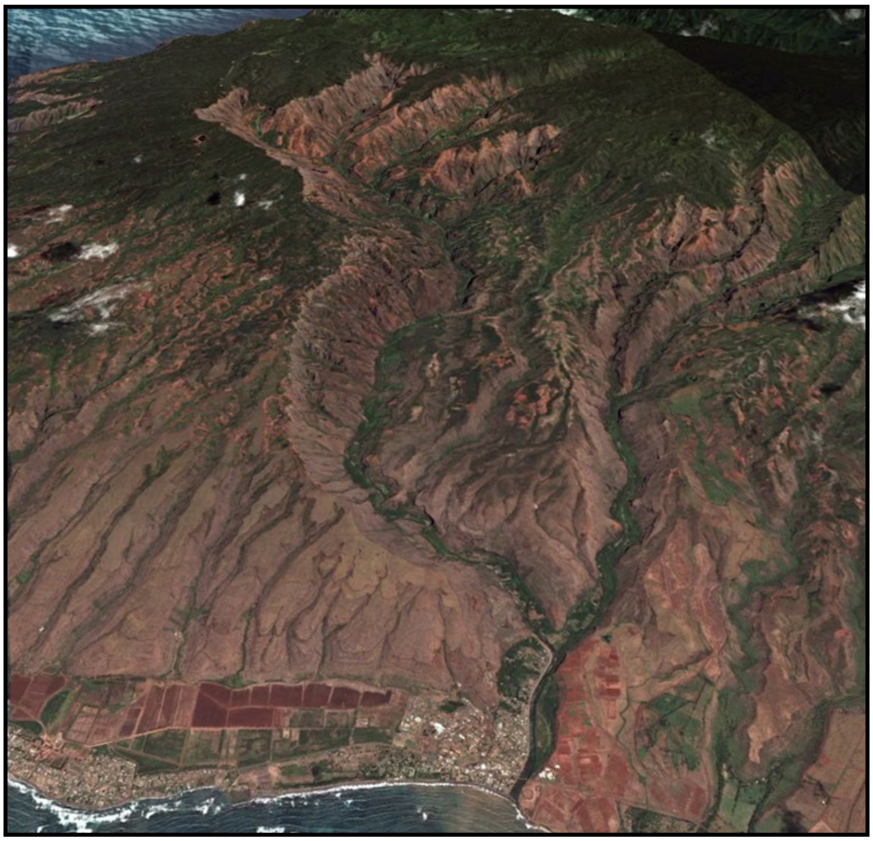
Instream Flow Standard Assessment Report

Island of Kauai
Hydrologic Unit 2060
Waimea

August 2016 **PR-2016-08**



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

COVER
Satallite image of Waimea canyon with the Waimea River flowing into the Pacific Ocean, southwest Kauai [Google Earth, 2008].

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

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Acronyms and Abbreviations

A&B	Alexander & Baldwin
AG	agricultural
ALISH	Agricultural Lands of Importance to the State of Hawaii
ALUM	agricultural land use maps [prepared by HDOA]
BFQ	base flow statistics
BLNR	Board of Land and Natural Resources (State of Hawaii)
C-CAP	Coastal Change Analysis Program
cfs	cubic feet per second
Code	State Water Code (State of Hawaii)
COM	commercial
Commission	Commission on Water Resource Management (DLNR)
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)
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
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
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
KAA	Kekaha Agriculture Association
KIUC	Kauai Island Utility Cooperative
LCA	Land Commission Award
LUC	Land Use Commission (State of Hawaii)
MECO	Maui Electric Company
MF	multi-family residential
mgd	million gallons per day
Mgal/d	million gallons per day
mi	mile
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
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

General Overview

The hydrologic unit of Waimea is located southwest of Mount Waialeale, forming part of the Hawaiian island of Kauai (Figures 1-3 and 1-5). It covers an area of 85.7 square miles from 5,240 feet in elevation to the sea, with a mean basin elevation of 2,600 feet and a mean basin slope of 59 percent (Figure 1-4). The longest flow path in Waimea is 25.7 miles in length, traversing in a south-southwesternly direction from its headwaters in the Alakai Marsh to Hoalua Bay. Waimea Stream is composed of many tributaries, the largest of which is the Makaweli Stream (26.35 square miles,15.6 miles in length), followed by the Koaie Stream (11.4 square miles, 14.4 miles in length), the Waiahulu Stream (20.5 square miles, 13.6 miles in length), and the Waiale Stream (8.44 square miles, 12.7 miles in length). The Waiahulu Stream is composed of five main tributaries: Kokee, Kauaikinana, Kawaikoi, Waiakoali, and Mohihi streams. Many other tributaries flow only intermittently in the upper sections in response to rainfall-runoff. The western half of the hydrologic unit is made up of the Na Pali-Kona Forest Reserve, the Waimea Canyon State Park and Kokee State Park (State of Hawaii) along with the Wainiha Preserve (The Nature Conservancy). The lower altitudes are very dry and occupied by grasses, shrubs and alien trees, while the upper regions support native ohia- and koa-dominated forests. In the lowest reaches along the stream there are cultivated taro lands. While most of the region has no permanent residences, the town of Waimea partialy lies within the unit resulting in a total population of 1297 people (U.S. Census Bureau Office of Planning 2011). The population figure does not account for residents living outside of the hydrologic unit who may rely on water from within the unit. Only a few state roads exist in the region, limiting access to large areas (Figure 1-6). Three main irrigation ditch systems divert water from the Waimea hydrologic unit: the Kokee Irrigation System, the Kekaha Irrigation System, and the Olokele Irrigation System.

Current Instream Flow Standard

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

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

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

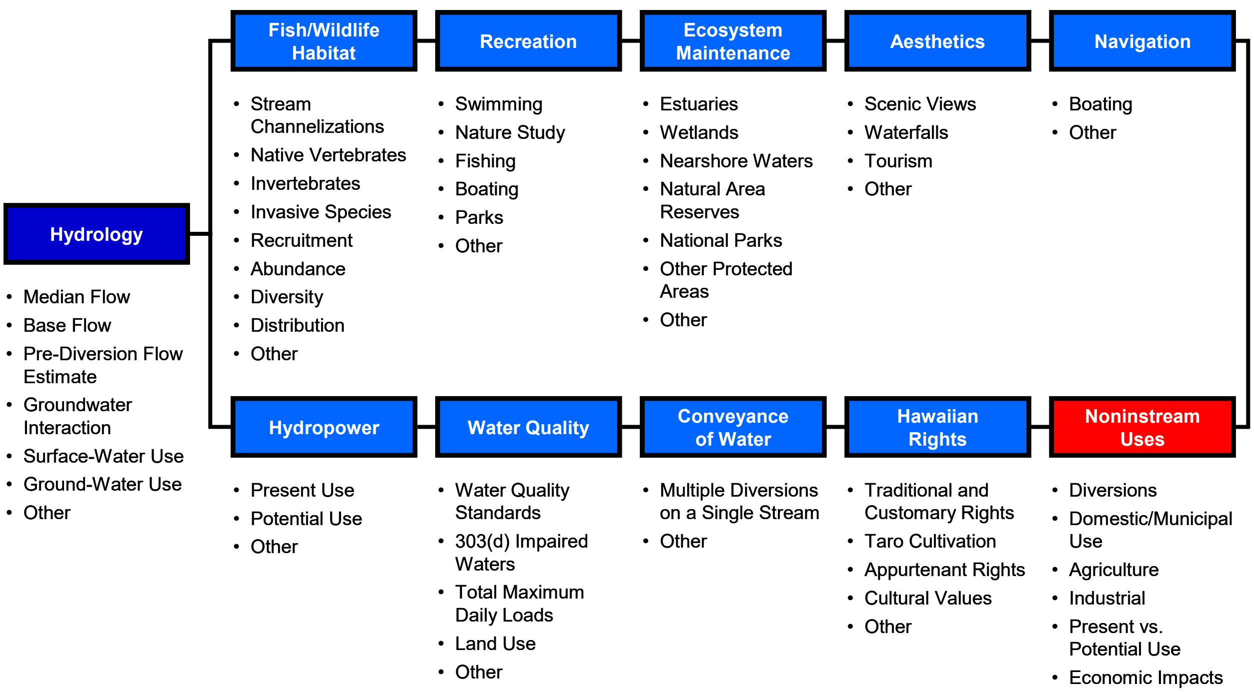
Instream Flow Standards

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

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

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

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

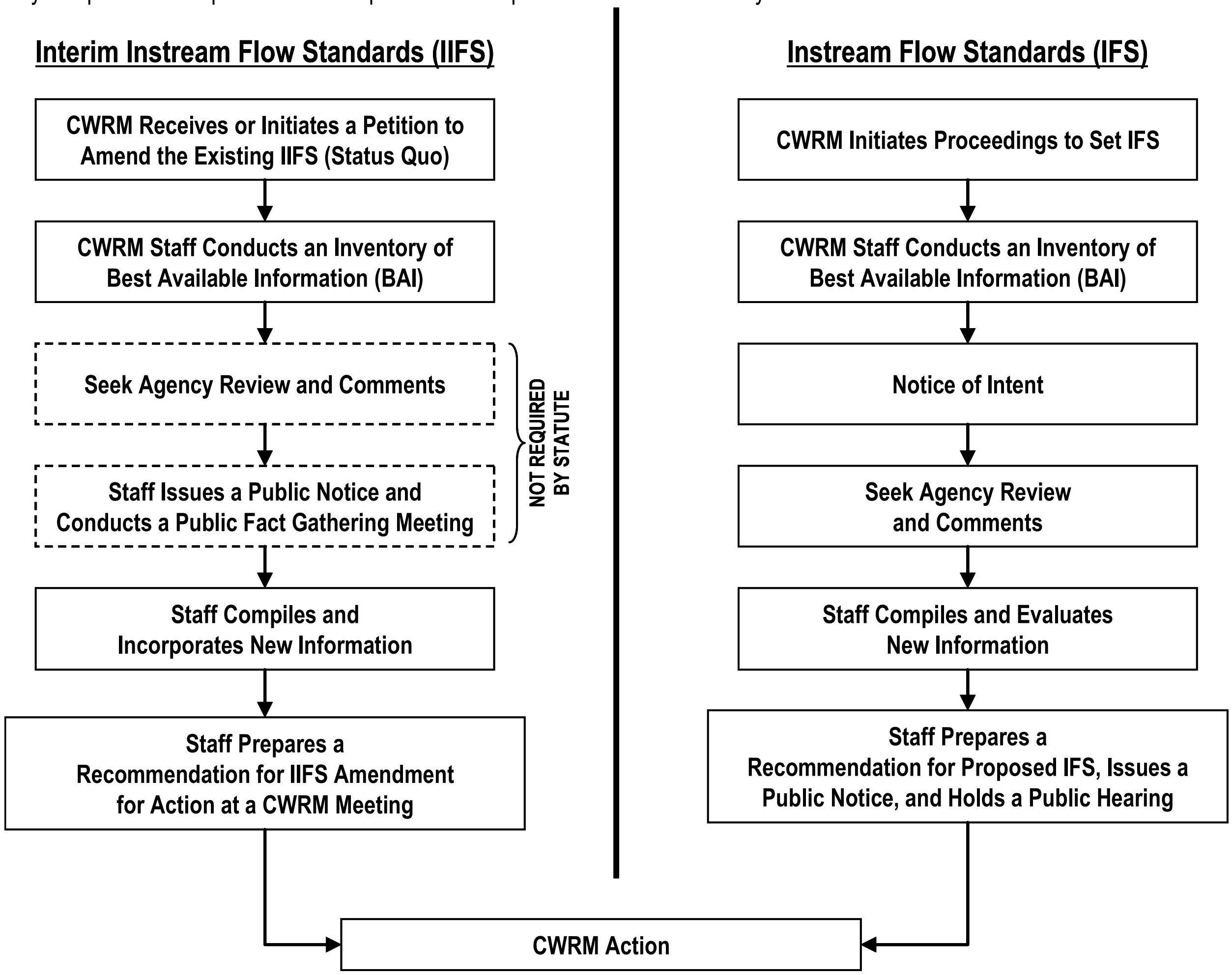


Interim Instream Flow Standard Process

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

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

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



Instream Flow Standard Assessment Report

The Instream Flow Standard Assessment Report (IFSAR) is a compilation of the hydrology, instream uses, and noninstream uses related to a specific stream and its respective surface water hydrologic unit. The report is organized in much the same way as the elements of IFS are depicted in Figure 1-1. The purpose of the IFSAR is to present the best available information for a given hydrologic unit. 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 in 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.

An important component of the IFSAR and the interim IFS process is the Compilation of Public Review Comments (CPRC). The CPRC serves as a supporting document containing the oral and written comments that are submitted as part of the initial public review process. Comments referred to within the IFSAR will identify both the section and page number where the original comment can be located in the CPRC. For example, a reference to "8.0-3" indicates the third page of comments in Section 8.0 of the CPRC.

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.

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.

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 Waimea hydrologic unit and streams in southeast Kauai, Hawaii. (Source: U.S. Geological Survey, 1996; State of Hawaii, Commission on Water Resource Management, 2015c; State of Hawaii, Division of Aquatic Resources, 2005)

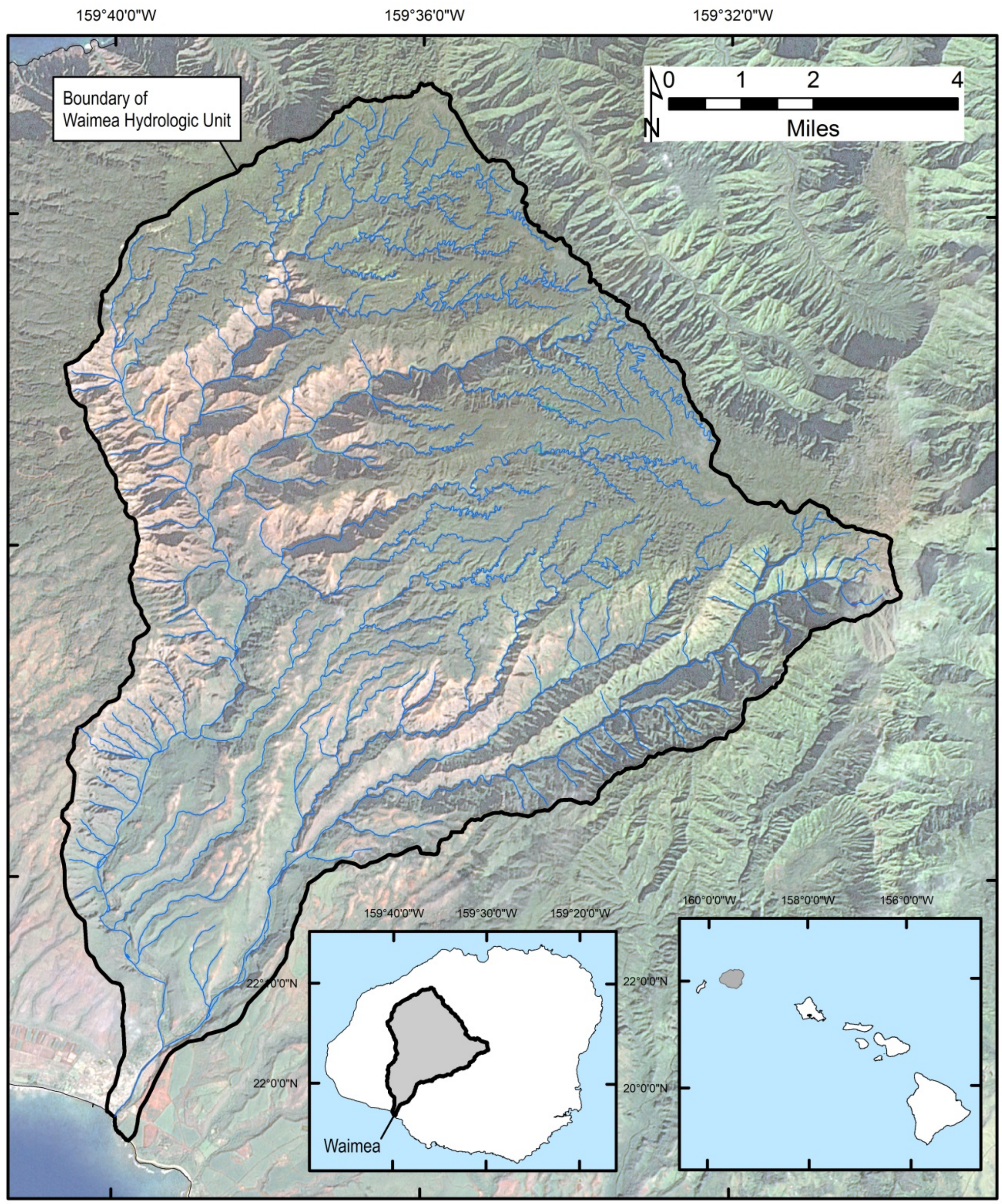


Figure 1-4. Elevation range and the location of Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2004e; U.S. Geological Survey, 2001)

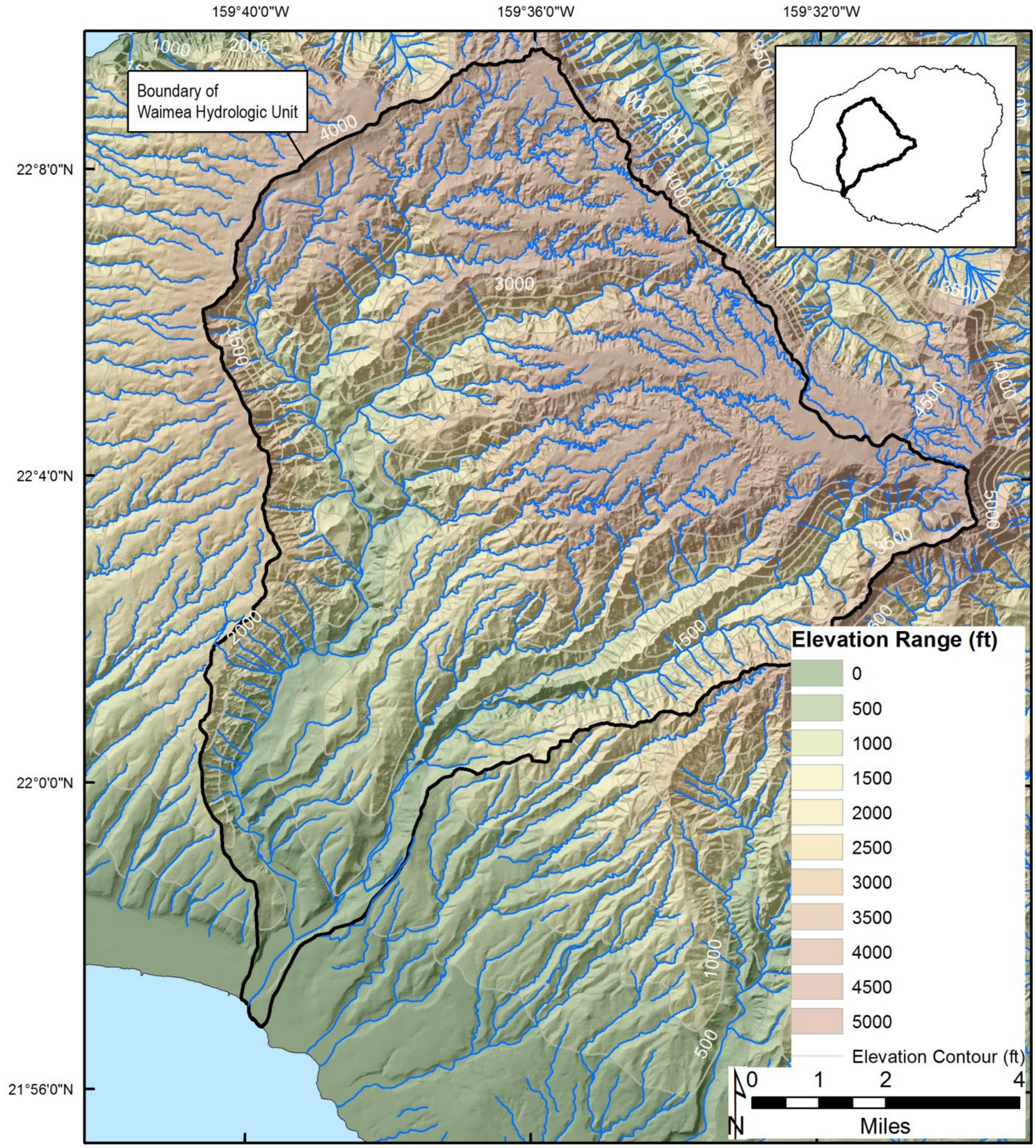


Figure 1-5. Quickbird satellite imagery of Waimea hydrologic unit. (Source: State of Hawaii, Planning Department, 2004)

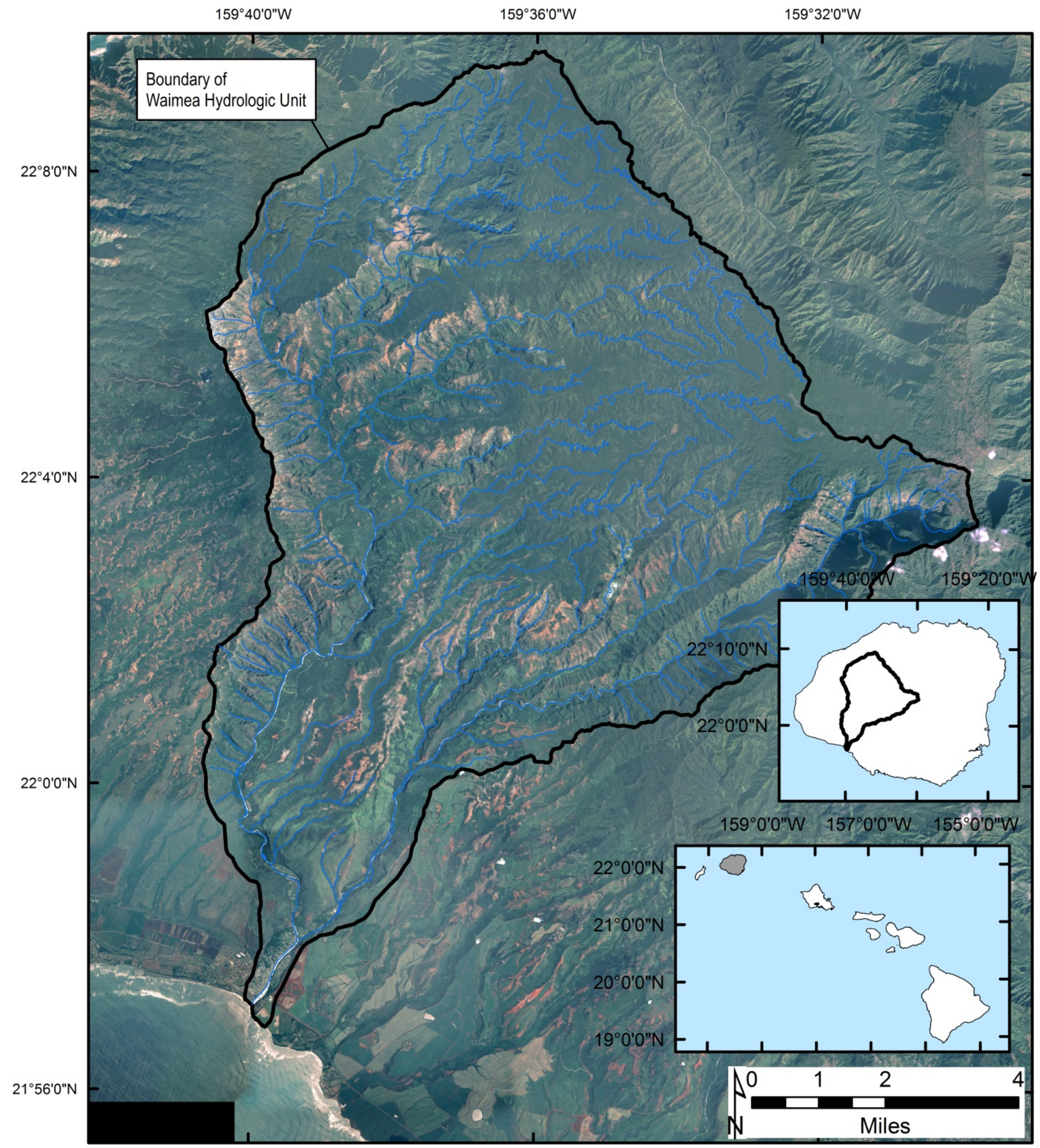
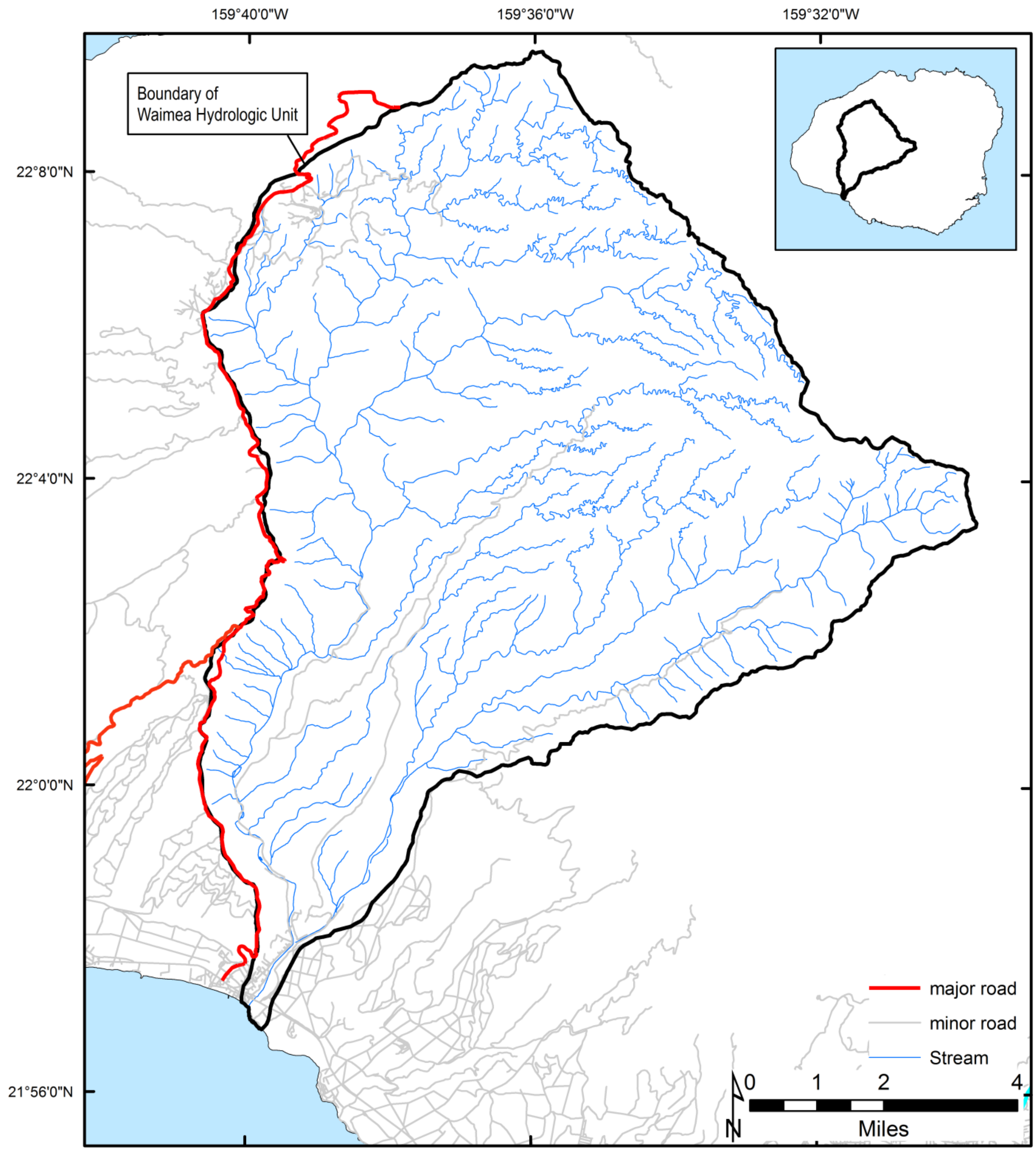


Figure 1-6. Major and minor roads for the Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning 2015)



2.0 Unit Characteristics

Geology

The geology of the Waimea hydrologic unit is characterized by Tholeiitic basalts in the form of aa (lava characterized by jagged, sharp surfaces with massive, relatively dense interior) or pahoehoe (lava characterized by smooth, ropy characteristics) lava flows that poured out at progressively longer intervals so that numerous valleys were cut between the later lavas. There are three main age classes of lava flows in Waimea: 4.0-5.5 mya, 4.0-4.3 mya, and 3.5-4.0 mya. The oldest flows extend from the highest elevations to the coastline (Waimea Canyon Volcanic Series) and represent the shield building phase of the island (Table 2-1). The majority of Kauai was created by the Napali formation, which is characterized by thin layers of olivine basalt lava flows sloping from the central vent. Occasionally thin layers of ash and tephra are overlain, but pyroclastic eruptions were rare and constitute less than 1% of the volume of material found in the Napali. This formation is highly permeable to water. The second oldest flows are thick cladera filling flows that remained in the upper regions of the hydrologic unit (>1800 ft above sea level). At the end of the shield building phase, lava flow shifted from thin to thick, massive flows referred to as the Olokele Formation. This primarily existed in the western and northwestern parts of the island. The roughly 16 km diameter caldera is believed to have collapsed and then subsequently filled by these flows, which then spilled out and filled the deeply cut vallys, forming flat areas impermeable to water (Macdonald et al., 1960). This region eventually became the Alakai swamp. Numerous dike complexes also exist on the western side (Waimea Gulch) of the unit, along with a few on the eastern side of Makaweli Gulch and in the central regions, providing high-level ground water that is held up by the relatively lower permeability[1] flows and associated weathered soils and ash beds (Gingerich, 1999a). Perched aquifers may also contribute to surface water flows. Along the coast is a relatively small exposed area of the younger Koloa volcanic series and deposited alluvium (mostly sand and gravel), together comprising 6 percent of the hydrologic unit's surface geology. Koloa Volcanics are characterized by basaltic lava flows, cinder cone formations and by the building of small secondary shield volcanos (Grady 2006). They are highly permeable but there is little fresh basal water[2] as salt-water intrusion is common due to the low elevations and extensive groundwater pumping (Stearns and MacDonald, 1942; U.S. Geological Survey, 2007). The generalized geology of the Waimea hydrologic unit is depicted in Figure 2-1.

Table 2-1 Area and percentage of surface geologic features for Waimea hydrologic unit. (Source: Sherrod et al, 2007)

Name	Rock Type	Area (mi^2)	Percent (%)
Waimea Canyon Basalt	Pahoehoe and Aa, Breccia, Near-vent Cinder	79.54	92.88
Koloa Volcanics	Pahoehoe and Aa, Conglomerate	3.10	3.62
Alluvium	Sand and Gravel	2.13	2.49
Older Alluvium	Sand and Gravel	0.62	0.73
Beach Deposits	Well-sorted sand and gravel	0.01	0.02

Soils

The Waimea hydrologic unit consists largely of soils that are fairly impermeable. The upper portion of the hydrologic unit has an impermeable basalt layer due to the collapsed Mount Waialeale caldera that

[1] Permeability is the ease with which water passes through material. It is a factor in determining whether precipitation runs off on the surface or descends into the ground.
[2] Basal water is generally considered to be ground water with a water table (the elevation of the top of the water) to be near sea level.

limits the downward movement of water, resulting in the Alakai marsh and associated with Alakai soils. Water moves laterally until it either seeps out as springs or base flow[3]. Most of the region has a thin layer of granular heavy clay loam (2" thick) underlain by dark reddish-brown clay about 12" thick. The substratum is hard rock and surface soil permeability is moderate to moderately slow resulting in rapid runoff and severe erosion hazard. The less sloping tops of ridges and interfluves (regions of higher land between valleys in the same hydrologic unit) are poorly drained but still support moderate infiltration (Figure 2-2).

The lowlands of the hydrologic unit are characterized by well-drained clay and rough broken land – very steep land broken by numerous intermittent drainage channels. The numerous gulches and mountainsides have slopes of 40 to 70 percent, leading to high rates of slopewash. Runoff is rapid in these soils and geologic erosion is active. The soils of rough broken land are not uniform (Table 2-2). The clay is moderately permeable with slow to medium runoff and a slight to moderate erosion hazard (U.S. Department of Agriculture, Soil Conservation Service, 1972).

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

Map Unit	Description	Area (mi^2)	Percent (%)
rAAE	Alakai	7.46	8.71
BM	Badland	1.61	1.88
BS	Beaches	0.01	0.01
HMA, HnA, HrB	Hanalei	0.58	0.68
HNUD, HNUF	Hulua, gr	0.28	0.32
IoB, IoC	Loleau	0.01	0.01
JkB	Jaucas va	0.05	0.06
Ke	Kalihi	0.07	0.08
KSKE, KSKF	Kokee	6.02	7.03
LuB	Lualualei	0.01	0.01
MaC, MaD, MaE, MaE3	Mahana	0.79	0.92
MgB, MgC, MgD, MgE2, MhB, MhC, MhD, MhE	Makaweli	0.87	1.01
NcC, NcD, NcD2	Niu	0.13	0.16
NnC	Nonopahu	0.01	0.01
OID, OME, OMF	Oli	2.11	2.46
PGE	Paaiki	<0.01	<0.01
PdA	Pakala	0.61	0.71
PHXC	Pakala, e	0.34	0.40
PwE, PwD, PwC	Puu Opae	0.09	0.10
rRH	Riverwash	0.18	0.21
rRO	Rock outcrop	30.19	35.25
rRR	Rough broken	6.16	7.19
rRT	Rough mountain	17.56	20.51
rRU	Rubble la	0.10	0.12
rWAF	Waialeale	5.39	6.30
WJF	Waiawa, e	3.35	3.92

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

[3] Base flow is the flow of water into a stream from the ground from persistent, sources (such as the seepage of ground water) and maintains streamflow between water-input events (i.e. during periods of no rainfall).

at which infiltration (intake of water) occurs when the soil is wet. The higher the infiltration rate, the faster the water is absorbed into the ground and the less there is to flow as surface runoff. Group A soils have the highest infiltration rates; group D soils have the lowest. In the Waimea hydrologic unit, 0.40 percent of soils are group A; 13.93 percent group B; 17.08 percent group C; and 68.28 percent group D. The hydrologic unit is largely dominated by steep gulches with soils in the Kokee series including numerous rock outcropings and rough mountain soils (Table 2-2). The center of the hydrologic unit consists of rough broken and rough mountainous soils while alluvium (riverwash) dominates the lower reaches (U. S. Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, 1986).

Rainfall

Rainfall distribution on Mount Waialeale is governed by the orographic[4] effect (Figure 2-3). 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 moist air cools, water condenses and the air mass releases precipitation. As a result, frequent and heavy rainfall is observed on windward mountain slopes. When cloud height is restricted by the temperature inversion[5], moist air reaches the fog drip zone, favoring fog drip over rain-drop formation (Sholl et al., 2002). 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 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 the sky is frequently clear (absence of clouds) with high solar radiation, creating an arid atmosphere with little rainfall.

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. Precipitation on Mount Waialeale is influenced by its northernmost position relative to the main Hawaiian Islands, providing more exposure to frontal systems during winter. The highest position lies in the trade wind inversion layer (6,000 feet above sea level) resulting in peak rainfall potential. The fog drip zone on the windward side of Waialeale 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). The steep gradient around the island forces moisture-laden air to rapidly rise in elevation (over 3,000 feet) in a short distance, resulting in a rapid release of rainfall in one location. Finally, the relatively round, conical shape of the mountain exposes all sides of the peak to wind and moisture.

The Waimea hydrologic unit is situated on the leeward flank of Mount Waialeale and as such receives little to no orographic rainfall (Figure 2-5). The high spatial variability in rainfall is evident where the mean annual rainfall decreases by about 40 inches with an average 500-foot drop in elevation. In the northwest regions rainfall is highest during the months of December and January, where the mean monthly rainfall is 10.6 inches. In the northeast regions mean monthly rainfall can reach as high as 18 inches from November to March. The driest months are May to September during which an average of less than 4 inches of rain fall each month.

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[4] 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.
[5] Temperature inversion refers to the elevation in the atmosphere at which there is a switch between decreasing air temperature with increasing elevation to increasing air temperature with increasing elevation.

