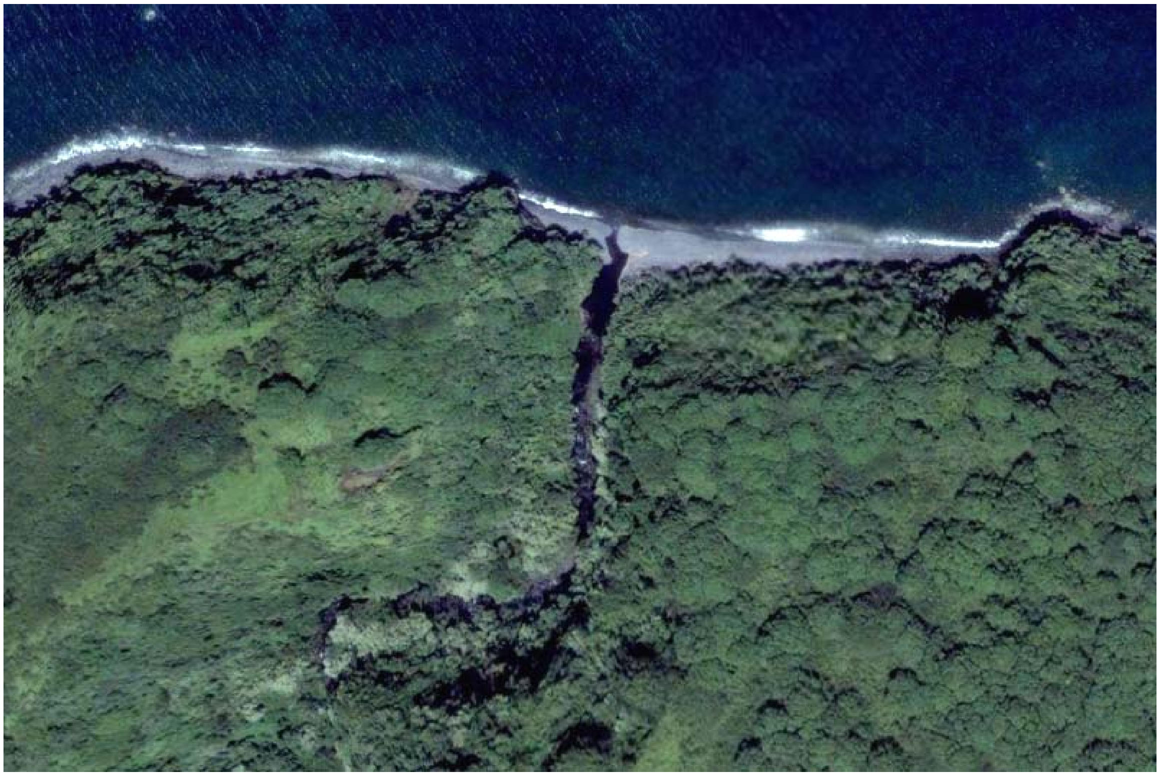
Instream Flow Standard Assessment Report

Island of Maui
Hydrologic Unit 6064
Hanawi

December 2009 **PR-2009-15**



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

COVER
Hanawi Stream (center) flows across a gravel beach with high sea cliffs on either side before entering Honolulu Nui Bay, which is popular local fishing spot [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

The hydrologic unit of Hanawi is located northeast 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 5.6 square miles[1] from the upper slopes of Haleakala at 8,000 feet elevation[2] to the sea (Figure 1-4). Hanawi Stream is about 7 miles[3] in length, traversing north from its headwater at the 7,300 feet altitude to the ocean. The stream rises from sea level to 600 feet elevation 0.8 miles from the coast, contributing to a slope gradient of 770 feet per mile, with the valley incised 240 feet below the upland surface (Gingerich, 1999b). The hydrologic unit is mostly conservation lands that lie within the Hanawi Natural Area Reserve and the Koolau Forest Reserve. Landcover is mostly native forests and shrub lands in the intermediate and upper elevations, and alien forests in the lower elevations (Figure 1-6).

1.2 Current Instream Flow Standard

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

> <u>Interim instream flow standard for East Maui</u>. 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.

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

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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).

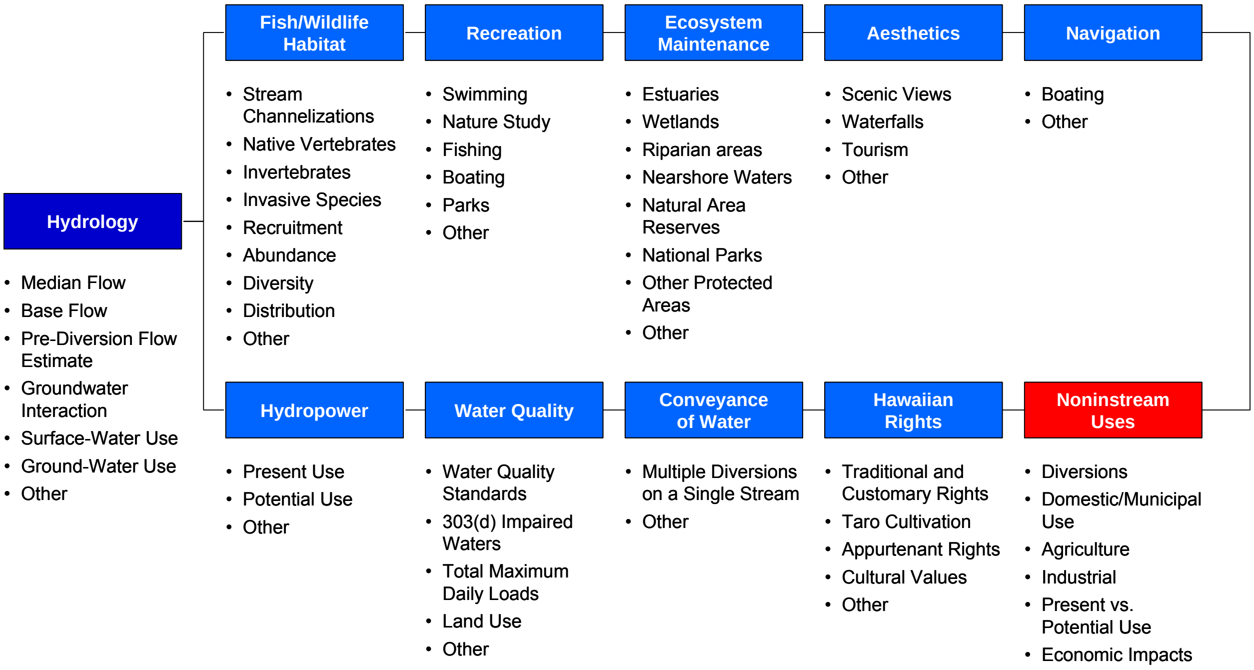
[2] Elevation data is derived from the 100 foot contours GIS data file (State of Hawaii, Office of Planning, 1997) unless otherwise noted.

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

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.

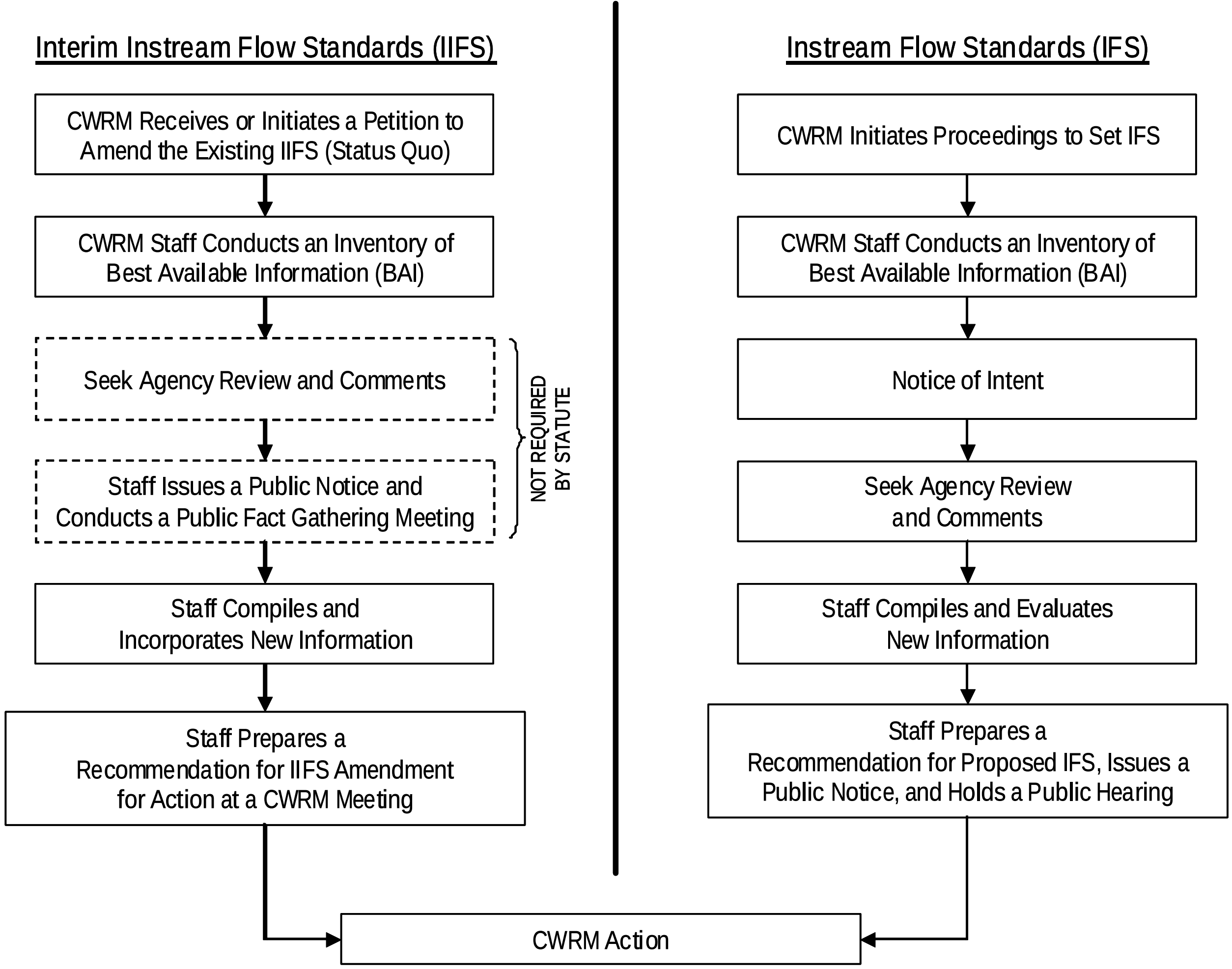


1.4 Interim Instream Flow Standard Process

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.

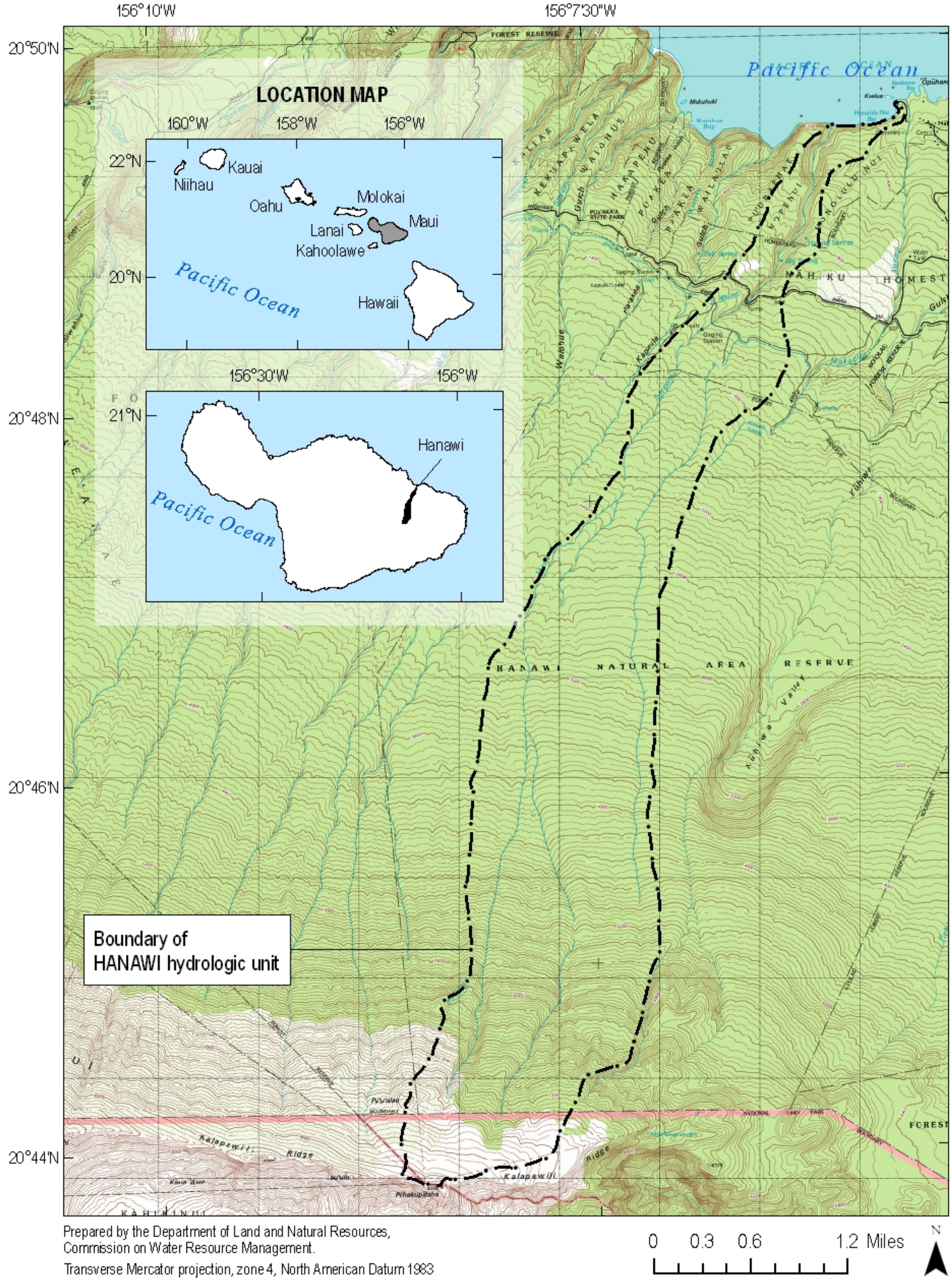
Surface water. Both contained surface water--that is, water upon the surface of the earth in bounds created naturally or artificially including, but not limited to, streams, other watercourses, lakes, reservoirs, and coastal waters subject to state jurisdiction--and diffused surface water--that is, water 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.

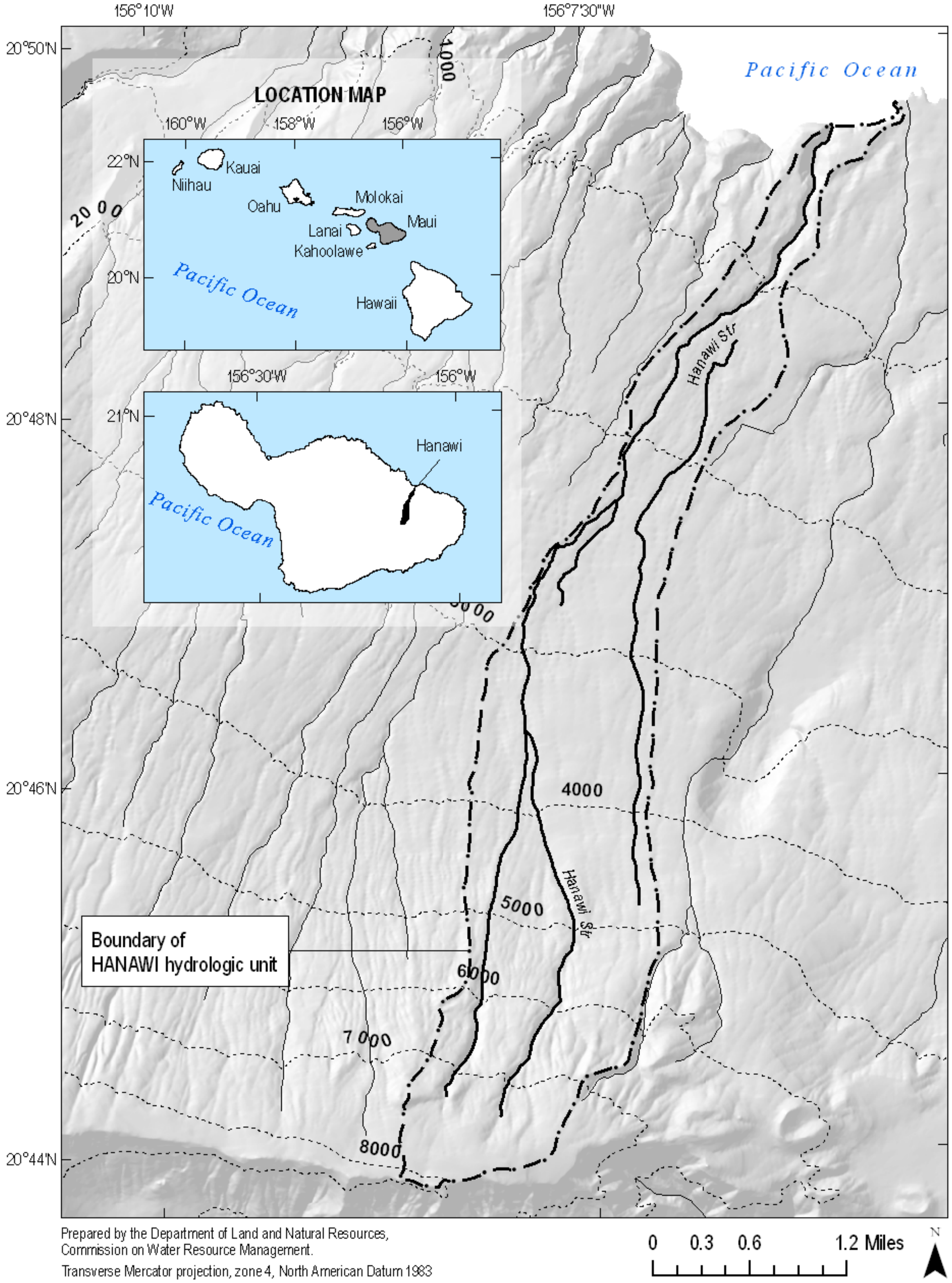
Figure 1-3. Topographic map of the Hanawi hydrologic unit in east Maui, Hawaii (Source: USGS, 1996).



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.

Transverse Mercator projection, zone 4, North American Datum 1983

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



Prepared by the Department of Land and Natural Resources,
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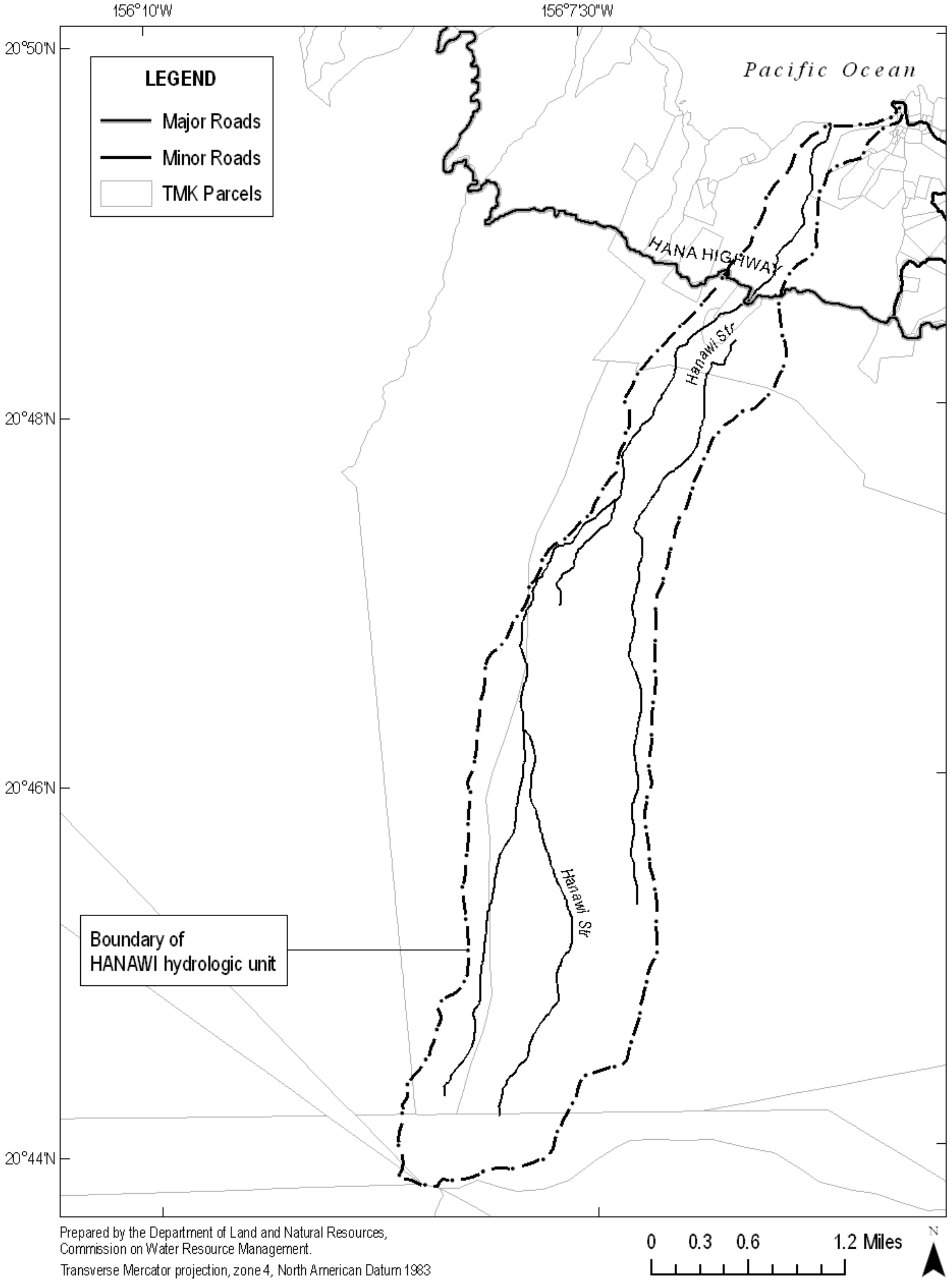
Transverse Mercator projection, zone 4, North American Datum 1983

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



Prepared by the Department of Land and Natural Resources,
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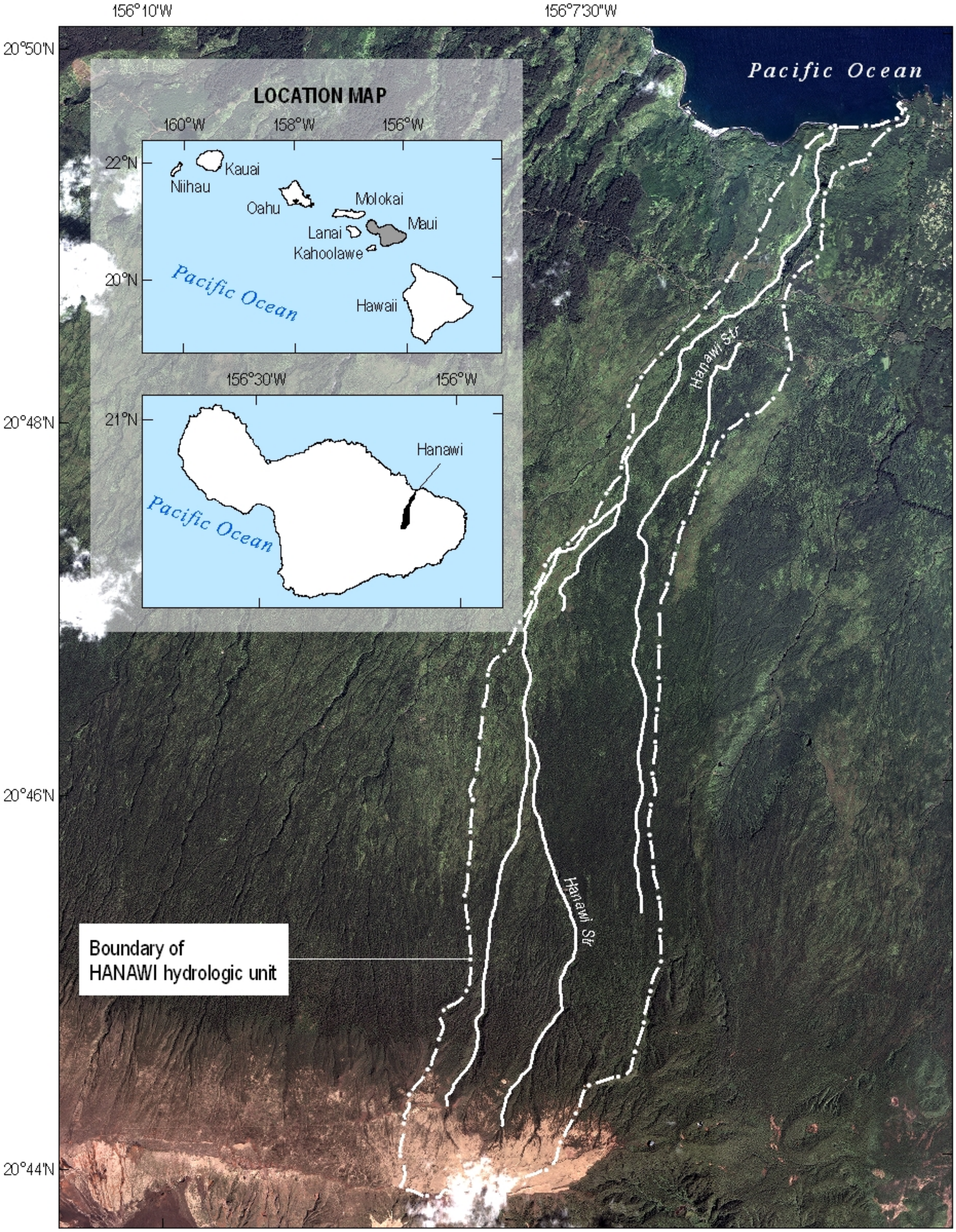
Figure 1-6. Quickbird satellite imagery of Hanawi hydrologic unit (Source: County of Maui, Planning Department, 2004; USGS, 2001b).



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

2.0 Unit Characteristics

2.1 Geology

Nearly 60 percent of the surface geology of the Hanawi hydrologic unit is characterized by Hana volcanics, primarily occurring as aa flows. Hana flows occur throughout the hydrologic unit with the greatest concentrations between 2,723 and 6,365 feet above mean seal level. Average flow thickness is 10 feet on steep, upper slopes and up to 50 feet near the coast (Stearns and MacDonald, 1942). Flows confined between valley walls or in depressions may be up to 500 feet thick.

Vitric ash deposits of the Hana volcanics are present in the uppermost reaches of the hydrologic unit, adjacent to the rift zone, above elevations of 7,119 feet. The ash deposits range in thickness from one to 20 feet (Stearns and MacDonald, 1942). Cinder and spatter deposits are also present in the upper reach of the hydrologic unit between 6,365 and 6,988 feet. The cinder cones range in height from a few feet up to 600 feet and are composed of loose, fresh, black, glassy cinders (Stearns and MacDonald, 1942).

The Hana lavas are extremely permeable and the lack of interstratfied perching beds allows most rain to percolate to the base of the Hana volcanics (Stearns and MacDonald, 1942). As a result, at high and mid altitudes no perennial streams are found flowing across Hana volcanics. Intermittent streams may form briefly in pre-existing channels during severe storm events; however, they dry up swiftly as the rain subsides. At low altitudes near the coast, some of these intermittent streams may become perennial, where stream beds are veneered with less permeable lavas and are fed by ground water that discharges into the stream as base flow (Takasaki and Yamanaga, 1970). In the eastern half of the mountain, vast quantities of groundwater are believe to flow seaward at the base of the Hana volcanics (Stearns and MacDonald, 1942).

Nearly 41 percent of the surface geology of the Hanawi hydrologic unit is characterized by Kula volcanics, primarily occurring as aa flows (lava characterized by jagged, sharp surfaces with massive, relatively dense interior) and pahoehoe flows (lava characterized by smooth or ropy surfaces, with layered flow units). The aa flows are common in the near summit areas as well as in the middle and lower reaches of the hydrologic unit. The pahoehoe flows are predominantly confined to near summit areas but are also found in more seaward areas at the base of the series transition zone. Pahoehoe and aa flows average 20 feet thick near the summit of Haleakala and 50 feet thick near the coast, but flows up to 200 feet thick are common (Stearns and MacDonald, 1942).

The upper Kula lavas were deposited during the waning phase of the volcano at a time when the intervals between flows became progressively longer allowing for the erosion of numerous valleys. Longer flow intervals, combined with the more silicious composition of later stage lavas, resulted in aggregations of flows up to 2,000 feet thick on the summit. These flow aggregates thin to approximately 50 feet towards the isthmus (Stearns and MacDonald, 1942).

Two small areas of near-vent cinder and spatter deposits is present in the center of the upper reach of the hydrologic unit between 6,857 and 7,021 feet mean sea level and 7,775 and 7,808 feet mean sea level. The cinder cones range in height from 10 feet to several hundred feet (Stearns and MacDonald, 1942). The cones are generally consolidated and composed of weathered red and yellow cinders. Fall-out deposits from the cones range in thickness from one foot to 40 feet (Stearns and MacDonald, 1942).

In the eastern end of the mountain near Haiku, perched high-level ground water[4] is held up by the relatively low permeability[5] Kula volcanics and associated weathered soils and ash beds (Gingerich, 1999a). Elsewhere they contain fresh water at sea level, but it is brackish along the leeward shore. Where surface rocks are poorly to fairly permeable, as with the Kula volcanics, much of the rainfall runs off overland as stream flow or is quickly returned to the surface as spring flow, and streams are mostly perennial (Takasaki and Yamanaga, 1970).

A thin band of Honomanu basalt, comprising one-tenth of a percent of the surface geology of the Hanawi hydrologic unit, is found in its lower reach along either side of Hanawi Stream. The Honomanu basalt is exposed over less than one percent of Haleakala but is believed to form the basement of the entire mountain to an unknown depth below sea level (Stearns and MacDonald, 1942). The Honomanu basalt occurs as aa and pahoehoe flows which are commonly vesicular. Individual flows range in thickness from 10 to 75 feet (Stearns and MacDonald, 1942). The Honomanu basalts are generally transitional into the overlying Kula volcanics and are extremely permeable. Surface water and ground water interactions are discussed in more detail in Section 3.0, Hydrology.

The generalized geology of the Hanawi 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 Hanawi hydrologic unit.

Symbol	Name	Rock Type	Lithology	Area (mi^2)	Percent of Unit
Qkul	Kula Volcanics	Lava flows	Aa	1.38	24.9
Qhn2	Hana Volcanics	Lava flows	Aa	1.36	24.5
Qhn4	Hana Volcanics	Lava flows	Aa	1.34	24.2
Qkul	Kula Volcanics	Lava flows	Aa and pahoehoe	0.85	15.3
Qhnt	Hana Volcanics	Ash, poorly to nonindurated	Well-sorted distal fallout	0.38	6.9
Qhn2	Hana Volcanics	Lava flows	Aa	0.12	2.2
Qhnv2	Hana Volcanics	Cinder and spatter	Coarse near-vent fallout deposits	0.05	1.0
Qhnv4	Hana Volcanics	Cinder and spatter	Coarse, near-vent fallout	0.03	0.6
Qkul	Kula Volcanics	Lava flows	Aa	0.01	0.2
Qkuv	Kula Volcanics	Cinder and spatter	Coarse near-vent fallout deposits	0.01	0.2
Qmnl	Honomanu Basalt	Lava flows	Pahoehoe and aa	0.01	0.1
Qhnv0	Hana Volcanics	Cinder and spatter	Coarse near-vent fallout deposits	< 0.01	< 0.1
Qkuv?	Kula Volcanics	Vent deposits (query)	Low mound, cinders eroded	< 0.01	< 0.1

2.2 Soils

Hanawi consists largely of soils that are permeable; thus allowing rainwater to feed both streams and ground water. The headwaters of the hydrologic unit lie on cinder land. This land type is composed of loose cinders, pumice, and volcanic ash with little or no soil development. Much of the intermediate elevations and a portion of the upper elevations are dominated by Hydrandepts-Tropaquods association. About 60 percent of the association are well-drained soils, occurring on the steeper slopes. The other 40 percent are poorly drained, with an ironstone sheet at a depth of 10 to 20 inches. The lower elevations surrounding the streambed are mostly well-drained soils of the Honomanu and Kailua silty clay. While both types of soil are formed from volcanic ash and are strongy acidic, the Honomanu silty clay has a

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[4] Perched water is water confined by an impermeable or slowly permeable layer, thus accumulating in a perched water table above the general regional water table. It is generally near-surface, and may supply springs.

[5] Permeability is the ease with which water passes through material. It is a factor in determining whether precipitation runs off on the surface or descends into the ground.

higher amout of organic matter in the surface layer; thus increasing the porosity of the soil. The lower reach of Hanawi Stream and the coastline consist of rough mountainous land (U.S. Department of Agriculture, Soil Conservation Service, 1972).

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 Hanawi, a majority of the soils belong to group C, indicating that the soils have relatively low infiltration rates and are prone to surface runoff. Group A soils occur in the headwaters; thus allowing rainwater to infiltrate into the ground for subsurface flow or ground water recharge. The lower reach of the streambed and small portions in the upper elevations consist of group D soils (U. S. Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, 1986).

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

Map Unit	Description	Hydrologic Group	Area (mi^2)	Percent of Unit
rHT	Hydrandepts-Tropaquods association	C	3.97	71.5
rCI	Cinder land	A	0.65	11.8
rHOD	Honomanu silty clay, 5 to 25 percent slopes	C	0.47	8.4
KBID	Kailua silty clay, 3 to 25 percent slopes	C	0.22	4.0
rRT	Rough mountainous land	D	0.22	3.9
MID	Makaalae silty clay, 7 to 25 percent slopes	B	0.01	0.1
rRO	Rock outcrop	D	0.02	0.3

2.3 Rainfall

Rainfall distribution in Hanawi is governed by the orographic[6] 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 (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.

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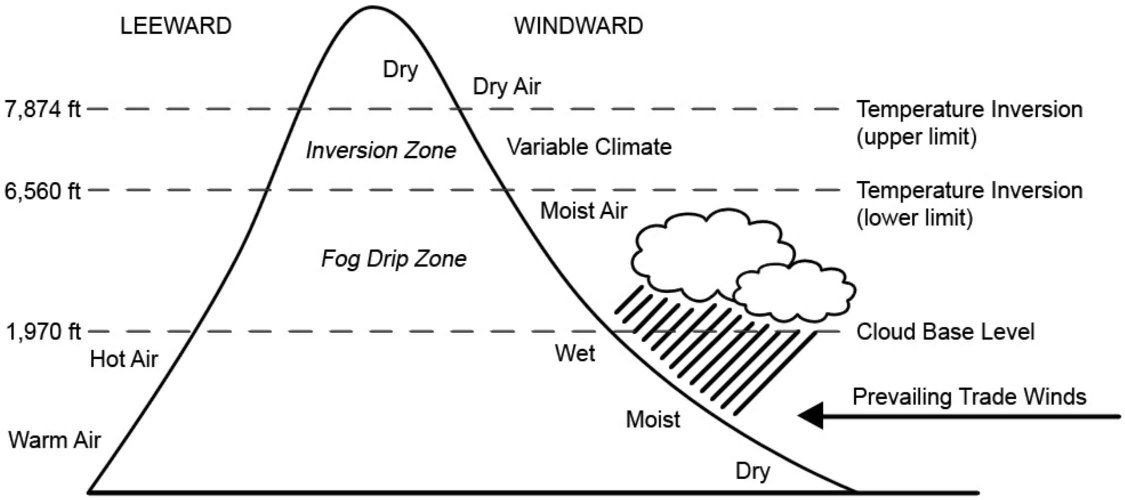
[6] Orographic refers to influences of mountains and mountain ranges on airflow, but also used to describe effects on other meteorological quantities such as temperature, humidity, or precipitation distribution.

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



The hydrologic unit of Hanawi is situated on the windward flank of the East Maui Volcano. Hanawi receives near-daily orographic rainfall of 160 inches per year at the coast to 280 inches per year in the intermediate slopes. This rainfall drops down to 120 inches per year 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 a 600-foot drop in elevation in the intermediate slopes. Rainfall is highest during the months of March and December where the mean monthly rainfall across the hydrologic unit is approximately 17 inches. In March, rainfall can reach as high as 26 inches in the mountains. For the rest of the year, the mean monthly rainfall ranges from 9 inches to 15 inches. The driest months are June, September, and October during which an average of 2-3 inches of rain per month 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 Hanawi, which was calculated by multiplying the ratios with the monthly rainfall values (Giambelluca et al., 1986). Calculations show that approximately 65 percent of Hanawi lies in the fog drip zone (Figure 2-4) with an estimated average annual fog drip rate of 80 inches per year. Since a relatively large portion of Hanawi 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 Hanawi, estimated daily solar radiation is about 300 to 400 calories per square centimeter per day near the coast and decreases toward the uplands, where there are more clouds. Above the temperature inversion zone, solar radiation rises to about 400 calories per square centimeter 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[7], rainfall, humidity, wind speed, surface temperature, and sensible heat advection[8]. 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[9] 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

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[7] Albedo is the proportion of solar radiation that is reflected from the Earth, clouds, and atmosphere without heating the receiving surface.

[8] Sensible heat advection refers to the transfer of heat energy that causes the rise and fall in the air temperature.

[9] Temperature inversion is when temperature increases with elevation.

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 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 almost 97 percent of the land in Hanawi 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 (Figure 2-5).

2.7 Land Cover

Land cover for the hydrologic unit of Hanawi 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 Hanawi, 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 Hanawi consists mainly of evergreen forests. The headerwaters of Hanawi Stream are fed by dense native Ohia forests and Uluhe shrub lands that lie within the Hanawi Natural Area Reserve. The intermediate slopes are also dominated by native Ohia forests and Uluhe shrub lands, part of which also lies in the Koolau Forest Reserve. The lower slopes are mostly alien forests with scattered native Ohia forests. Sparse vegetation inhabits the coastal lands.

The land cover maps (Figures 2-6 and 2-7) provide a general representation of the land cover types in Hanawi. 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 Hanawi (Source: National Oceanographic and Atmospheric Agency, 2000).

Land Cover	Description	Area (mi²)	Percent of Unit
Evergreen Forest	Areas where more than 67 percent of the trees remain green throughout the year	4.90	88.3
Scrub/Shrub	Areas dominated by woody vegetation less than 6 meters in height	0.11	2.0
Grassland	Natural and managed herbaceous cover	0.43	7.7
Bare Land	Bare soil, gravel, or other earthen material with little or no vegetation	0.11	1.9
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
Water	Areas of open water with less than 30 percent of trees, shrubs, persistent emergent plants, or other land cover	< 0.01	< 0.1

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

Land Cover	Area (mi²)	Percent of Unit
Closed Ohia Forest (native shrubs)	2.64	47.5
Open Ohia Forest (uluhe)	1.40	25.2
Alien Forest	0.62	11.1
Deschampsia Grassland	0.31	5.6
Closed Ohia Forest (uluhe)	0.17	3.0
Uncharacterized Open-Sparse Vegetation	0.10	1.8
Closed Koa-Ohia Forest (uluhe)	0.09	1.6
Native Shrubland / Sparse Ohia (native shrubs)	0.07	1.2
Closed Koa-Ohia Forest (native shrubs)	0.05	1.0
Uncharacterized Forest	0.03	0.6
Native Shrubland (alien grasses)	0.02	0.4
Uluhe Shrubland	0.02	0.4
Very Sparse Vegetation to Unvegetated	0.02	0.3
Alien Grassland	0.01	0.2
Kikuyu Grass Grassland / Pasture	< 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. Figure 8-2 illustrates the flood-risk areas in the hydrologic unit of Hanawi. The eastern tip of the hydrologic unit is prone to coastal flooding with a 1 percent annual chance of inundation due to their proximity to the sea.

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.

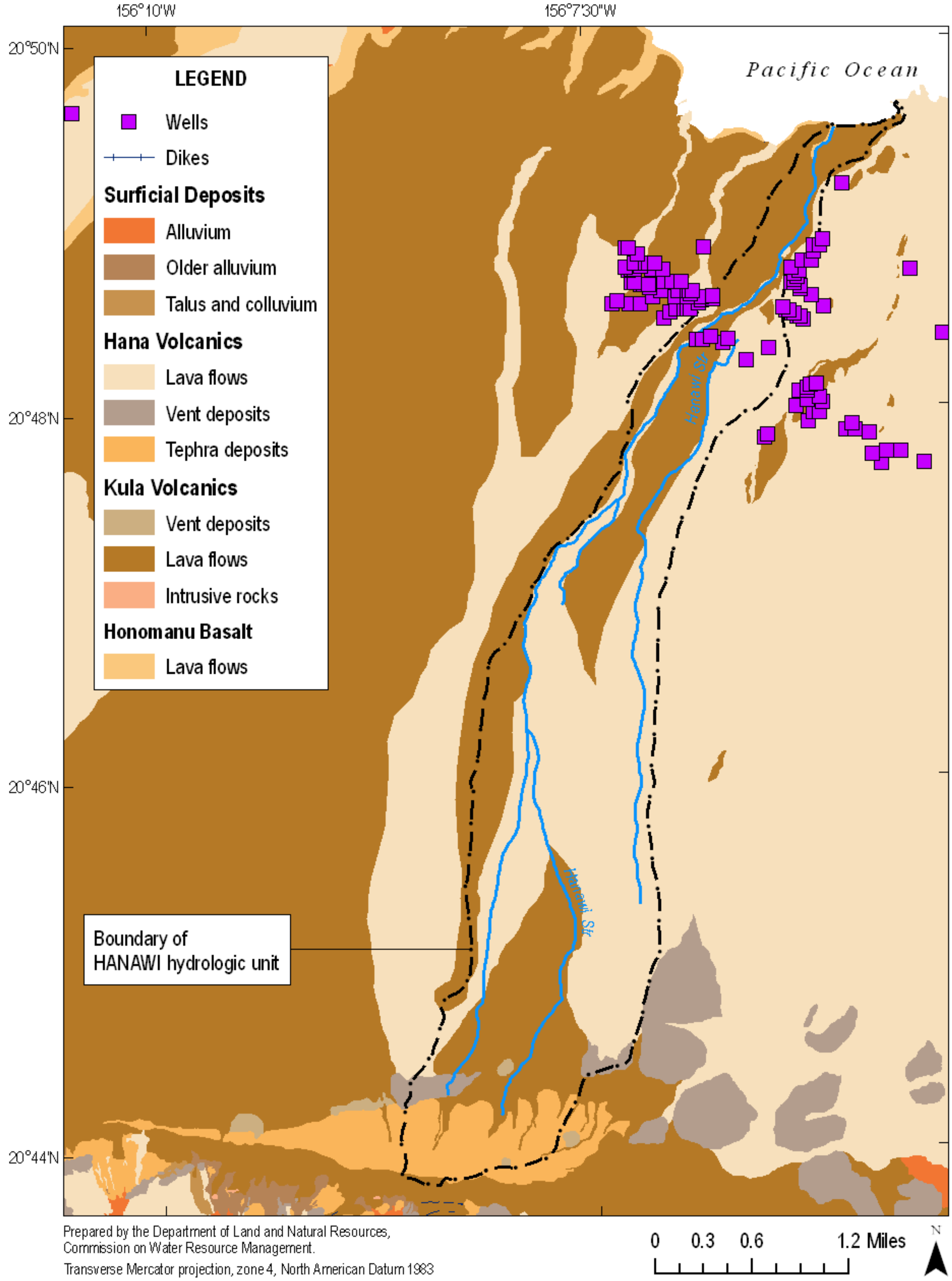
With Hawaii's limited water resources and growing water demands, droughts will continue to adversely affect the environment, economy, and the residents of the State. Aggressive planning is necessary to make wise decisions regarding the allocation of water at the present time, and conserving water resources 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

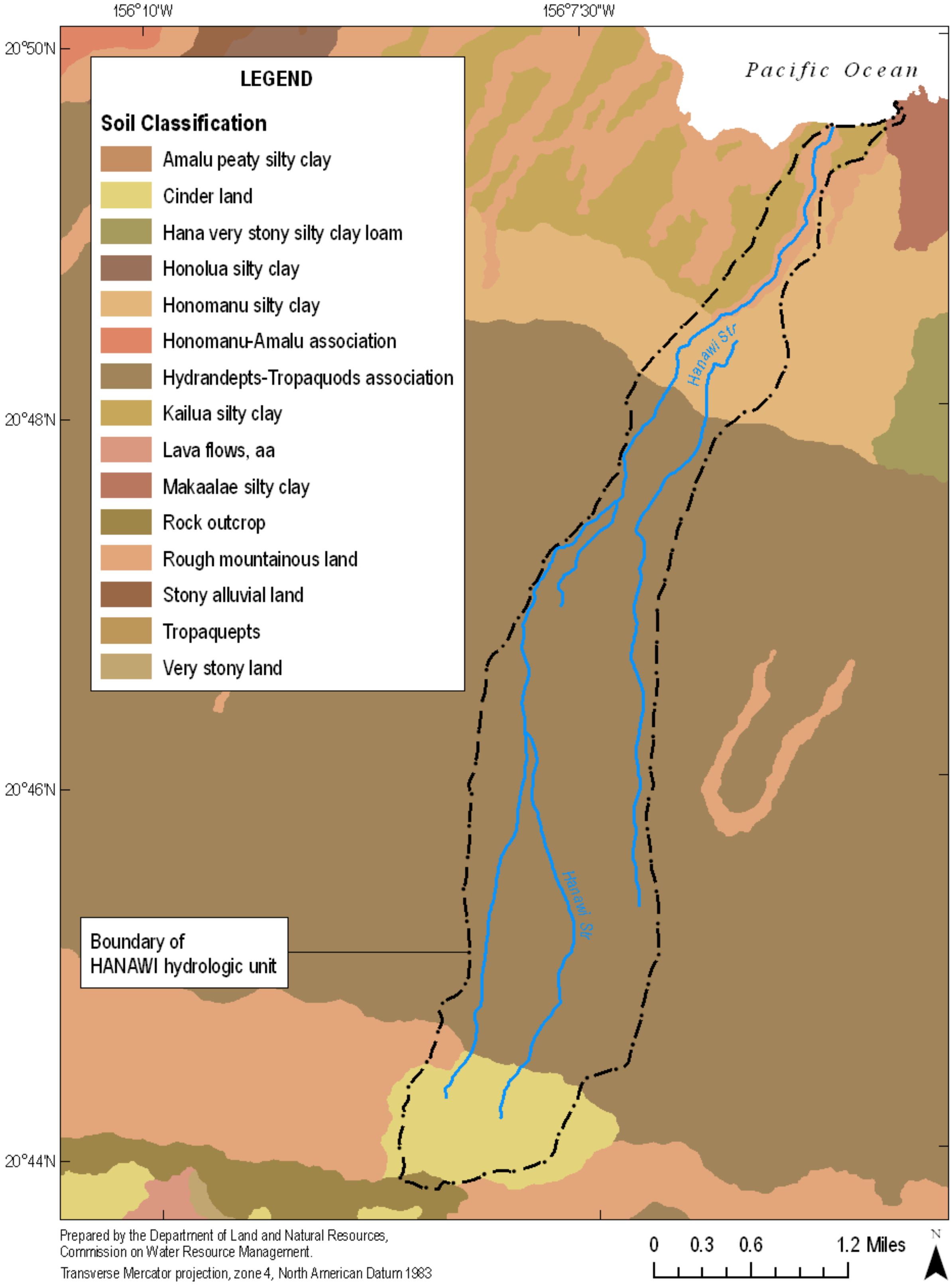
Figure 2-2. Generalized geology of Hanawi hydrologic unit (Source: Sherrod et al., 2007; State of Hawaii, Office of Planning, 2006a, and State of Hawaii, Commission on Water Resource Management, 2008d; USGS, 2001b).



