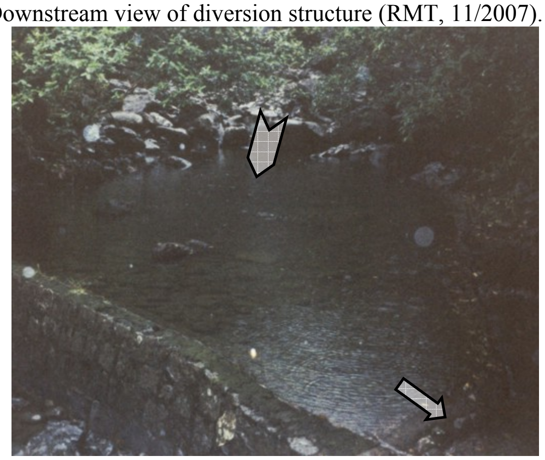
Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.163.6	EAST MAUI IRR	1-1-001:		Yes	No	Yes	No

Water is diverted from Waikamoi Stream at Intake S-10 into the Spreckels Ditch. Registrant identified water use is for irrigation of approximately 36,000 acres of sugar and pineapple, industrial cooling, manufacturing and milling, and livestock. The diversion structure is concrete and has a divertible capacity of 50 mgd. Measurement of total flow of Lowrie Ditch, including this and other intakes, is available from USGS gaging station 16592000 (Lowrie Ditch at Honopou Gulch near Huelo). A note in the record indicates that that Waikamoi Stream water is diverted to Kolea Stream.

Photos. a) Upstream view of concrete –masonry reinforced diversion structure with Wailoa Ditch running below intake grate perpendicular to streamflow (EMI, 05/1989); b) View of diversion structure from left bank of stream (RMT, 11/2007); c) Downstream view of diversion structure (RMT, 11/2007).

a)



b)

c)

d)

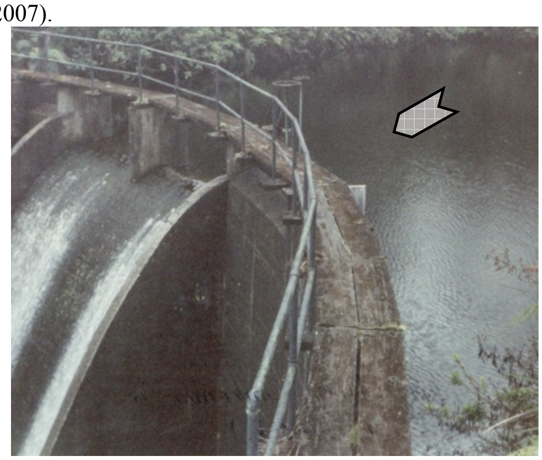
Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.164.6	EAST MAUI IRR MAUI DWS	2-4-016:		Yes	No	Yes	No

Water is diverted from Waikamoi Stream at Intake UF-4 into the Upper Kula Water System. Registrant identified water use is municipal. At this point, Waikamoi stream is impounded behind a concrete dam to create an instream reservoir with an estimated capacity of 10 million gallons. Water is conveyed to the downstream 1 million gallon reservoir (REG.149.6) via an 8-in. steel pipe. Measurement of total flow of the Upper Kula Water System, including this and other intakes, is available from Maui DWS Olinda Water Treatment Facility.

Photos. a) View of dam structure from left bank of stream (EMI, 05/1989); b) Downstream view of spillway (RMT, 11/2007); c) Upstream view from atop dam structure (RMT, 11/2007); d) View of dam structure from left bank (RMT, 11/2007).

a)



b)

c)

d)

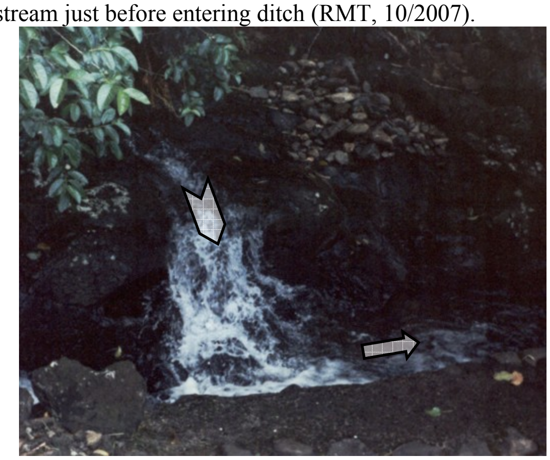
Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.205.6	EAST MAUI IRR	1-1-001:		Yes	No	Yes	No

Water is diverted from Wahinepee Stream at Intake ML-5 into the Manuel Luis Ditch. Registrant identified water use is for irrigation of approximately 36,000 acres of sugar and pineapple, industrial manufacturing and milling, and livestock. The diversion structure is natural and has a divertible flow is uncontrolled. Measurement of total flow of Manuel Luis Ditch, including this and other intakes, is available from USGS gaging station 16592000 (Lowrie Ditch at Honopou Gulch near Huelo).

Photos. a) Upstream view of stream flowing directly into the start of the Manuel Luis Ditch (EMI, 05/1989); b) Upstream view of Wahinepee Stream above ditch (RMT, 10/2007); c) Downstream view of ditch (RMT, 10/2007); d) Upstream view of stream just before entering ditch (RMT, 10/2007).

a)



b)

c)

d)

Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.207.6	EAST MAUI IRR	1-1-001:		Yes	No	Yes	No

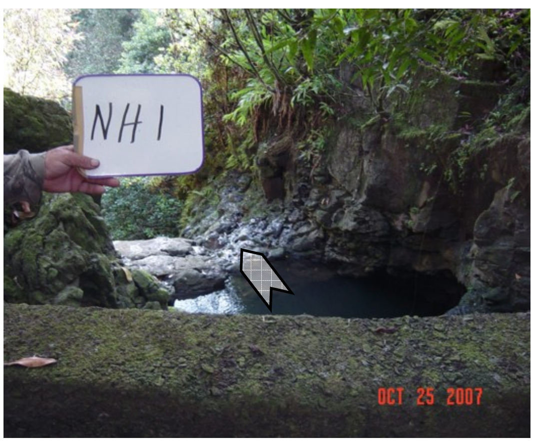
Water is diverted from Alo Stream at Intake NH-1 into the New Hamakua Ditch. Registrant identified water use is for irrigation of approximately 36,000 acres of sugar, pineapple, and a variety of other crops, industrial manufacturing and milling, and livestock. The diversion structure is concrete and has a divertible capacity of 60 mgd. Measurement of total flow of Wailoa Ditch, including this and other intakes, is available from USGS gaging station 16589000 (New Hamakua Ditch at Honopou near Huelo).

Photos. a) View of diversion structure and control gates (EMI, 05/1989); b) View of diversion structure and control gates (RMT, 101/2007); b) ; c) Downstream view from diversion structure (RMT, 10/2007); d) Upstream view from diversion structure (RMT, 10/2007).

a)

b)

c)



d)

Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.228.6	EAST MAUI IRR	1-1-001:		Yes	No	Yes	No

Water is diverted from Waikamoi Stream at Intake C-1 into the Center Ditch. Registrant identified water use is for irrigation of approximately 36,000 acres of sugar and pineapple, industrial manufacturing and milling, and livestock. The diversion structure is concrete and has a divertible capacity of 40 mgd. Measurement of total flow of Lowrie Ditch, including this and other intakes, is available from USGS gaging station 16592000 (Lowrie Ditch at Honopou Gulch near Huelo).

Photos. a) View of diversion structure and control gate from left bank of stream (EMI, 05/1989); b) Upstream view from atop diversion structure (RMT, 10/2007); c) Downstream view from atop diversion structure (RMT, 10/2007).

a)

b)

c)

d)

Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.235.6	EAST MAUI IRR	1-1-001:		Yes	No	Yes	No

Water is diverted from Waikamoi Stream at Intake W-2 into the Wailoa Ditch. Registrant identified water use is for municipal (County of Maui), irrigation of approximately 36,000 acres of sugar, pineapple, and a variety of other crops, industrial cooling, manufacturing, and milling, hydroelectric, and livestock. The diversion structure is concrete and has a divertible capacity of 40 mgd. Measurement of total flow of Wailoa Ditch, including this and other intakes, is available from USGS gaging station 16588000 (Wailoa Ditch at Honopou near Huelo).

Photos. a) Upstream view of diversion intake structure from left bank of stream (EMI, 05/1989); b) View of diversion structure (RMT, 11/2007).

a)

b)

Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

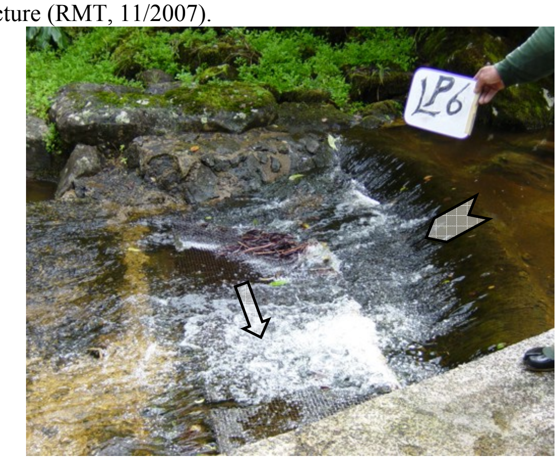
Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.297.6	EAST MAUI IRR MAUI DWS	2-4-016:		Yes	No	Yes	No

Water is diverted from East Waikamoi Stream at Intake LP-6 into the Lower Kula Water System. Registrant identified water use is municipal. The diversion structure is concrete and has a divertible capacity of 5 mgd. Measurement of total flow of the Lower Kula Water System, including this and other intakes, is available from Maui DWS Piiholo Water Treatment Facility.

Photos. a) Upstream view from just below diversion structure, with tunnel running below and perpendicular to the stream (EMI, 05/1989); b)View of intake grate from the left bank of stream (RMT, 11/2007); c) Downstream view from diversion structure (RMT, 11/2007); d) Upstream view from diversion structure (RMT, 11/2007).

a)

b)



c)

d)

Table 13-1. Continued. Registered diversions in the Waikamoi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.305.6	EAST MAUI IRR MAUI DWS	2-4-016:		Yes	No	Yes	No

Water is diverted from West Waikamoi Stream at Intake LP-7 into the Lower Kula Water System. Registrant identified water use is municipal. The diversion structure is concrete and has a divertible capacity of 5 mgd. Measurement of total flow of the Lower Kula Water System, including this and other intakes, is available from Maui DWS Piiholo Water Treatment Facility.

Photos. a) View of diversion structure, with tunnel running below and perpendicular to the stream (EMI, 05/1989); b) Close-up view of intake grate from the right bank of stream (RMT, 11/2007); c) Downstream view from diversion structure (RMT, 11/2007); d) Upstream view from diversion structure (RMT, 11/2007).

a)

b)

c)

d)

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.967.6	PUOKAMOA FARM	1-1-001:		No	No	No	No

Water is diverted from Wahinepee Stream via a 1-inch pipe. The diversion was installed in 1988 and serves domestic water supply needs to one main house and three farm dwellings. Water is also used for watering of livestock (20 to 30 cows), aquaculture (still under consideration at the time of registration), hydroelectric power generation, and irrigation. No photo available.

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

Diversion ID	EMI Ditch System	Description
LP-6a	Lower Kula	East Waikamoi Stream diversion to West Waikamoi.

No photo available.

Diversion ID	EMI Ditch System	Description
ML-4a	Manuel Luis	West Puohokamoa small stream intake.

Photos. a) Tributary seeps flow directly into Manuel Luis Ditch (EMI, 05/1998).

a)

Diversion ID	EMI Ditch System	Description
ML-5a	Manuel Luis	East Wahinepee small stream intake (#1 intake).

Photos. a) Tributary seeps flow directly into Manuel Luis Ditch (EMI, 05/1998); b) Close-up of water entering ditch (RMT, 10/2007).

a)

b)

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

Diversion ID	EMI Ditch System	Description
ML-5b	Manuel Luis	East Wahinepee small stream intake (#2 intake).

Photos. a) Tributary seeps flow directly into Manuel Luis Ditch (EMI, 05/1998); b) Another view of stream flowing directly into ditch (RMT, 10/2007); c) Upstream view of Manuel Luis Ditch at this location (RMT, 10/2007); d) Downstream view of Manuel Luis Ditch at this location (RMT, 10/2007).

a)

b)

c)

d)

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

Diversion ID	EMI Ditch System	Description
ML-5c	Manuel Luis	East Wahinepee small stream intake (#3 intake).

Photos. a) Tributary seeps flow directly into Manuel Luis Ditch (EMI, 05/1998); b) Close-up of water entering ditch (RMT, 10/2007).

a)

b)

Diversion ID	EMI Ditch System	Description
ML-5d	Manuel Luis	East Wahinepee small stream intake (#4 intake).

Photos. a) Tributary seeps flow directly into Manuel Luis Ditch (EMI, 05/1998); b) Close-up of water entering ditch (RMT, 10/2007).

a)

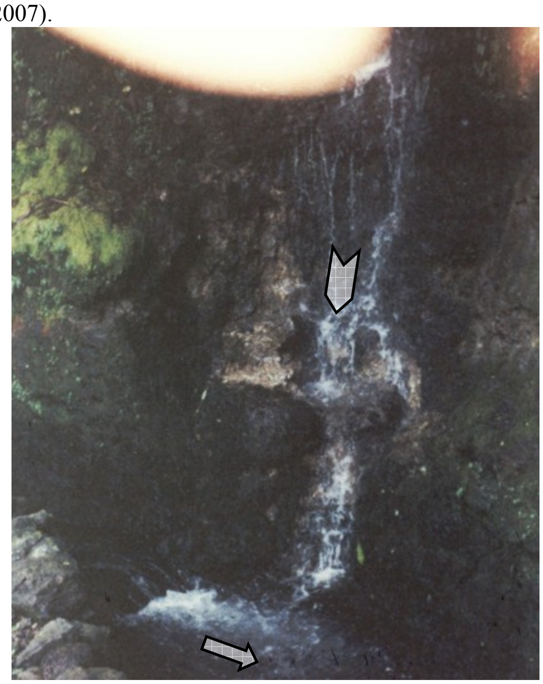
b)

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

Diversion ID	EMI Ditch System	Description
ML-5e	Manuel Luis	East Wahinepee waterfall intake.

Photos. a) Tributary seeps flow directly into Manuel Luis Ditch (EMI, 05/1998); b) Close-up of water entering ditch (RMT, 10/2007).

a)



b)

Diversion ID	EMI Ditch System	Description
ML-5f	Manuel Luis	West Wahinepee small stream intake.

Photos. a) Tributary seeps flow directly into Manuel Luis Ditch (EMI, 05/1998).

a)

Diversion ID	EMI Ditch System	Description
S-9c	Spreckels	West Puohokamoa small stream intake.

No photo available. Tributary seeps flow directly into Spreckels Ditch.

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

Diversion ID	EMI Ditch System	Description
S-9d	Spreckels	East Wahinepee small stream intake.

Photos. a) Tributary seeps flow directly into Spreckels Ditch (EMI, 05/1998).

a)

Diversion ID	EMI Ditch System	Description
S-9e	Spreckels	West Wahinepee small stream intake.

Photos. a) Tributary seeps flow directly into Spreckels Ditch (EMI, 05/1998).

a)

Diversion ID	EMI Ditch System	Description
S-9f	Spreckels	East Waikamoi small stream intake.

No photo available. Tributary seeps flow directly into Spreckels Ditch.

Table 13-2. Continued. Minor diversions on the EMI System (includes Maui DWS Systems) in the Waikamoi hydrologic unit.

Diversion ID	EMI Ditch System	Description
S-9g	Spreckels	West Waikamoi small stream intake.

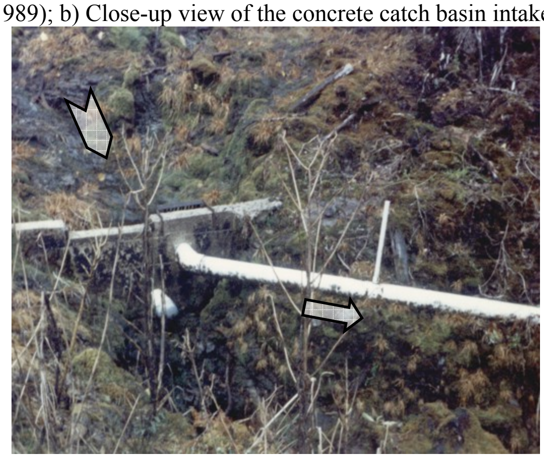
Photos. a) Tributary seeps flow directly into Spreckels Ditch (EMI, 05/1998).

a)

Diversion ID	EMI Ditch System	Description
UF-2d	Upper Kula	4-inch PVC pipe long intake.

Photos. a) Concrete catch basin captures seepage and conveys water to the Waikamoi Flume via a 4-in. PVC pipe (EMI, 05/1989); b) Close-up view of the concrete catch basin intake grate (RMT, 11/2007).

a)



b)

Table 13-2. Continued. Minor diversions on the EMI System (includes Maui DWS Systems) in the Waikamoi hydrologic unit.

Diversion ID	EMI Ditch System	Description
UF-2e	Upper Kula	6-inch aluminum pipe long intake.

Photos. a) Concrete catch basin captures seepage and conveys water to the Waikamoi Flume via a 6-in. aluminum pipe (EMI, 05/1989); b) Close-up view of the concrete catch basin (RMT, 11/2007); c) Pipe runs along the Waikamoi Flume (CWRM, 04/2009); d) The pipe empties into a junction box before going into the system pipe or overflow to the Waikamoi Stream reservoir (CWRM, 04/2009).

a)

b)

c)

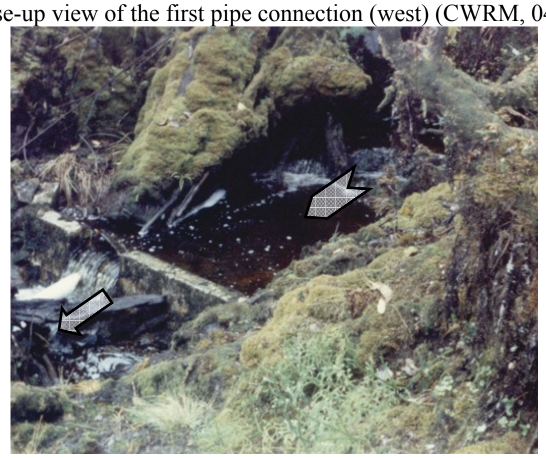
d)

Table 13-2. Continued. Minor diversions on the EMI System (includes Maui DWS Systems) in the Waikamoi hydrologic unit.

Diversion ID	EMI Ditch System	Description
UF-2f	Upper Kula	Two 4-inch pipe intakes.

Photos. a) Concrete catch basin captures seepage and conveys water to the Waikamoi Flume via two 4-in. PVC pipes (EMI, 05/1989); b) Close-up view of the concrete catch basin (RMT, 11/2007); c) View of the two pipes that connect directly to the left wall of the flume (CWRM, 04/2009); d) Close-up view of the first pipe connection (east) (CWRM, 04/2009); e) Close-up view of the first pipe connection (west) (CWRM, 04/2009).

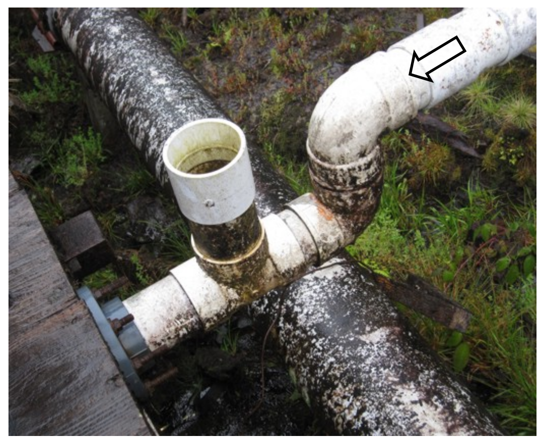
a)



b)

c)

d)



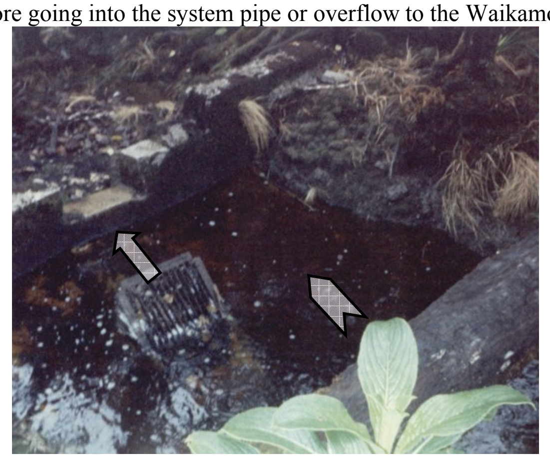
e)

Table 13-2. Continued. Minor diversions on the EMI System (includes Maui DWS Systems) in the Waikamoi hydrologic unit.

Diversion ID	EMI Ditch System	Description
UF-3a	Upper Kula	East Waikamoi 8-inch PVC pipe intake.

Photos. a) Concrete catch basin captures seepage and conveys water to the Waikamoi Flume via one 8-in. PVC pipe (EMI, 05/1989); b) Close-up view of the concrete catch basin intake grate (RMT, 11/2007); c) The pipe empties into a junction box before going into the system pipe or overflow to the Waikamoi Stream reservoi (CWRM, 04/2009).

a)



b)

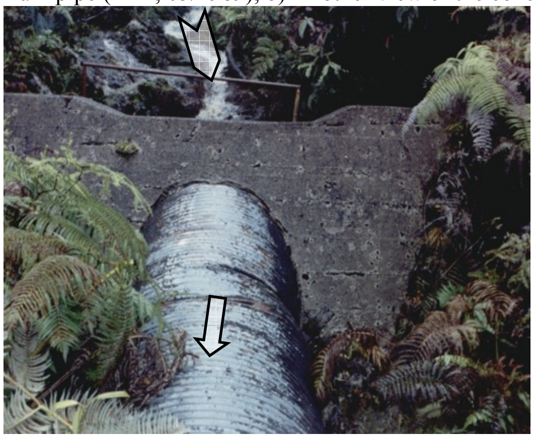
c)

Table 13-2. Continued. Minor diversions on the EMI System (includes Maui DWS Systems) in the Waikamoi hydrologic unit.

Diversion ID	EMI Ditch System	Description
UF-3b	Upper Kula	3-feet concrete runoff intake back of west 15 mg reservoir.

Photos. a) Concrete catch basin captures runoff streamflow and conveys water to the Waiakmoi reservoir via one 3-ft. aluminum pipe (EMI, 05/1989); b) Another view of the concrete catch basin (RMT, 11/2007).

a)



b)

Diversion ID	EMI Ditch System	Description
UF-3c	Upper Kula	6-inch pipe intake west of reservoir.

Photos. a) Runoff streamflow is captured by a 6-inch pipe intake and conveyed to the Waiakmoi reservoir (EMI, 05/1989).

a)

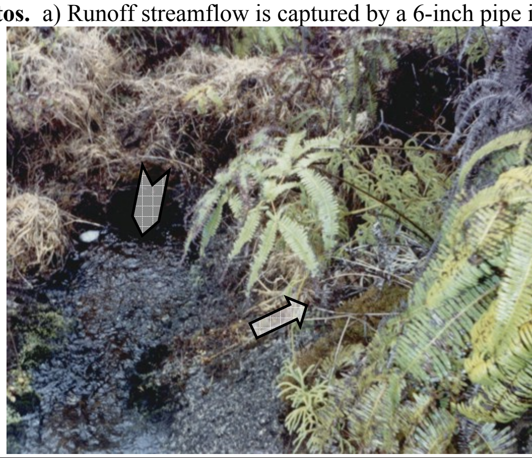
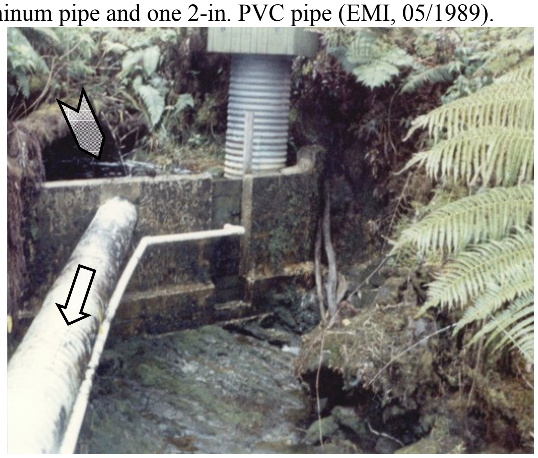


Table 13-2. Continued. Minor diversions on the EMI System (includes Maui DWS Systems) in the Waikamoi hydrologic unit.

Diversion ID	EMI Ditch System	Description
UF-3d	Upper Kula	No. 4 intake west of 15 mg reservoir, 10-inch and 2-inch pipes.

Photos. a) Concrete catch basin captures runoff streamflow and conveys water to the Waiakmoi reservoir via one 10-in. aluminum pipe and one 2-in. PVC pipe (EMI, 05/1989).

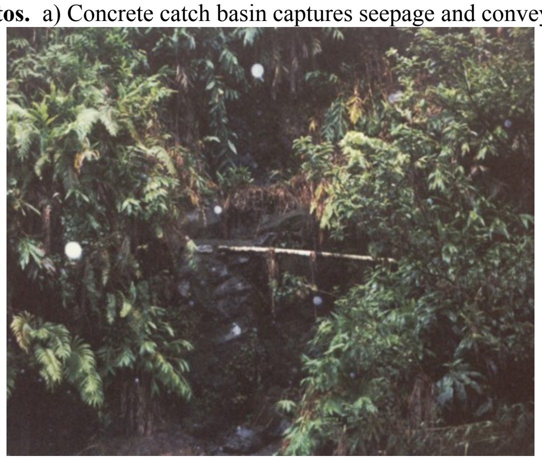
a)



Diversion ID	EMI Ditch System	Description
W-2a	Wailoa	Waikamoi 4-inch pipe intake.

Photos. a) Concrete catch basin captures seepage and conveys water to Wailoa Ditch via a 4-in. PVC pipe (EMI, 05/1989).

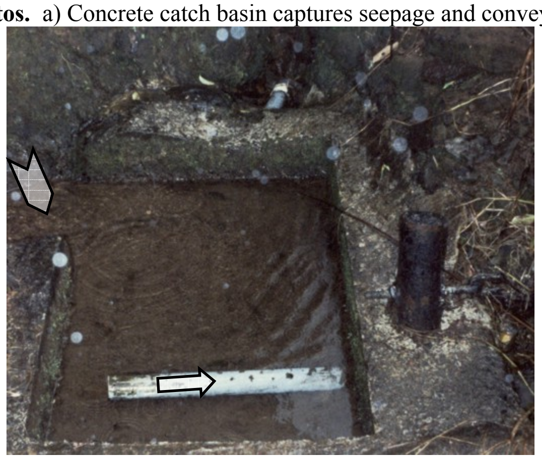
a)



Diversion ID	EMI Ditch System	Description
W-2b	Wailoa	Waikamoi 2-inch pipe intake.

Photos. a) Concrete catch basin captures seepage and conveys water to Wailoa Ditch via a 2-in. PVC pipe (EMI, 05/1989).

a)

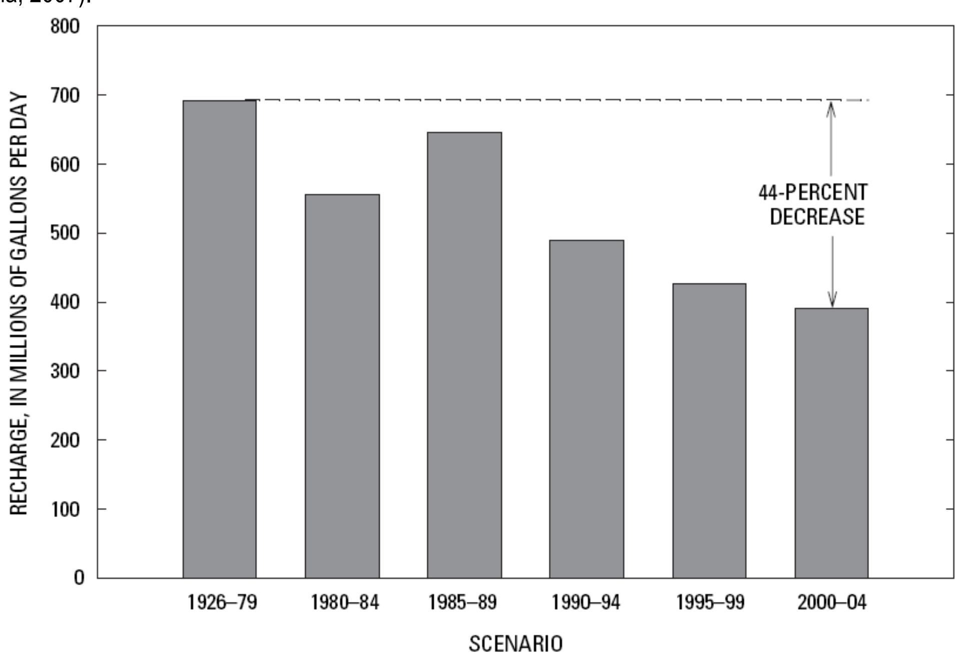


13.2 Ground Water Recharge

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 a 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[21]. 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 a 9 percent reduction in recharge. A similar study by Izuka et al. (2005) reported that a 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.

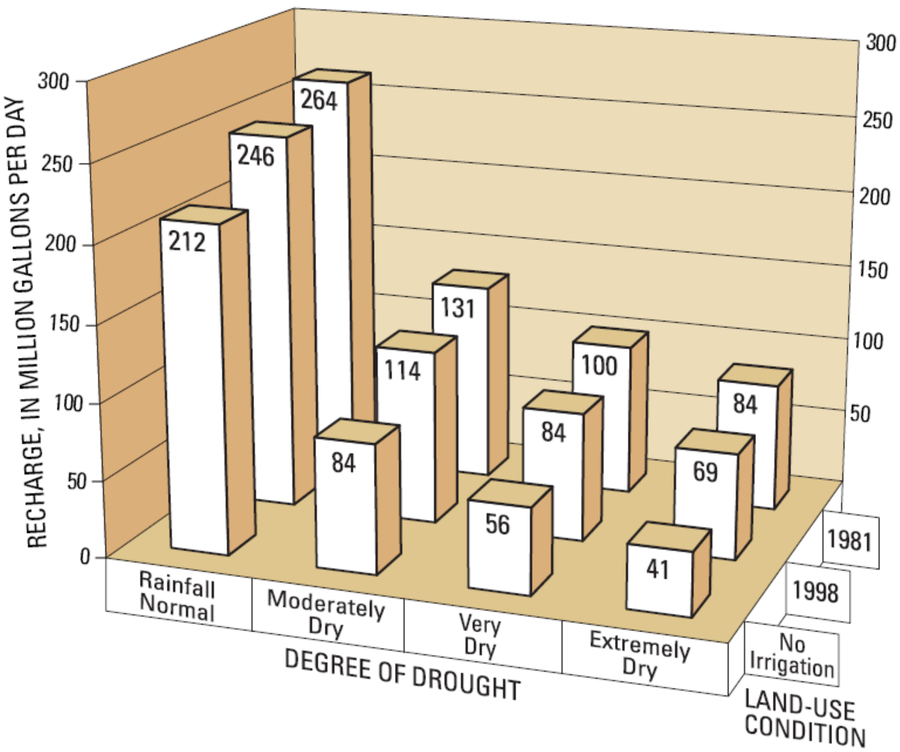
Figure 13-1. Estimated recharge for six historical periods between 1926 and 2004, central and west Maui, Hawaii (Source: Engott and Vana, 2007).



[21] 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, during which 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 to 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: Izuka et. al., 2005).



13.3 Classification of Agricultural Lands

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 the SCS in an 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. Waikamoi has no prime agricultural lands (Table 13-3).

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

Density	Area (mi²)	Percent of Unit
Other important agricultural land	0.40	7.6
Unclassified	< 0.01	0.1

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 Waikamoi hydrologic unit.

Density	Area (mi²)	Percent of Unit
Animal husbandry, grazing	0.56	10.7

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 13-15).

13.4 East Maui Irrigation System

There are two major irrigation systems in east Maui, the East Maui Irrigation System (EMI) and the County of Maui, Department of Water Supply (Maui DWS) Upcountry System. These systems add 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 both systems to agriculture and municipal water supply in Upcountry and Central Maui play a pivotal role in the consideration of economic impacts. This section includes a detailed discussion on the EMI System and its users, while the next section (Section 13.5) focuses on the Maui DWS Upcountry System.

13.4.1 System Overview

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. Supporting infrastructure includes 62 miles of private roads and 15 miles of telephone lines. The system primarily captures surface water from multiple drainage basins 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). The historic timeline of the EMI System is detailed in Table 13-5 and the complexity of the system illustrated in Figure 13-3. There have been few changes to the EMI System since the Wailoa Ditch was completed in 1923.