Figure 2-1. Generalized geology of Waimea hydrologic unit. (Source: Sherrod et al., 2007)

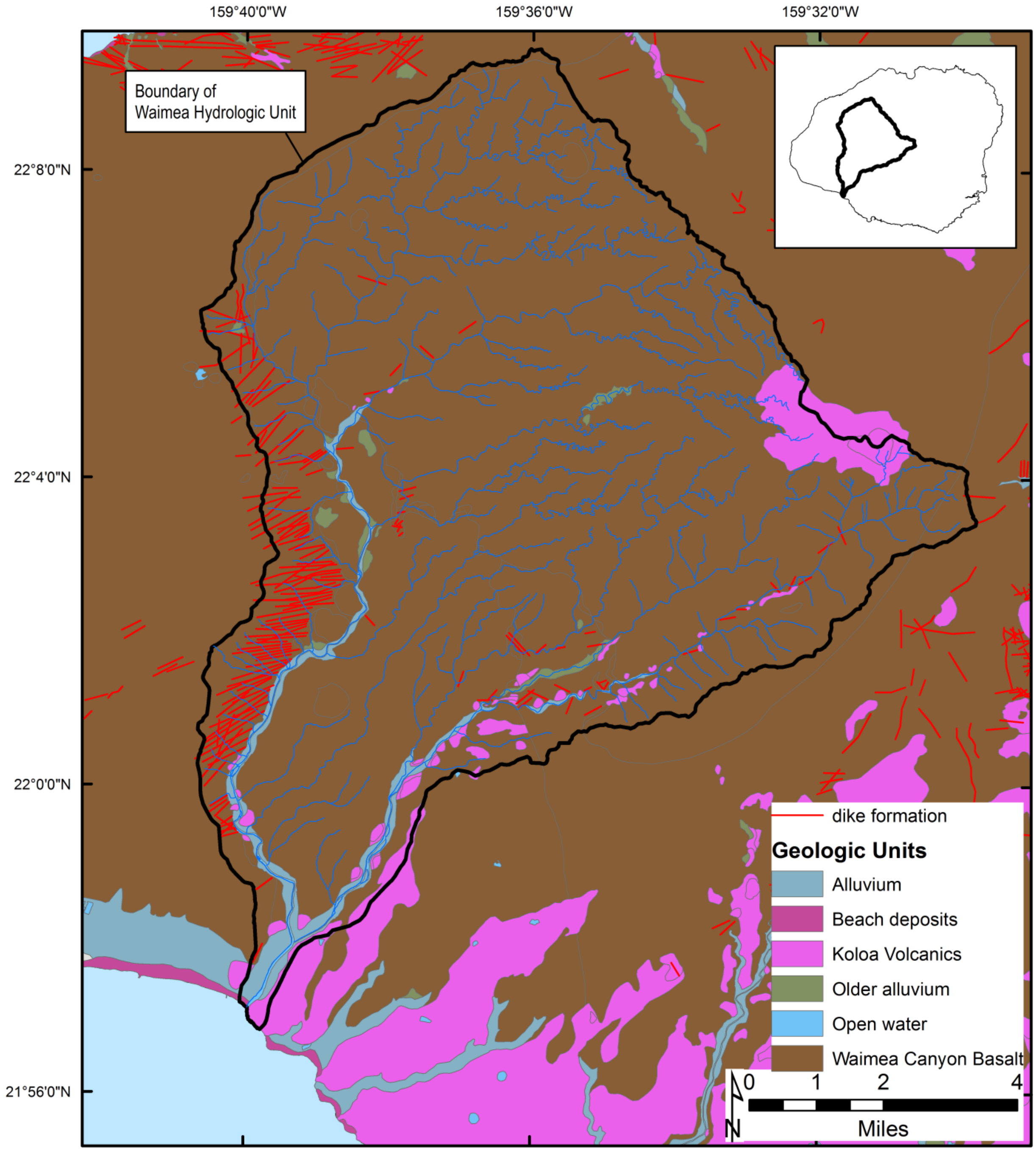


Figure 2-2. Soil classification in Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015m)

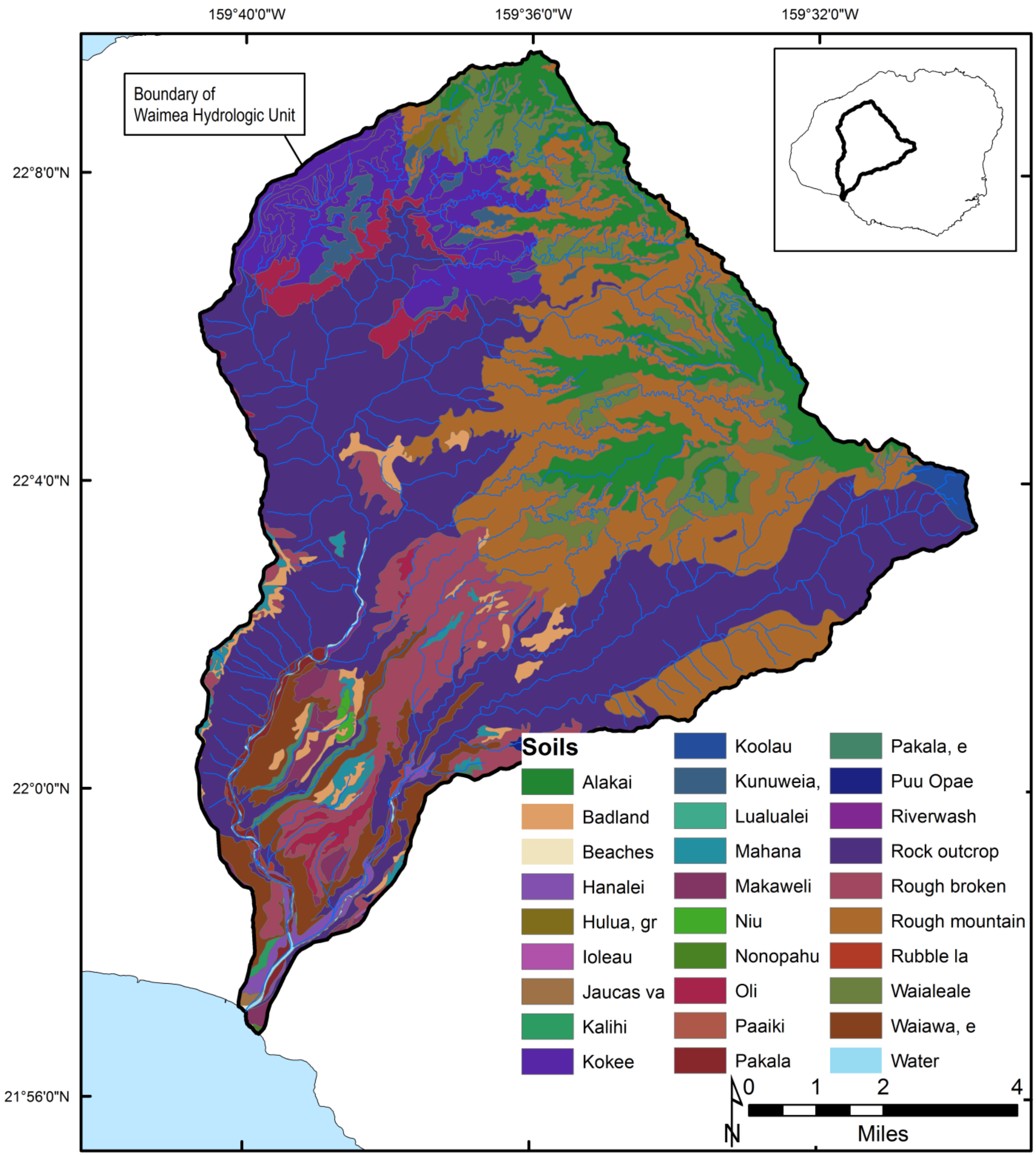
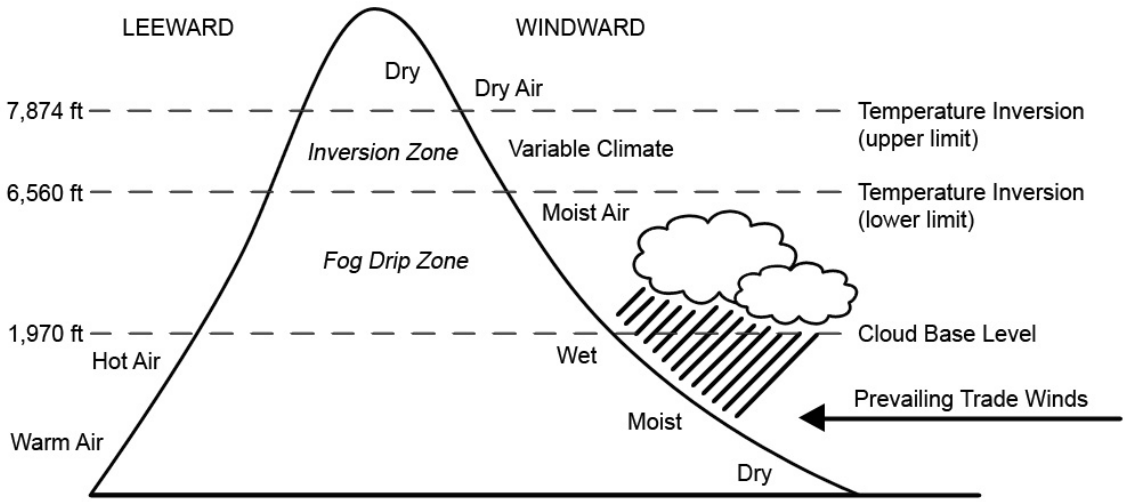


Figure 2-3. Orographic precipitation in the presence of mountains higher than 6,000 feet.



Currently, fog drip data for leeward slopes are non-existant. Shade (1999) used the monthly fog drip to rainfall ratios for the windward slopes of Mauna Loa on the island of Hawaii (Table 2-3) to calculate fog drip contribution to the water-budget in windward east Maui. The fog drip to rainfall ratios were estimated using: 1) the fog drip zone boundaries for east Maui (Giambelluca and Nullet, 1991); and 2) an illustration that shows the relationship between fog drip and rainfall for the windward slopes of Mauna Loa, island of Hawaii (Juvik and Nullet, 1995). This method was used to determine the contribution of fog drip in Waimea hydrologic unit, which is calculated by multiplying the ratios with the monthly rainfall values (Giambelluca et al, 2013). Calculations show that approximately 50 percent of Waimea lies in the fog drip zone based on elevation. The total contribution from fog drip to the water budget based on percent of fog drig from monthly rainfall is about 30%, assuming the same ratios apply to leeward slopes (Table 2-3).

Table 2-3. Fog drip to rainfall ratios for the windward slopes of Mauna Loa on the island of Hawaii and approximate contributions to the Waimea Hydrologic Unit based on an elevation range of 2000-6500 ft.

Month	Ratio (%)	Mean Rainfall (in)	Contribution (in)
January	13	11.91	1.55
February	13	9.87	1.28
March	13	12.06	1.57
April	27	9.69	2.62
May	27	8.52	2.30
June	27	6.18	1.67
July	67	7.14	4.78
August	67	6.45	4.32
September	67	6.51	4.36
October	40	8.47	3.39
November	40	11.72	4.69
December	27	12.75	3.44

Solar Radiation

Solar radiation is the sun's energy that arrives at the Earth's surface after considerable amounts have been absorbed by water vapor and gases in the Earth's atmosphere. The amount of solar radiation to reach the surface in a given area is dependent 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 Waimea, average annual solar radiation is 201.75 W/m^2 per day with a range of 148.2-219.9 W/m^2 per day (Figure 2-5). It is greatest at the coast and decreases toward the uplands, where cloud cover is more common (Giambelluca et al. 2014).

Evapotranspiration

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 is lost to the atmosphere. 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[6], rainfall, humidity, wind speed, surface temperature, and sensible heat advection[7]. 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). 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 and the cloud layer (Figure 2-3). At low elevations near the coast, pan evaporation rates are influenced by sensible heat advection from the ocean (Nullet, 1987). Pan evaporation rates are enhanced in the winter by positive heat advection from the ocean, and the opposite occurs in the summer when pan evaporation rates are diminished by negative heat advection (Giambelluca and Nullet, 1992). With increasing distance from the windward coasts, positive heat advection from dry land surfaces becomes an important factor in determining the evaporative demand at the slopes (Nullet, 1987). Shade (1999, Fig. 9) estimated pan evaporation rates of 30 inches per year below 2,000 feet elevation to 90 inches per year near the coast. Within the cloud layer, evaporation rates are particularly low due to the low radiation and high humidity caused by fog drip. Pan evaporation rates dropped 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. Actual annual

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

evapotranspiration in the Waimea hydrologic unit (Figure 2-6) averages 1.15 in per day and ranges from 0.37 to 2.67 in per day (Giambelluca et al. 2014).

Figure 2-4. Mean annual rainfall and elevation contour Waimea hydrologic unit. (Source: Giambelluca et al., 2013)

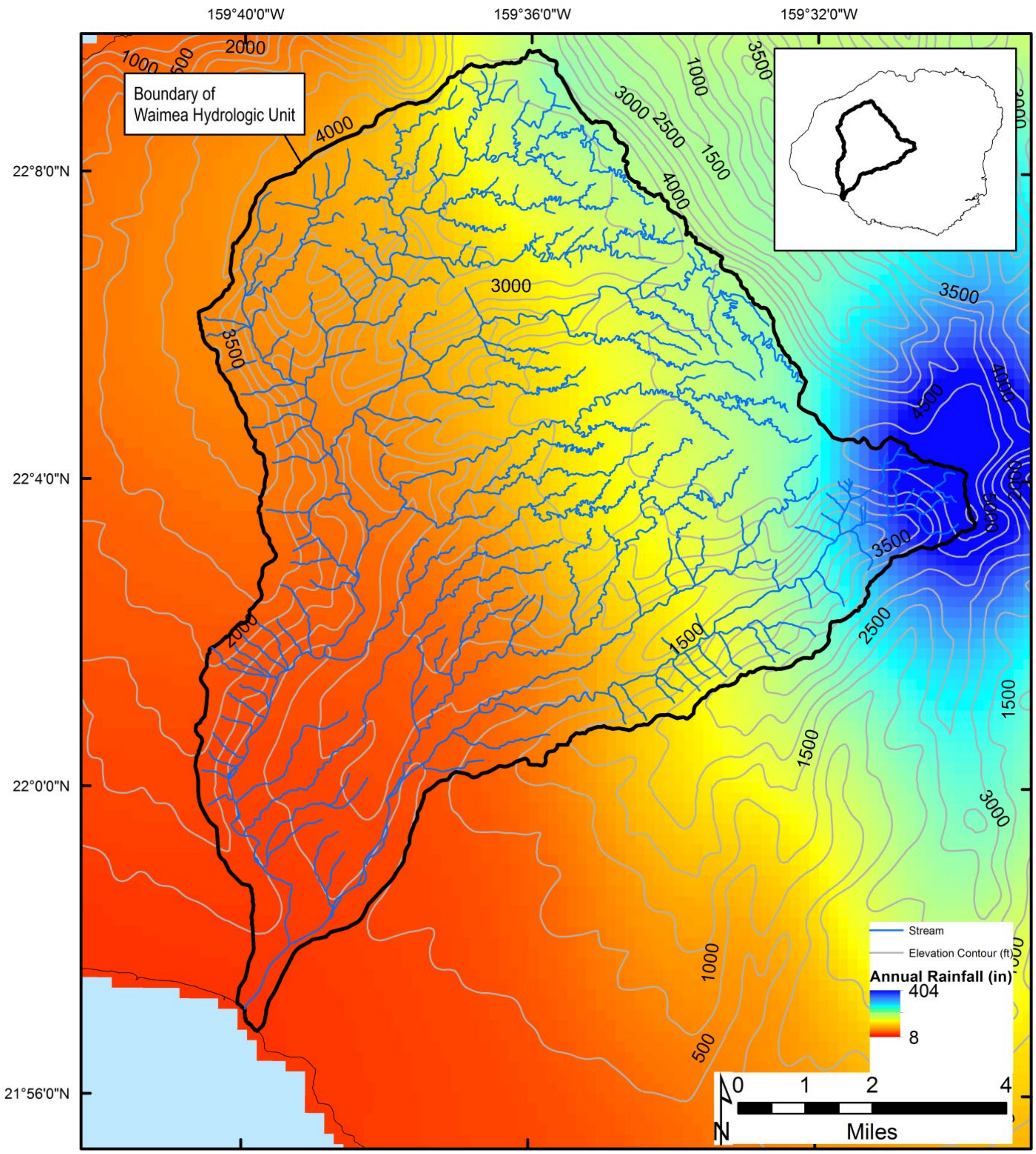


Figure 2-5. Mean annual solar radiation for the Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015c)

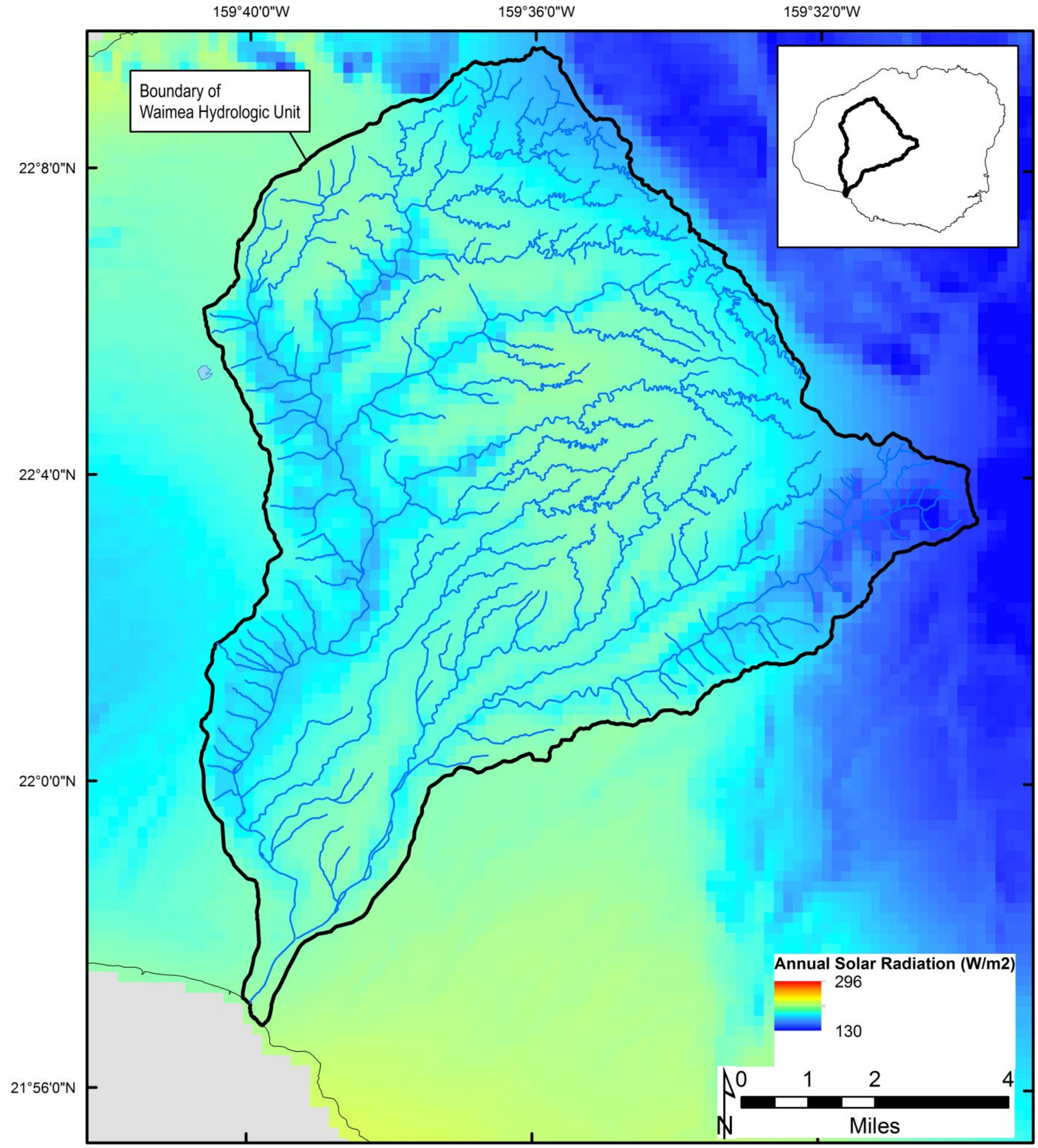
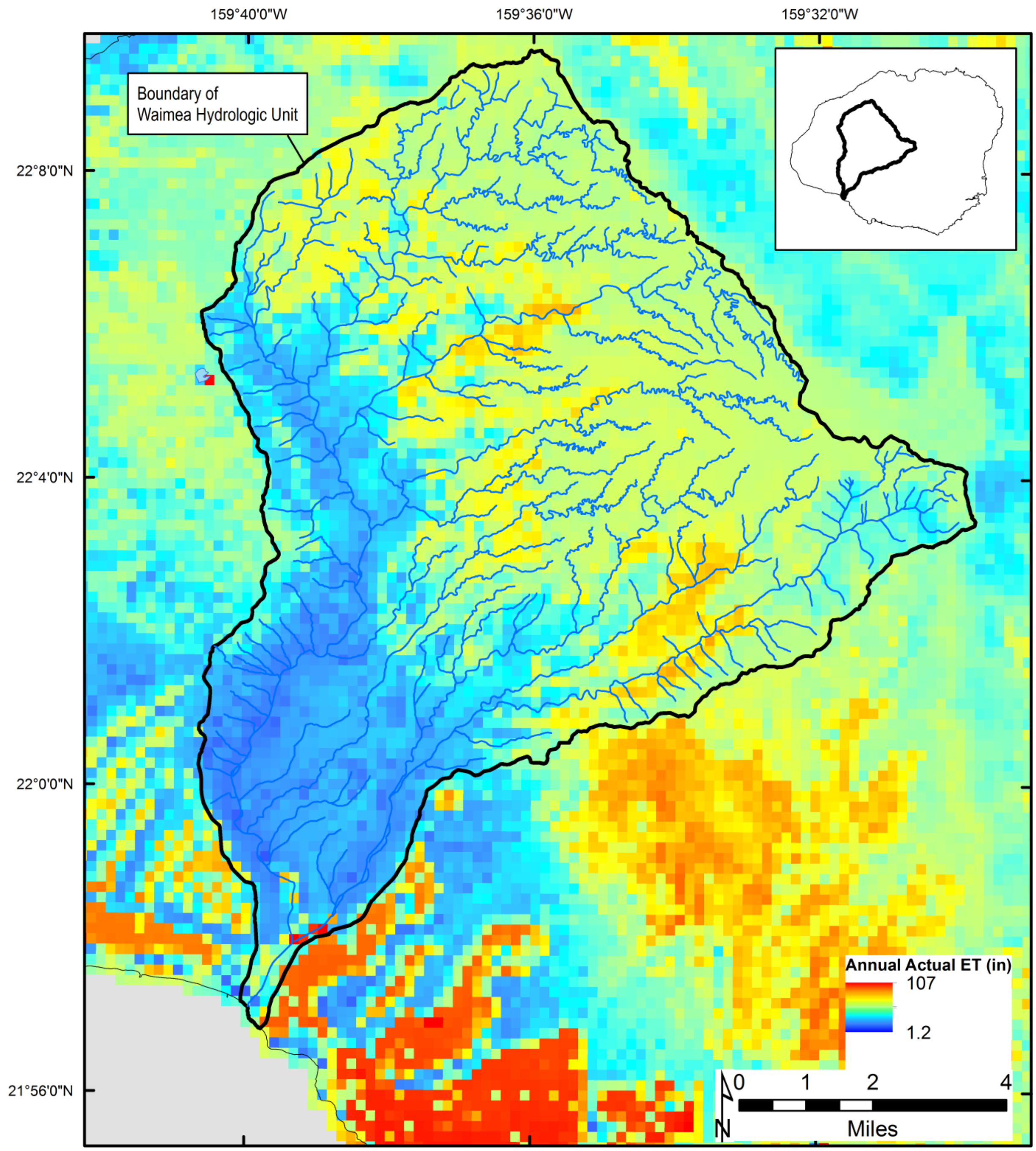


Figure 2-6. Mean annual actual evapotranspiration for the Waimea hydrologic unit. (Source: Giambelluca et al., 2014)



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 2014, the LUC designated 87 percent of the land in Waimea as conservation district, 13 percent as agricultural district and <1 percent as rural or urban (State of Hawaii, Office of Planning, 2015d). The conservation district is located in the upper part of the hydrologic unit, whereas the agricultural, rural, and urban districts lie in the lower part of the hydrologic unit (Figure 2-7).

Land Cover

Land cover for the hydrologic unit of Waimea is represented by two separate 30-meter Landsat satellite datasets. One of the datasets, developed by the Coastal Change Analysis Program (C-CAP), provides a general overview of the land cover types in Waimea, e.g., forest, grassland, shrub land, with minor developed areas, cultivated areas, and bare land (Table 2-4, Figure 2-8). 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 2-9).

Based on the two land cover classification systems, the land cover of Waimea consists mainly of forested areas. Over half of the hydrologic unit is made up of alien forests that spread throughout the upper slopes as part of the Na Pali-Kona Forest Reserve and the Kokee State Park. A mixture of ohia (*Meterosideros polymorpha*) forests and uluhe shrub lands can be found at intermediate slopes. Alien grasslands cover a majority of the lower altitudes near the coast with very little urban or industrial developments.

Table 2-4. C-CAP land cover classes and area distribution in Waimea hydrologic unit. (Source: National Oceanographic and Atmospheric Agency, 2015)

Land Cover	Description	Area (mi^2)	Percent of Unit
Evergreen Forest	Areas where more than 67% of the trees remain green throughout the year	54.8	64
Grassland	Natural and managed herbaceous cover	19.7	23
Scrub/Shrub	Areas dominated by woody vegetation less than 6 meters in height	9.1	10.6
Low Intensity Developed	Constructed surface with substantial amounts of vegetated surface	1.2	1.4
Bare Land	Bare soil, gravel, or other earthen material with little or no vegetation	0.3	0.4

The land cover maps (Figures 2-8, 2-9) provide a general representation of the land cover types in Waimea. 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. Community members have reported lands cultivated with tropical flowers, dryland (and some wetland) taro, sweet potato, banana, and papaya, primarily in the lowest portions of the hydrologic unit. Along the coast, a number of typical native and alien species have been reported. Some of those native species include ulei, naupaka kahakai, akia, lauwe, and hala.

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

Land Cover	Area (mi^2)	Percent of Unit
Alien Shrubland	18.994	22.18%
Alien Forest	16.404	19.16%
Very Sparse to Unvegetated	13.421	15.67%
Closed Ohia Forest	10.640	12.42%
Open Ohia Forest	8.418	9.83%
Native Wet Forest and Shrubland	4.773	5.57%
Native Mesic Forest	2.502	2.92%
Open Koa-Ohia Forest	2.157	2.52%
Closed Koa-Ohia Forest	2.147	2.51%
Alien Grassland	2.129	2.49%
Native Wet Cliff Vegetation	1.691	1.97%
Native Dry Cliff Vegetation	1.035	1.21%
Agriculture	0.461	0.54%
Low Intensity Developed	0.336	0.39%
Bog Vegetation	0.265	0.31%
Kiawe Forest	0.184	0.22%
High Intensity Developed	0.041	0.05%
Wetland Vegetation	0.027	0.03%
Water	0.005	0.01%

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 all the debris in their path down to the coast, causing water quality problems in the near-shore waters. Some floods can even trigger massive landslides, blocking off the entire stream channel. 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.

Natural stream flow data is only available in the headwater basins of the Waimea hydrologic unit, but based on regression modeling and actual stream gaging records, the flood magnitudes are extremely large in Waimea due to its large size. Based on U.S. Geological Survey Peak-Flow statistics at the long-term gaging station near Waimea town (station # 16031000), the 10 year, 50 year, and 100 year peak floods have magnitudes of 27,200 cfs, 41,200 cfs and 47,300 cfs, respectively. On August 15-18, 1950, the only known typhoon to reach the Hawaiian Islands produced rainfall totals as high as 50 in in 72 hours in (Chun, 1952). Peak flows topped the existing flood wall by one foot, causing tremendous damage in Waimea town. The Army Corps of Engineers constructed a flood control levee along the lowest reaches of the river to protect Waimea town. The Federal Emergency Management Agency (FEMA) developed maps that identify the flood-risk areas in an effort to mitigate life and property losses associated with flooding events. Based on these maps, FEMA identified a number of flood-risk zones in the Waimea hydrologic unit (Figure 2-10).

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 recent past years are associated with the El Niño Southern Oscillations[8]. 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). The most recent drought occurred in 2000-2002, affecting all islands, especially the southeastern end of the State. During this period, both mean annual flow and median flow in Kawaikoi Stream was 75% of normal.

Table 2-6. Drought risk areas for Kauai. (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	Hanalei to Alakai	Koloa, Kapaa, Wailua, Lihue, Poipu, Anahola	Kapaa, Wailua, Lihue, Poipu, Hanalei, Princeville, Kilauea, Anahola
Agriculture and Commerce	Waimea, Poipu, Lihue, Anahola, Kekeha/Mana	Lihue	Lihue
Environment, Public Health and Safety	Waimea	Lihue, Poipu, Wailua	Lihue, Poipu, Koloa

[8] El Niño Southern Oscillations (ENSO) are 3-7 year climate patterns that occur due to a generalized warming of mid-lattitude ocean water which influences the circulation patterns of air masses, driving changes in the distribution of rainfall

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 Kauai are summarized in Table 2-6. Based on the 12-month SPI, the Kapaa, Wailua, Lihue, and Poipu regions have the greatest risk to drought impact of the Kauai regions because of its dependence on surface water sources, limited rainfall, relatively high drought frequency, and high population density. The growing population in the already densely populated area further stresses the water supply. The Waimea region is vulnerable to drought in the agricultural sector and has substantial wildfire risk, but these are away from large population concentrations.

In addition to drought effects on agriculture and the community, drought can increase the risk of wildfire danger. Since 1999, there have been 70 wildfires in the Waimea hydrologic unit, with an average of 0.40 acres burned in each fire. Fire danger in regions adjacent to Waimea is also of concern as 123 separate wildfires have burned with an average size of 2.72 acres (Figure 2-11). With growth of fire-prone non-native species in the region, wildfire risk to life and property is high and water resources are often needed to fight such fires.

Figure 2-7. State land use district boundaries in Waimea hydrologic unit (Source: State of Hawaii, Office of Planning, 2015d).

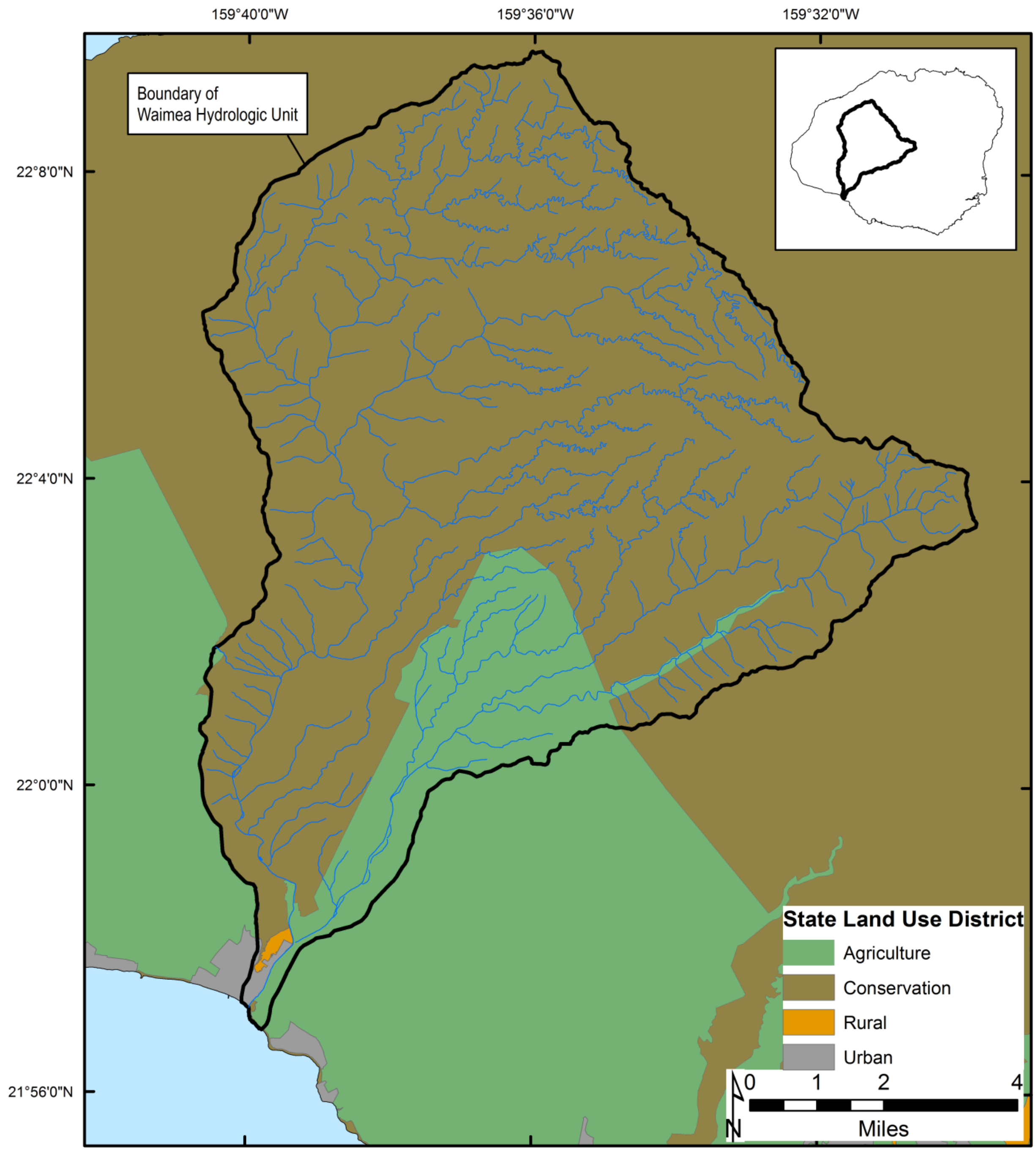


Figure 2-8. C-CAP land cover in Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015k).

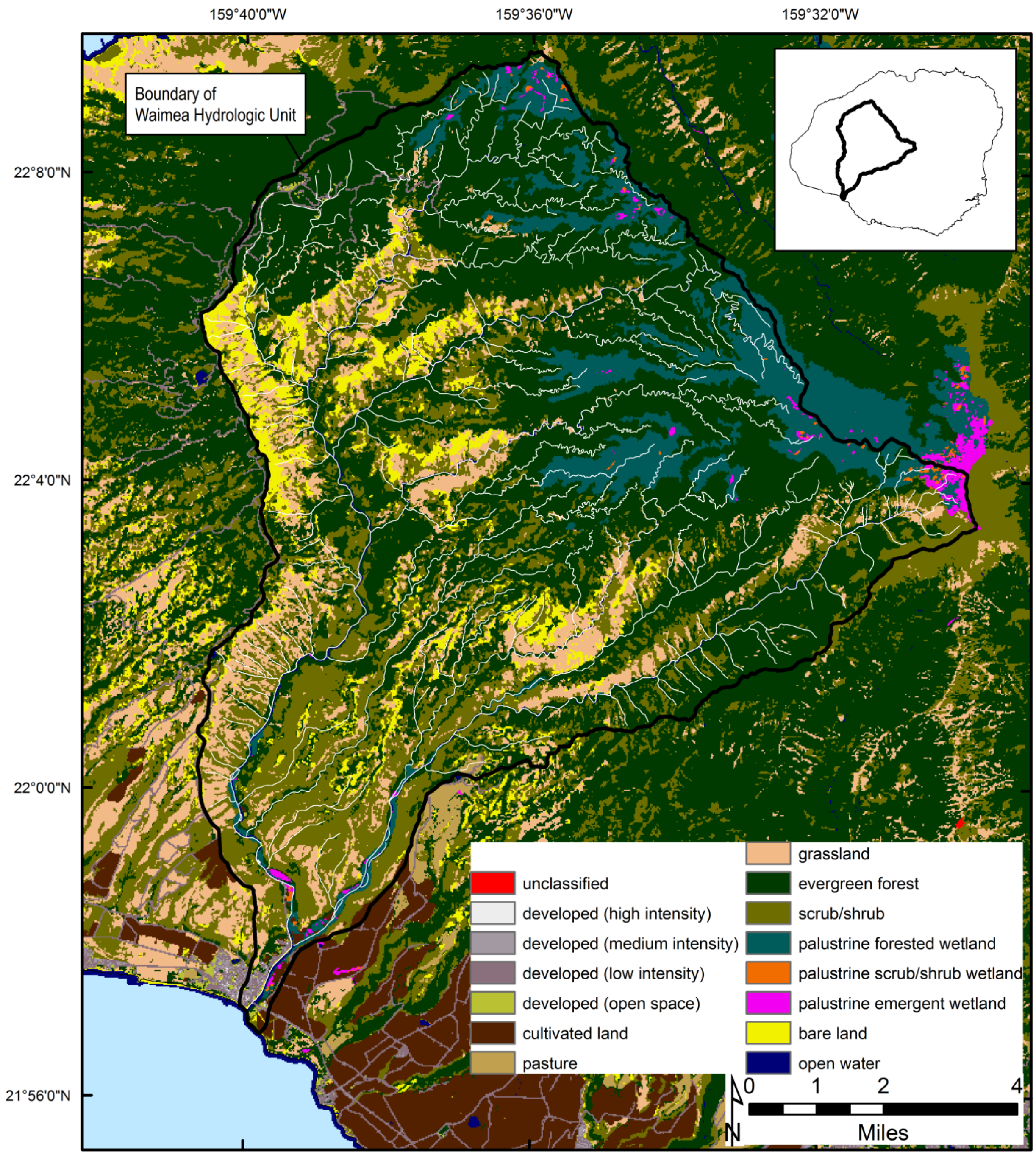


Figure 2-9. Hawaii GAP land cover classes in Waimea hydrologic unit (Source: State of Hawaii, Office of Planning, 2015f).