Prepared by the Department of Land and Natural Resources, Commission on Water Resource Management.

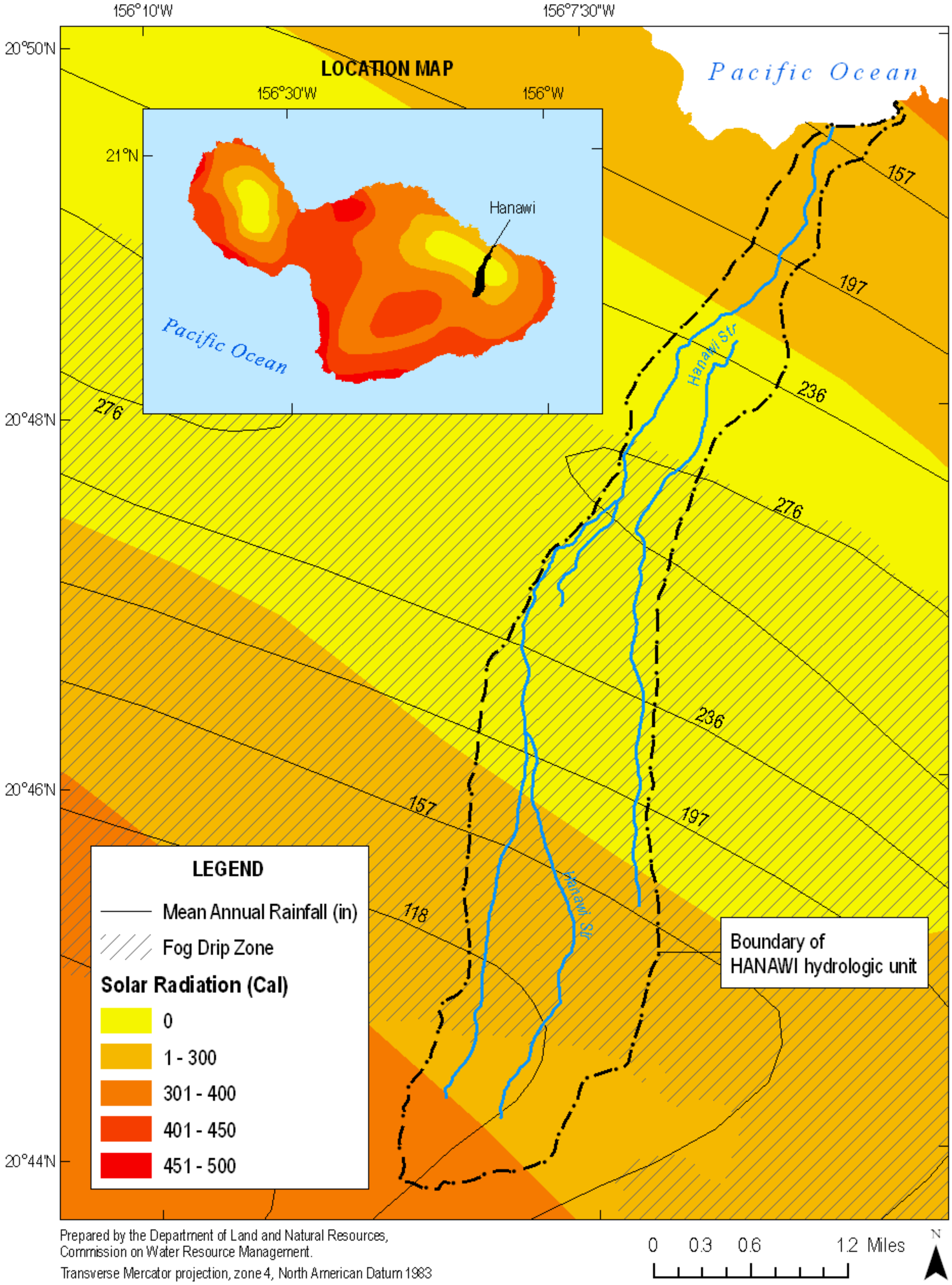
Transverse Mercator projection, zone 4, North American Datum 1983

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



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

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



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

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

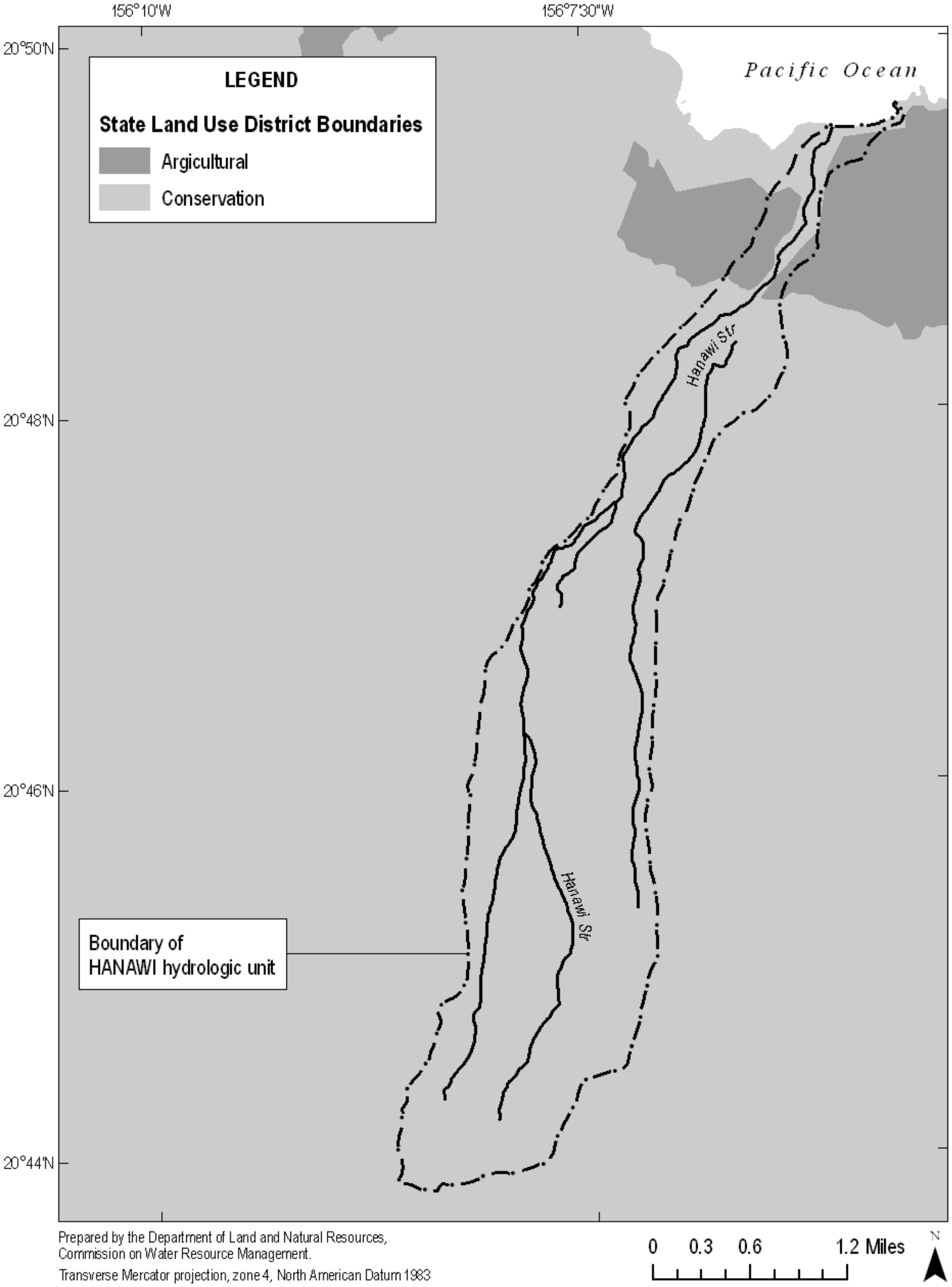
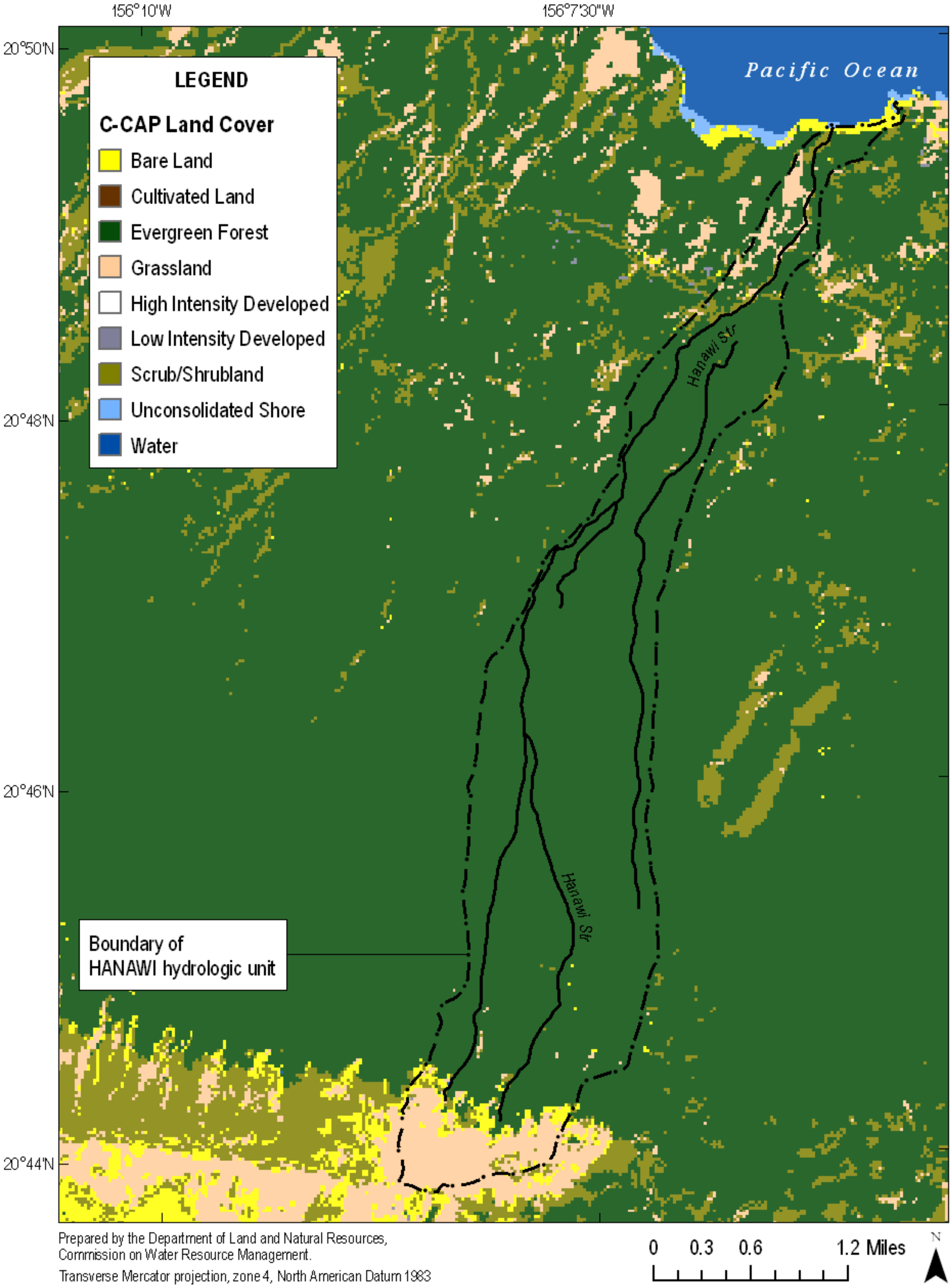


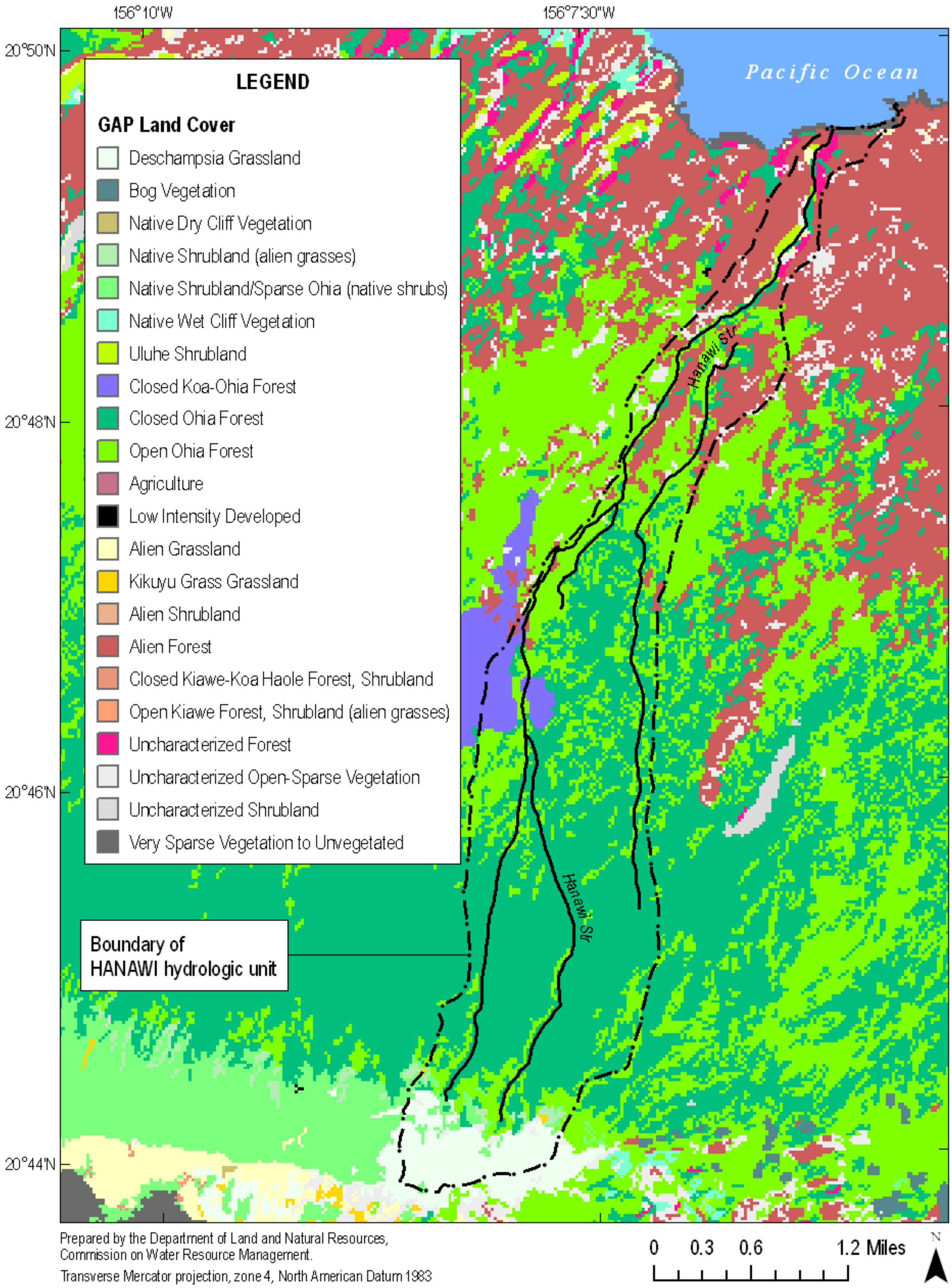
Figure 2-6. C-CAP land cover in Hanawi hydrologic unit (Source: National Oceanic and Atmospheric Administration, Coastal Services Center, 2000; USGS, 2001b).



Prepared by the Department of Land and Natural Resources, Commission on Water Resource Management.

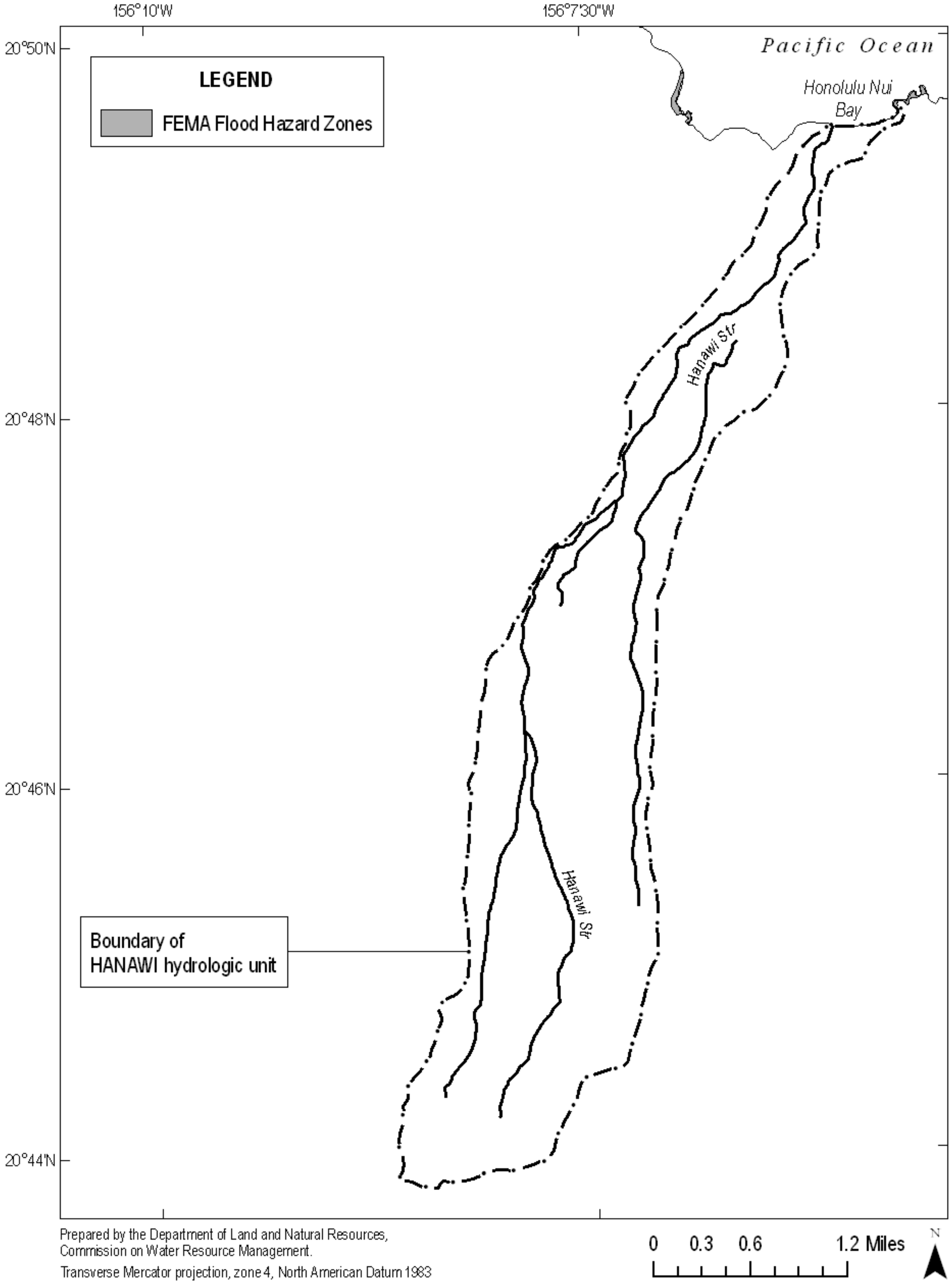
Transverse Mercator projection, zone 4, North American Datum 1983

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



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

Figure 2-8. FEMA flood hazard zones in Hanawi hydrologic unit (Source: Federal Emergency Management Agency, 2003; 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 Hanawi 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[10], 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[11] of Hawaiian streams. 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). When ground water is withdrawn from a well, the water level in the surrounding area is lowered. Nearby wetlands or ponds may shrink or even dry up if the pumping rate is sufficiently high (Gingerich and Oki, 2000). The long-term effects of ground water withdrawal can include the reduction of streamflow, which may cause a

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[10] 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.

[11] 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 Hanawi lies within the Keanae aquifer system that has an area of about 56 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. Hanawi Stream lies on lava flows of the Hana Volcanics for most of its length, with the exception of 2,000 feet of Honomanu Basalt near the coast as well as lava flows of the Kula Volcanics near the headwaters. It also appears that the stream runs adjacent to lava flows of the Kula Volcanics in the lower and intermediate slopes. The fresh water-lens system is vertically extensive, in which the saturated zone extends from the Honomanu Basalt at sea level through the Kula Volcanics and into the Hana Volcanics. Streams that intersect the water table continue to gain water as they descend to sea level. Ground water withdrawals from wells open to any part of the aquifer will reduce streamflow and discharge to the ocean. A total of 13 wells are located in the Hanawi hydrologic unit, all owned by the East Maui Irrigation (EMI) Company and located in the upper elevations. Seven of the wells are development tunnels, four of which actively supply water to EMI's Koolau Ditch. The remaining wells are test holes drilled to determine water yields. As of June 2008, the ground water demand of the Keanae aquifer system is only 0.162 million gallons per day, which is well below the aquifer's current sustainable yield of 83 million gallons per day (State of Hawaii, Commission on Water Resource Management, 2008c). Estimated total ground water recharge without accounting for fog drip contribution is 171 million gallons per day, which represents 37 percent of total rainfall (Shade, 1999).

Ground water use information is only available by island. Among the major Hawaiian Islands, Maui has the second highest number of production wells following Oahu. Of the 450 productions wells in Maui, 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).

Table 3-1. Information of wells located in Hanawi hydrologic unit (Source: State of Hawaii, Commission on Water Resource Management, 2008e).

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

Well number	Well Name	Year drilled	Use	Ground elevation (feet)	Well depth (feet)	Pump elevation (feet)	Pump depth (feet)	Pump rate (gpm)
4806-01	Hanawai Tun 2 [a]	--	Irrigation	--	--	--	--	--
4806-02	Hanawai Tun 3 [a]	--	Irrigation	--	--	--	--	--
4806-03	Hanawai Skylt Tu [a]	--	Irrigation	--	--	--	--	--
4806-04	Shishido Tunnel [a]	--	Irrigation	--	--	--	--	--
4806-05	Big Spring Tunnel	--	Unused	540	--	--	--	--
4806-06	Hanawi Gu Exp Tu	--	Unused	--	--	--	--	--
4806-13	Nahiku TH 22	1935	Unused	1295	129	--	--	--
4806-14	Nahiku TH 35	1935	Unused	1293	223	--	--	--
4806-26	Nahiku TH 57	1936	Unused	1294	129	--	--	--
4807-10	Hanawai Tun 1	--	Unused	--	--	--	--	--
4807-39	Nahiku TH 34	1935	Unused	1332	110	--	--	--
4906-03	Nahiku TH 94	1943	Unused	796	596	--	--	--
4906-04	Nahiku TH 95	1943	Unused	780	148	--	--	--

[a] Development tunnel serves EMI's Koolau Ditch and may contribute to streamflow.

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

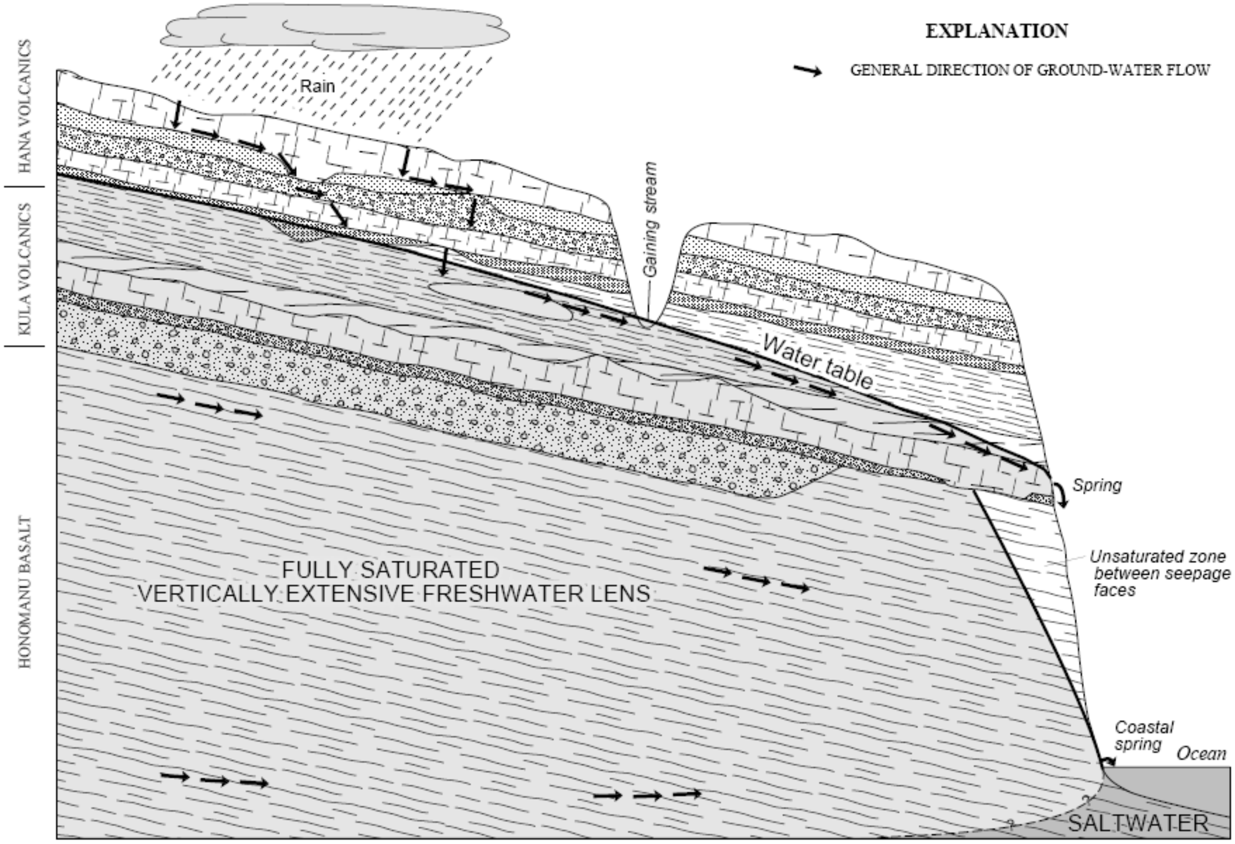


Table 3-2. Summary of ground water use reporting in the island of Maui (Source: State of Hawaii, Commission on Water Resource Management, 2008c).

[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

Hanawi Stream is about 7 miles in length, traversing north from its headwater at the 7,300 feet altitude to the ocean. The stream rises from sea level to 600 feet elevation 0.8 miles from the coast, contributing to a slope gradient of 770 feet per mile, and the valley is incised 240 feet below the upland surface (Gingerich, 1999b).

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).

Hanawi Stream has two USGS continuous-record stream gaging stations, one of which is currently in operation (Figure 3-1): 1) active station 16508000, immediately upstream of Koolau Ditch at the 1,318 feet altitude; and 2) inactive station 16509000, downstream of Koolau Ditch at the 500 feet altitude. Tables 3-3 and 3-4 contain information on the location and flow-duration characteristics of the stations. Flow in Hanawi Stream is currently captured by the Koolau Ditch at 1,300 feet elevation. Streamflow record for the active station dates back to 1914. Since the station is located upstream of the ditch, streamflow records reflect flows under natural (undiverted) conditions. Based on 86 years with complete record (1923-2008), the lowest daily mean flow of 0.9 cubic feet per second was recorded in 1984, and the highest daily mean flow of 1,610 cubic feet per second was recorded in 1948. Median streamflow (TFQ_{50}) is 7 cubic feet per second, and normal conditions of base flow in the stream can range between 2.3 cubic feet per second (TFQ_{95}) to 4.4 cubic feet per second (TFQ_{70}).

Streamflow records for the inactive station reflect flows under diverted conditions. Based on 17 years with complete record, the lowest daily mean flow of 13 cubic feet per second was recorded in 1936, and the highest daily mean flow of 2,320 cubic feet per second was recorded in 1938. Median streamflow is 20 cubic feet per second. Normal conditions of base flow in the stream can range between 16 to 18 cubic feet per second.

Table 3-3. General information and flow-duration characteristics of USGS stream gaging station on Hanawi Stream, upstream from Koolau Ditch (station 16508000).

Station number:	16508000		
Station name:	HANAWI STREAM NEAR NAHIKU, MAUI, HI		
Flow diverted or regulated?:	N	Altitude (feet):	1,318
Latitude (decimal degrees):	20.80707297	Altitude accuracy (feet):	1
Longitude (decimal degrees):	-156.11386264	Basin area (square miles):	3.49
Latitude/Longitude accuracy:	1 second	Period of record:	1914-1916, 1922-2005
Horizontal datum:	nad83	Complete water years:	1923-2005

Minimum daily mean discharge during period of record:		Maximum daily mean discharge during period of record:	
Discharge, cubic feet per second:	0.90	Discharge, cubic feet per second:	1,610
Number of occurrences:	1	Number of occurrences:	1
Most recent occurrence:	10/31/1984	Most recent occurrence:	01/25/1948

Flow-duration characteristics based on complete water years during period of record (83 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	24	7.0	6.2	5.6	5.0	4.4	4.0	3.6	3.2	2.8	2.3	1.8

Table 3-4. General information and flow-duration characteristics of USGS stream gaging station on Hanawi Stream, downstream from Koolau Ditch (station 16509000).

Station number:	16509000		
Station name:	HANAWI STREAM BL GOVT RD NR NAHIKU, MAUI, HI		
Flow diverted or regulated?:	Y	Altitude (feet):	500
Latitude (decimal degrees):	20.81762706	Altitude accuracy (feet):	not available
Longitude (decimal degrees):	-156.10358513	Basin area (square miles):	5.03
Latitude/Longitude accuracy:	unknown	Period of record:	1932-1947, 1992-1995
Horizontal datum:	nad83	Complete water years:	1933-1946, 1993-1995

Minimum daily mean discharge during period of record:		Maximum daily mean discharge during period of record:	
Discharge, cubic feet per second:	13	Discharge, cubic feet per second:	2,320
Number of occurrences:	8	Number of occurrences:	1
Most recent occurrence:	02/29/1936	Most recent occurrence:	04/07/1938

Flow-duration characteristics based on complete water years during period of record (83 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	40	20	20	19	19	18	18	18	17	17	16	15

The following is a summary of the flow conditions on Hanawi Stream, categorized by the approximate location of the stream reaches (i.e., upper, middle, and lower). Based on the available streamflow data, Hanawi Stream appears to be mostly a gaining stream, excepting two short reaches downstream from station 16509000 near the coast in which the stream may be losing flow.

Hanawi Stream, upper reach. The headwaters of Hanawi Stream consist of two tributaries that are headed at about 7,300 feet elevation. Between this elevation and the 3,500 feet altitude, it is unknown whether the stream is gaining flow from or losing flow to ground water sources. Gingerich's study (2005) did not identify any springs along these headwater tributaries, which may contribute ground water flow to the stream. Streamflow measurements taken in July of 1994 near the confluence of the two tributaries indicate a flow of 0.02 million gallons per day in the west tributary, and a flow of 0.06 million gallons per day in the east tributary.

Hanawi Stream, middle reach. According to Gingerich (1999b; 2005), Hanawi Stream is gaining ground water flow downstream from the confluence of the two headwater tributaries at 3,500 feet elevation to the active gaging station upstream from the Koolau Ditch at 1,300 feet elevation. The studies indicate five springs along the stream that may contribute to this gain in flow. Streamflow records show an average annual base flow of 3.66 million gallons per day upstream from the active station. A separate set of measurements made at different years indicate that flow at the active station ranged from 1 to 6 million gallons per day.

Hanawi Stream, lower reach. Downstream from the Koolau Ditch, a number of springs are located along the stream that contributes ground water flow to the stream. Estimates show an average annual base flow of almost 13 million gallons per day, and all of this flow is gained between the ditch and the inactive station at 500 feet elevation (Gingerich, 1999b). Based on independent sets of measurements, the stream had small gains of about 1 million gallons per day immediately downstream from the ditch. Between the 1000 and 620 feet altitudes, the stream gained substantially (6 to 7 million gallons per day). Downstream from the 620 feet altitude to the inactive station, additional gains of 4 to 8 million gallons per day were measured. Two small reaches near the coast were found to be losing flow in Gingerich's study (1999b). Between 420 and 190 feet altitude, streamflow decreased by 6 percent, and between 120 and 50 feet altitude, streamflow decreased by 2 percent. This apparent loss in streamflow may not be related to ground and surface water interaction, but instead attibuted to the difficulty in measuring all the water flowing in the stream.

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 the 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 for the stations in Hanawi Stream are presented in Table 3-5. Note that the measured flows for the inactive station are different from the TFQ_{50} values in Table 3-3 and 3-4. 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 3-6. Streamflow record for the active station was not adjusted because the period of record for the station was the same length as that of the index station.

Table 3-5. Selected estimated median and low-flow characteristics for continuous-record sites in the Hanawi 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)
5080	82	7.1	--	4.6	--	2.4	--	2.2	--
5090+ 5080	18	29	28	25	24	19	19	19	19

The regression equations performed very well in predicting the streamflow statistics for the active station (station 16508000). Relative errors between measured and estimated flows for this station were within 13 percent; therefore, all of the measured flows fall within the 90 percent confidence interval of the corresponding estimated statistics. The regression equations largely underestimated (over 70 percent) streamflow for the inactive station (station 16509000) because the equations did not account for additional ground water flow gained from springs located downstream from the ditch.

Table 3-6. Stream flow statistics estimated using regression equations, lower and upper confidence intervals, standard errors, measured flows, and relative errors for continuous-record stations in Hanawi (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}
16508000	Estimated flow	7.7	4.6	2.7	2.2
	90% LCL	6.8	3.8	2.1	1.7
	90% UCL	8.8	5.6	3.5	3
	Standard error	7.5	11.1	14.2	15.9
	Measured flow	***7.1***	***4.6***	***2.4***	***2.2***
	Relative error	8	0	13	0
16508000 + 16509000	Estimated flow	12	7.9	4.9	4.3
	90% LCL	10	6.1	3.4	2.8
	90% UCL	15	10	7.1	6.6
	Standard error	10.3	15.2	21.5	24.1
	Measured flow	28	24	19	19
	Relative error	-57	-67	-74	-77

The equations were also applied to low flow station HwL near the mouth of Hanawi Stream. Regression estimates were compared to measured flow estimates, which are a combination of streamflow records at the continuous-record gaging station and measurements taken in 1995 and 2003. Results are presented in Tables 3-7. Again, flow estimates were generally underestimated because the regresson equations did not account for flow gains from springs.

Table 3-7. Stream flow statistics estimated using regression equations, lower and upper confidence intervals, standard errors, measured flow, and relative errors for low flow station in Hanawi Stream (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
Hanawi lower (HwL)	Estimated flow	16	10	5.1	4.6	TFQ_{50}, BFQ_{50}, BFQ_{95}: combined flow statistics from 5080 and 5090 upstream; TFQ_{95}: average of flow on entire stream Feb. 22, 1995 [Q_{97}] (Gingerich,1999) and combined Q_{95} flows from 5080 and 5090 upstream plus flow Nov. 7, 2003 [Q_{94}]
	90% LCL	14	8.3	3.5	3	
	90% UCL	19	13	7.6	7	
	Standard error	9.1	13.4	22.1	24.8	
	Measured flow	> 28	> 24	25	> 19	
	Relative error	< -43	< -58	-79	< -76	

A summary of the natural (undiverted) streamflow statistics is presented in Table 3-8. Flow estimates at the low flow station in Hanawi Stream are a combination of low-flow measurements and regression estimates. The natural (undiverted) flow statistics for the streams are consistent with the nature of a gaining stream in which the streams are gaining flow from Koolau Ditch to the stream mouth. Low-flow statistics (TFQ_{95} and BFQ_{95}) suggest a possible ground water gain of about 17 cubic feet of flow per second from the active gaging station near the ditch to the coast without the effect of surface water diversion at Koolau Ditch.

Table 3-8. Estimates of natural (undiverted) streamflow statistics for gaged and low flow station in the hydrologic unit of Hanawi (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
lower (HwL)	32	26	22	19	Middle site estimate plus equation adj.; TFQ95: Middle site estimate plus low-flow measurements
middle (5090)	28	24	19	19	Continuous record gaging station plus upper site estimate
upper (5080)	7.1	4.6	2.4	2.2	Continuous record gaging station

Results of the study show that the streams in the eastern side of the study area (i.e., east of Keanae Valley) have the lowest reductions in streamflow due to diversions at the 1,300 feet elevation. Therefore, the stream reaches immediately downstream from the diversions are dry most of the time. Effects of diversions can be assessed by comparing the flow statistics under natural conditions (Table 3-8) with those under diverted conditions (Table 3-9). At the inactive station on Hanawi Stream, diversion at the Koolau Ditch could potentially reduce median total and base flows by 33 and 21 percent, and low flows by 16 percent. At the low flow station, diversion at the ditch could capture about 11 percent of streamflow during low flow conditions.

Table 3-9. Estimates of diverted stream flow statistics and percent flow reduction for gaged and low flow stations in the hydrologic unit of Hanawi (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	
lower (HwL)	25	22	21	24	20	9	17	11	Diverted at Koolau Ditch
middle (5090)	19	33	19	21	16	16	16	16	Diverted at Koolau Ditch
upper (5080)	7.1	0	4.6	0	2.4	0	2.2	0	Not diverted

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.

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 Hanawi hydrologic unit (Source: State of Hawaii, Office of Planning, 2006b; State of Hawaii, Commission on Water Resource Management, 2008d; USGS, 2001b).