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.

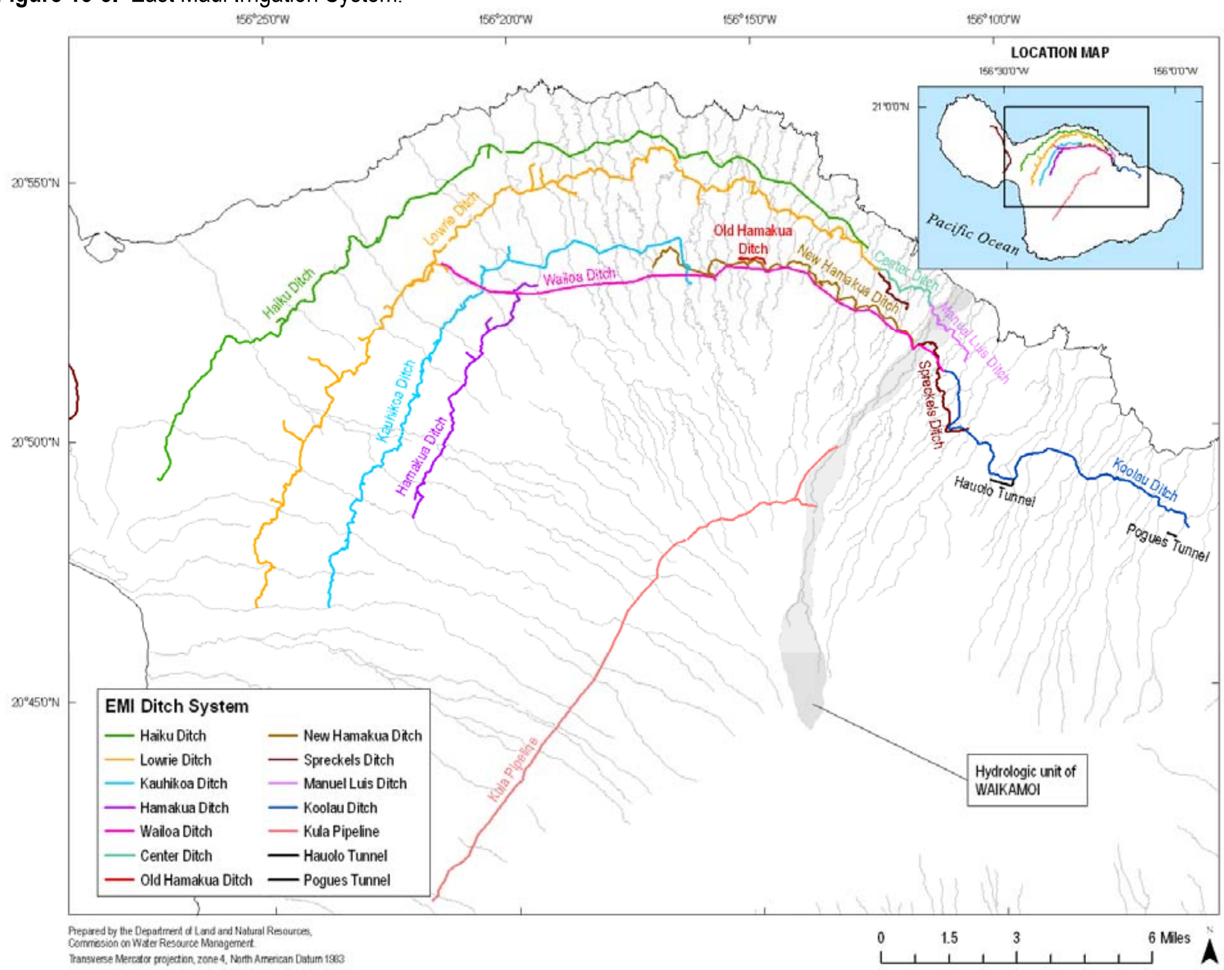
1914 - New Haiku Ditch is completed with a capacity of 100 million gallons per day. The system is mostly tunnel, partially lined, with a length of 54,044 feet.

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).

Figure 13-3. East Maui Irrigation System.



There are nine active ditches on the EMI System, some of which are essentially the same ditch with different names designated to different sections of the ditch. Refer to Figure 13-3 for a general system map or Figure 13-16 for a simplified schematic of the EMI system. The diversion system west of Maliko Gulch is not depicted in the schematic; however, that part of the system will be included in the following discussion. Koolau Ditch begins at Makapipi Stream and becomes Wailoa Ditch at Alo Stream. This ditch then ends at Kamole Weir, where the water may continue to flow to the Hamakua Ditch via the Hamakua Hydropower Plant, the Kauhikoa Ditch via the Paia Hydropower Plant, and the Lowrie Ditch via the Kaheka Hydropower Plant. Koolau/Wailoa Ditch is situated at the highest elevation of all ditches in the EMI System, except the Spreckels Ditch which begins near the 1,700 feet altitude at Nuaailua Stream. Flow in the Spreckels main ditch is conveyed to the Koolau/Wailoa Ditch via Puohokamoa Stream and Alo Stream. The lower elevation Spreckels distribution ditch conveys water from Alo Stream to the Kolea Reservoir, and from Oopuola Stream to the Papaaea Reservoir, where water can also be dropped to the Lowrie Ditch via Nailiilihaele Stream. New Hamakua Ditch begins at Alo Stream and the ditch water is eventually conveyed to Kauhikoa Ditch via Makaa, Halehaku, and Opana streams. Manuel Luis Ditch begins at Kolea Stream, transitions into Center Ditch at Waikamoi Stream, and then conveyed to Lowrie Ditch via Nailiilihaele Stream. Haiku Ditch is situated at the lowest elevation of all ditches in the EMI System. Its first intake is at Nailiilihaele Stream and the ditch continues through the HC&S plantation.

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 and Baldwin (A&B) and EMI currently hold revocable permits for the four license areas: Huelo, Honomanu, Keanae, and Nahiku (Figure 13-4).

13.4.2 History of Water Licenses

Leases and water licenses have been granted in this area as early as 1876, immediately after the signing and ratification of a Reciprocity Treaty between the Kingdom of Hawaii and the United States (Kumu Pono Associates, 2001a, p.443), thus making sugar cultivation a more reliable economic prospect. At one point there were five licenses issued for this area. Two were subsequently combined, resulting in the four license areas. As the licenses expired, they were not reissued; instead, revocable permits were issued to the license holders. The intent was to eventually issue one license to cover all areas once the existing licenses had all expired. The licenses, and also the subsequent revocable permits, included clauses protecting the water rights of the native tenants for domestic use, including cultivation of taro. The licenses, and subsequent revocable permits, allow the taking of surface water and development of ground water via tunneling from state land. Commission staff reviewed 20 files pertaining to the water licenses/revocable permits that are housed in the Department of Land and Natural Resources' Land Division (State of Hawaii, Land Division, 2008). Documents in those files date from 1876 to present.

According to a collection of native traditions and historical accounts of east Maui, "While testimonies in some public hearings have expressed the sentiment that 'the waters were taken without permission'…, the initial development of the ditch system was authorized as a part of the Hawaiian Kingdom's program to promote prosperity for all the people of the Kingdom…Of importance to the native Hawaiian families of the land, each of the Water Licenses issued under the Kingdom included clauses which protected the pono wai (water rights) of native tenants of the respective lands through which the ditch system was developed (Kumu Pono Associates, 2001a, p.444)." Yet, as early as 1913, the USGS was reporting that "the present system of ditches takes practically the entire water supply of the region at times when the streams are low (Martin and Pierce, 1913, p.259).

In 1938, the "East Maui Water Agreement" was signed between the Territory of Hawaii and EMI, which by then had been incorporated (in 1908, through an Agreement between five agricultural companies) and which had consolidated the ditch system through leases of all ditches, water rights and easements, etc.

(Kumu Pono Associates, 2001a, p.494). Under the terms of the East Maui Water Agreement, both parties granted to each other perpetual easements with a right to convey all waters, without charge, through any and all aqueducts owned respectively by EMI and the Territory, and over all lands owned by the two parties extending from Nahiku to Honopou inclusive. This agreement was made because the system traverses partly through government land and partly through EMI lands. Language in the Agreement allows for entities other than EMI to bid on the Water Licenses, but EMI has successfully bid on those licenses whenever they have been up for bid or renewal (State of Hawaii, Land Division, 2008).

The licenses were for different terms and with different covenants, and were renewed and changed from time to time. The final terms of the licenses follow; after which revocable permits were issued (Table 13-6).

Table 13-6. Terms of last license, before they became revocable permits

License area	General Lease number	Term
Huelo	GL 3578	1960-1981
Honomanu	GL 3695	1962-1986
Keanae	GL 3349	1950-1971
Nahiku	GL 3505	1955-1976

When the first of the four licenses expired, the State commissioned an appraisal to recommend rates to be charged for the Keanae License. The resulting report, published in 1972, summarizes some of the results of the 1938 Agreement. Because of the perpetual easements, "each party is assured of being able to convey its water through the aqueduct, with each paying the operation and maintenance cost in proportion to their respective use of it. So long as [EMI] is the successful bidder for all four State water licenses, it pays all the operation and maintenance costs…Subsequent to the agreement, the question of how much water was owned by each party was in effect settled by means of a study made in 1949 by Luna B. Leopold, Meteorologist…This map was used by [EMI] to determine the percentage of the rainfall on the government and private lands that are mauka of and tributary to the collection system for each of the four watersheds. It was assumed that the yields of the water collected in the aqueduct system are in proportion to the amount of rainfall on the respective land ownerships (Hull, 1972)." In other words, the ditch system collected water from both State and private lands. Ditch flow measurements were only collected at certain points, and included water originating on government as well as on private lands. In order to determine the amount of money to charge EMI for the water licenses, the State had to calculate the percentage of water in the ditch that came from government land and the percentage that came from private land (Table 13-7), and they did this using rainfall isohyets and acreage of the license areas. Those numbers were still in use as of 1972, and presumably until the end of all four water license agreements, as the other three (besides the then-recently expired Keanae License) were still in place at the time the 1972 report was published (Hull, 1972).

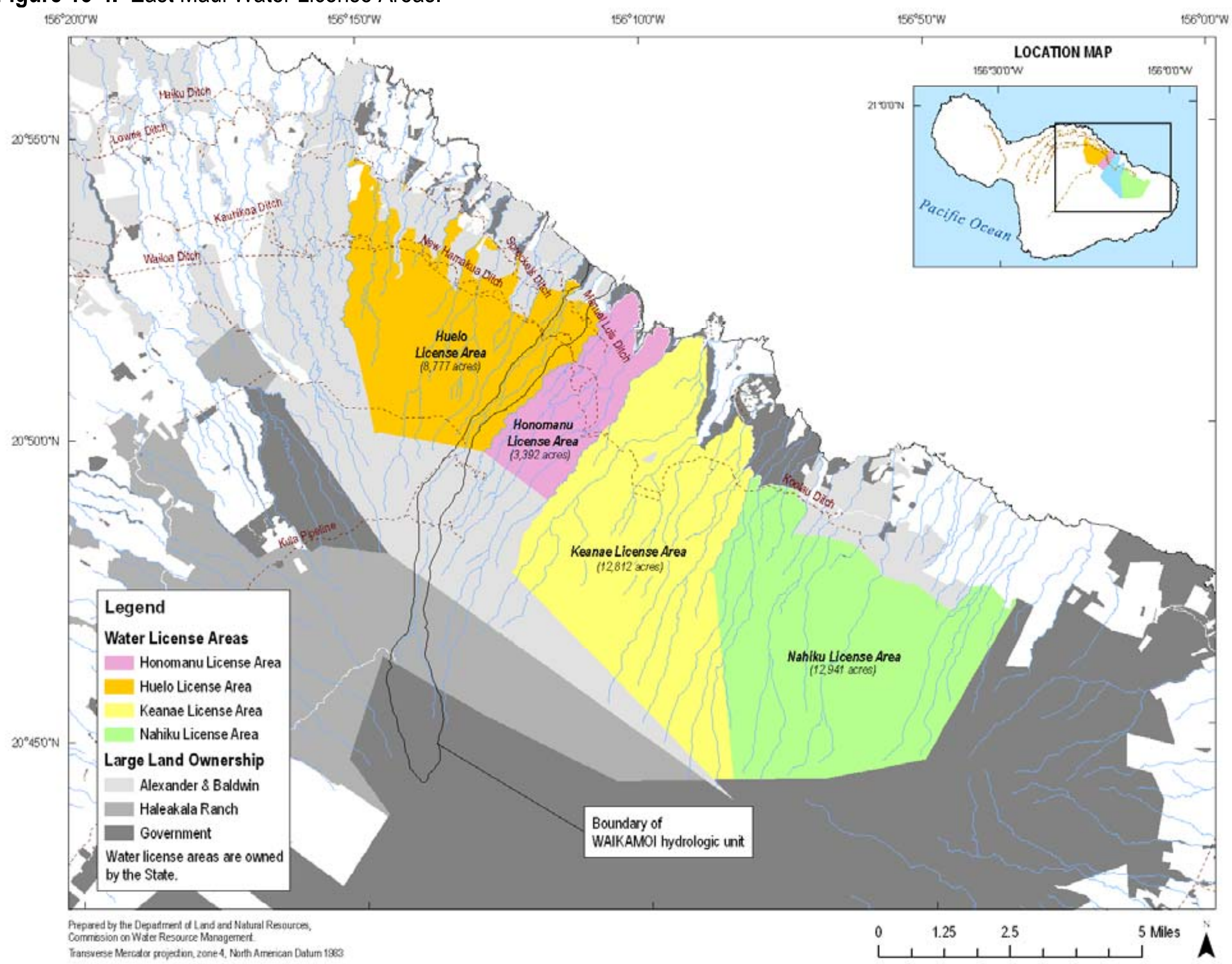
Table 13-7. Percentage of water yield from the four license areas (as of 1972).

Watershed	Government (%)	Private (%)
Huelo	64.49	35.53
Honomanu	47.39	52.61
Keanae	79.19	20.81
Nahiku	95.02	4.98

The correspondence and discussions over the course of many years indicate that the water was viewed as a commodity and that water permitted to flow into the ocean was considered waste. Originally the rates charged for the water licenses were low, to allow for construction costs. For many years after construction, lease amounts were determined according to the price of sugar, the annual quantity of water carried through the system, and the percentages of government and private lands from which the water contributed to the system (State of Hawaii, Land Division, 2008). Water yields were measured for each license area. Rate of the licenses fluctuated with the price of sugar, but the licenses included minimum and maximum sugar prices that could be used in the calculations, e.g. if the price of sugar exceeded the price ceiling in the license, the rental rate would be frozen for the remainder of the license period, using that maximum amount to calculate rent. The terms of the long-term licenses were renegotiated at the expiration of the license period, i.e. roughly every 20-35 years. Under the long-term lease, A&B was required to pay for a minimal take of water even if it was not available due to low flow, or not necessary due to high rainfall on the plantations (State of Hawaii, Land Division, 2008 and Hull, 1972).

Water yield is no longer measured per license area; flow for all four license areas is totaled at the Honopou Boundary. Total water supply is classified either as water runoff from EMI land or water runoff from State-owned land. The water license areas are shown in Figure 13-4, along with other large landowners.

Figure 13-4. East Maui Water License Areas.



In 1965, HRS 171-58, as amended, required water rights to be leased through public auction or permitted on a month-to-month basis up to one year. The existing leases were grandfathered until their expiration. As mentioned above, the last water license agreement expired in 1986, after which all four license areas were disposed of as month-to-month revocable permits that were renewed annually, alternating in issuance to EMI and A&B. A&B proposed the consolidation of the four leases into a single lease, and in 1985 the Land Board approved a public auction sale for a 30-year water license incorporating the four licenses into a single license. In 1986, Native Hawaiian Legal Corporation (NHLC) challenged the Department of Land and Natural Resources (DLNR)'s decision that an Environmental Impact Statement (EIS) was not required and an Environmental Assessment (EA) was sufficient for the issuance of the 30-year lease. The Circuit Court agreed that an EA was adequate, and NHLC appealed to the Supreme Court, who remanded back to Circuit Court to conduct a hearing pursuant to HRS section 343-7(b) on the matter. Further discussions resulted in several decisions, including that the Board of Land and Natural Resources (BLNR) and DLNR must work towards long-term resolution; and that interested parties work together to develop a watershed management plan for the water lease areas. The latter resulted in the creation of the East Maui Watershed Partnership and development of the East Maui Watershed Management Plan.

In 1987, the rate structure of the revocable permits was altered to a fixed flat fee independent of the amount of water diverted by A&B, and the rates were reduced by 25% to discount for the uncertainty that the annual permits would be renewed. However, the payments after 1987 were increased by 25% to remove the discount and convert the rates to long-term lease rentals. In 1988, the State performed an independent audit and set the benchmark rate based on the audit rate of five dollars per million gallons. In fiscal year 1999-2000, the permits were issued to A&B and EMI, with the fixed rates based on an assumed annual flow. The current revocable permits state that their rates are based on a staff appraisal dated May 7, 2001.

The revocable permits are currently regulated by the DLNR's Land Division, which collects fees for the permits. Those permits were most recently renewed in November 2007, with the following rental payments:

Table 13-8. Current revocable permits issued to A&B/EMI.

Revocable Permit No.	License Area	Area (acres)	Monthly Rent in 2008
S-7264	Huelo	8,752.69	$6,588
S-7263	Honomanu	3,381.00	$1,698
S-7265	Keanae	10,768.00	$3,477
S-7266	Nahiku	10,111.22	$1,427

In May 2001, A&B and EMI filed an Application for a Long Term Water License with the BLNR seeking a long-term 30-year lease rather than continue with year-to-year revocable permits. Shortly thereafter, Na Moku Aupuni O Koolau Hui, Inc. ("Na Moku") and Maui Tomorrow requested a contested case hearing, with NHLC filing on behalf of petitioners Na Moku, Elizabeth Lapenia, Beatrice Kekahuna, and Marjorie Wallett. (In May 2007, Elizabeth Lapenia withdrew from the case and is no longer represented in it.) Concurrently, the Petitioners filed with the Commission a Petition to Amend the Interim Instream Flow Standard for 27 Streams in East Maui.

In May 2002 the BLNR deferred the reissuance of interim revocable permits and granted a holdover of the existing revocable permits on a month-to-month basis pending the results of the contested case hearing. A January 2003 BLNR "Findings of Fact and Conclusions of Law and Order" indicates that the "BLNR may enter into a lease of water emanating from State lands for transfer outside of the watershed of origin provided that such lease is issued in accordance with the procedures set forth in HRS Chapter 171 and provided that all diversions of stream water shall remain subject to the Interim Instream Flow Standards set by CWRM, and to any judgment of a court of competent jurisdiction establishing appurtenant or riparian rights in favor of downstream users (p.12)." This part of the Order was reversed by Circuit Court in October 2003 and the BLNR advised that if it does not believe it has the requisite expertise, it should wait until CWRM has acted or make its own application to establish instream flows. However, the Court Order goes on to state that the BLNR cannot "rubber-stamp" any Commission determination, meaning that at any BLNR contested case hearing, any party may challenge a Commission decision "if its methodology is wrong or some other error is committed." The Order also indicates legal precedent suggests that an EA should be required for issuance of a long-term lease, and perhaps an EIS depending upon the result of the EA.

In March 2005, the Petitioners filed Motions For Summary Relief contesting the "Holdover Decision" that allowed continued renewal of the revocable permits. The motions for summary relief were denied. However, in the Order denying the motions for summary relief, the Hearings Officer indicated that an evidentiary hearing could be held upon request to determine if interim releases of water were required in order for the Board to fulfill its public trust duties pending the completion of an environmental assessment and determination of amendments to interim IFS. At an early pre-hearing conference the parties agreed the streams in issue in the evidentiary hearing concerning interim relief were Honopou, Puolua, and Hanehoi Streams in the Huelo license area, and Wailuanui, Waiokamilo, and Palauhulu Streams in Keanae. Accordingly, the evidentiary hearing was held in October and November 2005.

The resulting "Findings of Fact, Conclusions of Law, and Decision and Order ('Interim Order')" was issued by the Board of Land and Natural Resources in March 2007. This was intended to provide interim relief based on evidence introduced in the 2005 evidentiary hearing, and is not intended to foreshadow the Board's final decision in the case. The Interim Order concluded and ordered, among other things:

- That the DLNR "appoint an appropriate monitor… to ensure compliance with its order and to investigate and resolve if possible all complaints regarding stream flows by any of the parties to this proceeding."
- That A&B/EMI be immediately ordered to decrease current diversions on Waiokamilo Stream such that the water flow can be measured below Dam #3 at the rate of 6,000,000 gallons per day based on a monthly moving average on an annual basis.
- In the event that Beatrice Kekahuna increases the amount of acreage that she has in cultivation as taro loi, A&B/EMI may be required to decrease diversions (from Honopou Stream) to allow her sufficient water to irrigate her loi.

In May 2008, NHLC on behalf of the petitioners filed a Motion to Enforce the March 2007 Interim Order. Though there has been release of water into Waiokamilo and Kualani Streams, NHLC contends that the Interim Order has not been fully implemented largely due to the ability of the monitor to perform certain actions. Additionally, NHLC claims that Beatrice Kekahuna, Marjorie Wallett, and others still do not have adequate water to cultivate their taro.

13.4.3 Hawaiian Commercial and Sugar Company

Sugar Production

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. The other remaining plantation Gay and Robinson Inc. has announced its plan to cease sugar operations, harvesting its last crop in August 2010, and transition to biofuel (i.e., ethanol) production (Consillio, 2008). In 2006, HC&S produced about 81 percent of the total raw sugar in Hawaii, or approximately 173,600 tons, amounting to 3 percent of total U.S. sugar produced (A&B, 2007). However, production dropped in 2007 and 2008 to 165,000 and 145,000 tons, respectively, most likely a result from two consecutive years of severe drought conditions. HC&S also produces molasses, a by-product of sugar production, and specialty food grade sugars sold under their Maui Brand® trademark. Table 13-9 summarizes the harvest and production yields for HC&S from 2000 to 2008.

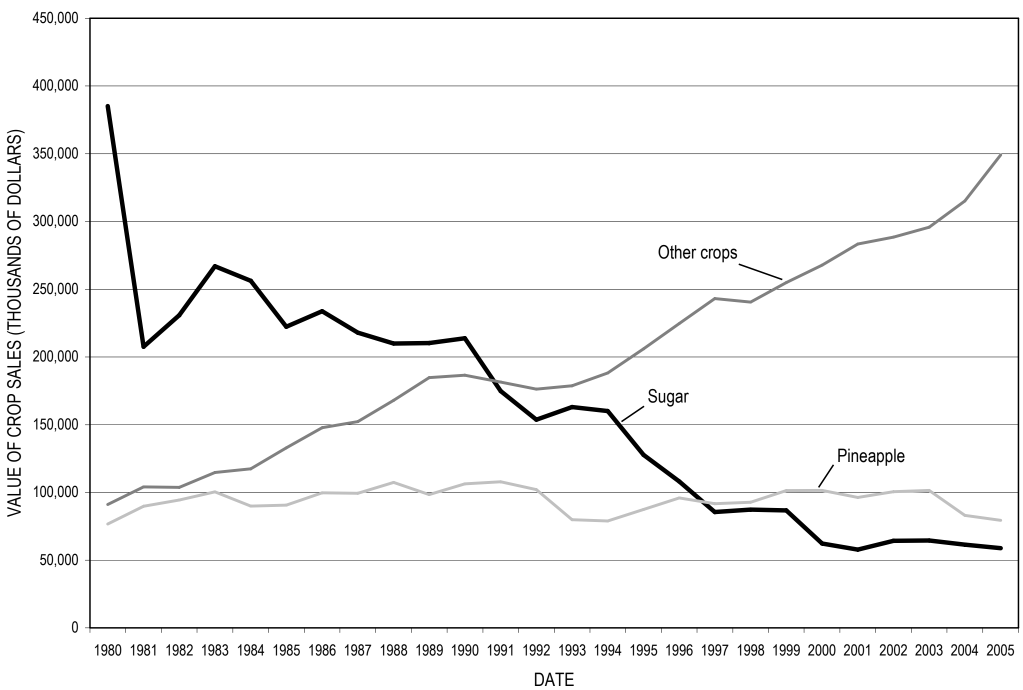
Table 13-9. Summary of sugar-related harvests by HC&S for 2000-2008 (Source: A&B, 2002; 2003; 2005; 2007, 2009).

[* 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)
2008	145,000	75.0	16,691	8.6	*	52,200	27,500
2007	165,000	80.0	16,865	9.7	*	51,700	21,200
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	*

Overall, Hawaii sugar growers produce more sugar per acre 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 longer distance to the U.S. mainland market. The DBEDT *State of Hawaii Data Book* (2006) shows the dramatic decline in sugar crop sales as plantations have closed over the last 25 years. Figure 13-5 illustrates the decline of sugar, the steady value of pineapple sales, and the increase of other crops generally considered as diversified agriculture.

Figure 13-5. Value of crop sales for sugar, pineapple and other crops from 1980 to 2005 (Source: DBEDT, 2006).



Energy Production

In addition to producing sugar, the HC&S Puunene Sugar Mill also provides 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. HC&S also produces hydroelectric power from three run-of-river hydroelectric facilities on the Wailoa Ditch, which is supplied with water from several sources in east Maui. The hydraulic turbine generators located at the Kaheka, Paia, and Hamakua facilities on the Wailoa Ditch are capable of producing 4.5 megawatts, 1.1 megawatts, and 150 kilowatts, respectively (G. Hew, personal communication, August 2009).

Power generated from bagasse and the hydroelectric facilities is used to satisfy sugar mill power requirements first, while remaining electricity not used by the mill is sold to Maui Electric Company (MECO) for distribution, which currently amounts to approximately 7 percent of MECO's power sales. 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. According to MECO, power is sold as available, with an estimated oil savings of 44,700 barrels per year (MECO, 2008a). The contract provides for monetary penalties if these requirements are not met by HC&S. During black-outs, MECO has requested the help of HC&S to generate backup power until MECO repairs its system.

Water Use

HC&S uses water from three main sources: 1) surface water from the EMI system; 2) surface water from the Wailuku Water system in west Maui that is operated jointly by HC&S and the Wailuku Water Company; and 3) ground water pumped from 16 brackish water wells located on the plantation. 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. For this reason, HC&S attempts to divert the maximum possible amount of water into the EMI system at the Wailoa Ditch level, which has a capacity of 195 million gallons per day, where the water can then be distributed by gravity flow to various fields and to HC&S' hydroelectric turbines to maximize the energy efficient use of this water (HC&S, 2009).

Currently, the HC&S sugar plantation consists of approximately 43,300 acres of land. Sugar is cultivated on roughly 35,000 acres, while the balance is leased to third parties, is not suitable for cultivation, or is used for plantation purposes (A&B, 2007). Approximately 29,000 acres are irrigated with water delivered by EMI. 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 surface water supply from EMI, while the remaining 29 percent was supplemental ground water. Of the 29,000 acres irrigated with EMI water, approximately 13,000 acres are located in elevations where irrigation with pumped water is either geographically impossible and/or economically impracticable. Since these fields are dependent on water from the EMI System, they are highly susceptible to diminished yields during drought conditions and in the summer months when ditch flows are low (HC&S, 2009).

HC&S uses drip irrigation for most of its fields. Drip irrigation is the most efficient irrigation technology available today, which is typically 90 percent efficient as compared to sprinkler system that is 75 to 85 percent efficient. In 1986, HC&S completed a 12-year project to install a drip irrigation system across the plantation. It was a 30 million dollar investment in water efficiency that would cost 90 million dollars if made today. The sugarcane fields not equipped with the drip irrigation system are irrigated with recycled mill water, which contains particulates that clog up the drip irrigation tubes. Thus, HC&S expended over 1 million dollars to install overhead sprinklers in these fields to be able to utilize the recycled mill water (HC&S, 2009).

Irrigation water is applied based on the daily needs of each field, and not the average daily water use statistic, which at most times is an inaccurate representation of the irrigation requirement for each field. The specific needs of each field are based on the crop cycle and real time measurements of rainfall and evaporation that determine the soil moisture content of each field. To ensure the most effective and efficient use of water on the plantation, HC&S determines the irrigation requirements for each field on a day-to-day basis using a computerized water balance model. The model is essentially a water budget accounting procedure that balances the moisture input of rainfall and irrigation; the moisture output of evapotranspiration; and the change in soil-moisture storage based on the soil type in each field. A system of 15 automated weather stations is installed across the plantation that transmits hourly data used to compute daily evaporation rates using a modified Penman equation. Rainfall data is recorded daily from 41 manual gauges. Pan ratios documented in Ekern and Chang (1985) are used to estimate the amount of water required in various crop stages. Lastly, irrigation flow rates and the number of irrigation hours applied are also used to determine the water status for each field. The model then prioritizes the irrigation requirements of the fields, indicating which field(s) should receive water next (HC&S, 2009).

Although HC&S does not use the average daily water use statistic in its everyday operations, HC&S did calculate the average daily water use for its west Maui fields for the purpose of the Na Wai Eha Contested Case Hearing. The average daily water use rates for the Waihee-Hopoi fields in west Maui for 2004, 2005, and 2006 were 6,395, 7,831, and 6,254 gallons per acre per day, respectively. For comparison, HC&S also computed the average daily water use for the 29,000 acres of plantation fields irrigated with water delivered from the EMI System, which are somewhat lower because of greater seasonal variation in streamflow and HC&S' inability to supplement the 13,000 acres with pumped well water. The water use rates for these 29,000 acres ranged from a low of 4,619 gallons per acre per day in 2008 to a high of 6,858 gallons per acre per day in 2005 (HC&S, 2009).

Economic Impact

The availability of surface water and securing this water at reasonable cost are essential to HC&S' ability to grow sugarcane at yields that will enable the company to remain financially viable. Table 13-10 provides a summary of A&B's agribusiness revenues for 2000 to 2008. A&B's four agribusiness companies, one of which is HC&S, saw a revenue increase of 3 percent ($4.2 million) in 2006 over the previous year, generating an operating profit of $6.9 million. HC&S itself earned a profit margin of $2.6 million in 2006. The increase in revenue 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). The last two years of severe drought conditions had significant impacts on the availability of surface water and crop yields, which lead to sizable financial losses. In 2008, A&B's agribusiness sector reported a $13 million loss, caused largely by losses at HC&S. HC&S expects its losses to be greater in 2009 as the effects of drought will have greater impact in the 2009 harvest.

Table 13-10. Summary of A&B's agribusiness revenues for 2000 to 2008 (Source: A&B, 2002; 2005; 2007; 2009).

Year	Revenue (dollars)	Operating Profit (dollars)	Operating Profit Margin (percent)
2008	$ 124,300,000	$(12,900,000)	(10.4)
2007	$ 123,700,000	$ 200,000	0.16
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

The EMI System was originally built for the purpose of supplying water to the HC&S sugarcane plantation. While other entities have become dependent on the EMI System, HC&S continues to be the largest user of the water delivered in the system. The adoption of interim IFS may result in the restriction of water in the system, which could cause severe economic impacts to HC&S. Figure 13-14 illustrates the interconnectedness of the different entities (including HC&S) dependent on the EMI System for water, and how this system is linked to the Maui DWS Upcountry System. Listed below are some of the possible economic impacts of limiting water availability to HC&S.

- **Employment and local economy**. Restricting water availability to HC&S will result in possible reduction of sugar production and sales, which will affect HC&S' ability to maintain and support its present staff. HC&S provides approximately 800 full-time jobs out of the estimated 1,750 agriculture-related jobs on Maui (Department of Business, Economic Development and Tourism [DBEDT], 2007). This amounts to $47 million annually in wages and benefits to employees and retirees. HC&S also spends approximately $100 million annually in the local economy to support its operations, primarily in Maui (HC&S, 2009).
- **Renewable energy**. The loss of hydroelectric and biomass fueled electric generation would greatly affect MECO's ability to comply with its statutory obligation to generate electricity from renewable resources, as well as supply adequate energy to the local residents, especially during black-outs. This will also undermine the State's Clean Energy Initiative (HC&S, 2009).
- **Kahului Trucking & Storage, Inc (KT&S)**. KT&S is a subsidiary of A&B. Its primary purpose is to provide trucking services like hauling sugar and molasses, mobile equipment maintenance and repair services, and self-service storage facilities for HC&S. In effect, KT&S depends on HC&S to remain a viable business. If HC&S were to downsize its operations, KT&S may have to do the same.
- **Other users**. Kula Agricultural Park (Park) is directly dependent on the viability of HC&S. The Park receives water from the Hamakua Ditch. While the Hamakua Ditch was described in Section 13.4.1 as part of the EMI System for simplicity, the jurisdiction of this ditch resides with HC&S because the ditch lies within the plantation. Restricting water availability to HC&S will affect its contractual obligation to provide the Park with 1.5 million gallons of ditch water per day. Maui Land and Pineapple Co. (MLP) is another entity that is dependent on HC&S for the delivery of water.