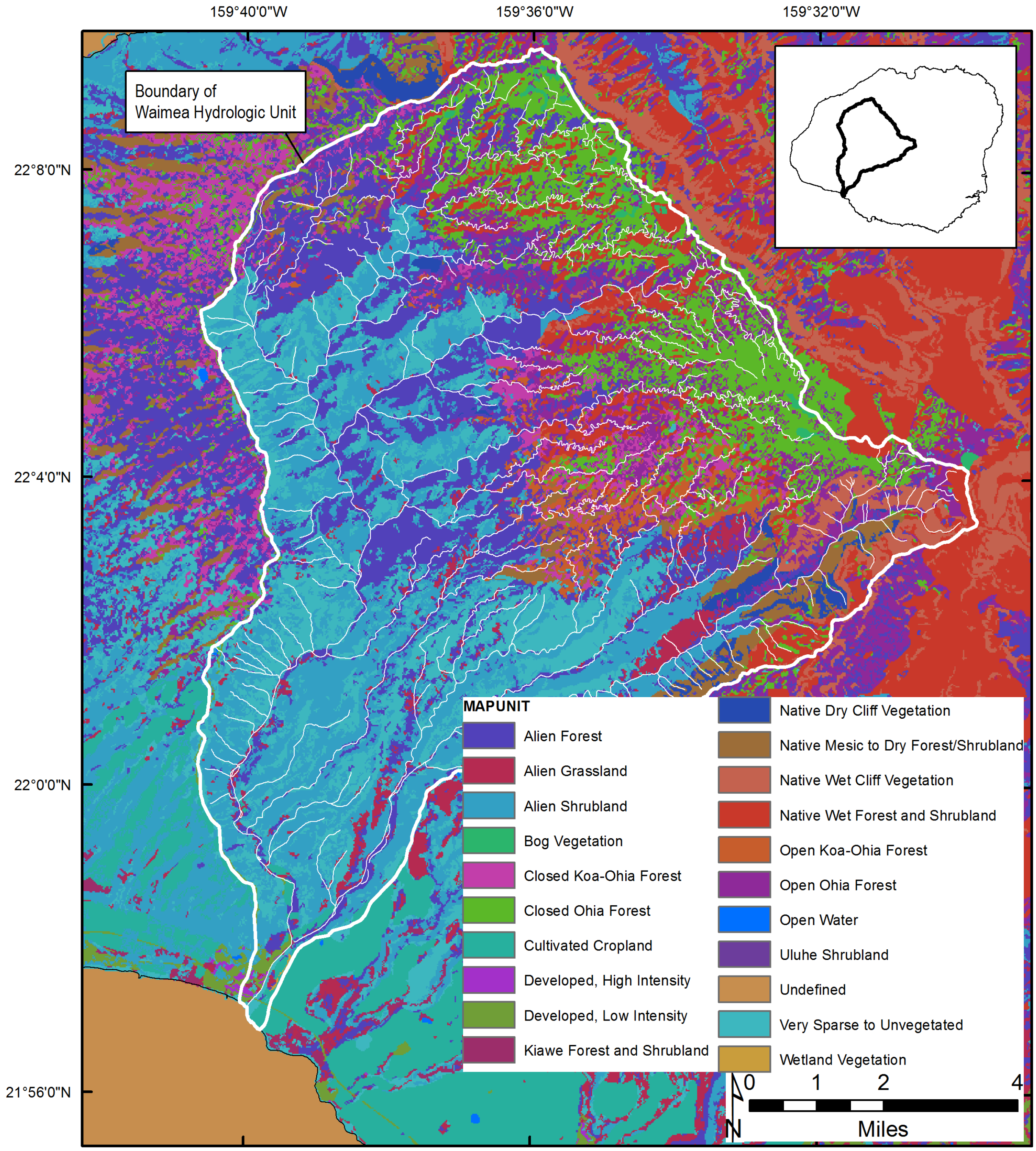


Figure 2-10. FEMA flood zone regions in Waimea hydrologic unit (Source: Federal Emergency Management Agency, 2014).

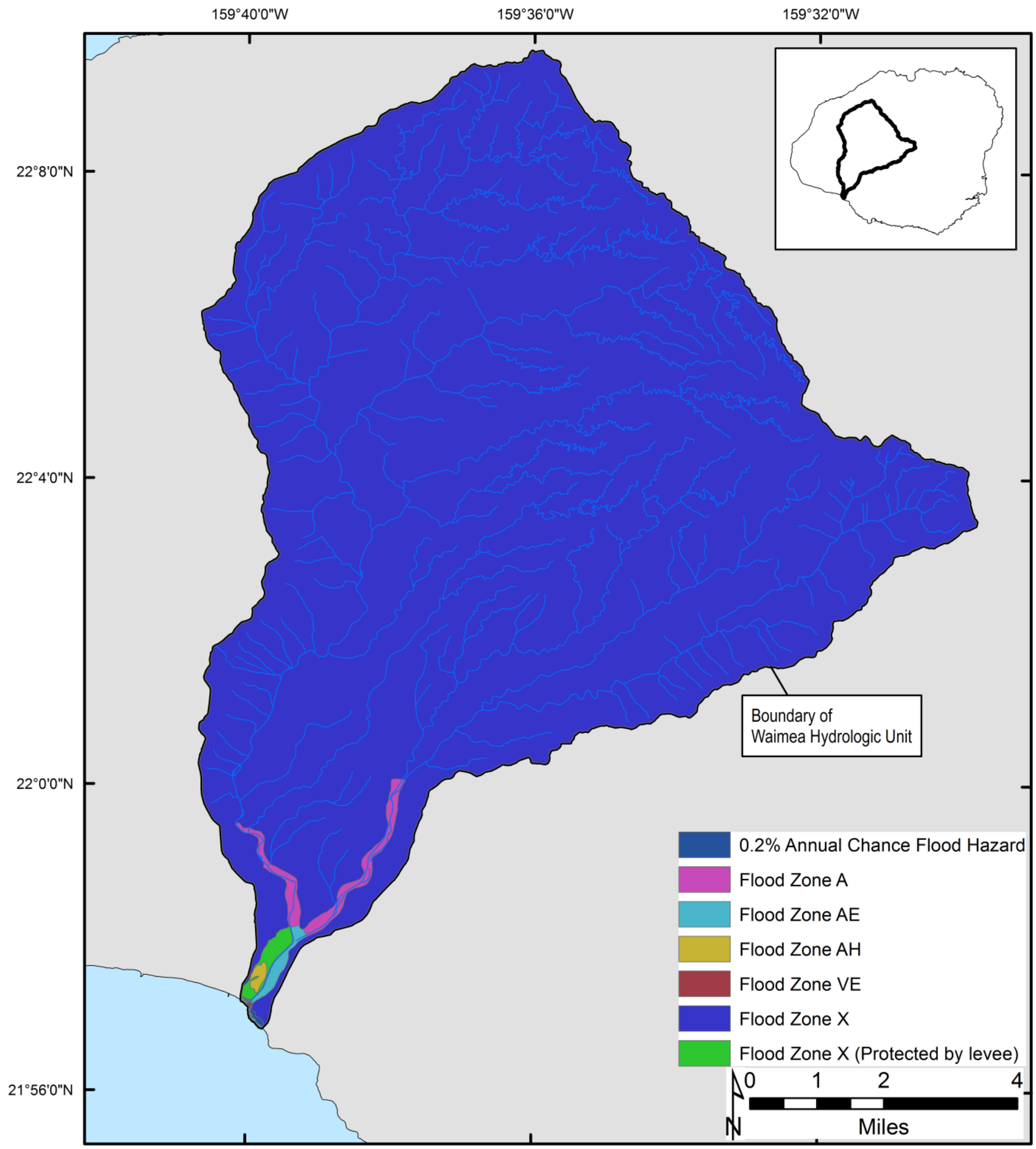
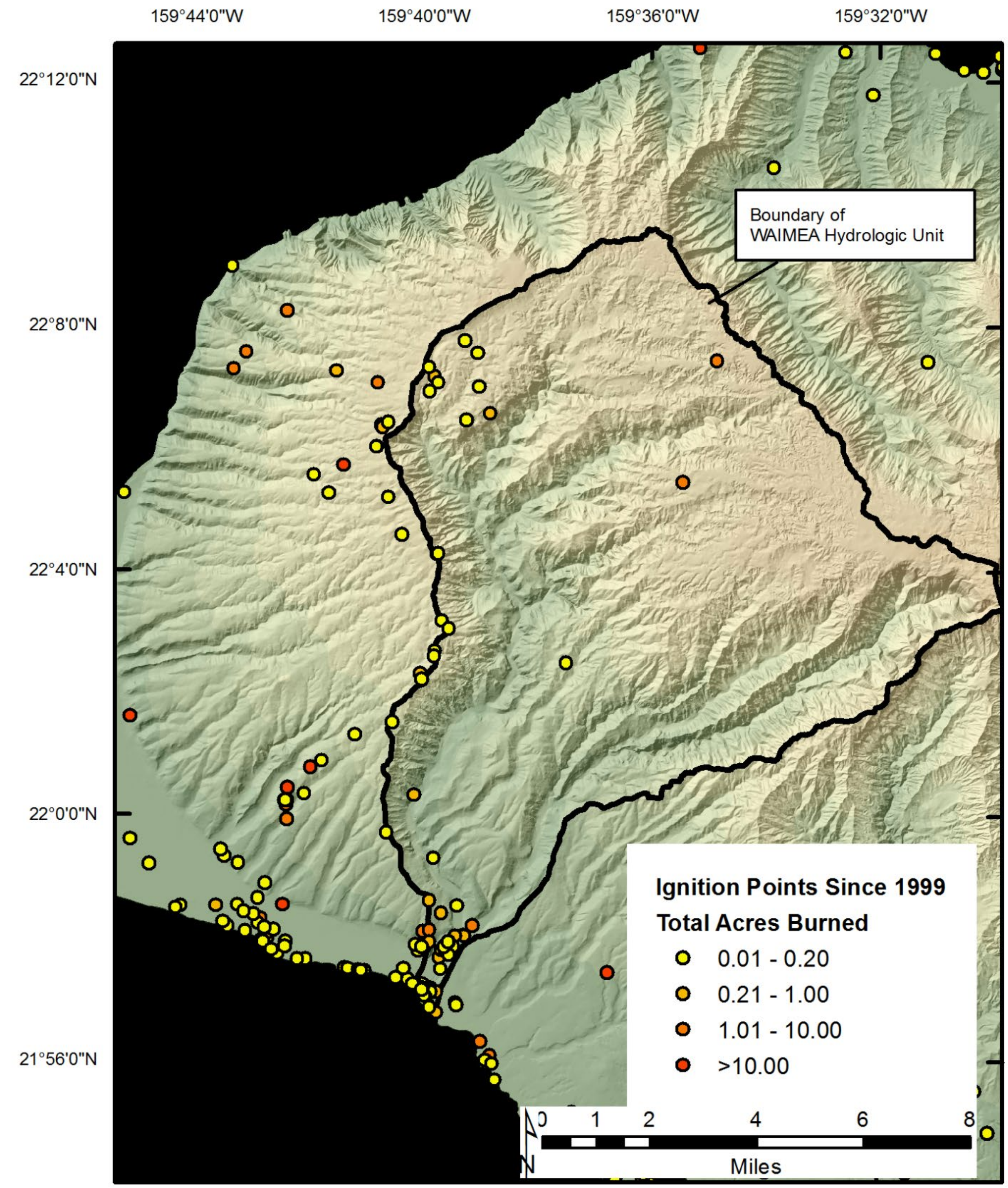


Figure 2-11. Map of wildfire ignition points in southwest Kauai since 1999. (Source: HWMO, 2013)



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 water in Waimea.

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

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. 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 that contribute to streamflow. At places where erosion has removed the caprock, ground water discharges either as springs or into the ocean as seeps. Currently, information on whether Waimea River or its tributaries are gaining or losing is unavailable.

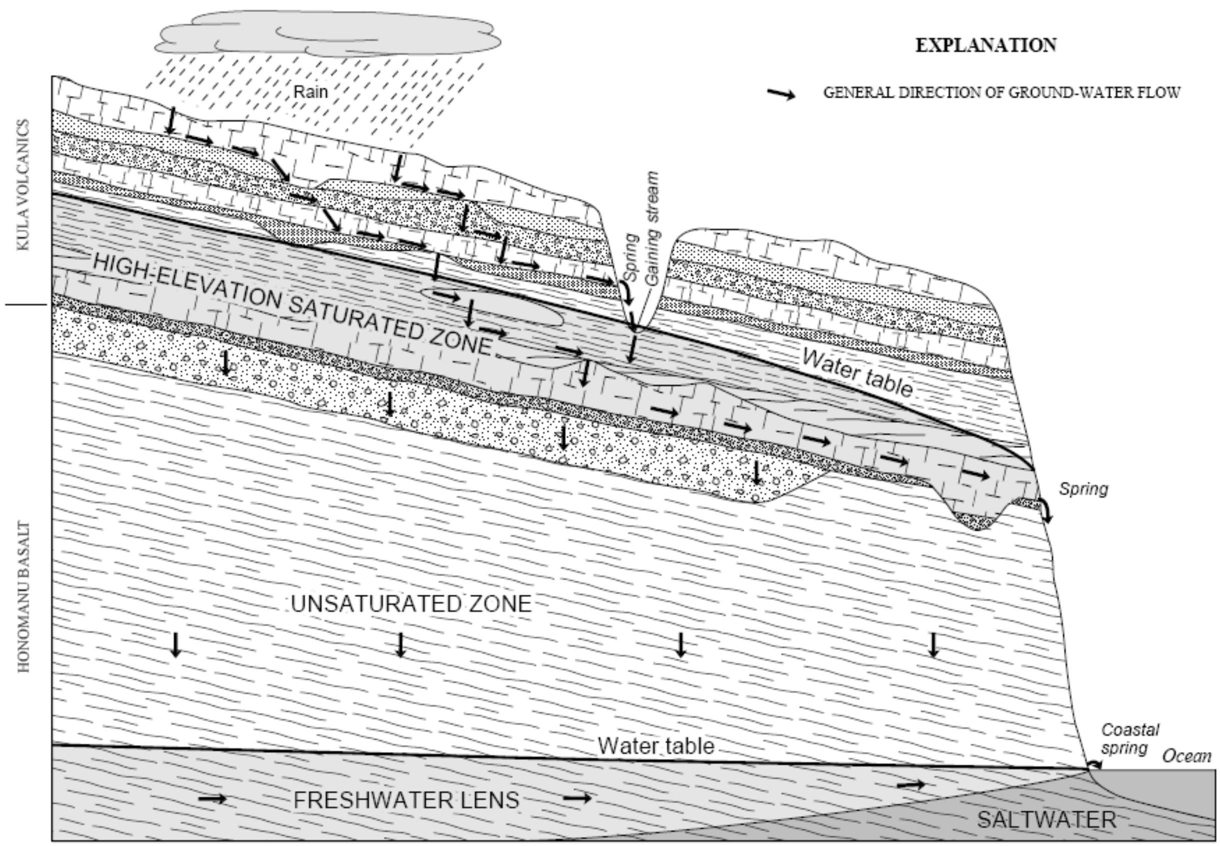
Ground Water

Ground water is an important component of streamflow as it constitutes the base flow[9] of Hawaiian streams. When ground water is withdrawn from a well, the water level in the surrounding area is lowered. Nearby wetlands or ponds may shrink or even dry up if the pumping rate is sufficiently high (Gingerich and Oki, 2000). The long-term effects of ground water withdrawal can include the reduction of streamflow, which may cause a decrease in stream habitats for native species and a reduction in the amount of water available for irrigation. The interaction between surface water and ground water warrants a close look at the ground water recharge and demand within the State as well as the individual hydrologic units.

[9] 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).

In Hawaii, ground water is replenished by recharge from rainfall, fog drip, and irrigation water that percolates through the plant root zone to the subsurface rock. This recharge is a critical part of the water cycle and provides the main source of water for consumption in Kauai. Recharge can be captured in three major ground water formations: 1) fresh water-lens; 2) dike-impounded; and 3) perched water. The fresh water-lens provides the most important sources of ground water for consumption and includes a lens-shaped layer of fresh water, an intermediate transition zone of brackish water, and underlying salt water (Figure 3-1). In Hawaii, 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 calderas of a volcano where low-permeability dikes compartmentalize areas of permeable volcanic rocks, forming high-level water bodies (Figure 3-1). Dikes may impound water to as high as 3,300 feet above mean sea level, as observed on Maui Island. 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).

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



The hydrologic unit of Waimea spans the Waimea and Makaweli aquifer systems. A general overview of the ground water occurrence and movement in this area is described in Gingerich (1999b) and illustrated in Figure 3-1. Ground water is found in dike-impounded structures of the Waimea Canyon Basalt as well as in the fresh water-lens system. A thick layer of impermeable caldera filling lava forms an aquitard in the upper region of the hydrologic unit known as the Alakai Marsh. This aquitard limits deep percolation of rainfall, resulting in numerous high-elevation fresh water streams. Additionally, the high-elevation saturated zone is not present near the coast because erosion has removed the low-permeability layers formed by the Koloa Volcanics. Withdrawal from wells at or below sea level should not affect the high-elevation water table because the thick unsaturated zone will prevent any significant changes in the vertical flow gradient. However, wells that remove water from the high-elevation water body can reduce streamflow and recharge into the freshwater lens.

The County of Kauai operates a municipal well near the coast (well no. 5939-01) and the State of Hawaii operates two wells for supplying the Kokee State Park Lodge and cabins (well no. 0739-01 and 0739-03). Detailed information for each well is specified in Table 3-1. Eight drill holes were bored in 1963 in the Kawaikoi catchment by the State of Hawaii Department of Land and Natural Resources Engineering Division as part of a study to determine the feasibility of generating a reservoir. These holes were never used as wells and are abandoned. As of 2005, the 12-month moving average for existing groundwater withdrawals from the Waimea aquifer section was 3.145 mgd and the 2006 total ground water demand of the Waimea aquifer system was only 4.762 mgd, which is well below the aquifer's current sustainable yield of 37 million gallons per day (State of Hawaii, Commission on Water Resource Management, 2015d). The nearby Kekaha and Makaweli aquifer systems have sustainable yields of 10 and 26 mgd, respectively. A majority of the reported ground water use is for domestic-residential single-family dwelling units (88 percent), municipal use (7.1 percent), and agriculture (2.9 percent) (Table 3-2).

Table 3-1. Information of wells located in Waimea hydrologic unit (Source: State of Hawaii, Commission on Water Resource Management, 2015d).

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

Well number	Well Name	Well Owner	Year drilled	Use	Ground elevation (feet)	Well depth (feet)	Pump elevation (feet)	Pump depth (feet)	Pump rate (gpm)
5939-01	Waimea Shaft 9	Kauai DWS	1932	Municipal County	40	43	--	--	300
0739-02	Kokee Park B	Hawaii State Parks	1986	Unused	3544	22	--	--	--
0738-01	Kokee-Waineke	Hawaii DLNR	2005	Unused	3558	119	--	--	0
0739-03	Kokee-Noe	Land Division	1996	Municipal State	3543	152	3430	113	40
0739-01	Kokee Park A	Hawaii State Parks	1986	Municipal State	3560	39	3533	27	40

Table 3-2. Summary of ground water use reporting in the island of Kauai (Source: State of Hawaii, Commission on Water Resource Management, 2015d).

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

Use Category	Use Rate (mgd)	Percent of Total (%)
Agriculture	0.137	2.88
Domestic	4.193	88.05
Industrial	0.022	0.46
Irrigation	0.058	1.21
Military	0.014	0.29
Municipal	0.338	7.10
Total	4.762	100

Streamflow Characteristics

Natural flow conditions are available from two long-term continuous monitoring sites maintained by the U.S. Geological Survey on Kawaikoi Stream (station #16010000) and Waiale Stream (station

#16019000). These stations were installed in 1919 and continue to collect data today. Historical streamflow data were also available from three additional stations at Kauikinana (station #16012000), Waiakoali (station #16011000), and Mohihi (station #16013000) streams from 1919 to 1925 (Figure 3-2).

Estimated natural (undiverted) flow statistics for the ungaged sites are presented in Table 3-3. Median total flows (TFQ_{50}) and baseflow (BFQ_{50}) are available from a six-year period of mean daily flows from 1919-1925 at Kauaikinana, Kowaikoi, Waiakoali, Mohihi, and Waiale. Values reported for Kokee stream are estimates based on regression values using differences in catchment area and flow yield from the other watersheds. Present-day flow conditions are also reported for the two streams with continuous data and estimated for the other four. 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 often times 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.

Figure 3-2. Ditches, diversions and gaging stations in the upper Waimea hydrologic unit that feed the Kokee Ditch system (Source: State of Hawaii, Commission on Water Resource Management, 2015a).

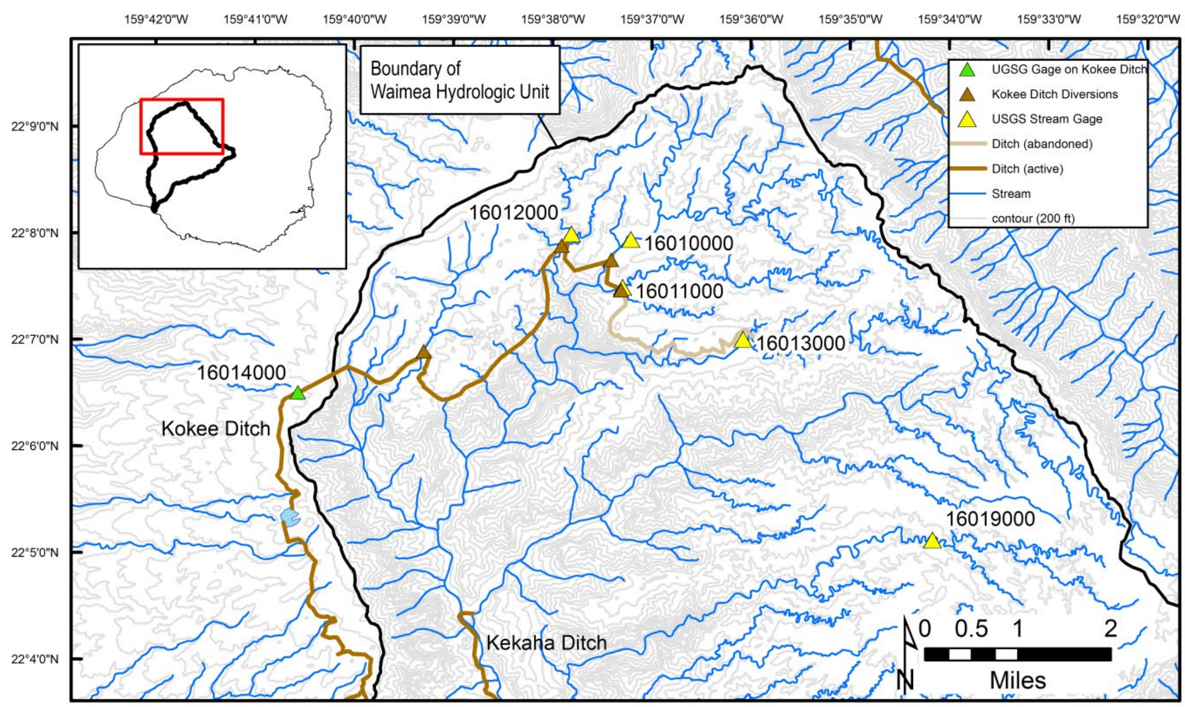


Table 3-3. Total flow (TFQ) and base flow (BFQ) actual (USGS) and estimated (by regression equation) flow statistics during historic (1919-1925) and current (1984-2013) time periods for undiverted streams in Waimea hydrologic unit.
[Flows are in cubic feet per second (cfs)]

	1919-1925					1984-2013				
location	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}	source	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}	source
Kokee	3.3	3.0	0.90	0.87	regression	2.8	2.6	0.82	0.76	regression
Kauaikinana	2.0	1.7	0.46	0.43	USGS	1.9	1.4	0.42	0.37	regression
Kawaikoi	13.5	10.3	3.6	3.3	USGS	11.0	8.7	3.1	2.9	USGS
Waiakoali	3.3	2.8	0.93	0.65	USGS	2.9	2.4	0.85	0.78	regression
Mohihi	3.4	2.7	0.62	0.52	USGS	2.9	2.3	0.57	0.45	regression
Waialae	6.0	4.9	2.0	1.8	USGS	12.0	9.3	3.4	2.8	USGS

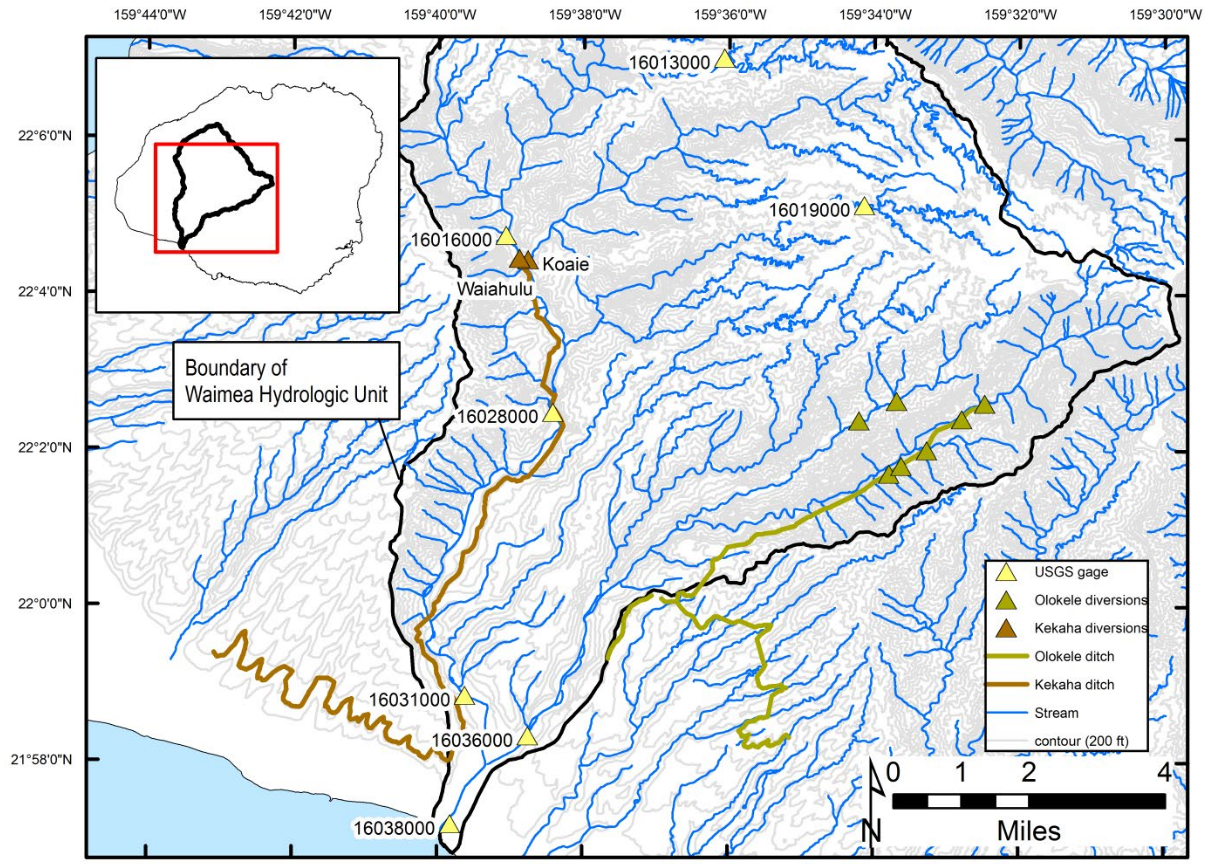
One of the limitations of the regression equations is that they do not account for variable subsurface geology, such as those of intermittent streams and where springs discharge high flow to streams. The equations may overestimate flow statistics in intermittent streams as they do not account for losing reaches. On the other hand, the equations may underestimate the additional streamflow gained from springs. The 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 East Maui were made using a combination of continuous-record gaging station data, low-flow measurements, and values determined from the regression equations.

In the lower Waimea hydrologic unit, water is diverted from the Koaie Stream and the Waimea River for the Kekaha Ditch and from the Olokele Stream, Waianuenue Stream and three minor tributaries for the Olokele Ditch. The U.S. Geological Survey monitored natural stream flow in the Koaie Stream (station #16017000) at an elevation of 3770 ft and regulated stream flow in the Waimea River (station #16016000) just above the diversion for the Kekaha Ditch as well as the Olokele Stream (station # 16034000) above the diversion for the Olokele Ditch (Figure 3-3). Regulated stream flow has also been monitored for extended periods of time below the ditches on the Waimea River (station #16031000) and Makaweli stream (station #16036000) above their confluence (Table 3-4).

Table 3-4. Natural and regulated total flow (TF) and base flow (BF) statistics and monitoring periods for streams feeding the Kekaha and Olokele ditch systems in the lower Waimea hydrologic unit.
[Flows are in cubic feet per second (cfs)]

Stream name	USGS station #	natural/regulation	Time period	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}
Koaie Stream	16019000	natural	1919-1932, 1954-1968	8.2	6.2	2.3	2.1
Olokele Stream	16034000	natural					
Waimea abv Kekaha ditch	16016000	regulated	1916-1918, 1925-1948, 1949-1968	19.0	17.0	12.0	10.6
Waimea nr Waimea	16031000	regulated	1910-1919,1943-1968, 1969-1972,1975-1997	16.0	11.5	1.4	1.1
Waimea blw Kekaha ditch	16028000	regulated	1921-1923, 1923-1924, 1925-1947, 1948-1955	1.5	1.06	0.0	0.0
Makaweli Stream	16036000	regulated	1943-2014	28.0	22.0	10.0	9.49

Figure 3-3. Ditches, diversions and gaging stations in the lower Waimea hydrologic unit that feed the Kekaha and Olokele ditch systems. (Source: State of Hawaii, Office of Planning, 2004c; State of Hawaii, Commission on Water Resource Management, 2015a; 2015e)



Ditch flow was monitored by the USGS (station #16032000) in the Olokele Ditch from 1910 to 1917. Mean ditch flow for this period was 44.71 mgd (Q_{50} = 42.64 mgd), which is higher than the 35.79 mgd more recently reported from December 2015 to March 2016. Assuming the diversion captures 100% of baseflow in the Olokele Stream, baseflow in the stream at the diversion can be approximated by the Q_{70} value of 35.46 mgd.

Long-term trends in flow

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. Figure 3-5 illustrates the results of the study for 7 long-term gaging stations around the islands. According to the analyses, low flows generally decreased from 1913 to 2002, which is consistent with the long-term downward trends in rainfall observed throughout the islands during that period. Monthly mean base flows decreased from the early 1940s to 2002, which is consistent with the measured downward trend of low flows from 1913 to 2002. This long-term downward trend in base flow may imply a reduction of ground water contribution to streams. Kowaikoi streamflow declined from the 1920s to present day while Waiale streamflow has increased during this same period, suggesting a shift in regional rainfall patterns or changes in the hydrology of the Alakai Marsh. Changing streamflow characteristics could pose a negative effect on the availability of off stream use, such as drinking water for human consumption, and habitat for native stream fauna (Oki, 2004).

Figure 3-4. Aquifer system area and well locations (with well numbers) in Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015d; State of Hawaii, Commission on Water Resource Management, 2015f)

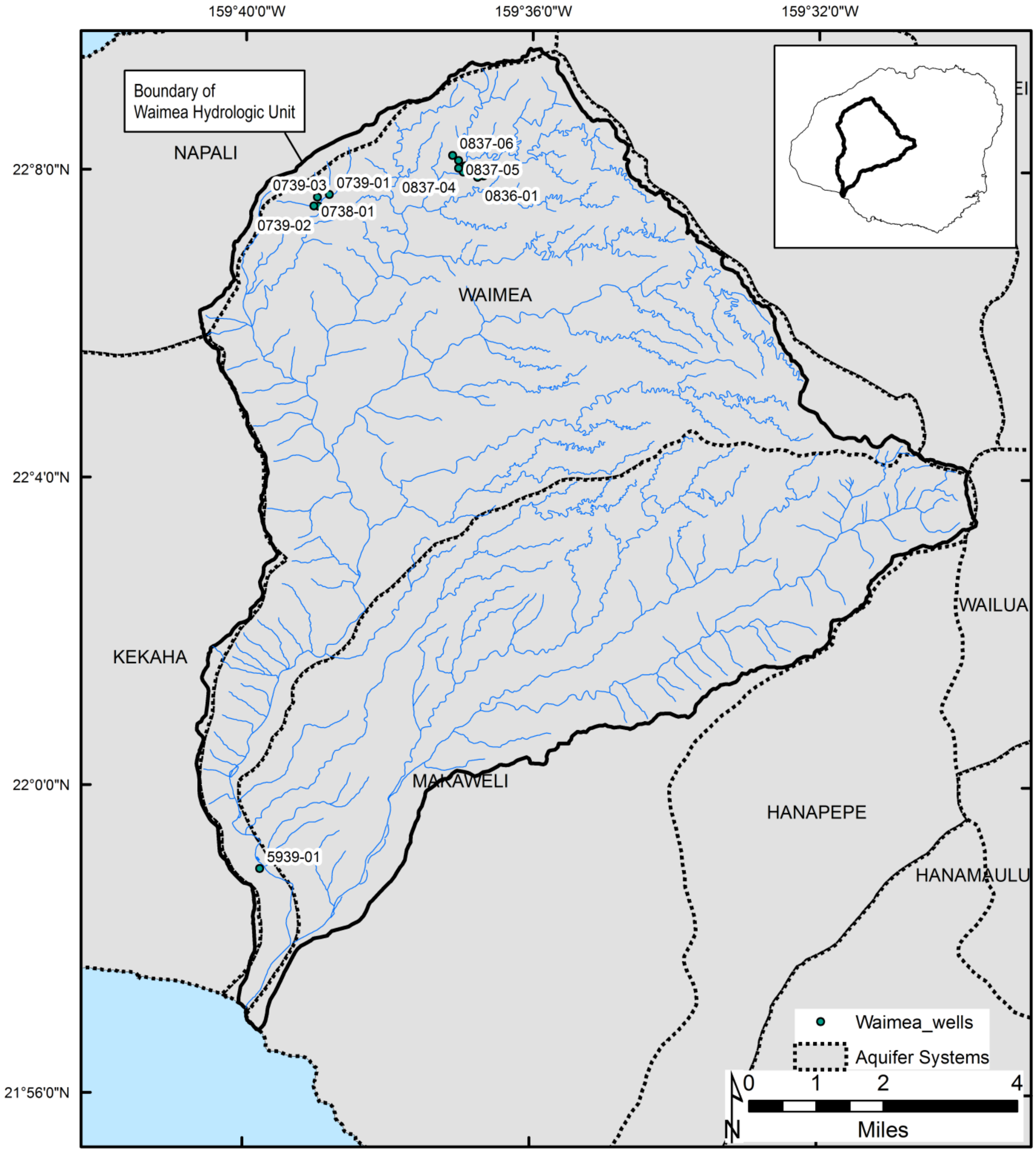
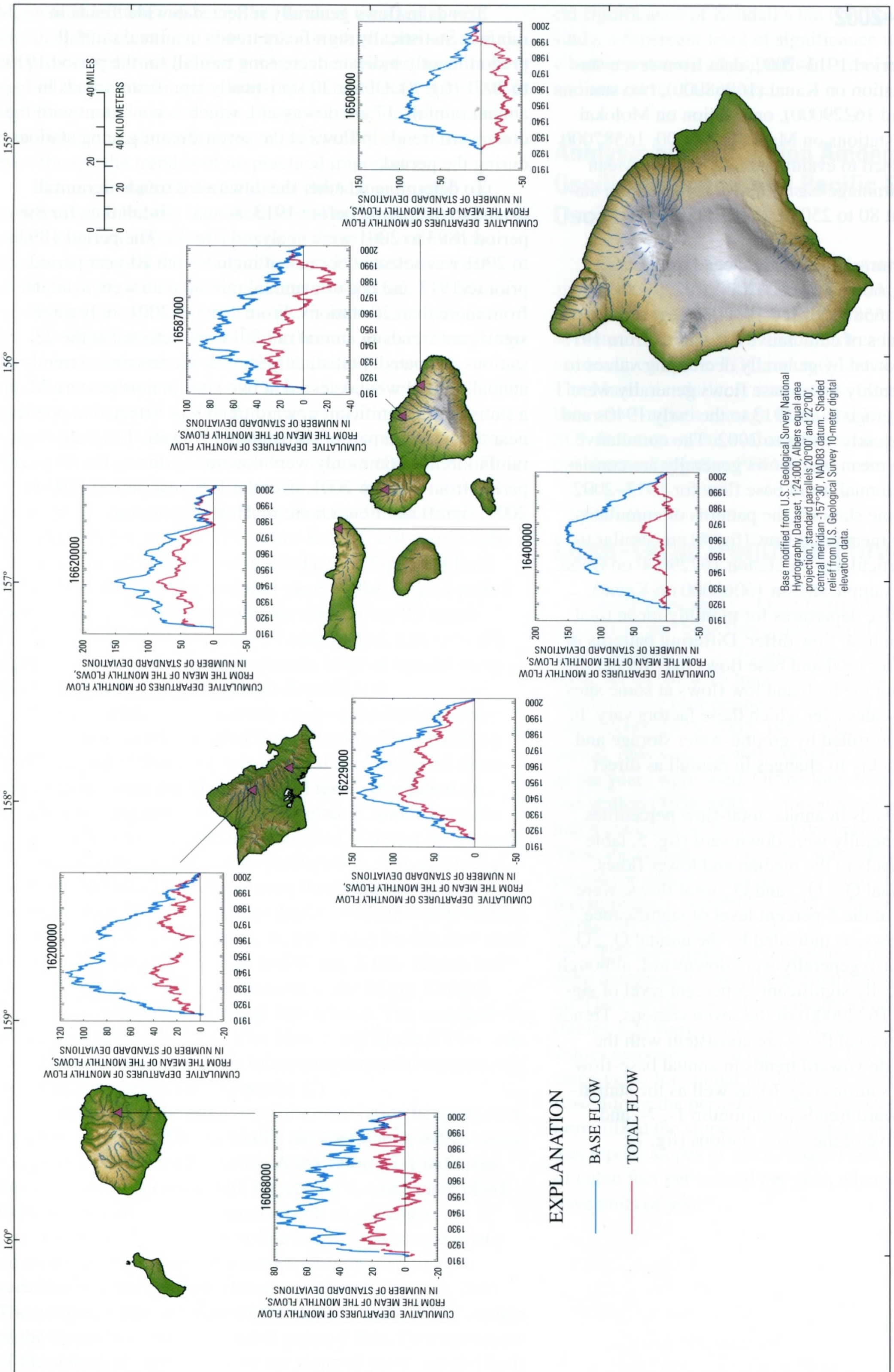


Figure 3-5. Cumulative departures of monthly mean flow from the mean of the monthly flows, Hawaii. This data is based on complete water years from 1913 through 2002. (Oki, 2004, Figure 4)



Climate fluctuations and dry season flows

Rainfall across Kauai is negatively correlated with the Pacific Decadal Oscillation (PDO), a recurring period (20-30 year) of climate fluctuations in the North Pacific Ocean. The PDO has warm (positive) and cool (negative) phases, which affect the movement of the upper levels of the troposphere. The warm phase is generally associated with above average ocean temperatures along the Pacific Coast of North America and the cool phase with above average ocean temperatures in the central Pacific with colder water in the eastern and tropical Pacific Ocean. Thus, during warm PDO phases there is less rainfall in Kauai while during cold PDO phases there is more rainfall. Warm PDO phases also suppress the occurrence of Kona storms. El Niño Southern Oscillations also interact with the PDO to generate drier winters during strong El Niño years and wetter winters during strong La Niña years. As a result, more or less stream flow may be available for instream and off-stream uses depending on the greater climatic fluctuations. Based on the availability of unregulated streamflow data in the Waimea hydrologic unit during cold-phase PDO from 1920-1924, and the current (2015) cold phase PDO, summer (May to October) season (dry season) streamflows were estimated to identify the lowest available flows for the Kokee System (Table 3-5). Data were scaled by upstream catchment size and monthly flows above diversions were then estimated. Such data were not available for the Kekaha System, however, ditch flows were monitored for 60 years (USGS station #16022000) and there is an overlapping period of streamflow data for the Waiahulu (USGS station #16016000) which can be used to partition the relative contribution of Koaie (56%) and Waiahulu (44%) streams assuming that the Kokee System is taking 100% of baseflows from the Waiakoali, Kawaikoi, Kauaikinana, and Kokee streams. Based on these estimates, the lowest available dry season flows are estimated in Table 3-4 at each of the current diversions.