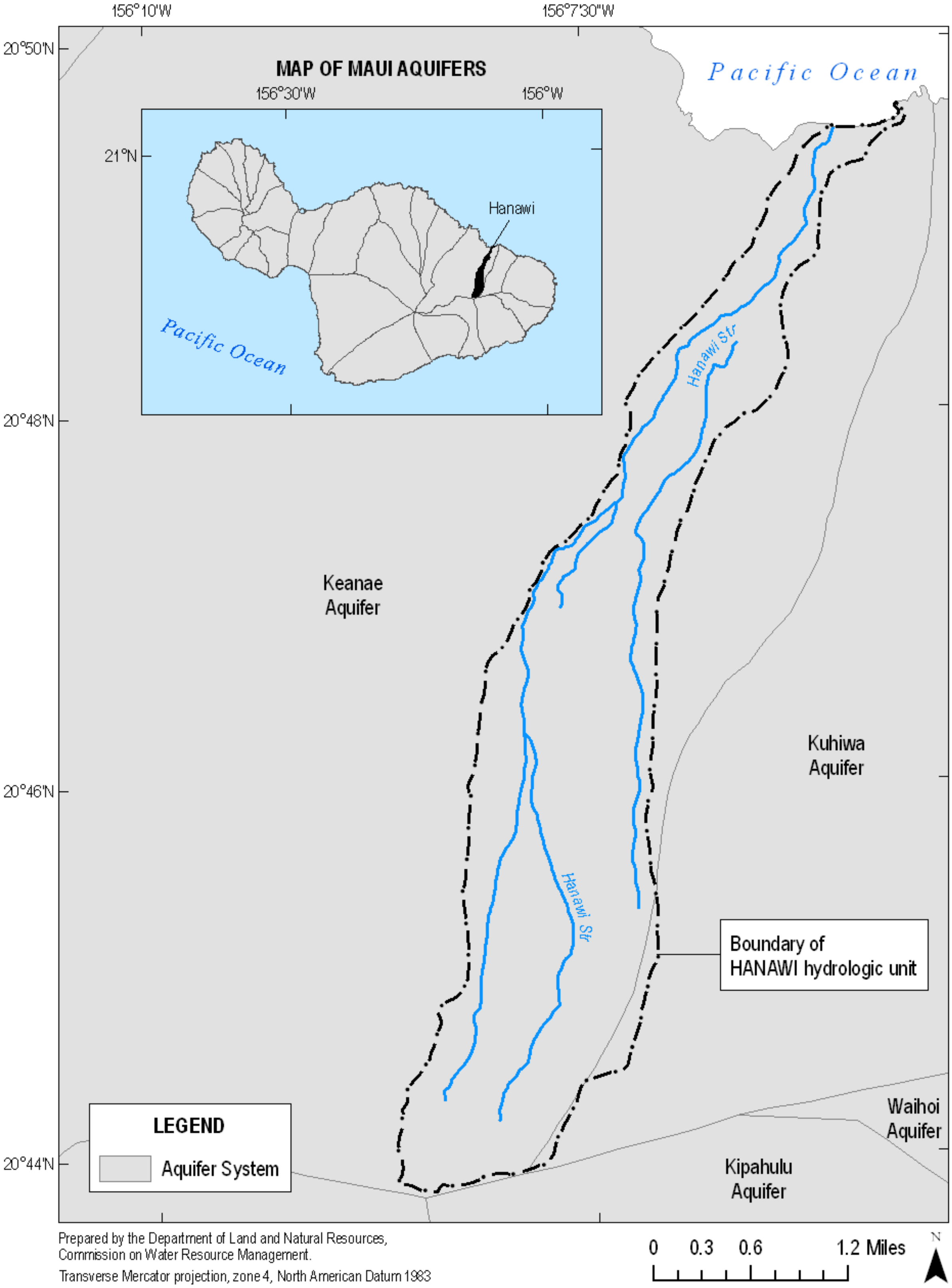
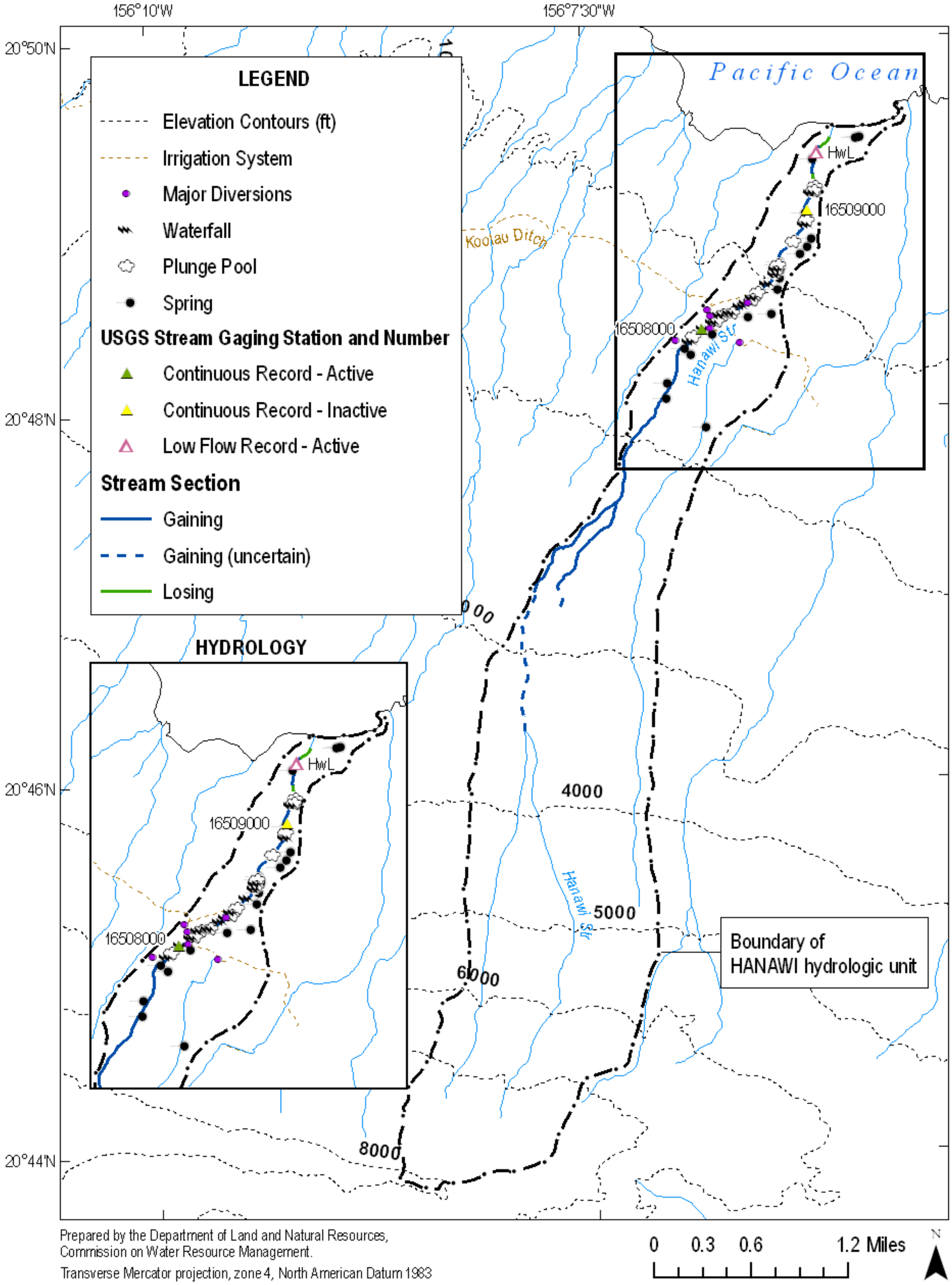
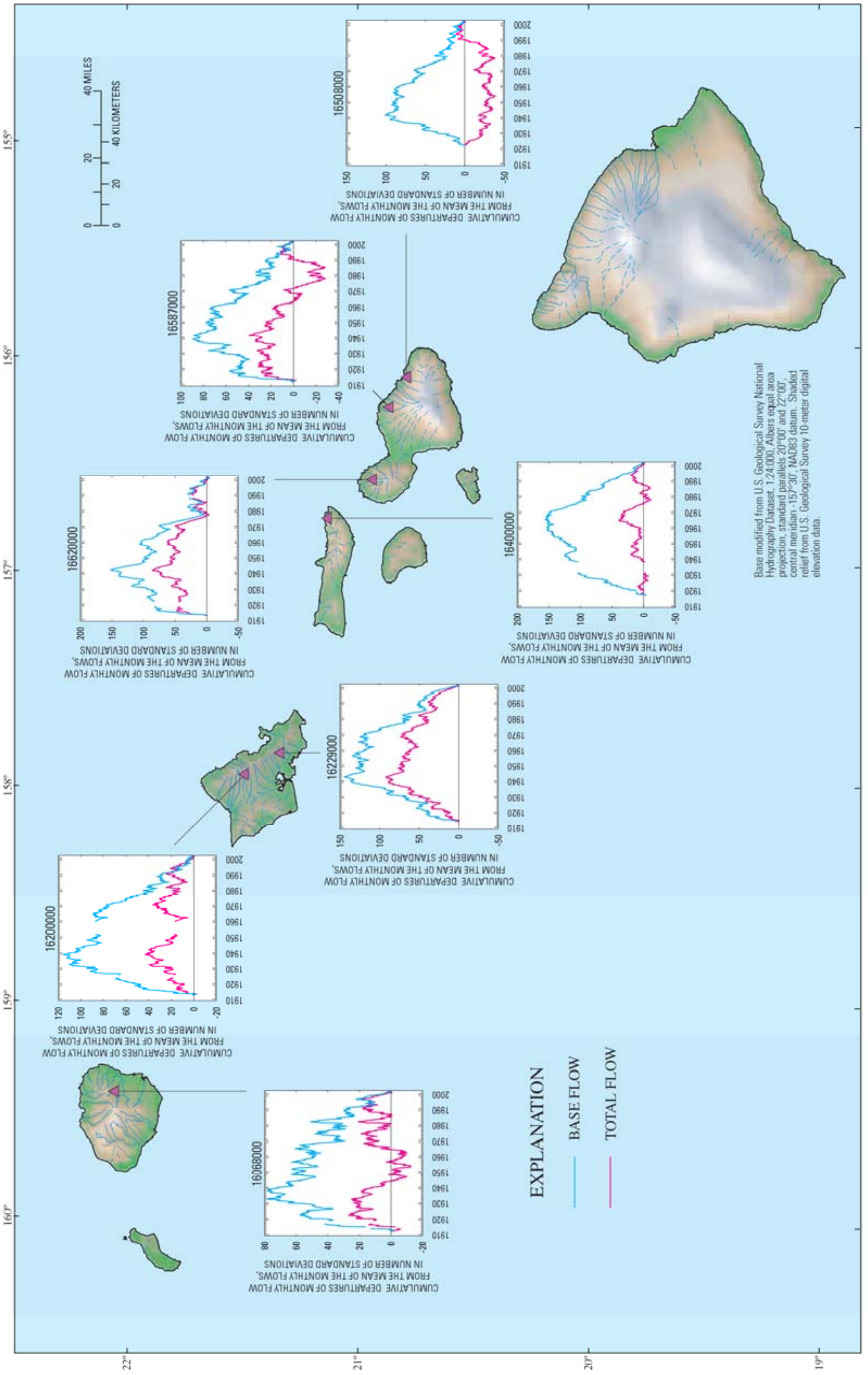


Figure 3-3. Location of diversions, irrigation systems, USGS gaging stations, and selected ungaged sites in Hanawi hydrologic unit (Source: State of Hawaii, Office of Planning, n.d.; 1996, 2004c; 2005; USGS, 2001b).



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

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

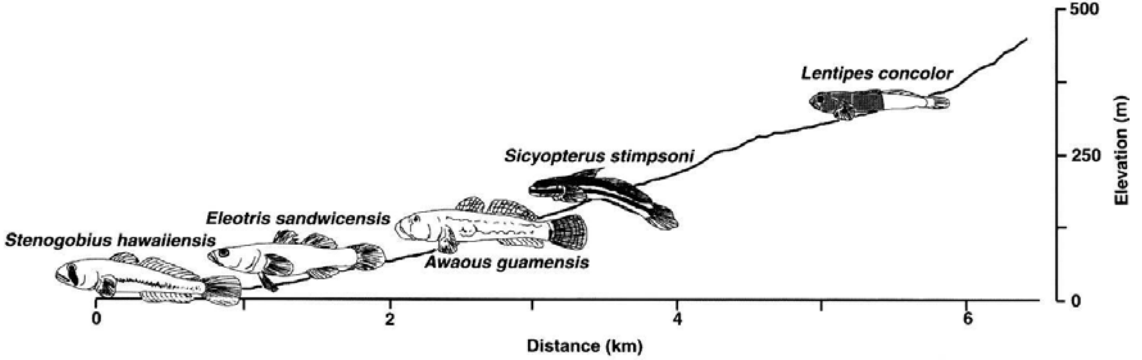
When people in Hawaii consider the protection of streamflows for maintaining fish habitat, their thoughts generally focus on a handful of native species, including five native fishes (four gobies and one eleotrid), two snails, one shrimp, and a prawn (Table 4-1). Four of the fish species - *Stenogobius 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	ʻOʻopu naniha	Goby	Endemic	●		
Awaous guamensis	ʻOʻopu nakea	Goby	Indigenous	●	●	
Sicyopterus stimpsoni	ʻOʻopu nopili	Goby	Endemic	●	●	
Eleotris sandwicensis	ʻOʻopu akupa (okuhe)	Eleotrid	Endemic	●	●	
Lentipes concolor	ʻOʻopu hiʻukole (alamoʻo)	Goby	Endemic	●	●	●
Macrobrachium grandimanus	ʻOpae ʻoehaʻa	Prawn	Endemic	●		
Atyoida bisulcata	ʻOpae kalaʻole	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.

Damselflies also depend on healthy freshwater ecosystems for their survival. Most of the damselflies native to Hawaii are aquatic as immatures, and return to the water only to mate (Polhemus and Asquith, 1996). Of the native Hawaiian damselflies, the *Megalagrion* species is endemic and found only in Hawaii. In July of 2009, the U.S. Fish and Wildlife Service proposed two of the *Megalagrion* damselflies, the flying earwig Hawaiian damselfly (*Megalagrion nesiotes*) and the Pacific Hawaiian damselfly (*Megalagrion pacificum*), to be listed as endangered species (Foote, 2009, July 8). Both damselflies species have been candidates for protection since the 1990s. Currently, the flying earwig Hawaiian damselfly can only be found in Maui, and the Pacific Hawaiian damselfly in the islands of Molokai, Oahu, and Maui (Foote, 2009, July 8).

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.

Another factor that affects the distribution of native species is the condition of the streambed. Stream channels are often overgrown with alien grasses and shrubs. Vegetation along the stream bank has exposed roots that take up large amounts of water when sufficient flow is in the stream. Thus, during a high flow event, streams that are normally dry become only partially wetted because invasive plants and water thirst roots eventually absorb much of the water. In addition, fallen trees and other debris are found to block sections of the stream, which may reduce streamflow and even divert flow away from the main stream channel in the long term. Without proper maintenance of the streambed, restored streamflow in the upper elevations may not reach the ocean. Plans to rebuld healthy streambeds should be considered to help maximize the flow in the stream.

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 Hanawi Stream, the aquatic resources were classified as "outstanding", meaning a divertisy of species were present. Alamoo, nakea, nopili, and hihiwai were identified in the surveys while no species from the Introduced Species Groups were identified. The HSA classification was based on eleven surveys, with the last one conducted in 1984.

Table 4-2. Hawaii Stream Assessment categorization of aquatic resources in Hanawi 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, ‘o‘opu alamo‘o (*Lentipes concolor*), ‘o ‘opu nakea (*Awaous stamineus*), ‘o‘opu nopili (*Sicyopterus stimpsoni),* and hihiwai (Neritina granosa), as representatives of potentially high quality stream ecosystems.	4	Excellent
Native Species Group 1 (NG2) The other seven native species considered more common comprised Native Species Group Two (NG2). These included two ‘o‘opu akupa (*Eleotris sandwicensis*), ‘o‘opu naniha (*Stenogobius genivittatus*), aholehole (*Kuhlia sandvicensis*), ‘ama‘ama (*Mugil cephalus*), ‘o‘pae kala‘ole (*Atyoida bisulcata*), ‘o‘pae ‘oeha‘a (*Macrobrachium grandimanus*), and hapawai (*Theodoxus vespertinus*). Presence of these species was considered to be typical of a healthy native stream ecosystem.	2	Excellent
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.

Hanawi 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 Koolau 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 representative for opae and alamoo upstream of large waterfalls.

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 Hanawi Stream and specific data are included in Tables 4-4 and 4-5. Upstream of Koolau Ditch where there are no diversions, the stream has no reduction in flow and thus, retains 100 percent of the natural habitat. Downstream from the ditch where the stream is diverted, the stream is dry (no available habitat) until more ground water is gained to provide about 50 to 75 percent of the expected natural habitat for all species. Further downstream, the stream gains more ground water flow from a number of springs, providing almost 100 percent of the available habitat all the way to the coast. Overall, close to 100 percent of the natural habitat for all species in Hanawi Stream was already maintained below Koolau 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).

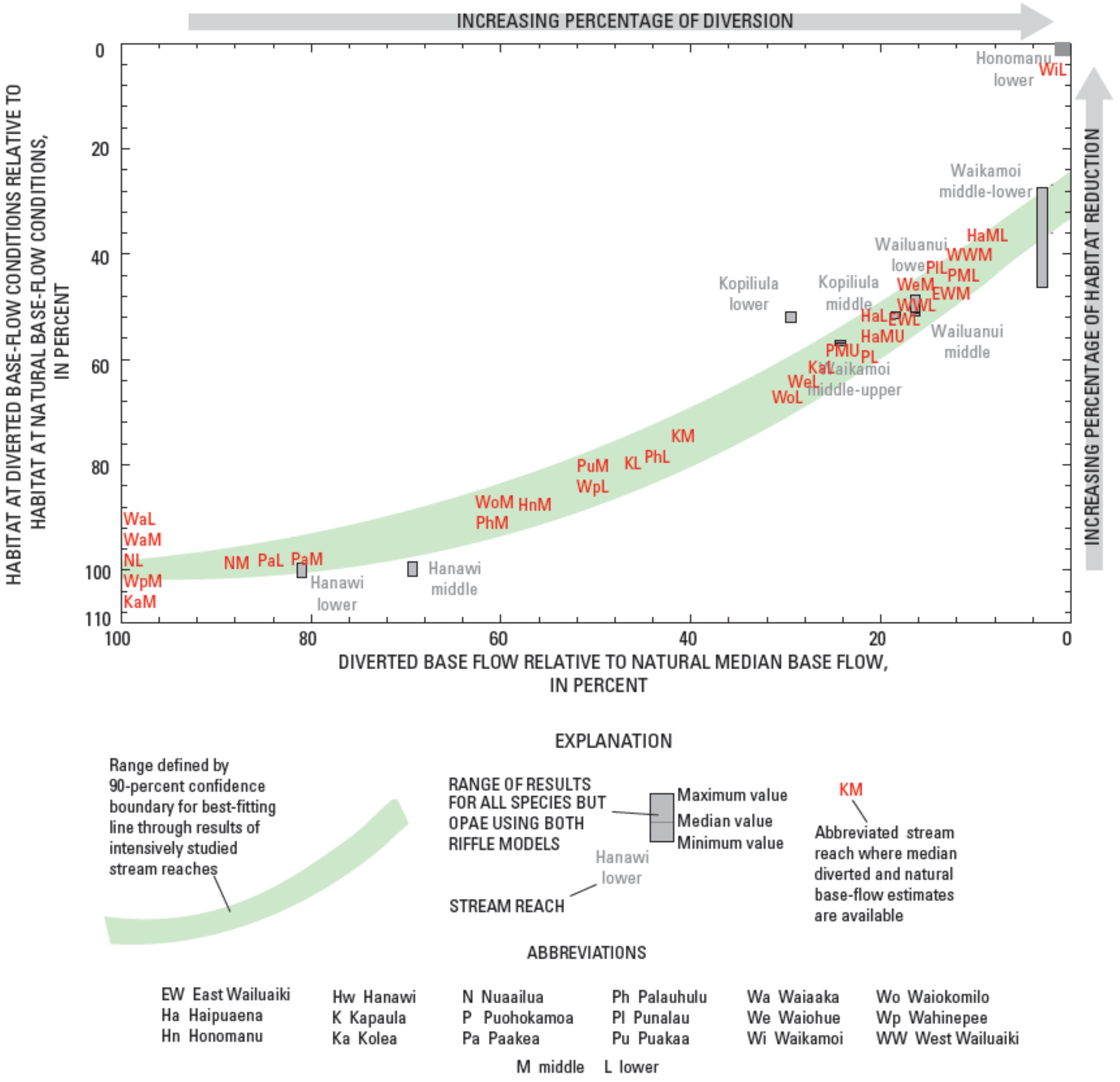


Table 4-3. Summary of estimated aquatic habitat distribution at diverted base flow relative to natural conditions, calculated using GIS from Gingerich and Wolff (2005).

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 Hanawi 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
lower	21	26	99 – 101	NA	NA	NA	99 – 101
middle	11	16	99 – 101	NA	NA	NA	100 - 101

Table 4-5. Summary of modeled opae habitat for Hanawi 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	11	16	94 – 95	NA	NA	NA	98 - 99

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 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 Hanawi 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. The following is a brief summary of findings for Hanawi Stream.

- **Point Quadrat Survey.** A number of native stream animals were observed in Kopiliula Stream, including oopu nakea (*Awaous guamensis*), oopu nopili (*Sicyopterus stimpsoni*), oopu akupa (*Eleotris sandwicensis*), oopu alamoo (*Lentipes concolor*), opae kalaole (*Atyoida bisulcata*), hihiwai (*Neritina granosa*), and aholehole (*Kuhlia xenura*). During the most recent surveys, most of these native species were observed in the lower and middle reaches below the ditch level. Oopu alamoo was abundant in the middle reach. All these stream animals except the oopu akupa were observed in the lower, middle, and upper reaches in past surveys. Introduced species such as river prawns (*Macrobrachium lar*) were also observed in the stream.

- **Estuary Survey.** Hanawi has a small estuary; however, no estuary survey was conducted.

- **Insect Survey.** Native damselfly species were observed in throughout Hanawi Stream. Of the damselflies observed were blackburn's Hawaiian damselfly (*Megalagrion blackburni*), beautiful Hawaiian damselfly (*Megalagrion calliphya*), Hawaiian upland damselfly (*Megalagrion hawaiiense*), blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrohamatum*), and pacific Hawaiian damselfly (*Megalagrion pacificum*). The pacific Hawaiian damselfly is currently proposed for listing as Endangered under the Federal Endangered Species Act..

- **Watershed and Biological Rating.** Hanawi watershed rates fairly well (score of 8 out of 10) for Maui and statewide. A combination of forested lands, high rainfall amounts, and moderate reach diversity contribute to the rating of this watershed. The stream rates fairly well (score of 8 out of 10) on biota due to the high diversity of native species observed in the stream.

Hanawi Stream provided excellent instream habitats and a diversity of native stream animals exists in the stream. Suvey sites in the lower reach had water depths ranging from 10 to 36 inches. In the middle reach below Hana Highway and the ditch, water depths were greater than 20 inches. Water temperatures decreased from 19 to 16 degrees Celsius from the lower to the middle reach, indicating ground water contribution by springs. Only the native shrimp was observed in the upper reach.

The SWCA Environmental Consultants, at the request of Hawaiian Commercial and Sugar Company, conducted a literature review of the existing data collected by DAR, USGS, and other investigators (Ford et. al., 2009). The objective of this document 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. On the other hand, there is no proof that continued habitat degradation in some of the streams due to dewaterment will not affect species survival (PR-2009-18, 85.0). 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, such as a change in the streambed composition due to a high flow event, that may result in absence of native stream animals should not be interpreted as a negative indicator of stream health.

The consultant summarized data mainly from the USGS habitat availability study (Gingerich and Wolff, 2005) and DAR's Atlas of Hawaiian Watersheds and Their Aquatic Resources (Tables 4-6 and 4-7). 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, a diversity of stream animals were observed in Hanawi Stream. Almost all the native amphidromous species, except the hapawai, were present throughout the stream. However, extensive surveys conducted by the USGS revealed no alamoo above the diversions, and results from DAR surveys do no specifically indicate aquatice species observed above the diversions. According to Table 4-6, the opae was the most conspicuous species that was found in most of the east Maui streams except Punalau and Ohia. The Tahitian prawn (alien amphidromous specie) was also observed in the stream. Since Hanawi Stream already has a diversity of native stream animals under diverted conditions, it has the potential to carry a full compliment of native stream fauna if allowed continous mauka to makai flow.

Table 4-6. 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 4-7. Distribution of amphidromous species in lower, middle, and upper reaches of east Maui streams within the USGS study area summarized from 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 Hanawi 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 Hanawi. While most native birds are found at the upper elevations, some species, especially *Amakihi* and *Apapane*, are also found at the lower elevations (PR-2009-18, 75.0).

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

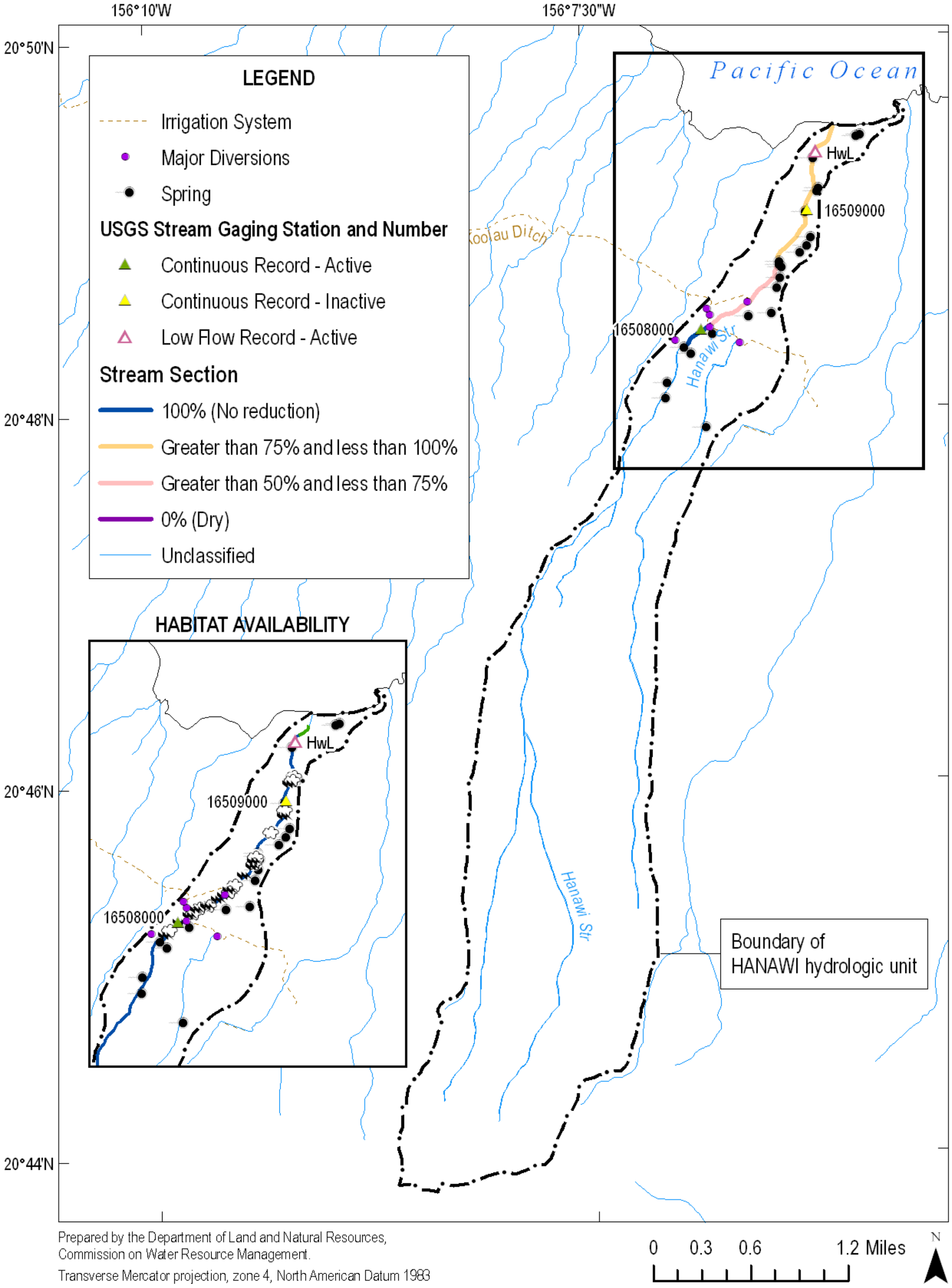


Figure 4-4. Division of Aquatic Resource survey points in Hanawi Stream (Source: DAR, 2009).

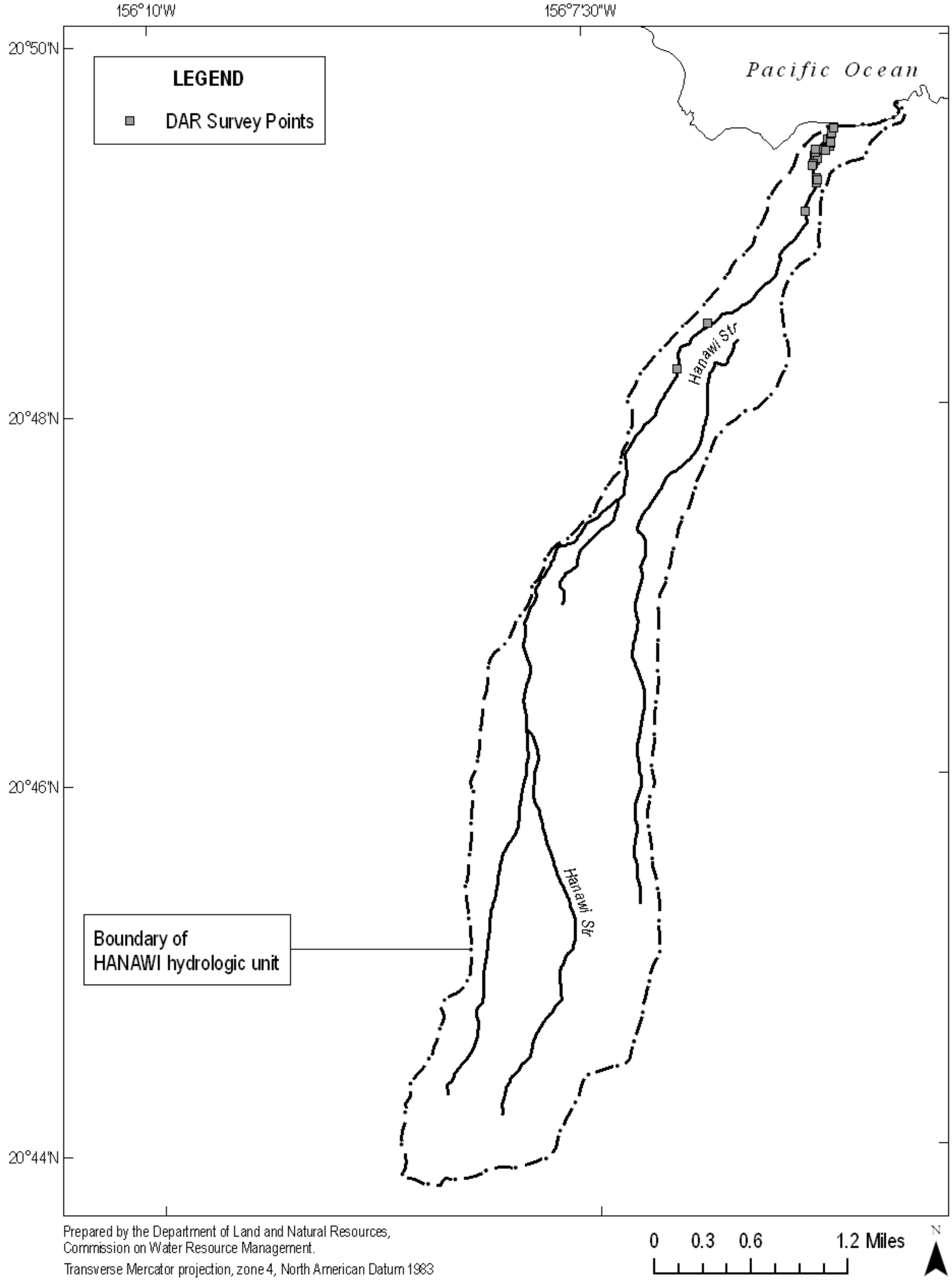
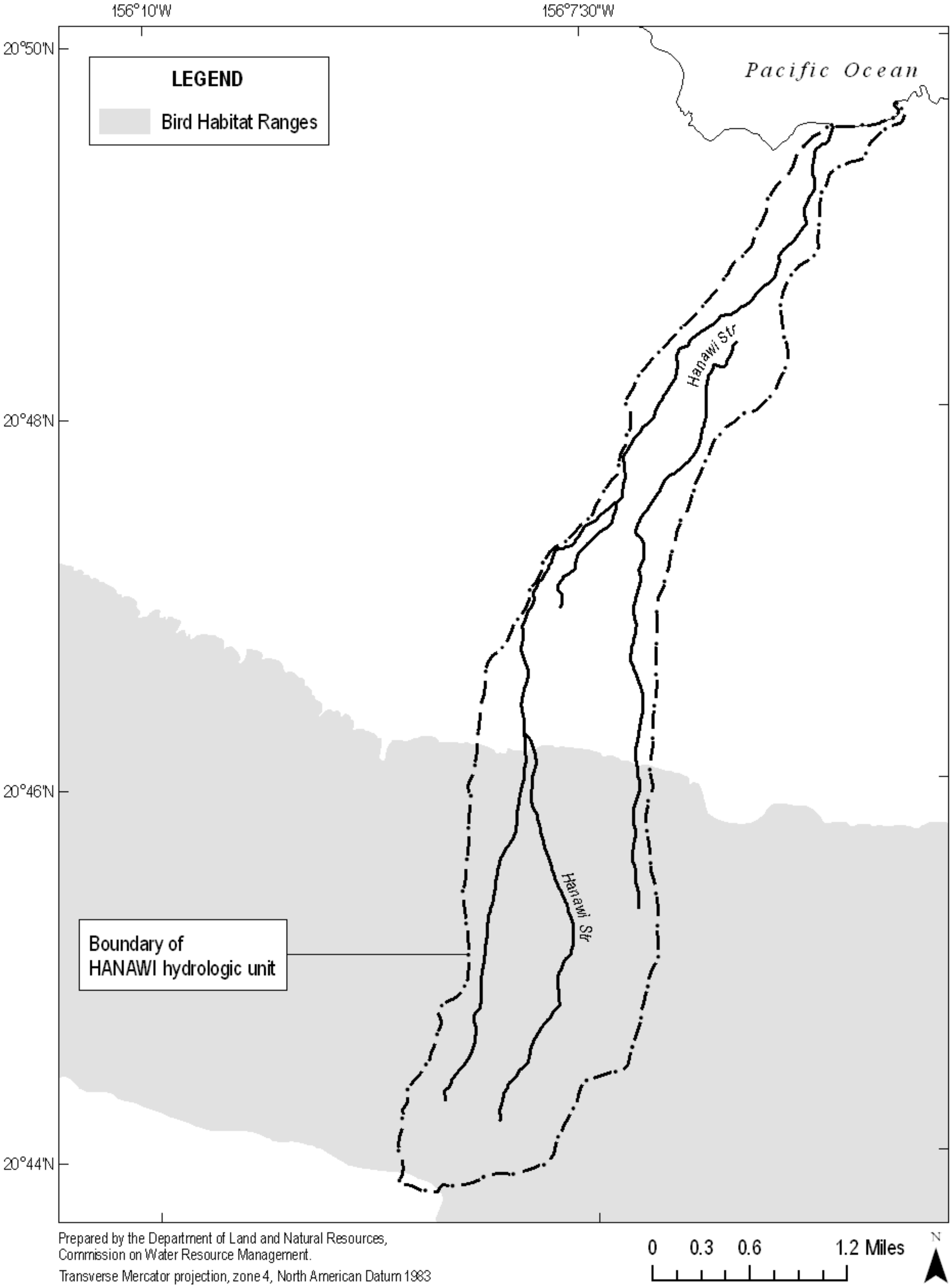


Figure 4-5. Native Hawaiian forest habitat ranges in Hanawi hydrologic unit (Source: U.S. Fish and Wildlife Service, n.d; USGS, 2001b).



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.

Transverse Mercator projection, zone 4, North American Datum 1983

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 Hanawi Stream were classified as "outstanding" by the HSA's regional recreation committee. The HSA identified opportunities for camping, hiking, fishing, hunting, swimming, and scenic views related to Hanawi, and only camping and hunting were not considered to be high-quality experiences (National Park Service, Hawaii Cooperative Park Service Unit, 1990) (Table 5-1).

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

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

According to public hunting data, Hunting Unit B on the island of Maui consists of portions of the Koolau Forest Reserve and Hunting Unit N1 consists of portions of the Hanawi Natural Area Reserve. Hunting Unit B within Hanawi occupies approximately 6 percent of the hydrologic unit, whereas Hunting Unit N1 occupies 74 percent of the 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 Hanawi Stream. A 1981 Maui Resource Atlas, prepared by the State of Hawaii Department of Transportation's Harbors Division, inventoried coral reefs and coastal recreational activities. Looking at available GIS data, the Commission identified the following activities that were known to occur or observed at or near Hanawi: pole and line fishing, spear fishing, throw and gill netting, opihi picking, lobster fishing, and some specialized fisheries (Figure 5-2).

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

> Nahiku means "the seven (districts of the area)" and it is the wettest place on Maui. This fact undoubtedly influenced Harry P. Baldwin, who started the Hamakua Ditch in 1876 to carry water from the mountains of Nahiku to Paia to irrigate his sugar cane.
>
> On January 24, 1905, the Nahiku Rubber Plantation, the first rubber plantation on American soil, was incorporated. High-quality rubber trees had bee planted in the area as early as 1899 to determine if they would grow well and also be commercially productive. By 1905 the firm was convinced that their rubber trees would thrive and produce good quality of latex. The Nahiku Rubber Plantation has purchased nearly 900 acres of fee simple property, and began planting on a large scale. Planting and tapping operations continued until 1916, when high labor costs finally forced the company to close. The three-mile winding road from the Hana Highway to the shoreline in Lower Nahiku passes many groves of rubber trees and the crumbling remains of a coral flume, and ends at the ruins of Nahiku Landing. The landing was constructed in 1903 and abandoned when the plantation closed.
>
> The cove in Lower Nahiku is located at the east end of Honolulunui Bay. This Honolulu, situated between Hanawi and Makapipi streams, and the one on the island of Hawaii are the only two places int eh islands that bear the same name as the state capital on Oahu.
>
> The shoreline of Lower Nahiku is composed of low sea cliffs with boulder beaches at their bases. The entire area is exposed to the open ocean and is subject to heavy surf and strong inshore currents. The access road from Hana Highway near the Makapipi Stream Bridge ends at a small unimproved park of *hau* and *kamani* trees, a pleasant picnic area with a beautiful view of the coase to Moku Mana. The ruins of the old landing are nearby on the rocks.

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 Hanawi 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. It is important to note that the recreational activities are not limited to the ocean as the figure may suggest. The stream and the surrounding areas are also used for recreational purposes (e.g., hiking, swimming).

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

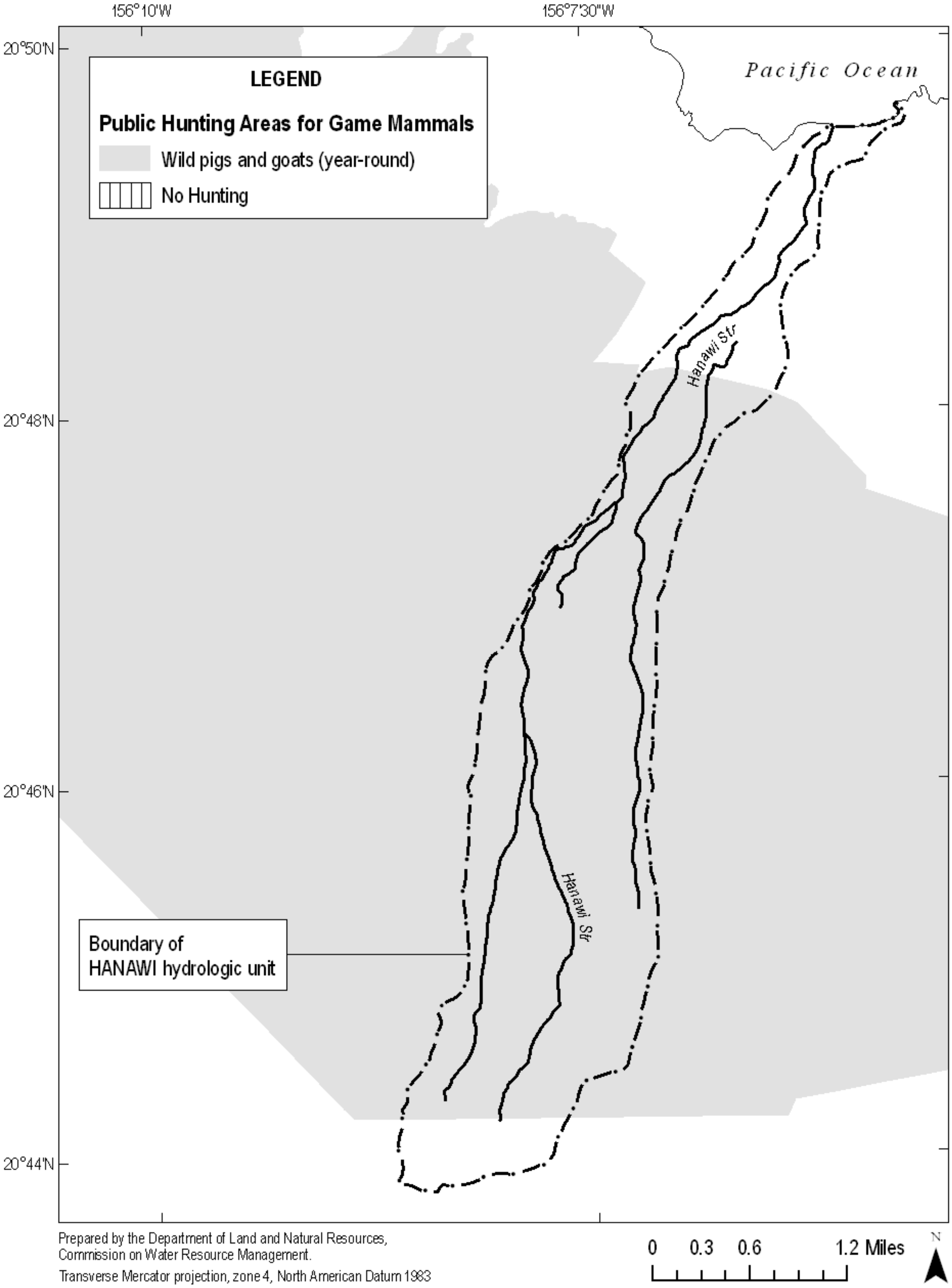
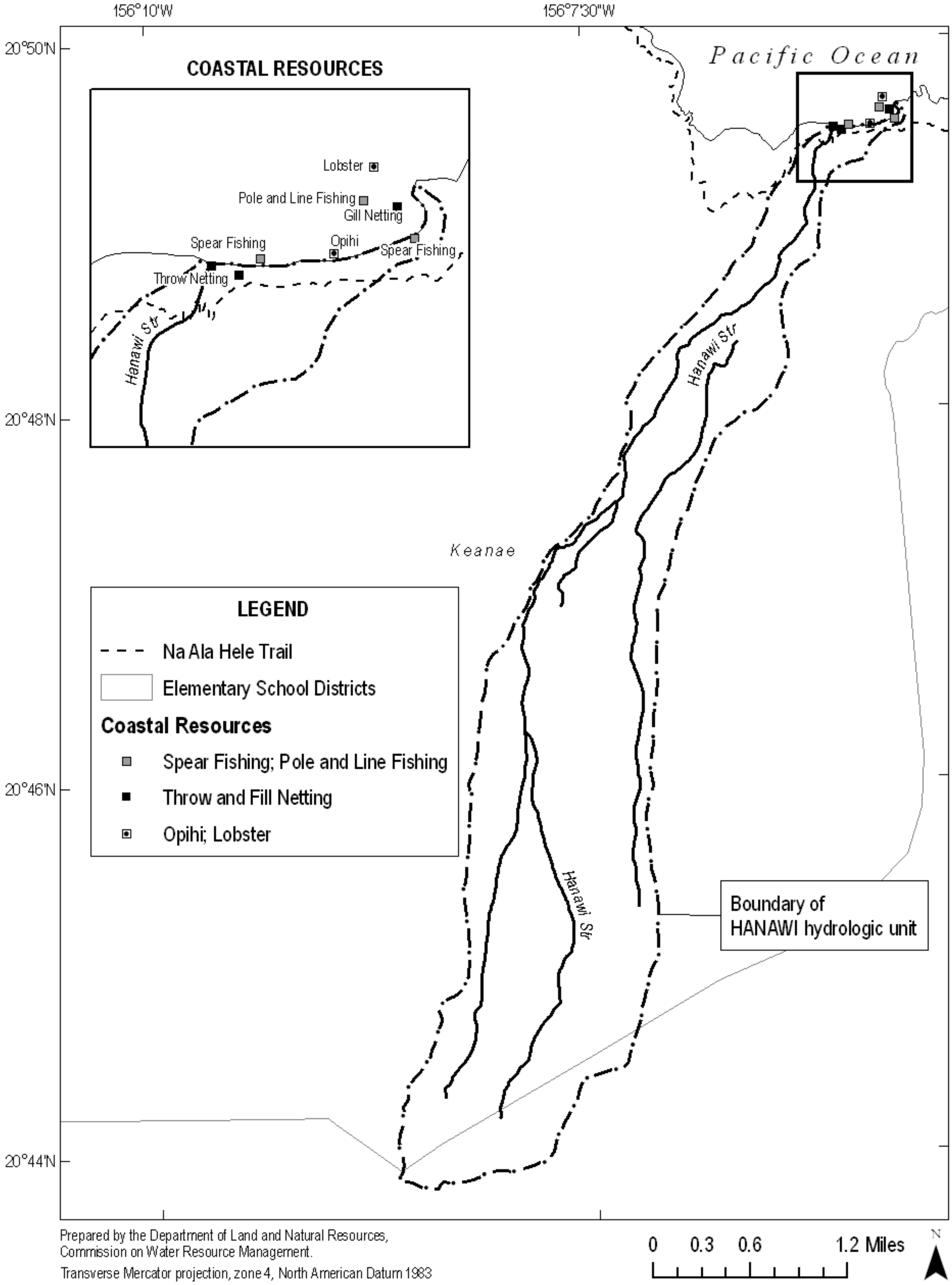


Figure 5-2. Recreational points of interest for Hanawi hydrologic unit (Source: State of Hawaii, Office of Planning, 1999, 2002a; 2002c; 2002d; 2004a; USGS, 2001b).