13.4.4 Maui Land and Pineapple Company

MLP cultivates roughly 6,000 acres of pineapple, of which over 2,800 acres 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 lands 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).

Water Use

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. 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 (Findings of Fact, Conclusions of Law, and Decision and Order, 2007).

Economic Impact

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 13-11 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, MLP ceased pineapple canning operations on Maui in June 2007, attributing the closure to increased imports of cheaper canned pineapple. Instead, MLP is 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 13-11. Summary of MLP's revenues and operating losses for 1999 to 2006 (Source: MLP, 2002; 2004; 2005; 2007).

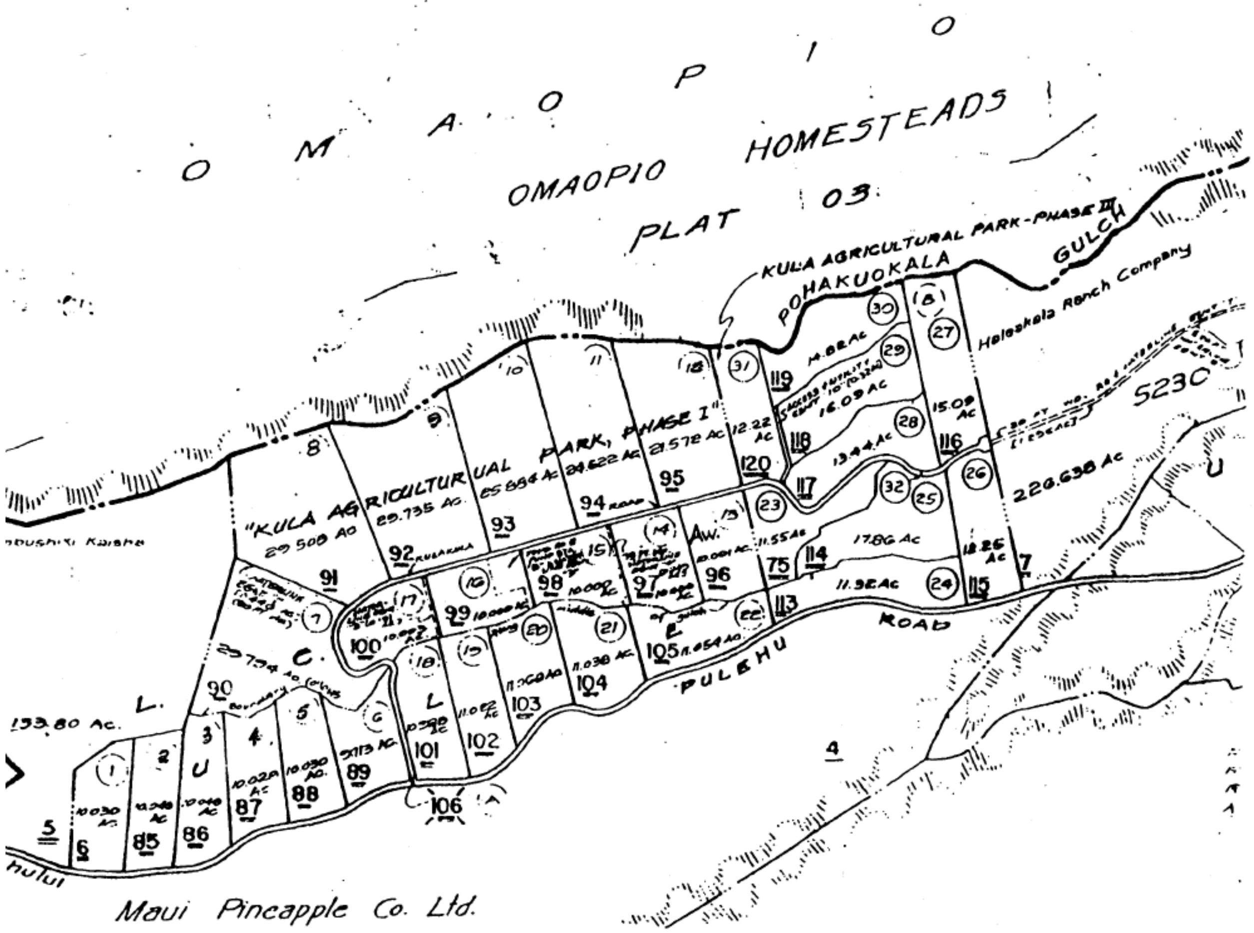
[Numbers in parentheses indicate operating losses; numbers not in parentheses are gains.]

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

13.4.5 Kula Agricultural Park

The Kula Agricultural Park consists of 445 acres of land divided into 31 lots that range from 7 to 29 acres in size (Fukunaga and Associates, Inc., 2006). These agricultural lots are leased out to farmers in an effort to promote the development of diversified agriculture. Lease rates are $100 per acre per year with tenure of the lease being 50 years. Currently, the lots are leased to a total of 26 farmers. Crops grown include vegetables (lettuce, tomato, Kula onions, zucchini, cucumbers, bush beans, sweet corn, eggplant, head cabbage, Chinese cabbage, peppers, ginger root), taro, bananas, mango, turf grass, nursery plants, tuberose, plumeria, and landscape plants. The Office of Economic Development (OED) serves as the County of Maui's land management entity for the Kula Agricultural Park, while the Maui DWS is responsible for the operation and maintenance of the Park's water supply needs. Figure 13-6 is a map of the Park.

Figure 13-6. Map of the Kula Agricultural Park (Source: Maui OED, n.d.).



Water Use

The County of Maui currently has an agreement with EMI and A&B, through its agribusiness partner of HC&S, to withdraw up to 1.5 million gallons of non-potable water per day from the Hamakua Ditch to serve the needs of the Park. This water may also be used to serve, if the County desires, the agricultural needs of a certain Haleakala Ranch Company property located adjacent to the Park that is to be used as an agricultural park. The agreement also requires users of this water to conserve during times of water shortage (Fukunaga and Associates, Inc., 2006).

Two storage reservoirs are located in the Park, the lower reservoir with a capacity of 1.2 million gallons and the upper reservoir with a capacity of 4.2 million gallons. Currently, water is withdrawn from the Hamakua Ditch and conveyed to the Park via the pump station just upstream of A&B's Reservoir 40. Water is pumped to the lower reservoir first, and then pumped to the upper reservoir. Water use at the Park is metered by Maui DWS, and the annual water consumption at the Park from 1998 to 2008 is provided in Table 13-12. Water use for the past ten years averages 0.55 million gallons per day, which is 37 percent of the maximum allowable withdrawal amount.

Table 13-12. DWS metered consumption for the Kula Agricultural Park (Source: Maui DWS, 2009).

Year	Consumption (million gallons per day)
2008	0.473
2007	0.585
2006	0.605
2005	0.647
2004	0.527
2003	0.529
2002	0.585
2001	0.578
2000	0.580
1999	0.516
1998	0.479

Economic Impact

Restricting water availability to the Kula Agricultural Park could have devastating impacts to the farmers and to the local economy. While some of the farmers have more than one lot, the farming operations within the Park are relatively small. Yet, most of the farmers' livelihoods rely on the profits made from their farms. Some of the farmers have made connections with mainland businesses and continue to provide a consistent supply of goods, while others have had difficulty in keeping up with the increasing demand for fresh local produce. While an adequate amount of water is needed to maintain a healthy crop, water is also required for shipping standards. To conserve water, most of the farms are equipped with drip irrigation. Vegetative cover and shade trees are planted to reduce evaporation losses. During the past two summers when farmers underwent a voluntary reduction of 10 percent in water use, many farmers had to curtail plantings in order to supply a sufficient amount of water for the main crops (County of Maui, Farm Bureau and Office of Economic Development, 2009). With further cuts in water availability, the farmers may not be able to maintain a dependable supply; therefore, losing the existing customer base. In the current economy, farmers are struggling to compete with mainland suppliers, who are able to sell produce at significantly lower prices because they operate at a larger scale. Small-scale farmers cannot operate at a loss due to the lack of an alternate source of income to cover that loss. For the same reason, it is nearly impossible to revive the business once a farm ceases operation.

The Park encourages diversified agriculture via small scale farming. Diversified agriculture involves a shift in farming practices toward planting crops high in demand. It helps to balance social and ecological factors, such as food and nutrition security, marketing and employment options, and natural resource management. On the social perspective, diversified agriculture broadens the household selection of foods and nutrition, creates more employment opportunities in the rural communities, and expands marketing options for food production systems. On the ecological perspective, diversified agriculture allows for optimization of land uses and the existing natural resource base; therefore, achieving practical and affordable means of agro-ecological management and reducing the risks associated with mono crop farm operations. Losing these contributions from small farmers could cause unpredictable social, ecological, and economic impacts.

13.4.6 County of Maui, Department of Water Supply

One of the Maui DWS Upcountry systems, the Makawao system, is served by EMI's Wailoa Ditch. As the second largest system out of the five separate water systems operated by Maui DWS, the Makawao system is supported by Maui's largest water treatment facility (WTF), the Kamole Weir WTF. This facility has an estimated drought capacity of 4.5 million gallons per day, but is capable of producing 8 million gallons per day at maximum capacity (Maui DWS, 2009). Maui 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), as well as expand the raw water storage at Kamole (Maui DWS, 2009).

Water Use

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 day for a term of 20 years, with an option for the County to receive an additional 4 million gallons per day 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.

A Memorandum of Understanding (MOU) that was executed on April 13, 2000 provides for the County to continue to receive 12 million gallons per day from EMI's 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).

Maui DWS receives an average of 7.1 million gallons per day from the EMI system, a portion of which goes directly to the Kula Agricultural Park and the remaining to Kamole. Water from the Kamole Weir WTF services approximately 6,571 water service connections in the Hailiimaile, Makawao, and Pukalani regions (Figure 13-7). It also serves as backup for the Haiku region in the event of pump failures or repairs and maintenance. During drought conditions, water from this facility is capable of servicing the entire Upcountry region (9,708 connections) if necessary (Maui DWS, 2007e). Metered consumption in the Makawao and Pukalani regions between 1998 and 2008 averaged 0.97 million gallons per day, while that of the Hailiimaile region averaged less than 0.1 million gallons per day (Maui DWS, 2009). Consumption in the Upper and Lower Kula regions is significantly higher.

In addition to the Upcountry District, Maui DWS also draws water from EMI's Koolau Ditch to supply the domestic uses in the Lower Nahiku region. Under an April 25, 1994 agreement between EMI, HC&S, and the County of Maui, EMI agrees to deliver to Maui DWS 20,000 gallons of water per day to serve the Nahiku community. In 2000, this agreement was extended for another 25 years. Ground water is collected in two storage tanks via a development tunnel (Nahiku Tunnel). A distribution line runs along Nahiku Road and serves the Nahiku area located makai of Hana Highway (J. Takakura, personal communication, August 2009). Based on the 1994 Agreement, the maximum daily usage of the Nahiku community is 12,600 gallons per day.

Economic Impact

Maui DWS relies on Kamole Weir WTF to provide a minimum of 4.5 million gallons per day to the Upcountry District. This is the drought period reliable capacity, a parameter used to characterize the capability of the reservoir or a WTF to maintain a reliable supply of water during the drier seasons or drought conditions (Freedman, 2009). With the recent drought, water use restrictions were applied to the Upcountry District based on historical use volume for each customer. Further reductions of consistent flow in EMI's Wailoa Ditch, may severely impact Maui DWS' ability to maintain the current drought period reliable capacity of the Kamole WTF. While the WTF is in the process of being upgraded with higher capacity filters, additional mitigative options will need to be considered should raw water supplied by Wailoa Ditch be reduced.

A statistical analysis (Freedman, 2009) was conducted to examine cost-effective strategies to maintain and even increase the drought period reliable capacity of the Kamole Weir WTF to meet the increasing water demands as well as to mitigate impacts of potential raw water supply reductions. One option is to provide raw water storage reservoir capacity to ensure a reliable supply of water to the Upcountry District in times of drought. The study shows that for less than 30 million gallon reduction in Wailoa Ditch flows, providing a 100 to 200 million gallon reservoir would maintain the existing drought period reliable capacity of the WTF. If Wailoa Ditch flow reductions are more than 30 million gallons, maintaining the drought period reliable capacity using additional basal ground water wells is most cost-effective.

Another option is to modify the existing Kamole Weir WTF intake structures to increase the amount of water that can be withdrawn from Wailoa Ditch during low flow conditions. The study shows that this method is more cost-effective than drilling new basal ground water wells to provide incremental drought period reliable capacity. However, under normal flow conditions, improvements to the intake structure would not appreciably increase the average supply of water to the Upcountry District.

The economic impacts to Maui DWS can be expressed in costs estimates for implementing the recommended strategies proposed in Freedman (2009). One of the drawbacks of providing raw water storage reservoir capacity is the large initial capital expenditures in reservoir construction. The study estimates an expenditure of $15 to 30 million in building a 100 million gallon reservoir, and $30 to 60 million for a 200 million gallon reservoir. The cost of providing new basal ground water wells to replace the existing drought period reliable capacity of 4.5 million gallons per day would be about $32 million, or $8 million for every 1 million gallons per day of additional Kamole Weir WTF's drought period reliable capacity. While specific plans to improve the WTF intake structures have not been examined, it can be assumed that these improvements would be more cost-effective than drilling basal wells.

13.5 County of Maui, Department of Water Supply Upcountry System

There are three Upcountry Maui DWS water systems served by east Maui streams: 1) Upper Kula system is served by Haipuaena, Waikamoi, and Puohokamoa Streams; 2) Lower Kula system is served by Honomanu, Haipuaena, and Waikamoi Streams; and 3) Makawao system, as previously discussed, is served by EMI's Wailoa Ditch. Maui DWS diverts the streams for the Upper and Lower Kula pipelines, and it is only the Makawao system whose source is the EMI System. Although the Makawao system has already been discussed in a previous section (Section 13.4.6), this section will include an in-depth discussion on the Maui DWS Upcountry System in its entirety, including the Makawao system, and present some of the data that can be used to compare water use in different Upcountry regions.

13.5.1 System Overview

The Maui DWS Upcountry Water District, illustrated as colored regions in Figure 13-7, includes the sub-districts of Upper and Lower Kula, Opana/Awalau, Kula Agricultural Park, Makawao-Pukalani, and Haiku-Kokomo (Maui DWS, 2009), with an estimated population of 30,981 people (Findings of Fact, Conclusions of Law, and Decision and Order, 2007). The Opana/Awalau and Kula Agricultural Park sub-divisions receive non-potable water while the rest of the sub-districts receive potable water. The potable water systems are supported by three water treatment facilities, Olinda WTF, Piiholo WTF, and Kamole Weir WTF.

The Upper Kula system is situated at the highest elevation (about 4,200 feet) of the three systems comprising the Maui DWS Upcountry System. It begins as a flume (also known as the Waikamoi Upper Flume), capturing surface water from Haipuaena Stream, middle and west branch of Puohokamoa Stream, and Waikamoi Stream. The flume is connected to a 36-inch transmission line at Waikamoi and then captures additional water from Kailua Stream. The transmission line passes through the Waikamoi

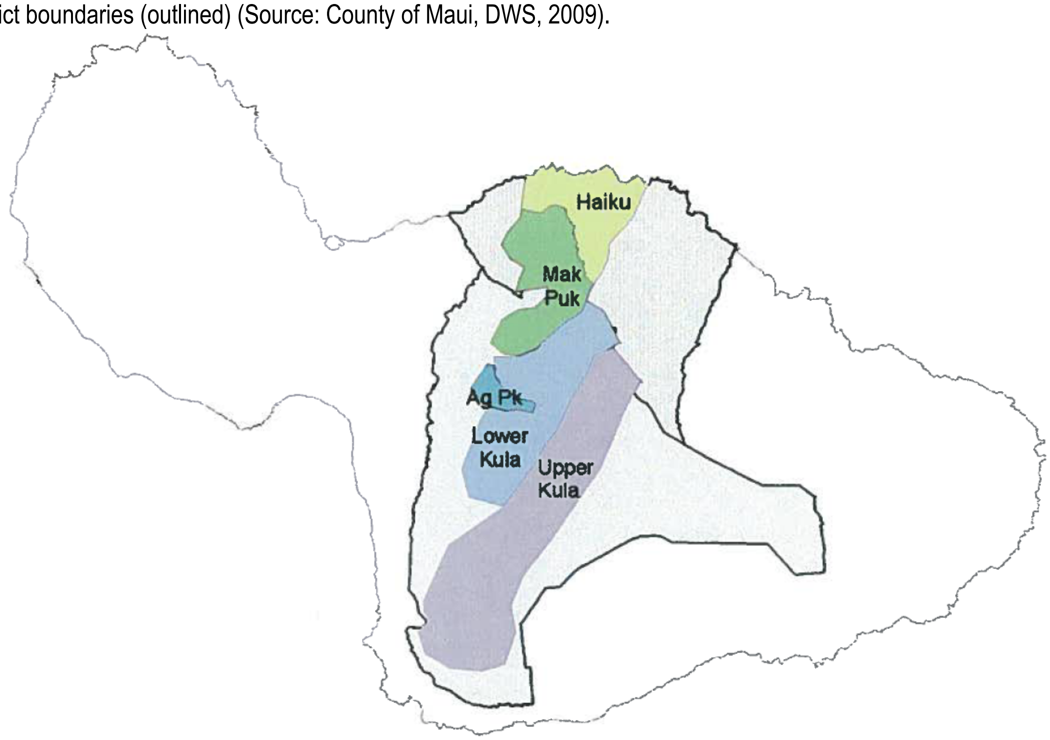
Reservoirs (two 15 million gallons reservoirs) and the Kahakapao Reservoirs (two 50 million gallons reservoirs) before reaching the Olinda WTF.

The Lower Kula system (also known as the Waikamoi Lower Pipeline) is situated at the 2,900 feet altitude and captures surface water primarily from Honomanu Stream, Haipuaena Stream, all branches of Puohokamoa Stream, and the east and west branch of Waikamoi Stream. Water from this system is treated at the Piiholo WTF and provides for domestic and agricultural uses in the Lower Kula region. Other than the 50 million gallon reservoir at the WTF, there are no other major reservoirs along the Lower Kula System.

The Makawao system is served by EMI's Wailoa Ditch that runs at approximately 1,100 feet elevation, and draws water from east Maui streams as far as Makapipi. Maui DWS treats the water at the Kamole Weir WTF and provides for domestic use in the Hailiimaile, Makawao, and Pukalani regions. It also serves as backup for the Haiku region in the event of pump failures or repairs and maintenance. During times of drought, water from this facility is pumped to the upper elevations to serve the Lower and Upper Kula regions (Maui DWS, 2009). Section 13.4.6 has more information on the Maui DWS Makawao system.

These three potable Upcountry systems are interconnected and rely on each other for backup during maintenance and repair. Surface water may also supplement the primary ground water sources (Haiku and Kuapakalua wells) for the region, but serves as backup in the event of pump failure or drought (Maui DWS, 2009). During drought conditions or times with lower than normal streamflow, water from the lower systems is frequently pumped to supplement the upper systems. Conversely, water from the upper systems may also be made available to supplement the lower systems during periods of higher than normal rainfall.

Figure 13-7. Maui DWS Upcountry District and its sub-districts (colored) overlaid on the Makawao-Pukalani-Kula Community Plan District boundaries (outlined) (Source: County of Maui, DWS, 2009).



13.5.2 System Users

The domestic users in the Upcountry District receive potable water from the Maui DWS via three WTFs. Served by the Olinda WTF are the Olinda, Upper Kula, Ulupalakua and Kanaio regions. According to Maui DWS, about 1.5 million gallons must be available in the Olinda WTF clearwell to serve the small community of users along Olinda Road because these users do not have an alternate water source. The Lower Kula region, including DHHL homesites are served by the Piiholo WTF. Under an existing Water Rights Agreement between the State of Hawaii, Department of Hawaiian Homelands (DHHL), and Maui DWS executed on December 9, 1997, Maui DWS shall deliver 0.5 million gallons of potable water per day to the DHHL homesites in the Lower Kula region. The Hailiimaile, Makawao, and Pukalani regions are served by the Kamole Weir WTF, whose water source is from EMI's Wailoa Ditch. Domestic users of the Haiku region also depend on water from the Kamole Weir WTF for backup.

The agricultural users in the Upcountry District include Haleakala Ranch, Ulupalakua Ranch, Kaonoulu Ranch, Kula Agricultural Park, vegetable and fruit farmers in the Omaopio region, and individual farmers and ranchers throughout the general area. Other agricultural operations such as slaughterhouses, i.e., Nakasone Meats in Pukalani and A. DeCoite Packing House in Haiku, are also among the agricultural users in the Upcountry District. All of these users, excepting Kula Agricultural Park, receive potable water for their irrigation needs. Kula Agricultural Park receives non-potable water from HC&S' Hamakua Ditch (refer to Section 13.4.5).

Maui DWS provided data on the different types of crops and livestock in the Upcountry Maui District (Table 13-13). Among the vegetables and melons category are onions, cabbage, tomato, beans, taro, lettuce, cucumber, zucchini, herbs, corn, egg plant, parsley, etc. Fruits include bananas, oranges, persimmons, avocado, grapes, limes, lemons, cherimoya, mango, plums, peaches, and loquat. Livestock agriculture is mainly cattle and hog operations. While the data may not reflect the true and present agricultural status, as farmers may plant vegetables and fruits simultaneously for crop rotation or certain lands may be left fallow, the data provide a general idea of the magnitude and diversity of agriculture that takes place in Upcountry Maui. Table 13-14 is a detailed look at the estimated counts and water needs for cattle and other livestock agriculture in Maui that depend on east Maui (between Waikamoi and Makapipi) water.

Table 13-13. Number of farms and estimated land area for the different types of crops and livestock in Maui (Source: County of Maui, DWS, 2009).

Type	Number of Farms	Acres
Pineapple	2	1,200
Vegetables and Melons	100	800
Fruits	150	600
Coffee	12	200
Nursery and Tropicals	12	150
Livestock	190	93,000

Table 13-14. Estimated counts and water needs for cattle and other livestock for cattle operations in Maui (Source: Maui Farm Bureau and OED, 2009).

[GPD is gallons per day; feral animals include feral goats, deer and pigs]

Animal Type	Count	Water Needs (GPD per head)	Total Water Needs
Cattle	13,850	20	277,000
Goats	1,630	3	4,890
Horses	935	20	18,700
Sheep	765	3	2,295
Elk	100	10	1,000
Feral Animals	17,100	5	85,500
Total	34,380	--	389,385

Currently, there is no prioritization of water uses among the system users although both DHHL and agricultural preservations are typically deemed high-priority uses in the county (Maui DWS, 2009). When a declaration of drought is in effect, Maui DWS may implement voluntary or mandatory water use restrictions for domestic users. While agricultural consumers have been exempt from water restrictions, agricultural users voluntarily conserve water usage by curtailing planting operations (Maui Farm Bureau and OED, 2009).

13.5.3 Water Use

While the Upcountry Water District and its sub-districts are determined by water sources and other operational parameters, some of the water use data presented is based on the Maui DWS Community Plan District boundaries, illustrated as outlines in Figure 13-7. These boundaries are political divisions used mainly for land use planning and do not shift with new source development or seasonal needs (Maui DWS, 2009). Although the two sets of boundaries do not match perfectly, water use data pertaining to the Upcountry Water District can be compared with those of the Community Plan District.

Historical and Current Uses

Metered water usage in the Upcountry District has steadily climbed over the past 12 years, with the largest portion going towards potable water use (Table 13-8). In 2005, the total potable use was almost 7 million gallons per day or 92 percent of the combined potable and non-potable water use in the Upcountry District (Maui DWS, 2009). For the Makawao-Pukalani-Kula Community Plan District, water use for agriculture and single-family residences constitute almost 50 percent of the total use. The two trends have been very similar over the past 5 years. In 2005, both uses were almost identical while in 2006, total single-family use was 3.118 million gallons per day and agricultural use was 2.732 million gallons per day. 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 13-9). Other water uses within the district are relatively low (Maui DWS, 2007d). The Lower Kula sub-district dominates total water use, averaging 2.2 million gallons per day from 1999 to 2008 (Figure 13-10).

Pookela Well is used as a back up well in the Makawao-Pukalani-Kula Community Plan District. An average of 0.188 million gallons per day was pumped from the well in 2008. From March 2008 to February 2009, an average of 0.328 million gallons per day was used. Two other wells, Kaupakalua and Haiku wells, are ground water sources that serve the Haiku sub-district (Maui DWS, 2009).

Figure 13-8. Maui DWS historical metered consumption for the Upcountry District, including Haiku (Source: Maui DWS, 2009).

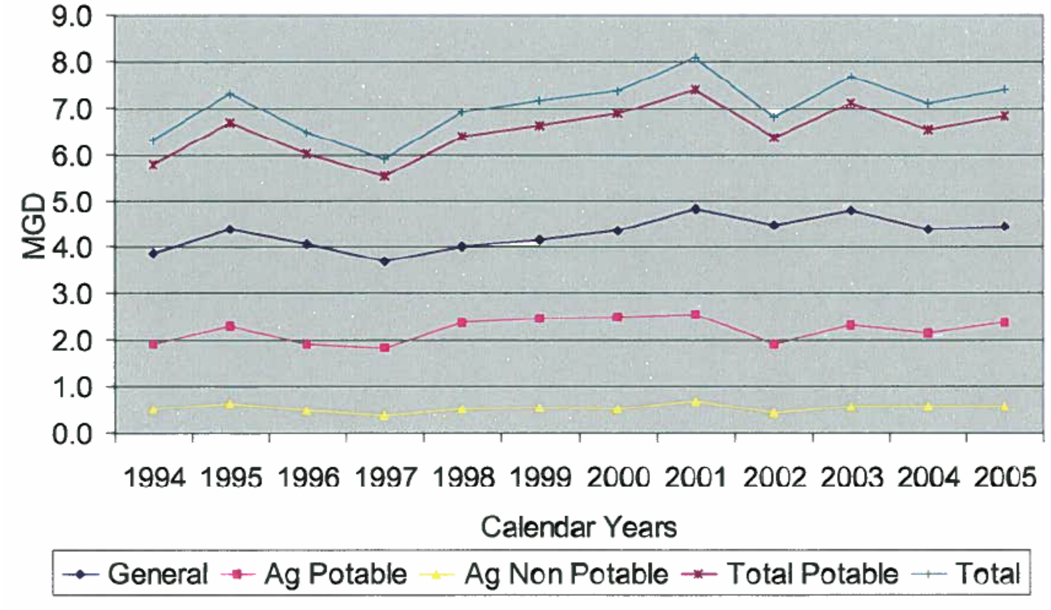


Figure 13-9. Historical monthly water consumption by use class code for the Makawao-Pukalani-Kula Community Plan District, Maui (Source: Maui DWS, 2007d).

[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]

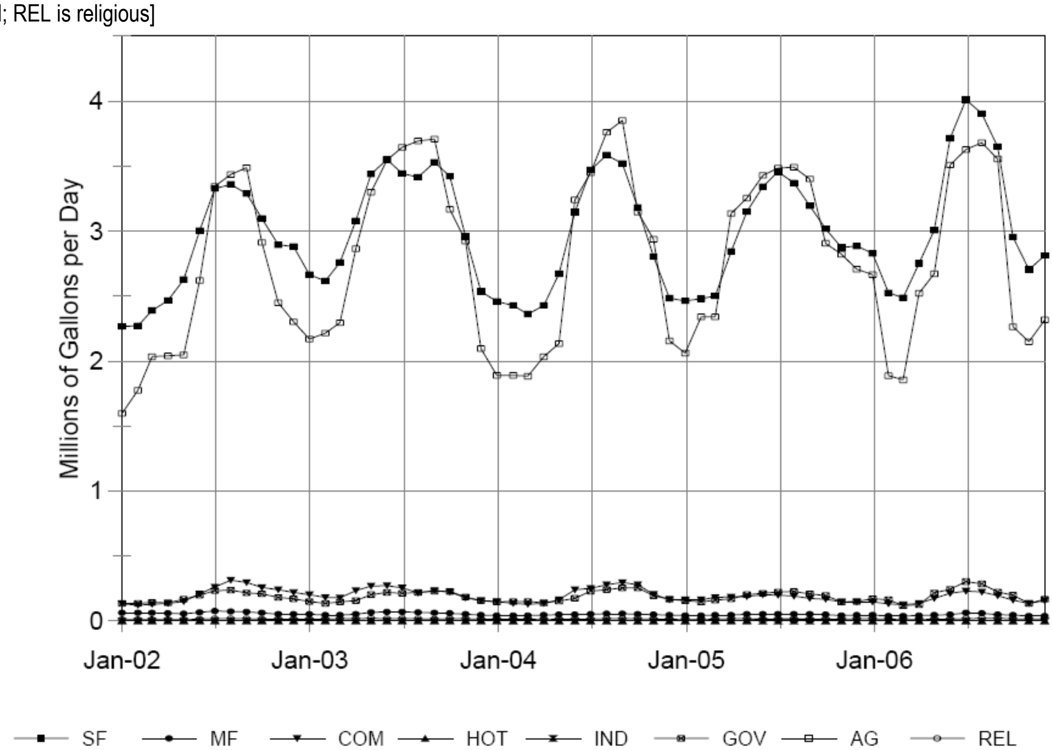
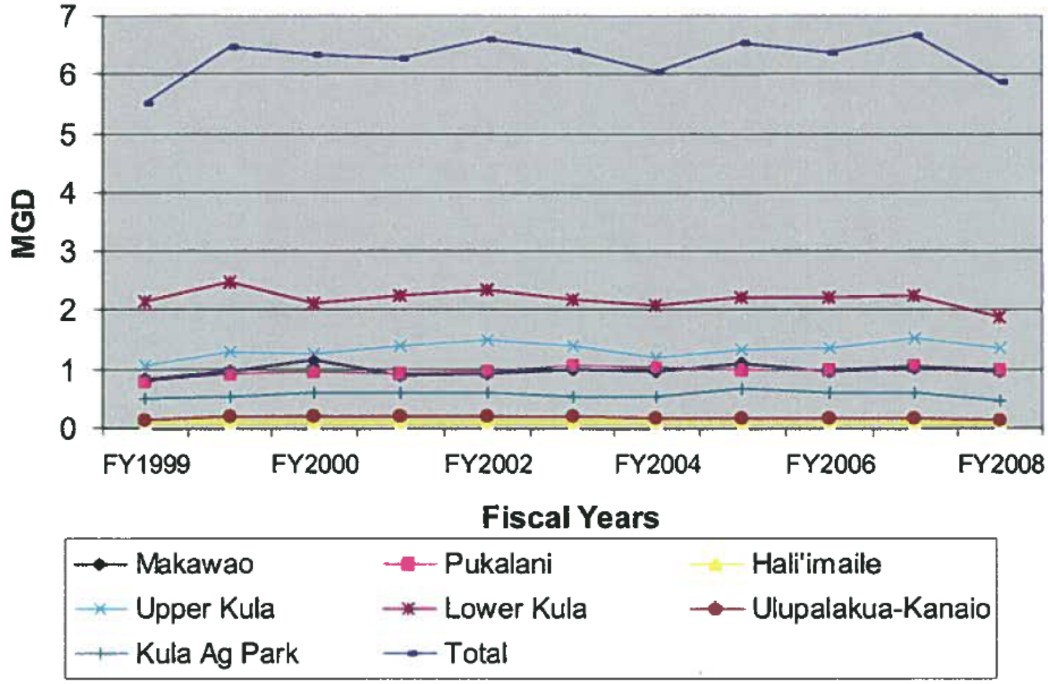
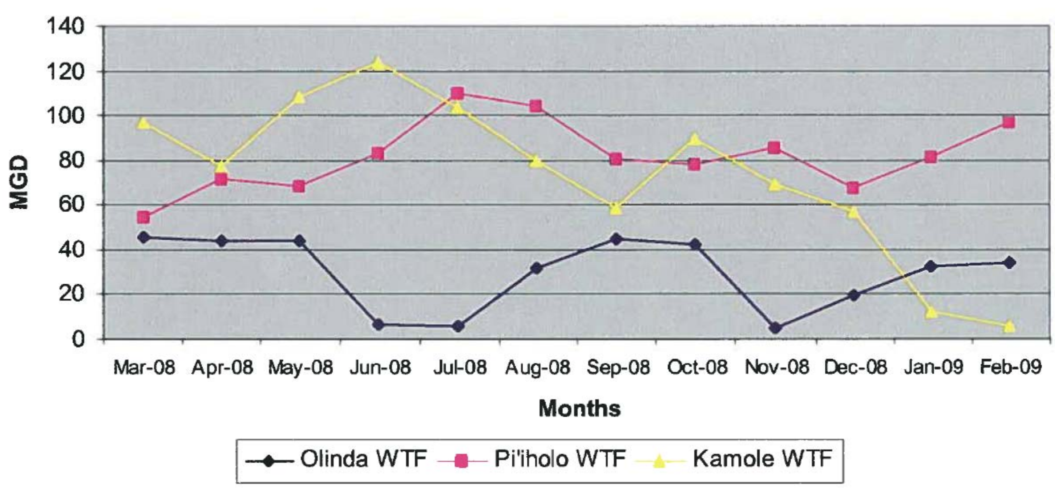


Figure 13-10. Maui DWS metered consumption for the Upcountry District by sub-division, excluding the Haiku sub-division (Source: Maui DWS, 2009).