Table 3-5. Estimated flow metrics for mean monthly dry season positive PDO phase stream flows for diversions feeding the Kokee and Kekaha ditch systems. (Source: Gomez, *pers. comm.*) [flow metrics are in million gallons per day, mgd]

system/stream	mean (±SD)	Q50	Q70	Q90
Kokee Irrigation System				
Waiakoali Stream	1.69 (±0.48)	1.31	0.76	0.42
Kawaikoi Stream	9.16 (±2.63)	6.43	3.99	2.30
Kauaikinana Stream	1.34 (±0.38)	1.19	0.62	0.29
Kokee Stream	1.37 (±0.83)			
Kekaha				
Waiahulu Stream*	9.16 (±2.71)	8.78	7.51	6.25
Koaie Stream	11.65 (±2.99)	11.17	9.55	7.91

*Waiahulu values assume Kokee ditch is taking 100% of baseflow from Kokee Ditch diverted streams in the upper Waimea hydrologic unit.

4.0 Maintenance of Fish and Wildlife Habitat

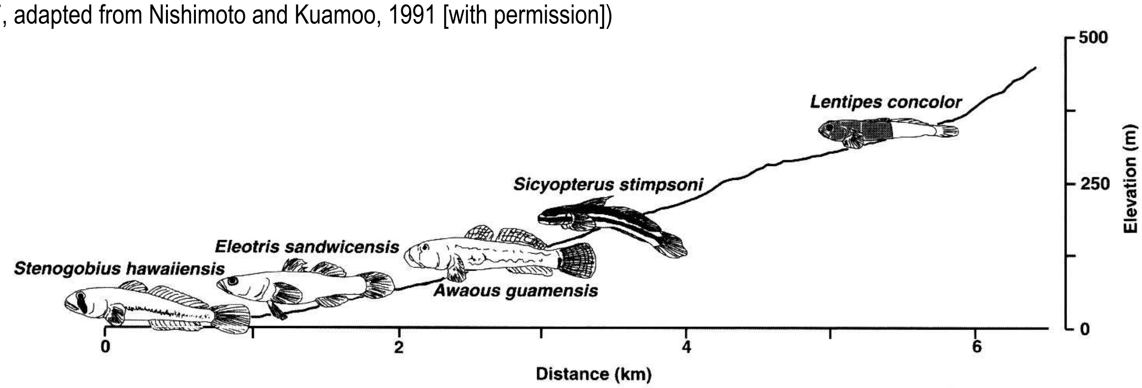
When people in Hawaii consider the protection of instream flows for the maintenance of fish habitat, they focus on a handful of native species including five native fishes (four gobies and one eleotrid), two snails, one shrimp, and one prawn. Table 4-1 below identifies native stream animals of Hawaii.

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

Scientific Name	Hawaiian Name	Type
Awaous guamensis	ʻOʻopu nakea	Goby
Lentipes concolor	ʻOʻopu hiʻukole (alamoʻo)	Goby
Sicyopterus stimpsoni	ʻOʻopu nopili	Goby
Stenogobius hawaiiensis	ʻOʻopu naniha	Goby
Eleotris sandwicensis	ʻOʻopu akupa (okuhe)	Eleotrid
Atyoida bisulcata	ʻOpae kalaʻole	Shrimp
Macrobrachium grandimanus	ʻOpae ʻoehaʻa	Prawn
Neritina granosa	Hihiwai	Snail
Neritina vespertina	Hapawai	Snail

Hawaii's native stream animals have amphidromous life cycles (Ego, 1956) meaning they spend their larval stages in the ocean (salt water), then return to freshwater 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 lower stream reaches. *Stenogobius hawaiiensis* has fused pelvic fins, but lacks the musculature necessary for climbing (Nishimoto and Kuamoo, 1997). *Awaous guamensis* and *Sicyopterus stimpsoni* are able to ascend moderately high waterfalls (less than ~20 meters) (Fitzsimons and Nishimoto, 1990), while *Lentipes concolor* has the greatest climbing ability and has been observed at elevations higher than 3,000 feet (Fitzsimons and Nishimoto, 1990) and above waterfalls more than 900 feet in vertical height (Englund and Filbert, 1997). Figure 4-1 illustrates the elevational profile of these native fresh water fishes.

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



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. The biological aspects of Hawaii's streams have an extensive history, and there is a wealth of knowledge, which continues to grow and improve.

Hawaii Stream Assessment

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 field work was conducted in its preparation, the HSA involved considerable research and analysis of existing studies and reports. The data were evaluated according to predefined criteria and each stream received one of five ranks (outstanding, substantial, moderate, limited, and unknown). Based on the stream rankings, the HSA offered six different approaches to identifying candidate streams for protection: streams with outstanding resources (aquatic, riparian, cultural or recreational), streams with diverse or "blue ribbon" resources, streams with high quality natural resources, streams within aquatic resource districts, free flowing streams, or streams within the National Wild and Scenic Rivers database.

Due to the broad scope of the HSA inventory and assessment, it continues to provide a valuable information base for the Commission's Stream Protection and Management Program and will continue to be referred to in various sections throughout this report. The HSA recommended that the Waimea hydrologic unit streams be listed as candidate streams for protection based on its substantial riparian, aquatic, cultural and recreational resources. Three out of four group one native species have been observed in Waimea stream: nakea (*Awaous stamineus*), nopili (*Sicyopterus stimpsoni*), and hihiwai (*Neritina granosa*). Additionally, seven group two native species have been observed in the stream. While the Waimea Stream originally provided habitat to a number of native species, due to significant land degradation from non-native ungulates and the introduction of non-native aquatic species, the HSA downgraded the stream to having only moderate aquatic resources.

The HSA inventory was general in nature, resulting in major data gaps, especially those related to the distribution and abundance of aquatic organisms – native and introduced – inhabiting the streams. The State of Hawaii Division of Aquatic Resources (DAR) has since continued to expand the knowledge of aquatic biota in Hawaiian streams. Products from their efforts include the compilation and publication of an *Atlas of Hawaiian Watersheds and Their Aquatic Resources* for each of five major islands in the state (Kauai, Hawaii, Oahu, Molokai, and Maui). Each atlas describes watershed and stream features, distribution and abundance of stream animals and insect species, and stream habitat use and availability. Based on these data, a watershed and biological rating is assigned to each stream to allow easy comparison with other streams on the same island and across the state. The data presented in the atlases are collected from various sources, and much of the stream biota data are from stream surveys conducted by DAR. Currently, efforts have been focused on updating the atlas with more recent stream survey data collected statewide, and developing up-to-date reports for Commission use in interim IFS recommendations. The following is a brief summary of findings.

- **Point Quadrat Survey.** In Waimea Stream the native freshwater shrimp *Atyoida bisulcata* was observed in all reach categories (estuary, lower, middle, upper, headwaters). Many native fish were observed in lower reaches (*Eleotric sandwicensis, Lentipes concolor, Sicyopterus stimpsoni, Stenogobius hawaiiensis, Kuhlia xenura, Awaous guamensis*) with *E. sandwicensis, S. hawaiiensis, and S. stimpsoni* and *A. guamensis* found in the middle reaches. *S. stimpsnoi* and *A. guamensis* were the only native fish species found in the upper reaches or headwaters. The endemic mollusk *Neritina granosa* and the native freshwater prawn *Macrobrachium grandimanus* were also both found in lower reaches. Introduced Crayfish (*Procambarus clarkii*), rainbow trout (*Oncorhynchus mykiss*), green swordtail (*Xiphophorus helleri*) and juvenile poeciliids were commonly found in the headwaters and ditches. Poeciliid fishes are known to transmit parasites to native fishes. Introduced species also found in the lower, middle and upper reaches included Tahitian prawn (*Macrobrachium lar*), mosquitofish (*Gambusia affinis*), *X. helleri*, Mozambique tilapia (*Oreochromis mossambiscus*), and other undetermined tilapia species. Although the post larval recruitment of native fish was not surveyed, diversions that fully dewater streams would likely restrict the upstream passage of larval and adult stream animals. Streamflow restoration would likely benefit recruitment and survival of native species in the lower, middle and upper reaches, but not the headwater reaches, although interactions with non-native species may complicate this.

- **Insect Survey.** Waimea Stream met the DAR qualification for native insect diversity (>19 spp) and native macrofauna diversity (>5 spp.) giving it a high score for native species. Waimea Stream supports a high diversity of native and introduced insect biota in all reaches including native dragonflies (*Anax strenuous*) native true flies (*Limonia hawaiiensis*) and native damselflies (*Megalagrion spp.*). The native damselfly is currently proposed for listing as Endangered under the federal Endangered Species Act. Streamflow restoration may increase insect biota diversity; however, steps must be taken to avoid the release of invasive species from ditch waters into the stream.

- **Watershed and Biological Rating.** The Waimea watershed rates above average for Kauai and average statewide for land cover. The extent of estuarine and shallow marine areas associated with Waimea ranks it higher than most watersheds on Kauai and across the state, while its stewardship rating is about average. The Waimea Stream is one of the largest in the state, supporting greater than average reach diversity resulting in a high total watershed rating. The high number and diversity of native species found thoroughout the watershed gives it one of the highest native species ratings on the island and across the state. These scores combined with Waimea Stream's relatively low rating for introduced genera resulted in its higher than average total biological rating and high overall rating.

The ditch diversions in Waimea hydrologic unit block the migration of native amphidromous animals. At high flows, stream diversions are overtopped and streamflow is continuous from the upper reaches to the sea. When flow returns to baseflow level, diversions remove 100% of water from the stream, leaving sections dry. This prevents the upstream migration of native stream animals, restricts surviving adult animals to the disconnected deeper pools, entrains larve in the ditches, and results in postlarvae recruits being stranded at the stream mouth. In most cases, the diversion structure itself is often an obstacle to upstream migration. Restoration of streamflow and increased connectivity could lead to the development of a richer and more native-dominated community in the stream, although there is potential for introducing species from invasive-dominated reaches and ditches to native-dominated reaches.

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 critical habitat areas associated with the watershed, including large areas of the Alakai marsh and some lower sloped regions that are habitat for plants such as *Nothocestrum peltatum, Solanum sandwicense, Lipochaeta micrantha, Exocarpos luteolus, Schiedea spergulina spergulina, Lipochaeta waimeaensis*. Further, increasing streamflow reduces breeding habitat for introduced mosquitoes that transmit diseases to threatened and endangered native birds.

Assessment of Upper Reaches

The Bishop Museum, in collaboration with the Smithsonian Institution, conducted stream surveys in Kokee State Park (Kauaikinana, Kawaikoi, Koaie, Waialae, Waiakoali) from 1997-1999 to assess stream habitat, including the availability of food and spawning areas for the establishment of a sustainable wild rainbow trout (*Onchorhynchus mykiss*) catch and release fishery (Englund et al. 2000). For many decades (possibly starting in the 1960s), rainbow trout had been introduced for sport fishing, but the long-term viability of rainbow trout reproduction had never been assessed. During this survey, riparian vegetation, stream substrate and water quality were evaluated at 10 locations (two per stream) along with aquatic insect sampling and trout gut content analysis to determine diet composition.

Based on survey results, all streams in Kokee State Park maintain a diverse assemblage of native aquatic insects, with or without rainbow trout, and included an exceptionally abundant sampling of adult native damselflies, a group of special concern. No native fish were collected during this survey, but there were introduced Dojo loach (*Misgurnus anguillicaudatus*) and green swordtail (*Xiphophorus helleri*) along with introduced crayfish (*Procambarus clarki)*. The lack of native amphidromous gobiids are most likely due to the high elevation at which no native fish are known to inhabit.

Surber (benthic) sampling of riffle habitat in the five streams was ineffective at assessing stream invertebrate diversity, as only five taxa (two native) were collected. Sweep and dip nets focusing on adult aquatic insects were more effective at qualitatively assessing insect species composition. Englund et al. (2000) also found high numbers of the endemic Na Pali Hawaiian skating fly (*Sigmatineurum napali*) in many streams. While pre-trout introduction survey results are not available for inland Kauai waters, Englund et al. (2000) concluded that these streams continue to support a large number of aquatic and terrestrial taxa, with an abundance of adult damselflies collected during the summer months and immature damselflies collected during winter months. Moreover, trout diets consisted mainly of terrestrial species, although there was little selective feeding by trout in regard to any particular aquatic or terrestrial taxon. All sampled streams had some representation of native aquatic insect taxa, and there was no statistical difference in native aquatic insect species in streams with and without trout (Table 4-3).

The gut contents of 80 trout indicated that while some native aquatic insects were consumed by the introduced fish, the majority of their prey items (92.4% by number) were of either introduced aquatic insects or other prey items (including snails, terrestrial insects or other invertebrates and vertebrates). Drift-feeding trout find few native aquatic insects because of the native species habitat preference (fast flowing, turbulent habitat) and behavior. The sampled trout preferred caddisflies (19%), terrestrial millipedes (13%) and aquatic snails (12%) for most of their diet (Table 5). A number of rare terrestrial beetles were found in the stomachs of trout from Koaie Stream but not in other streams. Native and introduced species of freshwater snails were found in many trout stomachs in Koaie and Waiale streams with up to 41 individuals per trout. *Atyoida bisulcata*, the endemic mountain shrimp, was found in six trout stomachs but never collected in the stream. This is likely because stream sites were above diversions and represent the upper limit (> 1037 m elevation) of the range of *A. bisulcata*.

Table 4-2. Number of aquatic insect species collected via general sampling and benthic (surber) sampling in Kokee State Park Streams. (Source: Englund et al., 2000)

	Kauaikinana	Kawaikoi	Waiakoali	Waialae
General sampling: native insects	21	22	23	20
General sampling: introduced insects	6	6	5	6
Benthic sampling: native insects	0	2	0	1
Benthic sampling: introduced insects	2	2	2	2

Trout stocking ceased in Kokee State Park streams in 1992, but naturally reproducing trout were observed in Kokee, Kauaikinana, Koaie, and Waialae streams. Trout that had escaped from the ditch were found in Kauaikinana, Kawaikoi, and Waiakoali streams. The presence of naturally reproducing trout populations is likely dependent on types of habitat, impediments to movement (waterfalls) and the occurrence of spring-fed groundwater inputs that temper maximum summer water temperatures. Kauaikinana and Kokee streams are spring-fed groundwater driven systems that increase pH and decrease stream temperatures. By contrast, Kawaikoi, Waiakoali, and Waialae streams are driven by runoff from the Alakai Marsh.

Table 4-3. Number of native prey items of special concern and non-native prey items collected in rainbow trout stomachs (n = 80) by stream from 1997-1999. (Source: Englund et al., 2000)

	Kauaikinana	Kawaikoi	Waiakoali	Waialae
Native Damselflies	0	0	0	4
Native Dragonflies	4	0	0	1
Other Native Aquatic Insects	11	2	6	51
Introduced Aquatic Insects	128	4	31	169
Other Prey Items[1]	164	34	184	300
Total	307	40	221	525

[1]includes snails, terrestrial insects, other invertebrates and vertebrates

Assessment of Lower to Middle Reaches

The lower to middle reaches of the Waimea hydrologic unit support many native species including *Atyoida bisulcata*, *Eleotric sandwicensis, Sicyopterus stimpsoni, Stenogobius hawaiiensis, Kuhlia xenura, Awaous guamensis*, *Macrobrachium grandimanus*. However, introduced crayfish (*Procambarus clarkii*), green swordtail (*Xiphophorus helleri*), tilapia sp., and gobiid sp. have also been found throughout these reaches. Introduced aquatic species can have a negative effect on native species by directly competing for food and habitat resources, introducing parasites, and preying on larval, juvenile, and sub-adult forms. The State of Hawaii Division of Aquatic Resources conducted point quadrat surveys in 1963, 1994 and 2002 to assess the distribution and density of native and non-native species (Figures 4-2 to 4-6). In the lower to middle reaches of the Waimea hydrologic unit, *Awaous guamensis* were fairly common in both 1994 and 2002 with similar densities. In 2002, *S. hawaiiensis* and *S. stimpsoni* were also fairly common. In all 1994 and 2002 surveys, *A. bisulcata* were absent, despite being observed in 1963. This may have been an artifact of sampling effort as the *A. bisulcata* 1963 observations were much farther upstream than either of the 1994 or 2002 sampling locations. Table 4-4 provides a summary of survey results for native aquatic species in the Waimea hydrologic unit. Given the presence of numerous native species below the waterfalls in the lower to middle reaches, restoration of flows are likely to benefit freshwater and estuarine species (Kido, 1996).

Table 4-4. Number of sites surveyed with identified species and mean (standard deviation, s.d.) number of native aquatic species by survey year based on point-quadrat survey methods. (Source: State of Hawaii Division of Aquatic Resources, 2015)

	1963 (n = 22)		1994 (n = 152)		2002 (n = 173)	
	sites	Mean (s.d.)	sites	Mean (s.d.)	sites	Mean (s.d.)
Atyoida bisulcata	11	1.00 (0.00)	0	--	0	--
Macrobrachium grandimanus	0	--	0	--	3	1.67 (1.54)
Awaous guamensis	7	1.00 (0.00)	60	2.25 (2.03)	61	2.84 (2.67)
Stenogobius hawaiiensis	1	1.00 (0.00)	0	--	44	3.82 (3.43)
Eleotric sandwicensis	1	1.00	0	--	4	1.00 (0.00)
Sicyopterus stimpsoni	9	1.00 (0.00)	6	1.33 (0.82)	19	2.21 (1.32)
Lentipes concolor	0	--	0	--	0	--
Neritina granosa	0	--	0	--	1	1.00
Neritina vespertina	0	--	0	--	1	2.00

Figure 4-2. Location of *Atyioda bisulcata* observations from 1963 surveys in the Waimea hydrologic unit. (Source: State of Hawaii Division of Aquatic Resources, 2015)

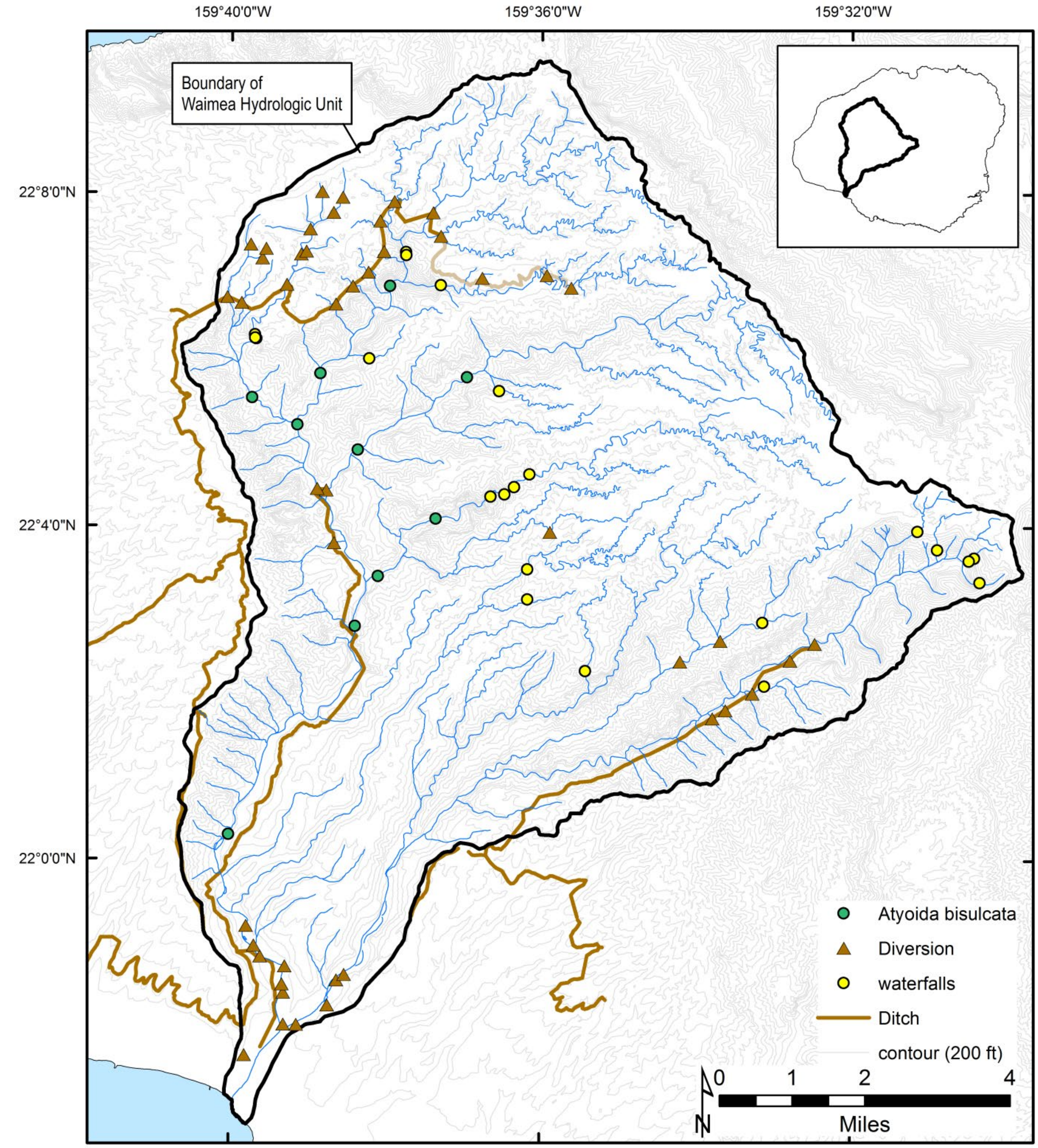


Figure 4-3. Location of *Awaous stamineus* observations from 1963, 1994 and 2002 surveys in the Waimea hydrologic unit. (Source: State of Hawaii Division of Aquatic Resources, 2015)

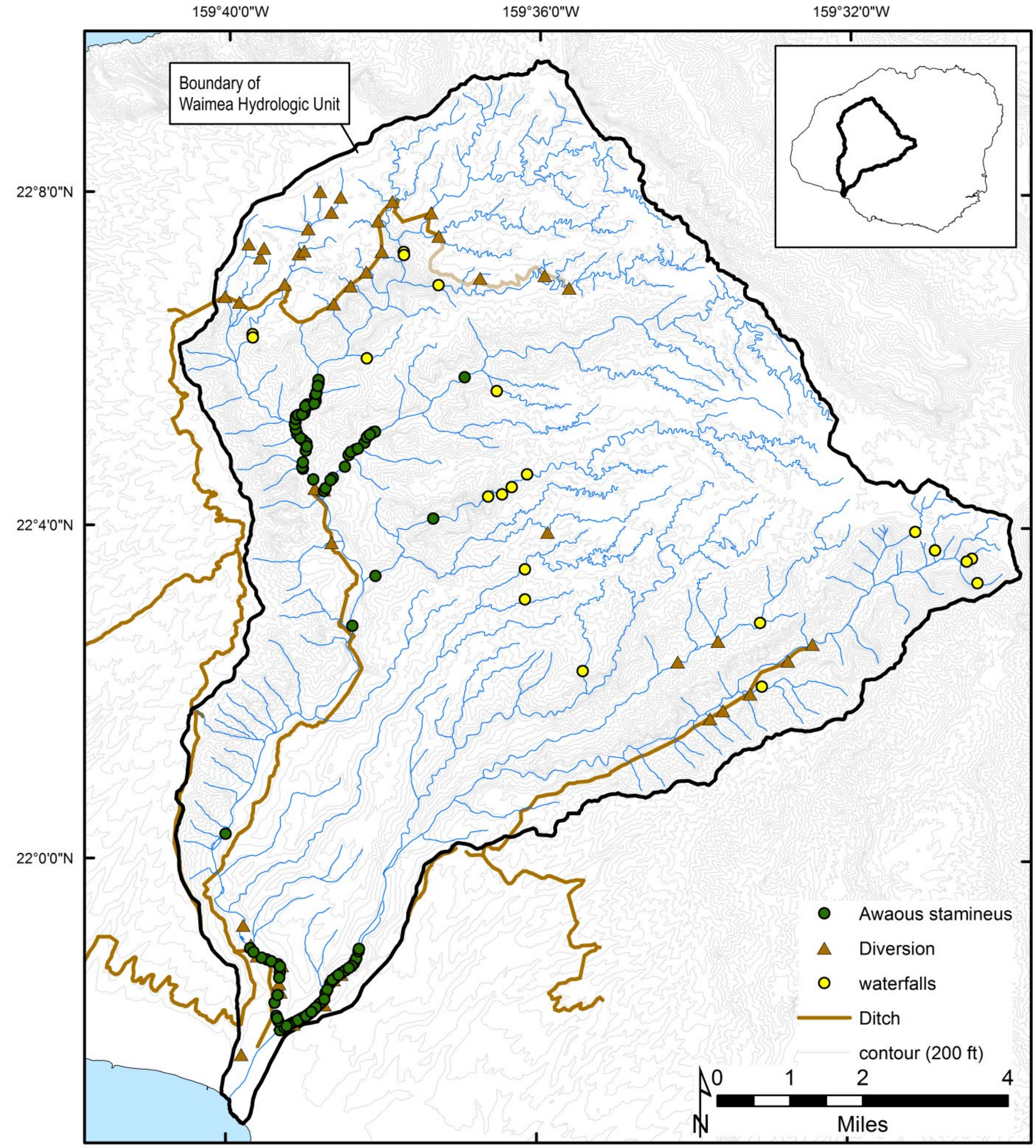


Figure 4-4. Location of *Stenogobius hawaiiensis* observations from 1963, 1994 and 2002 surveys in the Waimea hydrologic unit. (Source: State of Hawaii Division of Aquatic Resources, 2015)

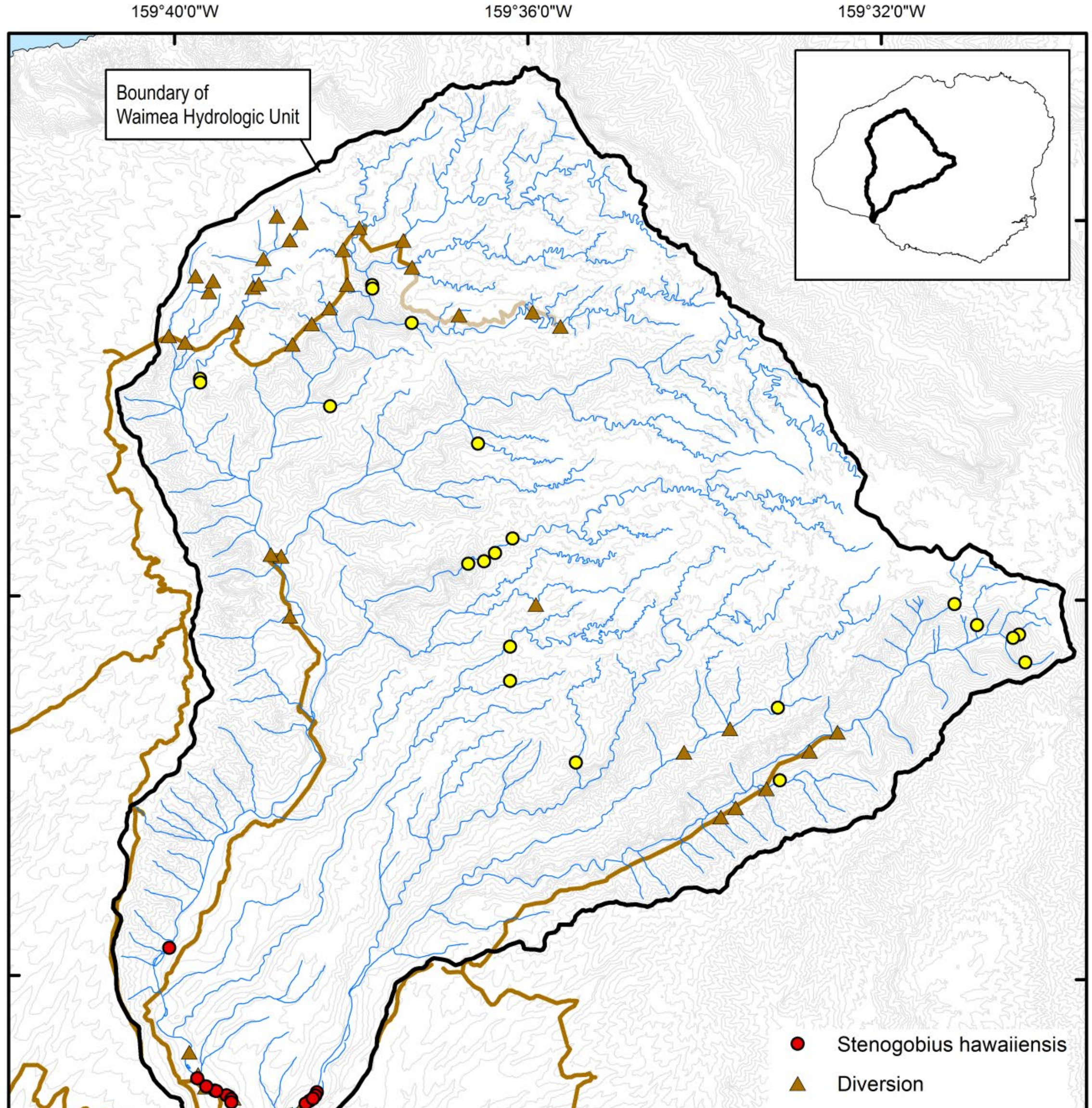
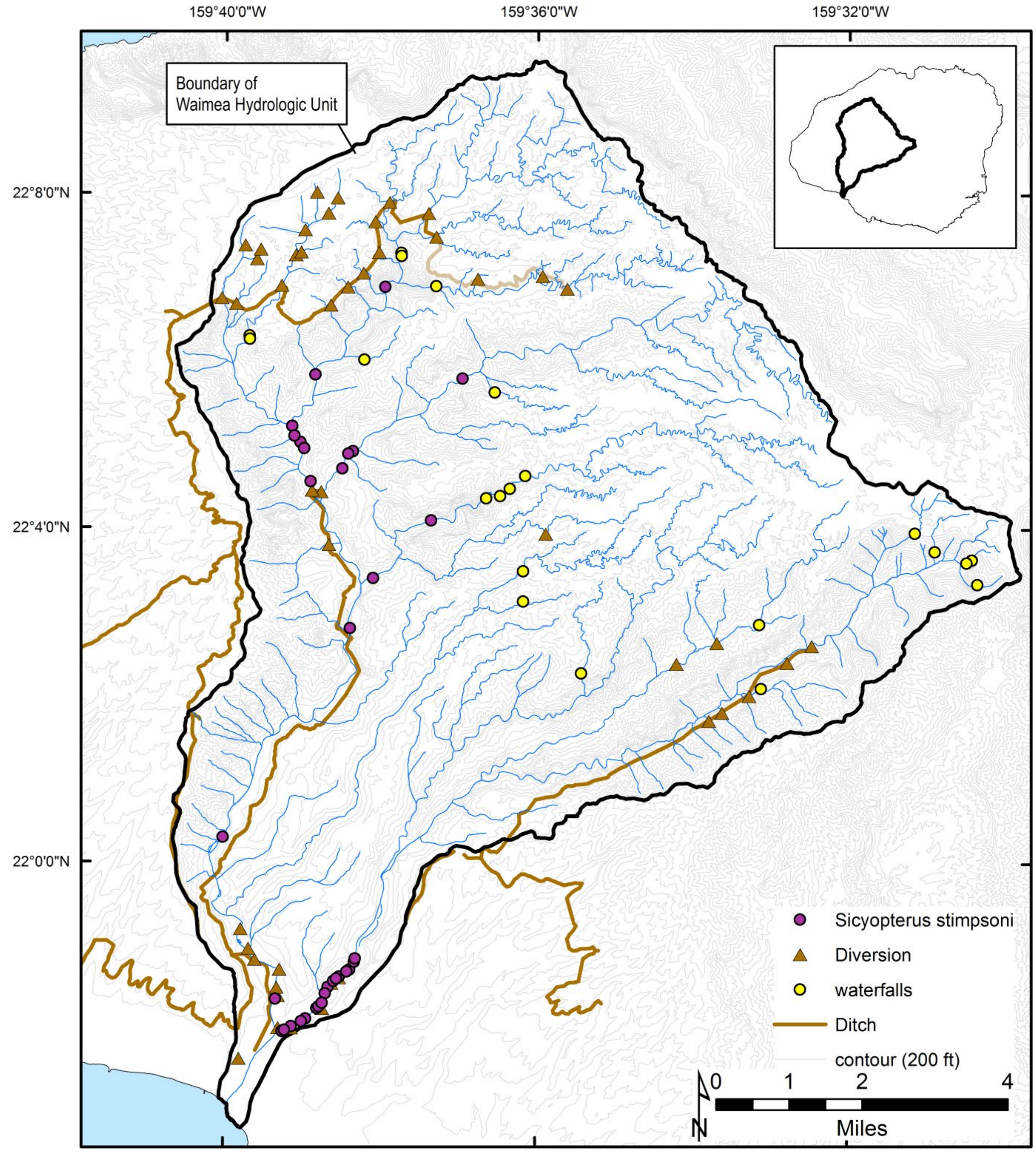


Figure 4-5. Location of *Sicyopterus stimpsoni* observations from 1963, 1994 and 2002 surveys in the Waimea hydrologic unit. (Source: State of Hawaii Division of Aquatic Resources, 2015)



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 geometric-mean of *Enterococcus spp.*, a fecal indicator: 33 colony-forming units per 100 mL of water or a single-sample maximum of 89 colonies per 100 mL. These standards are for full-body contact including swimming and if enterococci exceed those values, the water body is considered to be impaired. DOH also has a standing advisory for *Leptospirosis spp.* in all freshwater streams. The marine recreational zone, which extends from the shoreline seaward to 1,000 feet from shore, requires an enterococci geometric-mean of less than 7 colony-forming units per 100 mL of water, to protect human health.

