Instream Flow Standard Assessment Report

Island of Kauai
Hydrologic Unit 2018
Waioli

January 2021 **DRAFT PR-2021-01**

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

COVER
Satellite image of Waioli hydrologic unit with the Waioli Stream flowing into the Pacific Ocean, northern 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

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
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
KIUC	Kauai Island Utility Cooperative
LCA	Land Commission Award
LUC	Land Use Commission (State of Hawaii)
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. Introduction

General Overview

The hydrologic unit of Waioli (5.422 square miles) is located on the northern flank of Waialeale Mountain in the moku of Halelea, which forms the northern part of the Hawaiian island of Kauai (Figure 1-3). The watershed is sandwiched between the smaller Waipa and larger Lumahai watersheds to the west and the Hanalei watershed to the east. The watershed of Waioli covers an area of 5.27 square miles with a maximum elevation of 4410 feet, a mean basin elevation of 1300 feet, and a mean basin slope of 58.2 percent (Figures 1-4 and 1-5). Seventy-three percent of the basin has a slope greater than 30 percent. The longest flow path in Waioli is 6.48 miles in length, traversing in a northernly direction from its headwaters to Hanalei Bay. Waioli Stream drains an amphitheater-shaped watershed in the headwaters, transitioning to a narrower, v-shaped watershed through the middle reaches, and then opens up again closer to the coast with a broad flood plain typical of older Hawaiian watersheds. The north coast of Kauai is primarily composed of the shield-building stages of the Waimea Volcanic Series produced during the formation of the original Olokele Caldera, with the rejuvenated lavas of the Koloa Volcanic Series appearing primarily east of Hanalei. The coastal plain and current shoreline are the result of higher sea levels between 1500 and 4000 years ago supporting reef development further inland. Baseflow in Waioli is supported by continuous groundwater discharge from thick layers of thinly-bedded basalts and associated breccia of the Napali formation in the Waimea Canyon Basalt, supporting mauka to makai flow 100 percent of the time. The basin has a mean annual precipitation of 148 inches. Waioli Stream flows into Hanalei Bay, the largest bay on the north shore. The shoreline is fronted by large segments of fringing reef and the stream flows across coarse-grained calcareous sandy beaches mixed with terrigenous sediments. Trade-wind driven orographic rainfall supports continual transport of nutrient-rich sediments from Waioli to the coastal plain. The Hanalei census designated place had a 2010 population of 450 people (U.S. Census Bureau Office of Planning, 2011). The watershed is dominated by alien vegetation in the lower elevations and native forest in the upper elevations. Throughout the lower reaches, taro is extensively cultivated, supported by the East Waioli Ditch that transports large quantities of water to the floodplain. The state highway provides the primary access through Waioli, with a secondary road continuing up the valley providing limited access to some areas of the hydrologic unit (Figure 1-6). The stream supports habitat for native aquatic biota, although there are non-native species as well. There is substantial recreational value in the lower reaches.

Current Instream Flow Standard

The current interim instream flow standard (IFS) for Waioli 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 Kaua‘i. The Interim Instream Flow Standard for all streams on Kaua‘i, 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 off stream 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 December 31, 1988. Streamflow was not measured on that date; therefore, the current interim IFS is not a quantifiable value.