The Maui DWS monthly production logs for the three Upcountry water systems is illustrated in Figure 13-11. During the early summer months of May through July, the Kamole Weir WTF production increased from 77 million gallons per day in April to as high as 124 million gallons per day in June of 2008. During these drier periods, water was pumped from the lower systems to supplement the upper systems, especially the Olinda WTF, in which potable water production was much lower. In June and July of 2008, the water production at the Olinda WTF dropped to 5.4 million gallons per day.

Figure 13-11. Monthly production of water treatment facilities in the Upcountry System (Source: Maui DWS, 2009).

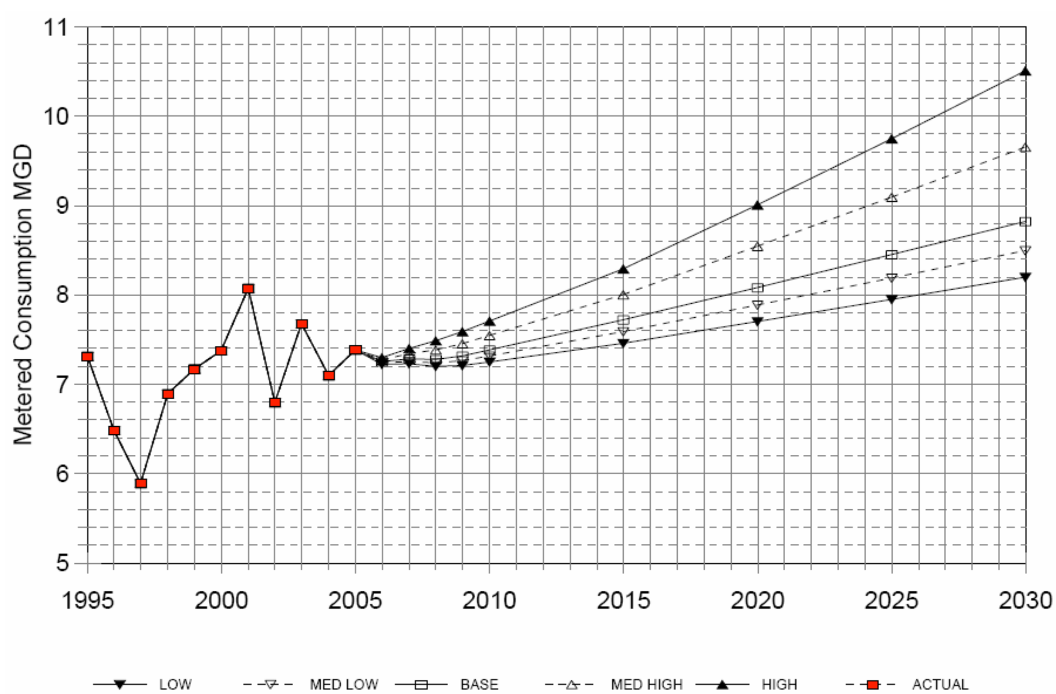


Future Demands

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, detecting system leaks, and increasing water storage capacity (Maui DWS, 2007c).

Upcountry water demands are expected to increase, as depicted in Figure 13-12, based upon five water demand projections derived from varying growth scenarios (low, medium low, base, medium high, and high) to the year 2030. Maui DWS expects the combined potable and non-potable water consumption to increase from a low of 7.2 million gallons per day in 2000 to 8.8 million gallons per day (base case) by the year 2030 (Freedman, 2009). This increase is largely a result of increased population projection in the Makawao-Pukalani-Kula Community Plan District, which is expected to increase by 45 percent from 2000 to 2030. Population increase is accompanied by increased demand for resident and non-resident housing units from 8,747 units in 2004 to a predicted 4,374 units in 2030 (County of Maui, DWS, 2009). The actual consumption for 2008 is actually lower than predicted due to higher water prices and the recent economic downturn starting mid-2008. Water production requirements are higher than consumption requirements to account for un-metered uses (i.e, fire protection and line flushing) and system losses (Freedman, 2009).

Figure 13-12. Actual and projected water demands of all metered use classes for the Upcountry District, Maui (Source: Maui DWS, 2007d).



A new non-potable water line has been constructed that would draw water from the Kahakapau Reservoirs to serve the agricultural needs of the Upper Kula region. Since water from this non-potable line would replace the potable water that is currently used for agricultural purposes (Freedman, 2009), more potable water would be available to serve the domestic needs of the Upper Kula region.

13.5.4 Economic Impact

The economic impacts of restricting water availability to the Maui DWS Upcountry System, particularly the Upper and Lower Kula systems, are complex due to the interconnectedness of the two systems, as well as the vast amount of users dependent on the systems for water. Figure 13-13 depicts the connection between the Maui DWS Upcountry System and the EMI System, and the users of the systems to help better understand and identify the different entities impacted by the possibility of water restriction resulting from the establishment of interim IFS. The following attempts to outline, in no particular order of importance, some if not all of the possible economic impacts of restricting water to the Maui DWS Upcountry System.

- **Power and pumping costs**. In 2007, over 26 percent (more than 10.5 million dollars) of Maui DWS' operating costs were attributed to power and pumping costs associated with pumping water from the lower elevations to supplement the upper regions. For instance, Maui DWS pumps water from the Kamole Weir WTF to the upper systems during the summer or drier months. In July 2008, power and pumping costs at the Kamole Weir WTF tripled that amount in February (Maui DWS, 2009). By restricting water availability to the Upper and Lower Kula systems, these power and pumping costs may increase.
- **Mitigation costs**. Various options are proposed to mitigate the impacts of potential raw water supply reductions on drought period reliable capacities of the Upcountry System. One of the options is additional reservoir capacity on the Lower Kula system that not only optimizes drought service reliability, but also reduces system pumping energy requirements (Freedman, 2009). The only raw water storage reservoir in the Lower Kula system is that at the Piiholo WTF. Potable water from EMI's Wailoa Ditch is pumped from Kamole Weir to supplement the Lower and Upper Kula systems. With increasing backlog of new water service demand in the Upcountry District, adding a raw water storage reservoir in the Lower Kula system would alleviate the long term operating costs. While the location of a new reservoir has not been determined, the optimum size of the reservoir would be between 100 to 300 million gallons. A new raw water storage reservoir would require total near term capital costs in excess of $50 million (Freedman, 2009).
- **Increasing demand**. Growth in water demand on the Upcountry District is very expensive. Statistical analyses (Freedman, 2009) show that a new water service costs $14 to $19 per gallon per day for the Upcountry System. A typical 600 gallon per day of new service connection averages over $9,000 of capital costs to provide for system source improvements.
- **Existing domestic needs**. Under existing conditions, the Upcountry residents are already prone to seasonal restrictions on water use. Further water use restrictions would negatively impact the community, especially those in the Olinda region and DHHL homesites. According to Maui DWS, the small community of domestic users along Olinda Road does not have an alternate source of water due to its location relative to the Olinda WTF. Maui DWS is also under an agreement with the State to provide DHHL's Waiohuli-Keokea sub-divisions 0.5 million gallons of potable water because DHHL does not have its own potable water source (County of Maui, DWS, 2009).
- **Agriculture**. When surface water availability decreases in the drier seasons or during drought conditions, farmers and ranchers alter planting and/or irrigation schedules to help conserve water. As a result, agricultural production and profits decrease. During the 2000-2002 drought, state-wide cattle losses were projected at $9 million (County of Maui, DWS, 2009). A similar statistic was reported for the 1996 drought that affected Hawaii, Maui, and Molokai. Another critical component of agriculture is its impact on the ability of Hawaii to remain self-sufficient. Hawaii is heavily dependent on imported goods, making it difficult for local farmers to stay viable. Local

farmers provide fresher and a greater diversity of products that are oftentimes more costly than imported goods. Diversified agriculture is also the ability to raise animal breeds or types of crops that are best adapted to Hawaii conditions, rather than importing those that may prove destructive to the agricultural community. While Hawaii may not become fully self-sufficient, continued and increased reliance on imported goods is unhealthy for its people and the economy.

Figure 13-13. A simplified schematic of the Maui DWS Upcountry System and the EMI System, and the system users.

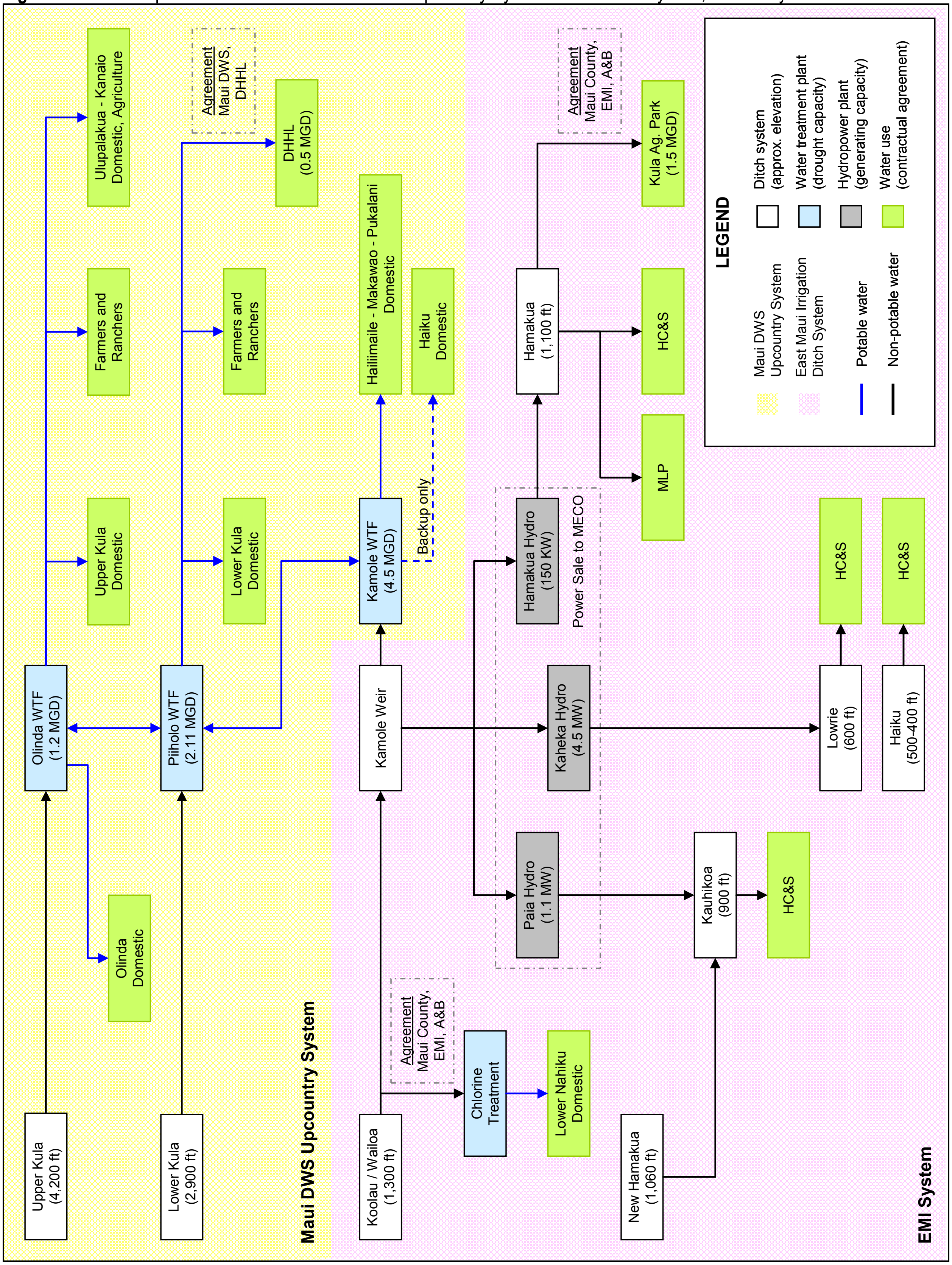


Figure 13-14. All registered diversions and EMI minor diversions identified in the Waikamoi hydrologic unit (Source: East Maui Irrigation Company, 1970; State of Hawaii, Commission on Water Resource Management, 2008f; USGS, 2001b).

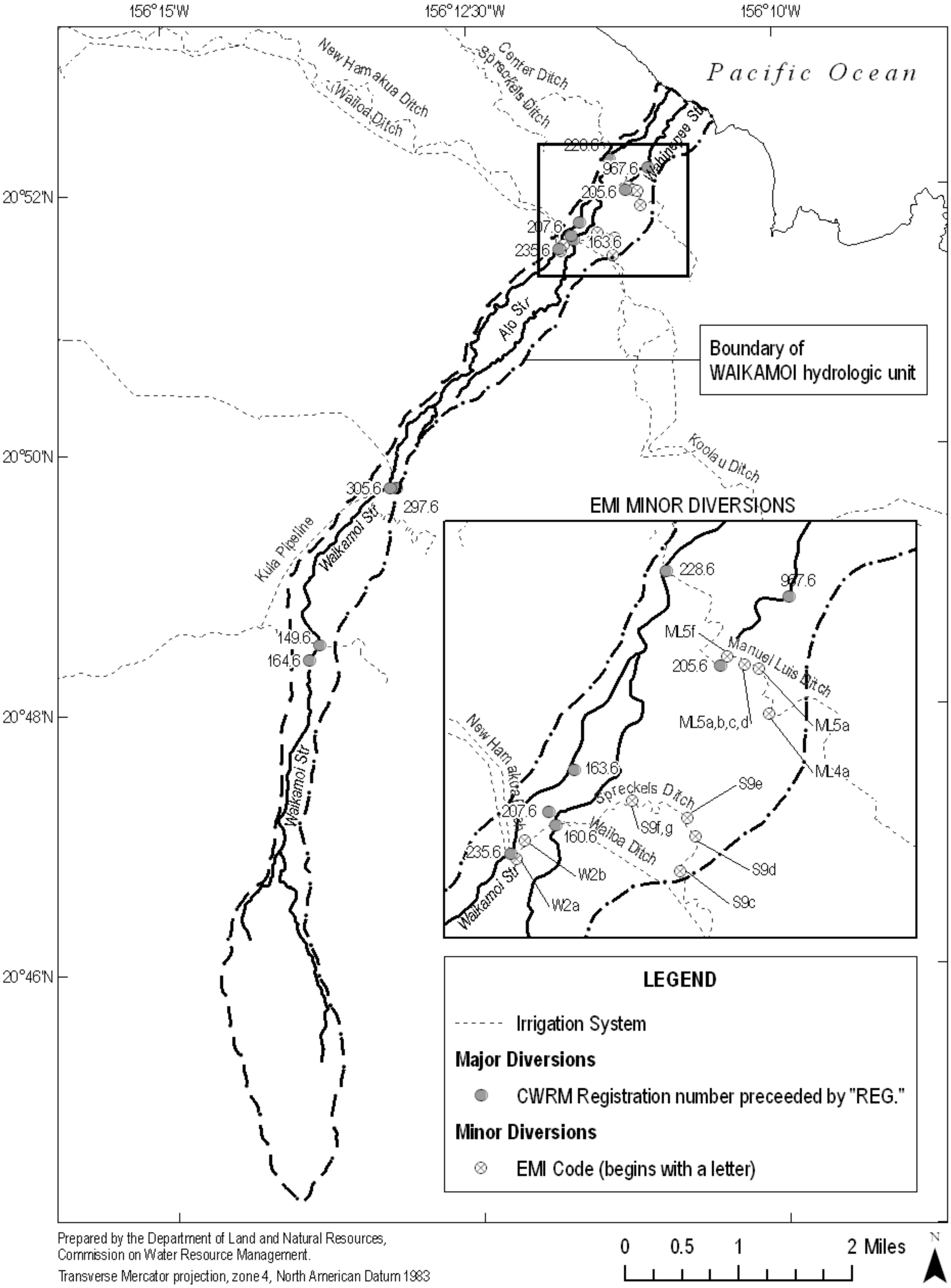


Figure 13-15. Potential agricultural land use for the Waikamoi hydrologic unit based on the ALISH and ALUM classification systems (Source: State of Hawaii, Office of Planning, 1977; 1980; USGS, 2001b).

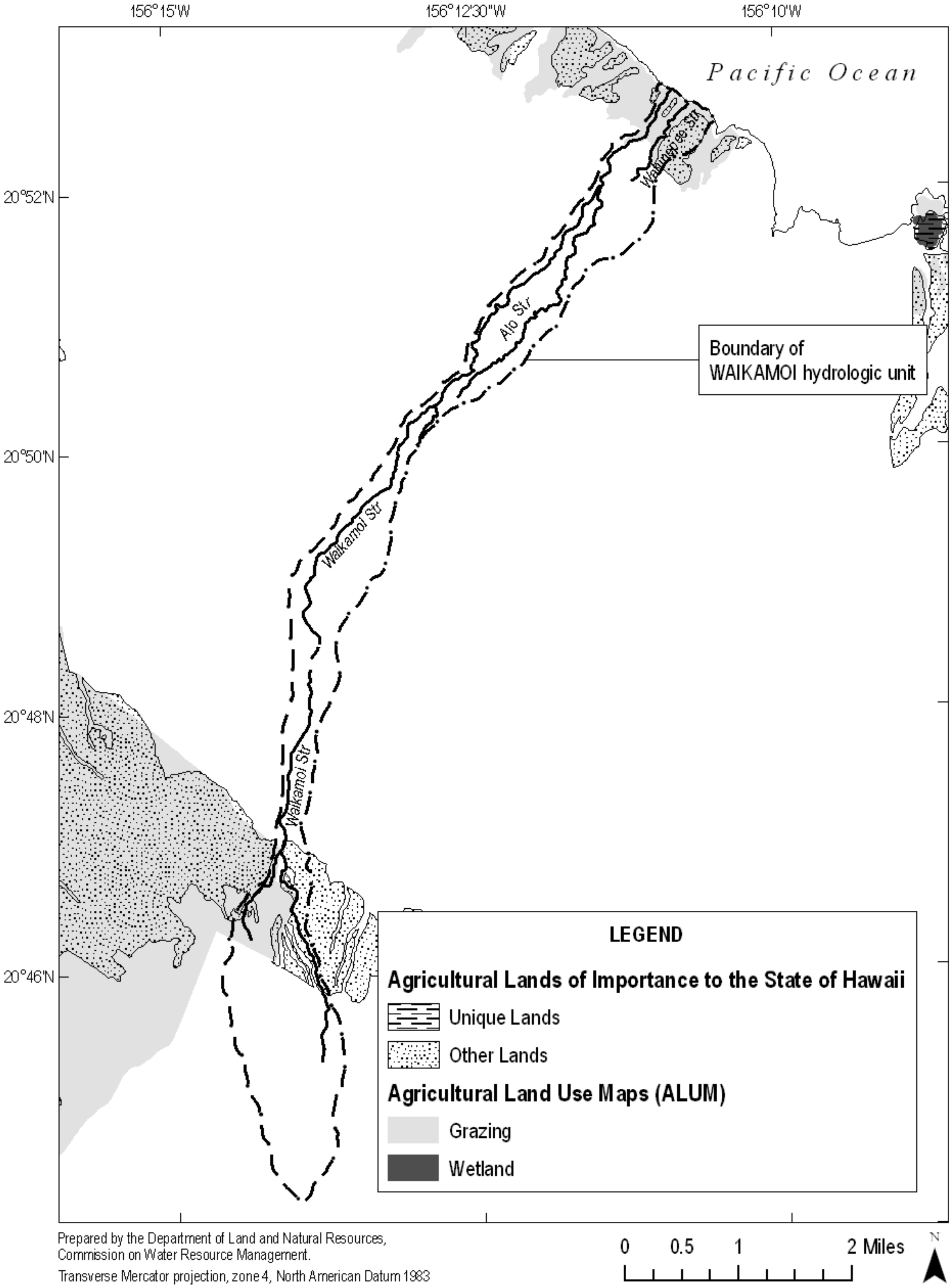
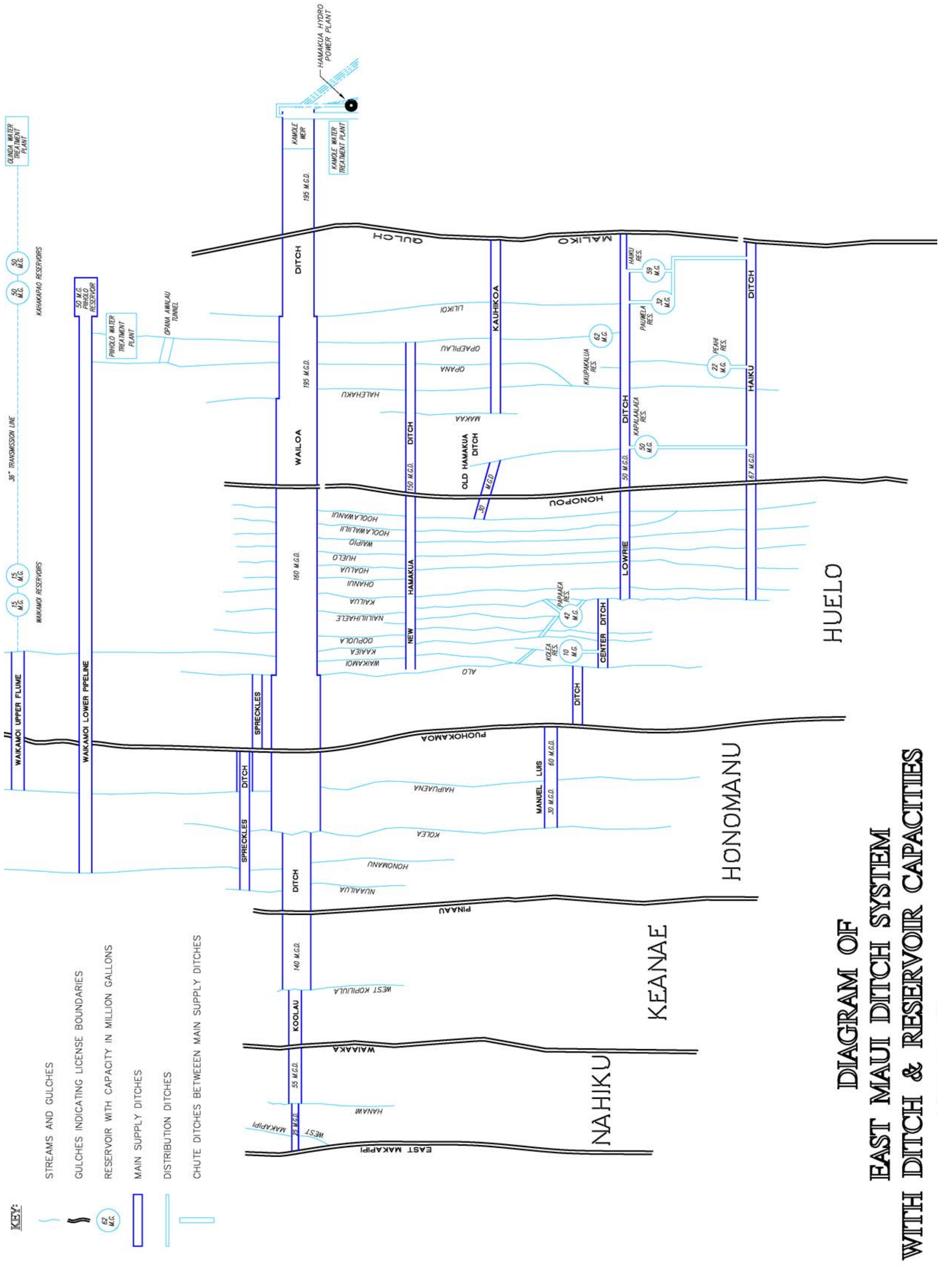


Figure 13-16. Simplified schematic of the EMI System.



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15.0 Appendices

Appendix A	Petition to Amend Interim Instream Flow Standards. Waikamoi Stream, East Maui. *State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management.*
Appendix B	Petition to Amend Interim Instream Flow Standards. Alo Stream, East Maui. *State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management.*
Appendix C	Petition to Amend Interim Instream Flow Standards. Wahinepee Stream, East Maui. *State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management.*

Appendix A

State of Hawaii
COMMISSION ON WATER RESOURCE MANAGEMENT
Department of Land and Natural Resources

22 P2:43 24 P3:10

PETITION TO AMEND INTERIM INSTREAM FLOW STANDARDS

WAIKAMOI STREAM, EAST MAUI

Instructions: Please print in ink or type and send completed petition with attachments to the Commission on Water Resource Management, P.O. Box 621, Honolulu, Hawaii 96809. Petition must be accompanied by a non-refundable filing fee of $25.00 payable to the Dept. of Land and Natural Resources. The Commission may not accept incomplete applications. For assistance, call the Regulation Branch at 587-0225.

1. PETITIONER

Firm/Name Na Moku 'Aupuni o Ko'olau Hui c/o Native Hawaiian Legal Corporation
Contact Person Alan Murakami, Attorney Ph: 521-2302
Address 1164 Bishop Street, Honolulu, Hawai'i 96813

2. STREAMFLOW DATA

USGS stream gaging station 16552600, 16552800, 165540, 1655500, 16556000 Period of Record Gages Inactive Data to follow.
Location/Reach SEE ATTACHED
(Attach a USGS map, scale 1"=2000', and a property tax map showing diversion location referenced to established property boundaries.)

TABLE 1. PERIOD OF RECORD AVERAGE MONTHLY STREAMFLOW WITHIN THE AFFECTED STREAM REACH, IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual

STREAMFLOW DATA TABLES TO FOLLOW.

Annual Median flow in cfs =

TABLE 2. PROPOSED AVERAGE MONTHLY STREAMFLOW DIVERSION FROM AFFECTED STREAM REACH, IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual

UNDETERMINED; SUFFICIENT FOR TARO FARMING AND/OR GATHERING.

Annual Median flow in cfs =

TABLE 3. AVERAGE MONTHLY STREAMFLOW IN AFFECTED STREAM REACH AFTER RESTORATION [redacted] (min release flow), IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual

NATURAL STREAMFLOW EXCEPT FOR EXERCISE OF APPURTENANT WATER RIGHTS.

Annual Median flow in cfs =

3. EXISTING INSTREAM AND OFFSTREAM WATER USES FOR ENTIRE STREAM REACH

TMK	OWNER	USE
RESEARCH IN PROGRESS.		

(If more space is necessary, attach an extended list following above format)

4. ANTICIPATED IMPACTS ON STREAM AND BASIS FOR SUCH IMPACTS:

RESTORATION OF INSTREAM NATURAL HABITAT AND BIOTA, AND BENEFICIAL APPURTENANT AND GATHERING USES.

(Attach supporting documentation, plans, letters, etc.)

May 24, 2001
Date

NATIVE HAWAIIAN LEGAL CORPORATION
Signature
Alan Murakami Petitioner
Attorney for Na Moku 'Aupuni o Ko'olau Hui

For Official Use
Date Received
Date Accepted

Waikamoi Stream

Waikamoi Stream is one of the longer streams in the study area. The stream is 8.5 mi long from the ocean to the head of several tributaries near Hosmer Grove Spring at 6,560 ft altitude (plate 1). Alo Stream, a major tributary, branches to the east at about 840 ft altitude. Waikamoi Stream rises from sea level to 600 ft altitude 0.8 mi from the coast (a gradient of 790 ft/mi) and at this altitude the stream valley is incised 280 ft below the upland surface. Waikamoi Stream lies on Honomanu Basalt for 3,000 ft from the coast and then on Kula Volcanics to the stream head where cinder cones of the volcano's north rift zone are located (Stearns and Macdonald, 1942). Streamflow is captured by five surface-water diversion systems (table 4).

Waikamoi Stream has not gone dry at any of the gaging stations downstream of 3,000 ft altitude during the periods of record despite the presence of Upper and Lower Kula diversion systems (table 2, plate 1). The stream has gone dry upstream of these diversion systems at gaging stations 5530 (4,250 ft altitude), 5528 (4,487 ft altitude), and 5526 (5,750 ft altitude). Base flow at 3,000 ft altitude in the two stream branches above gaging stations 5540 and 5545 is 1.7 Mgal/d and increases to 3.02 Mgal/d at 1,300 ft altitude (station 5550), a gain of 1.3 Mgal/d (table 2, fig. 15G–H). Alo Stream, headed at about 2,400 ft altitude, also gains an average of about 1.3 Mgal/d upstream of 1,248 ft altitude (station 5570), but along a shorter stream distance (plate 1).

Streamflow measurements made on October 18 and 24, 1994 during low-flow conditions show gains in flow of 1.68 Mgal/d between 3,160 ft and 490 ft altitude (table 11). The cumulative streamflow data were obtained by converting the October 24 measurements to equivalent October 18 measurements using a ratio of flow measurements made at site Waikamoi 33 on both days. Measurements were not made downstream of 490 ft altitude because the terrain prevented access. On the basis of the streamflow measurements, Waikamoi Stream (1) appears to be perennial upstream of 500 ft altitude and at the least downstream of 3,000 ft altitude, and possibly as high as 4,200 ft altitude and (2) does not have any measured sections that are losing water. No measurements were made where the stream flows on the Honomanu Basalt.

In the Waikamoi Stream water budget (Shade, 1999) of the 2.46-mi^2 area upstream of gaging station 5280, 9.19 Mgal/d of rainfall and 1.18 Mgal/d of fog drip is apportioned into 1.29 Mgal/d of runoff, 3.22 Mgal/d of evapotranspiration, and 5.87 Mgal/d of recharge (table 1, fig. 6). Because the gaged subbasin lies at higher altitudes with less precipitation than the rest of the subbasins included in Shade's study (fig. 3), it has a smaller ratio of precipitation to the stream subbasin area (fig. 6). Hence, the water-budget components are all proportionately smaller. The amount of base flow estimated from the streamflow record is only about 1 percent of the recharge to the subbasin (table 1). Most of the recharge is apparently following deeper groundwater flow paths and discharging downgradient of this gaging station.

Streamflow

Estimates of streamflow and base flow are based on streamflow records of varying length and from different times. The error associated with comparing these records is not considered significant because the average annual values used in the comparisons are expected to be within about 10 percent of the true value in most cases. A statistical analysis of five streamflow records, each with more than 60 years of record, shows that the average annual discharge for any 10-year period within that record has a standard error of 12 percent when compared with the whole record (Fontaine, 1996). When the length of the subset is increased to a 50-year period, the standard error only improves to 5 percent. Thirty nine of the streamflow records for the study area are equal to or greater than 10 years long.

For this study, the length of the period of record at each gaging station was determined to be unimportant by comparing each record to three reference records from the study area. The three longest streamflow records, 5080 (73 years), 5180 (76 years), and 5870 (85 years) were chosen as reference records. For each other individual record, a time period equal to the length of that record was chosen. A subset of a reference record was then selected from this same time period and the average flow during that time period was compared with the total reference record to estimate the ratio of flow during the subset period to the reference period. This analysis was made for all three reference records and the result was averaged to obtain a period-of-record scale factor for each of the other records. The scale factor ranged from 0.88 to 1.13 (table 2). This variability is consistent with the statistical analysis reported by Fontaine (1996). This range of accuracy is considered sufficient for the type of comparisons made in this study, and therefore, no corrections were made to any of the records to account for differences in length or period of record.