The recreational resources of Waimea hydrologic unit were classified as "outstanding" by the HSA's regional recreation committee, having extensive recreational opportunities, including camping, hiking, fishing, hunting, boating, parks, and scenic views (National Park Service, 1990).

Due to the Waimea hydrologic unit's large size, there are many different hunting units that overlap the region. According to public hunting data, Hunting Unit B on the island of Kauai consists of state-owned portions of the Na Pali-Kona Forest Reserve and Puu Ka Pele Forest Reserve that lie east of Waimea Canyon State Park and Kokee State Park, west of the Alakai Wilderness Preserve, south of Mohihi Stream and north of Waialae Stream. Hunting Unit D consists of the portions of the Kokee State Park east of Kokee and Maluapopoki streams, south of the Kokee-Puu O Kila Road and west of the boundary between Kokee State Park, and the eastern portion of the Na Pali-Kona Forest Reserve, including lands known as the Kumuwela Ridge, Berry Flats, and Kahuamaa Flats. Hunting Unit E has two parts: the first consists of the Alakai-Waialae area of the Na Pali-Kona Forest Reserve east of Kokee State Park, northeast of Waimea Canyon State Park, and southwest of Wainiha Pali, including areas known as the Alakai Wilderness Preserve, Hanakapiai and Hanakoa stream drainages above three-thousand feet; the second consists of the Mokihana Ridge Game Management Area which includes the Waimea Canyon State Park south of Waialae Stream, west of the boundary fence from Kalehuahakihaki along Mokihana Cart Road, and west of the pali which runs parallel and one-thousand feet to the east of Mokihana Stream to Waimea River and lands east of the six-hundred feet elevation contour between Waimea Ditch Intake and the Puu Ka Pele Forest Reserve Boundary. Hunting Unit F consists of lands within Waimea Canyon State Park south of Puu Ka Pele Forest Reserve, west of Hunting Unit E and north of the line due west of Waimea "Obake" Swinging Bridge, and east of Waimea Heights Road. Hunting Unit K consists of a strip of land extending one-half mile east of the Waimea Canyon State Park boundary, south of the Kaana Ridgeline and north of the Puu Ka Pele Forest Reserve Boundary. The portion the Waimea hydrologic unit in a hunting area is approximately 56.1285 square miles or 65.5 percent of the hydrologic unit (Figure 5-1).

Starting in the 1960s, rainbow trout (*Onchorhynchus mykiss*) was introduced for sport fishing in a number of streams in Kokee State Park. During a multi-year survey, The Bishop Museum, in collaboration with the Smithsonian Institution, evaluated riparian vegetation, stream substrate and water quality with the hopes of determining if a sustainable wild rainbow trout catch and release fishery could be established and what a fishery would do to the native ecosystem (Englund et al. 2000). Only particular reaches are groundwater fed such that summer stream temperatures could support viable populations. Trout fed primarily on terrestrial invertebrates, there was no competition with native fishes (which are absent at high elevations), and few native aquatic invertebrates were consumed. Rainbow trout continue to exist in some stream reaches, although DAR does not actively maintina thses populations. The Puu Lua Reservoir, which is maintained by water from the Kokee Ditch, continues to support an active trout fishery.

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 Waimea Stream. A 1981 Kauai Resource Atlas, prepared by the State of Hawaii Department of Transportation's Harbors Division, inventoried coral reefs and coastal recreational activities. Looking at available data, the Commission identified the following activities that were known to occur or observed at or near Waimea shore region: pole and line fishing, gill netting, and throw netting (Figure 5-3).

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

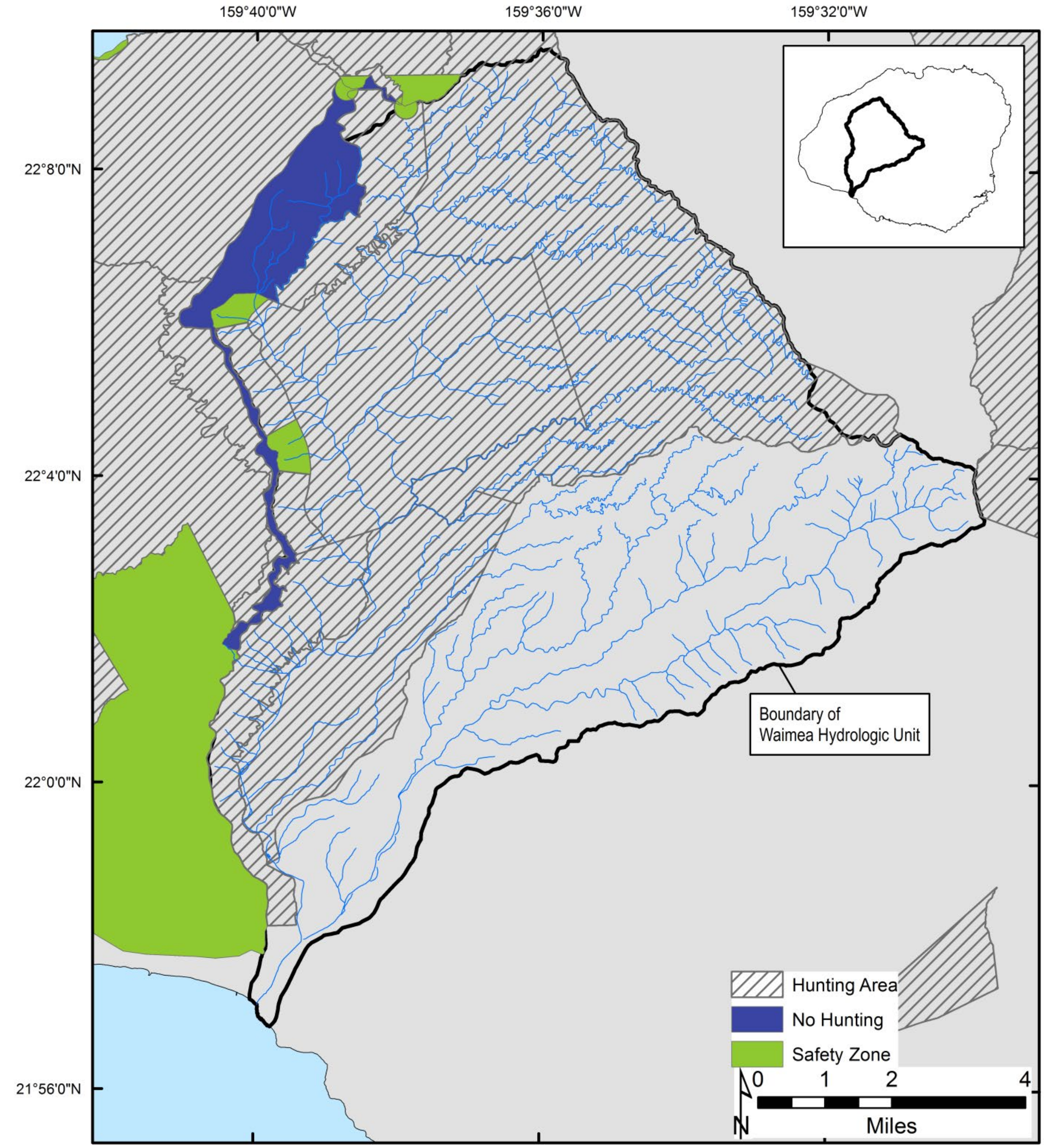
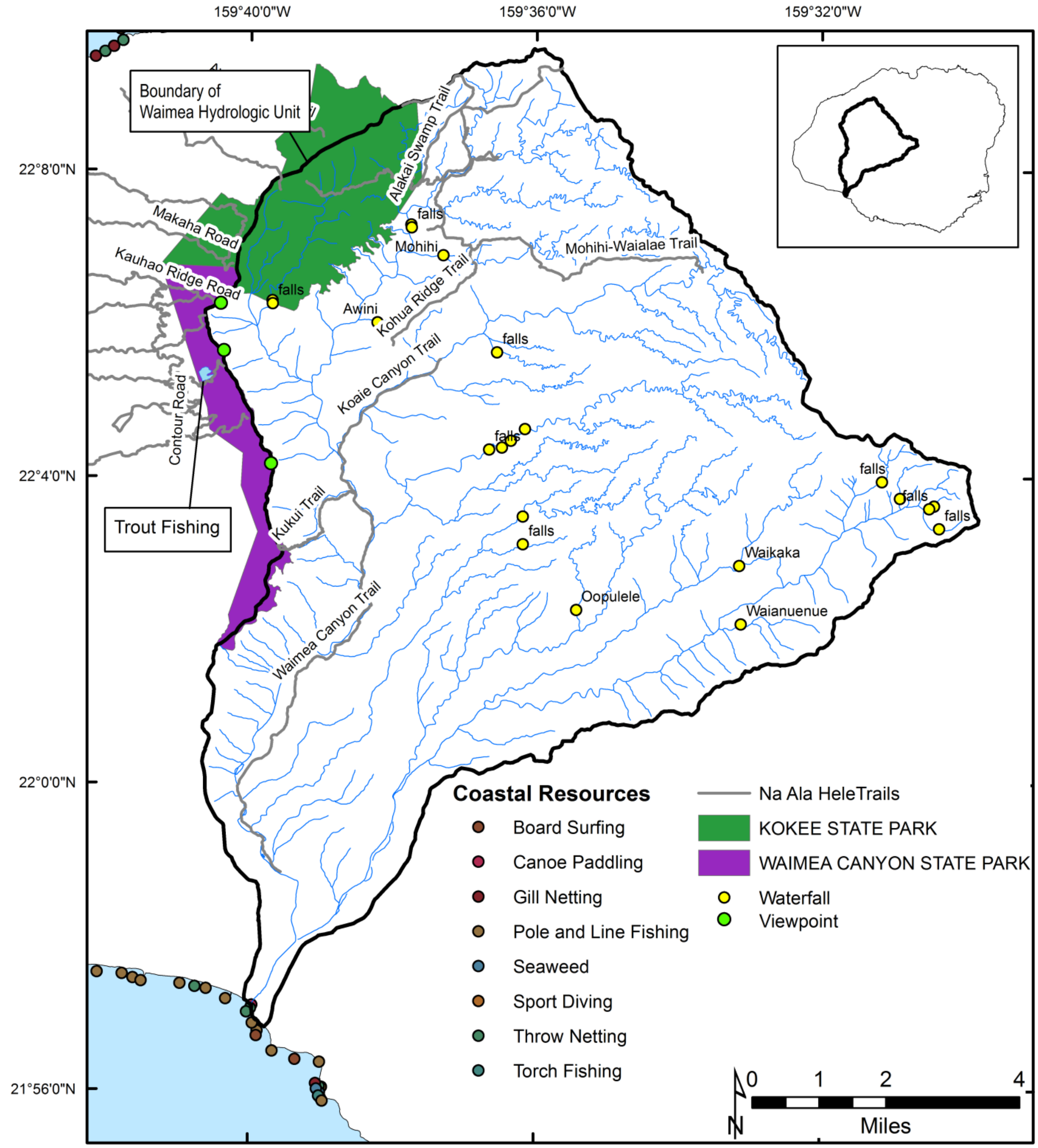


Figure 5-2. Recreational and aesthetic points of interest as well as coastal resources for Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 1999, 2002c; 2004a)

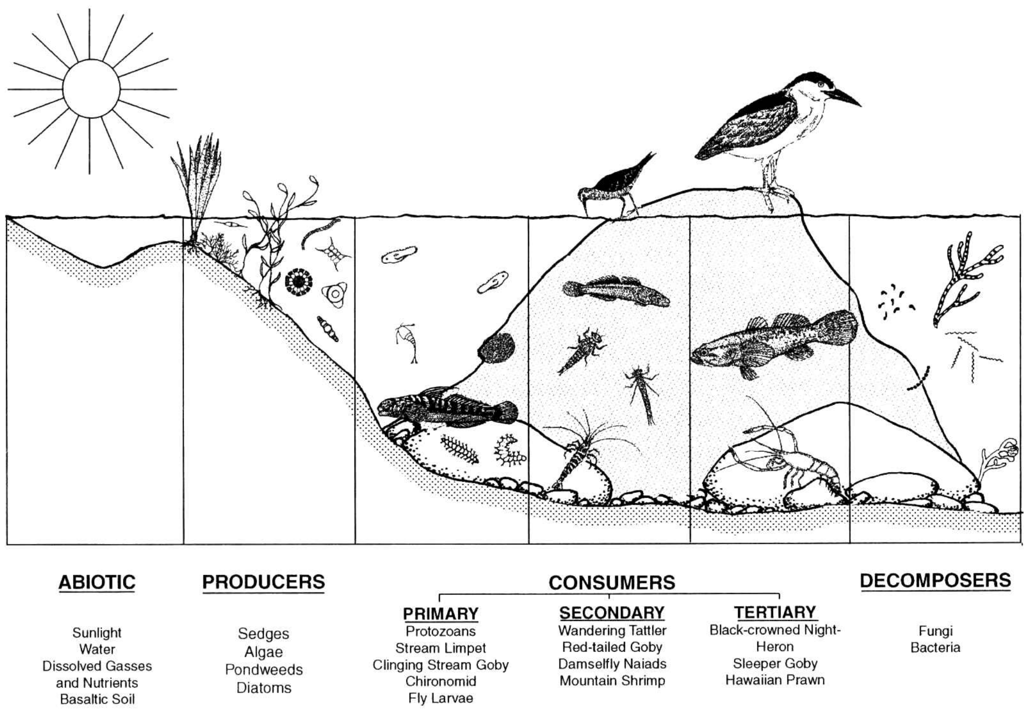


6.0 Maintenance of Ecosystems

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

The HSA determined that Waimea Stream deserved to be a candidate stream for protection based on both its Diversity of Resources scoring (outstanding riparian, cultural, and recreational resources) and its Blue Ribbon Resources scoring (outstanding riparian and recreational resources). Detrimental organisms (non-native species that have a negative effect on the ecosystem) were not considered in the final ranking; however their presence and abundance are considerable ecosystem variables. The destruction to both vegetation and soil resources in the Waimea hydrologic unit by ungulates is considered a major factor in alterations to the hydrology and water quality of the stream.

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 these resources. 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 Waimea Stream were classified by the HSA (National Park Service, Hawaii Cooperative Park Service Unit, 1990) and ranked according to a scoring system using six of the seven variables (Table 6-1).

Table 6-1. Hawaii Stream Assessment indicators of riparian resources for Waimea hydrologic unit.

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.	9
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.	17
Protected areas: The riparian resources of streams that pass through natural area reserves, refuges and other protected areas are accorded special protection from degradation. Protected areas were so designated because of features other than their riparian resources. The presence of these areas along a stream, however, indicates that native processes are promoted and alien influences controlled.	None
Wetlands: Wetlands are important riparian resources. They provide habitat for many species and are often important nursery areas. Because they are often extensive areas of flat land generally with deep soil, many have been drained and converted to agricultural or urban uses. Those that remain are, therefore, invaluable as well as being indicators of lack of disturbance.	W+ (over ½ square mile of Palustrine wetland)
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.	20%
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.	3 (Pigs, Goats, Black-tailed Deer)

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. Such designated areas include forest reserves, private preserves, natural area reserves, wildlife sanctuaries, national parks, and historic landmarks. In Waimea, over 65 percent of the hydrologic unit falls within either forest reserves or state parks (Table 6-2).

Table 6-2. Management areas located within Waimea hydrologic unit. (Source: State of Hawaii, Division of Forestry and Wildlife, 2008a).

Management Area	Managed by	Area (mi^2)	Percent of Unit
Puu Ka Pele Forest Reserve- Canyon Section	State Division of Forestry and Wildlife	21.815	25.4
The Puu Ka Pele Forest Reserve is one of nine reserves on the Island of Kauai that are managed by the State Department of Land and Natural Resources (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. The primary goals of reserve are to manage the lands for sustainable game hunting, protect existing rare native biological resources and provide native and non-native timber resources.			
Na Pali-Kona Forest Reserve-Alakai Wilderness Preserve Section	State Division of Forestry and Wildlife	15.325	17.9
The Alakai Wilderness Preserve section of the Na Pali-Kona Forest Reserve is one of nine reserves on the Island of Kauai that is managed by the State Department of Land and Natural Resources (DLNR)'s Division of Forestry and Wildlife. Infrastructure consists of a few rough roads, trails and many picnic and/or basic campsites. 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.			
Na Pali-Kona Forest Reserve-Kokee Section	State Division of Forestry and Wildlife	13.282	15.5
The Kokee section of the Na Pali-Kona Forest Reserve is one of nine reserves on the Island of Kauai that is managed by the State Department of Land and Natural Resources (DLNR)'s Division of Forestry and Wildlife. Infrastructure consists of a few rough roads, trails and many picnic and/or basic campsites. . 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. Public hunting is permitted for birds and mammals in this section			
Kokee State Park	State Parks Divsion	4.660	5.4
Kokee State Park is managed by the State Parks Division of the State Department of Land and Natural Resources (DLNR), just north of Waimea Canyon State Park on the western side of the Waimea hydrologic unit. The park consists of a lodge and visitor center, cabins for rent, and numerous hiking trails. Seasonal plum picking, trout fishing, and pig hunting are available in some areas.			
Hono O Na Pali Natural Area Reserve	State Division of Forestry and Wildlife	0.737	0.8
An extension was added to the Hono O Na Pali Natural Area Reserve managed by the State Department of Land and Natural Resources (DLNR)'s Division of Forestry and Wildlife located in the Waimea hydrologic unit northwest of Kokee State Park. This reserve protects intact native wet forest with several rare and endangered pants and animals.The area is accessible by a couple of trails.			
Waimea Canyon State Park	State Parks Divsion	0.272	0.3
Waimea Canyon State Park is managed by the State Parks Division of the State Department of Land and Natural Resources (DLNR), on the western side of the Waimea hydrologic unit. The park consists of a lookout with restrooms and two trails along with seasonal trout fishing (in Puu Lua Reservoir) and hunting.			
Russian Fort Elizabeth State Historical Park	National Park Service	0.030	<0.1
The historical park is managed by the National Park service as a reminder of the brief Russian presence in Hawaii. The park consists of the remains of the original fort constructed in 1817.			

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, one of which is on Kauai. Table 6-3 provides a summary of the partnership area, partners, and management goals of the Kauai Watershed Alliance.

Table 6-3. Watershed partnerships associated with the Waimea hydrologic unit. (Source: State of Hawaii, Division of Forestry and Wildlife, 2008b)

Management Area	Year Established	Total Area (mi^2)	Area (mi^2)	Percent of Unit
Kauai Watershed Alliance	2003	225	59.65	69.6
The Kauai Watershed Alliance (KWA) is comprised of the County of Kauai, Hawaii State Department of Land and Natural Resources (Division of Forestry and Wildlife, Division of State Parks, Land Management Division), McBryde Sugar Company Ltd., Grove Farm Company, Lihue Land Company, Kealia Ranch LLC, B.A. Dyer, Princeville Development LLC, Kamehameha Schools, and The Nature Conservancy. The management priorities of the KWA 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 11 percent of the Wiamea Hydrologic Unit is classified as seasonal, non-tidal palustrine wetlands occurring in the headwaters of the hydrologic unit (Table 6-4 and Figure 6-2). Palustrine wetlands are nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, or wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 percent.

Table 6-4. Wetland classifications for Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015n)

System Type	Class	Regime	Area (mi^2)	Percent of Unit
Palustrine	Estuarine and Marine Wetland	Seasonal non-tidal	0.001	< 0.01
Palustrine	Freshwater Pond	Seasonal non-tidal	0.007	0.01
Palustrine	Freshwater Emergent Wetland	Seasonal non-tidal	0.366	0.43
Palustrine	Riverine	Seasonal non-tidal	1.384	1.61
Palustrine	Freshwater Forested/Shrub Wetland	Seasonal non-tidal	7.542	8.80

A series of vegetation maps describing upland plant communities was prepared as part of a USFWS survey in 1976 to 1981 to determine the status of native forest birds and their associated habitats. Table 6-5 and Figure 6-3 present the degree of disturbance of native forest. Nearly a half of the unit is dominated by introduced species, while almost 40 percent of the unit is dominated by native species.

Table 6-5. Distribution of native and alien plant species for Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015f)

Canopy Type	Area (mi^2)	Percent of Unit
Communities totally dominated by native species of plants	33.354	38.96
Communities that are totally dominated by introduced plants; virtually no native species remaining	37.517	43.82

The density of threatened and endangered plant species is high at elevations above 1,200 feet, resulting in the majority of the Waimea hydrologic unit, roughly 54 percent, covered in a high density of threatened and endangered plant species (Table 6-6).

Table 6-6. Density of threatened and endangered plants for Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015i)

Density	Area (mi^2)	Percent of Unit
Very High concentration of threatened and endangered species	8.393	9.80
High concentration of threatened and endangered species	46.357	54.13
Medium concentration of threatened and endangered species	19.650	22.95
Low concentration of threatened and endangered species	7.468	8.72

A 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 6-7.

Table 6-7. 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 Kauai forests, noting the particular importance of the Waimea watershed as habitat for threatened and endangered species. In both the Oahu Koolaus and Waimea, some of 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 Waimea forests may have greater value due to greater species diversity and native habitat. Certain areas of Waimea provide some of the last remaining critical habitat for native forest birds and insects in Hawaii.

Figure 6-2. Reserves and wetlands for the Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2007b; 2015n)

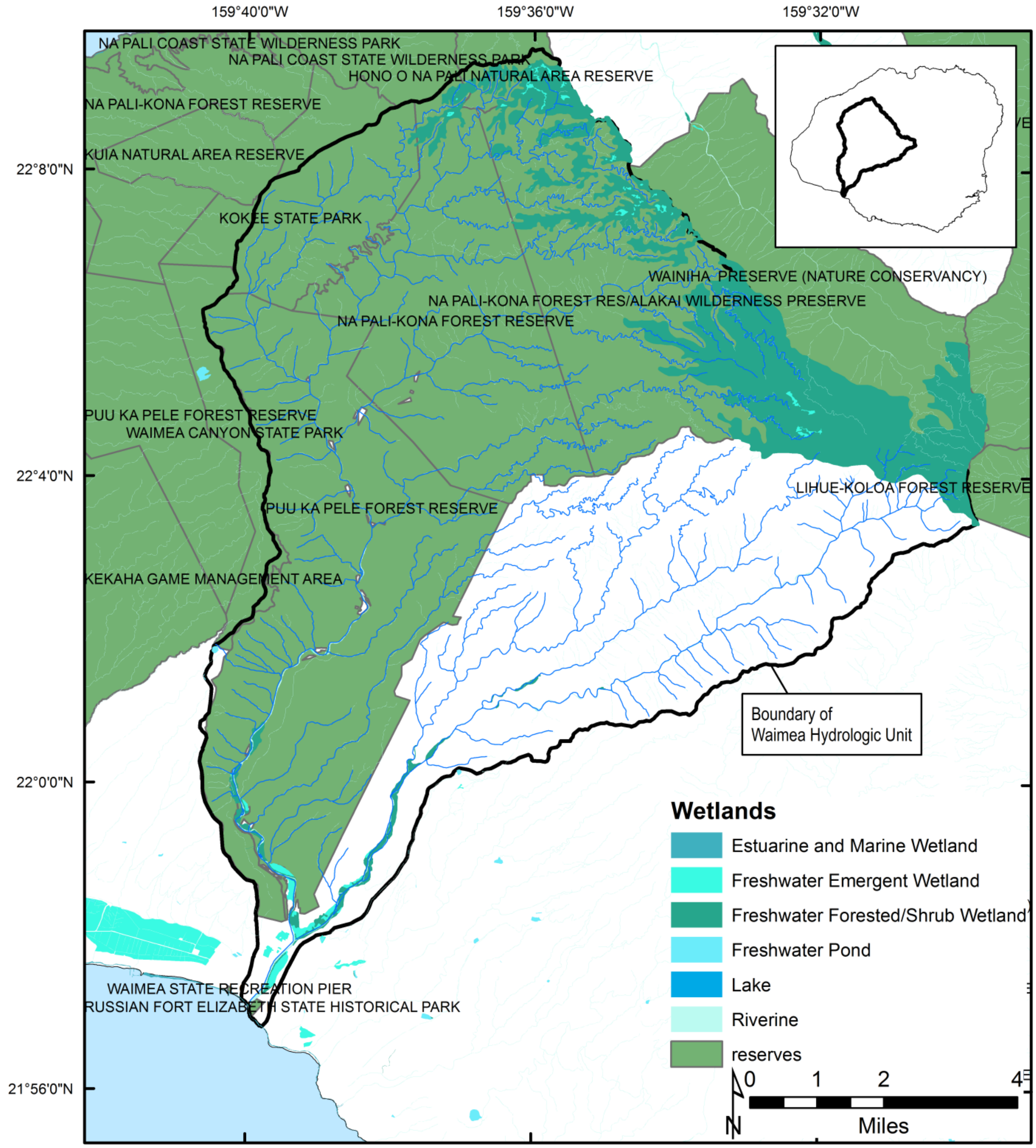


Figure 6-3. Distribution of native and alien plant species, and critical habitat for plant and bird species in the Waimea hydrologic unit. (Source: Scott et al., 1986; State of Hawaii, Office of Planning, 1996; 2004b)

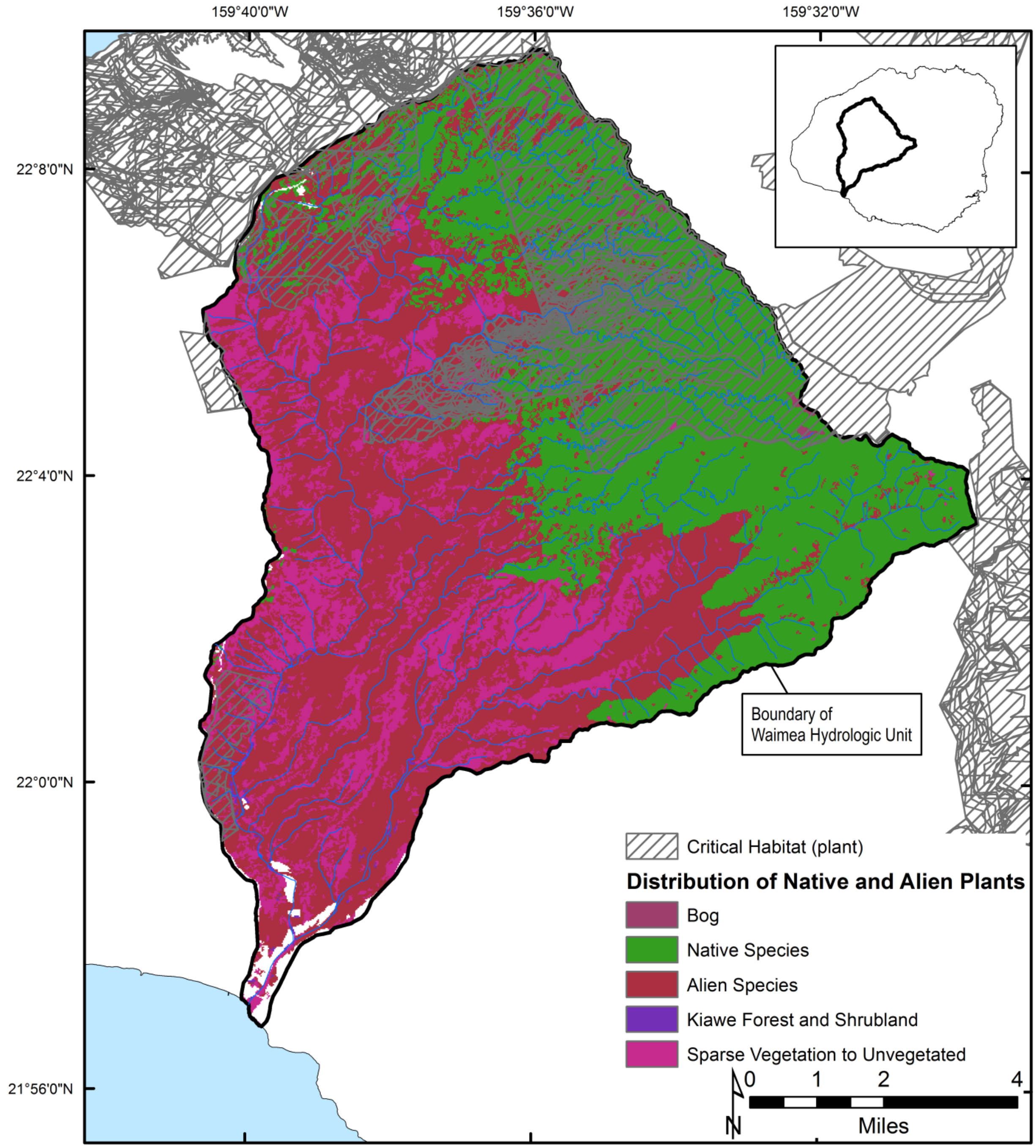
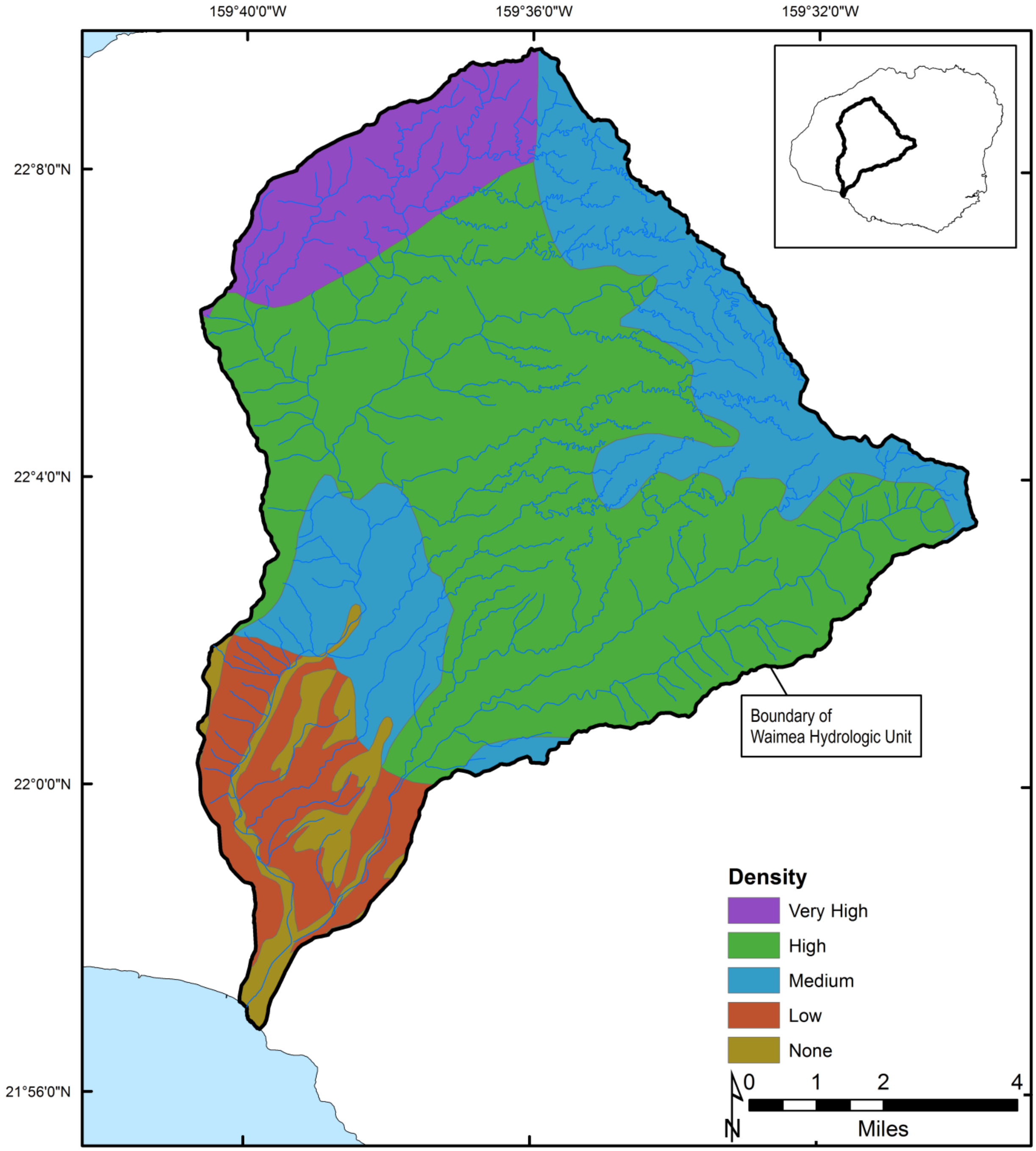


Figure 6-4. Density of threatened and endangered plants in the Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015h)



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. Visitors and residents can identify a point that has aesthetic value and continue to return to such a point to gain that value. Such points can potentially be identified, as maped in Figure 5-2. However, the points listed are not exhaustive and it is beyond the scope of this report to list all potential aesthetic values.

The headwaters of Waimea Stream originate in the Alakai Marsh, a unique ecological region of the Na Pali-Kona Forest Reserve and the Alakai Wilderness. This region is home to endemic and endangered birds and insects. The Waimea Canyon, a steeply cut gulch that traverses almost the entirety of the watershed, can be viewed from many points along the Hawaii State highway 550 as well as the numerous trails that crisscross the region. The Kokee Stream is the source of the Waipoo falls, an 800 ft waterfall that is a popular photographic target. The Waimea Canyon is popular with helicopter tours partially because of the waterfalls and streams that flow through the hydrologic unit. Waimea Stream empties into the Pacfic Ocean near the town of Waimea, which can be viewed from the Russian Fort Elizabeth State Historical Park or Lucy Wright Park. Waimea State Recreation Pier and associated beaches are also popular recreational areas in Waimea town.

In a 2007 Hawaii State Parks Survey, released by the Hawaii Tourism Authority (OmniTrak Group Inc., 2007), scenic views accounted for 21 percent of 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 Kauai, out-of-state visitors' most common reasons to visit state parks for scenic views (28 percent) were tied with outings with family and friends (28 percent). Similarly, residents primarily used state parks in Kauai for outings with family and friends (42 percent) followed by scenic views (16 percent). Overall, Kauai residents were very satisfied with scenic views giving a score of 8.9 (on a scale of 1 to 10, with 10 being outstanding), with out-of-state visitors giving a score of 9.2. Waimea Canyon State Park is one of the most popular parks in the state with 430,700 visitors in 2007, 85 percent of which were out-of-state. Additionally, 303,900 people visited Kokee State Park with approximately 87 percent of visitors from out-of-state. The primary reson behind tourist visits to Kauai are for nature and scenery (71 percent) and relaxation (67 percent).

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.

Outrigger boating has historically used the lowest portion of the Waimea River and this is considered the only instream use 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 tunnels, ditches, and pipes, and then through a penstock to the powerplant, finally returning 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.

There are three hydropower plants connected with water from the Waimea hydrologic unit: the Mauka (Waimea) hydropower plant and the Waiawa hydropower plant on the Kekaha irrigation system and the Makaweli hydropower plant on the Olokele irrigation system. Only the Waimea and Makaweli hydropower plants are considered instream hydropower generation. The Waiawa hydropower plant was initially constructed in 1907 by the Kekaha Sugar Company but ditch seepage loss and increased demand for power to pump water to the mauka lands required additional water and energy. In 1912, the Mauka powerhouse was constructed at the site of the original Kekaha ditch diversion on Waimea River and additional diversions at Koaie and Waihulu were constructed to feed the ditch and powerhouse (Wilox, 1996). Kekaha Agriculture Association currently operates these hydropower plants using water diverted by the Koaie and Waiahulu diversions. Since some of the water diverted for hydropower generation at the Mauka powerhouse is removed from the hydrologic unit and all of the water passing through the Waiawa powerhouse then supports agricultural irrigation, not all of the hydropower is considered instream hydropower generation, and more information is therefore found in the non-instream use section. Not all the water diverted into the Kekaha Ditch is needed for irrigation past the mauka hydropower plant, and some of it is returned to the stream. Recent water usage for hydropower production and the associated energy production are provided in Figure 13-6 and Figure 13-7. This volume cannot currently be quantified except for the total amount of water flowning in the stream at the USGS gaging station located at an elevation of 20 ft (station #16031000). Currently, energy generated by the hydropower plants are used by the Kekaha Agriculture Association lessees. Excess power not used by KAA is sold to KIUC via a power purchase agreement. Profits from this sale are put into capital improvements, including ditch maintenance and construction, road and electrical line repair, and irrigation infrastructure. The low cost of power provided by hydropower from the Waimea hydrologic unit keeps leases on the Mana plain low for agriculture.