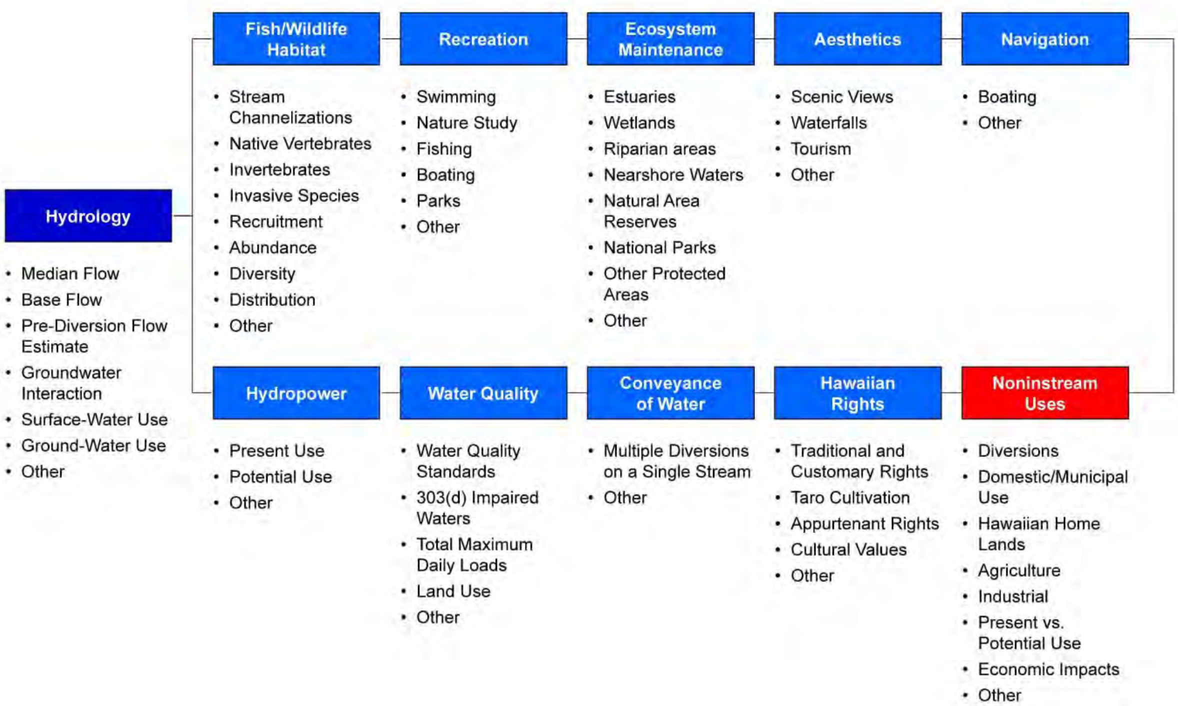
Instream Flow Standards

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

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

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

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

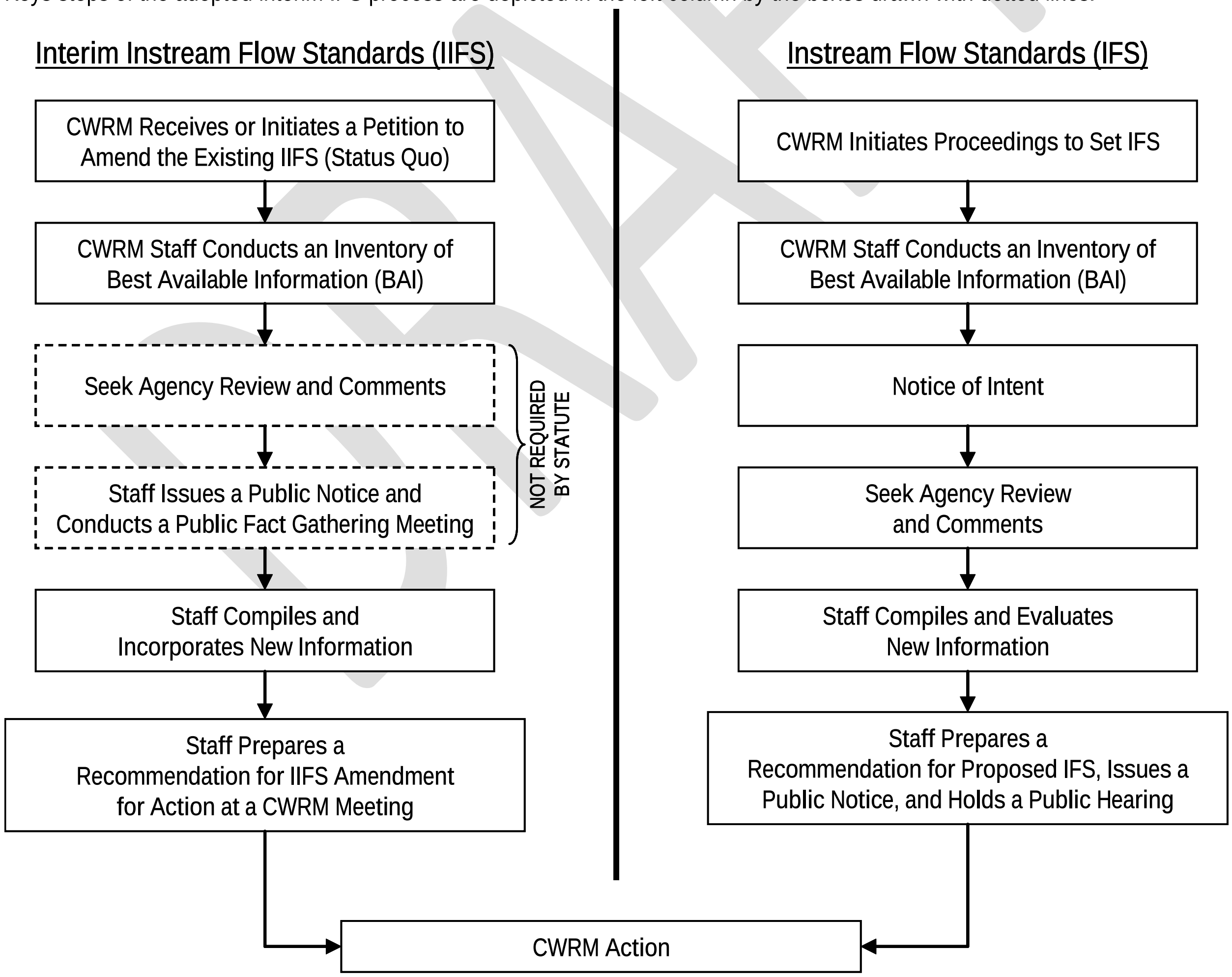


Interim Instream Flow Standard Process

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

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

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



Instream Flow Standard Assessment Report

The Instream Flow Standard Assessment Report (IFSAR) is a compilation of the hydrology, instream uses, and noninstream uses related to a specific stream and its respective surface water hydrologic unit. The report is organized in much the same way as the elements of IFS are depicted in Figure 1-1. The purpose of the IFSAR is to present the best available information for a given hydrologic unit. 