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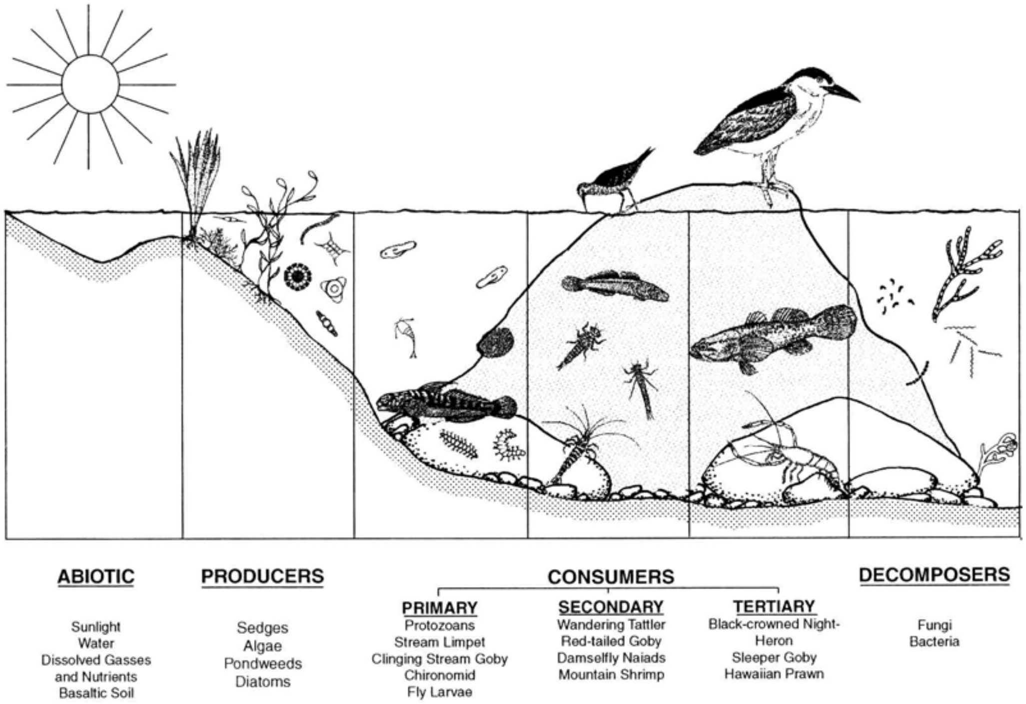
Transverse Mercator projection, zone 4, North American Datum 1983

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 Hanawi Stream were classified as “outstanding” by the HSA (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 Hanawi 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.	5
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.	1
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.	None
Native forest: The proportion of a stream course flowing through native forest provides an indication of the potential "naturalness" of the quality of a stream's watershed; the greater the percentage of a stream flowing through native forest most of which is protected in forest reserves the more significant the resource. Only the length of the main course of a stream (to the nearest 10 percent) that passes through native forest was recorded.	80%
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 Hanawi, about 74 percent of the unit lies within the Hanawi Natural Area Reserve, and 6 percent within the Koolau Forest Reserve and the Haleakala National Park (Table 6-2).

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

Management Area	Managed by	Area (mi^2)	Percent of Unit
Haleakala National Park	U.S. National Park Service	0.36	6.4
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.			
Hanawi Natural Area Reserve	State Division of Forestry and Wildlife	4.11	74.0
The Hanawi Natural Area Reserve comprises 7,500 acres (11.72 square miles) and is one of four Natural Area Reserves managed by DLNR's Division of Forestry and Wildlife. The Natural Area Reserves System (NARS) was established to preserve and protect, in perpetuity, unique examples of Hawaii's terrestrial and aquatic natural resources. Specific management policies, under the auspices of the NARS Commission, dictates public use or activities within each reserve. The Hanawi NAR extends into the subalpine zones of east Maui and includes a rare subalpine grassland (*Deschampia nubigena*). It is also home to a number or rare plants and the state's largest concentration of rare and endangered Hawaiian birds.			
Koolau Forest Reserve	State Division of Forestry and Wildlife	0.35	6.3
The Koolau Forest Reserve, consisting of over 31,000 acres (48.45 square miles) 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.			

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 Hanawi 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	5.16	93.0
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). Nearly 72 percent of Hanawi is classified as non-tidal palustrine wetlands occurring in the intermediate and 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 Hanawi hydrologic unit (Source: U.S. Fish and Wildlife Service, 1978).

System Type	Class	Regime	Area (mi^2)	Percent of Unit
Palustrine	Forested, broad-leaved evergreen	Seasonal/Unknown non-tidal	3.96	71.3
Palustrine	Scrub/shrub, broad-leaved evergreen	Seasonal/Unknown non-tidal	0.01	0.2

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. About 72 percent of the unit (mostly upper and intermediate slopes) is predominately native species with little or no alien species.

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

Canopy Type	Area (mi^2)	Percent of Unit
Communities totally dominated by native species of plants	3.98	71.8
Communities that have the dominant vegetation layer occupied by native species and the subdominant layer primarily occupied by exotic species	0.05	0.9
Communities dominated by introduced species but contain remnant populations of native species; no native community structure remaining	0.02	0.4
Unknown	0.70	12.6

Based upon the current designations, the Hanawi hydrologic unit contains critical habitat areas for six plant species (Table 6-6). The combined areas occupy less than 10 percent of the hydrologic unit.

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

Scientific Name	Common/Hawaiian Name	Description	Area (mi^2)	Percent of Unit
Branta sandvicensis	Hawaiian goose, Nene	Bird	0.03	0.5
Argyroxiphium sandwicense ssp. macrocephalum	Silversword, ‘Ahinahina	Plant	0.06	1.1
Clermontia samuelii	‘Oha wai	Plant	0.00	0.0
Geranium multiflorum	Nohoanu	Plant	0.37	6.6
Mariscus pennatiformis	No common name	Plant	0.01	0.2
Platanthera holochila	No common name	Plant	0.01	0.1

The density of threatened and endangered plant species is high at elevations above 1,400 feet, while the lower slopes of the Hanawi hydrologic unit has a low concentration of threatened and endangered plant species (Table 6-7 and Figure 6-4).

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

Density	Area (mi^2)	Percent of Unit
High concentration of threatened and endangered species	4.96	89.4
Low concentration of threatened and endangered species	0.59	10.6

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 6-8.

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 Hanawi hydrologic unit (Source: State of Hawaii, Office of Planning, 2003; 2007b; USGS, 2001b).

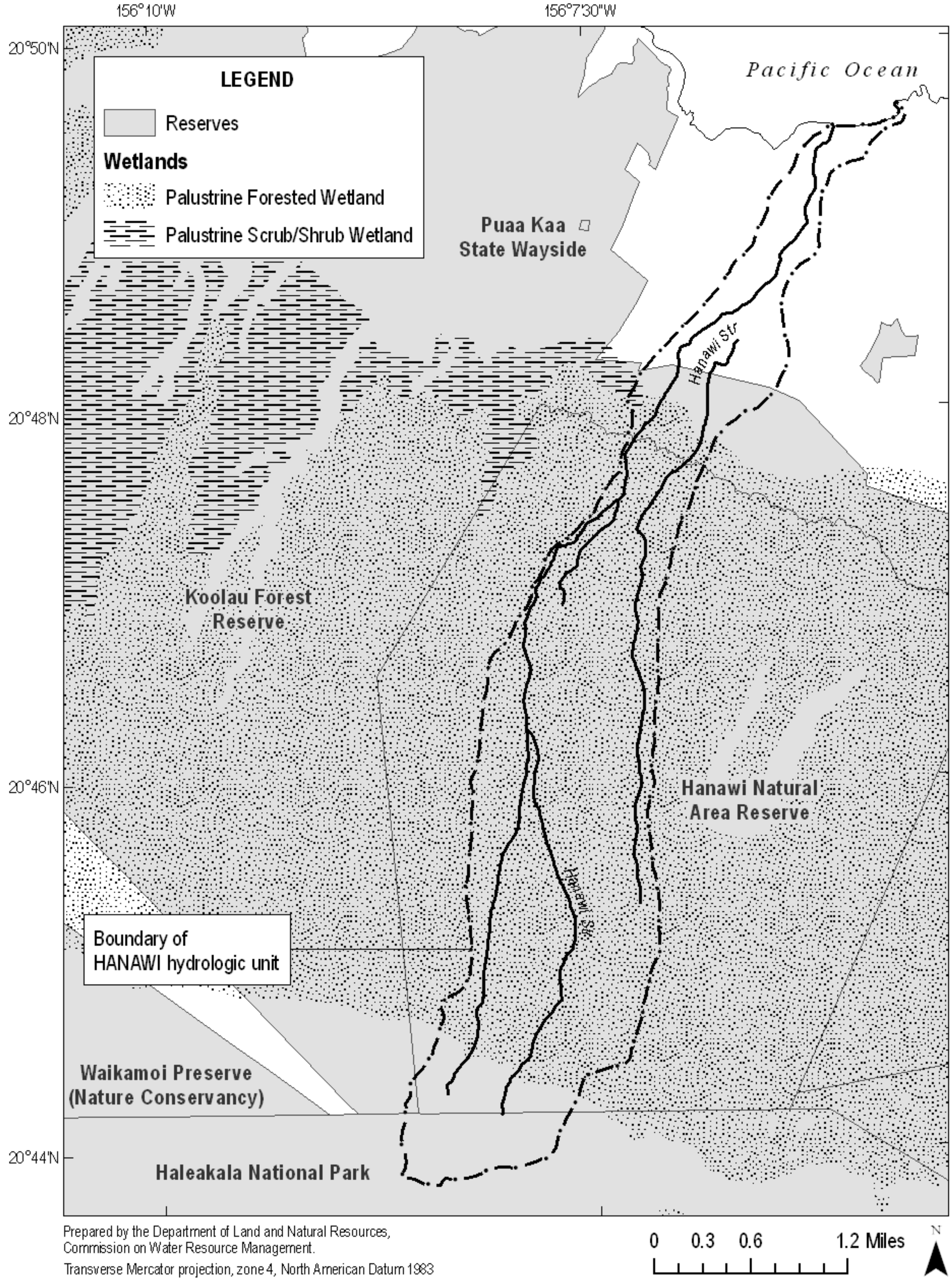
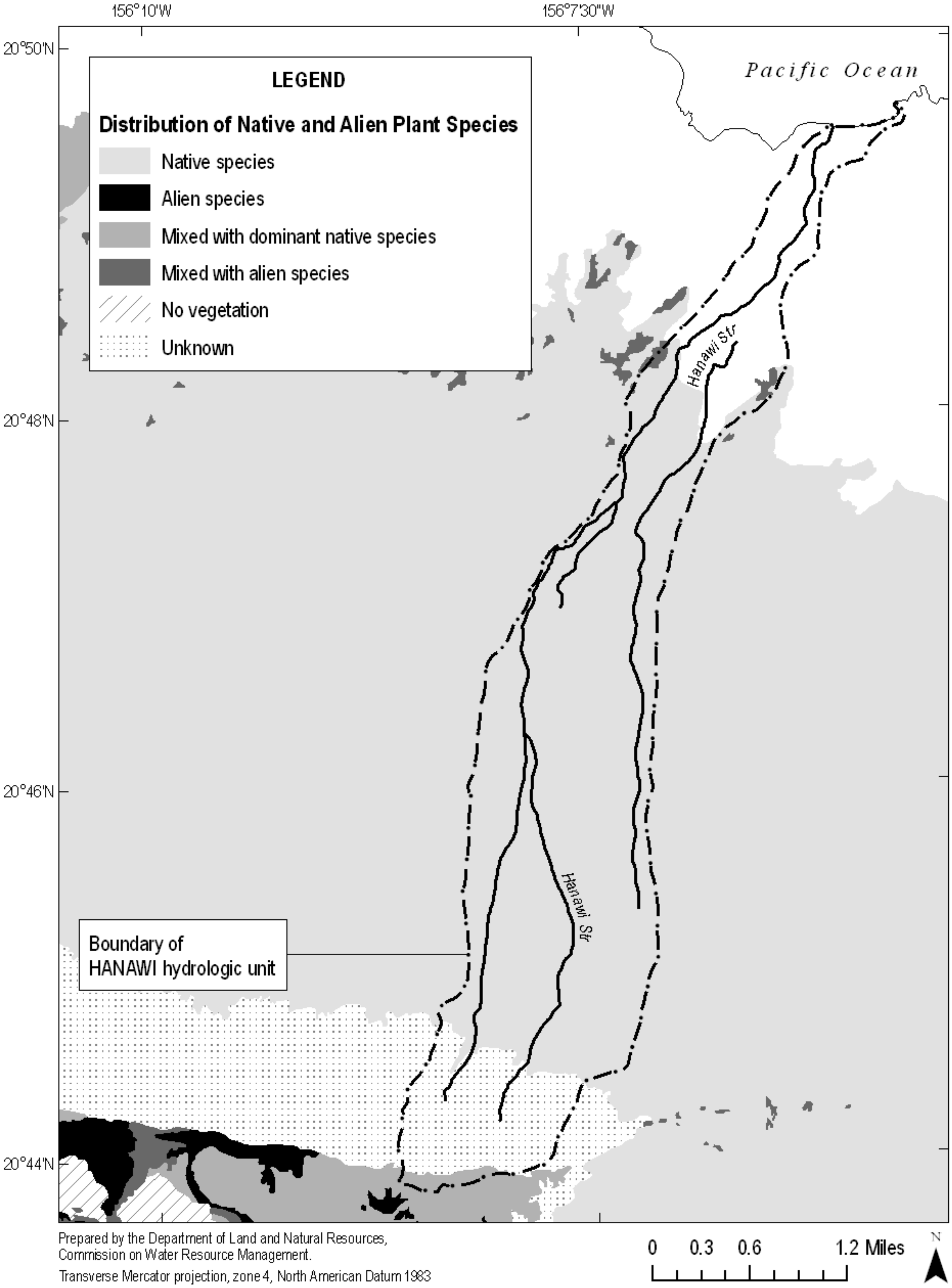
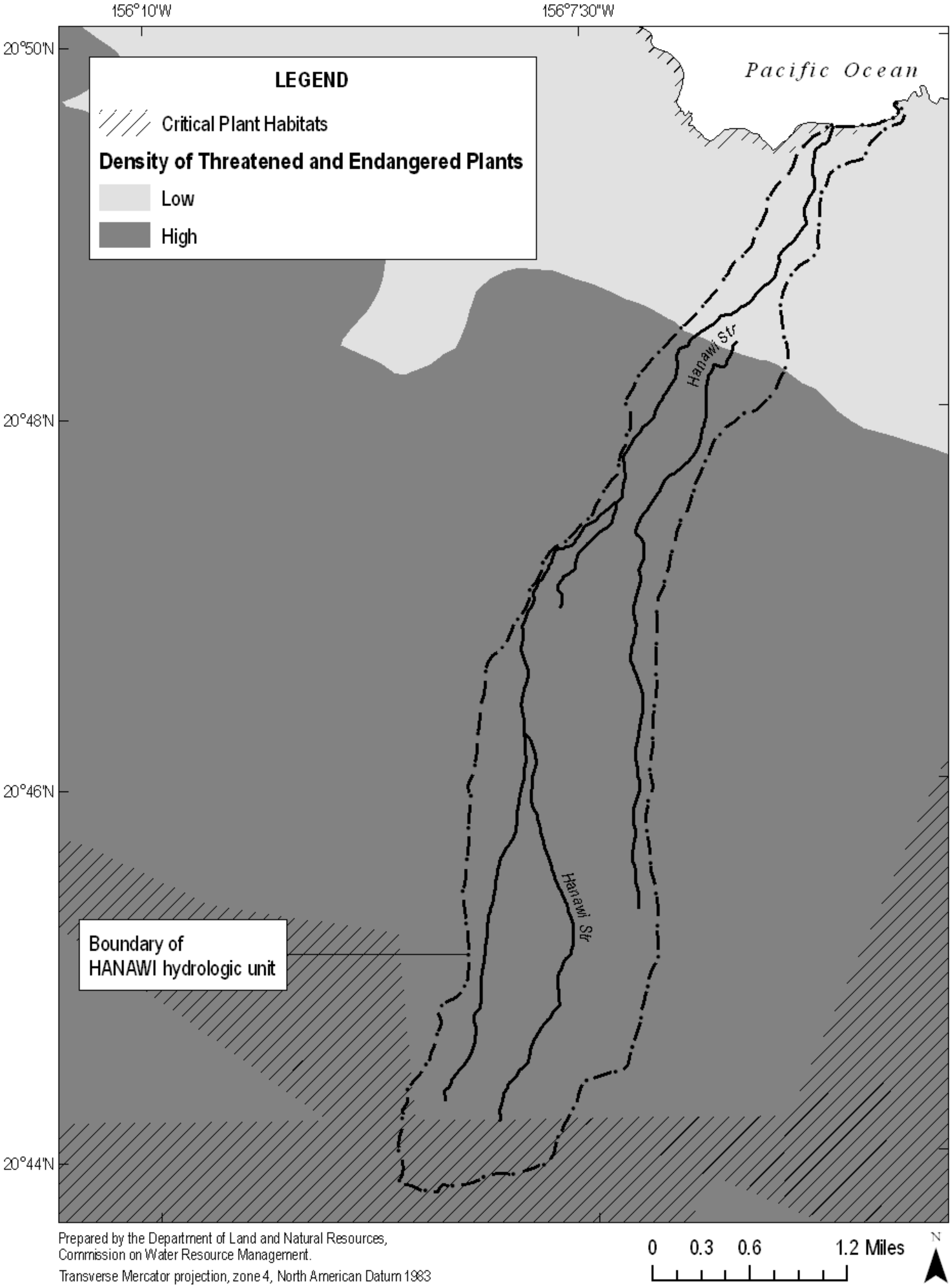


Figure 6-3. Distribution of native and alien plant species for Hanawi hydrologic unit (Source: Jacobi, 1989; Scott et al., 1986; State of Hawaii, Office of Planning, 1992, 2004b; 2004d; USGS, 2001b).



Prepared by the Department of Land and Natural Resources, Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

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



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Transverse Mercator projection, zone 4, North American Datum 1983

7.0 Aesthetic Values

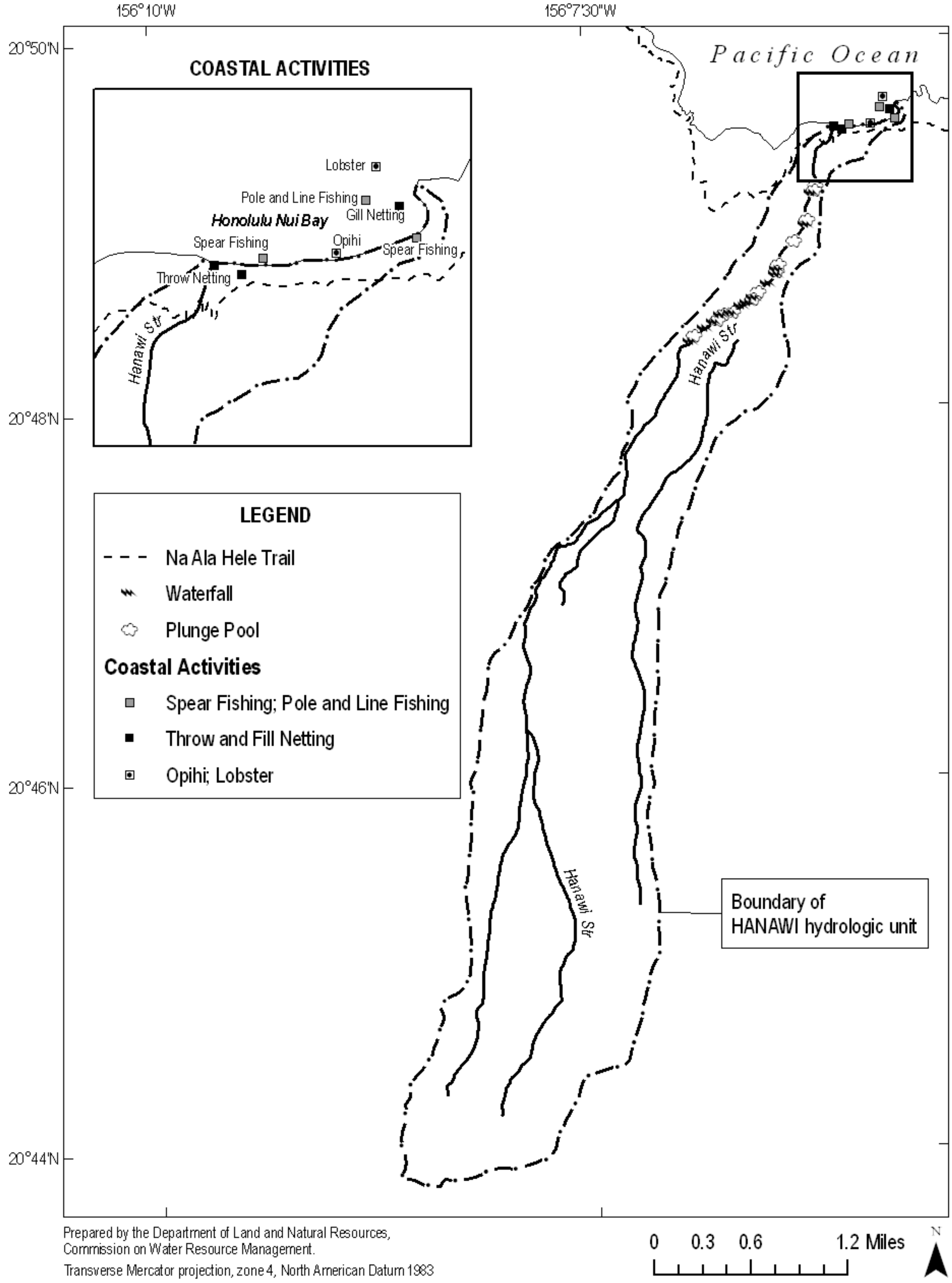
Aesthetics is a multi-sensory experience related to an individual's perception of beauty. Since aesthetics by definition is a subjective observation, a stream's aesthetic value cannot be determined quantitatively (Wilson Okamoto & Associates, Inc., 1983). However, there are certain elements, either within 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 Hanawi Stream a particular aesthetic quality.

Hanawi Stream is fed by lush native communities of Ohia forests and forested wetlands that dominate the upper and intermediate slopes of the hydrologic unit. Vegetation surrounding the lower reaches of the stream is predominately alien forests. A number of waterfalls are located along the lower reaches of the the stream, most of which are followed by a plunge pool. One of the waterfalls can be viewed from Hana Highway, and another waterfall is located immediately downstream from the highway. The hydrologic unit lies within two forest reserves, Koolau Forest Reserve and Hanawi Natural Area Reserve. Hanawi Stream empties into Honolulu Nui Bay, which is a popular fishing location (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 Hanawi Stream crosses Hana Highway there may be opportunities for scenic enjoyment. The scenic Hana Highway route to Hana town is also a popular tourist attraction (PR-2009-18, 85.0), in which visitors take photos of waterfalls and the valley where the stream crosses Hana Highway.

While a limited number of studies analyze the value of a free flowing stream, a stream that has mauka to maki flow could have direct economic benefits to the State and to the public. According to a Maui resident (PR-2009-18, 85.0), several Maui eco-tour companies are willing to pay the state $5 for each person that is allowed to enter and view one of the streams in west Maui that has mauka to makai flow. The State would potentially collect $60,000 a year for 12,000 participants.

Figure 7-1. Aesthetic points of interest for the Hanawi 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 Hanawi 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 Hanawi Stream. However, the stream was identified by W.A. Hirai & Associates, Inc. (1981) to have good hydropower potential. The study indicated that water from Hanawi Streams could contribute a plant capacity of 1,000 kilowatts of hydropower and 5 million kilowatts annually, based on a median discharge of 7.2 cubic feet per second. The total cost of constructing a hydropower plant utilizing flow from this stream is about $1.5 to 2.5 million (1980 dollars).

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 Hanawi 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).

A USGS report published in 2005, *Effects of Surface-Water Diversions on Habitat Availability for Native Macrofauna, Northeast Maui, Hawaii*, included surface water temperature data for Hanawi Stream. Results of that study are discussed in Section 4.0, Maintenance of Fish and Wildlife Habitat. In the USGS study, three of the thirteen monitored sites were on Hanawi Stream; the others were on Waikamoi, Honomanu, Kopiliula, and Wailuanui Streams. Temperature measurements were not made at the lower Waikamoi and Honomanu sites because those stream reaches were usually dry. Monitoring locations were in the shade, where possible, and chosen to avoid potentially stagnant or zero-flow reaches. Hanawi Stream temperature data follow in Table 10-1; the monitoring sites are depicted in Figure 10-1. The Middle Hanawi site, at 500 feet elevation, had lowest average temperatures of the 13 sites mainly due to ground water contribution from Big Spring (Gingerich and Wolff, 2005).

Table 10-1. Fifteen-minute temperature data from selected Hanawi Stream sites (Gingerich and Wolff, 2005, Table 4.)

[ºC, degrees Celsius]

			Temperature (ºC)					Temperature (ºC)		
Site	Altitude (feet)	Period of record	Average during common period	Range during common period	Average daily variation during common period	Percent of reading over 27ºC	Longest period over 27ºC (hours)	Average	Range	Daily variation
Upper	1,318	10/9/02-11/25/03	19.2	14.3-24.9	1.1	.00		19.3	14.3-24.9	1.1
Middle	500	10/9/02-1/16/04	16.8	15.3-21.4	0.9	.00		16.9	15.3-21.4	.9
Lower	20	10/9/02-1/15/04	18.5	15.7-21.4	1.6	.00		18.6	15.7-21.4	1.5

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)."[12] 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 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

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[12] 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.

§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. Hanawi Stream appears on the 2006 List of Impaired Waters in Hawaii, Clean Water Act §303(d). While some data exist for Hanawi, there were insufficient data for decision-making; therefore, no decision was made pertaining to the attainment of WQS or the applicable designated uses.

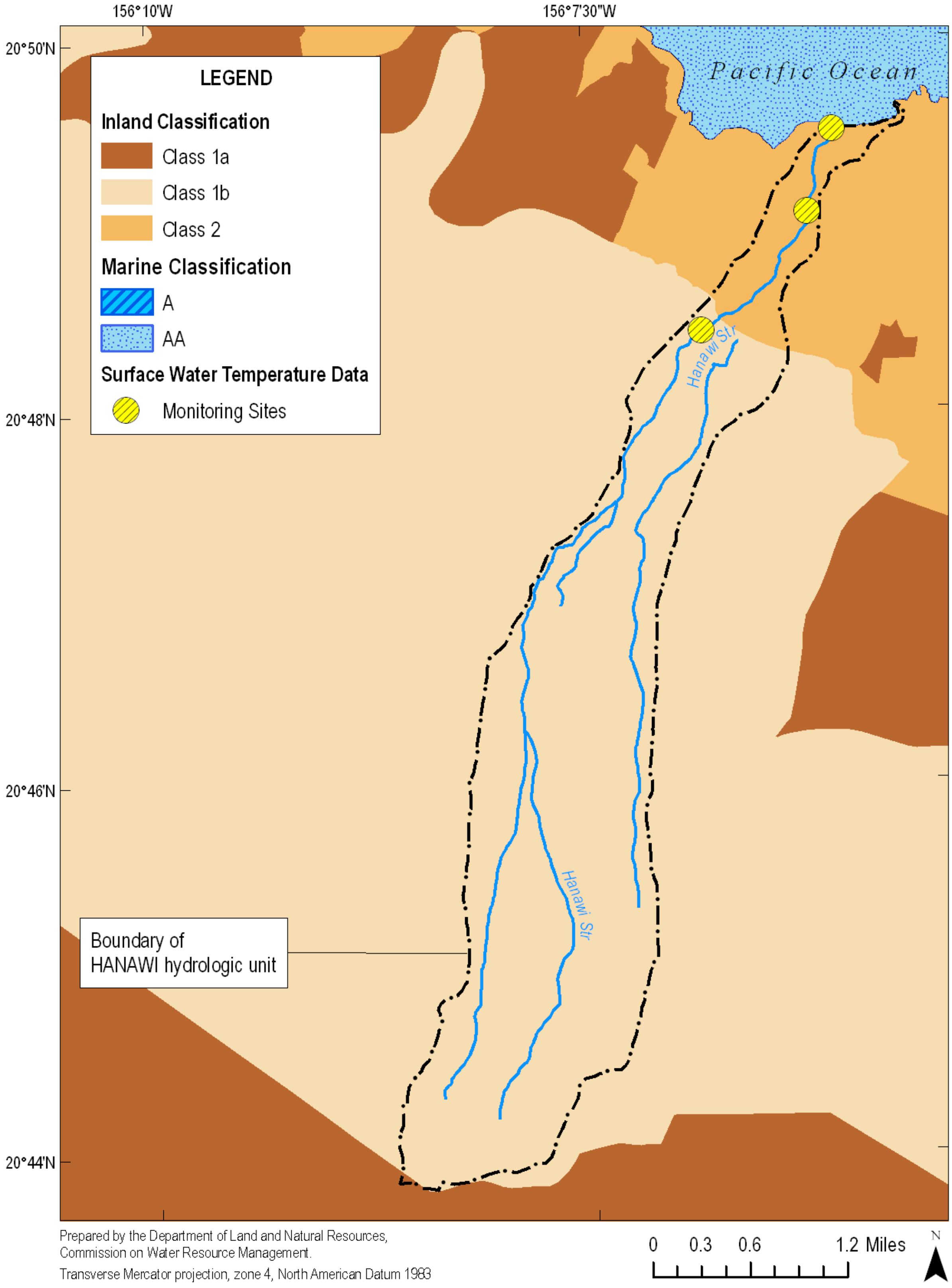
The 2006 Integrated Report indicates that the current WQS require the use of *Enterococci* as the indicator bacteria for evaluating public health risks in the waters of the State; however, no new data were available for this parameter in inland waters. As mentioned in Section 5.0, Outdoor Recreational 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)."

Hanawi Stream is classified as Class 1b inland waters from its headwaters to approximately 1,300 feet elevation, as the surrounding land is in the "protective" conservation subzone and the stream also lies in the Hanawi Natural Area Reserve and the Koolau Forest Reserve. The rest 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 entire Hanawi hydrologic unit are Class AA waters. Figure 10-1 shows the Hanawi hydrologic unit, including inland and marine (coastal) water classifications.

Figure 10-1. Water quality standards for the Hanawi 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.



Prepared by the Department of Land and Natural Resources, Commission on Water Resource Management.

Transverse Mercator projection, zone 4, North American Datum 1983

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 Hanawi indicate that there are a total of six registered diversions, of which five are East Maui Irrigation Company (EMI) diversions. The one remaining diversion is the Nahiku Pump which was registered by Maui Land & Pine (MLP, File reference: MAUI PINE 3). When needed, MLP pumps water from the stream and drops it into the Koolau Ditch for transport to MLP's Upcountry fields via the EMI System. Since EMI and MLP 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.

More information on the diversions for the Hanawi 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 Hanawi is primarily within the ahupuaa of Koolau 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.[13] 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.[14] Once established, future uses are not limited to the cultivation of traditional products approximating those utilized at the time of the Mahele[15], 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

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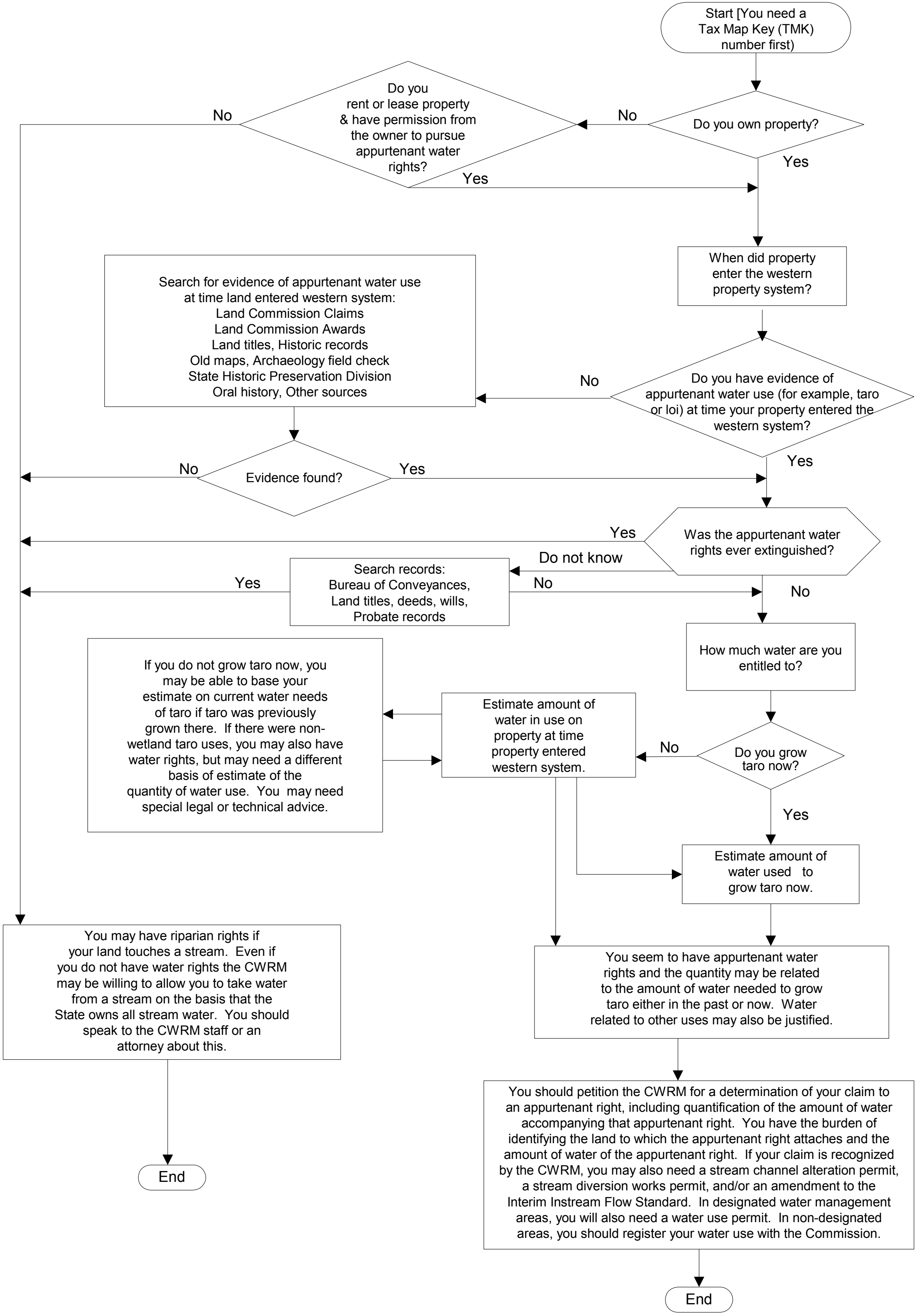
[13] 54 Haw. 174, at 188; 504 .2d 1330, at 1339.
[14] 65 Haw. 531, at 554; 656 P.2d 57, at 72.
[15] *Peck v Bailey*, 8 Haw. 658, at 665 (1867).

> 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 Hanawi. 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 Hanawi hydrologic unit.

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

TMK	Landowner	LCA	Grants/Leases	Notes
(2)1-2-001:001	East Maui Irrigation	none	Gr. 2090 Gr. 3066 Gr. 4443 Gr. 4449 Gr. 4529 Gr. 4530 (por.) Gr. 4895 (por.)	
(2)1-2-001:016	Kahookele, Herbert K. Trust	4871	none	
(2)1-2-001:025	East Maui Irrigation /Etal	none	Gr. 1914	
(2)1-2-001:026	Miller, Arthur E. & Mary E.	none	Gr. 2654	
(2)1-2-001:027	East Maui Irrigation /Etal	none	Gr. 3190 Gr. 3257	
(2)1-2-004:003	East Maui Irrigation /Etal	209 (por.)	Gr. 4874 Gr .4531 Gr. 4473 Gr. 4378 Gr. 11379 Gr. 4448 Gr. 4528 Gr. 4442 Gr. 4527 Gr. 4472	
(2)1-2-004:005	State of Hawaii /Etal	none	none	Includes dropped parcel 4 and Ld. Ct. App. 740.
(2)1-2-004:007	State of Hawaii	none	G.L. 3505	
(2)1-2-004:010	East Maui Irrigation /Etal	none	Gr. 4377	
(2)1-3-001:003	United States of America	none	Gr. S-14945	
(2)1-8-001:007	United States of America /Etal	none	Gr. 3602	
(2)2-4-016:004	East Maui Irrigation /Etal	none	Gr. 182	

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

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

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 Hanawi.

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		

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
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
	Problem Statement (Kalo): "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)."				
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."				

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
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	
Norman D. Martin Jr. (CPRC 29.2-15)	Waikane, Kulani, Waiokamilo	Waikane, Kulani, Waiokamilo	Waikane, Kulani, Waiokamilo	Waikane, Kulani, Waiokamilo	Waikane
	Problem Statement (Kalo): "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
	Problem Statement (Kalo): "There is lack of water to even push (?) the stream."				
Benjamin Smith Sr. (CPRC 29.2-37)	Wailua Nui		Wailua Nui, Ka Milo		
	Problem Statement (Kalo): "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]

				Temperature (ºC)			
Geographic designation	Area	Station	Period of record	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 Hanawi indicate that there are a total of six registered diversions, of which five are operated by EMI. The remaining diversion was registered by Maui Land & Pine for irrigation of pineapple and other horticulture. As needed, water is pumped from the stream and conveyed to Koolau Ditch for transport to Maui Land & Pine fields via the EMI System. None of the diversions were declared for taro cultivation or other domestic purposes. 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). Though Hanawi was specifically identified by only three declarants, the hydrologic unit of Hanawi falls within the area (Kolea/Honomanu to Makapipi/Kuhiwa) where many declarants claim gathering is practiced or would be practiced if water were available.

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
	<u>Problem Statement (Gathering):</u> “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
	<u>Problem Statement (Gathering):</u> “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
	<u>Problem Statement (Gathering):</u> “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
	<u>Problem Statement (Gathering):</u> “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
	Problem Statement (Gathering): "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
	Problem Statement (Gathering): "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)				
	Problem Statement (Gathering): "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
	Problem Statement (Gathering): "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 Hanawi 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.
>
> Beyond Wailuanui there are a succession of small deep gulches, each one having a few *lo‘i*: East Wailuaiki and West Wailuaiki (Little Wailua), Kapili‘ula, Waiohue, Pa‘akea, Kapa‘ula, Hanawi.
>
> 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 Hanawi 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 Hanawi 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 Hanawi 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.	Hanawi 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

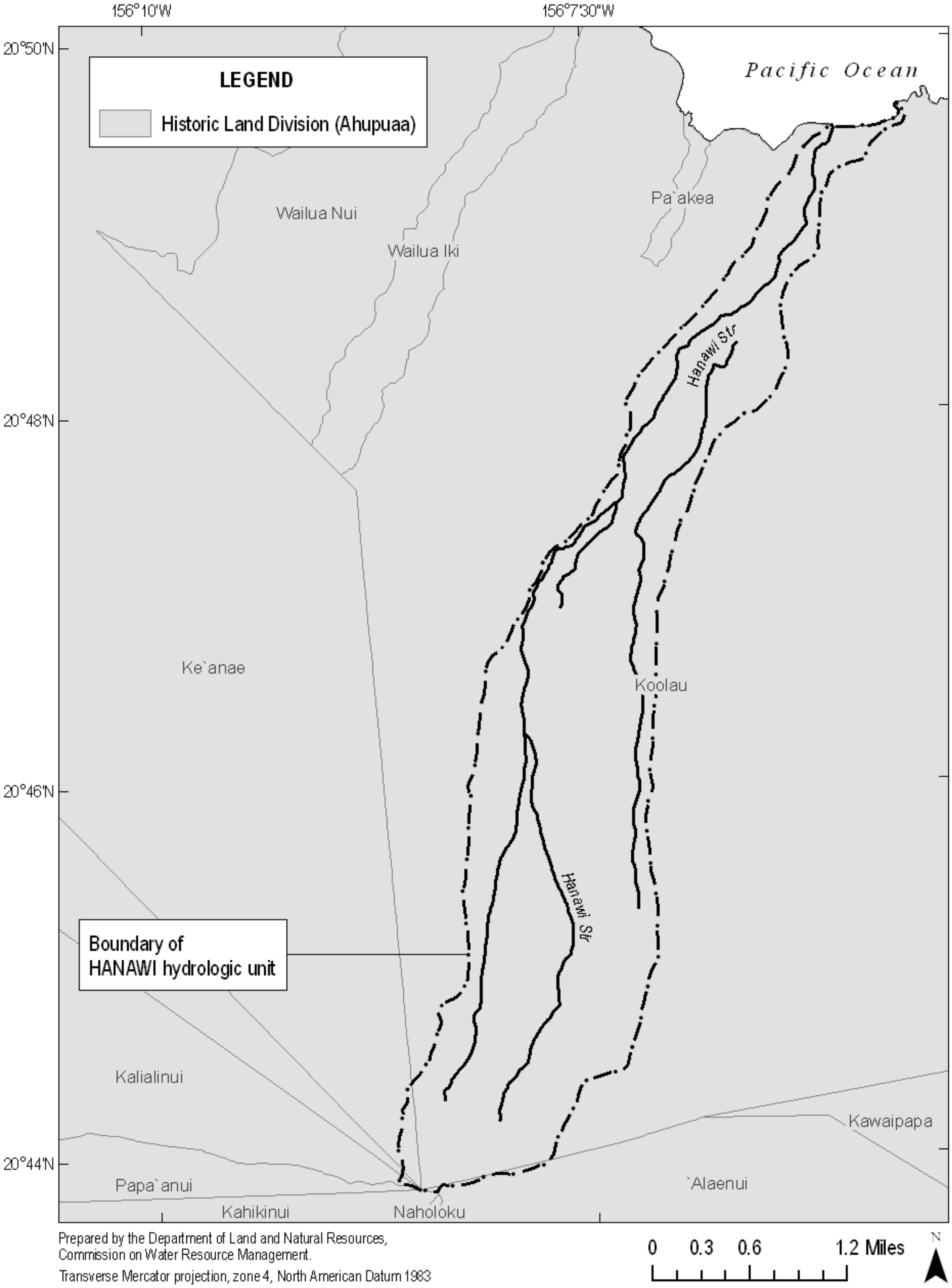
Fishponds are another integral part of traditional Hawaiian culture, which speaks volumes of Native Hawaiian skill and knowledge of aquaculture, which has also seen a resurgence of interest in recent years. Fishponds are found throughout the Hawaiian Islands and were either man-made or natural enclosures 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 Hanawi hydrologic unit (DHM, Inc., 1990).

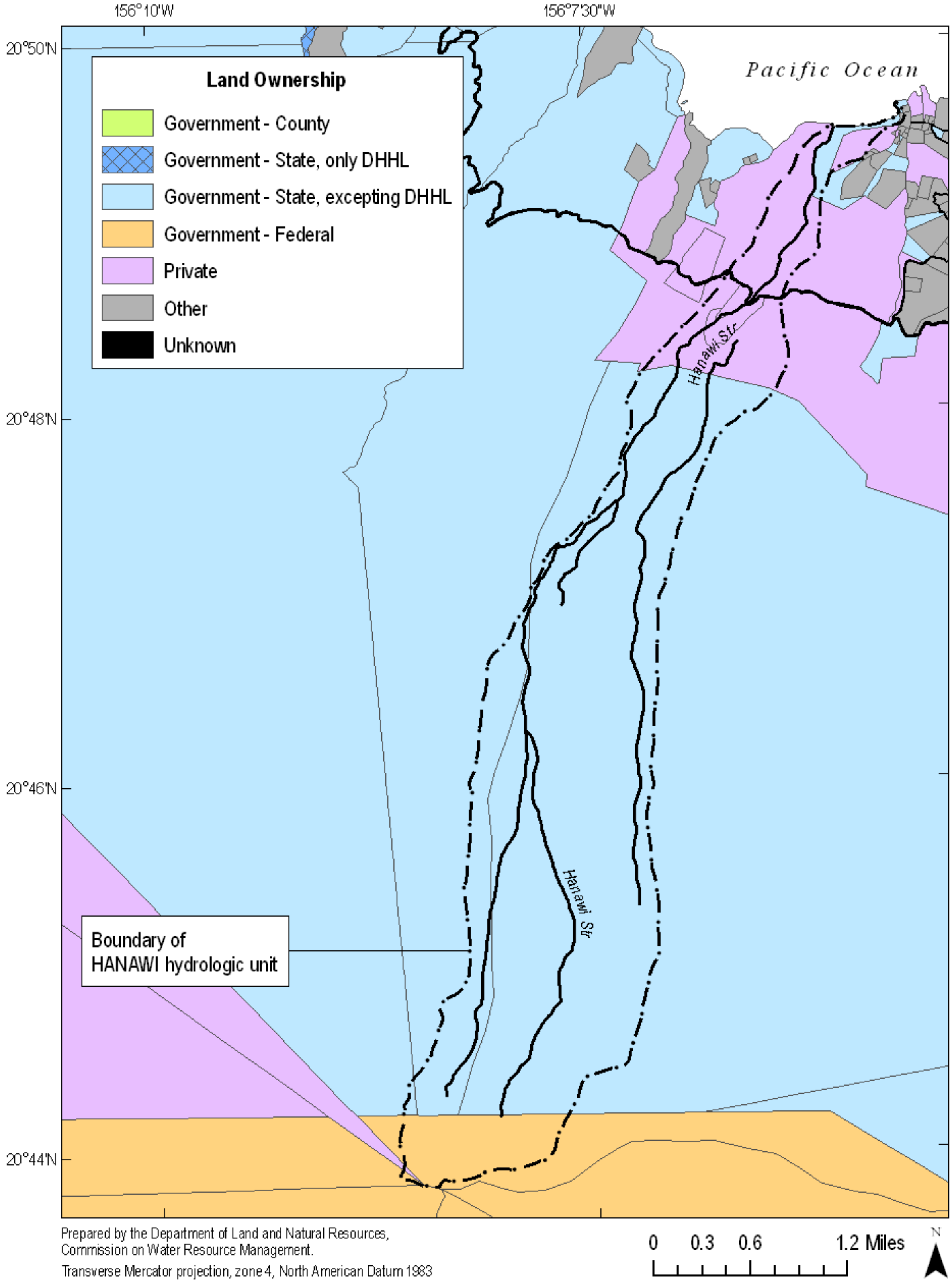
Another component in the assessment of traditional and customary Hawaiian rights is the presence of Department of Hawaiian Home Lands (DHHL) parcels within the surface water hydrologic unit. The mission of DHHL is to effectively manage the Hawaiian Home Lands trust and to develop and deliver land to 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 Hanawi hydrologic unit (Figure 12-3).