Gay & Robinson operate the Makaweli hydropower plant. The original plant was a 1.3 MW plant built in 1904, but by 2019, this plant will be upgraded to a 6.6 MW plant. Energy produced from this plant is sold to KIUC.

10.0 Maintenance of Water Quality

Water quality is important due to its direct impact on 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:

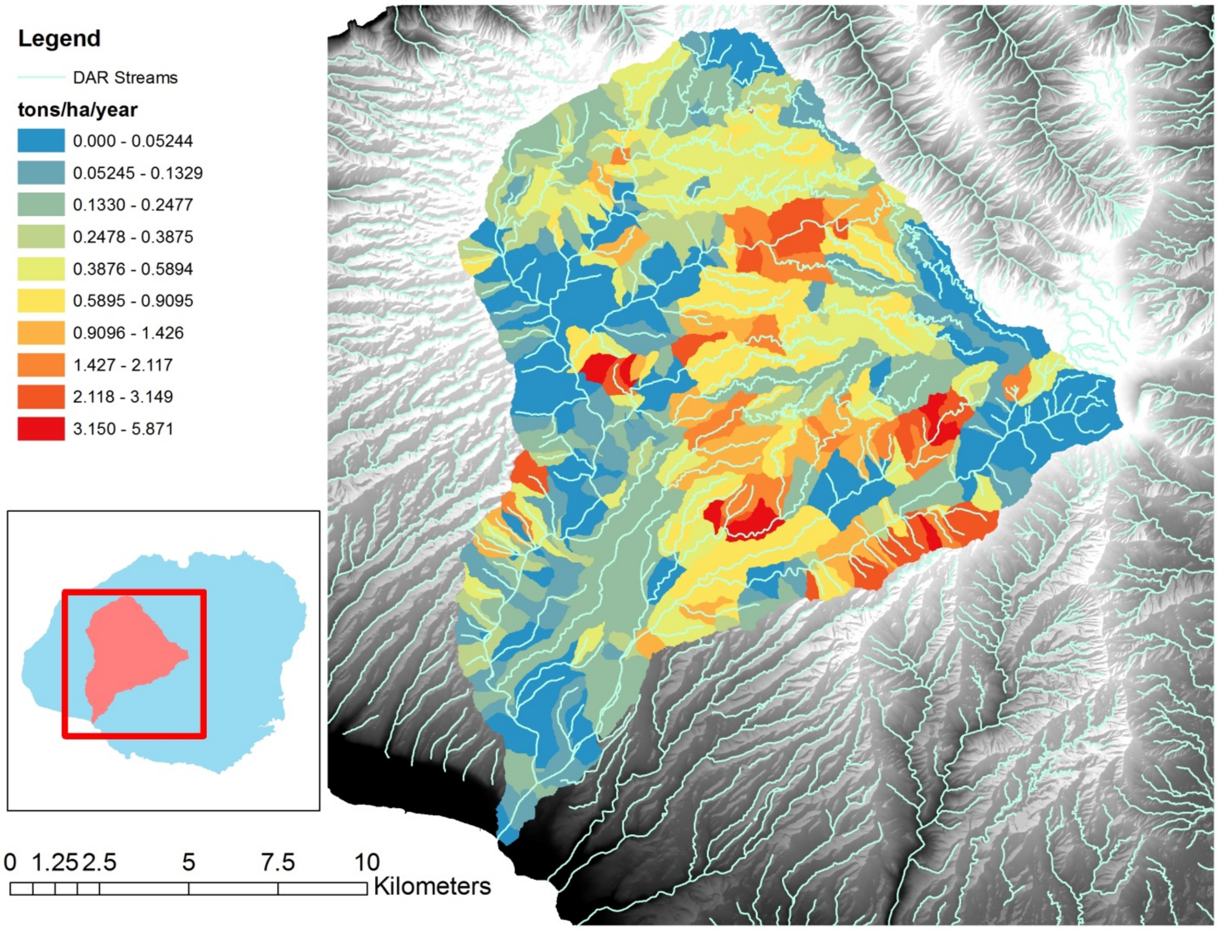
- Possible presence of water-borne human pathogens;
- Long-term physical, chemical and biological components of inland, coastal, and oceanic waters; and
- Watershed use-attainment assessments, identification of sources of contamination, allocation of those contributing sources, and implementation of 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 and 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 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 less sensitive to fluctuations in water temperature and more dependent on 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 water temperature in dewatered reaches 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 et al., 2004). Runoff transports large amounts of sediment from bare soil into surface water bodies, with consequences for in-stream and near-shore environments. Based on landscape modeling, the Waimea hydrologic unit generates 12,300 tons of sediment per year (Kim Falinski, pers. Comm.). Areas with more exposed soil, tend to generate higher quantities of sediment (Figure 10-1).

There are three types of water bodies: 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).

Figure 10-1. Modeled annual sediment export from sub-catchments in the Waimea hydrologic unit. (Source: Kim Falinski, *pers. comm.*)



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, bacteruam and chemical contaminants into the stream. According to the U.S. Environmental Protection Agency (USEPA), "[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 (USEPA, 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)."[1] 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

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[1] 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.

have specific concentrations (levels of pollutants) that must be attained based on water body type, e.g. fresh water stream. Qualitative standards are general narrative statements that are applicable to all State waters, such as "all waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants (State of Hawaii, Department of Health, 2004)." Conventional pollutants include nutrients and sediments. Toxic pollutants include pesticides and heavy metals. Indicator bacteria are utilized to assess bacterial levels. Biological assessments of aquatic communities are also included in the data collected.

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

The sources for the 2012 Integrated Report are Hawaii's 2010 §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 2010 list that was published in 2012), only 88 streams statewide had sufficient data for evaluation of whether exceedence of WQS occurred. Waimea Stream did not appear on the 2012 List of Impaired Waters in Hawaii, Clean Water Act §303(d). However, the Waimea Recreation Pear State Park was newly listed as impaired based on *Enterococci*. While some data exist for Waimea, there were not sufficient data for decision-making; therefore, no decision was made pertaining to the attainment of WQS or the applicable designated uses.

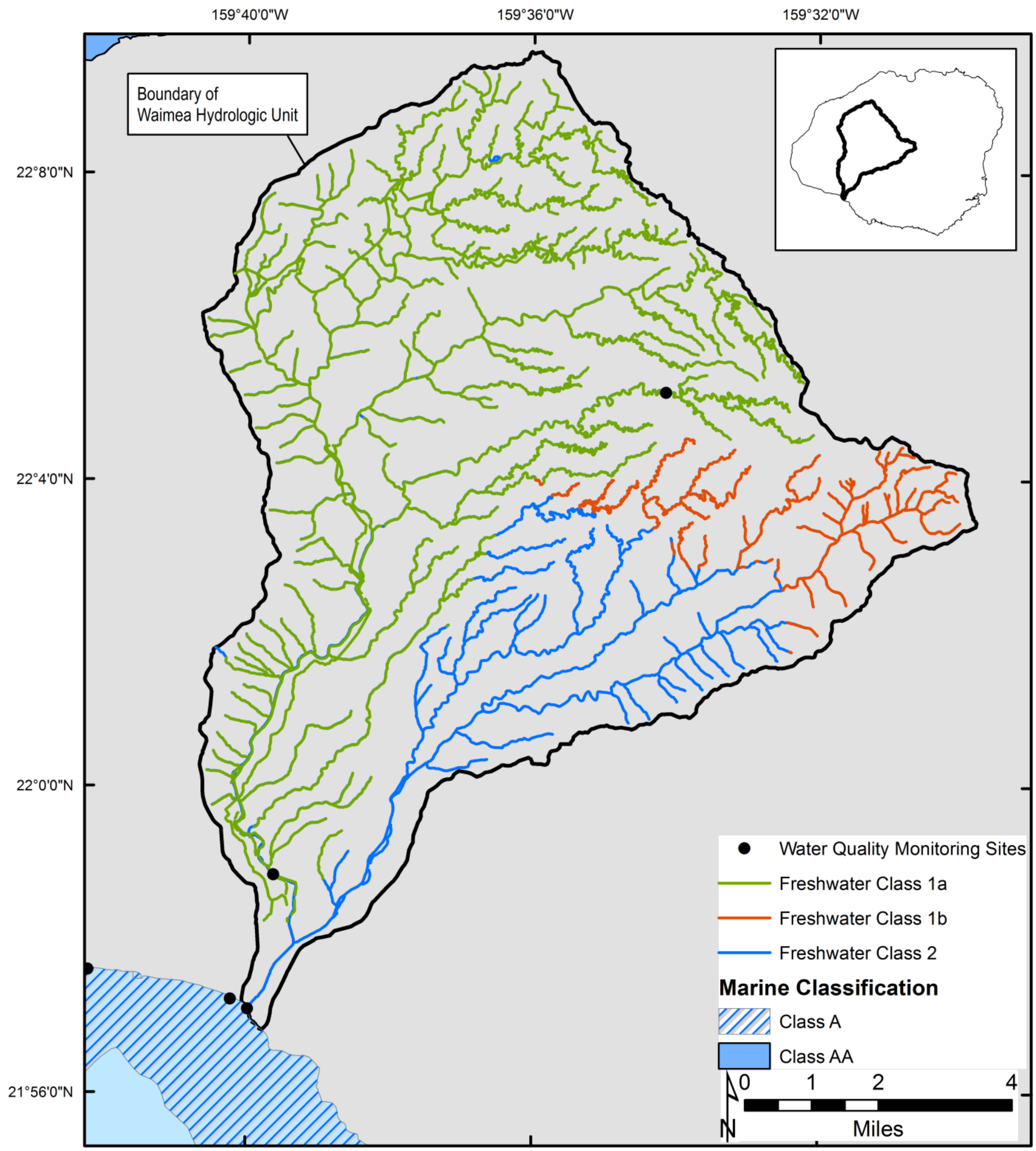
The 2006 Integrated Report indicates that the current WQS require the use of *Enterococci* as the indicator bacteria for evaluating public health risks in the waters of the State; however, no new data were available for this parameter in inland waters. As mentioned in Section 5.0, Outdoor Recreational 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 2012 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, 2007, Chapter II, p.3)."

Waimea Stream is classified as Class 1a inland waters from its headwaters to approximately its confluence with Makaweli Stream as the surrounding land is in the conservation subzone "protective." The headwaters of the Makaweli Stream is classified as Class 1b inland waters, while the majority of the downstream reaches of the Makaweli Stream are not classified. 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 Waimea hydrologic unit are mostly Class A waters. Figure 10-2 shows the Waimea hydrologic unit, including inland and marine (coastal) water classifications.

Figure 10-2. Water quality standards for the Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015e; 2008). The classifications are general in nature and should be used in conjunction with Hawaii Administrative Rules, Chapter 11-54, Water Quality Standards.



11.0 Conveyance of Irrigation and Domestic Water Supplies

Under the State Water Code, the conveyance of irrigation and domestic water supplies to downstream points of diversion is included as one of nine listed instream uses. The thought of a 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 Kauai Department of Water Supply 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. 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. However, there are no private water systems in the Waimea hydrologic unit regulated by the DOH, Safe Drinking Water branch.

12.0 Protection of Traditional and Customary Hawaiian Rights

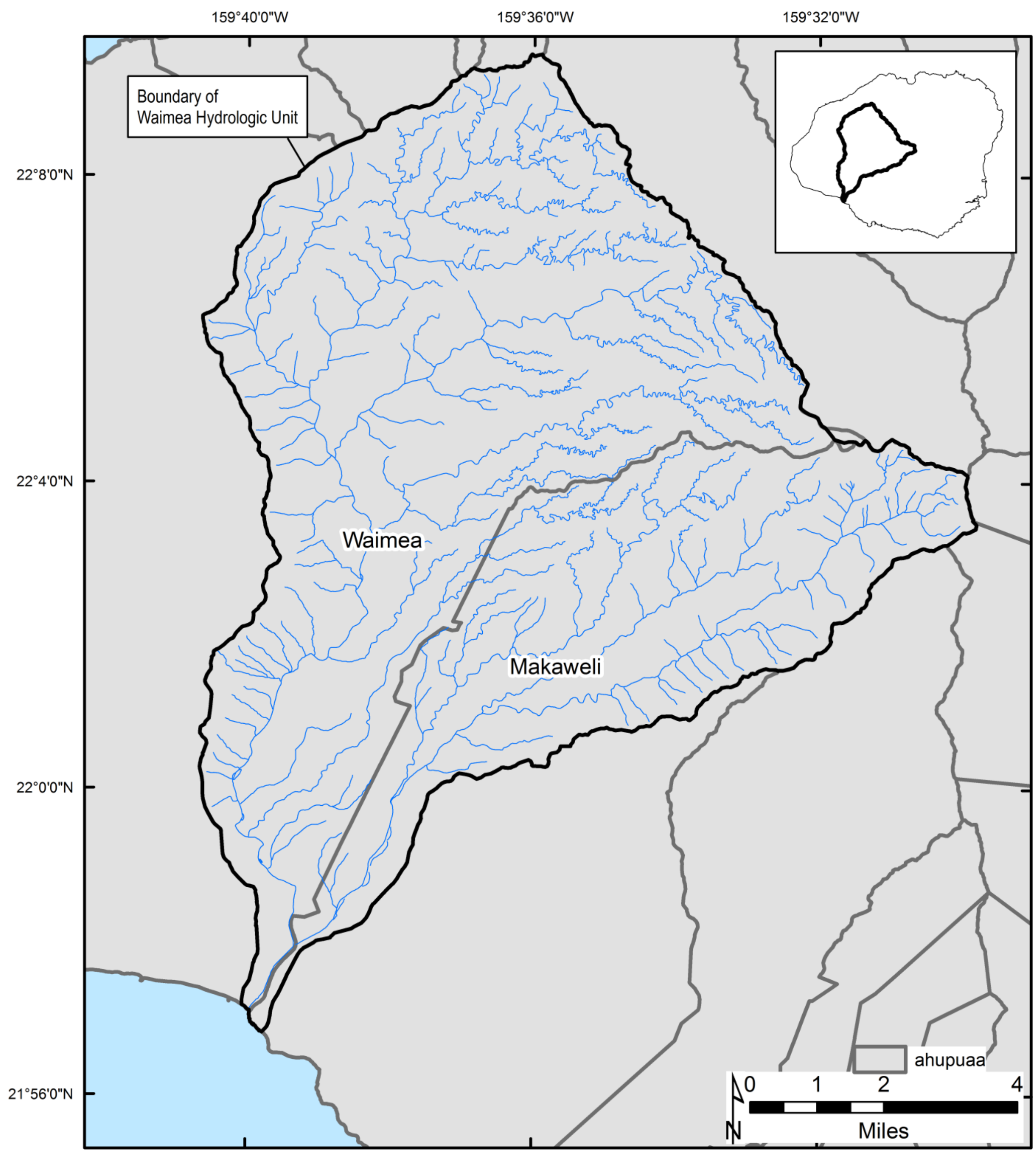
The maintenance of instream flows is important to the protection of traditional and customary Hawaiian rights, as they relate to the maintenance of stream resources (e.g., hihiwai, opae, oopu) for gathering, recreation, and the cultivation of taro. Article XII, Section 7 of the State Constitution addresses 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 Waimea includes parts of the ahupuaa of Waimea and Makaweli as shown in Figure 12-1. The ahupuaa boundaries are delineated based on the USGS Digital Line Graphs. These boundaries may be different from the information listed on legal documents such as deeds.

Figure 12-1. Traditional ahupuaa boundaries in the vicinity of Waimea hydrologic unit. This hydrologic unit spans two ahupuaa – Waimea and Makaweli. (Source: State of Hawaii, Office of Planning, 2015j)



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, Section (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 2007 *Water Resource Protection Plan – Public Review Draft*, incorporating a later revision[1] as follows:

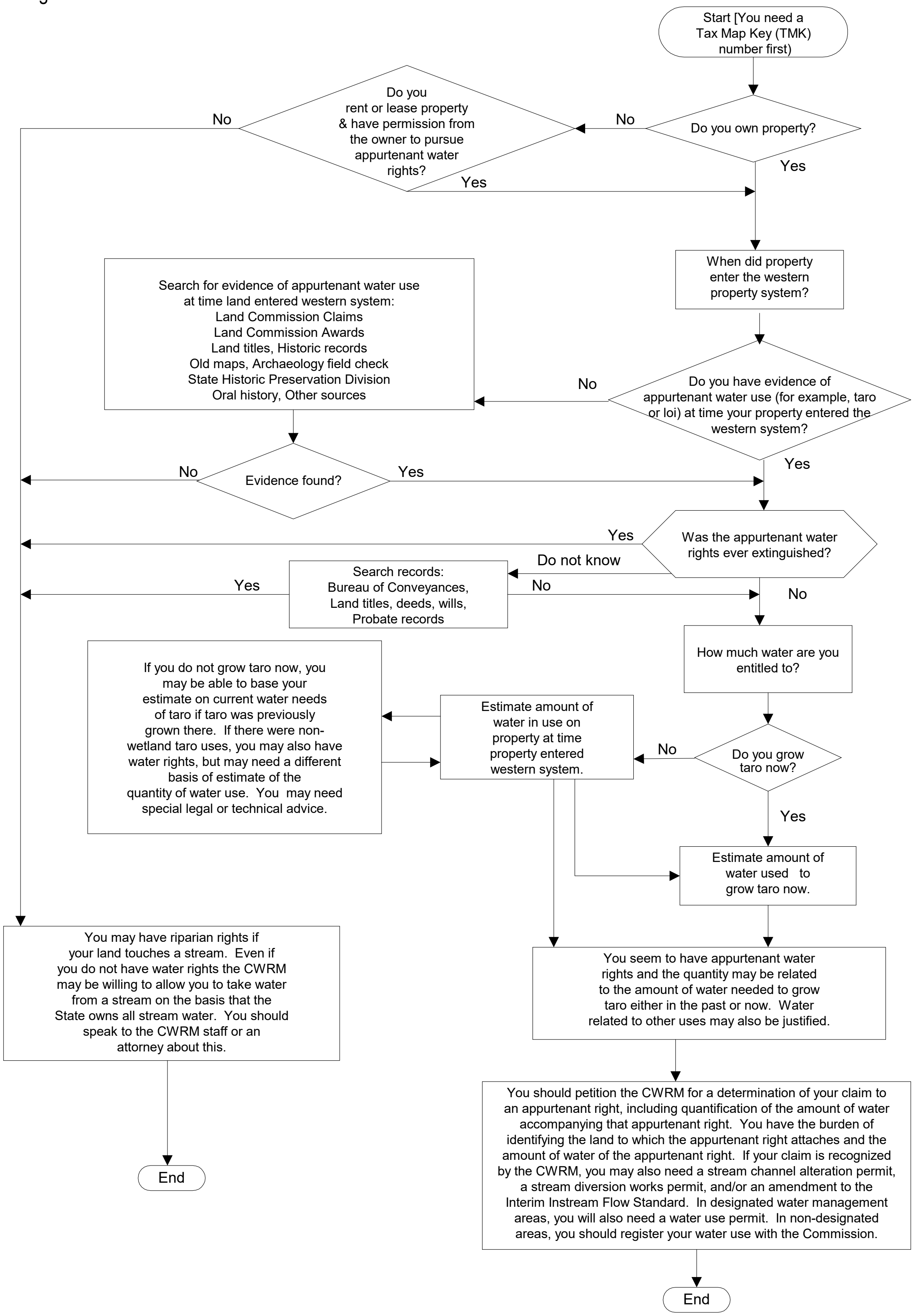
> Appurtenant water rights are rights to the use of water utilized by parcels of land at the time of their original conversion into fee simple lands i.e., when land allotted by the 1848 Mahele was confirmed to the awardee by the Land Commission and/or when the Royal Patent was issued based on such award, the conveyance of the parcel of land carried with it the appurtenant right to water.[2] 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.[3] Once established, future uses are not limited to the cultivation of traditional products approximating those utilized at the time of the Mahele[4], 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

[1] Although the final Water Resource Protection Plan had not been printed as of the date of this report, most edits had already been incorporated into the latest version, which the Commission utilized for this report.
[2] 54 Haw. 174, at 188; 504 .2d 1330, at 1339.
[3] 65 Haw. 531, at 554; 656 P.2d 57, at 72.
[4] *Peck v Bailey*, 8 Haw. 658, at 665 (1867).

in a manner which is both reasonable and consistent with the State and county land use plans and the public interest"). As mentioned earlier, appurtenant rights are preserved under the State Water Code, so even in designated water management areas, an unexercised appurtenant right is not extinguished and must be issued a water use permit when applied for, as long as the water use permit requirements are met [Figure 12-2].

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 12-2. 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 Waimea. 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 Waimea hydrologic unit.

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

TMK	Landowner	LCA	Grants/Leases	Notes
414001009	Gay & Robinson	11299		
414001010	Robinson Family	11302:1		
414001011	Robinson Family	11302:2		
414001012	Robinson Family	11302:3		
414002004	Govt. State		G.L. 5-4168	
414002005	Govt. State		G.L. 5-4036	
414003001	Govt. State		G.L. 5-4500	
414003003	Govt. State		G.L. 5-4069	
414003004	Govt. State		G.L. 4-4051	
414003005	Govt. State		G.L. 5-4052	
414003006	Govt. State		G.L. 5-4053	
414003007	Govt. State		G.L. 5-4054	
414003008	Govt. State		G.L. 5-3307	
414003009	Govt. State		G.L. 5-4082	
414003010	Govt. State		G.L. 5-4055	
414003011	Govt. State		G.L. 5-4068	
414003012	Govt. State		G.L. 5-3442	
414003013	Govt. State		G.L. 5-4056	
414003014	Govt. State		G.L. 5-4049	
414003016	Govt. State		G.L. 5-4050	
414003017	Govt. State		G.L. 5-4507	
414004001	Govt. State		G.L. 5-4480	
414004002	Govt. State		G.L. 5-4067	
414004004	Govt. State		G.L. 5-4065	
414004006	Govt. State		G.L. 5-4064	
414004008	Govt. State		G.L. 5-4088	
414004009	Govt. State		G.L. 5-4089	
414004011	Govt. State		G.L. 5-4091	
414004012	Govt. State		G.L. 5-4090	
414004013	Govt. State		G.L. 5-4084	
414004014	Govt. State		G.L. 5-4081	
414004016	Govt. State		G.L. 5-4063	
414004017	Govt. State		G.L. 5-4062	
414004018	Govt. State		G.L. 5-4061	
414004020	Govt. State		G.L. 5-4039	
414004021	Govt. State		G.L. 5-4058	
414004024	Govt. State		G.L. 5-4163	
414004027	Govt. State		G.L. 5-4142	
414004028	Govt. State		G.L. 5-4144	
414004030	Govt. State		G.L. 5-4085	
414004032	Govt. State		G.L. 5-3671	
414004033	Govt. State		G.L. 5-3863	
414004035	Govt. State		G.L. 5-4083	
414004036	Govt. State		G.L. 5-4508	
414004038	Govt. State		G.L. 5-4502	
414004040	Govt. State		G.L. 5-4071	
414004041	other		G.L. 5-4147	
414004043	Govt. State		G.L. 5-4086	
414004044	Govt. State		G.L. 5-4070	
414004047	Govt. State		G.L. 5-4078	
414004048	Govt. State		G.L. 5-4079	
414004049	Govt. State		G.L. 5-4080	
414004050	Govt. State		G.L. 5-4154	
414004052	Govt. State		G.L. 5-4151	
414004053	Govt. State		G.L. 5-4152	
414004054	Govt. State		G.L. 5-4153	
414004055	Govt. State		G.L. 5-4076	
414004058	Govt. State		G.L. 5-4077	

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

[LCA is Land Commission Award; Gr. is Grant; por. is portion; and G.L. is Government Lease; L.C.App.is Land Court Application]

TMK	Landowner	LCA	Grants/Leases	Notes
414004059	other		G.L. 5-4150	
414004062	Govt. State		G.L. 5-4510	
414004063	Govt. State		G.L. 5-4512	
414004068	Govt. State		G.L. 5-4074	
414004069	Govt. State		G.L. 5-4811	
414004073	Govt. State		G.L. 5-3671	
414004074	Govt. State		G.L. 5-3671	
414004075	Govt. State		G.L. 3671	
414004076	Govt. State		G.L. 5-5309	
415001003	Robinson Family	11278:1, 11278:1		
415001004	Robinson Family	11278:2		
415001005	Robinson Family	11278:2		
415001006	Robinson Family	11274, 11275		
415001007	Robinson Family	11277		
415001008	Gay & Robinson	11285		
415001009	Gay & Robinson	11283:1		
415001010	Gay & Robinson	11283:1		
415001011	Gay & Robinson	11280		
415001012	Robinson Family	11281		
415001013	Gay & Robinson	11279		
415001014	Gay & Robinson	11282		
415001015	Robinson Family	11285:1		
415001016	Robinson Family	11286:2		
415002001	other		Gr. 8810	
415002002	other	10092, 10095		
415002004	other	10721:1		
415002005	other	9201:1		
415002006	other	10637:2		
415002007	other		Gr. 7988	
415002008	other	9191	Gr. 8109	
415002009	other	9201:2		
415002010	other		Gr. 8025	
415002011	other	6310		
415002014	other	10721:2		
415002016	other	6531		
415002017	Robinson Family	6522:2		
415002020	other		Gr. 5-14,447	
415002021	other		Gr. 7183	
415002022	other		Gr. 7392:1	
415002023	other	5467		
415002024	other	9194		
415002026	other	6643:1		
415002027	other	5308		
415002028	other		Gr. 8128	
415002030	other	6700:2		
415002032	other		Gr. 7144	
415002033	Robinson Family	9192		
415002034	other		Gr. 8133	
415002035	Robinson Family	6522:1		
415002036	other		Gr. 10472	
415002037	other	6700:1		
415002037	other	6700:1		
415002039	other	10637:2		
415002041	other	6700:1		
415002042	other		Gr. 7144	
415002044	other		Gr. 7144	
415002046	other	9186		
415002047	other		Gr. 8026	
415002048	other		Gr. 7383	
415002049	other	6567:2		
415002050	other	10092, 1064		
415002051	other	8251		
415002053	other		Gr. 7183	
415002054	other	9202		

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

[LCA is Land Commission Award; Gr. is Grant; por. is portion; and G.L. is Government Lease; L.C.App.is Land Court Application]

TMK	Landowner	LCA	Grants/Leases	Notes
415002056	other		Gr. 7183	
415002057	other		Gr. 7392:2	
415002058	other		Gr. 8142	
415002059	other		Gr. 8127	
415002060	other		Gr. 8129	
415002061	other	6700:2		
415002063	other		Gr. 7144	
415003002	other			
415003003	other		L.C.App. 926	
415003004	other	10688	L.C.App. 927	
415003004	other	10688, 9227		
415003011	Robinson Family	235-V, 6280		
415003012	Robinson Family	4308-B		
415003023	Robinson Family	11276		
415003025	Robinson Family	11309		
415003026	other	11284		
415003028	other		L.C.App. 925	
415003029	Robinson Family			
416001003	Robinson Family	11272		
416001004	other		Gr. 8055	
416001005	other		Gr. 7113	
416001006	other	6524:2		
416001010	other	6337		
416001011	Robinson Family	6553, 6337		
416001014	other	6271		
416001017	other	3410:3		
416001018	Robinson Family		L.C.App. 928	
416001019	other	6331:2		
416001020	other	5612		
416001022	Robinson Family	6308-B, 6273:2, 11271		
416001023	other	5479		
416001024	other		L.C.App. 934	
416001025	Robinson Family		L.C.App. 936	
416001026	other	11270		
416001027	Robinson Family	6307		
416001046	other	6271		
416002004	Govt. State		Gr. 8111	
416002005	other	236-B, 235-Z, 236-G, 235-Y		
416002006	other		Gr. 7145	
416002009	other		L.C.App. 461	
416002010	other		L.C.App. 458	
416002013	other	3411		
416002014	other	3597:2		
416002017	other	3309:2		
416002018	other	3309:2		
416002019	other		L.C.App. 6336:1	
416002020	other	3309:2		
416002022	Robinson Family	235-X		
416002026	other	3354		
416002027	other	6382		
416002028	other	6389:1		
416002030	other	6383:2, 8223, 6565-B		
416002032	Robinson Family	6384:2		
416002033	other	6701:3		
416002034	other	2220		
416002035	Robinson Family	6701:1, 2290, 6701:2, 9903		
416002036	other	5396:2		
416002037	other	6112:2		
416002038	other		Gr. 8543	
416002039	other		Gr. 8538	
416002040	other		Gr. 5-15177	
416002041	Robinson Family		Gr. 8917	
416002042	other	7672:2		
416002044	Robinson Family	6755:3		

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

[LCA is Land Commission Award; Gr. is Grant; por. is portion; and G.L. is Government Lease; L.C.App. is Land Court Application]

TMK	Landowner	LCA	Grants/Leases	Notes
416002045	other		L.C.App. 6790	
416002047	other	3353:1		
416002048	other	3587:2		
416002049	Robinson Family	7672:1		
416002051	other	10086:2		
416002052	Robinson Family	6334:2		
416002053	other	10086:1		
416002056	Robinson Family	236-C, 3352, 3608:3, 2290:2, 1976:1		
416002057	other	6274:1		
416002058	other		Gr. 8247	
416002059	other	6274:2		
416002060	other	3587:3		
416002061	other		Gr. 5860	
416002063	other	6378:2, 3353:2		
416002065	Govt. State	387, 1976:2		
416002066	Robinson Family		Gr. 7146	
416002072	other	235-X		
416002073	other		L.C.App. 6336:1	
416002075	other		Gr. 8054	
416002076	other	5396:1		
416003019	Govt. State	11180, 11135, 11181		
416003020	other	3585		
416003021	other	3585		
416003022	other	3589		
416003023	other	3587:4		
416003024	Robinson Family	2064:2, 235W:1		
416003026	other		L.C.App. 1595	
416003027	other	2291, 3590, 3591:1		
416003028	other	3588		
416003030	other	3588		
416003031	other		L.C.App. 1277	
416003032	other		L.C.App. 460	
416003033	other		Gr. 7115	
416003034	other	6306		
416003035	other	6268:1		
416003037	other		Gr. 13532	
416003038	Robinson Family	6666		
416003043	other		Gr. 11534	
416003046	other		L.C.App. 7713:42	
416003051	other	3608:2		
416003052	Robinson Family	2064:3, 235W:2	Gr. 11410	
416003053	other	235W:2		
416003054	other		Gr. 8130	
416003055	other		Gr. 12539	
416003059	other		Gr. 10769	
416003060	other	3593:3	Gr. 11534	
416003068	other			
416003071	other	6306		
416003074	Govt. State	3589		
416003075	other	6524:3		
416003077	other		L.C.App. 459	
416003080	other	3588		
416003092	other	6268:1		
416003093	other		Gr. 10769	
416003094	other		Gr. 10769	
416003095	other		Gr. 10769	
416003096	other		Gr. 10769	
416003097	other		Gr. 10769	
416003098	other		Gr. 10769	
416003099	other		Gr. 10769	
416004004	other		Gr. 11243	
416004005	other		Gr. 12073	
416004006	other		Gr. 8551:2	

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

[LCA is Land Commission Award; Gr. is Grant; por. is portion; and G.L. is Government Lease; L.C.App. is Land Court Application]

TMK	Landowner	LCA	Grants/Leases	Notes
416004007	other		Gr. 8146	
416004008	other		Gr. 10805	
416004009	other		Gr. 12388	
416004010	other		Gr. S-14, Gr. 9	
416004011	Govt. State		Gr. 11994, Gr. 11494, Gr. 11501	
416004018	other		Gr. 12822	
416005004	other	6274:3, 7135, 6272, 6270:1		
416005005	other	6273		
416005007	other	6270:1		
416005022	other		Gr. 7223	
416005070	other	6568:1		
416006002	other	2291, 3590, 6305, 3591:2	7303:3	
416006006	other		Gr. 11674	
416006011	other		Gr. 8145	
416006025	other		Gr. 7779	
416006034	other		L.C.App. 878	
416006036	other		L.C.App.1322	
416006045	other	2291, 3590, 6305, 3591:2	Gr. 7303:3	
416006046	other		Gr. 7303:3	
416010001	other	7713		
416011009	other	3310:2		
417001001	Robinson Family			
417001002	other			
417001003	other			
417001004	other			
417001008	Gay & Robinson			
417001009	Robinson Family			
417002002	Gay & Robinson	11273:2, 11300, 11264		
417002003	Robinson Family	11273:1, 7713:1		
417002004	other	9655		
417002005	other	9662:2		
417002006	other	9040, 9656, 11024		
417002007	other	9655-B:1		
417002008	other	9662:1		
417002009	other	9655-B:2		
417002010	Gay & Robinson	10354		
417003001	other	8258		
417003002	Robinson Family	9653-B, 10670:1, 1035:2, 10350:1, 10669, 9130, 10943, 10670:2		
417003003	other	9665:2		
417003004	other	9665:1		
417003005	other	236-F		
417003006	other	6304		
417003007	other	6277:2		
417003008	other	3112:1		
417003009	other	6343		
417003010	other	9144		
417003011	other	6552:1		
417003012	other	6578:2		
417003013	other	6552-B		
417003014	other	6581		
417003015	other	9077		
417003016	other	9077		
417003017	other	6552:3		
417003018	other	236-E		
417003019	other	6297		
417003020	Robinson Family	10696:1		
417003021	Robinson Family	10696:2		
417003022	Robinson Family	9666:1		
417003023	Robinson Family	9666:2		
417003024	Gay & Robinson	9657, 387		
417003025	Gay & Robinson	236-D:1		
417003026	Gay & Robinson	3112:2		
417003027	Robinson Family	6333:1		

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

[LCA is Land Commission Award; Gr. is Grant; por. is portion; and G.L. is Government Lease; L.C.App. is Land Court Application]

TMK	Landowner	LCA	Grants/Leases	Notes
417003028	Robinson Family	6353		
417003029	other	6316		
417004001	other	6566:2		
417004002	Govt. County of Kauai	6514:2		
417004003	other	6566:3		
417004004	other	6338:1		
417004005	other	6342		
417004006	other	6578:3		
417004007	Robinson Family	6352:2, 6352:1, 7713:1, 6330, 6327, 6518:1 6514:1, 10009, 5307		
417004008	other	6566:1		
417004009	other	6534		
417004010	other	11301:2		
417004011	other	11301:3		
417004012	Robinson Family	6566:4		
417004013	other	6566:4		
417004015	Gay & Robinson	236-D:2		
417004016	Robinson Family	6340		
417004017	Robinson Family	6588		

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 they largely relate 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; 6) water temperature; and 7) 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).

Taro Production

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.

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 2007 USGS 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 12-2 below. The study indicated that the "values are consistent with previously reported inflow and are significantly higher than values generally estimated for consumption during kalo cultivation." It should also be noted that farmers were interviewed during field visits; most "believed that their supply of irrigation water was insufficient for proper kalo cultivation." Table 12-3 summarizes water-temperature statistics from the study.

Table 12-2. Summary of water use calculated from loi and loi complexes by island, and the entire state. (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

Table 12-3. Water-temperature statistics based on measurements collected at 15-minute intervals for loi complexes on the island of Maui. (Source: Gingerich et al., 2007, Table 7)

[ºC = degrees Celsius; na = not applicable]

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

Historical uses 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:

> East of Maliko the number of named *ahupuaʻa* is evidence of habitation along this coast.
>
> Two *kamaʻaina* at Keʻanae said that there were small *loʻi* developments watered by Hoʻolawa, Waipiʻo, Hanehoi, Hoalua, Kailua, and Naʻiliʻilihaele Streams, all of which flow in deep gulches. Stream taro was probably planted along the watercourses well up into the higher *kula* land and forest taro throughout the lower forest zone. The number of very narrow *ahupuaʻa* thus utilized along the whole of the Hamakua coast indicates that there must have been a very considerable population. This would be despite the fact that it is an area of only moderate precipitation because of being too low to draw rain out of trade winds flowing down the coast from the rugged and wet northeast Koʻolau area that lies beyond. It was probably a favorable region for breadfruit, banana, sugar cane, arrowroot; and for yams and *ʻawa* in the interior. The slopes between the gulches were covered with good soil, excellent for sweet-potato planting. The low coast is indented by a number of small bays offering good opportunity for fishing. The *Alaloa*, or ʻLong-road,ʼ that went around Maui passed through Hamakua close to the shore, crossing streams where the gulches opened to the sea.