Table 11. Streamflow, temperature, and specific conductance in Waikamoi Stream, northeast Maui, Hawaii

[ft, feet; Mgal/d, million gallons per day; °C, degrees Celsius; µS/cm, microsiemens per centimeter; --, not determined; all altitudes estimated from U.S. Geological Survey topographic maps, Haiku, Keanae, and Kilohana quadrangles; measured flow from October 24 was scaled by 0.828 to make flow equivalent to October 18 flow for cumulative flow calculation; 1931 flow data is from Hofmann (1934); all other data is unpublished in files of U.S. Geological Survey, Hawaii District office]

Station number	Stream name	Altitude (ft)	Date	Streamflow (Mgal/d)	Cumulative streamflow without diversion, October 18, 1994 (Mgal/d)	Water temperature (°C)	Water specific conductance (µS/cm)	Comments
Waikamoi 7a	Waikamoi	490	10/18/94	0.14	1.68	22.0	108	
Waikamoi 8	unnamed tributary	500	10/18/94	--	--	21.9	87	Tributary from spring on east bank
Waikamoi 8a	Waikamoi	510	10/18/94	0.11	1.65	21.9	153	
Waikamoi 9	Waikamoi	515	9/10/95	--	--	21.9	153	Waikamoi Spring at 515 ft, on west bank at highway
Waikamoi 9a	Waikamoi	520	10/18/94 9/10/95	-- --	-- --	21.2 22.8	119 119	Waikamoi Spring at 520 ft, on east bank
Waikamoi 10	Waikamoi	530	10/18/94	0.02	1.56	23.0	84	
Waikamoi 11	Waikamoi	680	10/18/94	0.01	1.54	22.2	74	Most flow diverted
Waikamoi 14	Waikamoi	720	10/18/94	0.37	1.54	22.4	80	Upstream of Manuel Luis Ditch diversion
Waikamoi 15	Waikamoi	760	10/18/94	0.32	1.50	22.8	78	
Waikamoi 16	Waikamoi	820	10/18/94	0.36	1.53	23.3	75	Downstream of confluence with Alo Stream
Waikamoi 17	Waikamoi	860	10/18/94	0.15	1.32	23.2	81	Upstream of confluence with Alo Stream
Waikamoi 29a	Alo	1,210	10/24/94	0.69	--	20.3	42	Upstream of Wailoa Ditch diversion
Waikamoi 32	Waikamoi	1,190	10/18/94	0.01	1.19	--	--	
Waikamoi 33	Waikamoi	1,250	10/18/94 10/24/94	0.53 0.64	1.19 --	21.8 20.2	42 40	Upstream of Wailoa Ditch diversion
Waikamoi 40	Waikamoi	1,780	10/24/94	0.55	1.11	20.6	37	
Waikamoi 45	Waikamoi	2,360	10/24/94	0.33	0.93	19.4	36	Downstream of confluence with East Branch Waikamoi
Waikamoi 45a	Waikamoi (east branch)	2,420	10/20/31	0.34	--	--	--	
Waikamoi 45b	Waikamoi (east branch)	2,560	10/20/31	0.20	--	--	--	
Waikamoi 46	Waikamoi	2,375	10/24/94	0.19	0.82	18.0	36	Upstream of East Branch Waikamoi
Waikamoi 55a	flume inflow	3,135	10/18/94	0.13	--	18.5	18	
Waikamoi 56	Waikamoi	3,160	10/18/94	0.72	0.72	19.0	38	Upstream of flume inflow
Waikamoi 60	Waikamoi	4,270	10/18/94	0.00	0.00	--	--	Downstream of Upper Kula Pipeline diversion dam
Waikamoi 65	Waikamoi	4,500	10/18/94	0.02	0.02	16.0	16	
Waikamoi 72	Waikamoi	6,290	10/17/94	0.00	0.00	--	--	
Waikamoi 73	Waikamoi (west branch)	6,400	10/17/94	0.00	0.00	--	--	

[a] Estimated flow

WAIKAMOI

STATION ID - 16554500
E BR WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

CLASS / WATER YEAR RANGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1919 1919		12		3	27		29	40	54	17	36	12	19	18	22	10	5	8	10	13	10	2	4	2	6	3	1				1	1			
1920 1920		17		25	89		54	23	37	9	23	11	10	13	7	8	6	6	2	4	6	2		4	1	1	2	2	1	1		1	1		
1921 1921		17		24	15		15	20	41	15	29	26	19	24	12	18	8	11	8	12	4	7	10	2	7	3	6	4	1	2	2	2		1	
1922 1922		19		38	22		11	9	15	10	18	15	11	28	17	18	18	14	13	11	9	17	7	3	3	5	4	5	3	3	4	6	5	2	2
1923 1923				10	16		12	35	51	35	26	29	13	25	19	21	13	5	13	4	4	5	5	3	7	6	4	1			2		1		
1924 1924				34	47		25	36	50	13	13	20	11	18	15	10	5	10	9	12	6	6	5	5	3	1	6	1	2		1	1	1		
1925 1925				36	39		18	27	40	13	12	30	16	23	9	19	9	9	13	3	4	5	12	4	5	8	3	1	1	2	3		1		
1926 1926		26		106	41		21	21	24	13	22	14	11	17	10	7	6	4	7	1	2	1	3	1	3		3	1							
1927 1927				16	55		23	23	36	15	23	22	13	35	12	21	5	17	6	8	7	6	4	1	6	4	1	4		1			1		

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	0	3287	100.00	13	2.10	123	1242	37.79	25	17.00	41	177	5.38
2	0.31	91	3287	100.00	14	2.50	201	1119	34.04	26	21.00	31	136	4.14
3	0.37	0	3196	97.23	15	3.00	123	918	27.93	27	25.00	30	105	3.19
4	0.44	292	3196	97.23	16	3.60	132	795	24.19	28	30.00	19	75	2.28
5	0.52	351	2904	88.35	17	4.30	75	663	20.17	29	35.00	8	56	1.70
6	0.63	0	2553	77.67	18	5.10	84	588	17.89	30	42.00	9	48	1.46
7	0.74	208	2553	77.67	19	6.10	81	504	15.33	31	50.00	13	39	1.19
8	0.89	234	2345	71.34	20	7.30	68	423	12.87	32	60.00	11	26	0.79
9	1.10	348	2111	64.22	21	8.70	52	355	10.80	33	71.00	10	15	0.46
10	1.30	140	1763	53.64	22	10.00	51	303	9.22	34	85.00	3	5	0.15
11	1.50	202	1623	49.38	23	12.00	50	252	7.67	35	101.00	2	2	0.06
12	1.80	179	1421	43.23	24	15.00	25	202	6.15					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16554500   E BR WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION,
AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 0)
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE	
95.0	0.46	(LOG = -0.33715)
90.0	0.51	(LOG = -0.29660)
85.0	0.55	(LOG = -0.25611)
80.0	0.61	(LOG = -0.21753)
75.0	0.80	(LOG = -0.09513)
70.0	0.93	(LOG = -0.03171)
65.0	1.08	(LOG = 0.03224)
60.0	1.18	(LOG = 0.07180)
55.0	1.27	(LOG = 0.10525)
50.0	1.47	(LOG = 0.16753)
45.0	1.71	(LOG = 0.23392)
40.0	1.98	(LOG = 0.29622)
35.0	2.40	(LOG = 0.37980)
30.0	2.83	(LOG = 0.45188)
25.0	3.47	(LOG = 0.54027)
20.0	4.36	(LOG = 0.63946)
15.0	6.26	(LOG = 0.79673)
10.0	9.36	(LOG = 0.97116)
5.0	18.2	(LOG = 1.26089)

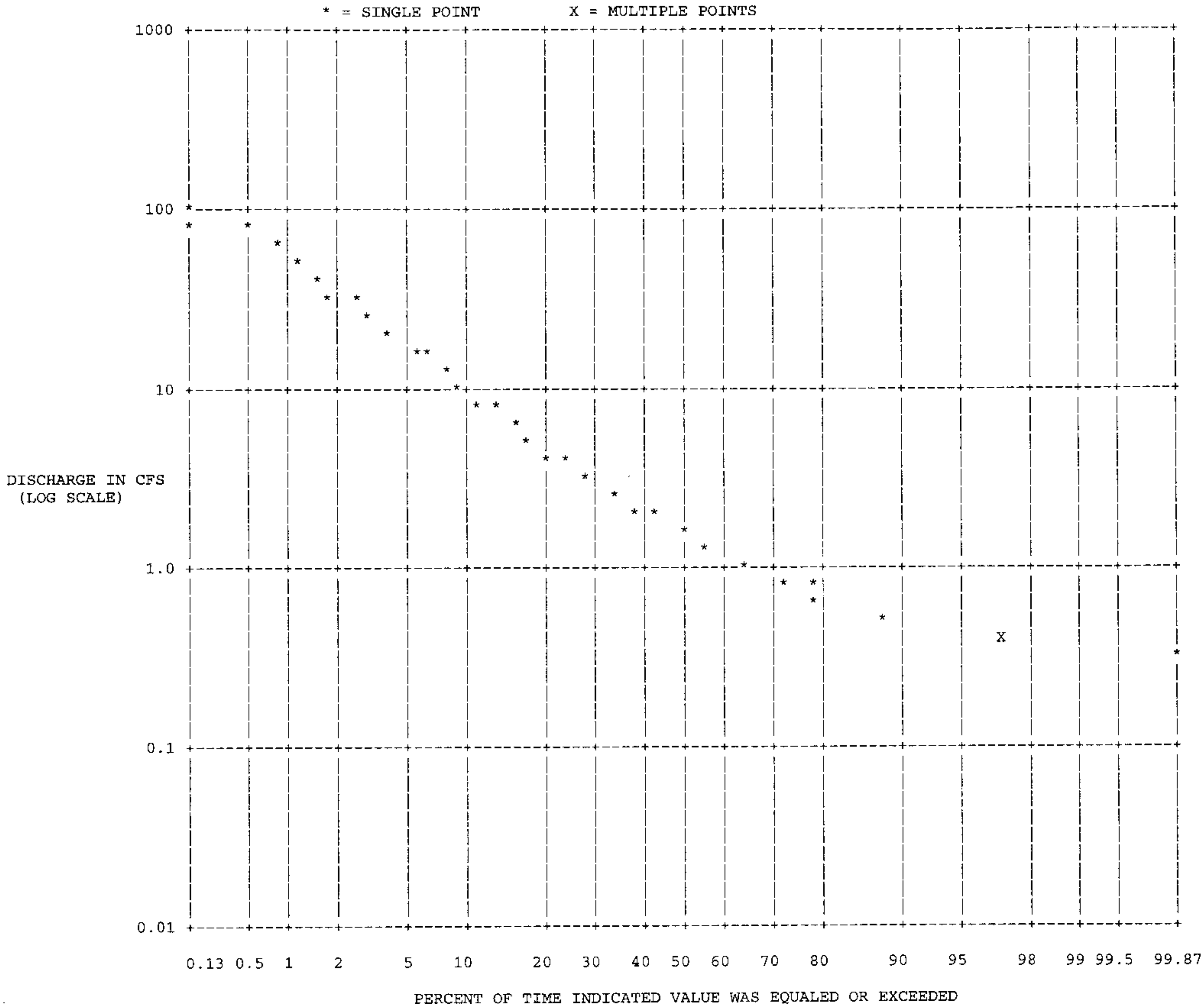
MEAN OF LOGS = 0.24805

STANDARD DEVIATION OF LOGS = 0.44475 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = 1.79299

COEFFICIENT OF SKEW = 0.70990

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1918 - 1933)
STATION ID: 16554500 E BR WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



STATION ID - 16554500
E BR WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		14		30		60		90		120		183	
1919 1919	.31	1	.31	1	.31	1	.39	4	.88	9	1.42	7	1.88	5	2.01	5	2.32	3
1920 1920	.31	2	.31	2	.31	2	.37	3	.47	4	.64	2	.77	1	1.36	3	1.94	2
1921 1921	.31	3	.31	3	.35	5	.41	5	.46	3	1.00	4	1.65	4	3.10	9	3.74	8
1922 1922	.31	4	.31	4	.31	3	.31	1	.38	1	.52	1	.95	2	1.32	2	2.57	5
1923 1923	.46	6	.46	6	.51	9	.51	8	.67	7	2.16	9	2.59	9	2.76	7	3.02	7
1924 1924	.46	7	.46	7	.46	6	.49	7	.66	6	1.05	5	2.11	8	1.91	4	2.51	4
1925 1925	.46	8	.46	8	.46	7	.52	9	.83	8	1.41	6	2.03	7	2.90	8	4.48	9
1926 1926	.31	5	.31	5	.31	4	.31	2	.45	2	.84	3	1.00	3	1.13	1	1.18	1
1927 1927	.46	9	.46	9	.46	8	.48	6	.61	5	1.61	8	1.94	6	2.74	6	2.80	6

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16554500
E BR WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		15		30		60		90		120		183	
1919 1919	68.0	8	37.3	7	30.4	4	17.6	6	11.0	6	6.92	7	5.54	6	5.59	6	4.54	6
1920 1920	71.0	7	48.3	5	42.3	2	22.4	4	12.8	4	7.24	6	5.46	7	4.93	7	3.68	8
1921 1921	90.0	2	57.0	2	29.1	5	24.0	2	15.8	3	11.5	2	9.75	2	8.43	2	7.39	2
1922 1922	104	1	85.3	1	73.6	1	42.5	1	30.6	1	21.1	1	19.6	1	20.1	1	15.1	1
1923 1923	74.0	6	48.7	4	37.3	3	22.9	3	12.5	5	8.42	4	7.10	4	6.12	4	5.21	4
1924 1924	80.0	3	53.0	3	25.3	7	14.4	7	8.89	7	7.56	5	6.12	5	6.12	5	5.05	5
1925 1925	79.0	4	41.7	6	27.5	6	19.7	5	16.8	2	10.1	3	7.99	3	6.85	3	6.02	3
1926 1926	34.0	9	17.7	9	10.1	9	6.76	9	5.72	9	3.71	9	3.20	9	2.71	9	2.25	9
1927 1927	79.0	5	34.7	8	19.1	8	10.9	8	6.87	8	5.88	8	5.46	8	4.55	8	4.46	7

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16554500
E BR WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN LOW-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE		
1919 1919	3.33	3
1920 1920	2.69	2
1921 1921	5.18	8
1922 1922	8.57	9
1923 1923	4.09	6
1924 1924	3.89	5
1925 1925	4.58	7
1926 1926	1.95	1
1927 1927	3.69	4

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN HIGH-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE		
1919 1919	3.33	7
1920 1920	2.69	8
1921 1921	5.18	2
1922 1922	8.57	1
1923 1923	4.09	4
1924 1924	3.89	5
1925 1925	4.58	3
1926 1926	1.95	9
1927 1927	3.69	6

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16554000
WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI, MAUI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

CLASS / WATER YEAR RANGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1920 1920		18			25	21	32	33	37	40	26	28	24	13	9	9	5	11	4	6	6	5	2		3	2		4		2				1	
1921 1921					3	7	10	5	6	47	30	50	50	11	24	22	8	10	14	14	4	6	12	5	5	6	4	1	3	3	2	3			
1922 1922					1	6	25	8	4	35	27	21	28	35	17	12	20	25	10	16	8	10	12	3	4	4	1	7	4	4	5	6	3	3	1
1923 1923								3	13	19	16	39	45	39	39	20	10	11	31	14	7	22	7	2	6	4	4	3	4	2	1	2		1	1
1924 1924						2	14	12	26	47	19	47	36	22	12	17	20	10	10	13	4	11	6	8	8	2	5	4	2	2	3	1	3		
1925 1925						1	9	7	14	40	18	42	43	22	26	20	16	18	11	8	11	10	9	3	9	4	4	6	4	2	3	1	3	1	
1926 1926					2	11	30	16	40	75	26	30	43	15	16	15	12	5	6	3	3	1	5	4		1	1		4	1					
1927 1927					1	5	20	23	19	44	24	40	38	13	19	20	22	13	6	9	10	10	5	3	4	2	6	4	3		1		1		
1933 1933					30	25	27	16	48	34	17	40	24	15	14	10	8	14	5	4	3	10	7	1	3	1	3	1	5						
1934 1934		3			44	13	37	9	36	18	8	15	12	20	23	12	20	9	12	12	10	14	8	9	2	6	3	5	2	1	2				

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	0	3652	100.00	13	2.20	343	1893	51.83	25	40.00	44	238	6.52
2	0.15	21	3652	100.00	14	2.80	205	1550	42.44	26	51.00	32	194	5.31
3	0.19	0	3631	99.42	15	3.50	199	1345	36.83	27	65.00	31	162	4.44
4	0.24	0	3631	99.42	16	4.50	157	1146	31.38	28	84.00	35	131	3.59
5	0.31	106	3631	99.42	17	5.80	141	989	27.08	29	106.00	31	96	2.63
6	0.40	91	3525	96.52	18	7.30	126	848	23.22	30	136.00	17	65	1.78
7	0.51	204	3434	94.03	19	9.40	109	722	19.77	31	173.00	17	48	1.31
8	0.65	132	3230	88.44	20	12.00	99	613	16.79	32	221.00	13	31	0.85
9	0.82	243	3098	84.83	21	15.00	66	514	14.07	33	282.00	10	18	0.49
10	1.00	399	2855	78.18	22	19.00	99	448	12.27	34	359.00	6	8	0.22
11	1.30	211	2456	67.25	23	25.00	73	349	9.56	35	458.00	2	2	0.05
12	1.70	352	2245	61.47	24	32.00	38	276	7.56					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16554000 WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI, MAUI
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION, AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 0)
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE	
95.0	0.47	(LOG = -0.33049)
90.0	0.61	(LOG = -0.21394)
85.0	0.81	(LOG = -0.09044)
80.0	0.95	(LOG = -0.02197)
75.0	1.09	(LOG = 0.03632)
70.0	1.22	(LOG = 0.08796)
65.0	1.46	(LOG = 0.16311)
60.0	1.78	(LOG = 0.24955)
55.0	2.04	(LOG = 0.30873)
50.0	2.32	(LOG = 0.36496)
45.0	2.64	(LOG = 0.42105)
40.0	3.10	(LOG = 0.49200)
35.0	3.84	(LOG = 0.58384)
30.0	4.92	(LOG = 0.69173)
25.0	6.61	(LOG = 0.82010)
20.0	9.26	(LOG = 0.96661)
15.0	14.0	(LOG = 1.14538)
10.0	24.0	(LOG = 1.38054)
5.0	56.0	(LOG = 1.74809)

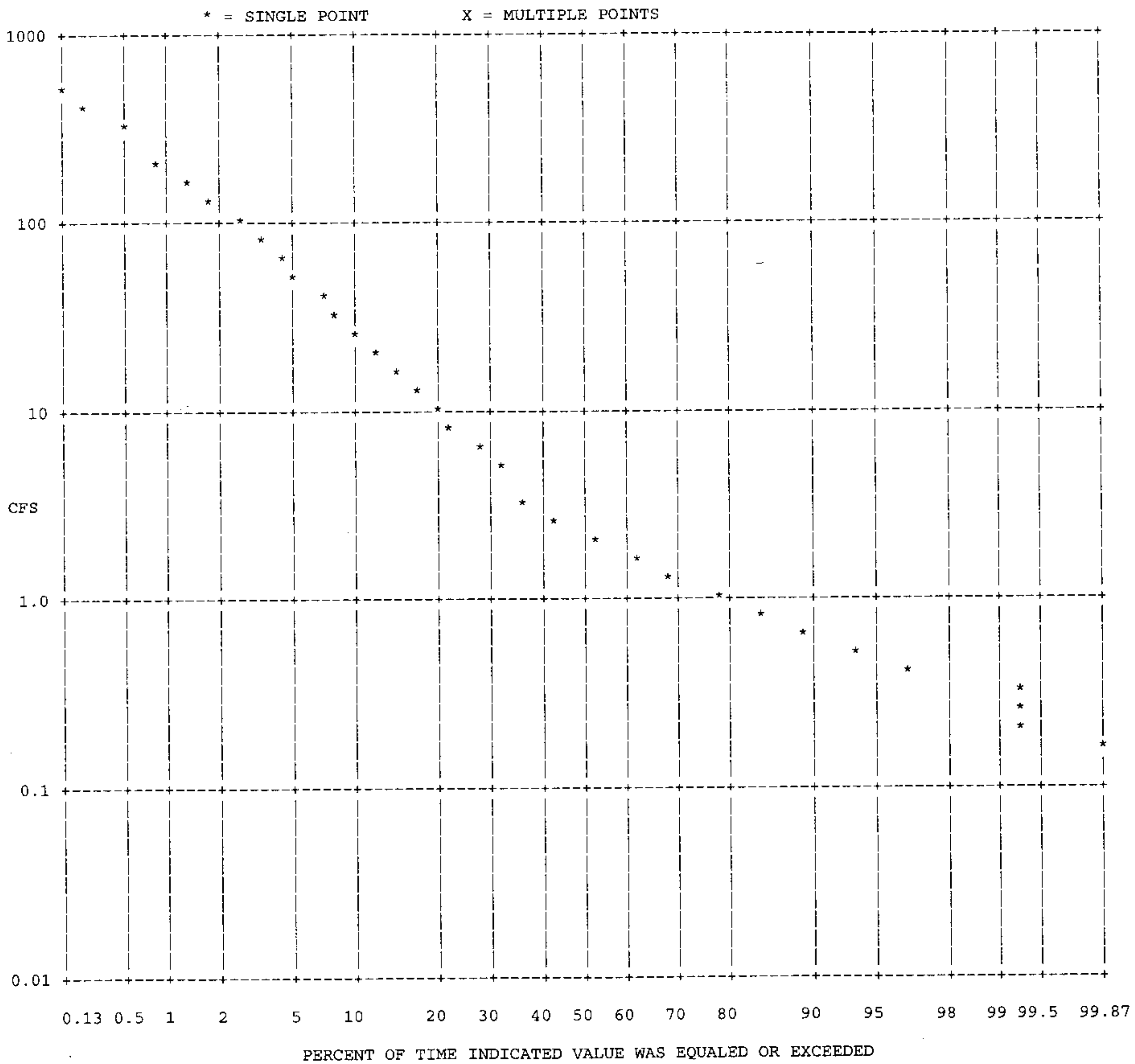
MEAN OF LOGS = 0.46332

STANDARD DEVIATION OF LOGS = 0.55431 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = 1.19637

COEFFICIENT OF SKEW = 0.77614

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1918 - 1935)
STATION ID: 16554000 WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI, MAUI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16554000
WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI, MAUI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		14		30		60		90		120		183	
1920 1920	.15	1	.15	1	.20	1	.20	1	.32	1	.78	1	.98	1	1.68	1	3.00	3
1921 1921	.31	3	.36	4	.44	5	.48	4	.64	4	1.22	4	1.88	5	3.78	5	6.37	6
1922 1922	.31	4	.41	5	.55	7	.58	7	.65	5	.99	3	1.62	3	2.19	3	4.42	4
1923 1923	.77	10	.77	10	.89	10	.95	9	1.34	10	5.21	10	5.67	8	6.82	9	8.09	9
1924 1924	.46	8	.51	8	.57	8	.67	8	.94	8	2.17	7	5.99	9	5.35	7	7.91	8
1925 1925	.46	9	.57	9	.66	9	.96	10	1.32	9	3.02	8	7.49	10	7.87	10	14.0	10
1926 1926	.31	5	.41	6	.44	4	.55	6	.72	7	1.47	5	1.66	4	2.35	4	2.80	1
1927 1927	.31	6	.41	7	.51	6	.54	5	.70	6	3.60	9	4.58	7	6.28	8	7.39	7
1933 1933	.31	7	.31	3	.31	3	.40	3	.49	3	.94	2	1.53	2	2.09	2	2.93	2
1934 1934	.15	2	.15	2	.24	2	.28	2	.48	2	1.49	6	3.82	6	3.89	6	4.88	5

STATION ID - 16554000
WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI, MAUI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		15		30		60		90		120		183	
1920 1920	360	4	169	5	141	4	73.2	5	39.6	6	20.7	7	15.9	7	13.3	8	9.12	9
1921 1921	269	7	166	6	94.3	6	79.5	4	58.3	4	41.0	4	33.6	3	26.9	3	21.8	4
1922 1922	500	1	332	1	262	1	145	1	107	1	69.6	1	66.8	1	66.8	1	46.6	1
1923 1923	458	2	325	2	234	2	130	2	68.5	3	46.1	2	36.1	2	28.8	2	22.9	3
1924 1924	343	5	239	4	109	5	66.4	7	36.8	7	32.9	5	24.7	6	24.6	5	19.8	5
1925 1925	427	3	250	3	151	3	100	3	75.4	2	41.8	3	31.0	4	26.5	4	23.0	2
1926 1926	145	9	68.8	10	36.1	10	23.9	10	17.6	10	10.1	10	8.92	10	7.23	10	5.49	10
1927 1927	340	6	152	7	76.0	9	41.1	8	24.3	9	16.4	9	14.5	9	13.2	9	11.0	7
1933 1933	116	10	116	9	77.4	8	38.3	9	26.9	8	18.7	8	15.6	8	14.0	7	11.0	8
1934 1934	217	8	149	8	84.0	7	69.5	6	44.2	5	30.7	6	25.4	5	21.8	6	16.6	6

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16554000
WAIKAMOI STR AT HAIKU-UKA BDRY NR KAILIILI, MAUI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR
PERIOD INCLUDED IN LOW-VALUE ANALYSIS
(OCT-SEP)

WATER YEAR RANGE		
1920 1920	6.00	2
1921 1921	12.8	6
1922 1922	25.3	10
1923 1923	15.2	8
1924 1924	14.4	7
1925 1925	17.1	9
1926 1926	5.11	1
1927 1927	9.71	4
1933 1933	6.28	3
1934 1934	10.4	5

MEAN VALUE AND RANKING FOR
PERIOD INCLUDED IN HIGH-VALUE ANALYSIS
(OCT-SEP)

WATER YEAR RANGE		
1920 1920	6.00	9
1921 1921	12.8	5
1922 1922	25.3	1
1923 1923	15.2	3
1924 1924	14.4	4
1925 1925	17.1	2
1926 1926	5.11	10
1927 1927	9.71	7
1933 1933	6.28	8
1934 1934	10.4	6

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16555000
WAIKAMOI STR AB WAILOA DITCH NR HUELO, MAUI,HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

CLASS / WATER YEAR RANGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1923 1923									7	13	21	29	43	44	54	34	28	18	15	12	10	11	5	4	9	2	2	2		2					
1924 1924									16	39	34	32	39	38	28	19	24	19	14	12	15	6	12	2	7	3	4	1	2						
1925 1925									7	25	25	27	34	39	29	31	44	15	18	9	8	5	21	10	3	9	2	2	2						
1926 1926						1	8	35	31	41	35	32	29	32	29	32	20	10	7	6	4	2	5	1	4	1									
1927 1927								11	16	17	25	27	38	40	35	32	28	23	15	19	7	9	7	6	7	1	1		1						
1928 1928									1	9	19	30	35	43	38	37	41	24	15	23	16	5	8	8	7	3	4								
1929 1929							3	8	10	13	23	47	41	31	29	32	23	19	9	15	16	11	14	7	6	3	4		1						
1930 1930						7	4	6	3	7	24	11	22	42	25	38	19	36	16	26	22	13	7	11	10	9	4	2	1						
1931 1931									1	15	38	41	39	30	32	29	21	32	13	19	12	13	12	5	5	4	3	1							
1932 1932											13	31	38	42	36	46	34	30	22	12	14	12	11	8	10	5		1	1						
1933 1933							4	18	49	22	59	40	42	23	27	16	11	12	6	12	10	3	2	5	1	1	1			1					
1934 1934						1	7	26	24	39	44	23	16	24	28	23	14	28	4	22	12	9	6	6	8							1			
1935 1935									2	14	17	33	45	36	41	43	30	28	14	14	10	9	6	7	4	7	1	3		1					
1936 1936								5	31	29	23	21	21	35	21	31	30	22	24	21	17	13	13	6	2	1									
1937 1937										1	7	13	18	23	37	47	32	26	36	30	21	12	13	19	11	4	5	5	1	4					
1938 1938									2	15	24	39	39	42	31	29	19	22	20	15	16	7	14	9	7	1	4	5	1	2	1			1	
1939 1939										5	24	19	43	44	28	47	32	23	22	15	16	9	15	9	7	3	2	1	1						
1940 1940					5	5	5	12	28	30	24	40	29	38	28	30	15	14	16	13	10	3	4	4	5	1	3	1	2		1				
1941 1941						4	3	10	23	19	28	28	28	35	35	28	19	21	18	14	14	12	8	7	4	2	2	2			1				
1942 1942					2	5	3	7	12	13	13	25	32	38	30	33	27	19	12	19	8	11	12	8	9	7	11	6	1		2				
1943 1943								10	22	36	38	34	29	40	28	32	18	10	14	12	10	9	7	3	7	4	1	1							
1944 1944				8	11	12	17	16	27	33	39	33	32	37	20	21	10	13	8	9	4	5	4	4	1	1	1								
1945 1945			13	10	7	5	7	10	39	15	27	30	21	32	27	20	18	21	11	14	13	7	8	4	2	4									
1946 1946				4	14	17	12	7	14	20	40	33	33	27	16	18	14	17	20	12	8	9	10	9	6	2		1		2					
1947 1947					4	4	8	7	11	16	26	46	38	32	28	31	25	14	15	12	9	6	9	8	4	3	4	2	1			1	1		
1948 1948									6	12	16	50	33	46	29	40	21	21	9	13	12	14	12	11	5	7	3	1	1	2					2
1949 1949							8	14	19	19	28	37	32	32	32	25	26	21	10	18	8	11	6	9	5	4			1						
1950 1950						3	7	6	13	8	22	32	39	42	31	22	21	24	16	11	20	15	9	7	7	2	3	3		1	1				
1951 1951							5	13	26	16	18	26	55	44	36	25	20	21	11	10	11	4	9	2	5	3	2	3							
1952 1952					1	4	2	5	2	7	16	17	35	54	65	31	30	22	17	16	9	11	6	7	5	3	1								
1953 1953			14	11	15	8	10	12	17	23	30	20	27	43	35	23	15	14	5	4	9	7	11	3	6		1	2							
1954 1954		1	8	6	11	6	9	6	11	17	14	20	27	39	38	26	25	23	18	11	15	8	13	5	2	4	2								
1955 1955					5	9	5	3	5	7	15	26	36	35	36	29	35	27	14	11	13	10	13	10	6	4	4	2	4				1		
1956 1956					8	8	8	14	12	14	18	17	28	39	36	24	30	18	22	17	11	11	9	3	7	6	2		1	1		2			
1957 1957					6	4	3	7	15	20	41	44	43	36	33	25	18	11	7	10	7	8	3	6	10	3	2	2		1					

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16555000
WAIKAMOI STR AB WAILOA DITCH NR HUELO, MAUI,HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES

CLASS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35

WATER YEAR

NUMBER OF DAYS IN CLASS

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	0	12784	100.00	13	4.40	1179	9019	70.55	25	128.00	204	503	3.93
2	0.20	1	12784	100.00	14	5.80	1297	7840	61.33	26	170.00	117	299	2.34
3	0.26	35	12783	99.99	15	7.70	1131	6543	51.18	27	225.00	79	182	1.42
4	0.35	39	12748	99.72	16	10.00	1049	5412	42.33	28	298.00	49	103	0.81
5	0.46	89	12709	99.41	17	14.00	837	4363	34.13	29	395.00	22	54	0.42
6	0.62	103	12620	98.72	18	18.00	718	3526	27.58	30	523.00	17	32	0.25
7	0.82	138	12517	97.91	19	24.00	513	2808	21.96	31	692.00	6	15	0.12
8	1.10	268	12379	96.83	20	31.00	508	2295	17.95	32	917.00	4	9	0.07
9	1.40	502	12111	94.74	21	42.00	417	1787	13.98	33	1210.00	2	5	0.04
10	1.90	629	11609	90.81	22	55.00	310	1370	10.72	34	1610.00	1	3	0.02
11	2.50	908	10980	85.89	23	73.00	324	1060	8.29	35	2130.00	2	2	0.02
12	3.30	1053	10072	78.79	24	97.00	233	736	5.76					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16555000   WAIKAMOI STR AB WAILOA DITCH NR HUELO, MAUI,HI
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION,
AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 0)
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE	
95.0	1.36	(LOG = 0.13423)
90.0	2.00	(LOG = 0.30073)
85.0	2.60	(LOG = 0.41499)
80.0	3.16	(LOG = 0.50013)
75.0	3.81	(LOG = 0.58042)
70.0	4.48	(LOG = 0.65160)
65.0	5.24	(LOG = 0.71953)
60.0	6.05	(LOG = 0.78164)
55.0	6.98	(LOG = 0.84416)
50.0	8.01	(LOG = 0.90347)
45.0	9.31	(LOG = 0.96881)
40.0	11.1	(LOG = 1.04680)
35.0	13.6	(LOG = 1.13275)
30.0	16.5	(LOG = 1.21807)
25.0	20.8	(LOG = 1.31718)
20.0	27.4	(LOG = 1.43819)
15.0	39.2	(LOG = 1.59298)
10.0	60.3	(LOG = 1.78045)
5.0	109.9	(LOG = 2.04091)