Figure 12-2. Traditional ahupuaa boundaries in the vicinity of Hanawi hydrologic unit. This hydrologic unit lies primarily within the ahupuaa of Koolau (Source: State of Hawaii, Office of Planning, 2007a; USGS, 2001b).



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

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



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

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 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 13-19.

In Hanawi, East Maui Irrigation Company (EMI) operates the Koolau Ditch system, 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 13-19.

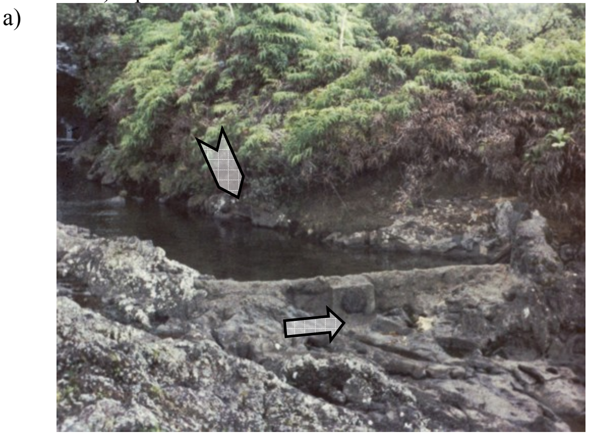
Table 13-1. Registered diversions in the Hanawi hydrologic unit.

[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 Cooperation (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.285.6	EAST MAUI IRR	1-2-004:		Yes	Yes	Yes	No

Water is diverted from Kapaula Stream at Intake K-6 into the Koolau Ditch. 15-inch PVC pipe diversion. Registrant identified water use is for 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 5 mgd. Measurement of total flow of Koolau Ditch, including this and other intakes, is available from USGS gaging station 16588000 (Wailoa Ditch at Honopou near Huelo).

Photos. a) Upstream view of the diversion intake structure from the right bank of the stream (EMI, 05/1989).



REG.292.6	EAST MAUI IRR	1-2-004:		Yes	Yes	Yes	No

Water is diverted from Hanawi Stream at Intake K-2 (Awaimakaino Intake) into the Koolau Ditch. Registrant identified water use is for 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 3 mgd. Measurement of total flow of Koolau Ditch, including this and other intakes, is available from USGS gaging station 16588000 (Wailoa Ditch at Honopou near Huelo).

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

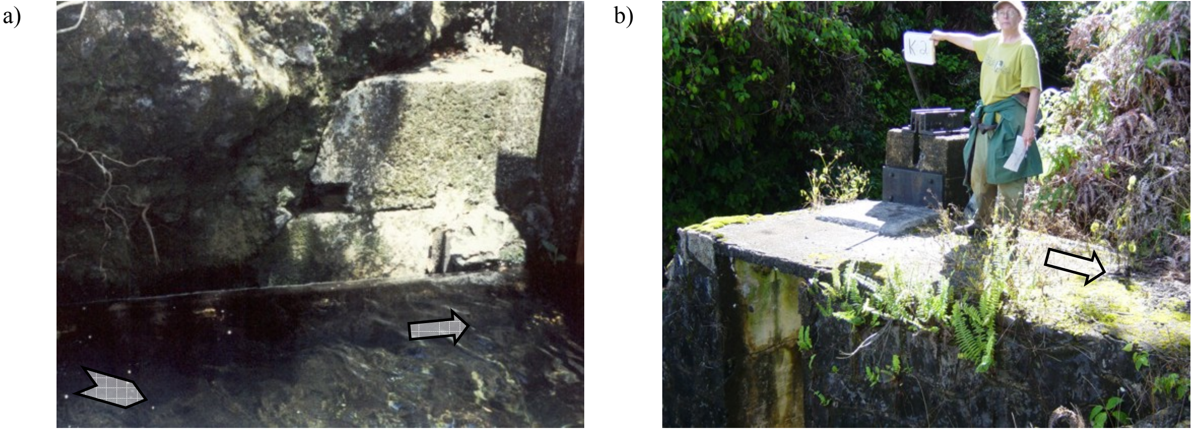


Table 13-1. Continued. Registered diversions in the Hanawi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.292.6 (Continued)	EAST MAUI IRR	1-2-004:		Yes	Yes	Yes	No

Photos. c) Upstream view of the diversion intake structure from below grade on the left bank (RMT, 11/2007); d) Upstream view from atop the diversion structure (RMT, 11/2007); e) View of the diversion intake structure and control gate mechanism (RMT, 11/2007); f) Downstream view from atop the diversion structure (RMT, 11/2007).

Table 13-1. Continued. Registered diversions in the Hanawi 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.293.6	EAST MAUI IRR	1-2-004:		Yes	Yes	Yes	No

Water is diverted from Hanawi Stream at Intake K-3 (Machine Tunnel Gulch Intake) into the Koolau Ditch. Registrant identified water use is for 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 10 mgd. Measurement of total flow of Koolau Ditch, including this and other intakes, is available from USGS gaging station 16588000 (Wailoa Ditch at Honopou near Huelo).

Photos. a) Close-up view of the diversion intake structure (EMI, 05/1989); b) .Upstream view of the diversion intake and control gate (RMT, 11/2007); c) Downstream view of the diversion intake structure (RMT, 11/2007); d) Upstream view from the diversion intake structure, with intake channel at right (RMT, 11/2007).

Table 13-1. Continued. Registered diversions in the Hanawi 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.293.6	EAST MAUI IRR	1-2-004:		Yes	Yes	Yes	No

(Continued)

Photos. e) Upstream flow before entering the diversion intake channel (RMT, 11/2007)

e)

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.294.6	EAST MAUI IRR	1-2-004:		Yes	Yes	Yes	No

Water is diverted from Hanawi Stream at Intake K-4 (Main Hanawi Intake) into the Koolau Ditch. Registrant identified water use is for 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 12 mgd. Measurement of total flow of Koolau Ditch, including this and other intakes, is available from USGS gaging station 16588000 (Wailoa Ditch at Honopou near Huelo).

Photos. a) View of the diversion intake structure on the left bank of the stream (EMI, 05/1989).

a)

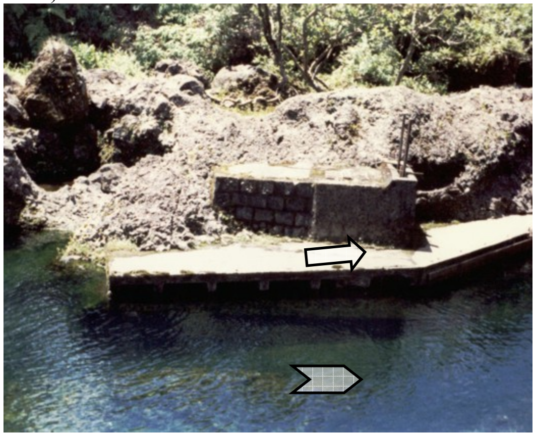


Table 13-1. Continued. Registered diversions in the Hanawi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.295.6	EAST MAUI IRR	1-2-004:		Yes	Yes	Yes	No

Water is diverted from Hanawi Stream at Intake K-5 (East Kapaula Intake) into the Koolau Ditch. Registrant identified water use is for 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 5 mgd. Measurement of total flow of Koolau Ditch, including this and other intakes, is available from USGS gaging station 16588000 (Wailoa Ditch at Honopou near Huelo).

Photos. a) View of diversion intake structure (EMI, 05/1989).

a)

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.772.6	MAUI PINE 3	1-2-001:035	0.57634	Yes	No	No	No

Water is diverted from Hanawi Stream. Declarant stated that water is used for pineapple and other horticultural purposes at it Haliimaile Plantation. The maximum divertible capacity of the Nahiku Pump is 3 mgd. As needed, water is pumped from the stream and conveyed to the Koolau Ditch for transport to Maui Land & Pine via the EMI System. See EMI's minor diversion K-4b for more information.

Photos. a) View of pumphouse on Hana Highway, downstream of bridge across Hanawi Stream (RMT, 09/2007); b) Downstream view of diversion intake pipe ofrom atop bridge on Hana Highway (RMT, 09/2007).

a)

b)

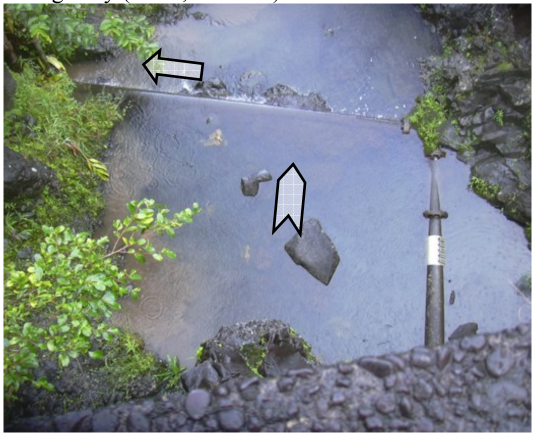


Table 13-1. Continued. Registered diversions in the Hanawi hydrologic unit.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.772.6 (Continued)	MAUI PINE 3	1-2-001:035	0.57634	Yes	No	No	No

Photos. c) Upstream view of diversion intake pipe from atop bridge on Hana Highway (RMT, 09/2007).

c)

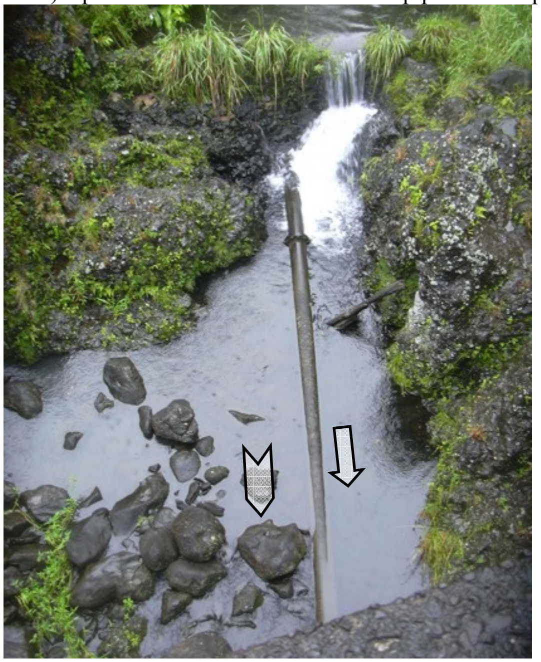


Table 13-2. Minor diversions on the EMI System in the Hanawi hydrologic unit.

Diversion ID	EMI Ditch System	Description
K-2a	Koolau	Hanawi small stream intake.

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

a)

Diversion ID	EMI Ditch System	Description
K-2b	Koolau	West Awaimakaino Stream intake – diverted to east.

Photos. a) View of diversion intake structure (EMI, 05/1989).

a)

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

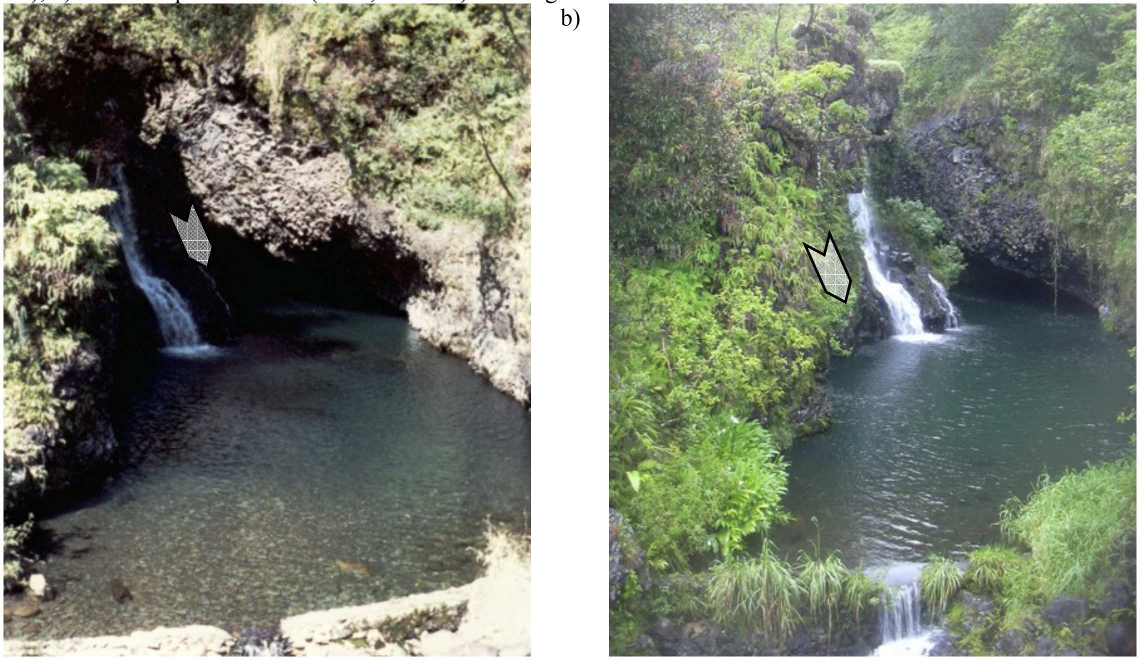
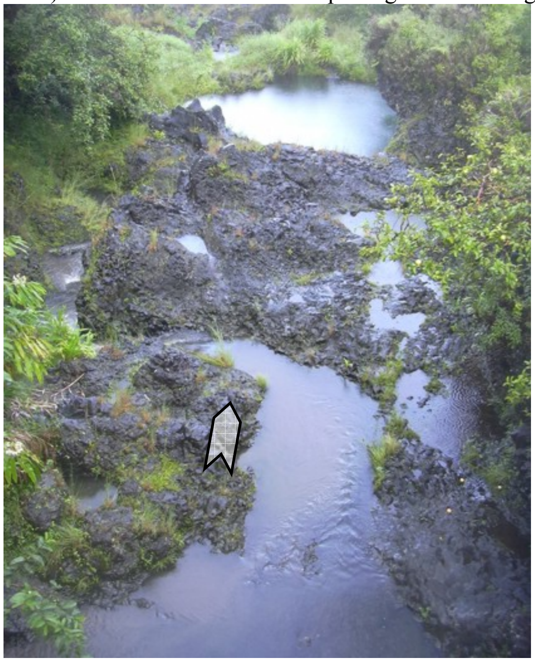
Diversion ID	EMI Ditch System	Description
K-4a	Koolau	2-inch intake pipe east of Main Hanawi Stream off Hana Highway.
		Photos. a) Concrete catch basin captures seepage and conveys water to the Koolau Ditch via a 2-in. pipe (EMI, 05/1989). a) 
K-4b	Koolau	Maui Land & Pine Hanawi dam mauka of Hana Highway bridge.
		Photos. a) Upstream view above Maui Land & Pine dam on Hanawi Stream for intake pipe for the Nahiku pump. (EMI, 05/1989); b) Another upstream view (RMT, 09/2007). See registered diversion REG.772.6 for more information.  a) b)

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

Diversion ID	EMI Ditch System	Description
K-4b (Continued)	Koolau	Maui Land & Pine Hanawi dam mauka of Hana Highway bridge.

Photos. c) Downstream view from atop bridge on Hana Highway (RMT, 09/2007).

c)



Diversion ID	EMI Ditch System	Description
K-4c	Koolau	8-inch aluminum pipe intake east of Hanawi.

Photos. a) Concrete catch basin captures seepage and conveys water to the Koolau Ditch via an 8-in. aluminum pipe (EMI, 05/1989).

a)

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

Diversion ID	EMI Ditch System	Description
K-4d	Koolau	6-inch PVC pipe intake east of Hanawi.

Photos. a) Concrete catch basin captures seepage and conveys water to the Koolau Ditch via a 6-in. PVC pipe (EMI, 05/1989).

a)

Diversion ID	EMI Ditch System	Description
K-4e	Koolau	4-inch PVC pipe intake diverted to Intake K-6.

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

a)

Diversion ID	EMI Ditch System	Description
K-4f	Koolau	2-inch driscoe pipe intake to crosscut below Hanawi sluice gate.

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

a)

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

Diversion ID	EMI Ditch System	Description
K-6a	Koolau	East Kapaula 6-inch PVC pipe intake diverted to Intake K-6.

Photos. a) Concrete catch basin captures tributary streamflow and conveys water to the Koolau Ditch via a 6-in. PVC pipe (EMI, 05/1989).

a)

Diversion ID	EMI Ditch System	Description
K-6b	Koolau	East Kapaula old 6-inch aluminum pipe intake diverted to Intake K-6. Notes indicate that the aluminum pipe was replaced with a 6-inch PVC pipe.

Photos. a) Concrete catch basin captures seepage and conveys water to the Koolau Ditch via a 6-in. PVC pipe (EMI, 05/1989).

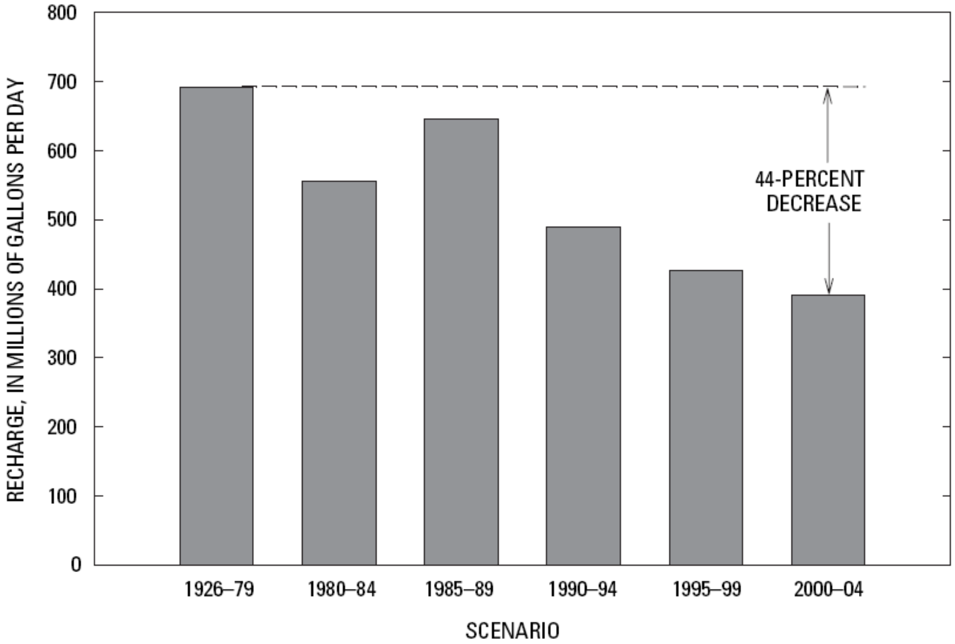
a)

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[16]. 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 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 central 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).



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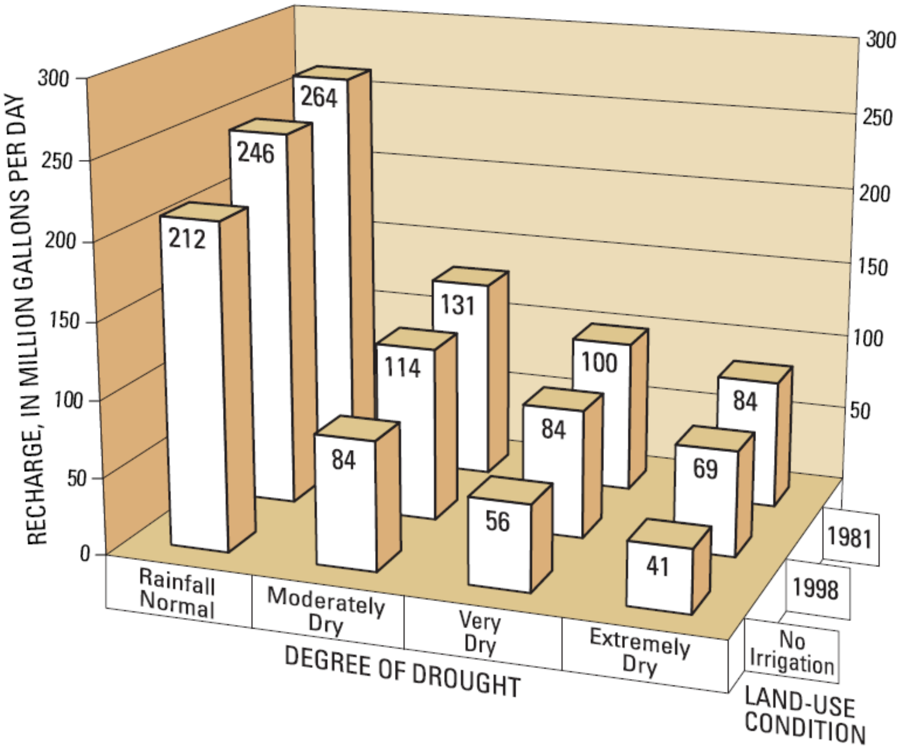
[16] Water-budget is a balance between the amount of water leaving, entering, and being stored in the plant-soil system. The water budget method/equation is often used to estimate ground water recharge.

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 identification and designation of Important Agricultural Lands (IAL) was approved in 1978 in an effort to promote agricultural viability. Important agricultural lands are those that are capable of producing sustained high agricultural yields for export or local consumption. These lands are identified based on current land use, soil and growing conditions, water availability, other agricultural land classifications, existing County plans, and proximity to supporting infrastructure conducive to agricultural productivity (DOA, 2009a). On June 29, 2009, the State Land Use Commission designated 27,102 acres of A&B agricultural lands at Wailuku and Makawao in the island of Maui as Important Agricultural Lands. More than 22,000 acres of the designated lands are irrigated with water from the EMI System (PR-2009-18, 72.0). This is the first IAL to be designated since the constitutional amendment for IAL was passed 30 years ago (PR-2009-18, 17.0).

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 IAL. Hanawi is comprised of less than 4 percent "other important agricultural lands", but does not contain any prime agricultural lands.

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. Hanawi does not contain any ALUM land classifications.

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 13-20).

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 (Figure 13-18). 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.

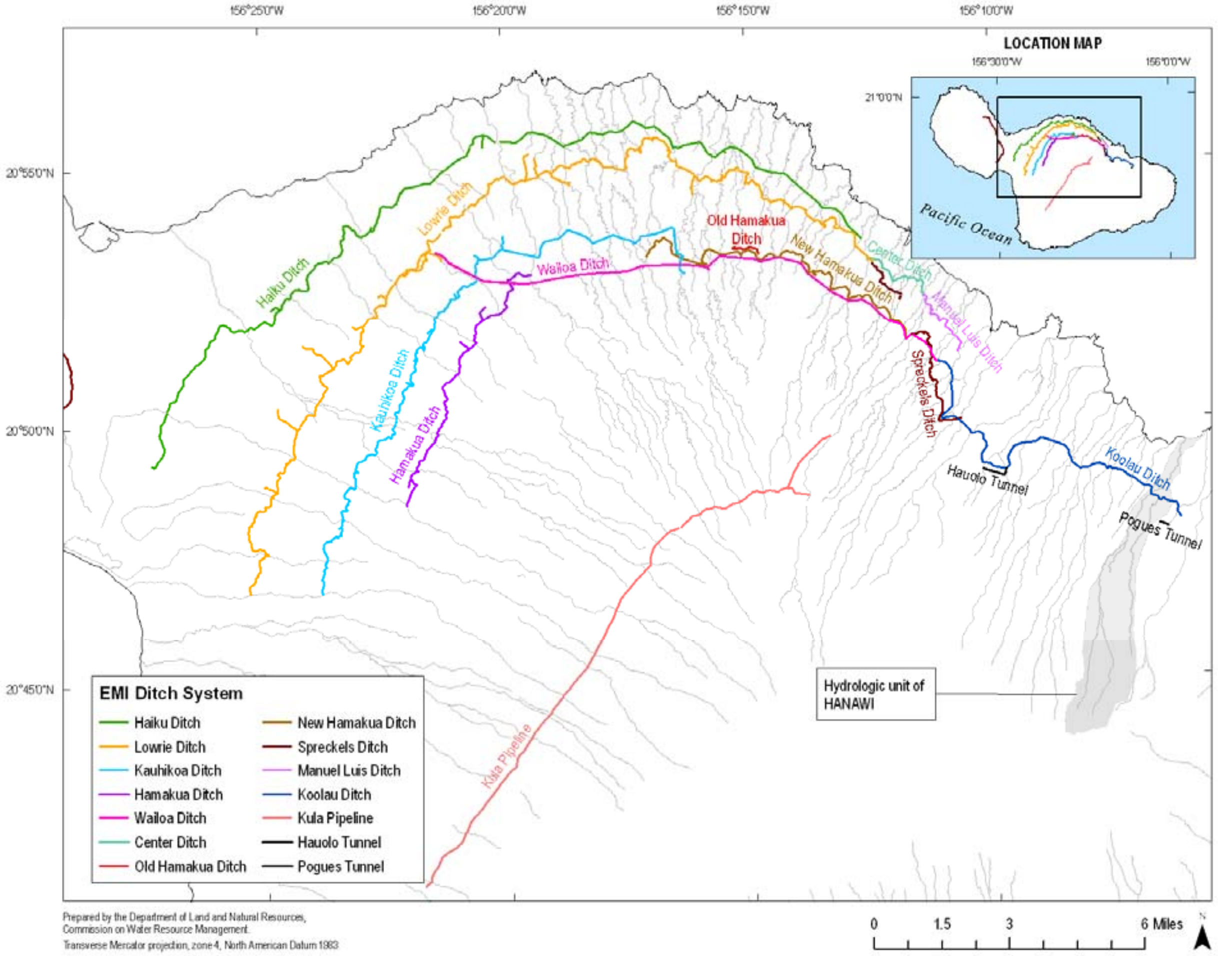
13.4.1 System Overview

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 13-3 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 13-3. 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.



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

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 13-21 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 13-4).

Table 13-4. 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 13-5), 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).

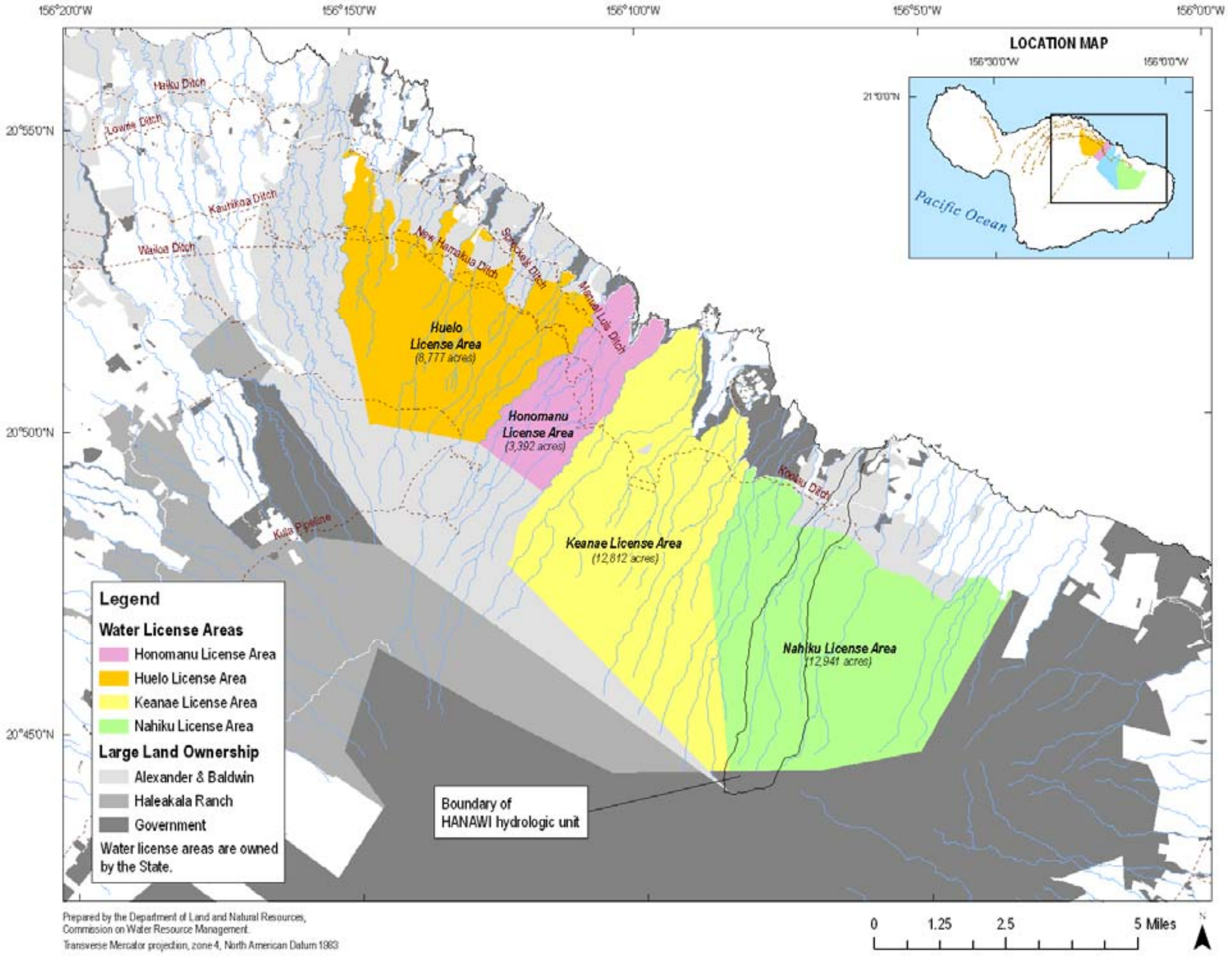
Table 13-5. Percentage of water yield from the four license areas (as of 1972).

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.



Prepared by the Department of Land and Natural Resources, Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

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 percent to discount for the uncertainty that the annual permits would be renewed. However, the payments after 1987 were increased by 25 percent 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 13-6. 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 13-7 summarizes the harvest and production yields for HC&S from 2000 to 2008.

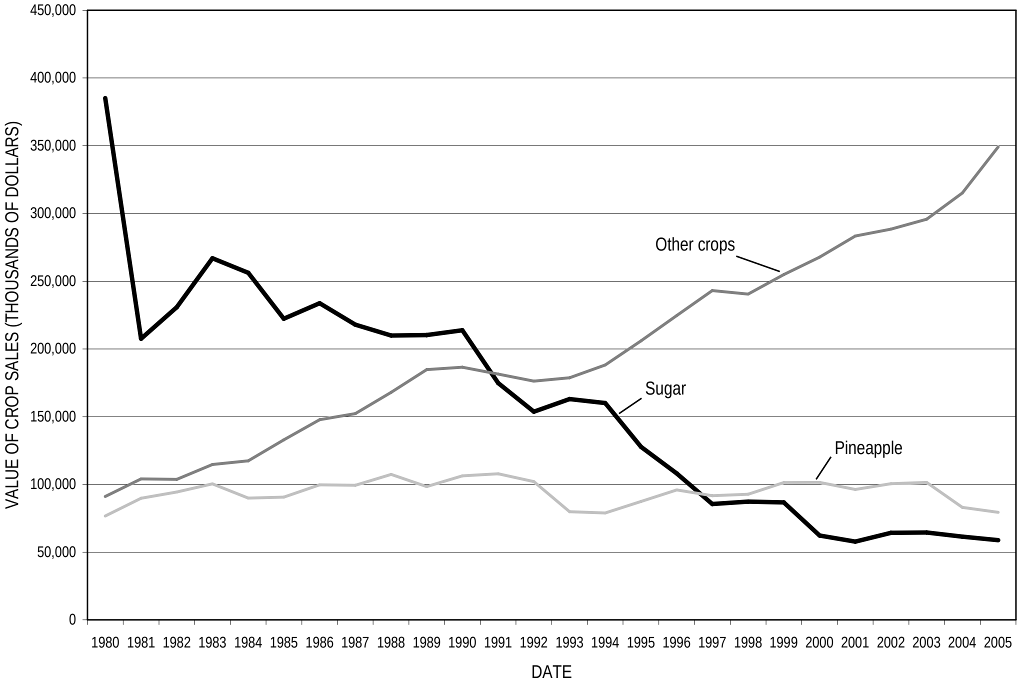
Table 13-7. Summary of sugar-related harvests by HC&S for 2000-2008 (Source: A&B, 2002; 2003; 2005; 2007, 2009).

[* 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. To avoid monetary penalties, HC&S would burn coal to generate power when bagasse and hydropower are not available.

The power generated by HC&S is critical to MECO because it is a "firm renewable energy, power that is available 24 hours a day, 7 days a week", as opposed to as-available power (e.g., solar and wind generated power) that cannot be consistenly relied upon (PR-2009-18, 25.0). Continued power production from HC&S helps to reduce overall dependence on fossil fuels, as well as to meet the Hawaii Clean Energy Initiative that 25 percent of the electricity sales are generated from renewable resources by 2010 (PR-2009-18, 25.0). 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 the higher elevations of the plantation (mainly above Lowrie Ditch) 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. To further maximize water use efficiency, the irrigation furrows were laid on exact 1.5 to 2 percent slope, which helps water move down the furrow without causing erosion (PR-2009-18, 43.0). 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).

Water is needed for irrigation as well as washing of the cane and to perform repairs on the drip irrigation tubing. During the summer when water is insufficient, the plantings are more prone to diseases and insect attacks. 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).

According to Lance Santo from the Hawaii Agriculture Research Center (PR-2009-18, 2.0), the conversion from furrow to drip irrigation in sugarcane fields resulted in less ground water recharge in the Kaanapali area and at the HC&S plantation. Consequently, irrigation wells in Kaanapali (Pump 6) and the sugarcane plantation (Well 16) have noticeable seawater intrusion and high electrical conductivity levels. The effects were more pronounced during the summer times when salinity reached as high as 6 mmhos per centimeter, while most crops cannot tolerate salinitly levels above 2 mmhos per centimeter. In general, vegetable crops are more sensitive to changes in salinity than sugarcane.

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).

Irrigation Water Requirement Estimation Decision Support System, IWREDSS (State of Hawaii, Commission on Water Resource Management, 2008b), is developed by the College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa for the State of Hawaii. IWREDSS is an ArcGIS-based numerical simulation model that estimates irrigation requirements (IRR) and water budget components for different crops grown in the Hawaiian environment. The model accounts for different irrigation application systems (e.g., drip, sprinkler, flood), and water application practices (e.g., field capacity versus fixed depth). Model input parameters include rainfall, evaporation, soil water holding capacities, depth of water table, and various crop water management parameters including length of growing season, crop coefficient[17], rooting depth, and crop evapotranspiration.

Calibration and validation of the model was based on the crop water requirement data for different crops from the Hawaii region United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) Handbook 38 (NRCS-USDA, 1996). Relative errors between the net irrigation requirements (NIR) estimated by the model and those estimated by NRCS range from less than 1 percent to a 26 percent overestimate. This difference may be attributed to the general nature of the technique NRCS used in estimating NIR. Results of the regression analysis indicate a good correlation ($R^2 = 0.97$) between the two techniques; however, the NIR calculations by NRCS were consistently 8 percent higher than those of the IWREDSS model. Overall, the model is an appropriate and practical tool that can be used to assess the IRR of crops in Hawaii.

The model was used to estimate the IRR of sugarcane grown on HC&S plantations. A GIS map of the sugarcane fields was provided by HC&S as part of their comment submission (see CPRC 13.1-20). Simulations were conducted on 188 fields with the following fixed input parameters: 1) drip irrigation with 85 percent efficiency; 2) irrigation water applied to field capacity; and 3) maximum leaf index of 5.5 by default. A number of scenarios were selected to determine an average range of IRR for sugarcane grown on all 188 fields. The first set of 4 scenarios focuses on the effects of differing periods of water application on the IRR (Table 13-8). All of the scenarios excluding No. 1 assume that irrigation has stopped in the last two months of the crop cycle to initiate crop maturity. The second set of scenarios highlights the seasonal effects on the IRR (Table 13-9).

According to the simulation results, the average IRR for sugarcane ranges from 1,400 to 6,000 gallons per acre per day. Applying irrigation water in the last two months of the crop cycle has insignificant effects on the IRR. As expected, IRR is lowest in the winter season when rainfall is high, and highest in the summer season when rainfall is low. The model calculates IRR based on long-term rainfall records available at the weather stations located nearest to the sugarcane fields. Thus, the estimated IRR represents an average value for average weather conditions as opposed to wet or dry year conditions. However, the estimated IRR for the winter and summer seasons could be extrapolated to represent the IRR for wet years and dry years, respectively.

Table 13-8. Scenarios modeled with IWREDSS that focuses on crop cycle changes, and average IRR in gallons per acre per day (gad) for sugarcane cultivated in all 188 fields for each scenario.

Scenario	Crop Cycle			Irrigation Period			IRR
	Total (months)	Planting (1st year)	Harvest (2nd year)	Total (days)	Start (1st year)	End (2nd year)	(gad)
1	24	Mar	Mar	730	Mar	Feb	4,711
2	24	Mar	Feb	671	Mar	Dec	4,957
3	24	May	May	669	May	Feb	4,443
4	22	May	Feb	610	May	Dec	4,771

Table 13-9. Scenarios modeled with IWREDSS that focuses on seasonal changes, and average IRR in gallons per acre per day (gad) for sugarcane cultivated in all 188 fields for each scenario.

Scenario	Season	Months	IRR (gad)
5	Fall	Sep-Nov	3,467
6	Winter	Dec-Feb	1,431
7	Spring	Mar-May	3,771
8	Summer	Jun-Aug	5,788

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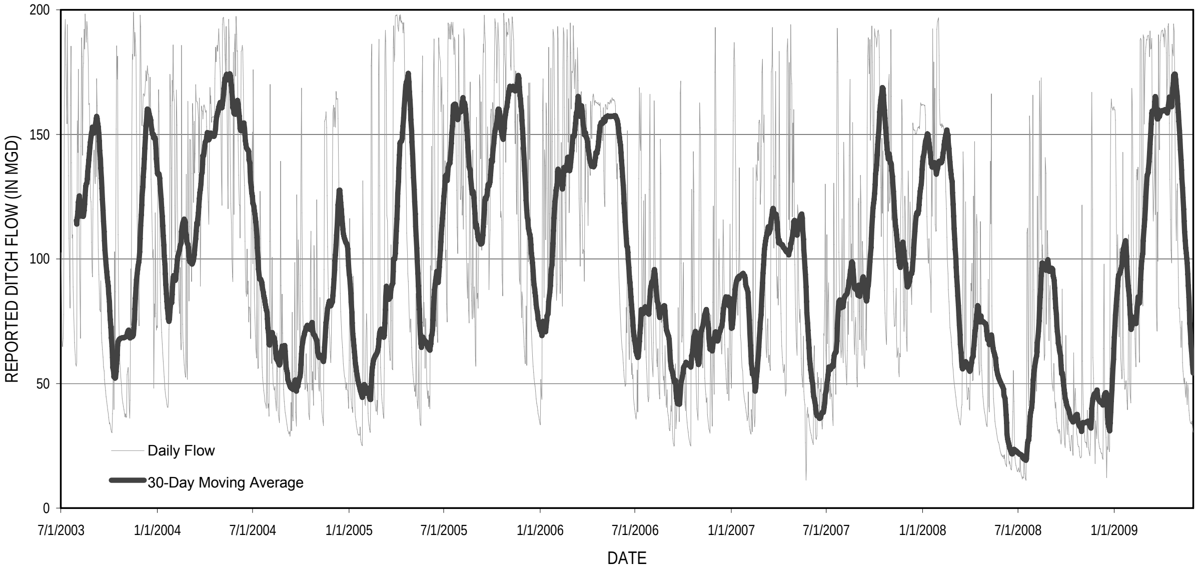
[17] Crop coefficient is an empirically derived dimensionless number that relates potential evapotranspiration to the crop evapotranspiration. The coefficient is crop-specific.

The IWREDSS model has not been verified with field data specific to Hawaii conditions. Therefore, the model estimates may not accurately represent the actual water use for sugarcane growing in Hawaii. Compared with the water use estimates that HC&S provided, which ranged from a low of 4,619 gallons per acre per day to a high of 6,858 gallons per acre per day, the model estimates on sugarcane IRR appear to be much lower. This is attributed to the model using normal rainfall conditions to estimate IRR. During a drought year or a drier year, rainfall decreases and irrigation needs are much higher. Thus, the seasonal IRR estimate for the summer months (i.e., 5,788 gallons per acre per day) is a more representative estimate for comparison with the HC&S estimates.

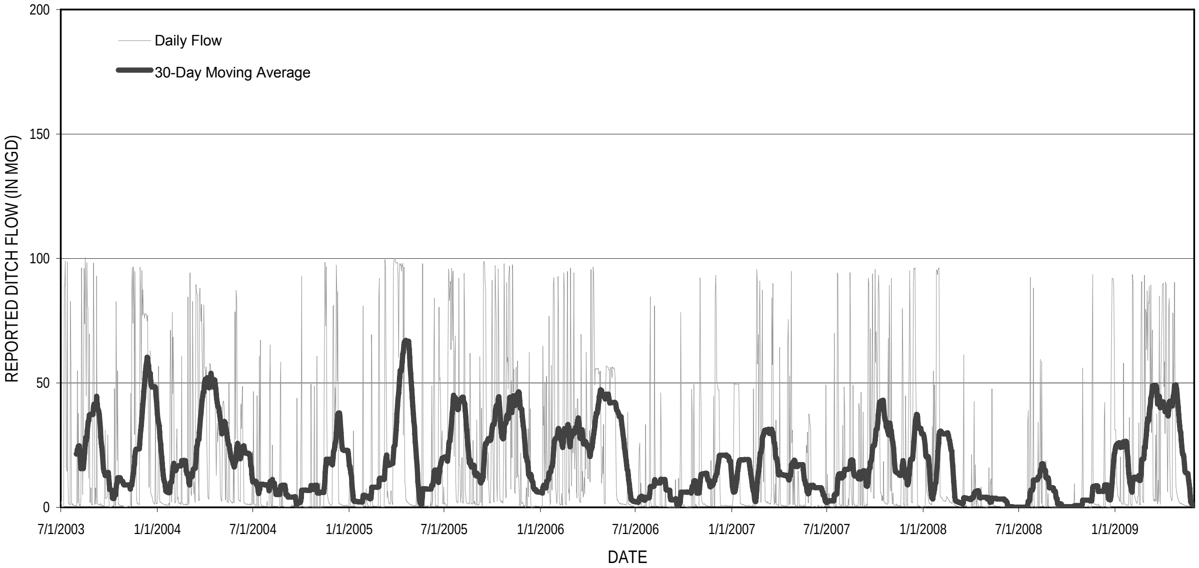
Based on the range of water use rates provided by HC&S and the IWREDSS model, a comparison with the supply of water from the east Maui streams can then be made. Daily ditch flow values (in mgd) from July 2003 to May 2009, as measured at Honopou, were provided by EMI. Figures 13-6 to 13-9 provide the daily ditch flow values and a 30-day moving average for the four major ditch systems at Honopou (from highest to lowest in elevation): Wailoa, New Hamakua, Lowrie, and Haiku. While the average flow for Wailoa Ditch from July 2003 to May 2009 is 98.57 mgd, the daily flow varies greatly from a low of 11.15 mgd (July 16, 2008) to a high of 199.00 mgd (November 16, 2003).

Figure 13-6. Daily ditch flow and 30-day moving average for Wailoa Ditch at Honopou (Source: EMI, 2009).