Individual cultural resources of Waimea Hydrologic Unit were not classified by the Hawaii Stream Assessment (HSA), but generally classified based on the Historic Preservation Division database. Data were collected 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 12-4).

Fishponds

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 Waimea hydrologic unit (DHM, Inc., 1990), but along the coastline near the hydrologic unit, there is a single historic fishpond located in the Kekaha area.

Table 12-4. Cultural resource elements evaluated as part of the Hawaii Stream Assessment for Waimea 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.	Partial
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.	All others
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.	8
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 were 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.	ACDE

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.	Medium
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.	
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.	High
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.	Yes
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.	Yes

Hawaiian Home Lands

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 June 2004, DHHL published the Kauai Island Plan which served to examine infrastructure needs, provide development cost estimates, and identify priority areas for homestead development. Of the more than 20,000 acres of DHHL land on the island of Kauai, no parcels occur within the Waimea hydrologic unit. However, DHHL manages a large (15,061 acre) parcel of acricultural land in the Kekaha hydrologic unit that receives water for crop and livestock irrigation from the Kokee Ditch originating in the Waimea hydrologic unit. Currently, water demand is only 0.29 mgd, but could be higher if further development takes place as planned (State of Hawaii, Department of Hawaiian Homelands, 2011). The development of the Waimea parcel is a top priority for DHHL, with a variety of proposed land uses (Table 12-5). In December 2015, DHHL placed a reservation of 31.45 mgd for water from the Waimea hydrologic unit. In June 2017, the Commission approved a modified reservation of 6.903 mgd of surface water for DHHL.

Table 12-5. Existing and proposed land uses and area for the DHHL Waimea parcel. (Source: State of Hawaii, Department of Hawaiian Homelands, 2011)

Existing land uses	Area (mi^2)	Proposed Land uses	Area (mi^2)
Pastoral	0.742	Pastoral	0.742
Vacant	1.313	Residential	0.316
Diversified agriculture	0.031	Subsistence Agriculture	0.334
Military (ammunition storage)	0.041	General Agriculture	19.573
DLNR game management	21.25	Special District	1.966
		Community Use	0.066
		Conservation	0.536

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. The Hawaii Farm Bureau Federation, Hawaii’s largest advocacy organization for general agriculture, states that agriculture is a public trust entity worthy of protection, as demonstrated in its inclusion in the State Constitution. They, on behalf of farmers and ranchers, point to the importance of large-scale agriculture to sustainability and self-sufficiency of our islands, particularly in times of catastrophe when imports are cut off. Currently, there are no designated Important Agriculture Lands in the Kekaha or Waimea hydrologic units.

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 large amounts of water.

Water Leaving the Waimea Hydrologic Unit in Ditch Systems

Water is most often used away from the stream channel and is not returned; however, as in the case of taro fields, water may be returned to the stream at some point downstream of its use. While the return of surface water to the stream would generally be considered a positive value, this introduces the need to consider water quality variables such as increased temperature, nutrients, and dissolved oxygen, which may impact other instream uses. The Kokee and Kekaha ditches were designed to remove water from the Waimea hydrologic unit without returning it to any of the streams in order to supply irrigation water for sugarcane lands (Table 13-1). Currently, there is limited demand for irrigation water from the Kokee system, with DHHL using an estimated 0.29 mgd and Wines of Kauai agricultural tenant using approximately 0.29 mgd. The DLNR managed dam on Puu Lua Reservoir (Kokee Ditch fed) is currently not up to code and reservoir water height is limited to 60 ft. Thus, for dam safety reasons, the rate of flow into Puu Lua Reservoir is currently restricted. The last sluice gate prior to Puu Lua Reservoir is the release into Kauhao Gulch (Figure 13-1). To maintain a debris free gate and to prevent silt buildup in the basin behind the gate, approximately 0.3 mgd is permitted to flow under the gate, although this flow may be eliminated with more frequent maintenance. Further, the top half of the gate has been removed so that any higher flows pass over the gate. As proper maintenance of the ditch requires a wetted surface to prevent ditch walls from collapsing (in unlined portions) and to limit vegetation growth, approximately 1.5 mgd is maintained up to to Puu Moi divide. This practice results in less than 1.0 mgd of discharge from the end of the Kokee ditch. An additional benefit of maintaining the ditch past the Puu Moi Divide is that ditch water can serve as a backup supply to the Menehune Ditch and Mana Plain water users when the Kekaha Ditch is shut down for repairs. The ditch that brings water from the Puu Moi divide to DHHL land is in poor condition and needs upgrading to properly service future DHHL development plans (State of Hawaii-DHHL, 2011). Additionally, discharge of water from a ditch system into a stream may introduce invasive species. For example, the Kokee Ditch system is known to provide habitat for many non-native species, including rainbow trout (*Oncorhynchus mykiss*), Tahitian prawn (*Macrobrachium lar*), and mosquito fish (*Gambusia affinis*).

Table 13-1. Historic Timeline of Irrigation Systems in West Kauai. (Source: Wilcox, 1996)

Hanapepe and Makaweli Streams		
1894	-	Alexander & Baldwin (A&B) is established as an agency
1889	-	Hawaiian Sugar Company (Makaweli Plantation) incorporated with Henry P. Baldwin as principal shareholder
1889	-	A&B signed 50-year lease of land from Gay & Robinson
1889	-	Hanapepe Ditch construction began
1889	-	Hanapepe Ditch construction completed at at cost of $152,013
1902	-	Olokele Ditch construction began, engineered by Michael M. O'Shaughnessy
1904	-	Olokele Ditch construction completed at a cost of $360,000
1898	-	A&B gain control of Hawaiian Commercial & Sugar (HC&S), then become its agent shortly thereafter.
1900	-	A&B is incorporated with accumulated assets of $1.5 million, compared with a net profit of just $2,627.20 in 1895
1940	-	Unable to reach agreement on new leases, Hawaiian Sugar Company is terminated and Olokele Sugar Company was formed under the agency of C. Brewer & Company
	-	Gay & Robinson assumes complete control of water collection systems and delivery to Olokele Sugar Company
1948	-	Gay & Robinson and C. Brewer & Company build the Koula Ditch Tunnel to replace the Hanapepe Ditch flumes, limited ditch leakage
1994	-	Olokele Sugar Company merges with Gay & Robinson
Waimea Streams		
1878	-	Kekaha Sugar Company started by Valdemar Knudsen with crown leases on Kekaha, Kokee and Mana lands
1884	-	Waimea Sugar Mill Company is established, leasing land from missionary George Rowell
1889	-	Kekaha Sugar installed 10 mgd pump for groundwater irrigation
1902	-	Irrigation from groundwater and nearby swamps resulted in increased salinity
	-	Waimea Ditch construction began
1903	-	Waimea Ditch (aka Kikiaola Ditch) construction completed at a cost of $36,278
1904	-	Hans Peter Fay, newphew of Knudsen, purchases Waimea Sugar Mill Company lands from Rowell principally for the water rights
1905	-	Mana wells drop by 4 feet and salinity goes from 7 to 100 grains per gallon due to overpumping
	-	crops fail or not planted due to lack of water
1906	-	Kekaha Ditch construction began with diversion at location site of Mauka Powerhouse
1907	-	Kekaha Ditch construction completed at a cost of $240,000 to $290,000
1912	-	Kekaha Ditch extended to Koaie and Waiahulu diversions including Mauka Powerhouse
1923	-	George R. Eward repaired and realigned Kikiaola Ditch for $45,471
	-	Kokee Ditch construction began following government leasing stipulating development of additional mauka acreage
1925	-	Kokee Ditch construction completed at a cost of $500,000 to $680,000
1969	-	Waimea Sugar Mill Company reorganized into Kikiaola Land Company, leasing ditch and cane lands to Kekaha Sugar
1969	-	Kikiaola Ditch closed
1999	-	Kekaha Sugar Company declared banrupcy
2003	-	Kekaha Agriculture Association forms to manage ditch, road and electrical infrastructure

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

Upon the enactment of the State Water Code and subsequent adoption of the Hawaii Administrative Rules, the Commission required the registration of all existing stream diversions statewide. The Commission categorized the diversions and filed registrations according to the registrant's last name or company name. While it is recognized that the ownership and/or lease of many of the properties with diversions has changed since then, the file reference (FILEREF) remains the name of the original registrant file (Table 13-2) with locations depicted in Figure 13-1. The Commission's records for the hydrologic unit of Waimea indicate that there are a total of 45 registered diversions, of which 12 are Gay & Robinson diversions and 17 are former Kekaha Sugar Co. diversions now managed by the Agriculture Development Corporation. This information is derived from original registration documents, much of which has not been field verified and may have changed. In 2007, the Commission contracted R.M. Towill Corporation to conduct a statewide diversion verification inventory starting with priority areas across parts of the island of Kauai. Data from this study, along with information collected from Commission staff site visits, and information extracted from the original registration files regarding the registered diversions may be found in Table 13-2.

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

Figure 13-1. All registered diversions and ditches identified in the Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2004d; State of Hawaii, Commission on Water Resource Management, 2015g)

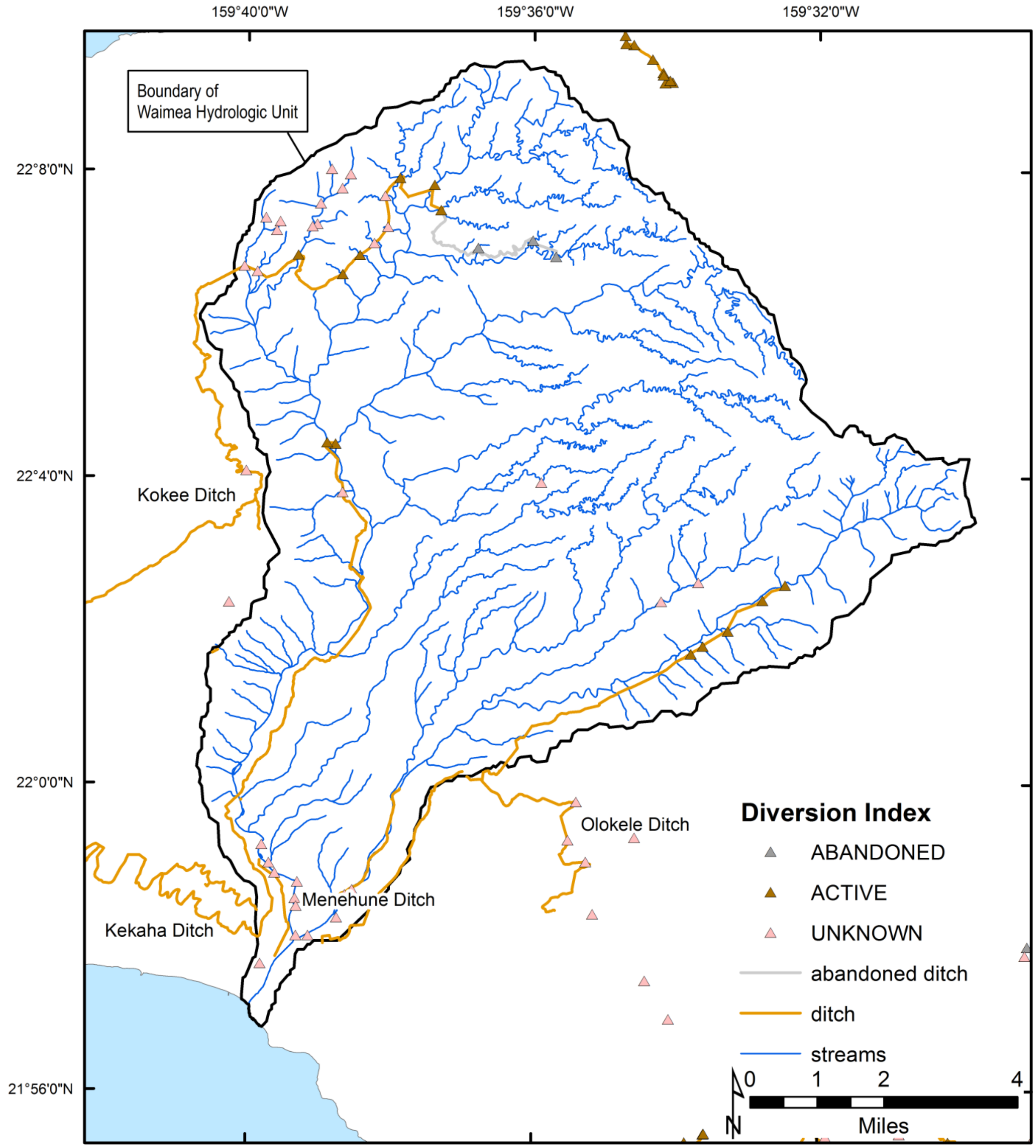


Table 13-2. Registered stream diversions for the Waimea Hydrologic Unit. (Source: State of Hawaii, Commission on Water Resource Management, 2015)

FILEREF	Stream Name	Notes
MILLER R&D	Elekeniiki	Stream diversion, Miller Intake from Elekeniike.
STATE PARK KAU	Elekeninui	Stream diversion, pump from Elekeninui Stream.
WILCOX C&G	Elekeninui	Stream diversion, pump from Unnamed stream.
WARTHER FX	Elekeninui	Stream diversion, pipe from Elekeninui stream. See also new entry for WARTHER FX; found another declaration form in file.
KIKIAOLA LAND	Halemanu	Stream diversion, pipe from Halemanu stream and rights claim.
HEE RJ	Halemanu	Stream diversion, dam in Halemanu stream. Located on State Forest Reserve land.
GAY & ROBINSON	Kahana	Stream diversion, pipe from Kahana stream. Diversion to Pilipiliahaumaka (no field verification, but has old div # assigned).
GAY & ROBINSON	Kahana	Stream diversion, Kahana stream-Halemoki. (no field verification, but has old div # assigned).
EGO K	Kokee	Stream diversion, pump from Kokee stream. Location of use is TMK 1-4-004:035
GAY & ROBINSON	Loli	Stream diverson, hand carry from Loli stream (no field verification, but has old div # assigned).
GAY & ROBINSON	Makaweli	Stream diversion, pump from Makaweli river (no field verification, but has old div # assigned).
GAY & ROBINSON	Makaweli	Stream diversion, Makaweli ditch #1 from Makaweli river. There are nine individual end users of this diversion (no field verification, but has old div # assigned).
GAY & ROBINSON	Makaweli	Stream diversion, Makaweli ditch #2 from Makaweli river. One end user of this diversion (no field verification, but has old div # assigned).
EGO K	Maluapopoki	Stream diversion, pipe from Maluapopoki stream. Location of use is TMK 1-4-004:035.
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Kumuwela #5 from Unnamed stream to Kokee ditch (new entry).
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Nawaimaka stream to Kokee ditch.
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Halemanu stream to Kokee ditch.
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Kumuwela #4 from Unnamed stream to Kokee ditch (new entry).
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Kokee stream to Kokee ditch.
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Mohihi #3 from Unnamed stream to Kokee ditch
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Mohihi #2 from Unnamed stream to Kokee ditch
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Kumuwela #3 from Unnamed stream to Kokee ditch (new entry).
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Kumuwela #2 from Unnamed stream to Kokee ditch (new entry).
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Waiakoali stream dam to Kokee ditch.
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Kumuwela #1 from Unnamed stream to Kokee ditch (new entry).
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Kawaikoi stream to Kokee ditch.
KEKAHA SUGAR	Mohihi Ditch	Stream diversion, Kauikinana stream to Kokee ditch.
KEKAHA SUGAR	Mohihi	Stream diversion, Mohihi stream intake to Kokee ditch.
GAY & ROBINSON	Olokele	Stream diversion, dam at Olokele river-Olokele. Declared Q=Nonopahu guage (included in Olokele System Q figures); (no field verification, but has old div # assigned).
HOOKANO I	Unnamed	Spring diversion, pump from spring. Diversion is on an intermittant stream.
GAY & ROBINSON	Unnamed	Stream diversion, Kalopopo stream-Olokele. Declared Q=Nonopahu guage (included in Olokele System Q figures); (no field verification, but has old div # assigned).
GAY & ROBINSON	Unnamed	Stream diversion, Kalopopo Stream-Olokele. Delcared Q=Nonopahu Guage (included in Olokele System Q figures); (no field verification, but has old div # assigned).
GAY & ROBINSON	Unnamed	Stream diversion, Kaluawai stream-Olokele. Declared Q=Nonopahu guage (included in Olokele System Q figures); (no field verification, but has old div # assigned).
WILLIAMSON HD	Unnamed	Stream diversion, pipe from Unnamed stream. Land is leased from the State.
GAY & ROBINSON	Unnamed spring	Spring diversion, from Unnamed spring to Kanekula. New entry, diverted flow is only used by one tenant.
GAY & ROBINSON	Waianuenue	Stream diversion, Waianuenue stream-Olokele. Declared Q=Nonopahu guage (included in Olokele System Q figures); (no field verification, but has old div # assigned).
KAOHI AG	Waimea	Stream diversion, pipe from Waimea river and rights claim.
NORTHRUP KING	Waimea	Stream diversion, pump from Waimea River.
PIONEER HI INT	Waimea	Stream diversion, pump from Waimea stream. Estimated water use declared for 1987 is 10 million acre-inches.
NORTHRUP KING	Waimea	Stream diversion, pump from Waimea River.
GAY & ROBINSON	Waimea	Stream diversion, Peekauai ditch from Waimea river. There are seven individual end users downstream (no field verification, but has old div # assigned).
NORTHRUP KING	Waimea	Stream diversion, pump from Waimea River.
DUNSENBERRY FD	Waimea	Stream diversion, occasional use of pump from Waimea stream and rights claim.
KEKAHA SUGAR	Waimea	Stream diversion, Kukui tributary-Waimea to Kekaha ditch.
KEKAHA SUGAR	Waimea	Stream diversion, Koaie stream dam to Kekaha ditch.
KEKAHA SUGAR	Waimea	Stream diversion, Waihulu dam on Waimea river to Kekaha ditch (called Waihulu dam in file).

Table 13-3. Registered diversions in the Waimea hydrologic unit: Kokee System.
[Source of photos are denoted at the end of each description; CWRM, Commission on Water Resource Management;Arrows (⇨)indicate general direction of natural water flow to and out of diversions; Chevrons ( ) indicate direction of diverted 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.620.2	KEKAHA SUGAR	4-1-4-001:003	unknown	Yes	Yes		

Waiakoali Stream is diverted by a concrete dam across the channel that captures 100% of base flow. Water is diverted along the right back into the Kokee Ditch. There is significant leakage of water underneath the diversion and along the left back where erosion has cut around the diversion. The abandoned Mohihi Ditch would have brought water to Waiakoali above this diversion.

Photos. a) Water flowing into diversion structure from Waiakoali Stream (CWRM, 07/2014); b) Diversion structure across the channel (CWRM, 07/2014); c) Diverted water along right bank of stream (CWRM, 07/2014); d) View of ditch from diversion structure along right bank (CWRM, 07/2014).

a)

b)

c)

d)

Table 13-3. Continued. Registered diversions in the Waimea hydrologic unit: Kokee System.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.620.2	KEKAHA SUGAR	4-1-4-001:003	unknown	Yes	Yes		

Waiakoali Stream [continued]

Photos. e) Diversion structure across the channel (CWRM, 07/2014); f) Downstream view of river from diversion structure (CWRM, 07/2014).

e)

f)

Table 13-3. Continued. Registered diversions in the Waimea hydrologic unit: Kokee System.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.616.2	KEKAHA SUGAR	4-1-4-001:003	unknown	Yes	Yes		

Water is diversted from Kowaikoi Stream along the right bank with a concrete structure inlaid between large boulders. Diverted water enters a tunnel and meets with water diverted from Waiakoali Stream flowing in a flume across the Kawaikoi gulch. Measurement of streamflow upstream of diversion is available from 1917-present by USGS (station #16010000)

Photos. a) Upstream view of Kawaikoi above diversion (CWRM 07/2014); b) diversion structure and gate channeling water into ditch on right bank (CWRM 07/2014); c) Water diverted from Waiakoali stream crosses Kawaikoi in a flume to combine with Kawaikoi diverted water(CWRM 07/2014); d) Diversion structure from the left bank (CWRM 07/2014).

a)

b)

c)

d)

Table 13-3. Continued. Registered diversions in the Waimea hydrologic unit: Kokee System.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.616.2	KEKAHA SUGAR	4-1-4-001:003	unknown	Yes	Yes		

Kawaikoi Stream [continued]

Photos. e) Diverted water flowing under gate into ditch along the right bank (CWRM 07/2014); f) Diverted water in ditch along the right bank flowing into tunnel past the control gate (CWRM 07/2014).

e)

f)

Table 13-3. Continued. Registered diversions in the Waimea hydrologic unit: Kokee System.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.607.2	KEKAHA SUGAR	4-1-4-001:013	unknown	Yes	Yes		

Water is diverted from Waiakoali and Kawaikoi streams into the Kokee Ditch. The ditch then dumps water into Kauaikinana stream up stream of the diversion pictured here. The diversion structure is concrete. Measurement of natural flow of Kauaikinana stream is available from 1919-1925 from the USGS (station #16012000). The ditch tunnel sluice gate only permits a portion of the water dumped into the stream to flow into the tunnel, unnaturally augmenting the flows in Kauaikinana downstream of the diversion.

Photos. a) Upstream view of stream before Kokee Ditch (CWRM, 07/2014); b) Pipe exiting tunnel transporting water from ditch into stream; c) Diversion structure across stream channel redirecting flow into tunnel (CWRM, 07/2014) d) Regulation gate on diversion structure (CWRM, 07/2014).

a)

b)

c)

d)

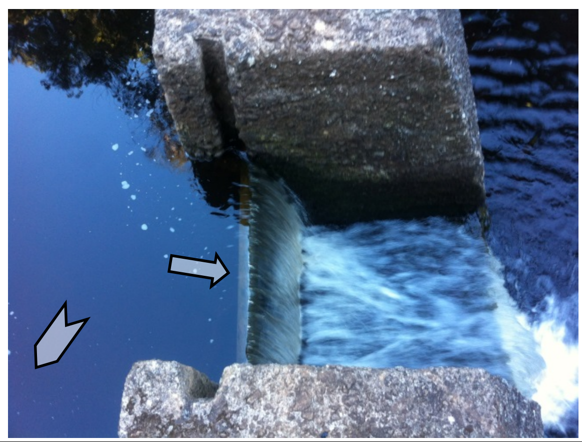


Table 13-3. Continued. Registered diversions in the Waimea hydrologic unit: Kokee System.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.622.2	KEKAHA SUGAR	4-1-4-001:013	unknown	Yes	Yes		

Water is diverted from Waiakoali, Kawaikoi, and Kauaikinana streams into Kokee Ditch which dumps water into Kokee Stream. A concrete diversion across the whole channel has a place for a sluice gate (nothing currently in place). Diversion of the combined flows is regulated by the sluice gate in front of the tunnel and the height of the gate regulating flow downstream. Currently (07/2015) downstream flow in the Kokee Stream is being augmented by excess flow from the ditch not taken by the tunnel.

Photos. a) Kokee Ditch dumping water into Kokee Stream (CWRM, 07/2015); b) Downstream view from diversion structure (CWRM, 07/2015); c) Diversion structure across channel (CWRM, 07/2015); d) Sluice gate regulating flow into the tunnel.

a)

b)

c)

d)

Table 13-3. Continued. Registered diversions in the Waimea hydrologic unit: Kekaha System.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
609.2	KEKAHA SUGAR	4-15-001-017		YES	YES		

Water is diverted from Koaie into the Waiahulu stream and then into Kekaha Ditch (tunnel). A concrete diversion across the whole channel has a place for a sluice gate (only two boards currently in place).

Photos. a) Koaie Stream flowing into a tunnel (CWRM, 12/2015); b) Upstream view from diversion structure (CWRM, 12/2015); c) Diversion structure across channel (CWRM, 12/2015); d) Upstream view looking at gate regulating flow into the tunnel; d) oopu in pool near diversion.

a)

b)

c)

d)

e)

Table 13-3. Continued. Registered diversions in the Waimea hydrologic unit: Kekaha System.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
605.2	KEKAHA SUGAR	4-1-5-001		YES	YES		

Waiahulu Stream receives water from the upstream catchment that includes the Kokee Ditch system. Regulated stream flows are available from USGS station #16016000 from 1925-1968.

Photos. a) Waihulu diversion structure (CWRM 12/2015); b) Waihulu Stream with tunnel bringing water from Koaie Stream diversion (CWRM 12/2015); c) Kekaha Ditch intake off Waihulu Stream (CWRM 12/2015); d) upstream view of Waihulu Stream from Waihulu Diversion (CWRM 12/2015); e) Downstream view past Waihulu control point with boards up (CWRM 12/2015)

a)

b)

c)

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)

d)

e)

Table 13-3. Continued. Other registered diversions in the Waimea hydrologic unit: Kokee System.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.619.2	KEKAHA SUGAR	4-1-4-001:013	unknown	Yes	Yes		
Kumuwela #1 diversion from unnamed ephemeral stream to Kokee ditch							
REG.614.2	KEKAHA SUGAR	4-1-4-001:013	unknown	Yes	Yes		
Kumuwela #2 diversion from unnamed ephemeral stream to Kokee ditch							
REG.603.2	KEKAHA SUGAR	4-1-4-001:013	unknown	Yes	Yes		
Kumuwela #3 diversion from unnamed ephemeral stream to Kokee ditch							
REG.621.2	KEKAHA SUGAR	4-1-4-001:013	unknown	Yes	Yes		
Kumuwela #4 diversion from unnamed ephemeral stream to Kokee ditch							
REG.615.2	KEKAHA SUGAR	4-1-4-001:013	unknown	Yes	Yes		
Kumuwela #5 diversion from unnamed ephemeral stream to Kokee ditch							

Kekaha Agriculture Association (KAA) under an agreement with the Agriculture Development Coorporation (ADC) operates the two ditch systems (Kokee and Kekaha) running south and west from Waimea. The KAA supplies <1 mgd to the Menehune Ditch from the Kekaha Ditch for private use, including taro loi and diversified agriculture. Gay & Robinson operate the Olokeli Ditch that transports water south and east from Waimea. For the years 2010 to 2014, the average water demand for users on the Kekaha irrigation system was 4.08 mgd, while the average water demand for the Kokee irrigation system was 0.58 mgd (Kekaha Agriculture Association, 2015). Information on these diversions is listed in Table 13-2, and their locations are depicted in Figure 13-1.

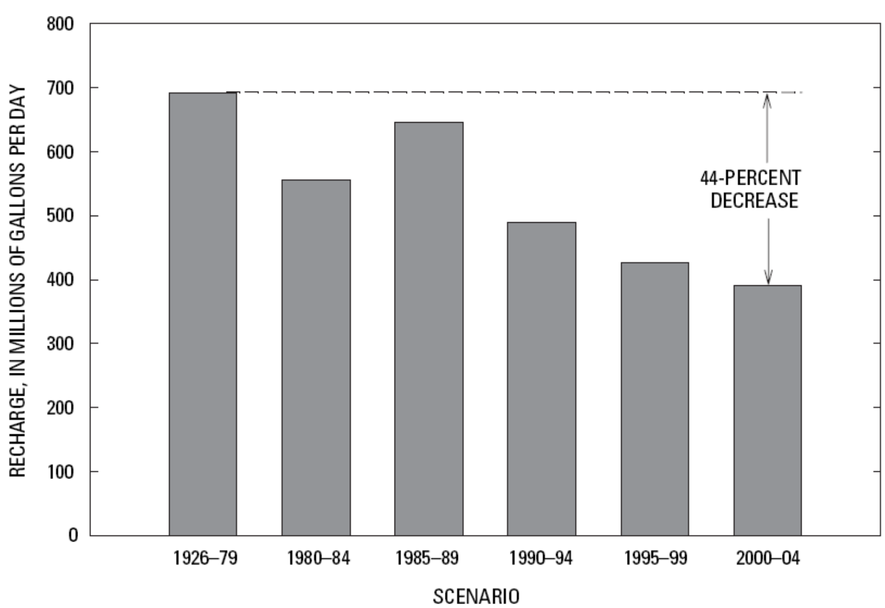
Gay & Robinson have not provided any photos of their diversions and refuse to permit CWRM staff to verify them. Their reported monthly water use from their diversions is currently 35.79 mgd from December 2015 to April 2016.

Modifications of Ditch Systems and Groundwater 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. The effects of irrigation water on ground water recharge can be analyzed using the water budget equation[1]. 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 13-2). 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.

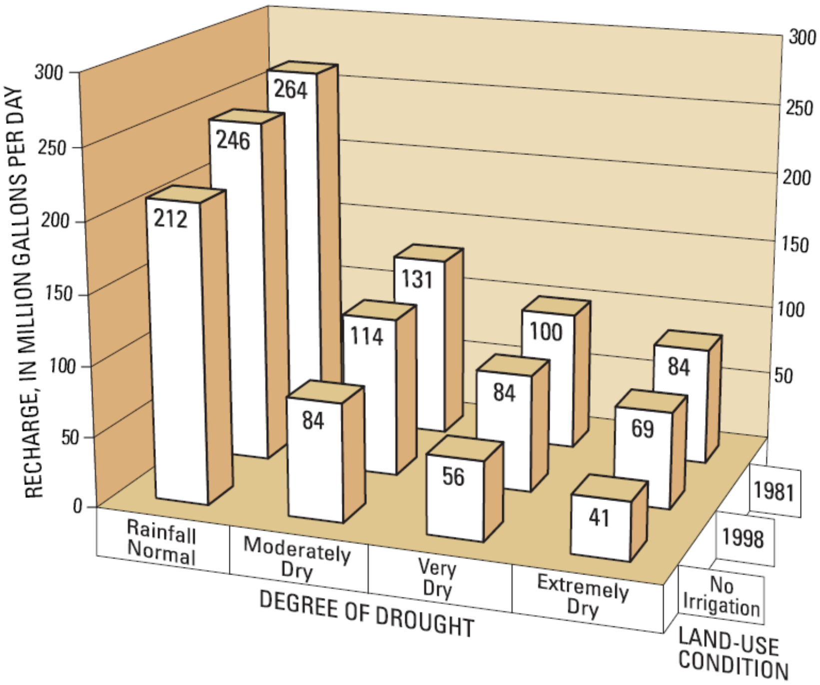
Droughts, or periods of lower than average rainfall, have been shown to drastically decrease ground water recharge (Figure 13-2). The period of drought that occurred in 1998-2002, during which rainfall was at least 30 percent lower than the average annual rainfall was estimated to reduce recharge by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

Figure 13-2. Estimated recharge for six historical periods between 1926 and 2004, central and west Maui, Hawaii. (Source: Engott and Vana, 2007)



[1] 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.

Figure 13-3. 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)



Utilization of Important Agricultural Lands

The Agricultural Lands of Importance to the State of Hawaii (ALISH) were completed by the State Department of Agriculture (HDOA) in 1977, with the assistance of the Soil Conservation Service (SCS), U.S. Department of Agriculture, and the College of Tropical Agriculture, University of Hawaii. Three classes of agriculturally important lands were established for Hawaii in conjunction with the SCS in an effort to inventory prime agricultural lands nationwide. Hawaii's effort resulted in the classification system of lands as: 1) Prime agricultural land; 2) Unique agricultural land; and 3) Other important agricultural land. Each classification was based on specific criteria such as soil characteristics, slope, flood frequency, and water supply. ALISH was intended to serve as a long-term planning guidance for land use decisions related to important agricultural lands. HDOA is currently in the process of developing agricultural incentives based on classifications of Important Agricultural Lands. The Waimea hydrologic unit is comprised of nearly 7.5 percent of agricultural land with 3.0 percent designated as ALISH (Table 13-4, Figure 13-4).

Table 13-4. Agricultural Lands of Importance to the State of Hawaii and area distributions in the Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015g)

Density	Area (mi^2)	Percent of Unit
Prime agricultural land	0.743	0.87
Unique agricultural land	0.119	0.14
Other lands	1.624	1.89

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

Table 13-5. Agricultural land uses and area distributions in the Waimea hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015h)

Density	Area (mi^2)	Percent of Unit
Grazing	0.415	0.48
Vegetables/melon	0.036	0.04
Forage and Grain	0.095	0.11
Sugarcane	0.224	0.26
Wetland	0.042	0.05

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 13-4 and 13-5).

When Kekaha Sugar Co. declared bankruptcy in 1999, the State of Hawaii took over their land holdings (former sugarcane land) in southwest Kauai. The Mana Plain region (west-northwest of Waimea town) was given to HDOA to manage. In 2008, the Agriculture Development Corporation (ADC) agreed to operate and maintain the infrastructure of the Kekaha Agriculture Association, a cooperative of lesees that depend on the infrasture to maintain their agriculture operations. Kekaha Sugar Co. invested heavily in the infrastructure that supported agriculture on these lands (e.g., diversions, ditches, flumes siphons, hydropower, electrical transmission lines, and reservoirs) and the HDOA valued the agricultural products of Kekaha at $35-50 million. The Waimea uplands parcel (23.532 square miles) was given to DHHL and is one of their largest land holdings. Lands in both regions fall under the important agricultural lands designation and thus it is the desire of both agencies to continue to develop agriculture on them. Of the 12,592 acre portion of state-owned land located in Kekaha (27,720 acres total) assigned to the Agribusiness Development Corporation, most are designated as prime agricultural land due to the excellent growing conditions, inexpensive access to water and available hydropower. Decreasing the amount of water diverted at the ditches affects the amount of water available for the irrigation of crops on these important agricultural lands.

The presence of the irrigation systems adds considerable complexity to the Commission's role in weighing instream and noninstream uses. While this is largely due to the transfer of water from one hydrologic unit to another, the importance of the system to agriculture plays a pivotal role in the consideration of economic impacts. In total, the ditch systems consist of many 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 draining the Alakai Marsh and tributaries to the Waimea River primarily owned by the State of Hawaii (Wilcox, 1996). The total acerage under cultivation fluctuates every year, but estimates are provided in Table 13-6.