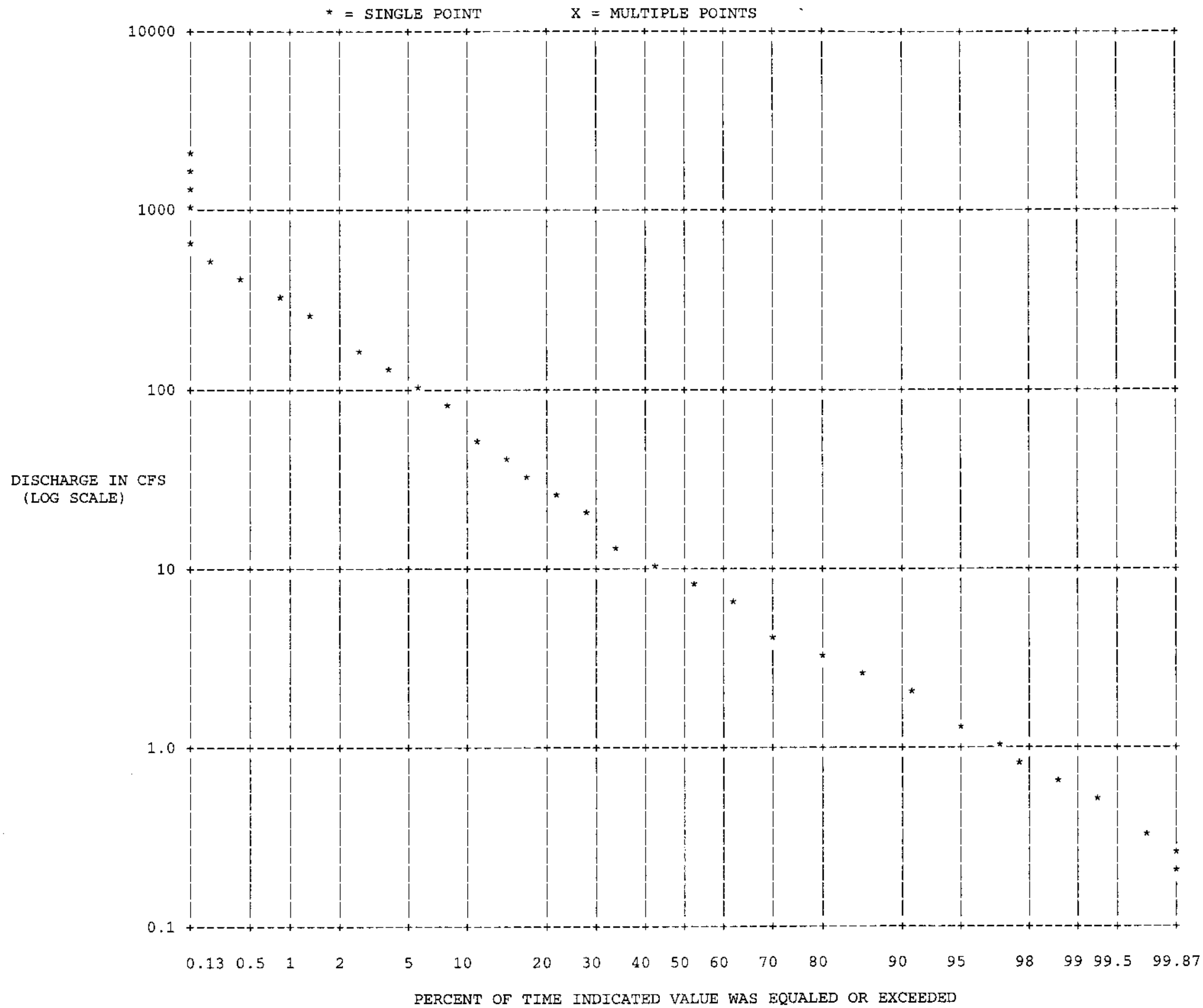
MEAN OF LOGS = 0.96669

STANDARD DEVIATION OF LOGS = 0.50947 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = 0.52703

COEFFICIENT OF SKEW = 0.44084

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1922 - 1958)
STATION ID: 16555000 WAIKAMOI STR AB WAILOA DITCH NR HUELO, MAUI,HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



STATION ID - 16555000
WAIKAMOI STR AB WAILOA DITCH NR HUELO, MAUI,HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1	3	7	14	30	60	90	120	183
1923 1923	1.50 28	1.63 27	1.81 27	1.93 26	2.72 18	9.80 28	11.7 19	12.9 18	15.5 14
1924 1924	1.40 25	1.43 25	1.53 25	1.84 24	2.74 19	5.13 16	12.0 20	10.8 13	15.1 13
1925 1925	1.40 26	1.53 26	1.94 29	2.53 30	3.90 26	6.89 18	13.1 23	18.5 31	27.6 31
1926 1926	.77 16	.93 20	.96 15	1.04 13	1.73 13	4.24 10	5.01 4	6.08 3	6.29 1
1927 1927	1.10 22	1.13 22	1.29 22	1.54 21	2.39 16	7.98 20	9.69 14	16.0 24	16.0 16
1928 1928	1.70 30	1.87 32	1.96 30	2.26 28	3.72 25	12.7 32	18.1 31	20.8 33	22.2 25
1929 1929	.93 20	.99 21	1.03 16	1.19 14	1.81 14	7.71 19	9.85 15	9.92 11	13.4 12
1930 1930	.62 13	.72 14	.80 11	.92 11	1.57 12	17.1 35	20.7 34	21.3 34	32.1 33
1931 1931	1.70 31	1.83 31	2.07 31	2.23 27	4.12 27	8.49 22	8.93 12	11.1 15	16.9 17
1932 1932	2.50 35	2.83 35	3.30 35	3.74 33	7.81 33	10.5 29	18.3 32	16.8 30	23.6 28
1933 1933	.93 21	.93 19	1.16 20	1.35 17	1.42 7	3.55 7	4.78 3	5.58 2	6.74 2
1934 1934	.77 17	.88 16	.95 14	1.21 15	1.33 6	2.93 4	4.21 1	4.59 1	7.14 3
1935 1935	1.70 32	1.77 29	1.91 28	2.28 29	6.66 31	8.66 23	9.95 16	11.2 16	17.8 20
1936 1936	1.20 24	1.20 24	1.41 24	1.51 20	2.47 17	4.93 15	6.59 8	7.39 7	12.0 9
1937 1937	2.30 34	2.50 34	3.24 34	4.15 34	11.9 35	16.6 34	30.9 35	31.5 35	35.1 35
1938 1938	1.50 29	1.80 30	2.10 32	3.01 31	6.06 30	9.73 27	13.1 24	16.4 28	32.3 34
1939 1939	2.00 33	2.17 33	2.79 33	4.75 35	9.39 34	12.2 31	15.6 28	20.7 32	26.7 30
1940 1940	.52 8	.53 6	.59 6	.82 9	1.56 11	5.41 17	6.00 5	6.73 5	11.3 8
1941 1941	.66 14	.70 13	.82 13	1.33 16	3.54 23	4.40 11	10.8 18	11.0 14	17.9 21
1942 1942	.56 10	.61 11	.82 12	.98 12	1.51 10	3.89 8	14.0 25	15.5 22	22.6 26
1943 1943	1.10 23	1.17 23	1.30 23	1.66 22	3.21 22	8.76 24	16.9 29	15.7 23	18.3 22
1944 1944	.35 4	.37 4	.46 4	.57 4	.89 2	3.18 5	6.55 7	8.80 9	8.92 4
1945 1945	.26 2	.28 2	.30 1	.33 1	1.22 4	2.51 2	4.70 2	6.34 4	12.1 10
1946 1946	.37 5	.55 7	.67 10	.72 5	1.22 5	2.87 3	12.1 21	13.1 19	17.2 18
1947 1947	.51 7	.57 9	.65 8	.79 8	1.45 9	8.83 25	12.7 22	14.5 21	18.8 23
1948 1948	1.40 27	1.67 28	1.77 26	3.10 32	4.71 29	13.6 33	18.5 33	16.6 29	23.7 29
1949 1949	.85 19	.92 18	1.12 19	1.47 19	2.76 20	4.60 13	6.62 9	9.64 10	10.8 6
1950 1950	.71 15	.74 15	1.19 21	1.81 23	3.13 21	9.26 26	14.2 26	16.1 26	23.4 27
1951 1951	.83 18	.90 17	1.06 17	1.42 18	3.63 24	4.57 12	6.03 6	7.39 8	10.9 7
1952 1952	.60 12	.65 12	1.07 18	1.88 25	6.93 32	10.6 30	15.2 27	16.0 25	17.3 19
1953 1953	.26 3	.29 3	.31 3	.38 2	.48 1	2.02 1	6.69 10	7.11 6	9.63 5
1954 1954	.20 1	.25 1	.30 2	.54 3	1.09 3	8.41 21	9.15 13	10.2 12	12.6 11
1955 1955	.57 11	.61 10	.66 9	.75 6	4.31 28	4.90 14	17.9 30	16.3 27	20.8 24
1956 1956	.46 6	.49 5	.57 5	.78 7	2.09 15	4.22 9	9.96 17	13.1 20	28.4 32
1957 1957	.54 9	.56 8	.59 7	.88 10	1.42 8	3.50 6	7.12 11	11.6 17	15.5 15

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16555000
WAIKAMOI STR AB WAILOA DITCH NR HUELO, MAUI,HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		15		30		60		90		120		183	
1923 1923	664	11	441	9	326	8	186	8	99.2	11	66.2	10	53.4	10	43.9	13	35.8	16
1924 1924	493	18	328	15	157	20	102	18	60.4	24	51.6	19	39.8	22	39.3	21	32.6	19
1925 1925	439	22	322	16	204	15	142	13	109	8	65.9	11	51.5	12	43.5	15	37.7	13
1926 1926	210	34	104	34	59.9	35	44.1	34	33.4	34	20.7	35	17.7	35	14.9	35	12.2	35
1927 1927	506	17	233	22	122	24	71.2	29	43.7	32	31.4	33	29.3	31	26.2	31	24.5	29
1928 1928	268	30	168	28	101	30	65.3	30	48.5	29	39.9	26	37.0	25	29.3	27	30.1	23
1929 1929	430	23	272	19	217	14	133	14	95.5	12	60.5	14	52.1	11	47.9	10	39.9	11
1930 1930	461	21	336	13	260	11	148	11	89.6	13	78.3	9	60.8	9	59.5	7	51.0	6
1931 1931	376	26	226	23	135	21	76.9	27	50.4	28	42.7	25	38.6	23	31.6	24	31.0	21
1932 1932	416	24	186	26	118	27	99.2	19	72.9	18	48.4	23	46.1	18	41.8	17	36.6	14
1933 1933	545	15	293	17	162	18	80.3	25	55.2	27	36.1	29	31.4	30	27.4	30	21.7	32
1934 1934	933	6	354	12	182	16	131	15	85.9	15	58.7	15	49.7	14	42.7	16	33.0	18
1935 1935	589	13	425	10	275	9	142	12	85.0	16	62.8	12	48.7	15	46.8	11	40.5	10
1936 1936	179	35	95.7	35	62.7	34	56.1	33	44.1	31	35.0	31	33.5	28	29.3	28	27.6	27
1937 1937	603	12	576	7	364	7	259	6	169	5	108	4	93.0	4	80.6	2	66.6	2
1938 1938	1830	2	1013	2	646	2	320	2	205	1	120	2	98.1	2	79.3	3	64.7	3
1939 1939	484	19	208	25	134	22	98.5	20	65.5	20	52.4	18	42.9	20	45.2	12	38.7	12
1940 1940	726	9	467	8	266	10	154	10	106	9	60.9	13	44.3	19	36.2	22	29.8	25
1941 1941	897	7	384	11	223	13	125	16	69.5	19	50.7	21	40.7	21	41.7	18	36.0	15
1942 1942	758	8	611	6	465	5	278	5	191	2	126	1	95.1	3	73.4	5	61.8	4
1943 1943	350	27	135	32	83.4	31	57.8	32	41.2	33	32.2	32	27.2	32	26.1	32	23.5	30
1944 1944	243	32	123	33	65.0	33	40.2	35	27.6	35	22.0	34	18.1	34	17.0	34	14.6	34
1945 1945	221	33	179	27	115	28	97.4	21	61.2	23	36.4	28	25.4	33	22.3	33	21.1	33
1946 1946	575	14	226	24	131	23	89.1	22	63.9	22	49.9	22	47.9	17	43.7	14	33.7	17
1947 1947	1520	3	932	3	573	3	286	4	170	4	98.9	5	71.6	6	56.5	8	47.2	8
1948 1948	2460	1	1562	1	691	1	327	1	172	3	116	3	101	1	85.8	1	68.5	1
1949 1949	466	20	281	18	169	17	119	17	89.6	14	58.1	16	50.1	13	39.7	20	31.8	20
1950 1950	693	10	331	14	229	12	155	9	102	10	82.4	8	63.3	8	53.7	9	45.5	9
1951 1951	388	25	257	20	121	25	87.5	24	58.0	25	54.5	17	48.5	16	40.8	19	30.5	22
1952 1952	257	31	161	29	119	26	79.1	26	56.0	26	35.6	30	32.1	29	30.6	26	27.2	28
1953 1953	347	28	151	31	115	29	71.3	28	64.4	21	51.0	20	37.7	24	28.5	29	23.2	31
1954 1954	278	29	154	30	82.1	32	61.1	31	46.1	30	38.2	27	34.7	27	34.2	23	30.1	24
1955 1955	1360	4	747	5	511	4	290	3	168	6	96.5	6	89.1	5	75.7	4	59.7	5
1956 1956	1110	5	779	4	385	6	254	7	137	7	84.9	7	68.3	7	61.3	6	49.0	7
1957 1957	535	16	245	21	161	19	88.9	23	75.0	17	46.4	24	36.9	26	30.9	25	28.0	26

STATION ID - 16555000
WAIKAMOI STR AB WAILOA DITCH NR HUELO, MAUI,HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN LOW-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE			
1923	1923	25.6	22
1924	1924	24.3	18
1925	1925	29.3	26
1926	1926	10.9	1
1927	1927	20.4	12
1928	1928	24.7	20
1929	1929	25.0	21
1930	1930	34.7	30
1931	1931	24.2	17
1932	1932	27.2	24
1933	1933	13.0	3
1934	1934	19.7	7
1935	1935	26.2	23
1936	1936	19.7	8
1937	1937	46.8	35
1938	1938	40.1	32
1939	1939	27.4	25
1940	1940	21.6	14
1941	1941	24.6	19
1942	1942	42.2	33
1943	1943	19.1	6
1944	1944	11.1	2
1945	1945	16.0	4
1946	1946	22.2	16
1947	1947	31.0	29
1948	1948	43.2	34
1949	1949	20.6	13
1950	1950	29.5	27
1951	1951	20.4	10
1952	1952	20.4	11
1953	1953	16.5	5
1954	1954	20.3	9
1955	1955	36.2	31
1956	1956	30.7	28
1957	1957	22.0	15

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN HIGH-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE			
1923	1923	25.6	14
1924	1924	24.3	18
1925	1925	29.3	10
1926	1926	10.9	35
1927	1927	20.4	24
1928	1928	24.7	16
1929	1929	25.0	15
1930	1930	34.7	6
1931	1931	24.2	19
1932	1932	27.2	12
1933	1933	13.0	33
1934	1934	19.7	29
1935	1935	26.2	13
1936	1936	19.7	28
1937	1937	46.8	1
1938	1938	40.1	4
1939	1939	27.4	11
1940	1940	21.6	22
1941	1941	24.6	17
1942	1942	42.2	3
1943	1943	19.1	30
1944	1944	11.1	34
1945	1945	16.0	32
1946	1946	22.2	20
1947	1947	31.0	7
1948	1948	43.2	2
1949	1949	20.6	23
1950	1950	29.5	9
1951	1951	20.4	26
1952	1952	20.4	25
1953	1953	16.5	31
1954	1954	20.3	27
1955	1955	36.2	5
1956	1956	30.7	8
1957	1957	22.0	21

STATION ID - 16556000
WAIKAMOI STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

WATER YEAR RANGE (CLASS)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1912 1912			9	3	3	2	4	7	12	13	26	44	36	39	44	34	13	23	19	11	9	8	5	2											
1913 1913					2	2	4	4	7	20	33	38	50	46	48	25	22	23	14	8	6	6	3	2	2										
1914 1914						2	10	5	8	13	8	13	13	19	26	19	10	35	22	25	21	16	19	22	14	11	14	10	4	4	1	1			
1915 1915								2	15	12	17	41	24	29	41	22	1	41	16	21	8	18	14	14	8	7	3	6	4			1			
1916 1916								3	6	6	11	17	13	19	35	20	14	41	20	22	25	27	18	23	7	12	6	6	4	3	2	2	2	1	1
1917 1917		8	2		3	2	4	5	11	19	23	26	34	47	23	28	22	27	13	13	10	9	11	6	8	2	2	1	1	3		1		1	
1918 1918		5	1	8	5	1	1	1	3	5	10	11	28	24	35	32	37	29	16	21	17	18	13	9	8	6	7	3	2	3	2	2	1	1	
1919 1919			1	1			7	4	2	9	13	61	19	17	11	12	18	41	37	45	13	8	16	10	7	5	3	3					1	1	
1920 1920		2	5	4	16	12	31	30	30	45	30	28	27	11	12	10	6	10	4	9	8	11	8	1	6	1	4	2		1	1	1			
1921 1921							6	17	13	29	11	19	28	22	21	23	12	36	10	15	28	20	13	6	9	14	6	1	5	1					

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	0	3653	100.00	13	4.50	272	2651	72.57	25	85.00	69	262	7.17
2	0.31	15	3653	100.00	14	5.80	273	2379	65.12	26	108.00	58	193	5.28
3	0.40	18	3638	99.59	15	7.40	296	2106	57.65	27	138.00	45	135	3.70
4	0.50	16	3620	99.10	16	9.40	225	1810	49.55	28	176.00	32	90	2.46
5	0.64	29	3604	98.66	17	12.00	155	1585	43.39	29	225.00	20	58	1.59
6	0.82	21	3575	97.86	18	15.00	306	1430	39.15	30	287.00	15	38	1.04
7	1.00	67	3554	97.29	19	20.00	171	1124	30.77	31	367.00	6	23	0.63
8	1.30	78	3487	95.46	20	25.00	190	953	26.09	32	468.00	8	17	0.47
9	1.70	107	3409	93.32	21	32.00	145	763	20.89	33	597.00	4	9	0.25
10	2.20	171	3302	90.39	22	41.00	141	618	16.92	34	762.00	4	5	0.14
11	2.80	182	3131	85.71	23	52.00	120	477	13.06	35	973.00	1	1	0.03
12	3.60	298	2949	80.73	24	66.00	95	357	9.77					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16556000 WAIKAMOI STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION, AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 0)
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE	
95.0	1.39	(LOG = 0.14157)
90.0	2.25	(LOG = 0.35222)
85.0	2.91	(LOG = 0.46450)
80.0	3.68	(LOG = 0.56589)
75.0	4.23	(LOG = 0.62654)
70.0	4.95	(LOG = 0.69450)
65.0	5.83	(LOG = 0.76542)
60.0	6.90	(LOG = 0.83867)
55.0	8.05	(LOG = 0.90603)
50.0	9.29	(LOG = 0.96795)
45.0	11.3	(LOG = 1.05384)
40.0	14.4	(LOG = 1.15825)
35.0	17.5	(LOG = 1.24241)
30.0	20.8	(LOG = 1.31851)
25.0	26.5	(LOG = 1.42266)
20.0	34.0	(LOG = 1.53162)
15.0	46.5	(LOG = 1.66712)
10.0	65.0	(LOG = 1.81312)
5.0	113.4	(LOG = 2.05443)

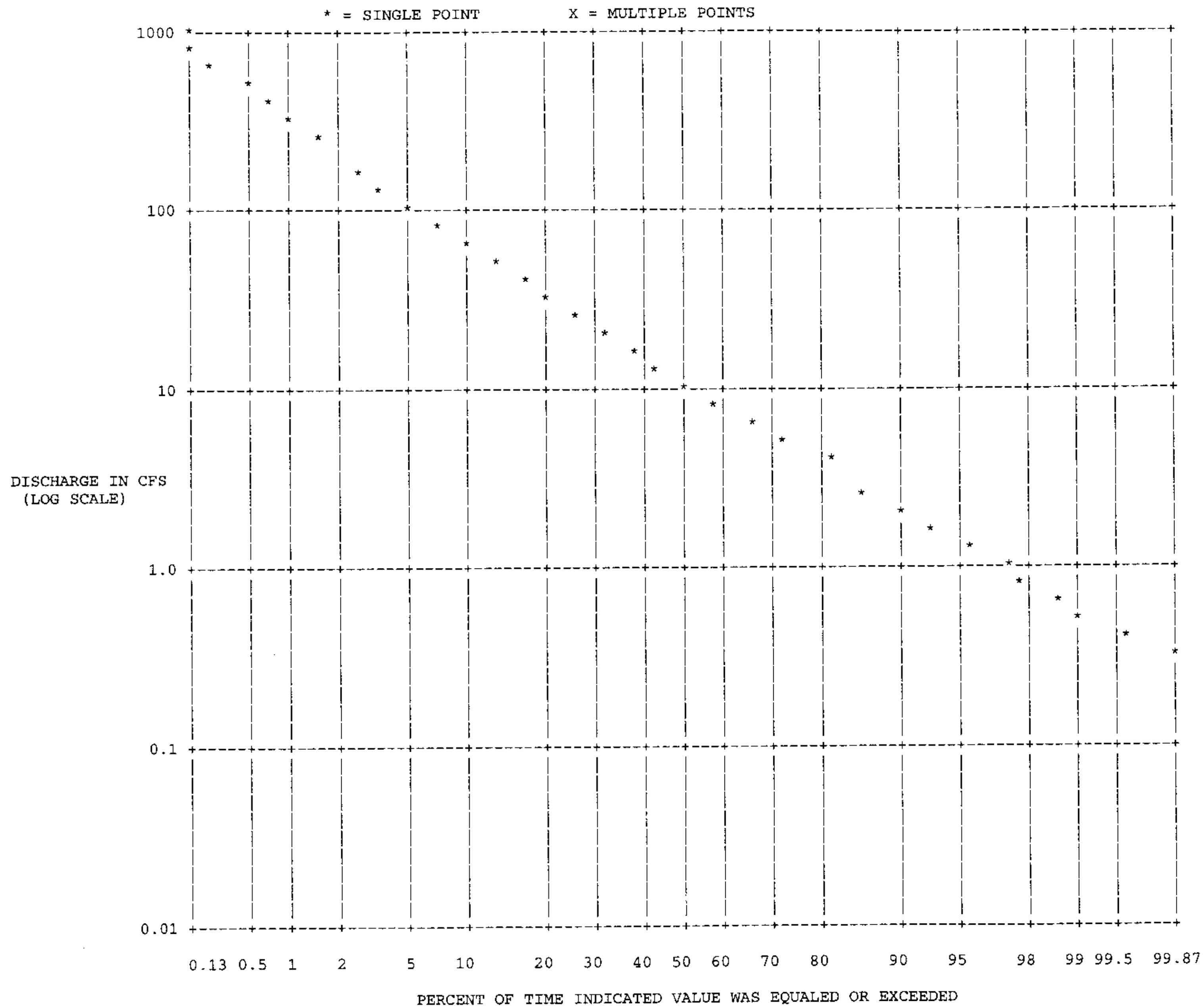
MEAN OF LOGS = 1.03080

STANDARD DEVIATION OF LOGS = 0.51666 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = 0.50122

COEFFICIENT OF SKEW = 0.27030

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1911 - 1922)
STATION ID: 16556000 WAIKAMOI STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16556000
WAIKAMOI STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1	3	7	14	30	60	90	120	183
1912 1912	.49 5	.49 4	.49 4	.69 2	1.57 4	3.86 3	5.52 3	5.83 2	8.50 1
1913 1913	.80 6	.83 6	1.38 8	2.04 8	4.00 9	4.92 5	6.49 4	7.07 4	9.78 2
1914 1914	.86 7	.94 7	1.17 6	1.41 6	2.37 6	6.47 6	11.4 7	16.5 9	28.0 8
1915 1915	1.50 9	1.83 10	2.00 10	2.26 9	3.96 8	9.19 8	15.0 9	14.8 8	19.5 7
1916 1916	1.50 10	1.57 9	1.87 9	2.75 10	8.09 10	20.7 10	19.1 10	31.0 10	46.9 10
1917 1917	.31 1	.31 1	.31 1	.77 3	1.23 2	3.76 2	4.64 2	6.21 3	12.7 4
1918 1918	.31 2	.31 2	.40 2	1.41 7	1.97 5	10.2 9	11.3 6	12.3 6	28.3 9
1919 1919	.46 4	.76 5	1.03 5	1.19 4	3.90 7	8.78 7	11.4 8	13.3 7	17.4 6
1920 1920	.31 3	.36 3	.44 3	.63 1	.94 1	1.58 1	2.25 1	5.11 1	11.2 3
1921 1921	1.10 8	1.17 8	1.26 7	1.33 5	1.56 3	3.97 4	8.43 5	12.0 5	17.0 5

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16556000
WAIKAMOI STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		15		30		60		90		120		183	
1912 1912	74.0	10	54.3	10	45.9	10	33.3	10	24.3	10	23.7	9	18.6	9	15.3	9	15.0	9
1913 1913	93.0	9	68.7	9	62.7	9	39.2	9	26.0	9	16.8	10	14.8	10	12.7	10	13.1	10
1914 1914	566	6	268	7	183	6	143	6	110	4	98.0	3	76.8	3	67.5	2	64.0	1
1915 1915	546	7	297	6	177	7	107	8	70.5	8	51.0	7	43.1	7	38.9	7	35.1	7
1916 1916	1300	1	698	1	541	1	297	1	168	1	102	1	78.9	1	71.1	1	62.2	2
1917 1917	804	3	542	2	290	3	187	3	113	3	79.5	4	60.1	5	47.1	6	36.6	6
1918 1918	787	4	445	3	249	5	209	2	123	2	101	2	78.5	2	66.3	3	58.1	3
1919 1919	823	2	380	4	304	2	163	4	96.0	5	66.4	6	49.5	6	47.9	5	39.6	5
1920 1920	585	5	321	5	283	4	159	5	91.9	6	48.6	8	33.3	8	30.8	8	23.6	8
1921 1921	308	8	232	8	161	8	124	7	85.7	7	79.4	5	65.7	4	55.3	4	44.6	4

STATION ID - 16556000
WAIKAMOI STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN LOW-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE			
1912	1912	10.6	2
1913	1913	10.2	1
1914	1914	46.1	9
1915	1915	28.8	6
1916	1916	52.7	10
1917	1917	23.2	4
1918	1918	37.6	8
1919	1919	28.1	5
1920	1920	16.0	3
1921	1921	29.0	7

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN HIGH-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE			
1912	1912	10.6	9
1913	1913	10.2	10
1914	1914	46.1	2
1915	1915	28.8	5
1916	1916	52.7	1
1917	1917	23.2	7
1918	1918	37.6	3
1919	1919	28.1	6
1920	1920	16.0	8
1921	1921	29.0	4

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16552800
WAIKAMOI STR AB RES AT KULA PL INTAKE NR OLINDA
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

WATER YEAR RANGE \ CLASS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1954 1954	3		49	30		61	24	23	23	16	17	13	21	16	15	7	12	6	11	6	4	2	4	1			1								
1955 1955			7	26		61	31	21	18	19	21	20	26	11	21	15	8	15	7	9	7	4	5	2	1	2	2	1	1	3				1	
1956 1956	16		24	37		56	18	20	21	17	19	17	21	21	16	12	11	6	5	5	3	8	3	1		1	1	1	4	2					
1957 1957				58		86	31	28	20	22	17	12	17	10	13	7	5	7	3	7	3	6	4	4		3		2							
1958 1958	3		10	22		55	33	27	23	19	19	18	21	19	17	13	15	12	9	3	6	7	5	3	4		1			1					
1959 1959			2	6		62	39	39	36	25	22	24	17	16	12	8	8	9	7	10	7	4	2		4	3	1	1				1			
1960 1960				32		83	27	29	25	16	26	14	14	18	14	6	13	9	10	8	5	2	4	2	2	1		2	2	1				1	
1961 1961			13	37		86	39	37	29	14	20	15	9	8	9	5	6	8	5	10	2	6	1		2	3	1								
1962 1962	11		37	40		75	27	24	12	23	19	16	14	11	10	5	12	9	7	2	3	2	4		1			1							
1963 1963	19		52	22		56	25	31	18	15	22	13	14	12	8	7	8	12	8	7	4	4	6			1			1						
1964 1964			4	27		82	30	33	20	24	27	18	13	19	11	8	4	12	7	5	10	5	3	2	1	1									
1965 1965			2	24		79	32	23	20	29	22	17	16	12	18	10	13	8	7	7	4	5	6	2	3	1	1	2	1		1				
1966 1966		1	22	28	5	66	36	41	18	24	17	12	19	14	11	8	12	6	8	2	5	3	3			3	1								
1967 1967		6	19	35	24	61	34	34	14	15	19	11	13	15	10	10	7	3	8	4	7	3	4		4	2	2			1					
1968 1968		7	24	31	18	70	23	23	6	25	15	13	12	20	7	4	12	14	9	9	10	2	3	5	3			1							

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	52	5479	100.00	13	0.48	247	1584	28.91	25	23.00	25	89	1.62
2	0.01	14	5427	99.05	14	0.66	222	1337	24.40	26	32.00	21	64	1.17
3	0.02	265	5413	98.80	15	0.91	192	1115	20.35	27	44.00	11	43	0.78
4	0.03	455	5148	93.96	16	1.30	125	923	16.85	28	60.00	11	32	0.58
5	0.04	47	4693	85.65	17	1.70	146	798	14.56	29	83.00	9	21	0.38
6	0.05	1039	4646	84.80	18	2.40	136	652	11.90	30	115.00	8	12	0.22
7	0.07	449	3607	65.83	19	3.30	111	516	9.42	31	159.00	1	4	0.07
8	0.10	433	3158	57.64	20	4.60	94	405	7.39	32	219.00	1	3	0.05
9	0.13	303	2725	49.74	21	6.30	80	311	5.68	33	303.00	0	2	0.04
10	0.18	303	2422	44.21	22	8.70	63	231	4.22	34	418.00	2	2	0.04
11	0.25	302	2119	38.67	23	12.00	57	168	3.07	35	0.00	0	0	0.00
12	0.35	233	1817	33.16	24	17.00	22	111	2.03					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16552800 WAIKAMOI STR AB RES AT KULA PL INTAKE NR OLINDA
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION,
AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 0)
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE	
95.0	0.03	(LOG = -1.55522)
90.0	0.03	(LOG = -1.45883)
85.0	0.05	(LOG = -1.32214)
80.0	0.06	(LOG = -1.25917)
75.0	0.06	(LOG = -1.21945)
70.0	0.07	(LOG = -1.18306)
65.0	0.07	(LOG = -1.13638)
60.0	0.09	(LOG = -1.03927)
55.0	0.11	(LOG = -0.95855)
50.0	0.13	(LOG = -0.88943)
45.0	0.17	(LOG = -0.76242)
40.0	0.23	(LOG = -0.63222)
35.0	0.32	(LOG = -0.49939)
30.0	0.45	(LOG = -0.34999)
25.0	0.64	(LOG = -0.19645)
20.0	0.95	(LOG = -0.02273)
15.0	1.62	(LOG = 0.21050)
10.0	3.09	(LOG = 0.48980)
5.0	7.41	(LOG = 0.86991)