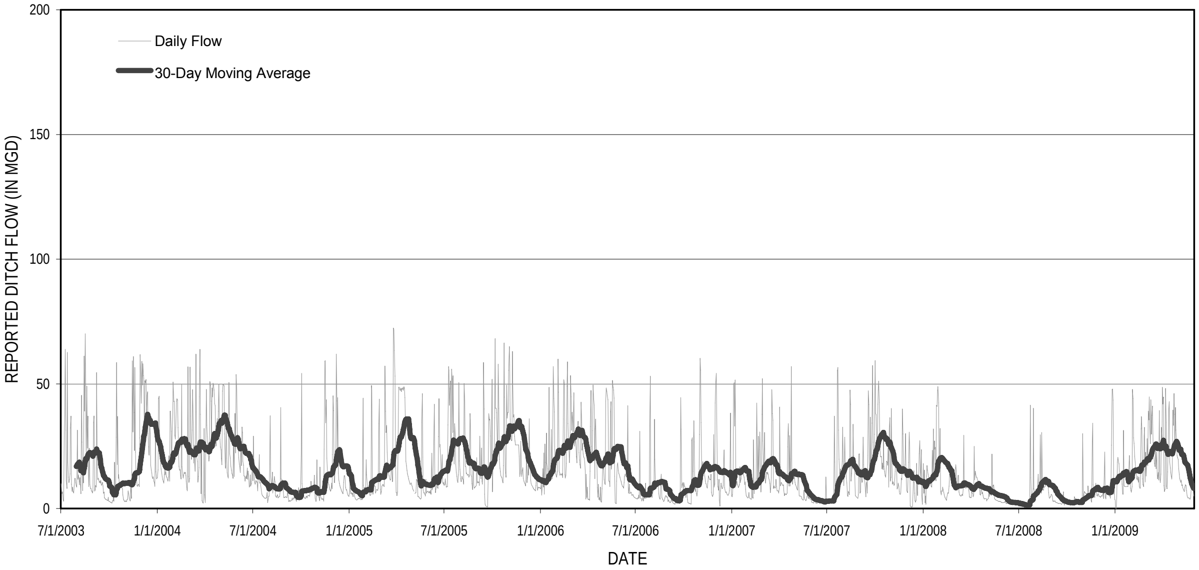
With New Hamakua Ditch located just below Wailoa Ditch for much of its length, the flow drops considerably to an average flow of 18.16 mgd for this period of record. The daily flows for New Hamakua range from 0 to 100.36 mgd (August 16, 2003) with a number of dry days experienced during June and July, 2008.

Figure 13-7. Daily ditch flow and 30-day moving average for New Hamakua Ditch at Honopou (Source: EMI, 2009).



Lowrie Ditch has an average flow of 15.17 mgd for this period of record, with daily flows ranging from 0 (January 2, 2009) to 72.40 mgd (March 26, 2005).

Figure 13-8. Daily ditch flow and 30-day moving average for Lowrie Ditch at Honopou (Source: EMI, 2009).



Haiku ditch is the lowest of the four ditches at Honopou. The average ditch flow during this period of record was 6.95 mgd, from a low of 0.05 mgd (June 6, 2008) to a high of 76.53 mgd (March 14, 2004).

Figure 13-9. Daily ditch flow and 30-day moving average for Haiku Ditch at Honopou (Source: EMI, 2009).

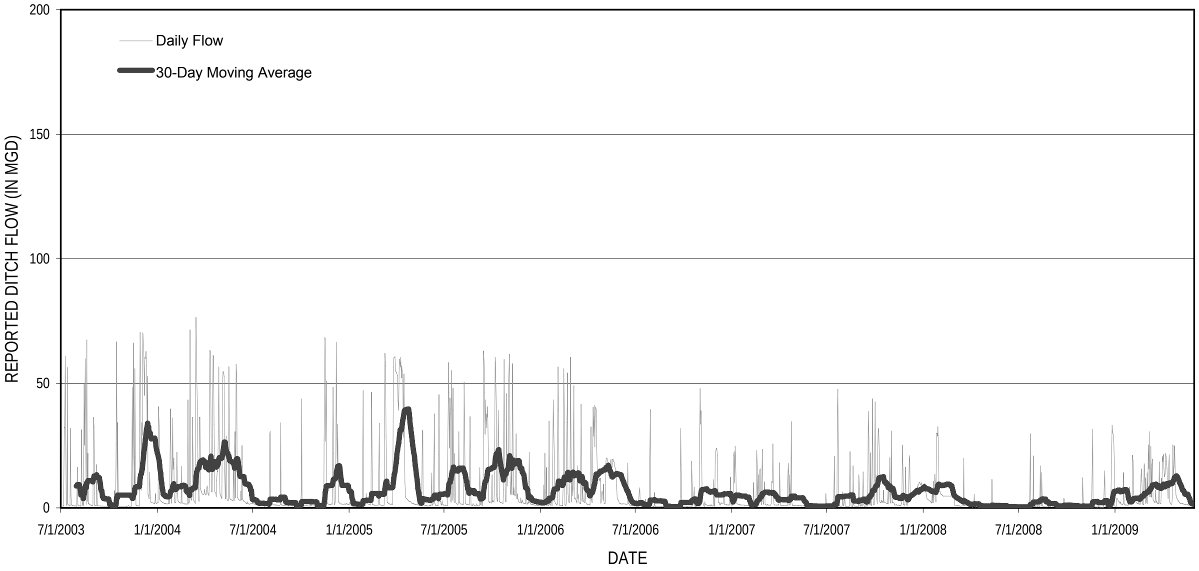
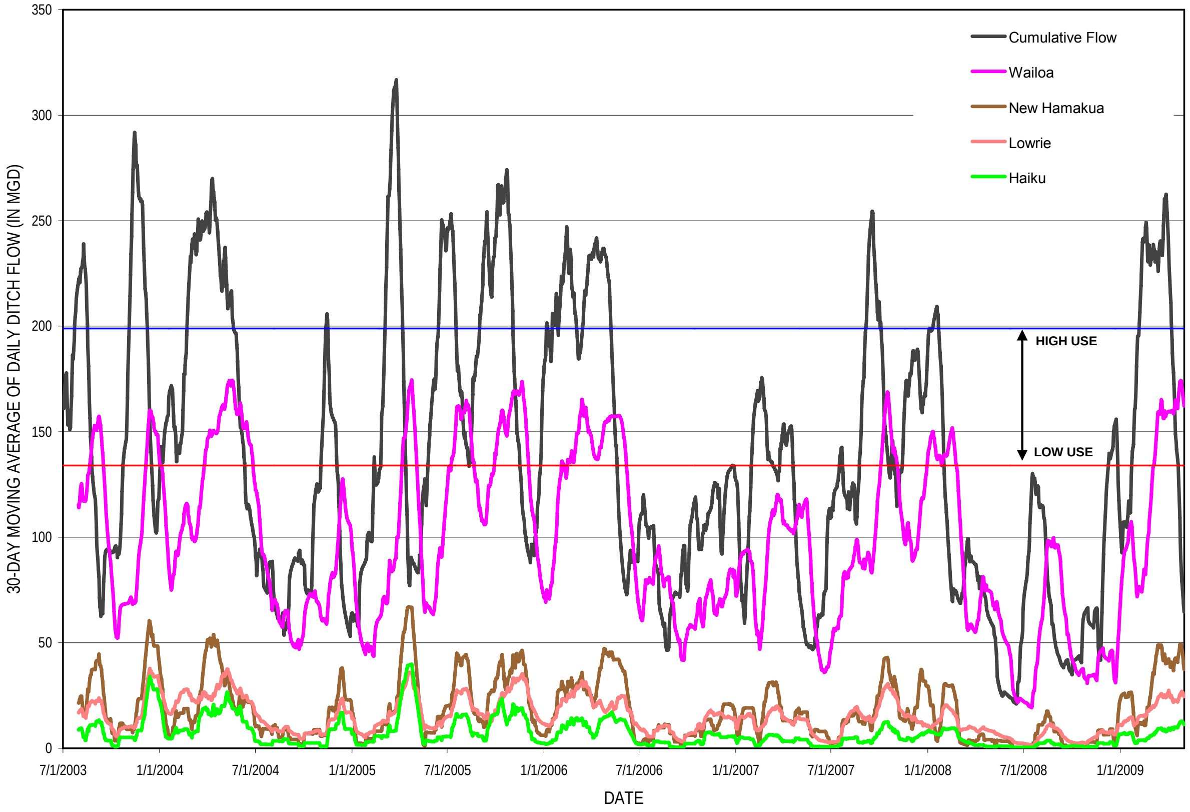


Figure 13-10 combines the 30-day moving averages of all four ditches, along with the cumulative 30-day moving average, into a single graph. The range of water use provided by HC&S is indicated by the blue and red lines, denoting the low end of 133.95 mgd (based on 4,619 gad for 29,000 acres) and the high end of 198.88 mgd (based on 6,858 gad for 29,000 acres). While the long-term average of water provided by the entire EMI system is estimated at 165 mgd, the cumulative average for this period of record is 138.85 mgd. These graphs highlight the wide range of daily flows conveyed by the EMI system, and what may be actually available for use on a day-to-day basis by HC&S and others.

Figure 13-10. Individual and cumulative 30-day moving averages for Wailoa, New Hamakua, Lowrie and Haiku Ditches at Honopou, including estimated range of water use by HC&S (Source: EMI, 2009; 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. Figure 13-18 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**. 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). The company also currently has 910 retirees (PR-2009-18, 56.0). This amounts to $47 million annually in wages and benefits to employees and retirees. HC&S has an apprenticeship program that not only maintains a skilled workforce for HC&S, but also provides a training ground for employees that move on to other companies in the public sector (PR-2009-18, 64.0). HC&S also partners with Ka Lima O Maui to provide employment services for individuals with disabilities (PR-2009-18, 66.0). Many companies and the Maui economy benefit from having locally trained employees rather than hiring from out-of-state.
- **Renewable energy**. The loss of hydroelectric and biomass fueled electric generation would 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).
- **Ground water**. Higher dependence on ground water for irrigation increases pumping costs. In addition, long term use of ground water that has even small amounts of sodium chloride can build up in the soil and affect crop yield. With decreased ground water recharge resulting from limiting surface water resources for irrigation, the wells within the plantation are even more susceptible to increased levels of salinity.
- **Landscape and tourism**. The HC&S plantation makes up a majority of the landscape in central Maui, keeping the island of Maui "green" as emphasized in many of the public review comments. Carol Reimann, Executive Director of the Maui Hotel & Lodging Association, stressed that "Maui's strength as a top tourism destination depends on the ability to showcase the island as a lush, green tropical paradise" (PR-2008-19). She further emphasized that it is lushness of the island that attracts visitors; thus, driving the local economy. The Visitor Industry provides 40 percent of all jobs on the island, generates 75 percent of the County's economy, and contributes about 40 percent of the total Real Property Tax collections (PR-2008-19).
- **Suppliers**. HC&S spends approximately $100 million annually in the local economy to support its operations, primarily in Maui (HC&S, 2009). Many companies service HC&S; among them

are Maui Disposal Company, ChemSystems, Maguire Bearing Company, CWR Hawaii, Maui Petroleum, and BEI Hawaii – Maui. The viability of these suppliers may be challenged with any impacts to HC&S operations. According to Greg Heyd, Maui Branch Manager for BEI Hawaii, HC&S and upcountry farmers represent sales exceeding $5 million (PR-2009-18, 60.0). 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.

- **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 may affect its contractual obligation to provide the Park with 1.5 million gallons of ditch water per day (actual water use is included in Section 13.4.5). Maui Land and Pineapple Co. (MLP) is another entity that is dependent on HC&S for the delivery of water.
- **DHHL**. A Native Hawaiian Rehabilitation Fund was created to support the native Hawaiian community. A portion of the funding comes from the sale of sugarcane from State lands and the sale of surface water derived from public lands (PR-2009-18, 96.0). In 2009, DHHL received $289,000 in total revenue from these sources. The DHHL also receives annual revenue of $65,000 from the use of Hawaiian home lands (about 686 acres) at Puunene for sugarcane cultivation (PR-2009-18, 96.0). Reduction on stream water available for sugarcane cultivation will directly impact the Native Hawaiian Rehabilitation Fund

13.4.4 Maui Land and Pineapple Company

Note: On November 3, 2009, MLP announced that it would cease all pineapple operations on the island of Maui and lay off an estimated 285 employees, or 45 pecent of its workforce (Segal, 2009). Due to the uncertainty of long-term plans for MLP, its land holdings, and water use associated with its operations, the Commission staff has decided to retain the information on water use and economic impact as part of this report. With regards to Kuhiwa Well, which sits adjacent to Makapipi Stream, it should be noted that condition 4 of the Decision and Order in the Kuhiwa Well Contested Case Hearing states “Use of water from the well shall be for pineapple irrigation only” (Findings of Fact, Conclusions of Law, and Decision and Order, 1991). Further dicussions between MLP and the Commission will be necessary to determine impacts to continued water use and existing infrastructure.

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 the west Maui lands are less susceptible to drought (MLP, 2007), MLP will begin to concentrate pineapple growing exclusively in their east Maui fields. This is done in an effort to consolidate agricultural operations and to reduce transportation costs (PR-2008-18, 27.0). The company plans to downsize its pineapple cultivation in east Maui by 43 percent, from 2,800 acres to approximately 1,600 acres.

Water Use

MLP relies on several sources of surface and ground water for irrigation. The Kailiili Water System and the Kailiili Reservoir are surface water systems owned and operated by MLP. The Kailiili Reservoir receives water from Opana and Awalau Streams. Flow from the east and west Opana Streams are diverted by EMI intake structures, and then passes through the Opana transmission tunnel for MLP, Haleakala Ranch, Kaonoulu Ranch, and Maui DWS use. MLP also diverts surface water from Hanawi Stream via the Nahiku Pump Station and into EMI’s Koolau/Wailoa Ditch. The maximum divertible capacity of the pump is 3 million gallons per day. In 2008, MLP diverted less than 11 million gallons as compared to 42 million gallons in 2003. The decrease in water use is a result of weather patterns and less pineapple being cultivated over the years. MLP’s ground water sources include the Kuhiwa and

Hailiimaile well, where water is pumped into the Koolau/Wailoa Ditch. Only water from the Hailiimaile well can be pumped directly to irrigate the pineapple fields. During the drier seasons when surface water sources are limited, MLP relies more on its ground water sources and DWS agricultural meters for irrigation (J. Pearson, personal communication, October 2009).

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 3.1 million gallons per day from 2009 to 2016 (PR-2008-18, 27.0).

In late 2008, concerns were raised by Nahiku residents that the pumping of the Kuhiwa Well (Well No. 6-4806-08) was impacting streamflow in Makapipi Stream. This issue stems from the Commission's contested case hearing (MA-CC-91-1) on the Pump Installation Permit Application filed by Maui Pineapple Company, Ltd. for the Kuhiwa Well in August 1990. The central issue raised by the Hana Community Association was the possible effect of well pumpage on streams and springs in the area, including Hanawi and Makapipi Streams and the Behren's spring and Big Spring. The Commission had issued its final Decision and Order in October 1991, which placed 17 conditions on the approval of the pump installation permit for the Kuhiwa Well (Findings of Fact, Conclusions of Law, and Decision and Order, 1991). The pump installation was completed December 3, 1991, followed by the pump test completed by USGS in May 1992. USGS indicated that any impact of pumping the Kuhiwa Well upon Makapipi and Hanawi Streams could not be confirmed due to inadequate or absence of data (B. Rozeboom, personal communication, June 12, 1992).

In December 2008, the Commission prepared a letter on the status of conditions for Kuhiwa Well pump installation approval in response to the concerns raised. The Commission's Ground Water Regulation Branch reported, based on a review of the records, that use of the Kuhiwa Well did not appear to impact stream flows, and that continued monitoring was unnecessary. During normal rainfall periods, use of the Kuhiwa Well does not have major impact on streams, but during prolonged drought, the effects would need to be explored more carefully (K.C. Kawahara, personal communication, December 4, 2008).

Monthly pumpage reports from both the Kuhiwa Well (Table 13-11) and the Nahiku Pump on Hanawi Stream (Table 13-12), indicate that pumpage from both sources is sporadic and far below the allowable combined maximum annual capacity of approximately 180 million gallons per year (Findings of Fact, Conclusions of Law, and Decision and Order, 1991).

Table 13-11. Reported monthly pumpage for MLP's Kuhiwa Well, 6-4806-48, January 2003 to June 2009 (Source: CWRM, 2009a).

[-- indicates no pumpage occurred; [a] On June 9, 2005, MLP submitted a revised pumpage report for May 2004, which may not be reflected in Table 13-1; Note that the pumpage total for 2009 represents only half of the calendar year.]

Month	2003	2004	2005	2006	2007	2008	2009
January	0.050	--	--	--	--	0.912	--
February	0.048	--	--	--	--	--	--
March	--	--	--	--	--	--	--
April	--	--	--	--	--	1.488	--
May	0.315	35.745 [a]	.045	--	--	1.047	0.013
June	--	--	0.062	6.400	7.157	0.134	--
July	--	--	--	2.580	1.198	0.007	
August	--	--	--	--	2.453	0.010	
September	--	--	0.063	4.060	3.375	--	
October	--	--	--	4.870	3.760	--	
November	--	--	--	5.440	3.655	--	
December	--	--	--	3.963	0.989	--	
TOTAL	0.413	35.745	0.17	27.313	22.587	3.598	0.013

Table 13-12. Combined report of water pumped into the Koolau Ditch for MLP's Nahiku Pump on Hanawi Stream, REG.772.6, and Kuhiwa Well, 6-4806-48, as reported by EMI, January 2003 to June 2009 (Source: CWRM, 2009b).

[na = monthly pumpage report not available; -- indicates no pumpage occurred; [a] On June 9, 2005, MLP submitted a revised monthly pumpage report for Kuhiwa Well for May 2004 (see Table 13-11), which may not be reflected here; [b] indicates that EMI began reporting quarterly pumpage thus pumpage is prorated across three months; Note that the pumpage total for 2009 represents only half of the calendar year.]

Month	2003	2004	2005	2006	2007	2008	2009
January	2.864	1.990	--	--	--	-- [b]	-- [b]
February	0.000	0.841	0.724	--	--	-- [b]	-- [b]
March	0.000	0.451	4.923	--	--	-- [b]	-- [b]
April	0.000	--	--	--	--	-- [b]	-- [b]
May	6.655	1.267[a]	4.305	--	5.259	-- [b]	-- [b]
June	6.120	8.874	8.250	6.400	11.832	-- [b]	-- [b]
July	6.994	8.804	5.819	2.322	na	0.249 [b]	
August	3.812	4.311	5.193	--	na	0.249 [b]	
September	4.586	7.807	5.789	3.654	na	0.249 [b]	
October	6.938	4.998	--	4.383	3.987 [b]	3.300 [b]	
November	4.152	1.688	--	4.896	3.987 [b]	3.300 [b]	
December	--	--	--	3.567	3.987 [b]	3.300 [b]	
TOTAL	42.121	41.031	35.003	25.222	29.052	10.647	0.000

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 13-13 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 13-13. 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.]

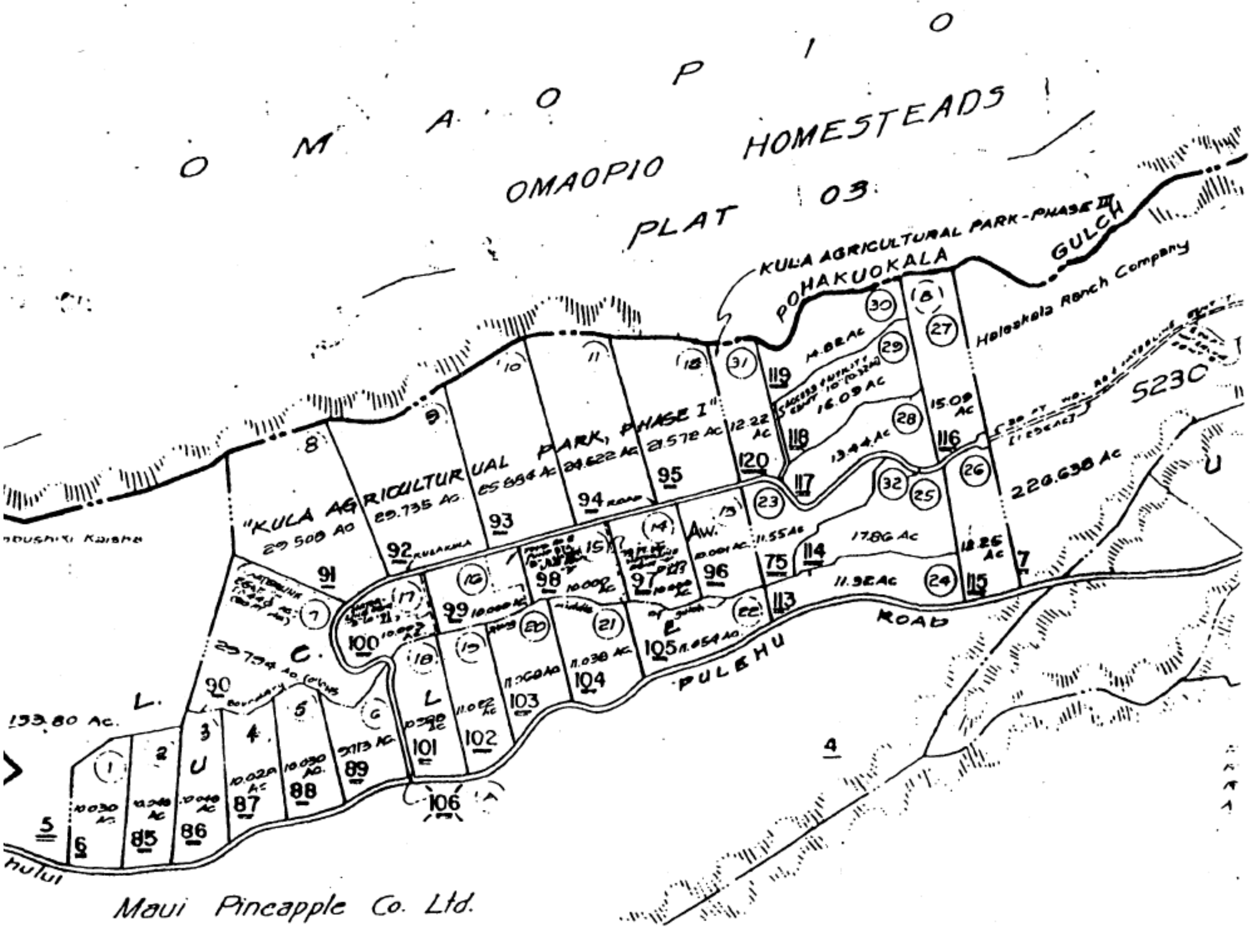
Year	Revenue (dollars)	Operating Loss (dollars)
2006	$ 65,200,000	$ (18,600,000)
2005	$ 74,500,000	$ (11,400,000)
2004	$ 80,000,000	$ (10,800,000)
2003	$ 105,000,000	$ (921,000)
2002	$ 92,500,000	$ (8,500,000)
2001	$ 92,000,000	$ (3,000,000)
2000	$ 85,900,000	$ (2,900,000)
1999	$ 94,400,000	$ 6,100,000

Restricting water availability to MLP by establishing interim IFS on Hanawi Stream, one of the 27 petitioned streams, may add to the company's continued operating losses. Pumping costs will increase as MLP will need to supplement its irrigation needs with ground water from Kuhiwa and Hailiimaile wells. While MLP will shift all of the plantings to its east Maui field, MLP may need to further decrease the cultivated acreage by more than 43 percent as planned.

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. The Kula area is known as a prime agricultural area for vegetable and flower farming in Maui (PR-2009-18, 58.0). 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 13-11 is a map of the Park.

Figure 13-11. 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 13-14. 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 13-14. 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. According to the Maui Office of Economic Development (PR-2008-18, 16.0), the economic value of the Park is over $5 million annually. 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 13-12). 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.

The Maui DWS water system (via the Upper Kula or Lower Kula systems) does not divert water directly from the hydrologic unit of Hanawi. However, Maui DWS' Makawao system does receive water from the Wailoa Ditch which includes water from Hanawi. The interconnected nature of the Maui DWS system during periods of water shortage thus warrants a full description of the Upcountry System as provided in this section.

13.5.1 System Overview

The Maui DWS Upcountry Water District, illustrated as colored regions in Figure 13-12, 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.

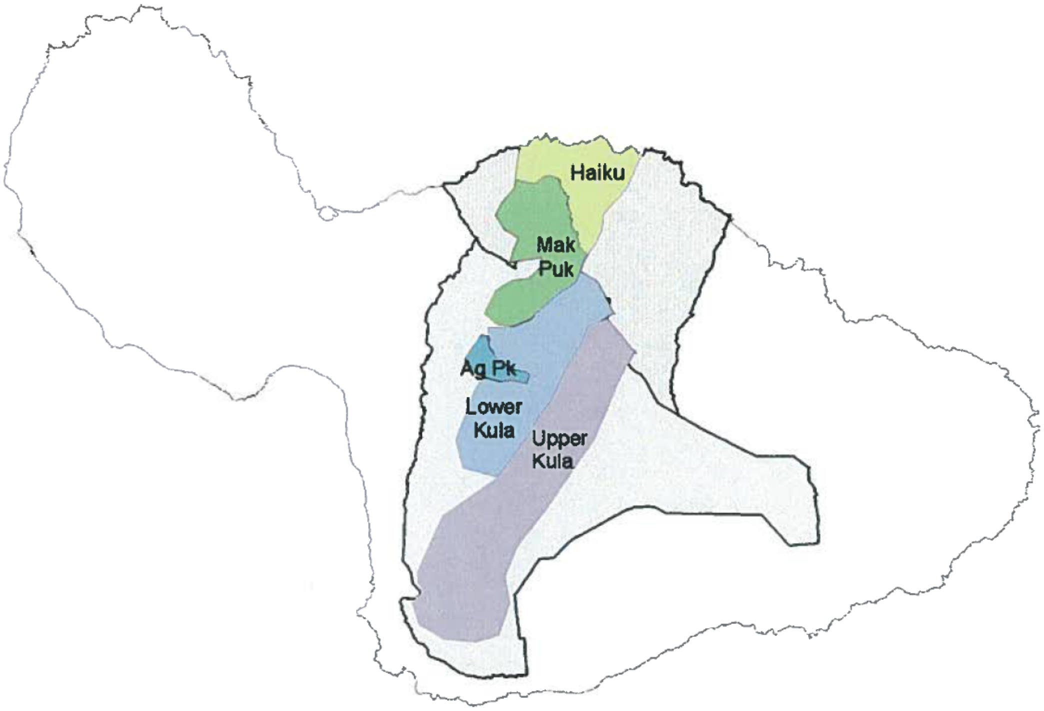
The Upper Kula system is situated at the highest elevation (about 4,200 feet) of the three systems comprising the Maui DWS Upcountry System. It begins as a flume (also known as the Waikamoi Upper Flume), capturing surface water from Haipuaena Stream, middle and west branch of Puohokamoa Stream, and Waikamoi 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 Kaupakalua 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 13-12. 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 (about 676 residential units). 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 13-15). 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 13-16 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. Feral animals are wild goats, deer, and pigs that roam free on farm and ranch lands. While water is not intentionally provided to these animals, the presence of these feral animals is unavoidable even with proper fencing around the property. Therefore, the amount of water they use, which make up 22 percent of the total water use, is included in the table.

Table 13-15. 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 13-16. 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 13-12. 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 (Figure 13-13). 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 13-14). 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 13-15).

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

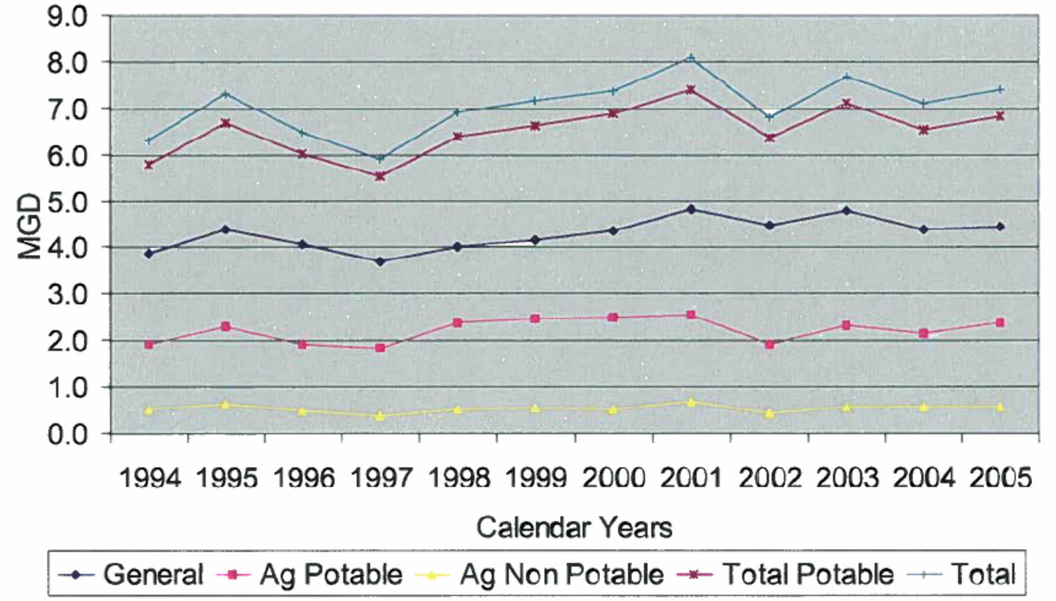


Figure 13-14. Historical monthly water consumption by use class code for the Makawao-Pukalani-Kula Community Plan District, Maui (Source: Maui DWS, 2007d).

[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]

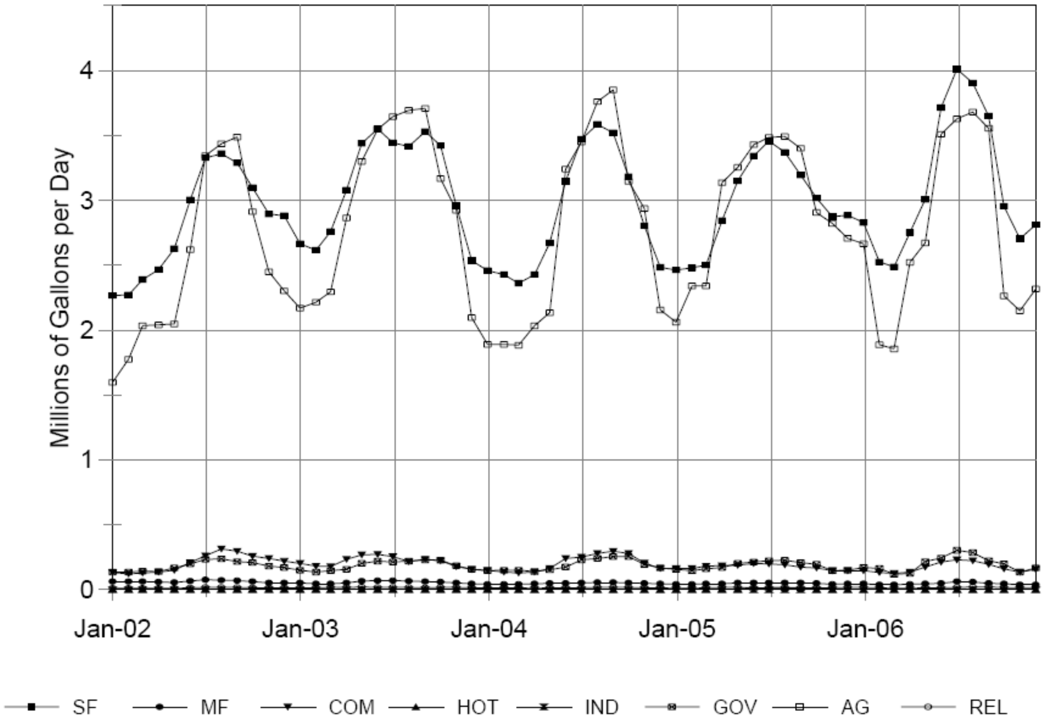
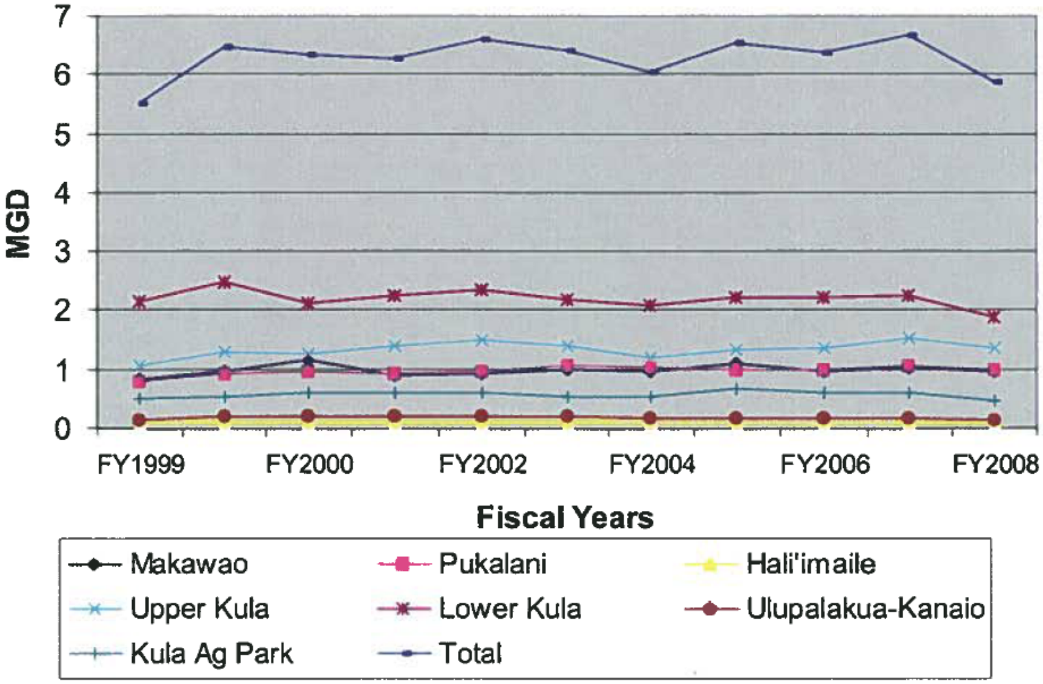
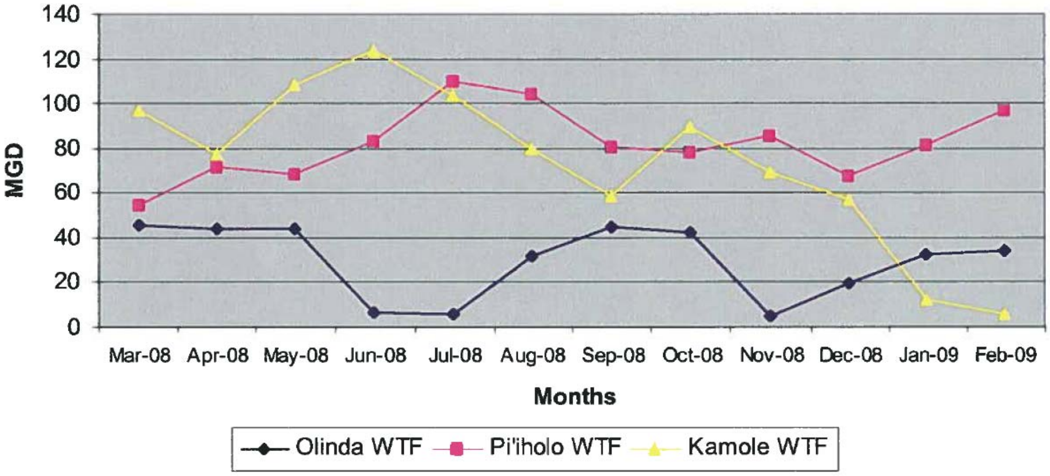


Figure 13-15. Maui DWS metered consumption for the Upcountry District by sub-division, excluding the Haiku sub-division (Source: Maui DWS, 2009).



The Maui DWS monthly production logs for the three Upcountry water systems is illustrated in Figure 13-16. 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 13-16. Monthly production of water treatment facilities in the Upcountry System (Source: Maui DWS, 2009).

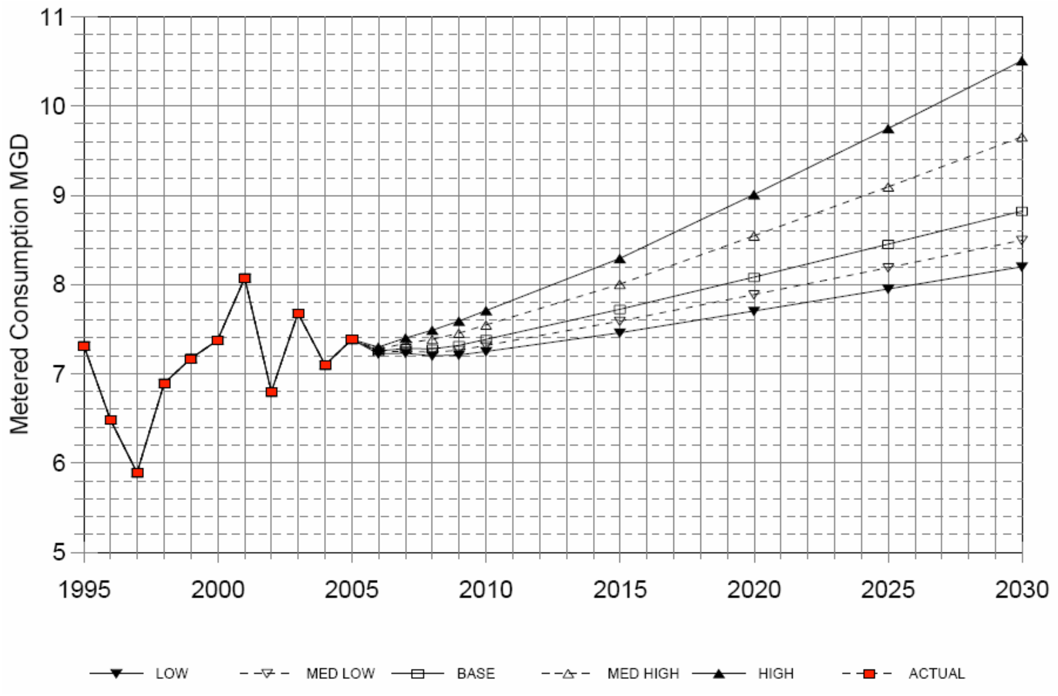


Future Demands

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 13-17, 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 an expected increase of 4,374 additional 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 13-17. 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.

The number of DHHL homesites is also expected to increase; therefore, increasing the surface water demand. Currently, there are 676 residential units in Waiohuli with an additional 800 lots planned in development. The estimated water needs for the new development is 0.72 million gallons per day (PR-2009-18, 96.0). The DHHL also recently completed the development of 66 agricultural lots (about 75 acres) in Keokea an estimated water demand of 0.23 million gallons per day (PR-2009-18, 96.0). Irrigation water will be provided by the new non-potable water line that would draw water from the Kahakapau Reservoirs to serve the agricultural needs of the Upper Kula region (PR-2009-18, 58.0). The Hawaii Farm Bureau Federation together with the Maui County Farm Bureau is working with NRCS to develop this new water line that originates from the Olinda WTF to Keokea, a distance of 9.4 miles with 15 miles of lateral service line (PR-2009-18, 17.0). The system is designed to deliver 3 million gallons per day and services 473 acres (DOA, 2009b). 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 13-18 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. In addition, the new upcountry water line that is under construction is planned to serve 473 acres of agricultural lands. Limiting water supply to this line is estimated to produce approximately $2 million (1997 dollar) in sconomic loss (DOA, 2009b).
- **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 13-18. A simplified schematic of the Maui DWS Upcountry System and the EMI System, and the system users.

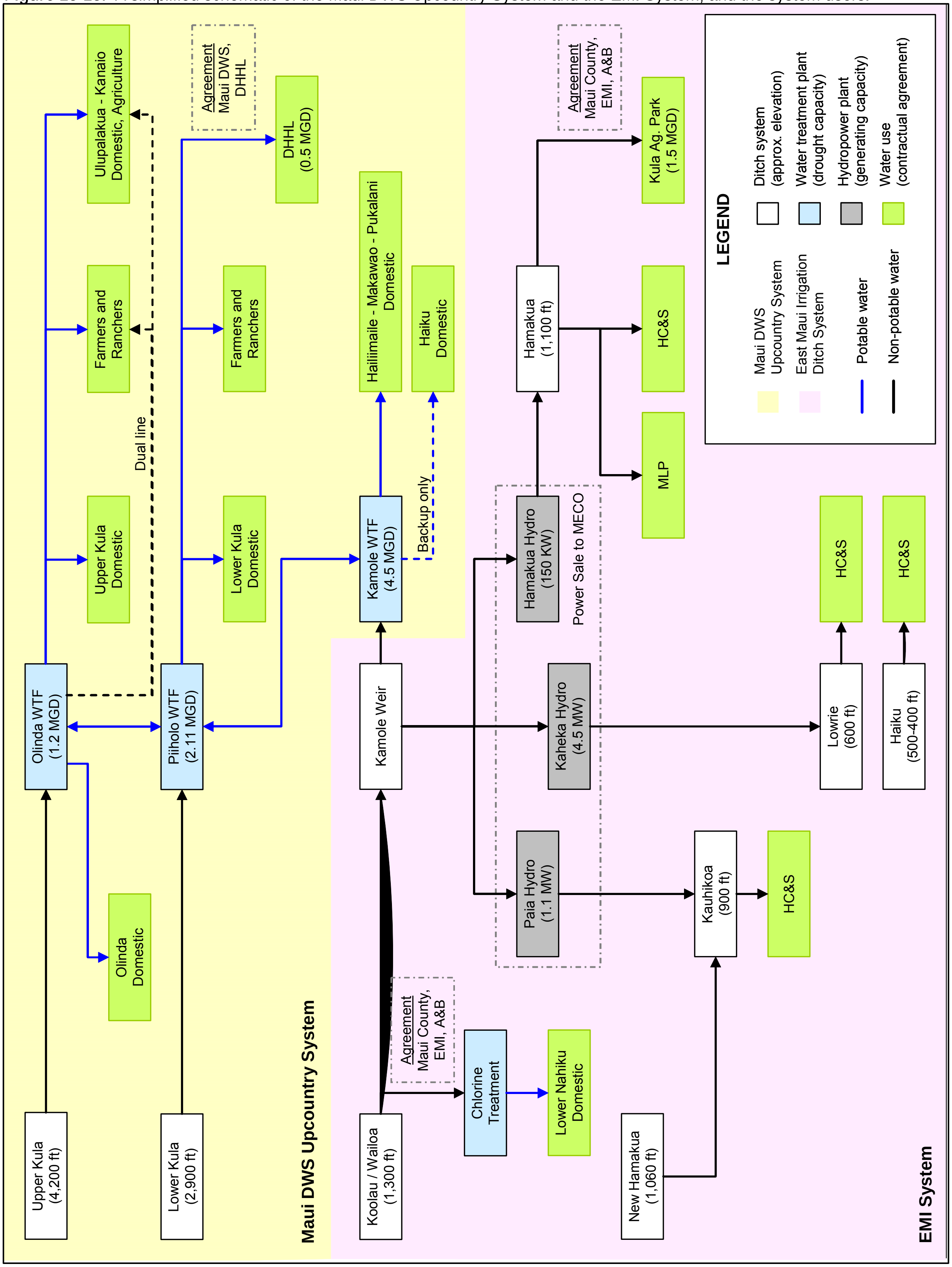
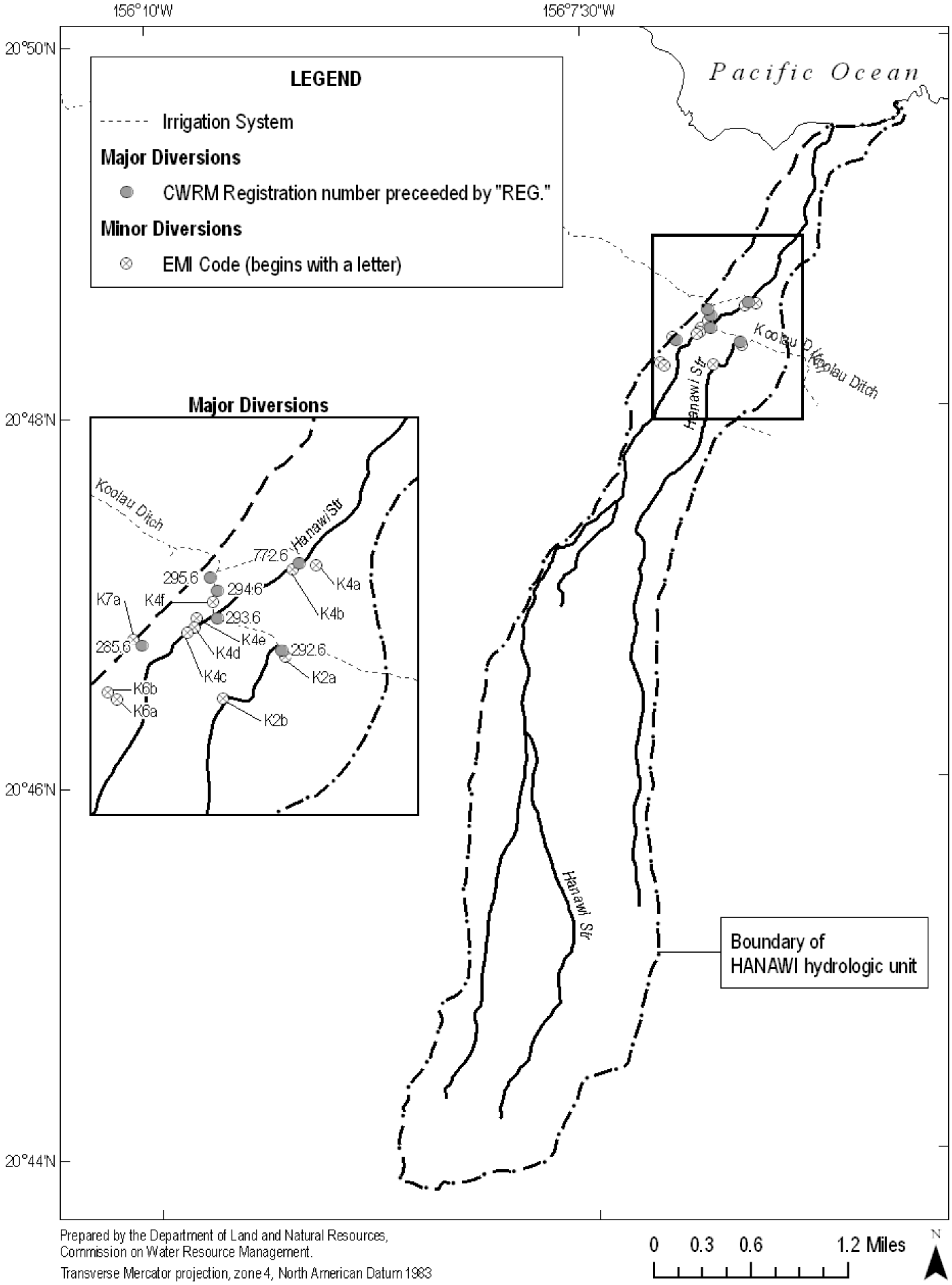


Figure 13-19. All registered diversions and EMI minor diversions identified in the Hanawi hydrologic unit (Source: East Maui Irrigation Company, 1970; State of Hawaii, Commission on Water Resource Management, 2008f; USGS, 2001b).



Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management.
Transverse Mercator projection, zone 4, North American Datum 1983

Figure 13-20. Potential agricultural land use for the Hanawi hydrologic unit based on the ALISH and ALUM classification systems (Source: State of Hawaii, Office of Planning, 1977; 1980; USGS, 2001b).

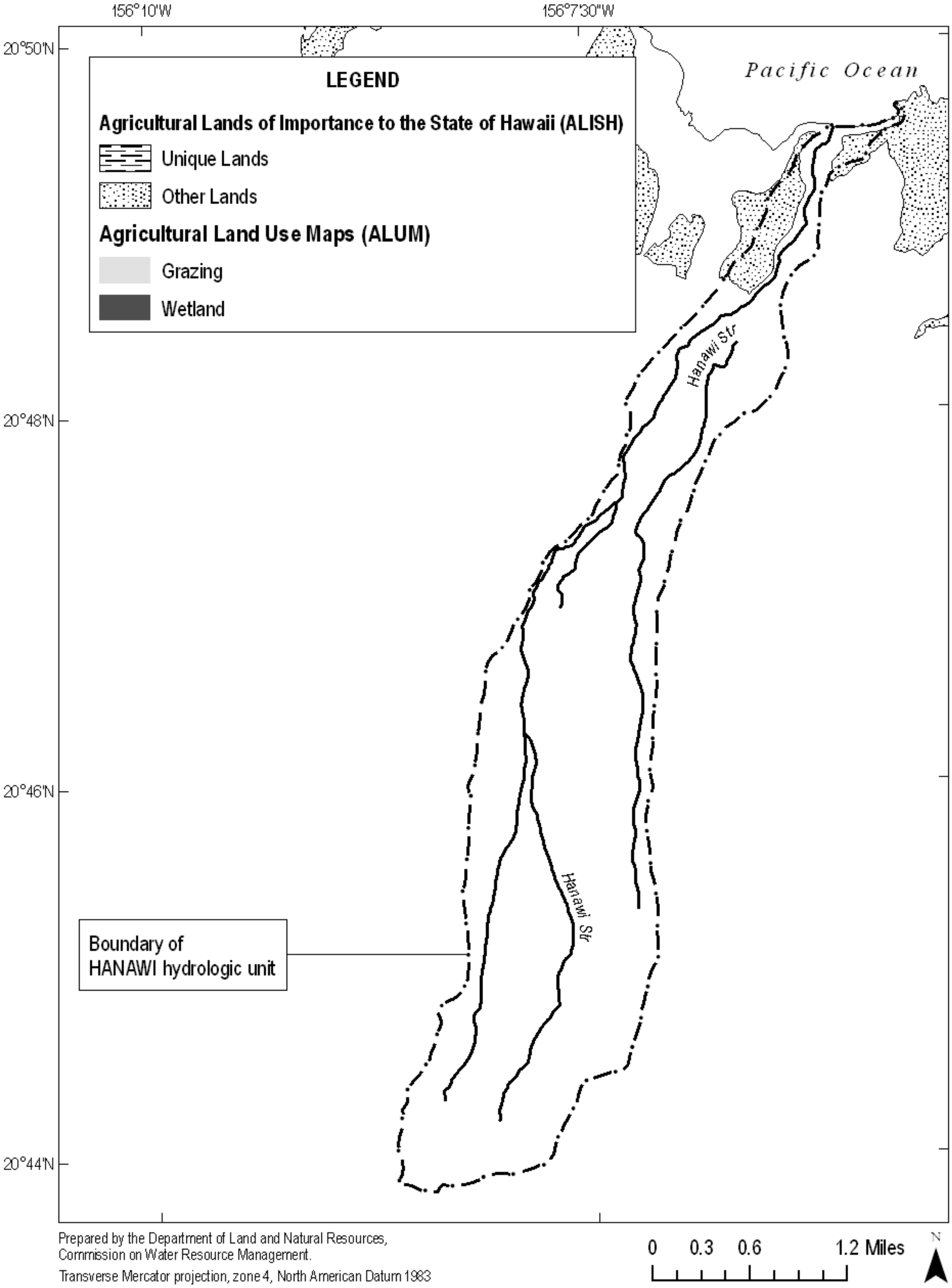
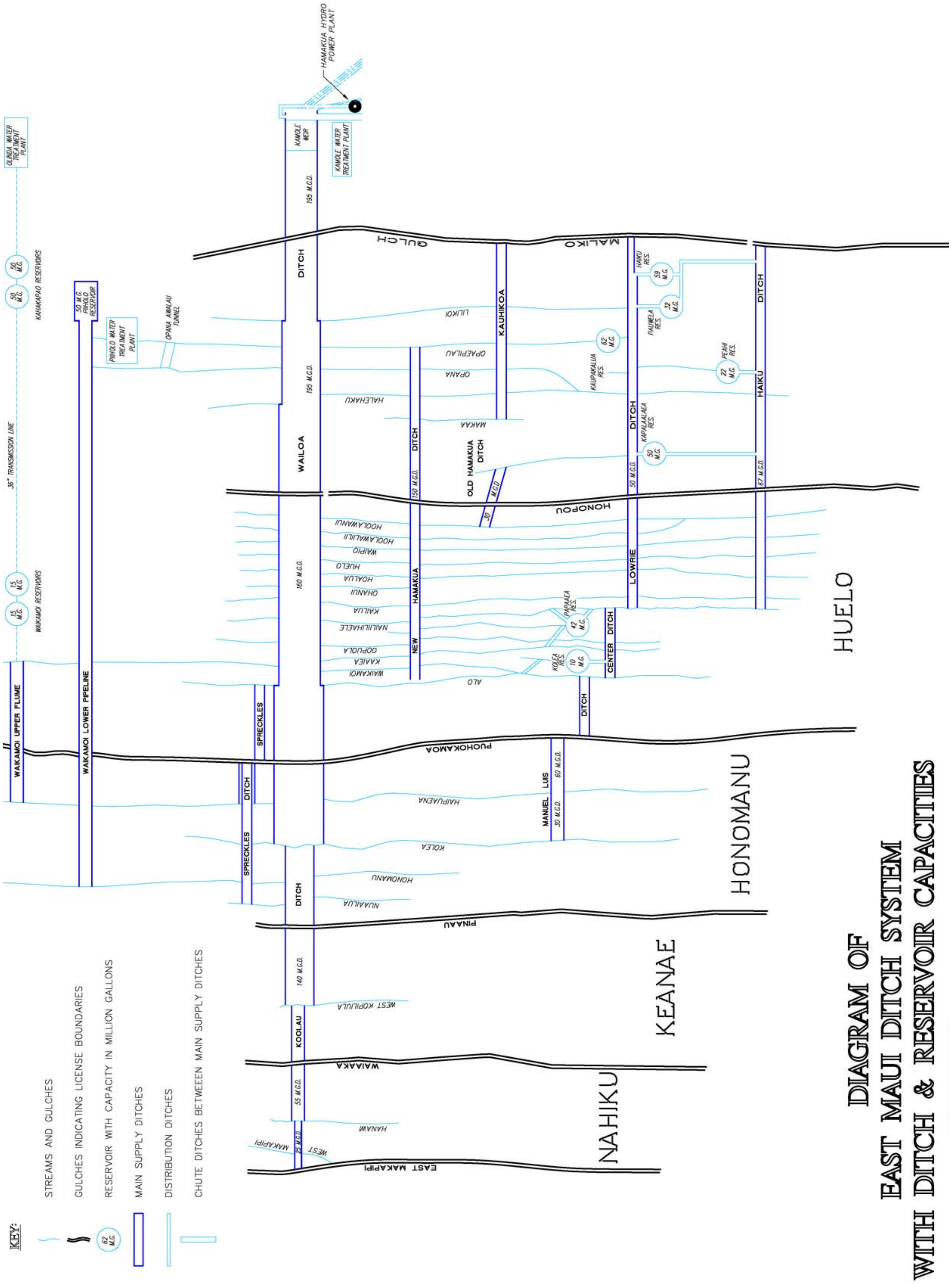


Figure 13-21. Simplified schematic of the EMI System.



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15.0 Appendices

Appendix A	Petition to Amend Interim Instream Flow Standards. Hanawi 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

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PETITION TO AMEND INTERIM INSTREAM FLOW STANDARDS

HANAWĪ 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 16508000, 16509000 Period of Record SEE ATTACHED.
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
Alan Murakami Petitioner
Attorney for Na Moku 'Aupuni o Ko'olau Hui

For Official Us
Date Received
Date Accepted

Hanawi Stream

The Hanawi Stream basin has been evaluated more thoroughly than any of the other subbasins in the study area (Meyer, in press). The stream is headed at 7,400 ft altitude 6.8 mi inland (plate 1). The stream rises steeply from sea level to 600 ft altitude 0.8 mi from the coast (a gradient of 770 ft/mi) and at this altitude the stream valley is incised 240 ft below the upland surface. The stream has eroded into the Honomanu Basalt for 2,000 ft from the coast and in Kula Volcanics to 5,000 ft from the coast (Stearns and Macdonald, 1942) The contact between the two geologic units has been arbitrarily located because in the Nahiku area, the exposed rocks of the Honomanu Basalt are petrographically transitional to the overlying Kula Volcanics and are more like the Kula Volcanics than the typical rocks of the Honomanu Basalt (Stearns and Macdonald, 1942). Hana Volcanics are found further upstream. Base flow is diverted by the Koolau Ditch at about 1,300 ft altitude (table 4).

Two surface-water gaging stations have been operated on Hanawi Stream by the USGS (table 2, plate 1). The upstream gaging station (5080), that records flow upstream of the Koolau Ditch, had a minimum flow of 0.58 Mgal/d and an average annual base flow of 3.66 Mgal/d (table 2, fig. 15R). The downstream gaging station (5090) records streamflow at 500 ft altitude. Streamflow at this altitude includes water discharging at Big Springs, and Hanawi Springs 1 and 2 (plate 1). The lowest recorded streamflow during the 17 years that the gaging station was operated was 8.21 Mgal/d (table 2). The estimate of average annual base flow is by far the largest in the study area, about 12.99 Mgal/d. All of this base flow is gained between the Koolau Ditch at 1,300 ft altitude and the gaging station at 500 ft altitude.

Independent sets of streamflow measurements were made five times, twice as part of this study (table 19). The measurements show flow during extended dry periods as high as 2,120 ft altitude in the stream channel. On the days of measurement, flow at the upstream gaging station ranged from about 1 to 6 Mgal/d. Between 1,300 ft and 1,000 ft altitude, the stream had small gains (1 Mgal/d) and then gained substantially (6 to 7 Mgal/d) downstream to 620 ft altitude. Between 620 ft and 550 ft altitude, additional gains of 4 to 8 Mgal/d were measured. Downstream to about 50 ft altitude, an additional 1 to 2 Mgal/d of flow was gained, but two sections that lost flow were measured in this reach. Between 420 ft and 190 ft altitude, the streamflow decreased by about 6 percent and between 120 ft and 50 ft altitude streamflow decreased by about 2 percent. The downstream measurement site for each respective stream section was considered only fair by the USGS personnel making the measurements because the streambed consisted of cobbly alluvium that probably allowed a part of the streamflow to bypass the measurement site (R.A. Fontaine, USGS, oral commun., 1998). Therefore, the apparent loss of streamflow in these sections is probably not related to actual ground-water/surface-water interaction but may instead be attributed to the difficulty in measuring all of the water flowing in the stream channel.The total flow in Hanawi Stream on July 26, 1994 was estimated to be 19.6 Mgal/d, all of which is assumed to be base flow (table 19).

A water budget for the entire Hanawi Stream drainage basin to the coast has been estimated (Shade, 1999). Water-budget estimates for the other stream subbasins in the study area included only the area upstream of the upstream gaging station on each respective stream. Total recharge to the basin was estimated to be 38.1 Mgal/d, 61 percent of which discharges into the stream or the Koolau Ditch crossing the basin (fig. 20); the remaining 39 percent discharges to the ocean. Sixty-two percent of the ground-water discharge to the stream is estimated to be between the altitudes of 1,300 ft and 550 ft where the stream channel is the most deeply incised.

Ground-Water Occurrence and Contribution to Streamflow, Northeast Maui, Hawaii, by Stephen B. Gingerich, U.S. Geological Survey, Water-Resources Investigations Report 99-4090 (1999) at page(s) 58 - 61.

16508000 HANAWI STREAM NEAR NAHIKU

LOCATION.--Lat 20°48′37″, long 156°07′00″, Hydrologic Unit 20020000, on left bank 200 ft upstream from Koolau ditch intake and trail, 1.9 mi southwest of Nahiku, and 4.5 mi southeast of Keanae.

DRAINAGE AREA.--3.49 mi^2.

PERIOD OF RECORD.--January 1914 to January 1916, November 1921 to current year. Monthly discharge only April to June 1915, published in WSP 1319.

REVISED RECORDS.--WSP 1045: 1922-43(M). WSP 1569: Drainage area. WSP 1719: 1915(M), 1922, 1924-25, 1927, 1930-35, 1937, 1939-40, 1942-43.

GAGE.--Water-stage recorder. Datum of gage is 1,318 ft above mean sea level (by vertical angles). Prior to November 1, 1921, at site 50 ft downstream of gage at datum 0.12 ft lower.

REMARKS.--Records computed by Matt Wong. Records good. No diversion upstream of station.

AVERAGE DISCHARGE.--77 years (water years 1923-99), 24.0 ft^3/s (17,400 acre-ft/yr).

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, about 5,570 ft^3/s, January 18, 1916, gage height, 11.6 ft, present site and datum, from rating curve extended above 814 ft^3/s by physical model of station site; minimum, 0.90 ft^3/s, October 28 to November 1, 1984.

EXTREMES FOR CURRENT YEAR.--Peak discharges greater than base discharge of 1,700 ft^3/s and maximum (*):

Date	Time	Discharge (ft^3/s)	Gage height (ft)	Date	Time	Discharge (ft^3/s)	Gage height (ft)
Jan. 31	0445	*2,030	*7.08	No other peak greater than base discharge.			

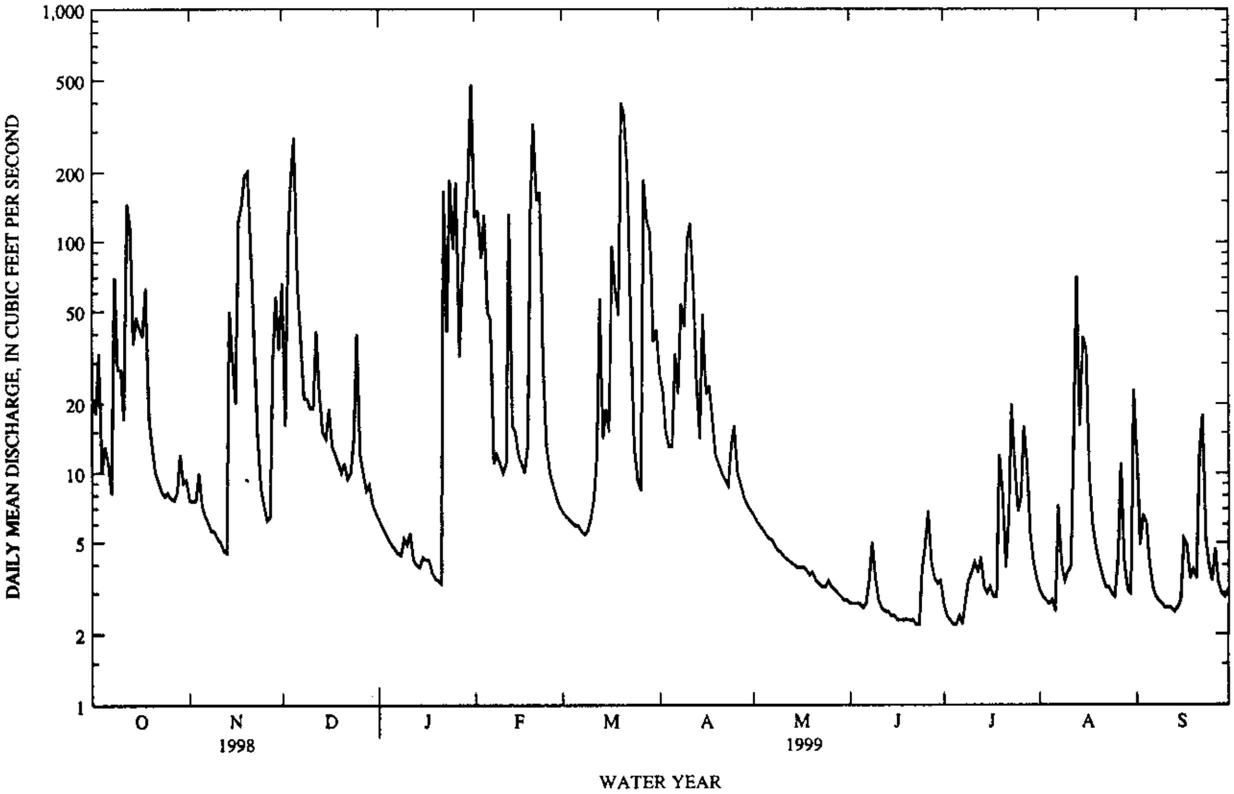
Minimum discharge, 2.0 ft^3/s, July 4, 7.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1998 TO SEPTEMBER 1999
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	21	7.6	66	6.3	128	6.8	27	6.6	2.7	2.7	3.1	12
2	18	7.5	16	5.9	137	6.5	23	6.2	2.7	2.4	2.9	4.9
3	33	7.6	97	5.5	85	6.3	15	5.9	2.7	2.3	2.8	6.6
4	10	10	184	5.2	131	6.1	13	5.7	2.7	2.2	2.7	6.1
5	13	7.2	283	4.9	50	5.9	13	5.4	2.6	2.2	2.8	4.1
6	11	6.5	65	4.7	46	5.9	33	5.2	2.7	2.4	2.5	3.2
7	8.1	6.1	40	4.5	11	5.6	22	5.1	3.4	2.2	7.2	2.9
8	70	5.6	21	4.4	12	5.4	54	4.8	5.0	2.8	4.0	2.8
9	28	5.6	21	5.2	11	5.6	43	4.6	3.5	3.4	3.4	2.7
10	28	5.2	19	4.9	10	6.3	102	4.5	2.8	3.7	3.7	2.6
11	17	5.0	19	5.5	11	7.7	121	4.3	2.6	4.1	3.9	2.6
12	145	4.6	41	4.2	132	12	62	4.2	2.5	3.7	13	2.6
13	115	4.5	22	4.0	16	57	24	4.1	2.5	4.3	71	2.5
14	36	50	15	3.9	15	14	14	4.0	2.4	3.2	16	2.6
15	47	31	14	4.3	12	19	49	3.9	2.4	3.0	39	2.8
16	42	20	19	4.2	11	15	22	3.9	2.3	3.2	34	5.2
17	39	123	13	4.2	10	96	24	3.9	2.3	2.9	9.7	4.9
18	63	144	12	3.7	13	61	17	3.8	2.3	2.9	5.9	3.5
19	17	193	11	3.5	134	48	12	3.6	2.3	12	4.8	3.8
20	13	201	10	3.4	325	401	11	3.7	2.3	8.4	4.1	3.5
21	10	85	11	3.3	151	352	10	3.4	2.3	3.9	3.6	12
22	9.1	37	9.4	166	164	194	9.4	3.3	2.2	6.4	3.2	18
23	8.3	15	10	41	29	41	8.8	3.2	2.2	20	3.2	5.2
24	7.9	8.6	14	185	13	13	13	3.2	3.8	11	3.0	4.0
25	8.2	7.2	40	93	10	9.2	16	3.4	4.8	6.8	2.9	3.4
26	7.7	6.2	12	181	8.9	8.4	10	3.2	6.8	7.8	4.2	4.7
27	7.6	6.4	10	32	7.9	185	8.9	3.1	4.1	16	11	3.3
28	8.3	30	8.4	71	7.2	123	7.9	3.0	3.5	11	4.1	3.0
29	12	58	8.9	123	---	110	7.3	2.9	3.3	5.4	3.1	2.9
30	9.0	34	7.3	188	---	37	6.9	2.8	3.4	4.1	3.0	3.1
31	9.3	---	6.7	480	---	42	---	2.8	---	3.5	23	---
TOTAL	871.5	1132.4	1125.7	1655.7	1691.0	1905.7	799.2	127.7	91.1	169.9	300.8	141.5
MEAN	28.1	37.7	36.3	53.4	60.4	61.5	26.6	4.12	3.04	5.48	9.70	4.72
MAX	145	201	283	480	325	401	121	6.6	6.8	20	71	18
MIN	7.6	4.5	6.7	3.3	7.2	5.4	6.9	2.8	2.2	2.2	2.5	2.5
AC-FT	1730	2250	2230	3280	3350	3780	1590	253	181	337	597	281
STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1914 - 1999, BY WATER YEAR (WY)												
MEAN	14.9	30.0	32.2	30.3	31.0	41.4	36.5	20.3	11.4	16.2	16.9	11.7
MAX	101	110	129	123	182	235	161	68.2	61.2	62.0	66.2	52.3
(WY)	1942	1991	1947	1979	1969	1980	1989	1987	1997	1997	1957	1914
MIN	1.15	2.99	2.71	1.87	2.25	2.10	2.75	2.82	2.16	2.42	2.40	1.88
(WY)	1985	1990	1981	1977	1983	1983	1992	1945	1981	1926	1973	1974

16508000 HANAWI STREAM NEAR NAHIKU--Continued

SUMMARY STATISTICS	FOR 1998 CALENDAR YEAR		FOR 1999 WATER YEAR		WATER YEARS 1914 - 1999	
ANNUAL TOTAL	7678.6		10012.2			
ANNUAL MEAN	21.0		27.4		24.0	
HIGHEST ANNUAL MEAN					52.6	1969
LOWEST ANNUAL MEAN					7.59	1926
HIGHEST DAILY MEAN	283	Dec 5	480	Jan 31	1610	Jan 25 1948
LOWEST DAILY MEAN	1.9	Mar 20	2.2	Jun 22	.90	Oct 31 1984
ANNUAL SEVEN-DAY MINIMUM	2.0	Mar 16	2.3	Jun 17	.96	Oct 25 1984
ANNUAL RUNOFF (AC-FT)	15230		19860		17400	
10 PERCENT EXCEEDS	49		71		52	
50 PERCENT EXCEEDS	10		7.3		7.2	
90 PERCENT EXCEEDS	2.7		2.8		2.8	



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.

Ground-Water Occurrence and Contribution to Streamflow, Northeast Maui, Hawaii, by Stephen B. Gingerich, U.S. Geological Survey, Water-Resources Investigations Report 99-4090 (1999) at page(s) 14.

Table 19. Streamflow, temperature, and specific conductance in Hanawi Stream, northeast Maui, Hawaii

[ft, feet; Mgal/d, million gallons per day; °C, degrees Celsius; µS/cm, microsiemens per centimeter; --, not determined; <, less than; altitudes estimated from U.S. Geological Survey topographic map, Nahiku quadrangle; 1974 and 1975 data from U.S. Geological Survey (1976); 1985 data from Chinn and others (1986); 1994 daily-discharge data from Matsuoka and others (1995); 1995 daily-discharge data from Fontaine and others (1997); all other data is unpublished in files of U.S. Geological Survey, Hawaii District office; gaging-station number is preceded by 16 and ends in 00]

Station number	Stream name	Altitude (ft)	Date	Streamflow (Mgal/d)	Cumulative streamflow without diversion, July 26, 1994 (Mgal/d)	Water temperature (°C)	Water specific conductance (µS/cm)	Comments
Hanawi 6	Hanawi	50	7/26/94	--	19.6[a]	--	--	
			2/22/95	14.61	--	17.6	198	
Hanawi 8	Hanawi	120	10/9/74	12.28	--	--	--	
			5/21/75	14.22	--	--	--	
			7/26/94	--	20.0[a]	--	--	
			2/22/95	14.93	--	18.9	197	
Hanawi 10	Hanawi	190	7/26/94	--	17.6[a]	--	--	
			2/22/95	12.54	--	19.2	181	
Hanawi 13	Hanawi	420	10/9/74	11.63	--	--	--	
			5/22/75	12.3	--	--	--	
			7/26/94	--	18.4[a]	--	--	
			2/22/95	13.4	--	--	--	
5090	Hanawi	550	10/9/74	9.0	--	--	--	Daily mean at gaging station
			5/22/75	10.3	--	--	--	
			11/2/84	11.6	--	--	--	
			7/26/94	12.7	17.8	--	--	
			2/22/95	12.8	--	--	--	
Hanawi 23	Hanawi	620	11/2/84	9.7	--	--	--	
			7/26/94	7.5	12.7	--	--	
			2/22/95	7.4	--	--	--	
Hanawi 27a	Hanawi	920	5/21/75	0.36	--	--	--	
Hanawi 27	Hanawi	1,020	7/26/94	1.2	6.3	21.0	40.0	
			2/22/95	0.52	--	19.4	48.7	
Hanawi 29	Hanawi	1,130	7/26/94	0.78	5.9	21.3	40.0	
5080	Hanawi	1,318	10/9/74	0.97	--	--	--	Daily mean at gaging station; upstream of Koolau Ditch diversion
			5/21/75	3.0	--	--	--	
			11/2/84	0.71	--	--	--	
			7/26/94	5.2	5.2	--	--	
			7/28/94	5.8	--	--	--	
			2/22/95	1.5	--	--	--	
Hanawi 38	Hanawi	2,240	7/28/94	1.8	1.8	--	--	Downstream of confluence with tributary
Hanawi 40	Hanawi (east unnamed tributary)	2,280	7/28/94	0.56	0.56	--	--	
Hanawi 45	Hanawi (west branch)	3,500	7/28/94	0.02	0.02	20.9	16	
Hanawi 46	Hanawi (west branch)	3,580	7/28/94	< 0.01	< 0.01	19.5	15	
Hanawi 48	Hanawi (east branch)	3,550	7/28/94	0.06	0.06	21.4	17	
Hanawi 51	Hanawi (west branch)	4,100	7/28/94	0.01	0.01	18.5	12	

[a] Estimated on the basis of February 22, 1995 measurements

Ground-Water Occurrence and Contribution to Streamflow, Northeast Maui, Hawaii, by Stephen B. Gingerich, U.S. Geological Survey, Water-Resources Investigations Report 99-4090 (1999) at page(s) 60.

HANAWI

```
                                          DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16508000
Hanawi Stream near Nahiku, Maui, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN

                                                DURATION TABLE OF DAILY VALUES
                                                    FOR PERIOD OCT TO SEP

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
   RANGE


1923 1923                                 14  45  67  45  48  35  30  12  14  21   8   2   1   2   5   4   3       9
1924 1924                             11  51  49  45  47  35  25  20  23  10  11   8   7   2   1   5   2   5   1   2   4       2
1925 1925                             14  16  55  30  51  40  38  34  18  10   4  14  13   3   3   5   6   1   4   2   2   1               1

1926 1926                         95  55  47  33  45  26  16  12   4   5   6   8   2   4   2   2       1   2
1927 1927                             28  40  31  44  34  46  52  31  15   5   6   6   6   2   5   8   2   1   1       2
1928 1928                              7  21  36  37  43  48  40  34  26  10  12  12  15   4   4   4   1   5   3   4
1929 1929                             16  30  42  54  51  35  25  21  22  12   4   7   8   9   6   9       4   7       2   1
1930 1930                             25   9  17  15  29  39  50  33  29  17  21  15  12   8   6   8   7   6   9   4   2   1   2   1

1931 1931                                 26  66  59  37  50  30  24  12   9  18   9   4   4   1   5   4       4   1   1           1
1932 1932                                  6  14  27  40  46  59  37  28  16  18  14   6   6  11  10  10   4   7   3   1   1   2
1933 1933                         28  60  44  44  32  31  29  23  18   9   9  10   8   5   7   3       1   1   1   1               1
1934 1934                  1  62  61  15  16  22  18  27  19  20  25  12  11   9   7   8   5  10   5   3   3   3       1           1           1
1935 1935                                 16  47  51  50  33  39  45  25  10   7   9   5   1   4   7   4   3   2   2   1   1       1   1       1

1936 1936                     18  31  44  24   9  12  26  42  32  25  30  11  11  11  15  10   6   6   1   1   1
1937 1937                                     12  17  31  22  36  52  36  27  19  19  18   8  15  11   8  12   3   6   6   3   1   1   2
1938 1938                                  5  31  37  45  53  46  25  17  15  17  10  13  10  10   7   7   1   2   6   5   1       1   1
1939 1939                                  5  11  37  41  61  43  49  15  15  12  15  12  12   9   9   6   5   2   3   1       1           1
1940 1940                         50  48  55  39  30  24  25  20  14  16  10   3   6   4   5   3   4   4   1   3       1           1

1941 1941                          6  16  22  52  50  45  36  35  21  24   9   5  12   8   7   3   4   4           2   2       2
1942 1942                          6  10  20  38  34  37  32  41  28  19  12  14   7   7   4   4   6   7   9  11   5   5   4   1       1   2       1
1943 1943                         18  37  46  47  33  31  31  31  17  14  12  11   6   6   6   5   1   4   1   5   1   1           1
1944 1944                     24  70  31  32  51  40  29  18  17   5  14   6   8   3   5   1   3   3   4   1       1
1945 1945                      8  61  39  35  24  21  27  39  28  16  15   8   7   8   7   7   2   3   2   2   2   2   1       1

1946 1946                          8  39  57  60  35  23  15  14  12  19  12  11   8  12   7   7   7   4   4   4   4           1   1   1
1947 1947                          8  15  32  60  57  32  27  23  24  14  12  11   7   8   4   3   7       4   6   4   3   1       1       1   1
1948 1948                              4  30  41  62  35  32  33  17  12  11  16  14   3   8   7   9  10   4   3   6   1   2   2   2                   2
1949 1949                             39  50  49  37  35  24  23  17  11   4  11  15   7   9   4   9   3   6   9       2           1
1950 1950                          9  25  44  42  47  32  21  22  17   8  12  18   9  13  12   6   7   7       5   3   1   1   3       1

1951 1951                          3  61  54  44  33  36  30  20  11   5   8   7   8   8   6   5   8   1   2   3   5   2   4   1
1952 1952                         10  20  17  30  55  49  37  31  23  16  11  11  13   7   9   2   3   9   3   5       4       1
1953 1953                      3  38  55  67  36  29  25  20  19  17   7   8   3   4   1  11   5   5   7   1       1   2   1
1954 1954                     10  45  25  36  32  20  32  24  26  20  16   9  12  12  11   6  10   6   5   1   3   2   2
1955 1955                          9  13  10  48  31  41  31  31  28  23  16  13   4   7  11  13   8   4   3   6   3   5   3   2   1       1
```

```
                                                    DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM


STATION ID - 16508000
Hanawi Stream near Nahiku, 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
1956 1956                 9 41 36 18  33  36  31  35  13  24  11  11  14   7  11   8   7   3   3   2   3   3  2     2  2     1
1957 1957                   49 50 51  34  40  25  19  13  18   6  13   3   5   6   6   4   6   5   3   2   2  3  1  1
1958 1958                   11 26 50  37  43  33  22  14  25  10  16  12  15  15   4   6   4   4  10   3   2     2     1
1959 1959                   16 45 41  51  57  26  22  16  11   8  10  10   6   6   7   7   5   7   2   2   5  2  1  1  1
1960 1960              4 18 34 45 47  42  34  18  13   4  14  14  12  13   8   8   3  13   6   3   4   1   1  2  2        2  1

1961 1961              5 30 68 63 35  38  20  17  13  10   7   6  12  10   3   4   3   3   2   6   3   1   1  1     1  2     1
1962 1962             34 30 65 55 32  32  18   8  11  11   9  10   9   9   6   3   1   5   1   6   4   1   2  1  2
1963 1963           5 69 45 23 22 22  38  19  16  19  15  11   7   8   8   3   9   6   1   6   6   2   2      2  1
1964 1964                    4 36 49  56  48  43  27  18   7   9  14  10   8   7   1   7   4   6   6   1   2  2  1
1965 1965                16 19 46 71  43  40  23  12  11  13   7   8  10   8   6   4   5   6   1   6   3   1  1  3  2

1966 1966             21 26 25 33 44  53  30  26  23  15   6   6  13  11   7   3   4   4   3   3   1   5   1  1  1
1967 1967                 8 31 34 49  49  29  35  22  13  14  12   7  12   4   5   9   6   4   7   3   4   3  2  2  1
1968 1968              5 24 49 50 35  29  20  24  22  17  11  12   6   5   6   5   6   5   7  11   7   2   4  2     1  1
1969 1969                32 20 29 25  14  20  28  28  25  17  11  12  11  10   8   9  13  12   7   7   7   7  3  1  3  2  1  1  2
1970 1970                 2 50 44 39  38  30  33  22  21  13  11   9   8  10   6   5   6   1   4   3   4   2  1  2        1

1971 1971             22 36 30 29 30  29  23  26  21  14  14  11   9   8  11   5   4   8   6   6   7   7   3  2  1  1     2
1972 1972              6 33 67 59 39  36  27  23  12   9   8   8   9   3   5   5   3   2   3   3   2   3      1
1973 1973             29 22 52 45 39  32  21  18  16  16   9   9  10   9   5   4  10   6   4   2   3   1   1  1     1
1974 1974           5 30 35 72 42 32  25  20  21  11   6   8   3   7   7   7   3   7   3   3   6   1   2   5  1  2              1
1975 1975        1 20  2 16 69 34 21  32  34  19  26  16  11  13   9   7   4   5   3   5   4   6   1   1   2  2  1  1

1976 1976                28 65 57 38  30  21  20  22  12  12  10  13   6   1  10   4   3   4   4   4          1           1
1977 1977          20 30 20 46 47 40  26  19  19  17   9  15   5   7   6   6   5   2   6   6   4   4   4   1     1
1978 1978              8 59 41 43 31  29  27  34  17  11  16  10   8   8   4   7   2       4   2   2       2
1979 1979                19 33 39 46  50  25  22  19  13  13  15  12   7   9  10   3   4   6   3   5       4  1  4  1  2
1980 1980              1 13 28 37 19  31  29  38  24  13  14  13  14  11  11   8  10   6   6   8   3   5   6  6  2  1  4  4  1

1981 1981          10 96 79 61 27 27  14   9   8   6   4   2   3   5   2   1   1   1   3       2   2       1           1
1982 1982                   24 23 22  21  44  28  24  21  26  10  16  16  11  10  11  10   9  10   5   6   6  2  3     4  2     1
1983 1983           4 51 21 19 24 37  46  28  33  21  16  15  10   5   4   6   6   5   3   5   2   3                 1
1984 1984           3 22 34 61 45 37  27  25  22  18  10  10   7   6   6   3   7   6   7   4   4   2
1985 1985     10 26 10 39 23 27 31 18  23  22  19  16  12  11   9  12   8   5   4   6   5   9   2   6   3   3  3  1  1  1

1986 1986           7 16 28 30 40 36  25  22  25  27  18  13  13   9   6  14   2   6   5   6   3   4   1       2  1  2  1     2  1
1987 1987                12 38 32 31  37  32  31  31  12  15  11   8   8   6  12   6  13   4   3   3   8   6  1  2  2  1
1988 1988              7 23 16 35 34  45  51  31  25  11  10   9   7   8   8   4   7   8   6   8   4   1   3  2  1  1     1
1989 1989                 2 11 19 37  32  33  25  35  19  21  11  17   6  11  13   8  14   4   6  10   8   8  4  4  4  1  1  1
1990 1990             11 23 21 28 25  23  45  35  31  21  16   7  17   8   4   5   7  10   5   3   7   2   4  3  1  2  1
```

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                                        DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16508000
Hanawi Stream near Nahiku, 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
1991 1991                  1 17 33 31  44  32  36  26  18  22  19  14   7   4   9   9   8   4   3   3   8  4  1  1  4  2  4  1
1992 1992               28 80 54 28 21  19  10  14  26  13  18   7   9   8   4   4   3   2   4   2   4   5  1  2
1993 1993                 30 23 41 43  36  48  36  12  12  13   6   6   9  13   8   5   7   1   3   4   4  2  2  1
1994 1994                  2  9  6 15  34  59  42  40  18  18  16  11  15  12  13   8  11   6   7   5   9  3  2     1  1  1     1
1995 1995               17 24 33 41 45  39  22  29  14  13  15   8   7  14   9   6   9  10   3   3   1   2           1

1996 1996                 15 48 42 47  56  48  22  17   7  11  11   5   9   5   7   1   5   1           3  1  1  3     1
1997 1997               16 27 29 28 64  25  19  16  14  15  16   4  18   8   9  12  11   7   9   5   3   2  3  2  2        1
1998 1998               12 24 29 27 41  21  21  14  44  23  23  14  11  15  10  12   5   4   3   4   2   2  2     2
1999 1999                 26 44 41 26  31  25  19  32  19  14  10   6  10  11   8   8   2   5  10   5   8     2  2  1
2000 2000               14 46 47 42 43  37  24  20   8  13  15   9   7   6   4   8   3   1   3   3   4   4  2  2     1


CLASS   VALUE   TOTAL   ACCUM   PERCT         CLASS   VALUE   TOTAL   ACCUM   PERCT         CLASS   VALUE   TOTAL   ACCUM   PERCT
  1      0.00       0   28490  100.00          13     10.00    1981   10560   37.07          25    142.00     287     987    3.46
  2      0.90      10   28490  100.00          14     13.00    1424    8579   30.11          26    177.00     222     700    2.46
  3      1.10      27   28480   99.96          15     16.00    1191    7155   25.11          27    220.00     169     478    1.68
  4      1.40      85   28453   99.87          16     20.00     798    5964   20.93          28    274.00      96     309    1.08
  5      1.70     720   28368   99.57          17     24.00     823    5166   18.13          29    342.00      76     213    0.75
  6      2.20    1597   27648   97.04          18     30.00     701    4343   15.24          30    426.00      52     137    0.48
  7      2.70    2401   26051   91.44          19     38.00     586    3642   12.78          31    531.00      37      85    0.30
  8      3.40    2656   23650   83.01          20     47.00     522    3056   10.73          32    662.00      27      48    0.17
  9      4.20    2880   20994   73.69          21     59.00     429    2534    8.89          33    824.00      12      21    0.07
 10      5.20    2783   18114   63.58          22     73.00     464    2105    7.39          34   1030.00       7       9    0.03
 11      6.50    2536   15331   53.81          23     91.00     349    1641    5.76          35   1280.00       2       2    0.01
 12      8.10    2235   12795   44.91          24    114.00     305    1292    4.53
```

```
DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16508000          Hanawi Stream near Nahiku, 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       DATA
EQUALED OR EXCEEDED        VALUE

       95.0                  2.38       (LOG =  0.37701)
       90.0                  2.82       (LOG =  0.45018)
       85.0                  3.23       (LOG =  0.50985)
       80.0                  3.66       (LOG =  0.56330)
       75.0                  4.09       (LOG =  0.61146)
       70.0                  4.56       (LOG =  0.65943)
       65.0                  5.06       (LOG =  0.70411)
       60.0                  5.68       (LOG =  0.75408)
       55.0                  6.34       (LOG =  0.80222)
       50.0                  7.19       (LOG =  0.85644)
       45.0                  8.08       (LOG =  0.90762)
       40.0                  9.29       (LOG =  0.96798)
       35.0                 10.9        (LOG =  1.03708)
       30.0                 13.1        (LOG =  1.11619)
       25.0                 16.1        (LOG =  1.20707)
       20.0                 21.3        (LOG =  1.32906)
       15.0                 30.8        (LOG =  1.48845)
       10.0                 51.8        (LOG =  1.71398)
        5.0                105.3        (LOG =  2.02230)

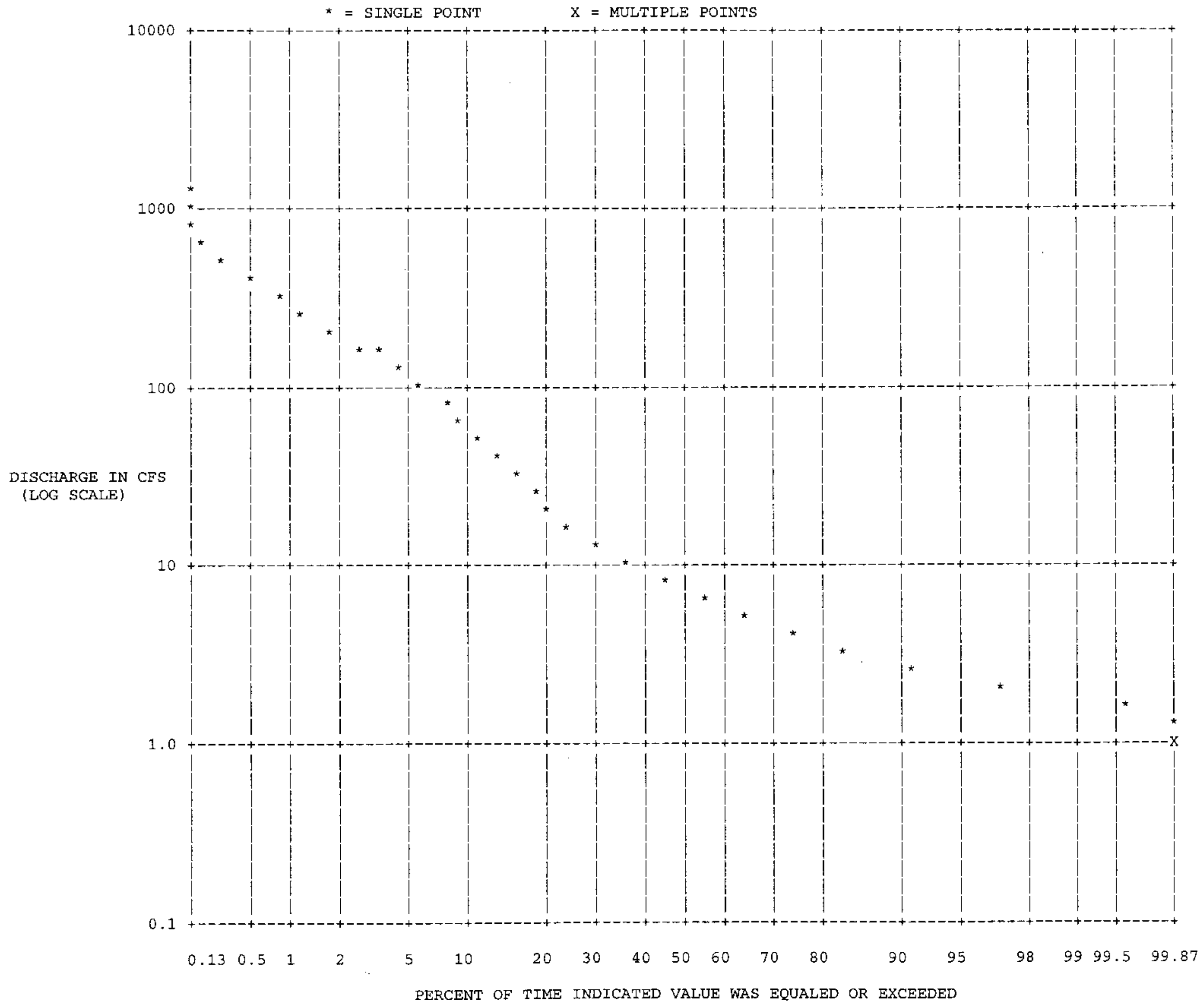
MEAN OF LOGS =  0.95146

STANDARD DEVIATION OF LOGS =  0.44224 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION   =  0.46480