Table 13-6. Acerage and crop by year on the Mana Plain for the main lesees of the Kekaha Agriculture Assocation. (Source: Kekaha Agriculture Association, 2015) *average provided applicable to all years

year	Pioneer Hi-Bred (seed corn)	Syngenta (seed corn)	Syngenta (soy)	BASF* (seed corn, canola)	BASF* (rice)	BASF* (cover crop)
2010	405.10	514.95	1.84	106	6	300
2011	246.37	562.82	18.62	106	6	300
2012	343.77	605.15	21.35	106	6	300
2013		543.81	27.89	106	6	300
2014		420.28	24.81	106	6	300

Figure 13-4. Agricultural land use for the Waimea hydrologic unit based on the Agricultural Lands of Importance for the State of Hawaii (ALISH) classification systems. (Source: State of Hawaii, Office of Planning, 2015g)

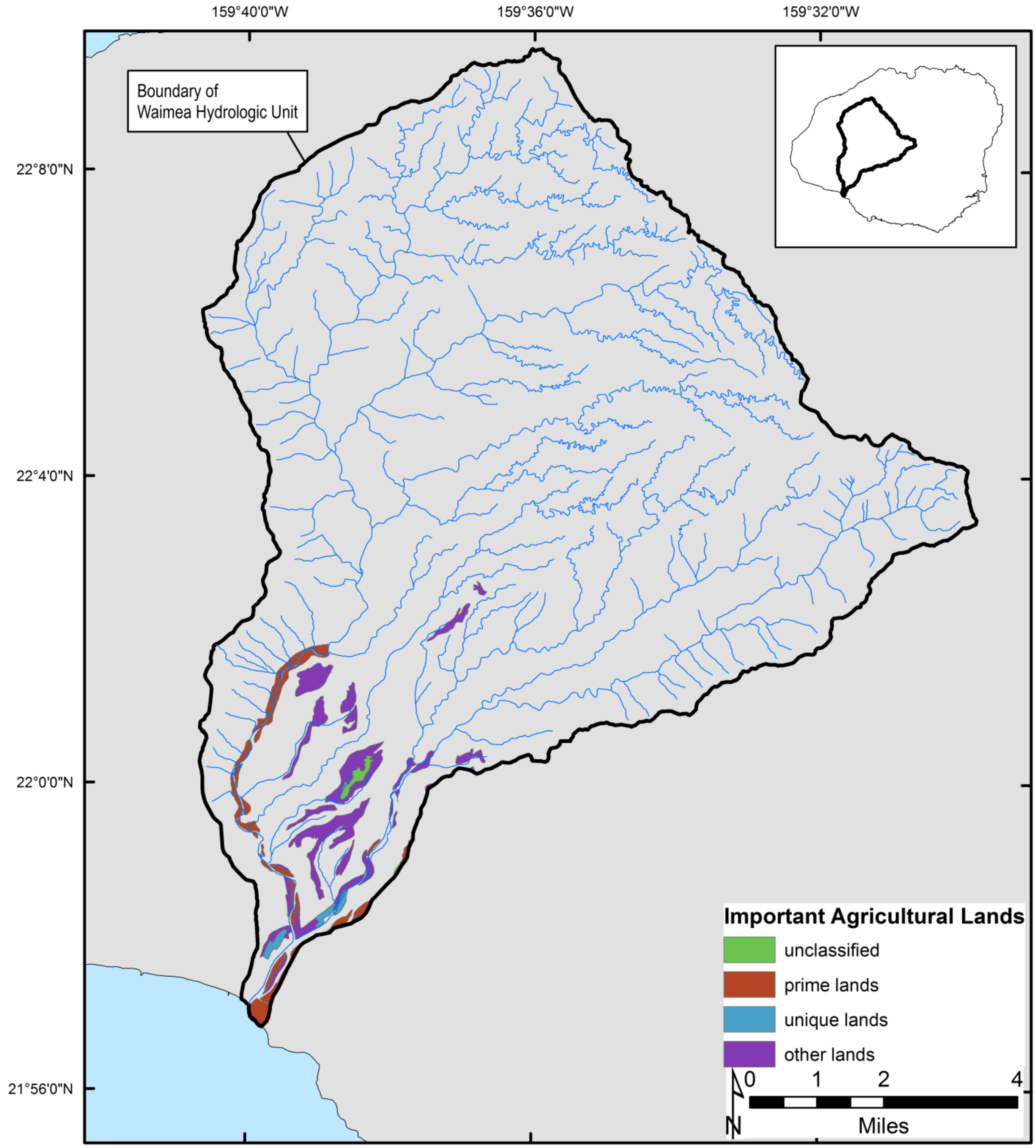
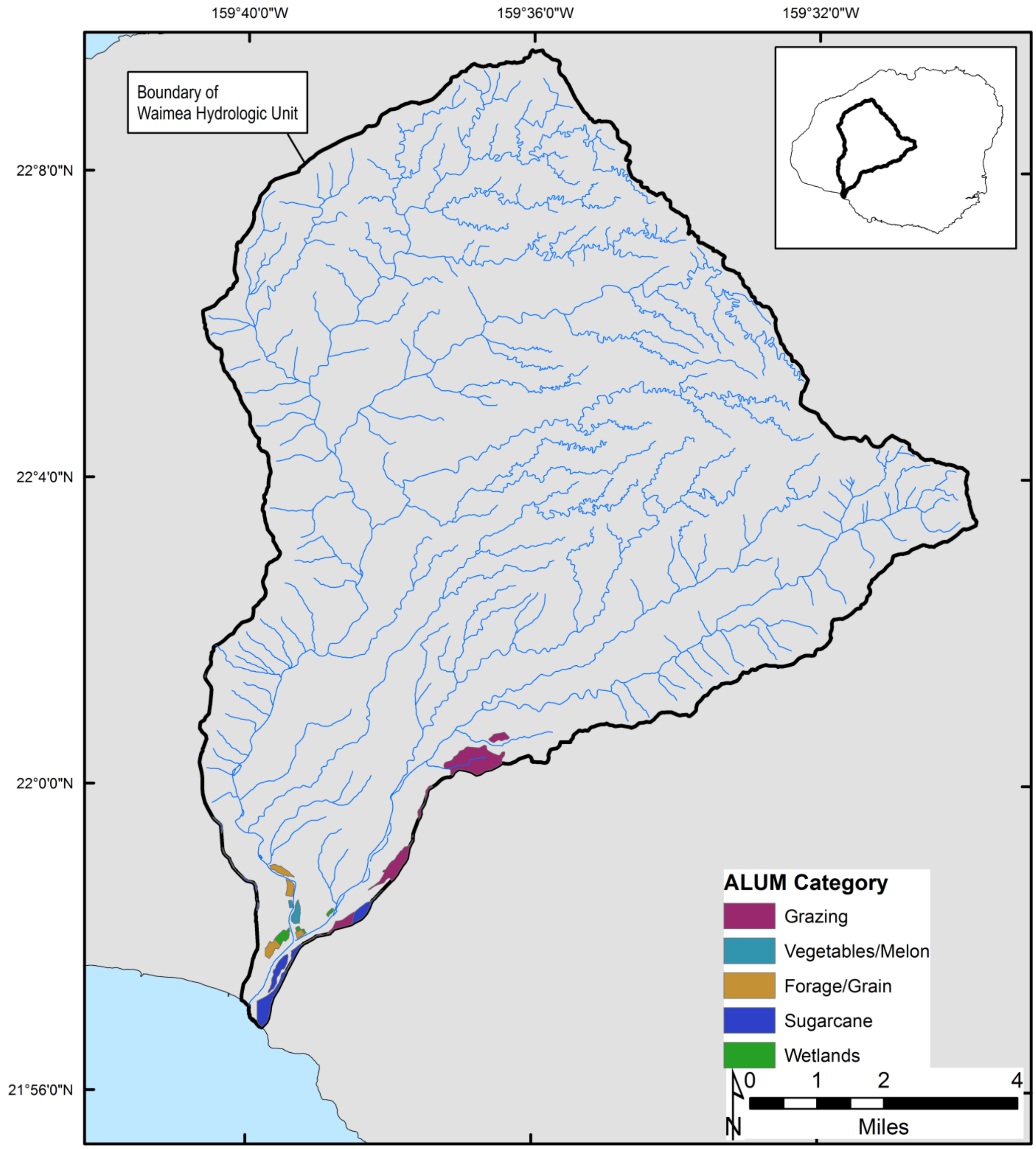


Figure 13-5. Designated agricultural land use for the Waimea hydrologic unit based on the Agricultural Land Use Map (ALUM). (Source: State of Hawaii, Office of Planning, 2015h)



Diverted Water and Non-Instream Power Production

Energy is generated from two hydropower plants on the Kekaha ditch (Figure 13-9). This energy was necessary to make agriculture viable by powering drainage pumps needed to keep the water table below the rooting depth of the Mana Plain, pressurize the Mana Plain irrigation system, prevent the Pacific Missle Range Facility and the town of Kekaha from flooding, and power pumps that opened up previously inaccessible fields in the Waimea mauka lands to sugarcane cultivation. Mean daily (± standard deviation) power generated by the Waimea (mauka) and Waiawa powerplants from 2010 to 2015 was 432 (±161) kw and 328 (±106) kw, respectively (Kekaha Agriculture Association, 2015). Mean (± standard deviation) daily water used to generate this energy was 24.54 (±5.24) mgd and 19.0 (±3.05) mgd, respectively. Daily energy generated on a monthly timescale from 2010 to 2015 is provided in Figure13-6. Box-and-whisper plots of daily energy and water usage of the two hydropower plants are provided in Figure 13-7. Energy from these powerplants is being used by the Kawaiele, Kekaha, and Nohili pump stations which keep the brackish water table below rooting depth and prevents flooding in the region (Figure 13-8). Energy is also used to power the pumps for irrigation water distribution. Excess energy generated by hydropower is sold back to Kauai Island Utility Cooperative (KIUC) as depected in Figure 13-9. Mean (± standard deviation) monthly energy sold to KIUC is 65.0% (±16.9%).

Figure 13-6. Mean daily energy generated by month from the Waimea (Mauka) and Waiawa hydropower plants on the Kekaha Ditch. (Source: Kekaha Agriculture Association, 2015)

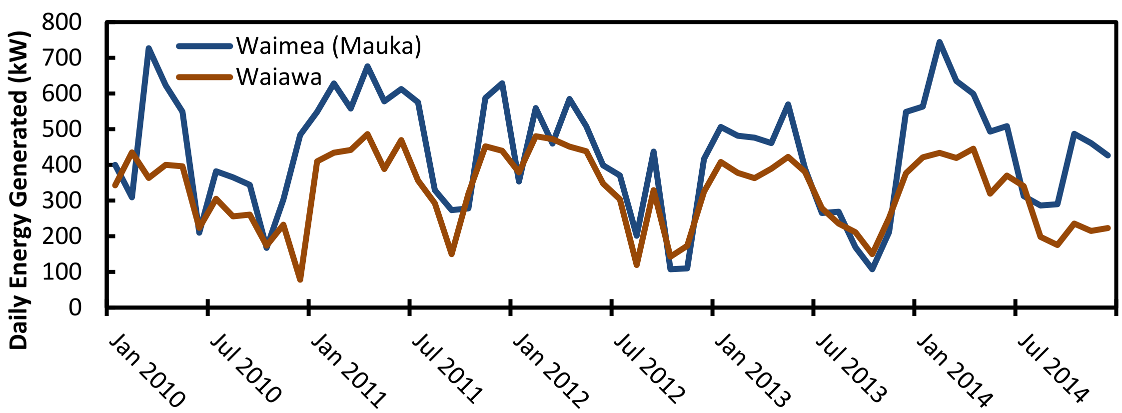


Figure 13-7. Box-and-whisker plots of daily energy generation (left) and daily water usage (right) the Waimea (Mauka) and Waiawa hydropower plants on the Kekaha Ditch. (Source: Kekaha Agriculture Association, 2015)

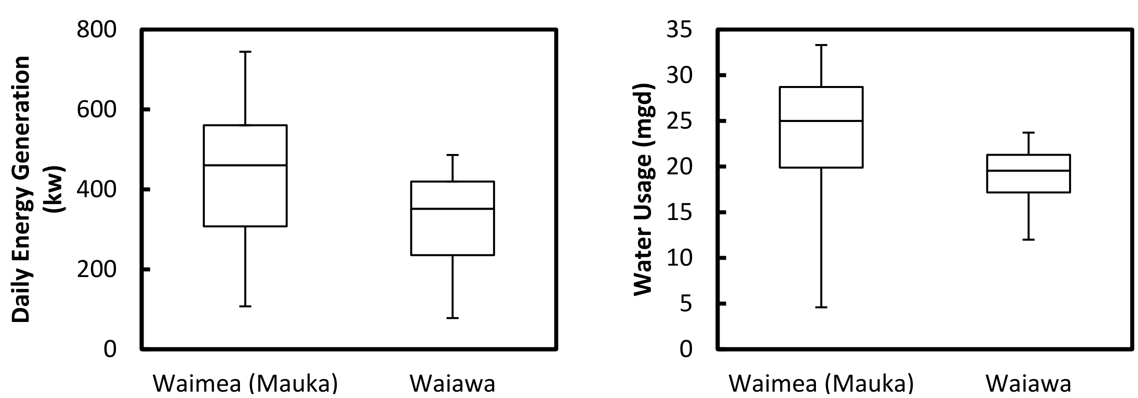


Figure 13-8. Area of land between mean sea level (m.s.l.) and 7 feet above m.s.l. in elevation in the Mana Plain, Kauai. (Source: NOAA, Digital Coast Data Request, 2015)

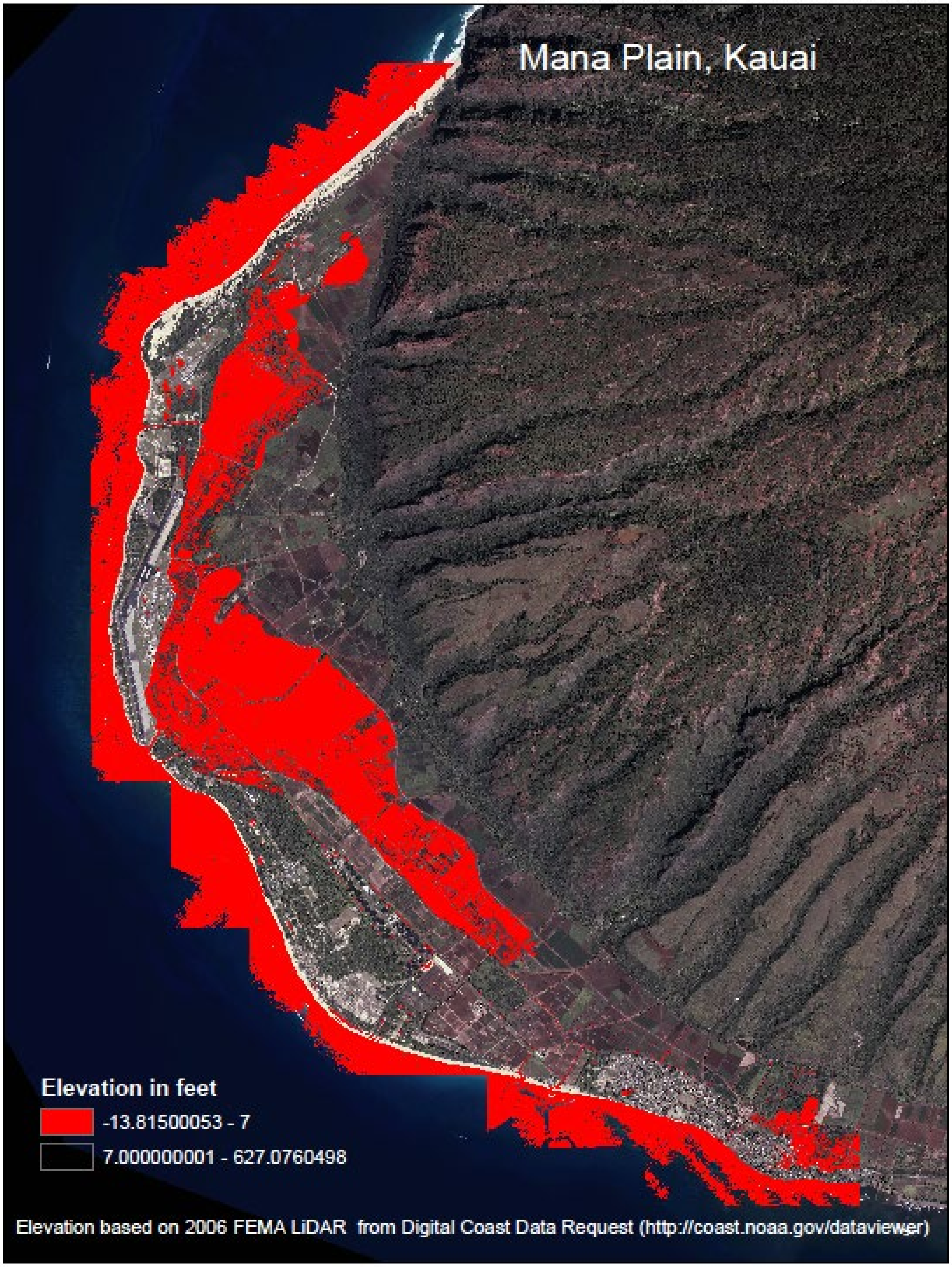
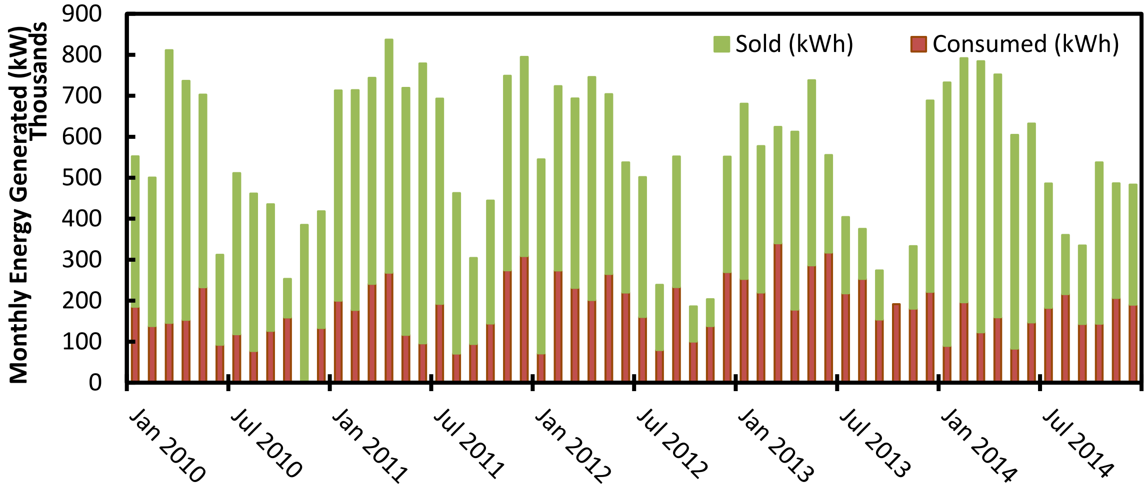


Figure 13-9. Bar chart of total monthly energy produced and consumed by Kekaha Agriculture Association and their lessees and the total energy sold to Kauai Island Utility Cooperative. (Source: Kekaha Agriculture Association, 2015)



Irrigation Needs of the Kekaha Service Area

The Kekaha Agriculture Association maintains the Kokee and Kekaha ditch systems to supply current lesees with irrigation water, non-lesee farmers with irrigation water, and water needed to support other operations in the Waimea and Kekaha region. While individual water users are not metered, estimates of daily water demands for the largest water users are provided in Figure 13-10. The Kokee ditch system has a design capacity of 55 mgd up to the Puu Lua Reservior and 26 mgd past the reservoir. The Kekaha ditch system has a design capacity of 50 mgd.

The Commission funded the development of a GIS-based software program the utilizes the state of Irrigation Water Requirement Estimation Decision Support System, IWREDSS (State of Hawaii, Commission on Water Resource Management, 2015b) was 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[1], 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

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

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.

Figure 13-10. Map of the Kekaha Agriculture Assocation Service Area along with the Department of Hawaiian Home Lands (DHHL) Waimea parcel. (Source: State of Hawaii, Department of Hawaiian Homelands, 2011; State of Hawaii Office of Planning, 2004c; State of Hawaii, Commission on Water Resource Management, 2015f)

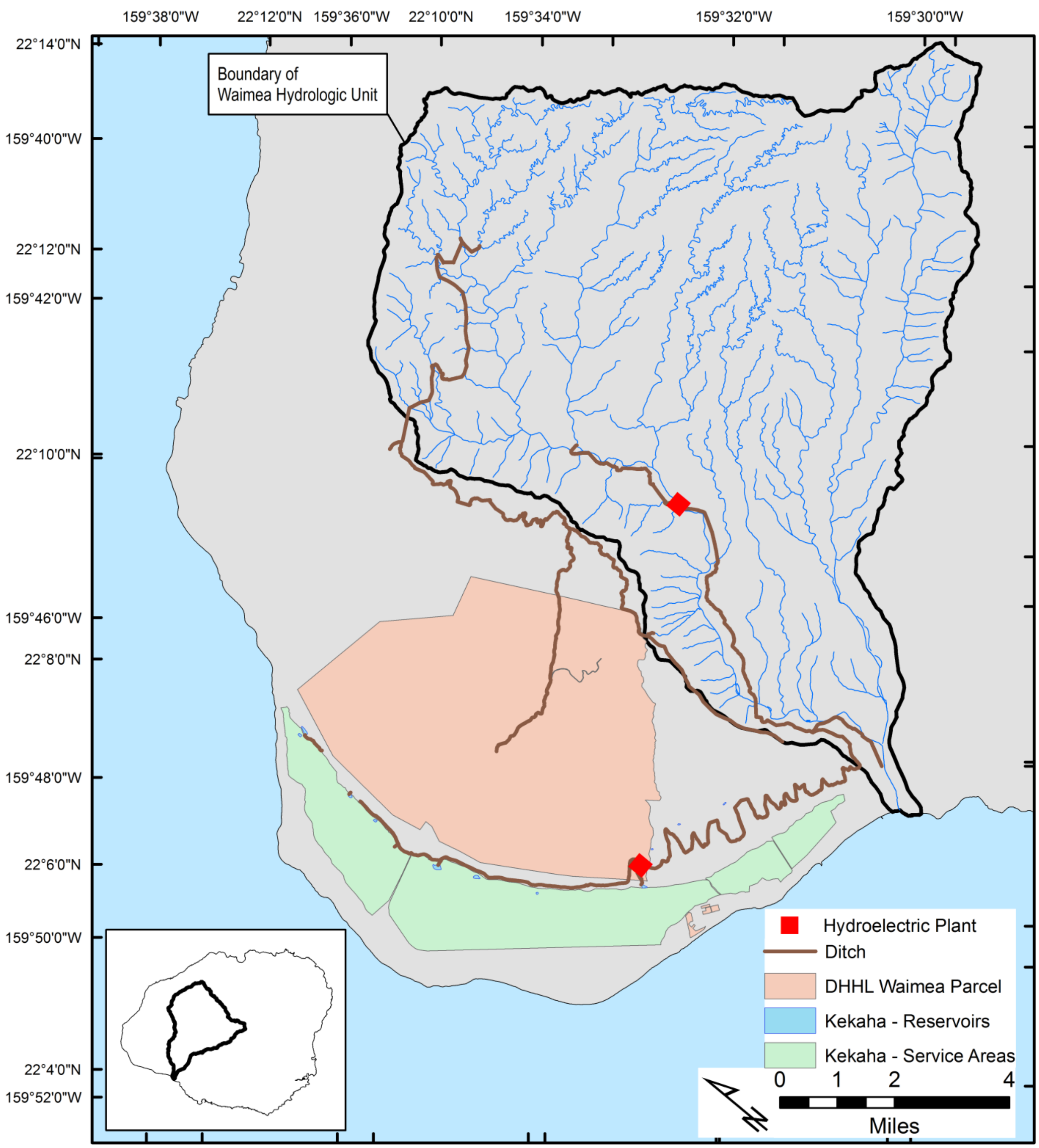
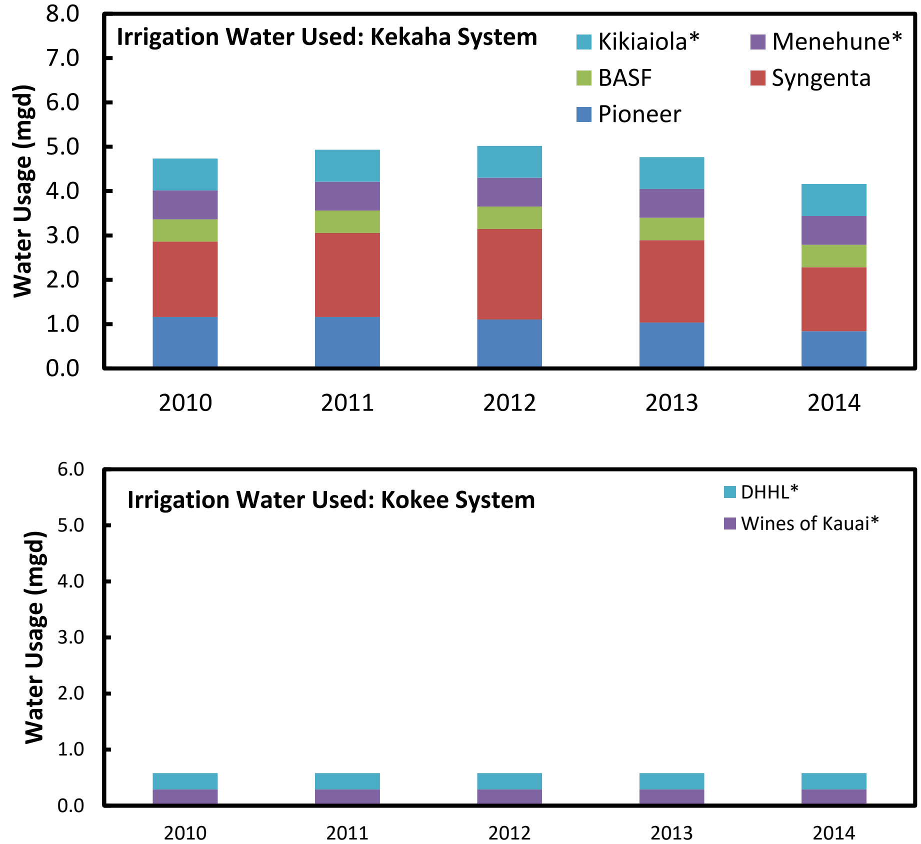


Figure 13-11. Mean daily irrigation water usage for primary users of the Kekaha (top) and Kokee (bottom) irrigation systems from 2010 to 2014 (Source: Kekaha Agriculture Association, 2015). *values estimated



Understanding that water demand is highly site, weather, application, and crop dependent, IWREDSS can still provide a useful approximation of water needs. According to the simulation results, the IRR for the most common crop currently grown on the Mana plain (seed corn) is approximately 3900 gallons per acre per day (Table 13-7). As expected, IRR is lowest when a cover crop is used between crops. The model calculates IRR based on long-term rainfall records available at the weather stations located nearest to the 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 relative drought year frequencies could be extrapolated to represent the highest demand scenarios.

Table 13-7. Mean drip rrigation demand estimates for seed corn in the Kekaha Ditch service area based on IWREDSS scenarios modeled for two soil management techniques and two cover crop options given a 10 ft depth to water table. Irrigation Requirement (IRR) value in gallons per acre per day for the 1 in 5 year drought scenario is provided.

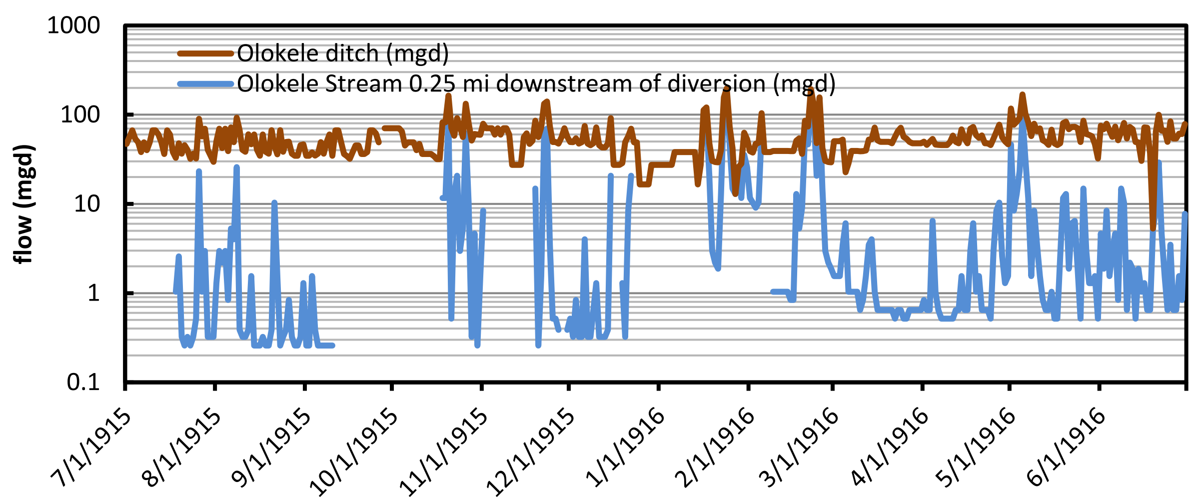
				Mean annual irrigation demand (in/acre) for drought frequency		
Scenario	soil management	straight row (SR) and/or cover residual (CR)	IRR (gallons per acre per day)	1 in 5 (20%)	1 in 10 (10%)	1 in 20 (5%)
1	Poor	SR+CR	3912	52.59	54.10	55.25
2	Poor	SR	3924	51.75	54.24	55.36
3	Good	SR+CR	3874	52.08	53.67	54.86
4	Good	SR	3898	52.40	53.94	55.10

The KAA lesees have provided estimated water demand for their lands based on crop acerage grown from crop cycles 2009 to 2014. Pioneer Hi-Bred estimated water use from 2010 to 2014 was an average of 3,999.04 gallons per acre per day while Syngenta estimated water use was 3287.67 gallons per acre per day for corn and 2465.75 gallons per acre per day for soy (Kekaha Agriculture Association, 2015). BASF estimated their seed corn production used 2785.4 gallons per acre per day, while their rice used 21,877 gallons per acre per day and their other leased lands (uncleared acerage, native grasses, cover crop) used 260.4 gallons per acre per day (Kekaha Agriculture Association, 2015).

Olokele Ditch System

Gay and Robinson operate a diversion and ditch system that removes water from the Olokele tributary of the Waimea River, originally for sugar cane production and domestic use but now for hydropower, pasture and some agriculture use. The amount of water used for hydropower and the amount of hydropower generated has not been reported. The diversion on Olokele Stream was The USGS gaged ditch flow for many years on the Olokele Ditch at tunnel No. 12 (station 16036000) which is 2 miles from the intake and provides reliable information regarding total water diverted. There was also a gaging station below the diversion for one year (station 16034000) and provides some idea of how much water was left in the stream below the diversion. For that year, approximately 90% of total stream flow was diverted, assuming the intervening reach is not gaining due to groundwater. The mean annual flow in the ditch from 1910 to 1917 ranged from 40.65 mgd to 50.49 mgd. In 2009, Gay and Robinson declared that they formalized an agreement to lease approximately 3,500 acres of land to Agrigenetics, Inc. utilizing approximately 17.375 mgd from the Koula and/or Olokele Ditch systems, with the remainder for hydropower and agricultural uses. Current water use reporting states that Gay and Robinson are diverting approximately 36 mgd from the Olokele Stream. At this time, it is unclear how much water is being used for agriculture.

Figure 13-12. Mean daily flow in the Olokele Ditch at Tunnel No. 12 (USGS station 16036000) and in Olokele Stream 0.25 mi downstream of diversion (USGS station 16034000) from July 1915 to June 1916 (Source: USGS).



Proposed KIUC West Kauai Energy Project

Kauai Island Utility Cooperative, in cooperation with DHHL, is in the planning phases to develop renewable energy projects that are compatible with agriculture (State of Hawaii-DHHL, 2011). Such a project would have direct benefits for DHHL and the larger community in terms of energy security, rental income, and environmental benefits. One such project, pumped storage, is a method of storing energy made available during peak production (daytime for solar) and shifting it to peak demand (evening). Pumped storage necessitates two reservoirs, using energy to pump water uphill and generating energy as water is released downhill. KIUC has identified two sites in the region that could potentially be developed for pumped storage: Puu Lua Reservoir-Haeleele Reservoir and Puu Opae Reservoir-Mana Reservoir. The Puu Lua Reservoir is on DLNR-owned land while the Puu Opae Reservoir is on DHHL-owned land. The development of pumped storage would have ancilliary benefits to the region by rehabilitating reservoirs and providing long-term maintenance, improving and maintaining access roads in the region, and potentially moderninzing the Kokee ditch system. In 2016, both options were in the 20% engineering phase, with final decisions regarding which system to fund likely in early 2016.

As of 2021, KIUC has moved forward with the Puu Opae hydropower project, which includes the rehabilitation of three reservoirs (Puu Lua, Puu Opae, and Mana reservoirs), two penstocks (one between the Puu Moi divide and a powerhouse at the Puu Opae Reservoir; one between the Puu Opae Reservoir and a powerhouse/pumphouse at the Mana Reservoir), and associated roads and transmission lines (Figure 13-13).

Following the 2013 petition to amend instream flow standards by Poai Wai Ola/West Kauai Watershed Alliance, Commission staff and the Commission's consultant conducted an assessment of best available information to assess the hydrology, instream values, and non-instream uses of water from the Waimea Watershed. Following two years of intensive study, the parties agreed to work towards mediating a resolution to support the concerns of the community and protect instream values, while providing KAA, DHHL, and KIUC the potential to develop agriculture and energy for the island of Kauai. In support of the mediation effort, staff used hydrological data from 1919 to 1925 to model the availability of water for non-instream uses in the Kokee Irrigation System.

Modeled water for non-instream uses in the Kokee Irrigation System

Mean daily flow from Kauaikinana (USGS 16012000), Kawaikoi (USGS 16010000), and Waiakoali (USGS 16011000) for dates between 07/01/1919 to 12/31/1925 were utilized with gap-filled data based on modeled flows for overlapping periods of record. USGS Station 16010000 on Kawaikoi Stream is the only continuous long-term (1919-present) record among these streams. While Cheng (2020) identified a significant ($p<0.05$) negative trend in mean and median (Q_{50}) flow for USGS 16010000 from 1961 to 2019, no significant negative trend was identified for Q_{70} or Q_{90} for this period of record. Compared to the 1919 to 1925 period, low-flow duration values for the 1961 to 2019 period were only -6.5%, -4.1%, -1.7%, -2.4%, and -9.1% for the Q_{60}, Q_{70}, Q_{80}, Q_{90}, and Q_{95} magnitude flows, respectively.

In the process of developing interim instream flow standards, the Waimea Watershed Agreement established that during low-flow periods, two-thirds of each stream's flow would remain in the respective stream. Streamflow greater than the low-flow set point would be available for non-instream usage with an instream flow standard of 0.6 mgd, 4.0 mgd, and 0.8 mgd for Kauaikinana, Kawaikoi, and Waiakoali, respectively. In the final mediated agreement, the set points were 1.2 mgd, 6.4 mgd, and 1.3 mgd for Kauaikinana, Kawaikoi, and Waiakoali, respectively.

Commission staff simulated the results of the proposed mediated solution without assuming any contribution from Kokee Stream. No contribution from Kokee stream could be simulated because streamflow is relatively small, no continuous record gaging data are available for this stream, and only flows greater than 1.2 mgd would be available to be diverted. Simulated daily results for the 6.5 years are provided in Figure 13-14 with flow statistics available in Table 13-8. Statistics do not reflect the maximum capacity of individual diversions, rather the maximum capacity of the Kokee Ditch, thus the flow remaining in the stream in excess of the diversion capacity is not reflected in the downstream flow statistics simulated for the IIFS.

Figure 13-13. Diagram of KIUC's West Kauai Energy Project (Source: KIUC.coop/wkep, [accessed 2021])

Figure 13-14. Mean daily simulated diverted flow into Kokee Ditch after contributions from Waiakoali Stream, Kawaikoi Stream, and Kauaikinana Stream (grey dots), 30-day moving average (black line), and the 11 mgd reference (red line) from 07/01/1919 to 12/31/1925.

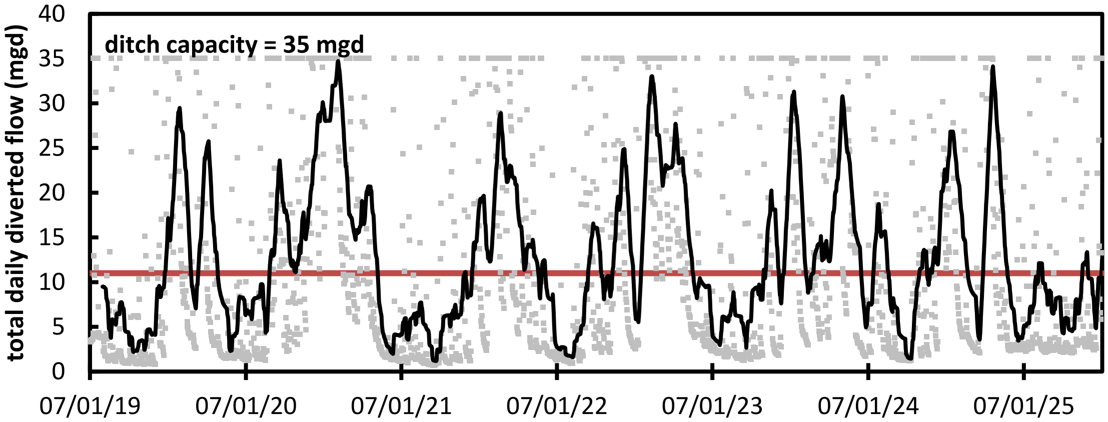


Table 13-8. Flow duration statistics (in millions of gallons per day, mgd) and mean daily flow (MDF) for Kokee Ditch, Waiakoali Stream, Kawaikoi Stream, and Kauaikinana Stream, and the stream flow below each diversion given the interim instream flow standards agreed upon by the Waimea Watershed Agreement based on the simulation of available water from 07/01/1919 to 12/31/1925.
[note: statistics for streamflow below diversion do not reflect the flow remaining in the stream in excess of the maximum diversion capacity, which occurs during flows greater than Q50 and cannot be simulated]

	Waiakoali		Kawaikoi		Kauaikinana		Kokee Ditch
Percentile	**at USGS 16011000**	**Below diversion**	**at USGS 16010000**	**Below diversion**	**at USGS 16012000**	**Below diversion**	**at USGS 16014000**
Q_{50}	2.13	0.80	8.40	4.00	1.29	0.60	6.80
Q_{60}	1.87	0.80	6.40	4.00	1.03	0.60	4.14
Q_{70}	1.49	0.80	4.98	3.32	0.77	0.51	2.91
Q_{80}	1.23	0.80	3.81	2.54	0.60	0.40	2.23
Q_{90}	0.90	0.60	2.78	1.85	0.50	0.33	1.54
Q_{95}	0.71	0.47	2.33	1.55	0.30	0.20	1.20
MDF	3.34		24.29		5.40		12.73

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14.0 Appendix

Appendix A. Parham et al. (2008). Waimea River, Kauaʻi. In: Atlas of Hawaiian Watersheds & Their Aquatic Resources. State of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources. Watershed Code: 24004. pp. 485-498.

Appendix B. Investigation of Kōkeʻe and Kekaha Ditch Irrigation Systems, Waimea, Kauaʻi, Hawaiʻi. (2016). State of Hawaiʻi Commission on Water Resource Management. Prepared by Element Environmental, LLC.

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Appendix D. Strauch, A.M. (2016) Impacts of Wamea Trial Flow Release on the instream hydrology and freshwater habitat. State of Hawaii, Commission on Water Resource Management, Honolulu, HI. 11 p.