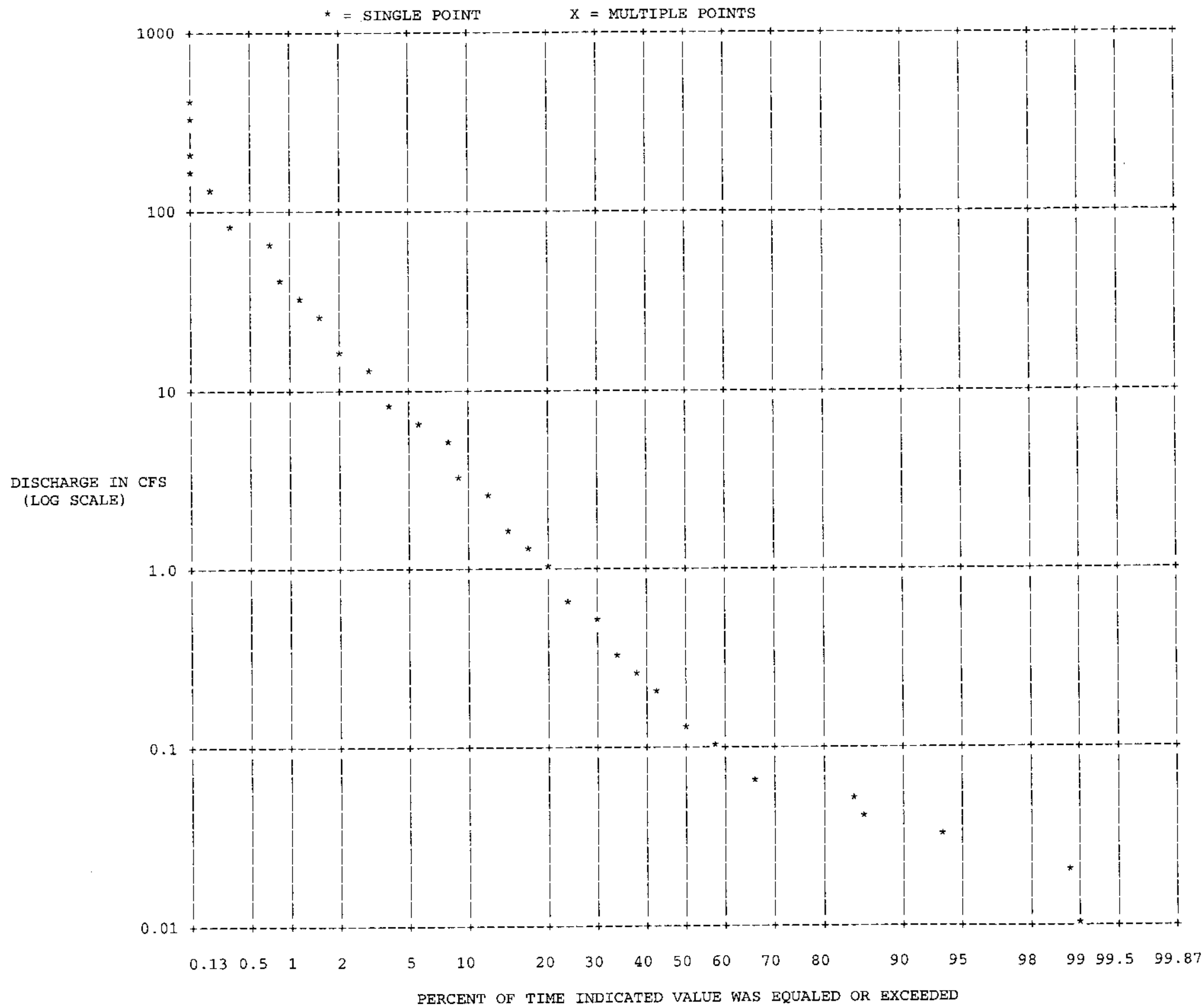
MEAN OF LOGS = -0.67971

STANDARD DEVIATION OF LOGS = 0.68732 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = -1.01119

COEFFICIENT OF SKEW = 0.84194

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1953 - 1968)
STATION ID: 16552800 WAIKAMOI STR AB RES AT KULA PL INTAKE NR OLINDA
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



STATION ID - 16552800
WAIKAMOI STR AB RES AT KULA PL INTAKE NR OLINDA
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1	3	7	14	30	60	90	120	183
1954 1954	.0000 1	.007 5	.014 5	.019 4	.020 3	.33 13	.31 9	.60 10	.70 3
1955 1955	.020 9	.020 8	.023 9	.028 9	.11 14	.17 10	.73 13	.78 13	.92 7
1956 1956	.0000 2	.0000 1	.0000 1	.011 3	.028 5	.10 5	.75 14	1.06 15	1.28 14
1957 1957	.030 14	.030 14	.030 12	.031 10	.040 8	.088 3	.24 6	.51 8	1.24 13
1958 1958	.0000 3	.0000 2	.011 4	.022 7	.18 15	.54 15	.45 12	.69 12	.99 10
1959 1959	.020 10	.023 11	.030 13	.041 15	.051 9	.17 9	.34 10	.47 7	.98 9
1960 1960	.030 15	.030 15	.030 14	.035 13	.055 10	.22 12	.28 8	.39 4	.80 5
1961 1961	.020 11	.020 9	.024 10	.031 11	.084 13	.19 11	.25 7	.43 6	.89 6
1962 1962	.0000 4	.0000 3	.003 3	.004 1	.014 2	.067 2	.11 2	.19 3	.27 2
1963 1963	.0000 5	.0000 4	.0000 2	.004 2	.011 1	.15 8	.23 5	.62 11	1.00 11
1964 1964	.020 12	.023 12	.027 11	.034 12	.037 7	.14 6	.35 11	.43 5	.79 4
1965 1965	.020 13	.023 13	.030 15	.036 14	.061 12	.41 14	.92 15	.81 14	1.35 15
1966 1966	.010 6	.020 10	.020 8	.020 5	.025 4	.055 1	.089 1	.11 1	.17 1
1967 1967	.010 7	.010 6	.017 7	.027 8	.055 11	.10 4	.18 4	.59 9	1.09 12
1968 1968	.010 8	.010 7	.014 6	.021 6	.035 6	.14 7	.17 3	.17 2	.98 8

STATION ID - 16552800
WAIKAMOI STR AB RES AT KULA PL INTAKE NR OLINDA
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		15		30		60		90		120		183	
1954 1954	45.0	13	15.8	15	6.91	15	3.46	15	3.05	15	2.04	15	1.65	15	1.57	15	1.38	15
1955 1955	473	1	251	1	146	1	72.6	1	37.5	1	19.4	1	15.8	1	12.5	1	8.58	1
1956 1956	158	5	86.7	5	37.3	5	27.3	4	15.2	4	10.7	3	10.0	3	8.04	3	5.83	3
1957 1957	70.0	9	42.0	8	25.3	8	12.2	8	7.06	9	3.91	10	3.32	11	2.66	12	2.09	11
1958 1958	147	7	56.9	7	26.4	6	14.4	7	9.84	7	5.28	6	3.66	7	2.95	8	2.35	8
1959 1959	254	3	114	3	55.7	4	26.1	5	13.3	5	9.33	5	7.26	4	5.71	4	4.58	4
1960 1960	418	2	206	2	114	2	55.5	2	28.1	2	14.8	2	12.3	2	9.44	2	6.73	2
1961 1961	52.0	12	32.3	10	18.2	10	12.1	9	6.49	10	4.78	9	3.34	10	2.76	10	2.25	9
1962 1962	63.0	11	26.9	12	12.3	13	8.02	12	6.34	11	3.72	12	2.60	14	1.97	14	1.60	14
1963 1963	100	8	39.0	9	16.9	11	8.18	11	5.63	13	3.67	13	2.68	12	2.80	9	2.22	10
1964 1964	41.0	15	19.7	14	10.4	14	7.64	13	5.68	12	3.34	14	2.68	13	2.37	13	1.75	13
1965 1965	217	4	104	4	74.1	3	37.0	3	19.6	3	10.2	4	6.91	5	5.69	5	4.58	5
1966 1966	45.0	14	29.7	11	18.3	9	10.1	10	8.54	8	4.84	8	3.61	8	3.04	7	2.07	12
1967 1967	152	6	60.8	6	26.3	7	17.6	6	10.2	6	5.23	7	4.30	6	4.06	6	3.15	6
1968 1968	65.0	10	23.0	13	12.7	12	7.41	14	5.04	14	3.89	11	3.43	9	2.75	11	2.89	7

STATION ID - 16552800
WAIKAMOI STR AB RES AT KULA PL INTAKE NR OLINDA
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR
PERIOD INCLUDED IN LOW-VALUE ANALYSIS
(OCT-SEP)

WATER YEAR RANGE		
1954 1954	.98	2
1955 1955	4.59	15
1956 1956	3.14	13
1957 1957	1.67	8
1958 1958	2.11	10
1959 1959	2.56	11
1960 1960	3.57	14
1961 1961	1.31	6
1962 1962	.93	1
1963 1963	1.27	5
1964 1964	1.21	4
1965 1965	2.77	12
1966 1966	1.12	3
1967 1967	2.00	9
1968 1968	1.58	7

MEAN VALUE AND RANKING FOR
PERIOD INCLUDED IN HIGH-VALUE ANALYSIS
(OCT-SEP)

WATER YEAR RANGE		
1954 1954	.98	14
1955 1955	4.59	1
1956 1956	3.14	3
1957 1957	1.67	8
1958 1958	2.11	6
1959 1959	2.56	5
1960 1960	3.57	2
1961 1961	1.31	10
1962 1962	.93	15
1963 1963	1.27	11
1964 1964	1.21	12
1965 1965	2.77	4
1966 1966	1.12	13
1967 1967	2.00	7
1968 1968	1.58	9

STATION ID - 16552600
WAIKAMOI STREAM AT PUU LUAU NR OLINDA, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

WATER YEAR RANGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1951 1951	342	3			2	2	1	2					1	1	1	1					1	1	1	2	1		1	1	1						
1952 1952	348	4	1		1	3	1	1		1	1	1				1	1			1		1													
1953 1953	344	2	4			2	2	2	2	1	1	1						1	1	1									1						
1954 1954	349	4	1		1	3		1	1	2	1	1											1												
1955 1955	314	13	7		2	3	1	2		1	4	2	1			1	1	1	1	1		1	1	1		2	1	1	1	1					1
1956 1956	333	5	3		2	3	2	3						1	1		2	1			1			1	2	1		1	2	2					
1957 1957	333	5	3		2	1	3	1	3	1			1	1		3		1	1	1			2			3									
1958 1958	326	4	4		2	2	1	3	3	3	2	2	1		1	1		1	2	3		2		1						1					
1960 1960	343	2	1		1	1	1	2	1		1		3						1		2	1			2		2							1	1
1961 1961	342		5				2	5		1	1		1			1	1				2	1		1	2										
1962 1962	349	5			3			1	1	1							1	1	2									1							
1963 1963	342	3	4		1	2	1	3		1		1		1		1					4								1						
1964 1964	337	10	1		2	6	3			2	2			2								1													
1965 1965	334	1	3		3	3	1			2			3	3			1		1	2	2			2		1	2				1				
1966 1966	344	3	4		3	2	1				1			1				2		1		1		1	1										

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	5080	5479	100.00	13	0.50	11	141	2.57	25	17.00	8	39	0.71
2	0.02	64	399	7.28	14	0.68	10	130	2.37	26	23.00	7	31	0.57
3	0.03	41	335	6.11	15	0.91	3	120	2.19	27	31.00	6	24	0.44
4	0.04	0	294	5.37	16	1.20	9	117	2.14	28	41.00	4	18	0.33
5	0.05	25	294	5.37	17	1.60	7	108	1.97	29	55.00	6	14	0.26
6	0.06	33	269	4.91	18	2.20	8	101	1.84	30	74.00	4	8	0.15
7	0.09	20	236	4.31	19	2.90	9	93	1.70	31	99.00	1	4	0.07
8	0.12	26	216	3.94	20	3.90	10	84	1.53	32	133.00	0	3	0.05
9	0.16	11	190	3.47	21	5.30	12	74	1.35	33	178.00	0	3	0.05
10	0.21	16	179	3.27	22	7.10	9	62	1.13	34	239.00	1	3	0.05
11	0.28	14	163	2.97	23	9.50	5	53	0.97	35	320.00	2	2	0.04
12	0.38	8	149	2.72	24	13.00	9	48	0.88					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16552600 WAIKAMOI STREAM AT PUU LUAU NR OLINDA, MAUI, HI
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION, AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 9)

SUBSTITUTION FOR ZERO AND NEAR-ZERO VALUES = 0.0000
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE		
95.0	0.00	(LOG = -Inf)	*
90.0	0.00	(LOG = -Inf)	*
85.0	0.00	(LOG = -Inf)	*
80.0	0.00	(LOG = -Inf)	*
75.0	0.00	(LOG = -Inf)	*
70.0	0.00	(LOG = -Inf)	*
65.0	0.00	(LOG = -Inf)	*
60.0	0.00	(LOG = -Inf)	*
55.0	0.00	(LOG = -Inf)	*
50.0	0.01	(LOG = -1.96716)	
45.0	0.01	(LOG = -1.92577)	
40.0	0.01	(LOG = -1.88798)	
35.0	0.01	(LOG = -1.85322)	
30.0	0.02	(LOG = -1.82103)	
25.0	0.02	(LOG = -1.79107)	
20.0	0.02	(LOG = -1.76304)	
15.0	0.02	(LOG = -1.73671)	
10.0	0.02	(LOG = -1.71189)	
5.0	0.06	(LOG = -1.23642)	

* INDICATES SUBSTITUTION FOR ZERO OR NEAR-ZERO VALUES

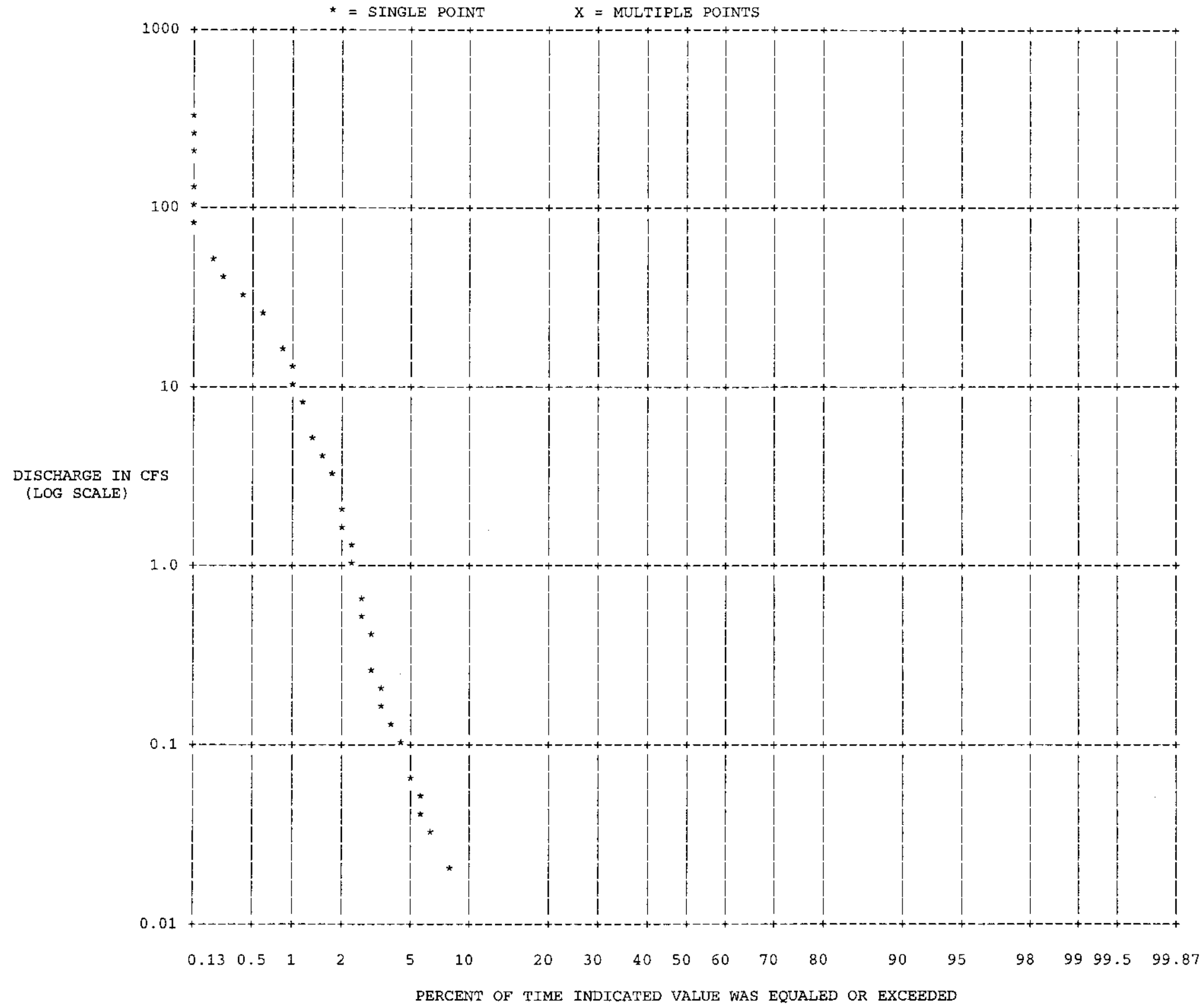
MEAN OF LOGS = -Inf

STANDARD DEVIATION OF LOGS = NaN (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = NaN

COEFFICIENT OF SKEW = NaN

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1950 - 1967)
STATION ID: 16552600 WAIKAMOI STREAM AT PUU LUAU NR OLINDA, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16552600
WAIKAMOI STREAM AT PUU LUAU NR OLINDA, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1	3	7	14	30	60	90	120	183
1951 1951	.0000 1	.0000 1	.0000 1	.0000 1	.0000 1	.0000 1	.0000 1	.0000 1	.008 10
1952 1952	.0000 2	.0000 2	.0000 2	.0000 2	.0000 2	.0000 2	.0000 2	.0000 2	.002 4
1953 1953	.0000 3	.0000 3	.0000 3	.0000 3	.0000 3	.0000 3	.0000 3	.0000 3	.001 3
1954 1954	.0000 4	.0000 4	.0000 4	.0000 4	.0000 4	.0000 4	.0000 4	.007 15	.007 9
1955 1955	.0000 5	.0000 5	.0000 5	.0000 5	.0000 5	.0000 5	.0000 5	.001 9	.002 5
1956 1956	.0000 6	.0000 6	.0000 6	.0000 6	.0000 6	.0000 6	.002 13	.004 14	.004 7
1957 1957	.0000 7	.0000 7	.0000 7	.0000 7	.0000 7	.0000 7	.0000 6	.003 11	.035 11
1958 1958	.0000 8	.0000 8	.0000 8	.0000 8	.0000 8	.0000 8	.0000 7	.001 10	.098 13
1960 1960	.0000 9	.0000 9	.0000 9	.0000 9	.0000 9	.0000 9	.0000 8	.0000 4	.002 6
1961 1961	.0000 10	.0000 10	.0000 10	.0000 10	.0000 10	.0000 10	.0000 9	.0000 5	.10 15
1962 1962	.0000 11	.0000 11	.0000 11	.0000 11	.0000 11	.0000 11	.0000 10	.0000 6	.0000 1
1963 1963	.0000 12	.0000 12	.0000 12	.0000 12	.0000 12	.0000 12	.0000 11	.0000 7	.083 12
1964 1964	.0000 13	.0000 13	.0000 13	.0000 13	.0000 13	.0000 13	.003 14	.003 12	.004 8
1965 1965	.0000 14	.0000 14	.0000 14	.0000 14	.0000 14	.0000 14	.004 15	.003 13	.099 14
1966 1966	.0000 15	.0000 15	.0000 15	.0000 15	.0000 15	.0000 15	.0000 12	.0000 8	.0000 2

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16552600
WAIKAMOI STREAM AT PUU LUAU NR OLINDA, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1	3	7	15	30	60	90	120	183
1951 1951	57.0 7	21.4 7	9.20 8	4.29 8	3.10 6	2.20 5	1.94 5	1.71 5	1.12 5
1952 1952	8.20 14	2.76 15	1.18 15	.58 15	.29 15	.28 13	.19 13	.14 13	.095 13
1953 1953	56.0 8	19.4 8	8.33 9	3.89 9	1.94 9	.97 10	.65 10	.57 10	.38 10
1954 1954	11.0 13	3.69 13	1.58 13	.74 13	.37 13	.19 14	.13 14	.10 14	.068 14
1955 1955	404 1	175 2	89.4 2	44.8 1	22.4 1	11.2 1	8.19 1	6.15 1	4.03 1
1956 1956	94.0 4	56.6 3	24.2 4	11.3 4	10.4 3	5.36 3	5.00 3	3.75 3	2.46 3
1957 1957	30.0 10	18.8 9	9.98 6	4.66 6	2.37 8	1.19 8	.80 8	.60 9	.41 8
1958 1958	79.0 5	29.6 5	12.8 5	6.19 5	3.25 5	1.63 6	1.08 6	.81 6	.61 6
1960 1960	320 2	205 1	94.0 1	43.9 2	22.0 2	11.2 2	7.94 2	5.95 2	3.90 2
1961 1961	18.0 12	12.2 11	6.62 11	3.12 11	1.74 11	1.09 9	.79 9	.61 8	.40 9
1962 1962	45.0 9	17.1 10	7.33 10	3.45 10	1.89 10	.95 11	.63 11	.47 11	.31 11
1963 1963	61.0 6	22.5 6	9.64 7	4.50 7	2.46 7	1.23 7	.82 7	.74 7	.49 7
1964 1964	7.50 15	2.77 14	1.20 14	.61 14	.33 14	.17 15	.11 15	.086 15	.058 15
1965 1965	123 3	54.0 4	35.9 3	17.1 3	8.53 4	4.34 4	2.89 4	2.17 4	1.52 4
1966 1966	19.0 11	8.57 12	5.92 12	2.77 12	1.73 12	.87 12	.58 12	.43 12	.28 12

STATION ID - 16552600
WAIKAMOI STREAM AT PUU LUAU NR OLINDA, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN LOW-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE		
1951 1951	.57	11
1952 1952	.048	3
1953 1953	.19	6
1954 1954	.035	2
1955 1955	2.02	15
1956 1956	1.23	13
1957 1957	.33	9
1958 1958	.38	10
1960 1960	1.95	14
1961 1961	.20	7
1962 1962	.16	5
1963 1963	.24	8
1964 1964	.031	1
1965 1965	.77	12
1966 1966	.14	4

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN HIGH-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE		
1951 1951	.57	5
1952 1952	.048	13
1953 1953	.19	10
1954 1954	.035	14
1955 1955	2.02	1
1956 1956	1.23	3
1957 1957	.33	7
1958 1958	.38	6
1960 1960	1.95	2
1961 1961	.20	9
1962 1962	.16	11
1963 1963	.24	8
1964 1964	.031	15
1965 1965	.77	4
1966 1966	.14	12

Appendix B

State of Hawaii
COMMISSION ON WATER RESOURCE MANAGEMENT
Department of Land and Natural Resources

P3:42 P3:09

PETITION TO AMEND INTERIM INSTREAM FLOW STANDARDS

ALO STREAM, EAST MAUI

Instructions: Please print in ink or type and send completed petition with attachments to the Commission on Water Resource Management, P.O. Box 621, Honolulu, Hawaii 96809. Petition must be accompanied by a non-refundable filing fee of $25.00 payable to the Dept. of Land and Natural Resources. The Commission may not accept incomplete applications. For assistance, call the Regulation Branch at 587-0225.

1. **PETITIONER**

Firm/Name: Na Moku 'Aupuni o Ko'olau Hui c/o Native Hawaiian Legal Corporation
Contact Person: Alan Murakami, Attorney   Ph: 521-2302
Address: 1164 Bishop Street, Honolulu, Hawai'i 96813

2. **STREAMFLOW DATA**

USGS stream gaging station: 16552200, 16557000, 16558000   Period of Record: Data to follow. Gages Inactive
Location/Reach: SEE ATTACHED
(Attach a USGS map, scale 1"=2000', and a property tax map showing diversion location referenced to established property boundaries.)

TABLE 1. PERIOD OF RECORD AVERAGE MONTHLY STREAMFLOW WITHIN THE AFFECTED STREAM REACH, IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
STREAMFLOW DATA TABLES TO FOLLOW.												

Annual Median flow in cfs =

TABLE 2. PROPOSED AVERAGE MONTHLY STREAMFLOW DIVERSION FROM AFFECTED STREAM REACH, IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
UNDETERMINED; SUFFICIENT FOR TARO FARMING AND/OR GATHERING.												

Annual Median flow in cfs =

TABLE 3. AVERAGE MONTHLY STREAMFLOW IN AFFECTED STREAM REACH AFTER RESTORATION [redacted] (min release flow), IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
NATURAL STREAMFLOW EXCEPT FOR EXERCISE OF APPURTENANT WATER RIGHTS.												

Annual Median flow in cfs =

3. **EXISTING INSTREAM AND OFFSTREAM WATER USES FOR ENTIRE STREAM REACH**

TMK	OWNER	USE
RESEARCH IN PROGRESS.		

(If more space is necessary, attach an extended list following above format)

4. **ANTICIPATED IMPACTS ON STREAM AND BASIS FOR SUCH IMPACTS:**

RESTORATION OF INSTREAM NATURAL HABITAT AND BIOTA, AND BENEFICIAL APPURTENANT AND GATHERING USES.

(Attach supporting documentation, plans, letters, etc.)

May 24, 2001
Date

Signature: NATIVE HAWAIIAN LEGAL CORPORATION [signature]
Alan Murakami   Petitioner
Attorney for Na Moku 'Aupuni o Ko'olau Hui

For Official Use
Date Received
Date Accepted

ALO

STATION ID - 16557000
ALO STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

CLASS / WATER YEAR RANGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1912 1912		1		4		5	6	2	9	12	20	14	30	27	21	31	29	20	37	31	21	20	11	8	2	2	2			1					
1913 1913								2	11	9	28	30	40	39	27	37	25	29	24	21	11	4	2	9	8	2	3	1	2	1					
1914 1914			7			2	7	7	19	6	9	7	12	7	7	21	21	16	18	42	16	28	18	27	22	9	13	12	2	7	3				
1915 1915											11	29	24	35	46	38	30	24	15	32	16	15	7	15	16	3	5	1			2	1			
1916 1916												8	19	21	24	39	30	31	26	42	25	32	14	23	11	4	5	4	3	2	2				1
1917 1917								2	16		37	35	26	38	48	36	26	18	9	25	16	12	4	5	6			3	2		1				
1918 1918								18	11		14	13	17	28	32	34	33	32	25	31	10	19	9	8	8	5	4	2	2	2	2	3	1	2	
1919 1919									2	5	21	50	43	27	32	37	29	30	20	15	13	12	10	3	9	3			3			1			
1920 1920								12	58	36	41	42	20	23	21	23	12	19	17	11	4	10	5	2	1	1		3	1	1	2			1	
1921 1921									6	2	13	27	20	25	46	43	31	28	31	19	39	11	7	4	3	1	1		8						
1922 1922										16	15	31	36	41	30	31	27	18	16	18	16	15	10	10	6	5	4	5	6	3	3	2	1		
1923 1923										7	13	23	38	43	35	36	43	22	16	18	13	15	8	8	3	8	3	6	3		2	2			
1924 1924										18	29	22	47	42	39	16	22	13	30	15	28	5	10	4	6	6	3	3	2	3	1	1	1		
1925 1925										10	20	29	46	41	34	42	25	24	14	17	12	9	12	9	4	7	2	3	2	2			1		
1926 1926									21	37	34	58	49	50	21	20	10	18	7	8	8	7	6	1	2	1	2	4	1						
1927 1927									3	11	1	12	48	67	39	15	10	18	20	14	45	7	10	22	3	4		10	3	1		1			1
1928 1928									8	8	2	25	25	14	39	41	30	30	35	12	14	15	8	6	13	14	9	4	2	10	1		1		
1929 1929										4	45	36	50	27	39	28	3	28	15	22	10	4	8	15	7	2	12	4	3	3					
1930 1930								5	7	2	6	14	24	43	39	41	27	21	26	15	12	27	6	7	9	9	5	6	6	5	2	1			
1931 1931									9	9	17	18	49	46	36	25	22	20	28	23	12	15	11	7	7	2	3	3	1		1			1	
1932 1932										1	8	24	39	38	40	25	24	28	29	22	21	15	10	12	10	10	3	5		2					
1933 1933						8		24	19	19	31	31	45	40	29	25	21	19	16	15	4	8	3	3	1	2	1			1					
1934 1934						5		7	34	39	20	30	23	18	26	32	14	24	13	20	21	11	6	7	8	3	2	1				1			
1935 1935								3	14	14	12	26	35	37	37	29	32	30	21	18	14	9	12	7	3	3	4		1	4					
1936 1936							1	9	10	22	20	24	23	22	23	28	26	29	23	16	22	27	15	12	7	2	3	1	1						
1937 1937											2	4	19	13	20	37	42	44	24	33	30	14	19	13	15	11	11	6	5	2		1			
1938 1938										5	9	21	40	42	38	24	24	27	18	15	20	16	18	10	10	10	7	3	3	4			1		
1939 1939									1	2	2	18	30	35	37	33	35	27	26	20	24	25	19	12	10	2	5		2						
1940 1940								11	10	17	15	46	35	40	23	30	21	15	17	20	14	8	10	10	12	3	6			2	1				
1941 1941								2	12	23	14	27	29	29	28	24	17	28	22	25	13	19	13	9	12	6	7	3	1	1	1				
1942 1942								1	12	14	11	21	35	30	32	26	29	24	19	21	12	15	16	14	11	4	4	3	4	3	3		1		
1943 1943									17	33	24	36	31	29	29	26	23	23	10	20	15	9	13	14	2	4	2	4	1						
1944 1944							3	38	26	28	24	34	30	34	29	27	18	7	17	8	15	6	7	3	5	3	1	3							
1945 1945							4	28	26	29	26	37	28	20	16	26	17	17	15	19	15	9	7	10	7	8			1						
1946 1946								16	34	16	20	37	40	25	18	28	17	17	18	21	10	9	11	10	4	8	2	2		2					

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16557000
ALO STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES

NUMBER OF DAYS IN CLASS

WATER YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1947 1947								2	7	11	16	32	40	33	30	39	33	16	14	24	16	6	12	4	6	8	6	3	4	1	1		1		
1948 1948										3	4	31	49	42	36	36	24	24	18	18	12	12	11	13	10	6	7	4	3	1	1	1			
1949 1949									5	37	17	47	32	25	31	26	21	28	15	21	17	9	13	10	5	2	2	1		1					
1950 1950									6	11	19	38	45	31	27	27	19	20	12	18	23	10	22	10	7	7	4	4	3	1		1			
1951 1951									3	22	37	43	46	33	36	28	22	14	14	14	15	11	9	5	1	5		4	1	2					
1952 1952									7	4	5	21	32	31	37	55	23	29	25	24	14	15	17	11	5	5	3	1	1	1					
1953 1953							7	14	26	13	19	37	44	32	24	33	13	23	12	12	14	9	9	9	3	6	4	1		1					
1954 1954								10	15	7	11	30	43	26	29	24	18	31	25	18	21	16	13	12	4	7	4	1							
1955 1955									8	8	12	22	33	28	28	40	26	31	23	19	19	15	15	13	6	4	6	6	2	1					
1956 1956									6	22	19	31	35	35	29	29	24	19	16	24	15	16	16	15	3	3	1	2	3	2			1		
1957 1957									9	21	18	43	65	33	25	29	20	18	13	15	12	6	7	9	2	6	5	6	1		1	1			

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	0	16802	100.00	13	1.40	1609	13324	79.30	25	24.00	315	1079	6.42
2	0.11	1	16802	100.00	14	1.80	1485	11715	69.72	26	30.00	226	764	4.55
3	0.14	7	16801	99.99	15	2.30	1412	10230	60.89	27	38.00	176	538	3.20
4	0.18	4	16794	99.95	16	2.90	1420	8818	52.48	28	48.00	138	362	2.15
5	0.22	0	16790	99.93	17	3.70	1088	7398	44.03	29	60.00	89	224	1.33
6	0.28	20	16790	99.93	18	4.60	1071	6310	37.56	30	76.00	73	135	0.80
7	0.35	28	16770	99.81	19	5.80	904	5239	31.18	31	96.00	30	62	0.37
8	0.45	213	16742	99.64	20	7.30	931	4335	25.80	32	121.00	17	32	0.19
9	0.56	487	16529	98.38	21	9.30	769	3404	20.26	33	153.00	9	15	0.09
10	0.71	613	16042	95.48	22	12.00	607	2635	15.68	34	193.00	4	6	0.04
11	0.90	791	15429	91.83	23	15.00	499	2028	12.07	35	244.00	2	2	0.01
12	1.10	1314	14638	87.12	24	19.00	450	1529	9.10					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16557000 ALO STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION, AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 0)
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE	
95.0	0.73	(LOG = -0.13381)
90.0	0.98	(LOG = -0.00981)
85.0	1.18	(LOG = 0.07238)
80.0	1.37	(LOG = 0.13772)
75.0	1.58	(LOG = 0.19855)
70.0	1.79	(LOG = 0.25248)
65.0	2.07	(LOG = 0.31539)
60.0	2.36	(LOG = 0.37351)
55.0	2.72	(LOG = 0.43460)
50.0	3.13	(LOG = 0.49623)
45.0	3.61	(LOG = 0.55729)
40.0	4.26	(LOG = 0.62943)
35.0	5.08	(LOG = 0.70595)
30.0	6.13	(LOG = 0.78740)
25.0	7.59	(LOG = 0.88018)
20.0	9.45	(LOG = 0.97557)
15.0	12.6	(LOG = 1.09923)
10.0	17.8	(LOG = 1.25013)
5.0	28.6	(LOG = 1.45561)

MEAN OF LOGS = 0.55148

STANDARD DEVIATION OF LOGS = 0.43986 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = 0.79761