COEFFICIENT OF SKEW        =  0.96937
```

LOG-NORMAL DURATION PLOT FOR PERIOD OCT TO SEP (YEARS 1914 - 2001)
STATION ID: 16508000 Hanawi Stream near Nahiku, Maui, HI
PARAMETER CODE - 00060 DISCHARGE
STATISTIC CODE - 00003 MEAN



```
                                    DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM


STATION ID - 16508000
Hanawi Stream near Nahiku, 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    3.40 72    3.77 76    3.89 73    4.06 71    4.95 66    8.72 61    8.92 44    9.15 40    12.7 30
1924 1924    2.90 65    2.97 66    3.13 66    3.29 62    3.64 53    5.26 43    7.63 38    7.12 28    11.0 27
1925 1925    2.90 66    2.90 65    3.31 69    3.41 65    4.54 63    5.43 44    9.21 47    11.6 49    19.3 58

1926 1926    2.20 33    2.20 33    2.23 30    2.34 29    2.41 19    2.68  9    2.84  4    3.57  1    4.31  1
1927 1927    2.80 63    2.80 62    2.91 60    2.99 54    3.43 48    8.24 58    9.05 45    12.8 55    13.6 34
1928 1928    3.10 68    3.23 69    3.27 67    3.49 68    4.30 62    9.98 66    14.0 64    16.2 68    16.2 42
1929 1929    3.10 69    3.23 70    3.31 70    3.41 66    3.94 58    4.93 40    6.32 29    6.81 26    9.69 21
1930 1930    2.80 64    2.80 63    2.81 58    3.01 56    3.12 37    13.1 75    16.9 73    17.8 71    28.3 70

1931 1931    3.70 77    3.70 75    3.80 72    3.86 70    4.54 64    6.87 53    7.01 32    8.34 34    12.9 31
1932 1932    3.60 75    3.67 74    4.04 74    4.31 72    7.78 76    8.20 57    14.1 65    12.7 53    20.4 60
1933 1933    2.30 40    2.30 40    2.60 45    2.64 42    2.83 33    3.85 22    4.69 16    5.09 12    6.81  8
1934 1934    1.60  5    1.70 10    1.70 10    1.76 10    1.92  9    4.11 27    6.79 31    6.25 24    8.70 15
1935 1935    3.40 73    3.40 72    4.13 75    4.74 75    6.35 70    7.47 55    8.37 41    8.70 38    13.2 32

1936 1936    1.90 16    1.90 16    1.90 13    1.93 13    2.27 15    3.86 23    3.73  7    6.67 25    8.63 14
1937 1937    4.20 78    4.23 78    4.41 77    5.11 76    10.9 78    11.9 71    25.7 77    25.7 76    28.3 71
1938 1938    3.60 76    3.80 77    4.17 76    5.91 77    7.00 74    9.47 65    9.65 50    12.9 56    29.0 74
1939 1939    3.40 74    3.40 73    4.60 78    6.49 78    9.77 77    13.0 74    14.1 66    14.5 60    21.9 64
1940 1940    2.20 34    2.20 34    2.33 38    2.46 36    2.86 34    3.99 24    5.01 19    5.10 13    6.62  6

1941 1941    2.60 53    2.60 52    2.70 51    2.94 52    3.27 40    4.53 35    9.87 53    10.6 45    14.1 36
1942 1942    2.50 46    2.57 50    2.61 47    2.86 49    3.36 45    6.29 50    10.3 54    10.6 46    16.6 44
1943 1943    2.30 41    2.30 41    2.46 42    2.68 44    3.63 52    8.83 63    14.7 69    14.1 59    15.3 39
1944 1944    1.90 17    1.90 17    1.94 17    2.04 16    2.20 13    3.32 16    7.65 39    7.69 31    9.21 20
1945 1945    2.00 23    2.00 23    2.09 25    2.20 25    2.54.22    3.25 14    4.11  9    5.79 18    12.3 29

1946 1946    2.60 54    2.60 53    2.76 55    2.94 53    3.34 44    4.52 34    9.80 52    9.31 42    14.2 37
1947 1947    2.50 47    2.53 48    2.63 48    2.89 51    3.81 57    8.77 62    10.3 55    13.5 58    15.7 40
1948 1948    3.20 71    3.33 71    3.59 71    4.35 73    5.29 67    12.3 72    14.6 68    15.0 64    22.9 67
1949 1949    2.70 59    2.83 64    2.97 63    3.22 60    3.42 47    5.17 42    6.08 27    7.67 30    9.19 19
1950 1950    2.50 48    2.53 49    2.70 52    3.14 57    4.20 60    10.3 67    13.6 63    12.7 54    22.0 65

1951 1951    2.60 55    2.63 54    2.71 53    2.88 50    3.75 56    4.31 32    5.14 21    6.10 21    8.55 13
1952 1952    2.50 49    2.50 46    2.63 49    2.69 45    6.05 69    7.21 54    9.49 48    11.3 47    13.8 35
1953 1953    2.10 28    2.13 29    2.16 28    2.20 26    2.47 20    4.17 29    5.69 25    5.80 19    7.89 10
1954 1954    1.90 18    1.97 22    2.03 22    2.11 22    2.78 30    6.68 51    7.16 33    8.42 35    13.3 33
1955 1955    2.30 42    2.40 43    2.49 43    2.66 43    3.69 54    5.68 46    12.8 60    12.0 51    16.9 46

1956 1956    2.50 50    2.57 51    2.63 50    2.79 47    3.37 46    5.97 48    13.0 61    17.2 70    22.4 66
1957 1957    2.70 60    2.73 59    2,87 59    3.17 59    3.33 42    4.68 37    8.39 42    14.8 61    16.3 43
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                              DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16508000
Hanawi Stream near Nahiku, 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
1958 1958    3.00 67    3.03 67    3.11 65    3.38 64    6.65 72    14.1 76    13.2 62    15.3 67    17.9 54
1959 1959    2.70 61    2.73 60    2.91 61    3.31 63    4.94 65    6.70 52    10.5 56    11.9 50    17.0 47
1960 1960    2.10 29    2.13 30    2.23 31    2.41 32    2.72 27    4.21 31    7.26 34    8.85 39    22.9 68

1961 1961    2.10 30    2.13 31    2.23 32    2.56 39    2.96 35    4.90 39    5.02 20    6.17 23    14.5 38
1962 1962    1.80 13    1.87 14    1.93 15    2.01 15    2.33 16    3.55 19    4.86 17    4.58  7    5.94  2
1963 1963    1.60  6    1.63  8    1.69  9    1.74  9    1.87  5    3.32 17    4.36 12    5.22 15    6.03  4
1964 1964    3.10 70    3.10 68    3.29 68    3.83 69    4.21 61    7.92 56    8.14 40    9.30 41    15.9 41
1965 1965    2.20 35    2.20 35    2.27 34    2.41 33    2.80 31    6.27 49    9.10 46    9.70 43    17.9 55

1966 1966    1.70 11    1.70 11    1.80 11    1.88 12    2.09 11    3.30 15    4.60 15    5.53 17    6.49  5
1967 1967    2.50 51    2.50 47    2.54 44    2.71 46    3.53 50    8.40 59    11.5 58    15.2 66    19.7 59
1968 1968    2.00 24    2.00 24    2.09 26    2.21 27    3.70 55    5.71 47    6.09 28    6.16 22    18.5 56
1969 1969    2.20 36    2.23 36    2.29 36    2.34 30    2.56 23    14.9 77    17.4 74    20.4 74    31.9 76
1970 1970    2.50 52    2.63 55    2.74 54    2.79 48    3.61 51    4.63 36    11.8 59    13.3 57    21.2 62

1971 1971    1.90 19    1.93 20    1.97 19    2.08 19    2.72 28    3.16 13    3.40  5    3.60  2    17.6 51
1972 1972    2.00 25    2.03 26    2.16 29    2.45 35    3.01 36    4.20 30    5.70 26    7.39 29    11.9 28
1973 1973    1.70 12    1.73 12    1.84 12    1.86 11    1.94 10    2.35  4    3.45  6    4.25  5    7.97 11
1974 1974    1.60  7    1.60  4    1.63  6    1.68  5    1.88  6    2.64  6    4.41 14    4.76  9    17.7 52
1975 1975    1.30  2    1.37  2    1.41  2    1.48  2    3.19 38    4.00 25    4.15 10    5.12 14    7.75  9

1976 1976    2.20 37    2.27 38    2.31 37    2.42 34    2.82 32    4.40 33    4.86 18    4.63  8    10.7 26
1977 1977    1.40  3    1.40  3    1.49  3    1.51  3    1.63  2    1.85  1    2.49  3    4.95 11    17.5 50
1978 1978    2.10 31    2.10 28    2.11 27    2.24 28    2.50 21    3.61 20    8.39 43    7.90 33    10.2 23
1979 1979    2.30 43    2.30 42    2.37 39    2.53 38    3.23 39    4.86 38    7.51 36    8.67 36    8.78 16
1980 1980    2.10 32    2.17 32    2.26 33    2.62 40    3.98 59    11.7 70    19.1 75    20.3 73    34.9 77

1981 1981    1.60  8    1.60  5    1.61  5    1.66  4    1.81  3    2.16  3    2.48  2    3.66  3    5.96  3
1982 1982    2.70 62    2.77 61    2.94 62    3.14 58    6.49 71    12.4 73    20.1 76    28.1 78    31.7 75
1983 1983    1.50  4    1.60  6    1.66  7    1.70  7    1.83  4    2.01  2    2.30  1    3.78  4    8.52 12
1984 1984    1.60  9    1.63  9    1.67  8    1.69  6    1.90  7    3.45 18    4.20 11    4.36  6    9.87 22
1985 1985     .90  1     .94  1     .96  1    1.02  1    1.12  1    2.63  5    9.73 51    8.68 37    21.5 63

1986 1986    1.60 10    1.60  7    1.60  4    1.71  8    1.91  8    2.66  8    5.59 24    15.0 65    28.7 72
1987 1987    2.40 45    2.40 44    2.44 41    2.63 41    3.32 41    10.3 68    16.5 72    20.6 75    28.7 73
1988 1988    2.00 26    2.03 27    2.06 24    2.17 24    2.56 24    5.50 45    7.46 35    7.05 27    17.3 49
1989 1989    2.60 56    2.63 56    3.10 64    4.67 74    5.65 68    18.5 78    26.0 78    27.4 77    50.7 78
1990 1990    1.90 20    1.90 18    1.97 20    2.10 21    2.67 26    3.07 12    11.3 57    19.5 72    17.7 53

1991 1991    2.60 57    2.67 58    2.77 57    3.00 55    6.66 73    8.98 64    9.57 49    11.5 48    16.6 45
1992 1992    1.80 14    1.87 15    1.93 16    2.04 17    2.36 17    2.74 10    4.40 13    4.93 10    6.69  7
1993 1993    2.20 38    2.27 39    2.43 40    2.52 37    3.45 49    4.16 28    14.5 67    14.9 62    17.1 48
1994 1994    2.60 58    2.63 57    2.76 56    3.46 67    7.38 75    11.5 69    15.2 70    14.9 63    22.9 69
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                                  DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM


STATION ID - 16508000
Hanawi Stream near Nahiku, 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
1995 1995       1.80 15     1.83 13     1.91 14     1.99 14     2.15 12     2.65  7     5.35 22     7.82 32     8.80 17

1996 1996       2.30 44     2.40 45     2.60 46     3.24 61     3.33 43     4.96 41     6.46 30     9.79 44     10.2 24
1997 1997       1.90 21     1.90 19     1.94 18     2.08 20     2.26 14     8.60 60     16.4 71     16.6 69     20.7 61
1998 1998       1.90 22     1.93 21     1.97 21     2.04 18     2.59 25     4.05 26     7.53 37     12.6 52     18.9 57
1999 1999       2.20 39     2.23 37     2.27 35     2.39 31     2.75 29     3.04 11     4.01  8     5.45 16     8.91 18
2000 2000       2.00 27     2.00 25     2.04 23     2.11 23     2.40 18     3.74 21     5.35 23     5.92 20     10.6 25
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                          DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM


STATION ID - 16508000
Hanawi Stream near Nahiku, 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   186 75   186 65   186 31   122 37   69.1 51  43.3 57  35.5 56  31.9 51  26.3 57
1924 1924   404 53   253 47   170 39  97.5 49   60.4 57  46.4 53  35.7 54  34.4 50  27.3 54
1925 1925   811 17   351 28   157 46  91.4 55   76.0 43  46.3 54  35.1 57  29.2 56  27.8 50

1926 1926   128 78  63.0 78  34.9 78  27.0 78   20.7 77  14.5 78  12.3 78  10.9 78  8.60 78
1927 1927   268 71   131 71  69.0 73  41.4 74   28.2 76  24.0 74  21.5 72  20.2 71  17.6 72
1928 1928   196 74   116 73  84.3 71  49.6 71   41.9 66  34.0 64  30.3 60  24.2 64  24.5 60
1929 1929   295 67   207 61   161 44   105 47   80.3 40  52.5 43  43.8 40  38.5 43  32.3 41
1930 1930   438 49   292 37   215 26   129 30   82.1 36  70.4 22  55.6 25  57.1 15  47.6 15

1931 1931   506 39   287 40   138 58  74.0 64   40.8 68  26.2 71  21.5 73  18.3 74  20.0 70
1932 1932   370 61   298 35   198 29   129 31   94.4 26  65.2 30  53.2 27  49.3 21  41.4 24
1933 1933   497 40   263 44   132 60  70.0 65   46.6 63  32.7 65  29.8 62  25.7 62  20.3 68
1934 1934   990  8   372 25   178 34   129 32   84.7 32  53.7 40  45.2 39  38.9 40  29.3 46
1935 1935   937 14   690  7   354 11   175 17    105 17  67.5 26  52.5 28  46.7 29  38.3 30

1936 1936   156 76  78.3 77  52.5 76  37.1 76   30.9 74  27.4 68  25.1 68  22.2 67  21.7 65
1937 1937   656 25   488 18   289 17   199 14    141  8   107  6  91.8  6  79.1  6  63.0  7
1938 1938   588 31   428 19   298 15   151 20    109 16  68.3 24  58.9 21  52.3 19  45.4 19
1939 1939   806 18   367 27   258 19   143 25   79.9 41  64.9 31  51.3 31  48.7 23  39.2 28
1940 1940   439 48   253 48   153 49  96.2 52   61.8 56  37.6 62  27.8 66  21.7 68  17.7 71

1941 1941   356 64   174 68   109 66  64.2 67   38.5 72  28.9 67  26.2 67  25.4 63  23.3 61
1942 1942  1080  5   746  5   556  1   330  2    211  3   128  3  94.8  5  73.2  7  64.7  6
1943 1943   435 50   160 69  71.6 72  46.5 72   39.4 70  26.7 70  22.5 71  21.7 69  20.2 69
1944 1944   206 73  93.3 76  44.1 77  29.5 77   20.6 78  18.6 77  17.2 77  15.2 76  13.5 76
1945 1945   371 60   223 58   111 65  81.5 60   50.9 62  41.0 58  28.4 65  23.3 66  21.8 64

1946 1946   651 27   242 51   134 59   126 34   70.5 49  54.8 37  54.8 26  47.8 26  36.5 33
1947 1947   985  9   630 11   419  6   214 10    139  9  80.7 16  59.3 20  47.8 27  39.2 29
1948 1948  1610  1   982  1   435  4   207 12    112 15  83.3 14  78.4  9  68.0  9  56.4 10
1949 1949   495 41   297 36   170 41   124 35   99.6 23  68.0 25  55.8 24  45.1 31  36.1 35
1950 1950   537 37   277 42   209 28   156 19    100 22  76.2 19  59.4 19  49.2 22  39.3 27

1951 1951   350 65   235 56   178 35   116 38   82.9 33  54.5 39  50.0 33  48.1 25  35.3 39
1952 1952   359 63   191 64   161 43   113 40   72.0 48  44.1 55  39.1 47  38.3 44  32.2 42
1953 1953   285 69   126 72   102 68  56.7 70   51.5 61  40.3 61  29.6 63  23.5 65  21.3 66
1954 1954   269 70   147 70  93.9 70  77.9 62   43.0 65  30.1 66  30.2 61  27.7 60  27.6 51
1955 1955   743 22   497 16   367  9   206 13    135 12  80.7 17  78.9  7  71.0  8  55.6 11

1956 1956   956 11   601 12   317 14   219  9    118 14  84.5 13  69.4 15  61.7 13  50.3 12
1957 1957   467 45   235 55   158 45  89.7 57   67.9 52  41.0 59  35.7 55  31.7 52  26.6 55
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                                DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16508000
Hanawi Stream near Nahiku, 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
1958 1958     653 26     342 31     174 36     109 44     103 18     66.3 28    51.9 29    44.7 32    36.3 34
1959 1959     616 29     389 21     222 25     150 22     92.5 28    67.4 27    56.5 23    47.0 28    41.6 23
1960 1960     947 13     655  9     380  8     188 15     102 19     68.7 23    66.0 16    55.8 17    50.0 13

1961 1961     927 15     494 17     243 23     173 18     93.7 27    75.4 20    51.4 30    43.6 33    37.0 32
1962 1962     402 54     218 59     153 50     96.3 51    64.1 55    47.0 51    33.9 59    29.2 57    29.1 47
1963 1963     394 55     263 45     140 57     109 43     96.3 25    60.4 33    45.8 38    38.8 41    29.5 45
1964 1964     376 58     212 60     116 63     95.8 53    82.5 34    48.8 47    41.4 45    39.0 39    31.4 43
1965 1965     476 44     373 24     251 20     151 21     91.8 29    53.2 42    39.9 46    35.9 48    35.4 38

1966 1966     367 62     197 63     104 67     93.5 54    70.0 50    52.0 44    46.2 36    40.4 37    29.1 48
1967 1967     478 43     291 38     154 47     106 46     65.6 53    43.4 56    42.2 43    38.6 42    35.8 36
1968 1968     574 34     347 29     172 38     123 36     79.5 42    70.9 21    50.8 32    43.0 34    46.4 18
1969 1969    1150  3     790  3     527  2     252  4     214  2     157  2     138  1     113  1    89.8  1
1970 1970     691 24     346 30     245 22     144 24     86.0 31    53.3 41    37.6 51    42.5 35    35.5 37

1971 1971     768 20     369 26     245 21     142 26     101 21     94.0 10    74.4 11    59.3 14    57.4  8
1972 1972     316 66     205 62    96.1 69    64.9 66    41.0 67    25.3 72    23.5 70    21.3 70    20.7 67
1973 1973     431 52     182 67     141 55     108 45     80.4 39    54.8 38    43.1 41    37.1 47    26.6 56
1974 1974    1100  4     543 13     236 24     146 23     88.7 30    51.0 46    41.5 44    37.6 45    37.7 31
1975 1975     433 51     225 57     181 33    97.3 50    73.7 46    55.4 35    45.9 37    40.4 38    33.2 40

1976 1976     711 23     272 43     123 62    80.1 61    44.4 64    41.0 60    37.7 50    35.5 49    27.5 52
1977 1977     375 59     239 52     153 51    86.1 58    80.9 38    65.7 29    48.2 34    37.3 46    30.1 44
1978 1978     234 72     115 74    68.0 74    40.7 75    30.0 75    21.7 75    19.0 75    17.0 75    15.9 74
1979 1979     642 28     510 14     339 13     238  6     133 13     101  9    75.9 10    67.4 10    48.7 14
1980 1980     963 10     694  6     452  3     398  1     276  1     176  1     126  2     111  2    86.0  2

1981 1981     599 30     286 41     130 61    62.4 68    34.0 73    19.8 76    18.3 76    14.3 77    12.0 77
1982 1982    1170  2     688  8     360 10     237  7     161  7     107  5    99.8  3    84.1  4    71.9  5
1983 1983     582 33     239 53     115 64    59.2 69    39.0 71    26.8 69    24.8 69    19.4 72    15.9 75
1984 1984     156 77     107 75    65.1 75    43.5 73    39.9 69    25.1 73    20.0 74    18.5 73    16.7 73
1985 1985     549 36     323 32     279 18     213 11     135 11    82.0 15    71.9 14    55.9 16    43.0 21

1986 1986    1050  7     636 10     343 12     177 16     168  5     104  7    74.1 12    62.8 11    47.2 17
1987 1987     587 32     386 22     196 30     130 29    82.2 35    59.6 34    47.7 35    45.8 30    40.4 25
1988 1988     781 19     314 34     150 53    91.4 56    73.8 44    48.6 48    42.4 42    41.7 36    40.2 26
1989 1989     927 16     509 15     293 16     227  8     162  6     119  4    95.1  4    95.1  3    78.5  3
1990 1990     572 35     380 23     215 27     132 28     102 20    87.0 11    65.9 17    51.1 20    43.7 20

1991 1991     953 12     762  4     403  7     328  3     178  4     104  8    78.7  8    81.5  5    73.6  4
1992 1992     290 68     238 54     146 54    82.7 59    54.6 60    48.2 49    37.6 52    30.2 55    22.0 63
1993 1993     379 57     290 39     140 56    76.7 63    57.0 59    37.3 63    29.4 64    28.3 59    26.3 58
1994 1994    1060  6     799  2     429  5     238  5     137 10    85.4 12    72.2 13    61.8 12    56.8  9
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                              DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16508000
Hanawi Stream near Nahiku, 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
1995 1995     451 47     250 50     151 52     98.0 48   73.8 45    46.7 52    36.8 53    29.2 58    22.6 62

1996 1996     537 38     252 49     173 37      128 33   72.2 47    51.3 45    38.5 49    30.6 54    25.6 59
1997 1997     747 21     390 20     170 40      113 41   81.7 37    62.3 32    57.0 22    48.6 24    41.8 22
1998 1998     392 56     183 66     153 48      115 39   64.6 54    47.5 50    34.7 58    27.3 61    28.0 49
1999 1999     480 42     316 33     182 32      139 27   98.9 24    76.5 18    65.2 18    52.8 18    47.3 16
2000 2000     467 46     256 46     166 42      110 42   59.9 58    55.1 36    38.8 48    31.4 53    27.5 53
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                         DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16508000
Hanawi Stream near Nahiku, Maui, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN

                              ANNUAL AND/OR SEMI-ANNUAL VALUES

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

      WATER YEAR                                         WATER YEAR
        RANGE                                              RANGE
       1923 1923          18.3    26                      1923 1923          18.3    53
       1924 1924          19.4    32                      1924 1924          19.4    47
       1925 1925          21.8    39                      1925 1925          21.8    40
       1926 1926          7.59     1                      1926 1926          7.59    78
       1927 1927          14.5     9                      1927 1927          14.5    70
       1928 1928          18.8    30                      1928 1928          18.8    49
       1929 1929          19.8    33                      1929 1929          19.8    46
       1930 1930          31.3    66                      1930 1930          31.3    13
       1931 1931          16.9    17                      1931 1931          16.9    62
       1932 1932          28.6    59                      1932 1932          28.6    20
       1933 1933          12.4     4                      1933 1933          12.4    75
       1934 1934          18.8    29                      1934 1934          18.8    50
       1935 1935          23.6    46                      1935 1935          23.6    33
       1936 1936          15.2    13                      1936 1936          15.2    66
       1937 1937          42.1    73                      1937 1937          42.1     6
       1938 1938          29.2    62                      1938 1938          29.2    17
       1939 1939          26.6    53                      1939 1939          26.6    26
       1940 1940          13.8     8                      1940 1940          13.8    71
       1941 1941          17.3    20                      1941 1941          17.3    59
       1942 1942          40.7    72                      1942 1942          40.7     7
       1943 1943          16.3    14                      1943 1943          16.3    65
       1944 1944          9.92     3                      1944 1944          9.92    76
       1945 1945          15.0    12                      1945 1945          15.0    67
       1946 1946          22.6    44                      1946 1946          22.6    35
       1947 1947          26.3    51                      1947 1947          26.3    28
       1948 1948          36.7    70                      1948 1948          36.7     9
       1949 1949          22.0    40                      1949 1949          22.0    39
       1950 1950          25.5    49                      1950 1950          25.5    30
       1951 1951          21.7    38                      1951 1951          21.7    41
       1952 1952          21.2    36                      1952 1952          21.2    43
       1953 1953          14.6    10                      1953 1953          14.6    69
       1954 1954          18.4    27                      1954 1954          18.4    52
       1955 1955          32.6    69                      1955 1955          32.6    10
       1956 1956          30.3    64                      1956 1956          30.3    15
       1957 1957          22.1    41                      1957 1957          22.1    38
       1958 1958          28.3    58                      1958 1958          28.3    21
       1959 1959          26.9    54                      1959 1959          26.9    25
       1960 1960          28.7    61                      1960 1960          28.7    18
       1961 1961          21.6    37                      1961 1961          21.6    42
       1962 1962          17.5    22                      1962 1962          17.5    57
       1963 1963          17.4    21                      1963 1963          17.4    58
```

```
                          DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16508000
Hanawi Stream near Nahiku, Maui, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN

                                   ANNUAL AND/OR SEMI-ANNUAL VALUES

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

       WATER YEAR                                                 WATER YEAR
         RANGE                                                      RANGE
        1964 1964             22.3    42                           1964 1964             22.3    37
        1965 1965             24.1    47                           1965 1965             24.1    32
        1966 1966             17.6    23                           1966 1966             17.6    56
        1967 1967             25.9    50                           1967 1967             25.9    29
        1968 1968             27.0    55                           1968 1968             27.0    24
        1969 1969             52.6    78                           1969 1969             52.6     1
        1970 1970             23.3    45                           1970 1970             23.3    34
        1971 1971             31.9    67                           1971 1971             31.9    12
        1972 1972             13.6     7                           1972 1972             13.6    72
        1973 1973             17.1    18                           1973 1973             17.1    61
        1974 1974             22.4    43                           1974 1974             22.4    36
        1975 1975             19.2    31                           1975 1975             19.2    48
        1976 1976             16.8    16                           1976 1976             16.8    63
        1977 1977             17.7    25                           1977 1977             17.7    54
        1978 1978             12.6     5                           1978 1978             12.6    74
        1979 1979             28.7    60                           1979 1979             28.7    19
        1980 1980             50.9    76                           1980 1980             50.9     3
        1981 1981             8.91     2                           1981 1981             8.91    77
        1982 1982             48.5    75                           1982 1982             48.5     4
        1983 1983             14.7    11                           1983 1983             14.7    68
        1984 1984             13.2     6                           1984 1984             13.2    73
        1985 1985             25.1    48                           1985 1985             25.1    31
        1986 1986             30.5    65                           1986 1986             30.5    14
        1987 1987             32.4    68                           1987 1987             32.4    11
        1988 1988             26.4    52                           1988 1988             26.4    27
        1989 1989             51.5    77                           1989 1989             51.5     2
        1990 1990             29.7    63                           1990 1990             29.7    16
        1991 1991             45.2    74                           1991 1991             45.2     5
        1992 1992             16.7    15                           1992 1992             16.7    64
        1993 1993             21.2    35                           1993 1993             21.2    44
        1994 1994             38.5    71                           1994 1994             38.5     8
        1995 1995             17.3    19                           1995 1995             17.3    60
        1996 1996             17.6    24                           1996 1996             17.6    55
        1997 1997             27.7    57                           1997 1997             27.7    22
        1998 1998             20.8    34                           1998 1998             20.8    45
        1999 1999             27.4    56                           1999 1999             27.4    23
        2000 2000             18.4    28                           2000 2000             18.4    51
```

```
                              DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16508000
Hanawi Stream near Nahiku, Maui, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN

                                ANNUAL AND/OR SEMI-ANNUAL VALUES

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

        WATER YEAR                                            WATER YEAR
          RANGE                                                 RANGE
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                                             DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16509000
HANAWI STREAM BL GOVT RD NR NAHIKU, MAUI, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN

                                                   DURATION TABLE OF DAILY VALUES
                                                        FOR PERIOD OCT TO SEP

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
   RANGE
1933 1933           5210 94 21  9  5   3   4       2   2   2           1   1   1   1                   2         1           1
1934 1934       48227 32 11  7  3  5   5   5   3   1   2   2   1   1       2   2   1   2   2       1       1                       1
1935 1935       11210 79 20 10  3  4   1   2   3   5   1   3   2       4   1           2           1       1  1  1

1936 1936    32204 62 19  5  5  7  5   8   3   1   2   4   1   1   1   2   3                           1
1937 1937       39 52 59 69 30 14 13   8   4   5   5   4  10   5   3   7   6   3   6   1   4   2   1   4   2  2  4  1  1     1
1938 1938             41194 28  9 10  10   4   5   7   4   7   2   4   7   2   7       4   3   2   3   1   5  1  2  1  1           1
1939 1939              8213 54 15  8   9   7   6   5   7   5   5   5   2   3   2   2   3   1       1   1   1              1     1
1940 1940       77 54 67105 23  4  3   2   4   4   2   1   5   1   2   1   1   3   1   2   1       2             1

1941 1941       84166 52 11 11  3 10   4           1   3   5   4       3           1   2       2   1   1      1
1942 1942       90 46142 13 10  4  4   3   5   4   3   6   5   5   4   7   3       1   1   2       1   1   1  2           1  1
1943 1943         171125 25  7  6  5   4   3   4   1   2   1   3   1       2   1   1   2                            1
1944 1944       64251 27  7     2      1   6   2   1   2   1   1               1
1945 1945      222 80 19  7 11  1  5   4   1   4   1   2       1       5           1           1

1946 1946       84167 40 12  7  7  8   3   4   8   5   2   2   4   3   2   1   3                   1       1  1




1993 1993       65198 36  9 12  8  5   5   5   3   3   2   4   1   4   2       3
1994 1994       70142 49 16 11 13 11   4   3  12   5   2   3   4   8   4   2   1   1       2           1         1
1995 1995       54145 60 34 18  7  7   8   9  11   1   2   3   2   2   1                   1
```

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                                  DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16509000
HANAWI STREAM BL GOVT RD NR NAHIKU, MAUI, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN


CLASS    VALUE    TOTAL    ACCUM    PERCT        CLASS    VALUE    TOTAL    ACCUM    PERCT        CLASS    VALUE    TOTAL    ACCUM    PERCT
  1       0.00        0     6208   100.00          13     71.00       50      464     7.47          25    453.00       12       67     1.08
  2      13.00       32     6208   100.00          14     83.00       48      414     6.67          26    528.00       12       55     0.89
  3      15.00     1112     6176    99.48          15     97.00       59      366     5.90          27    617.00       12       43     0.69
  4      18.00     1976     5064    81.57          16    113.00       42      307     4.95          28    720.00        8       31     0.50
  5      21.00     1065     3088    49.74          17    132.00       38      265     4.27          29    840.00       10       23     0.37
  6      24.00      845     2023    32.59          18    154.00       48      227     3.66          30    980.00        3       13     0.21
  7      28.00      265     1178    18.98          19    179.00       27      179     2.88          31   1140.00        2       10     0.16
  8      33.00      115      913    14.71          20    209.00       27      152     2.45          32   1330.00        2        8     0.13
  9      38.00      108      798    12.85          21    244.00       16      125     2.01          33   1560.00        3        6     0.10
 10      45.00       82      690    11.11          22    285.00       19      109     1.76          34   1820.00        1        3     0.05
 11      52.00       69      608     9.79          23    333.00       16       90     1.45          35   2120.00        2        2     0.03
 12      61.00       75      539     8.68          24    388.00        7       74     1.19
```

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DURATION CURVE STATISTICAL CHARACTERISTICS FOR ...
STATION ID: 16509000          HANAWI STREAM BL GOVT RD NR NAHIKU, 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       DATA
EQUALED OR EXCEEDED        VALUE

       95.0                  15.8        (LOG =  1.19731)
       90.0                  16.6        (LOG =  1.21981)
       85.0                  17.4        (LOG =  1.24120)
       80.0                  18.1        (LOG =  1.25883)
       75.0                  18.6        (LOG =  1.26997)
       70.0                  19.1        (LOG =  1.28082)
       65.0                  19.6        (LOG =  1.29141)
       60.0                  20.0        (LOG =  1.30175)
       55.0                  20.5        (LOG =  1.31185)
       50.0                  21.0        (LOG =  1.32172)
       45.0                  21.8        (LOG =  1.33904)
       40.0                  22.7        (LOG =  1.35610)
       35.0                  23.6        (LOG =  1.37251)
       30.0                  24.8        (LOG =  1.39375)
       25.0                  26.2        (LOG =  1.41879)
       20.0                  27.7        (LOG =  1.44246)
       15.0                  32.7        (LOG =  1.51397)
       10.0                  50.9        (LOG =  1.70678)
        5.0                 112.1        (LOG =  2.04952)

MEAN OF LOGS =  1.38356

STANDARD DEVIATION OF LOGS =  0.19967 (VARIABILITY INDEX - SEE USGS WSP 1542-A)

COEFFICIENT OF VARIATION    =  0.14431

COEFFICIENT OF SKEW         =  2.42848
```

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LOG-NORMAL  DURATION PLOT FOR PERIOD OCT TO SEP                        (YEARS 1932 - 1995)
STATION ID: 16509000          HANAWI STREAM BL GOVT RD NR NAHIKU, MAUI, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN
```

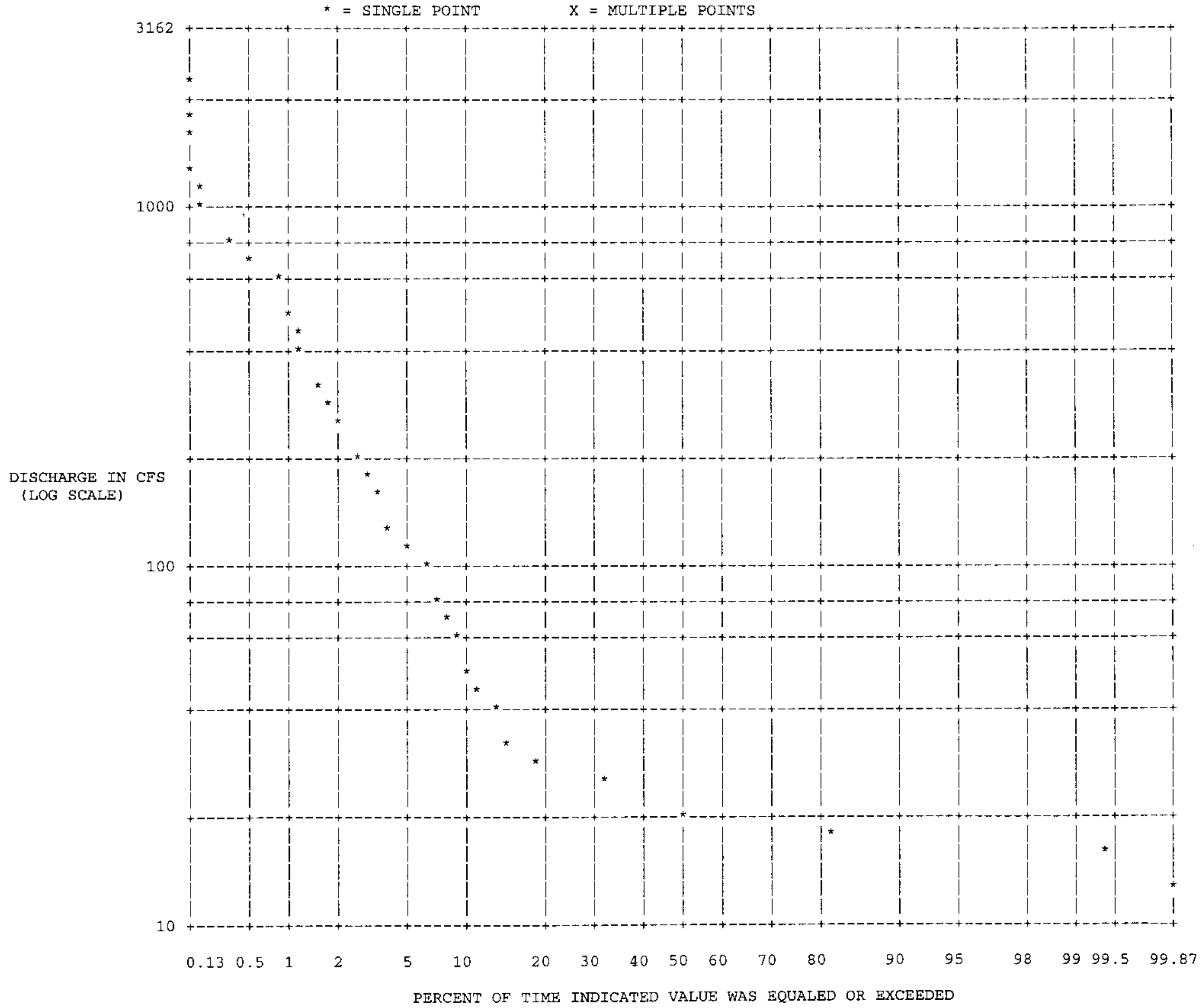

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                              DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16509000
HANAWI STREAM BL GOVT RD NR NAHIKU, 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
1933 1933    20.0 15    20.0 15    20.3 15    20.6 15    20.8 15    21.2 13    21.4  8    21.4  6    23.5  8
1934 1934    16.0  5    16.0  5    16.0  4    16.0  4    16.3  5    19.1 11    22.8 12    22.0  8    26.7 11
1935 1935    17.0 12    17.0 12    17.4 13    17.4 13    18.8 12    19.1 12    19.6  6    19.7  4    22.4  5

1936 1936    13.0  1    13.0  1    13.0  1    13.4  1    13.8  1    16.6  3    16.5  1    17.5  1    20.7  2
1937 1937    16.0  6    16.0  6    16.1 10    16.6 11    19.4 14    21.6 15    51.2 17    47.2 17    54.0 16
1938 1938    22.0 16    22.0 16    22.0 16    22.4 16    24.0 16    25.6 16    27.7 15    33.1 16    71.5 17
1939 1939    23.0 17    23.0 17    23.1 17    23.5 17    26.5 17    29.8 17    29.9 16    30.1 15    43.1 15
1940 1940    16.0  7    16.0  7    16.0  5    16.0  5    16.2  2    16.5  1    16.9  3    22.5 10    23.1  6

1941 1941    16.0  8    16.0  8    16.0  6    16.1  9    16.4  7    17.1  4    22.2 10    27.5 14    31.1 14
1942 1942    15.0  2    15.7  4    16.0  7    16.0  6    16.2  3    18.1  6    21.0  7    21.5  7    23.4  7
1943 1943    18.0 14    18.7 14    19.0 14    19.0 14    19.3 13    21.5 14    24.2 14    23.9 13    27.0 12
1944 1944    17.0 13    17.0 13    17.0 12    17.0 12    17.0  8    18.3  7    18.7  4    18.7  3    20.1  1
1945 1945    15.0  3    15.0  2    15.0  2    15.4  2    16.3  6    16.5  2    16.6  2    17.5  2    22.1  4

1946 1946    16.0  9    16.0  9    16.0  8    16.0  7    16.2  4    18.7  9    21.8  9    23.4 12    25.1 10




1993 1993    16.0 10    16.0 10    16.0  9    16.0  8    17.0  9    18.5  8    23.9 13    23.1 11    24.7  9
1994 1994    15.0  4    15.0  3    15.0  3    15.5  3    17.7 11    19.0 10    22.2 11    22.1  9    27.4 13
1995 1995    16.0 11    16.0 11    16.1 11    16.4 10    17.2 10    17.9  5    19.3  5    21.2  5    20.9  3
```

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                                   DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM


STATION ID - 16509000
HANAWI STREAM BL GOVT RD NR NAHIKU, 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
1933 1933   1780  4      960  4      457  5      232  6      136  7     83.6  6     79.3  5     68.1  5     53.5  5
1934 1934   2120  2      807  6      367  6      245  5      161  5     97.1  5     75.7  6     63.9  6     51.7  6
1935 1935    871 10      632  7      309  9      158 10     96.4  9     76.1  8     64.6  8     58.5  7     49.3  8

1936 1936    579 13      228 14      117 14     69.5 15     47.0 16     36.1 16     31.3 16     28.2 16     28.5 16
1937 1937   1760  5     1277  3      739  3      481  2      317  1      230  1      203  1      165  1      130  2
1938 1938   2320  1     1547  1      928  1      483  1      300  2      206  2      171  2      149  2      131  1
1939 1939   1980  3      925  5      668  4      343  4      193  4      142  4      110  3     99.7  3     79.2  4
1940 1940    959  8      566  9      337  8      219  7      140  6     82.5  7     60.7 10     49.6 10     42.3 10

1941 1941    812 12      360 11      225 10      122 11     70.6 12     53.3 12     48.9 11     44.1 11     41.6 11
1942 1942   1640  6     1279  2      803  2      443  3      259  3      149  3      108  4     85.6  4     79.3  3
1943 1943   1090  7      379 10      174 12      108 12     82.0 11     56.1 11     46.2 12     42.5 12     38.5 12
1944 1944    243 16      108 17     57.4 17     39.1 17     33.5 17     26.6 17     25.2 17     24.8 17     24.0 17
1945 1945    424 14      235 13      112 15     75.5 14     51.9 15     46.0 14     36.1 14     32.0 15     29.6 15

1946 1946    818 11      303 12      180 11      166  9     96.1 10     72.3  9     66.0  7     57.3  8     45.4  9




1993 1993    232 17      196 16      101 16     58.5 16     52.1 14     38.7 15     31.9 15     33.3 14     31.1 14
1994 1994    937  9      621  8      342  7      187  8      111  8     71.7 10     62.6  9     54.6  9     50.2  7
1995 1995    333 15      204 15      132 13     85.9 13     67.8 13     51.3 13     43.2 13     38.5 13     31.7 13
```

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                              DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16509000
HANAWI STREAM BL GOVT RD NR NAHIKU, MAUI, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN


                                  ANNUAL AND/OR SEMI-ANNUAL VALUES

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

       WATER YEAR                                                   WATER YEAR
         RANGE                                                        RANGE
        1933 1933            37.6    11                              1933 1933            37.6     7
        1934 1934            37.7    12                              1934 1934            37.7     6
        1935 1935            34.4     9                              1935 1935            34.4     9
        1936 1936            24.6     3                              1936 1936            24.6    15
        1937 1937            85.0    17                              1937 1937            85.0     1
        1938 1938            80.7    16                              1938 1938            80.7     2
        1939 1939            55.7    15                              1939 1939            55.7     3
        1940 1940            36.4    10                              1940 1940            36.4     8
        1941 1941            34.0     8                              1941 1941            34.0    10
        1942 1942            51.5    14                              1942 1942            51.5     4
        1943 1943            31.1     6                              1943 1943            31.1    12
        1944 1944            21.3     1                              1944 1944            21.3    17
        1945 1945            23.9     2                              1945 1945            23.9    16
        1946 1946            33.7     7                              1946 1946            33.7    11
        1993 1993            27.1     4                              1993 1993            27.1    14
        1994 1994            38.1    13                              1994 1994            38.1     5
        1995 1995            27.5     5                              1995 1995            27.5    13
```

```
                                        DVSTAT  -  DAILY VALUES STATISTICAL PROGRAM

STATION ID - 16509000
HANAWI STREAM BL GOVT RD NR NAHIKU, MAUI, HI
PARAMETER CODE  -  00060 DISCHARGE
STATISTIC CODE  -  00003 MEAN

                                            ANNUAL AND/OR SEMI-ANNUAL VALUES

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

                WATER YEAR                                                    WATER YEAR
                  RANGE                                                         RANGE
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