COEFFICIENT OF SKEW = 0.43984

STATION ID - 16557000
ALO STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1	3	7	14	30	60	90	120	183
1949 1949	.59 22	.63 28	.68 27	.80 26	1.23 27	2.00 16	3.08 22	3.54 22	3.95 13
1950 1950	.62 32	.64 30	.78 35	.91 34	2.25 41	3.98 39	4.92 37	4.59 30	6.65 35
1951 1951	.70 35	.71 33	.79 36	.89 31	1.28 30	1.39 8	2.00 5	2.30 3	3.37 7
1952 1952	.60 23	.66 31	.76 30	1.00 39	3.02 44	4.26 42	5.86 42	6.36 40	6.71 36
1953 1953	.40 5	.40 5	.42 5	.47 5	.53 2	1.10 4	2.84 18	2.62 9	3.75 11
1954 1954	.46 16	.51 16	.53 12	.68 18	1.14 25	1.96 15	3.17 24	3.49 21	4.07 15
1955 1955	.60 24	.62 22	.63 22	.73 23	1.80 38	2.19 27	6.06 43	5.41 39	7.07 37
1956 1956	.63 33	.63 29	.66 25	.74 24	1.10 23	2.07 20	2.20 11	3.00 13	6.48 33
1957 1957	.60 25	.62 27	.62 21	.67 17	.88 14	1.56 9	2.79 16	4.30 28	4.41 17

STATION ID - 16557000
ALO STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1	3	7	15	30	60	90	120	183
1912 1912	80.0 36	43.3 39	31.1 33	20.5 34	14.2 40	12.8 30	10.4 30	8.52 36	8.00 30
1913 1913	80.0 37	41.0 42	30.1 36	18.6 39	14.7 38	10.2 42	9.42 40	8.32 38	7.50 38
1914 1914	110 24	66.7 23	49.0 18	37.5 16	31.5 5	27.1 2	23.8 1	22.7 2	20.3 1
1915 1915	124 21	63.0 25	34.2 32	21.4 31	15.1 36	13.7 24	11.3 23	9.27 28	9.09 24
1916 1916	244 2	116 5	77.7 3	47.4 5	28.8 8	21.2 6	17.3 9	15.6 8	12.6 10
1917 1917	114 23	50.7 32	34.4 31	25.3 25	20.3 21	15.3 19	12.0 21	9.84 25	7.84 34
1918 1918	207 4	127 3	74.4 6	62.7 2	40.1 1	28.5 1	23.6 2	19.5 3	17.1 2
1919 1919	145 16	60.3 28	43.0 23	27.1 22	17.4 27	12.2 35	8.86 42	8.86 34	7.61 35
1920 1920	234 3	146 1	98.1 2	50.6 3	28.3 9	15.1 20	10.5 28	8.99 31	7.22 41
1921 1921	70.0 40	70.0 22	44.0 21	38.7 10	23.9 16	15.6 17	12.6 18	10.9 20	9.18 23
1922 1922	179 8	124 4	75.3 5	43.9 6	30.5 6	24.9 4	23.6 3	23.1 1	17.1 3
1923 1923	147 14	111 7	75.6 4	48.9 4	27.0 11	17.2 13	14.3 14	13.2 13	11.0 17
1924 1924	166 11	83.0 17	45.6 19	30.8 21	20.2 22	15.6 18	12.5 20	11.9 17	9.68 20
1925 1925	186 7	96.7 11	43.2 22	23.1 28	16.9 28	11.1 39	10.1 36	8.96 32	8.64 26
1926 1926	63.0 44	56.0 31	29.3 37	17.3 42	13.2 43	7.97 44	6.32 46	5.35 46	4.43 46
1927 1927	248 1	100 9	50.5 16	31.0 20	18.9 24	14.4 21	13.3 17	11.2 19	11.3 15
1928 1928	164 12	85.0 16	68.1 8	41.9 7	32.0 4	24.5 5	22.2 4	17.5 5	15.1 5
1929 1929	93.0 28	93.0 12	56.4 13	35.7 17	32.2 3	20.7 10	17.4 8	15.3 9	12.9 9
1930 1930	147 15	90.8 15	60.3 12	35.6 18	23.4 17	19.8 11	15.0 12	15.1 10	14.0 6
1931 1931	198 5	107 8	63.3 10	38.3 13	22.1 18	13.2 26	10.4 31	8.30 39	7.41 40
1932 1932	91.0 31	58.3 29	44.7 20	38.5 12	25.7 14	16.8 14	14.2 15	13.2 14	11.1 16
1933 1933	79.0 38	32.8 45	19.7 46	11.0 46	8.63 46	6.67 46	6.73 44	6.23 45	5.14 45
1934 1934	132 18	58.3 30	35.5 30	24.1 27	19.6 23	13.8 23	11.7 22	10.4 24	8.08 29
1935 1935	93.0 29	82.7 18	42.1 24	22.6 29	15.3 35	13.2 27	10.6 26	9.10 30	8.51 27
1936 1936	67.0 42	35.3 44	20.4 43	15.2 43	13.9 41	11.1 40	10.2 33	9.22 29	9.31 21
1937 1937	122 22	81.7 19	52.0 15	38.3 14	29.5 7	21.2 7	21.6 5	18.4 4	15.9 4
1938 1938	162 13	92.0 13	66.3 9	38.6 11	25.9 13	20.9 9	18.6 7	16.0 6	13.7 7
1939 1939	67.0 43	44.7 37	35.6 29	21.3 33	13.7 42	12.7 31	10.6 27	10.5 22	9.20 22
1940 1940	96.0 26	63.0 26	39.8 25	26.9 23	21.7 20	14.2 22	11.1 24	8.96 33	7.59 37
1941 1941	108 25	64.7 24	36.0 28	20.1 35	15.8 33	11.2 38	11.1 25	10.5 23	10.3 19
1942 1942	187 6	132 2	100 1	63.1 1	38.8 2	25.4 3	20.2 6	16.0 7	13.2 8
1943 1943	74.0 39	42.0 41	22.0 42	19.1 37	14.6 39	12.1 36	9.77 38	8.67 35	8.30 28
1944 1944	57.0 45	31.7 46	20.2 44	12.1 45	9.14 45	7.72 45	6.48 45	6.38 43	5.72 44
1945 1945	68.0 41	42.7 40	28.1 39	18.6 40	15.9 32	10.3 41	8.02 43	6.30 44	6.75 42
1946 1946	94.0 27	46.0 36	25.5 41	18.8 38	15.5 34	12.4 32	10.2 34	9.77 27	7.86 32
1947 1947	176 10	92.0 14	68.4 7	37.6 15	25.1 15	16.0 15	12.6 19	11.8 18	10.5 18
1948 1948	141 17	98.3 10	49.3 17	34.8 19	26.3 12	17.6 12	16.0 11	13.3 12	11.8 11

STATION ID - 16557000
ALO STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1	3	7	15	30	60	90	120	183
1949 1949	82.0 35	47.0 35	30.6 34	21.4 32	16.2 30	12.3 33	10.2 35	8.24 40	7.48 39
1950 1950	130 19	73.0 20	56.3 14	41.2 8	27.5 10	21.0 8	16.3 10	13.9 11	11.4 13
1951 1951	93.0 30	62.7 27	30.4 35	25.9 24	16.9 29	12.3 34	10.4 32	9.79 26	7.61 36
1952 1952	85.0 33	40.5 43	19.9 45	14.5 44	11.9 44	9.95 43	8.99 41	8.39 37	7.93 31
1953 1953	87.0 32	50.3 33	28.7 38	19.7 36	16.0 31	13.2 28	10.0 37	7.71 42	6.46 43
1954 1954	52.0 46	43.7 38	28.1 40	18.3 41	15.1 37	11.5 37	10.5 29	10.8 21	9.00 25
1955 1955	84.0 34	48.7 34	37.1 27	24.9 26	17.7 26	13.5 25	13.4 16	12.3 16	11.6 12
1956 1956	178 9	114 6	62.0 11	39.7 9	22.1 19	15.8 16	14.4 13	13.1 15	11.4 14
1957 1957	128 20	70.7 21	37.9 26	22.6 30	18.3 25	13.0 29	9.74 39	7.75 41	7.85 33

STATION ID - 16557000
ALO STREAM NEAR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN LOW-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE		
1953 1953	5.21	6
1954 1954	6.37	17
1955 1955	7.92	32
1956 1956	7.31	25
1957 1957	6.58	20

MEAN VALUE AND RANKING FOR PERIOD INCLUDED IN HIGH-VALUE ANALYSIS (OCT-SEP)

WATER YEAR RANGE		
1953 1953	5.21	41
1954 1954	6.37	30
1955 1955	7.92	15
1956 1956	7.31	22
1957 1957	6.58	27

Appendix C

State of Hawaii
COMMISSION ON WATER RESOURCE MANAGEMENT
Department of Land and Natural Resources

22 P3:43 24 P3:10

PETITION TO AMEND INTERIM INSTREAM FLOW STANDARDS

WAHINEPE'E STREAM, EAST MAUI

Instructions: Please print in ink or type and send completed petition with attachments to the Commission on Water Resource Management, P.O. Box 621, Honolulu, Hawaii 96809. Petition must be accompanied by a non-refundable filing fee of $25.00 payable to the Dept. of Land and Natural Resources. The Commission may not accept incomplete applications. For assistance, call the Regulation Branch at 587-0225.

1. PETITIONER

Firm/Name: Na Moku 'Aupuni o Ko'olau Hui c/o Native Hawaiian Legal Corporation
Contact Person: Alan Murakami, Attorney Ph: 521-2302
Address: 1164 Bishop Street, Honolulu, Hawai'i 96813

2. STREAMFLOW DATA

USGS stream gaging station: Ungaged. Period of Record: N/A
Location/Reach: SEE ATTACHED
(Attach a USGS map, scale 1"=2000', and a property tax map showing diversion location referenced to established property boundaries.)

TABLE 1. PERIOD OF RECORD AVERAGE MONTHLY STREAMFLOW WITHIN THE AFFECTED STREAM REACH, IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
CURRENT DATA UNAVAILABLE												

Annual Median flow in cfs =

TABLE 2. PROPOSED AVERAGE MONTHLY STREAMFLOW DIVERSION FROM AFFECTED STREAM REACH, IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
NONE. UNDETERMINED; SUFFICIENT FOR TARO FARMING AND/OR GATHERING.												

Annual Median flow in cfs =

TABLE 3. AVERAGE MONTHLY STREAMFLOW IN AFFECTED STREAM REACH AFTER RESTORATION [redacted] (min release flow), IN CFS

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
NATURAL STREAMFLOW EXCEPT FOR EXERCISE OF APPURTENANT WATER RIGHTS.												

Annual Median flow in cfs =

3. EXISTING INSTREAM AND OFFSTREAM WATER USES FOR ENTIRE STREAM REACH

TMK	OWNER	USE
RESEARCH IN PROGRESS.		

(If more space is necessary, attach an extended list following above format)

4. ANTICIPATED IMPACTS ON STREAM AND BASIS FOR SUCH IMPACTS:

RESTORATION OF INSTREAM NATURAL HABITAT AND BIOTA, AND BENEFICIAL APPURTENANT AND GATHERING USES.

(Attach supporting documentation, plans, letters, etc.)

May 24, 2001
Date

Signature: NATIVE HAWAIIAN LEGAL CORPORATION
Alan Murakami Petitioner
Attorney for Na Moku 'Aupuni o Ko'olau Hui

For Official Use
Date Received ______
Date Accepted

WAIHINEPE`E

STATION ID - 16552000
SPRECKELS DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

WATER YEAR RANGE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1929	1929											2		2	3	1	2	3	15	15	15	31	26	18	28	30	19	29	46	57	23					
1930	1930	5							4			3			5	2	3	7	6	19	10	26	28	16	17	24	24	48	46	35	36	1				
1932	1932	1							139			14		3	5	3	4	3		7	4	14	11	2	5	14	10	22	22	32	40	10	1			
1933	1933	74							194			14		3	5	2	2	2	1	5	4	2	5	6	6	14	6	2	8	7	3					
1934	1934	108			8		11		88	15	3	4	5	5	6	2	6	6			4	4	8	10	8	8	8	6	7	13	12	9	1			
1935	1935	12	2	2	10		34		40	37	31	10	9	6	20	12	9	8	3	6	4	7	2	7	8	8	15	4	12	8	11	10	8	10		
1936	1936	11	11	1	16		10	1	28	48	28	40	14	7	15	2	5	8	2	5	2	6	6	6	3	9	12	6	12	13	9	9	10	10	1	
1937	1937				3		20		36	40	26	13	6	3	6	6	3	2	2	5	4	9	6	6	7	10	12	14	18	11	24	26	18	28	1	
1938	1938				40		50		41	30	20	11	16	11	5	6	7	1	3	2	4	6	7	4	6	8	7	11	10	13	7	16	10	13		

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	211	3287	100.00	13	0.46	40	1848	56.22	25	11.00	125	1107	33.68
2	0.02	13	3076	93.58	14	0.60	70	1808	55.00	26	14.00	113	982	29.88
3	0.03	3	3063	93.19	15	0.78	36	1738	52.87	27	18.00	142	869	26.44
4	0.04	77	3060	93.09	16	1.00	41	1702	51.78	28	23.00	181	727	22.12
5	0.06	0	2983	90.75	17	1.30	40	1661	50.53	29	30.00	189	546	16.61
6	0.07	125	2983	90.75	18	1.70	32	1621	49.32	30	39.00	165	357	10.86
7	0.10	1	2858	86.95	19	2.20	64	1589	48.34	31	51.00	81	192	5.84
8	0.12	570	2857	86.92	20	2.90	51	1525	46.39	32	66.00	48	111	3.38
9	0.16	170	2287	69.58	21	3.70	105	1474	44.84	33	85.00	61	63	1.92
10	0.21	108	2117	64.41	22	4.80	99	1369	41.65	34	111.00	2	2	0.06
11	0.27	111	2009	61.12	23	6.30	75	1270	38.64	35	0.00	0	0	0.00
12	0.35	50	1898	57.74	24	8.10	88	1195	36.36					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16552000 SPRECKELS DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION, AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 0)
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE	
95.0	0.02	(LOG = -1.80748)
90.0	0.08	(LOG = -1.11960)
85.0	0.12	(LOG = -0.90509)
80.0	0.14	(LOG = -0.86660)
75.0	0.15	(LOG = -0.83123)
70.0	0.16	(LOG = -0.79854)
65.0	0.20	(LOG = -0.68984)
60.0	0.30	(LOG = -0.52794)
55.0	0.60	(LOG = -0.22157)
50.0	1.48	(LOG = 0.16879)
45.0	3.62	(LOG = 0.55861)
40.0	5.62	(LOG = 0.74983)
35.0	9.57	(LOG = 0.98083)
30.0	13.9	(LOG = 1.14306)
25.0	19.7	(LOG = 1.29367)
20.0	25.7	(LOG = 1.40979)
15.0	32.5	(LOG = 1.51217)
10.0	41.1	(LOG = 1.61340)
5.0	56.1	(LOG = 1.74912)

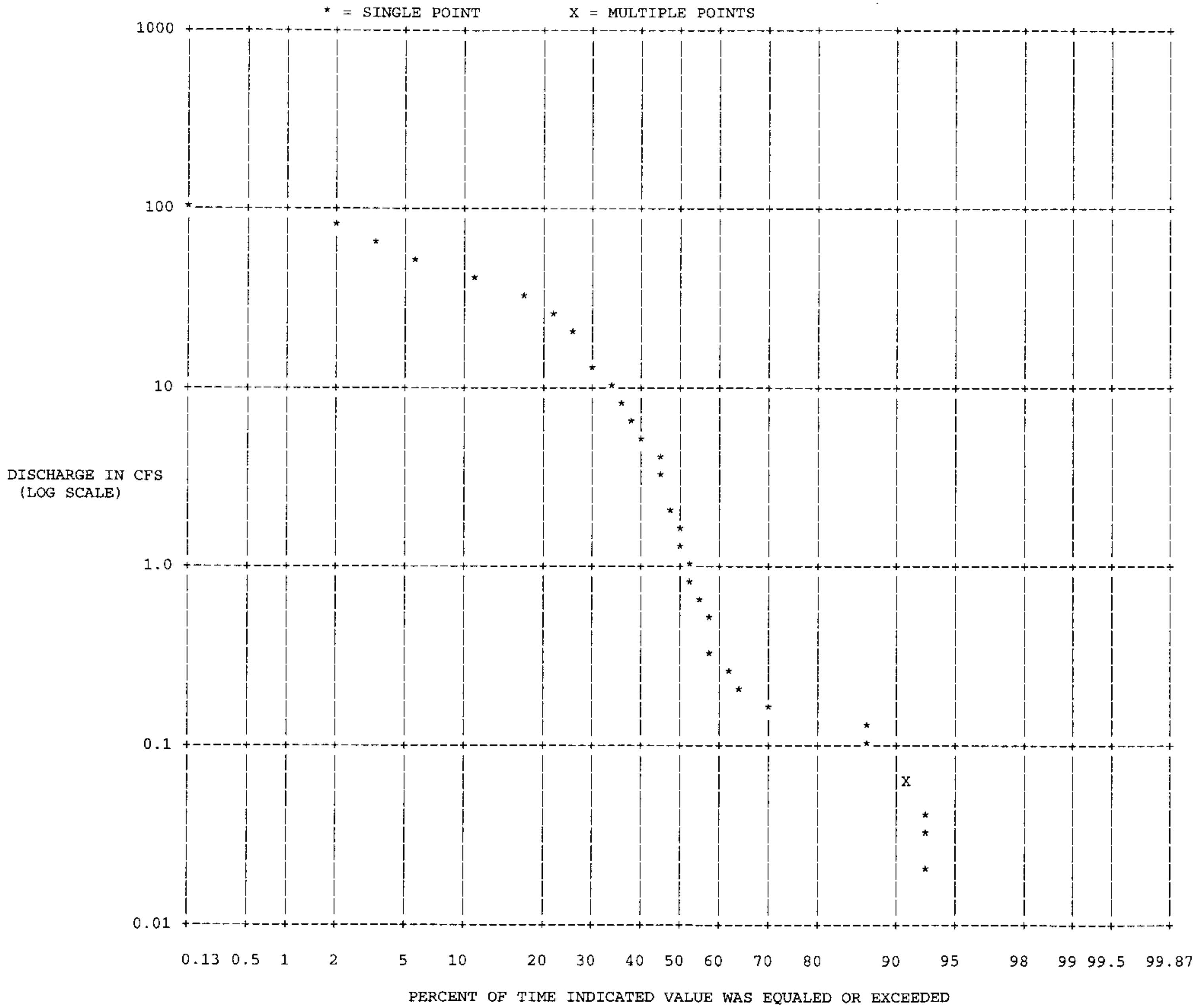
MEAN OF LOGS = 0.17955

STANDARD DEVIATION OF LOGS = 1.11535 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = 6.21203

COEFFICIENT OF SKEW = -0.06391

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1928 - 1939)
STATION ID: 16552000 SPRECKELS DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



STATION ID - 16552000
SPRECKELS DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		14		30		60		90		120		183	
1929 1929	.31	9	.36	9	1.51	8	3.23	8	6.09	9	9.60	8	11.9	7	12.3	7	13.8	7
1930 1930	.0000	1	.0000	1	1.67	9	3.48	9	4.40	8	10.9	9	11.9	8	12.4	8	14.7	8
1932 1932	.0000	2	.10	8	.13	7	.15	7	.87	6	2.76	5	8.28	6	7.33	6	11.8	6
1933 1933	.0000	3	.0000	2	.0000	1	.0000	1	.015	2	.29	1	.57	1	1.08	1	1.30	1
1934 1934	.0000	4	.0000	3	.0000	2	.0000	2	.0000	1	1.08	2	1.19	3	1.34	2	2.81	2
1935 1935	.0000	5	.0000	4	.051	5	.093	5	.43	5	3.13	6	3.37	4	4.32	4	8.28	4
1936 1936	.0000	6	.0000	5	.020	3	.046	3	.26	4	1.12	3	1.01	2	2.71	3	5.39	3
1937 1937	.050	7	.090	7	.090	6	.10	6	2.59	7	7.50	7	15.6	9	17.1	9	20.6	9
1938 1938	.050	8	.050	6	.050	4	.067	4	.17	3	2.07	4	4.37	5	6.08	5	10.6	5

STATION ID - 16552000
SPRECKELS DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		15		30		60		90		120		183	
1929 1929	50.0	8	50.0	7	39.1	7	35.1	7	29.0	6	26.7	4	24.1	4	23.2	3	21.2	2
1930 1930	53.0	7	50.3	6	45.4	6	40.7	5	35.7	3	26.1	5	21.8	6	20.8	5	19.6	4
1932 1932	68.0	6	63.3	5	47.4	5	39.3	6	31.0	4	27.8	3	25.9	2	23.7	2	20.9	3
1933 1933	50.0	9	37.7	9	21.6	9	11.9	9	11.0	9	8.61	9	7.30	9	6.38	9	5.14	9
1934 1934	71.0	5	47.7	8	35.1	8	25.3	8	21.5	8	16.5	8	13.8	8	13.2	8	10.9	8
1935 1935	108	3	92.7	3	78.1	2	45.8	4	28.4	7	24.3	6	20.4	7	17.7	7	16.3	7
1936 1936	111	2	84.0	4	70.3	4	54.1	2	44.0	2	29.3	2	25.3	3	21.2	4	17.7	5
1937 1937	124	1	101	1	86.1	1	68.8	1	55.7	1	41.8	1	38.5	1	33.5	1	29.3	1
1938 1938	104	4	97.7	2	76.0	3	49.0	3	30.1	5	23.1	7	23.2	5	19.8	6	16.8	6

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16552000
SPRECKELS DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR
PERIOD INCLUDED IN LOW-VALUE ANALYSIS
(OCT-SEP)

WATER YEAR RANGE		
1929 1929	16.8	7
1930 1930	17.2	8
1932 1932	13.8	6
1933 1933	2.95	1
1934 1934	6.42	2
1935 1935	10.5	3
1936 1936	11.1	4
1937 1937	22.6	9
1938 1938	12.4	5

MEAN VALUE AND RANKING FOR
PERIOD INCLUDED IN HIGH-VALUE ANALYSIS
(OCT-SEP)

WATER YEAR RANGE		
1929 1929	16.8	3
1930 1930	17.2	2
1932 1932	13.8	4
1933 1933	2.95	9
1934 1934	6.42	8
1935 1935	10.5	7
1936 1936	11.1	6
1937 1937	22.6	1
1938 1938	12.4	5

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16551000
KOOLAU DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

DURATION TABLE OF DAILY VALUES
FOR PERIOD OCT TO SEP

NUMBER OF DAYS IN CLASS

CLASS / WATER YEAR RANGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1923 1923		8																	6	2	4	9	7	6	10	20	19	32	40	53	53	96			
1924 1924																			7	10	17	30	22	16	22	21	23	23	26	29	32	88			
1925 1925												2		2	1		1				1	11	9	24	18	29	13	34	40	35	87	58			
1926 1926																	6	8	25	28	20	36	45	13	21	23	20	19	23	17	31	30			
1927 1927																				11	8	13	19	11	20	23	23	22	36	31	44	99	5		
1928 1928																			2	5	3	11	7	10	21	34	21	24	33	30	56	108	1		
1929 1929				1	1	2	1										1		5	13	10	6	12	15	18	40	34	30	22	26	72	55	1		

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
1	0.00	0	2557	100.00	13	11.00	0	2542	99.41	25	59.00	130	2014	78.76
2	2.30	8	2557	100.00	14	13.00	2	2542	99.41	26	68.00	190	1884	73.68
3	2.70	0	2549	99.69	15	14.00	1	2540	99.34	27	79.00	153	1694	66.25
4	3.00	1	2549	99.69	16	17.00	0	2539	99.30	28	91.00	184	1541	60.27
5	3.50	1	2548	99.65	17	19.00	8	2539	99.30	29	104.00	220	1357	53.07
6	4.10	2	2547	99.61	18	22.00	8	2531	98.98	30	120.00	221	1137	44.47
7	4.70	1	2545	99.53	19	25.00	45	2523	98.67	31	139.00	375	916	35.82
8	5.40	0	2544	99.49	20	29.00	69	2478	96.91	32	160.00	534	541	21.16
9	6.20	0	2544	99.49	21	34.00	63	2409	94.21	33	184.00	7	7	0.27
10	7.10	0	2544	99.49	22	39.00	116	2346	91.75	34	212.00	0	0	0.00
11	8.20	0	2544	99.49	23	45.00	121	2230	87.21	35	244.00	0	0	0.00
12	9.40	2	2544	99.49	24	52.00	95	2109	82.48					

DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16551000 KOOLAU DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE = 00060
STATISTIC CODE - 00003 MEAN

DURATION DATA VALUES ARE INTERPOLATED FROM DURATION TABLE:
DATA ARE NOT ANALYTICALLY FITTED TO A PARTICULAR STATISTICAL DISTRIBUTION, AND THE USER IS RESPONSIBLE FOR ASSESSMENT AND INTERPRETATION.

ADDITIONAL CONDITIONS FOR THIS RUN ARE:
STATISTICS ARE BASED ON LOGARITHMS (BASE 10).
NUMBER OF VALUES IS REDUCED FOR EACH NEAR-ZERO OR ZERO VALUE.

NUMBER OF VALUES = 19 (NUMBER OF NEAR-ZERO VALUES = 0)
LISTING OF DATA FOLLOWS:

PERCENT OF TIME VALUE EQUALED OR EXCEEDED	DATA VALUE	
95.0	32.5	(LOG = 1.51242)
90.0	41.3	(LOG = 1.61608)
85.0	48.3	(LOG = 1.68369)
80.0	56.7	(LOG = 1.75337)
75.0	65.7	(LOG = 1.81732)
70.0	73.4	(LOG = 1.86598)
65.0	81.5	(LOG = 1.91119)
60.0	91.5	(LOG = 1.96133)
55.0	100.5	(LOG = 2.00222)
50.0	109.7	(LOG = 2.04024)
45.0	119.0	(LOG = 2.07557)
40.0	129.8	(LOG = 2.11334)
35.0	140.2	(LOG = 2.14668)
30.0	147.3	(LOG = 2.16832)
25.0	154.5	(LOG = 2.18892)
20.0	161.3	(LOG = 2.20772)
15.0	167.1	(LOG = 2.22292)
10.0	172.8	(LOG = 2.23760)
5.0	178.6	(LOG = 2.25181)

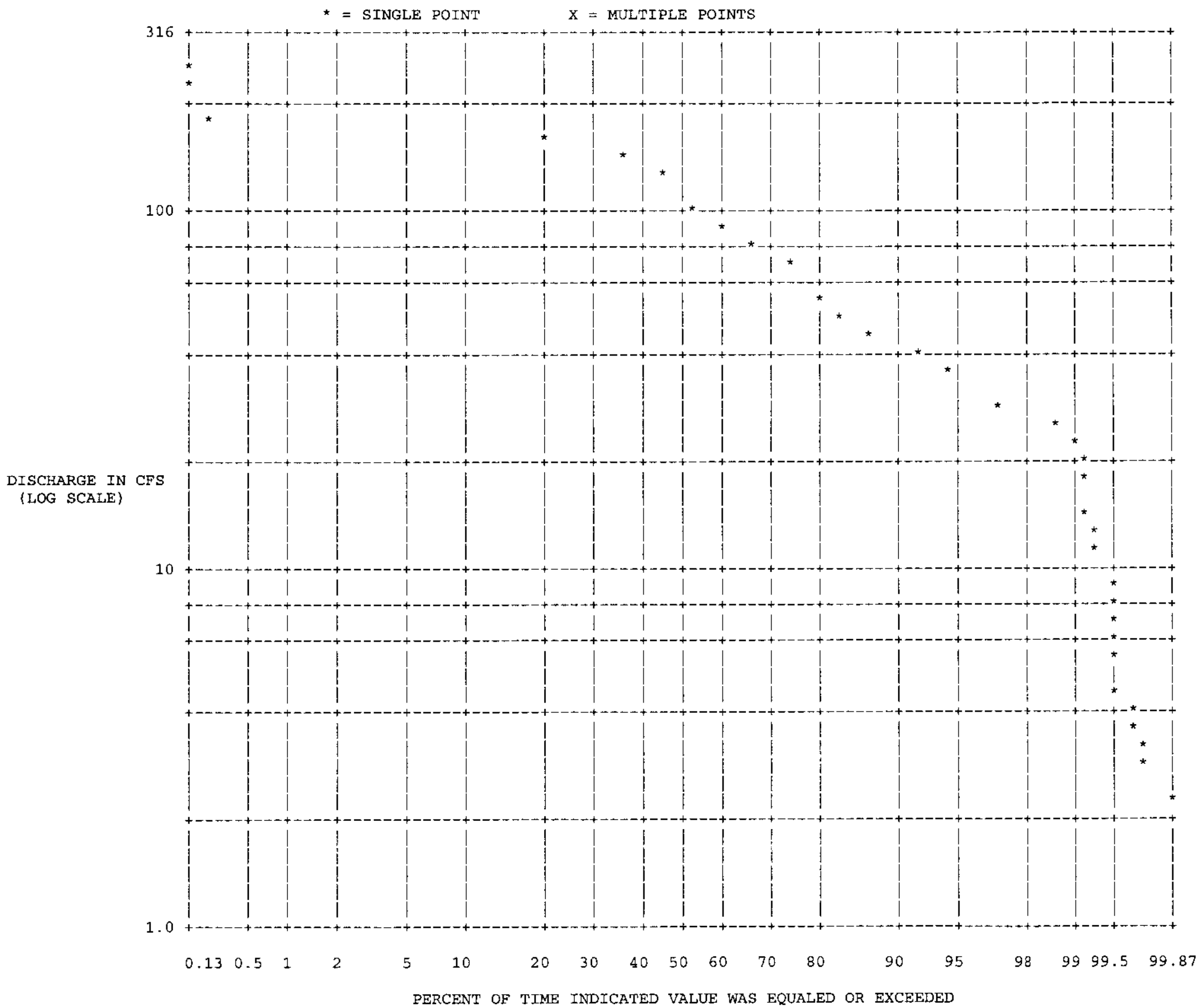
MEAN OF LOGS = 1.98825

STANDARD DEVIATION OF LOGS = 0.22639 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION = 0.11386

COEFFICIENT OF SKEW = -0.69474

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1922 - 1930)
STATION ID: 16551000 KOOLAU DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16551000
KOOLAU DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		14		30		60		90		120		183	
1923 1923	2.30	1	2.30	1	2.30	1	12.7	1	60.4	6	63.4	4	82.4	6	94.3	7	112	7
1924 1924	26.0	5	26.3	5	28.7	5	35.9	6	49.9	5	59.7	3	79.3	4	86.3	5	97.5	5
1925 1925	10.0	3	11.0	3	16.9	3	43.9	7	61.2	7	74.7	6	79.5	5	83.4	4	93.3	4
1926 1926	20.0	4	20.0	4	21.1	4	24.8	2	27.9	1	40.6	1	45.0	1	49.7	1	52.1	1
1927 1927	30.0	7	30.3	7	32.0	7	34.3	4	45.5	3	59.5	2	74.2	2	80.5	3	90.1	3
1928 1928	27.0	6	28.0	6	29.9	6	35.1	5	47.8	4	80.2	7	91.9	7	91.4	6	106	6
1929 1929	3.40	2	3.83	2	14.0	2	29.7	3	39.6	2	72.1	5	74.4	3	76.1	2	86.2	2

STATION ID - 16551000
KOOLAU DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

HIGHEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
FOR PERIOD OCT TO SEP

WATER YEAR RANGE	1		3		7		15		30		60		90		120		183	
1923 1923	179	4	175	4	169	4	168	4	159	3	153	3	149	3	143	1	138	2
1924 1924	175	6	170	6	169	5	166	5	154	5	143	6	132	6	119	6	114	6
1925 1925	175	7	175	5	167	6	160	7	151	6	147	4	142	4	137	4	131	4
1926 1926	176	5	169	7	167	7	164	6	144	7	128	7	105	7	94.2	7	79.0	7
1927 1927	184	2	182	1	179	1	177	1	171	1	162	2	149	2	137	3	139	1
1928 1928	184	3	181	2	177	2	172	3	168	2	163	1	158	1	140	2	132	3
1929 1929	189	1	178	3	176	3	174	2	159	4	145	5	139	5	132	5	127	5

DVSTAT - DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16551000
KOOLAU DITCH AT WAHINEPEE NR HUELO, MAUI, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN

ANNUAL AND/OR SEMI-ANNUAL VALUES

MEAN VALUE AND RANKING FOR
PERIOD INCLUDED IN LOW-VALUE ANALYSIS
(OCT-SEP)

WATER YEAR RANGE		
1923 1923	119	6
1924 1924	102	2
1925 1925	113	4
1926 1926	76.1	1
1927 1927	115	5
1928 1928	120	7
1929 1929	105	3

MEAN VALUE AND RANKING FOR
PERIOD INCLUDED IN HIGH-VALUE ANALYSIS
(OCT-SEP)

WATER YEAR RANGE		
1923 1923	119	2
1924 1924	102	6
1925 1925	113	4
1926 1926	76.1	7
1927 1927	115	3
1928 1928	120	1
1929 1929	105	5