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. Section 13.0 describes public trust uses of water not covered in other sections. Noninstream uses are summarized in Section 14.0. Maps are provided at the end of each section to help illustrate information presented within the section's text or tables. Finally, Section 15.0 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. World View 2 satellite imagery of the Waioli hydrologic unit and streams in northern Kauai, Hawaii. (Source: State of Hawaii, Planning Department, 2004; State of Hawaii, Commission on Water Resource Management, 2015c; State of Hawaii, Office of Planning - Division of Aquatic Resources, 2005)

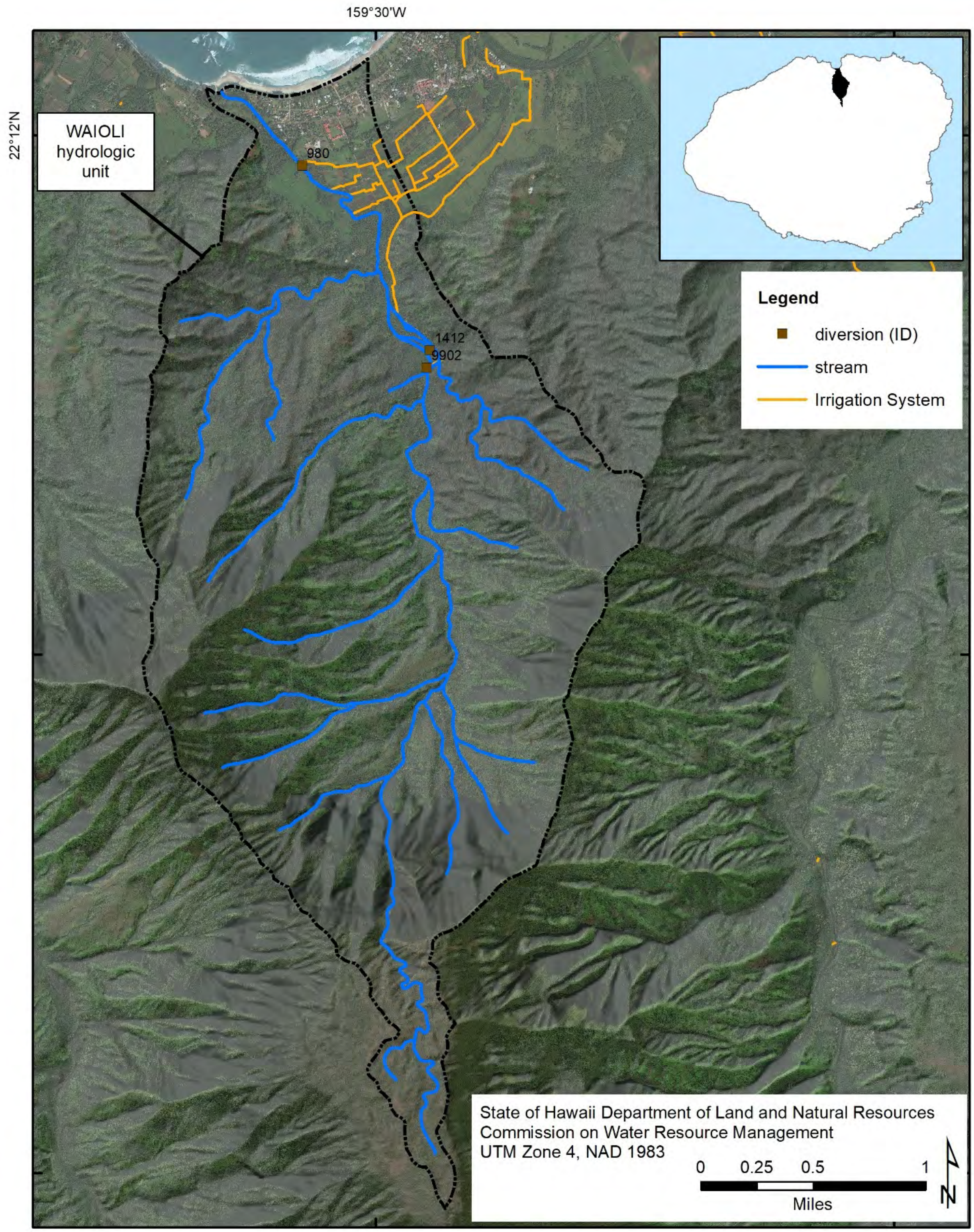


Figure 1-4. Elevation range of the Waioli hydrologic unit. (Source: State of Hawaii, Office of Planning, 2004e; U.S. Geological Survey, 2001)

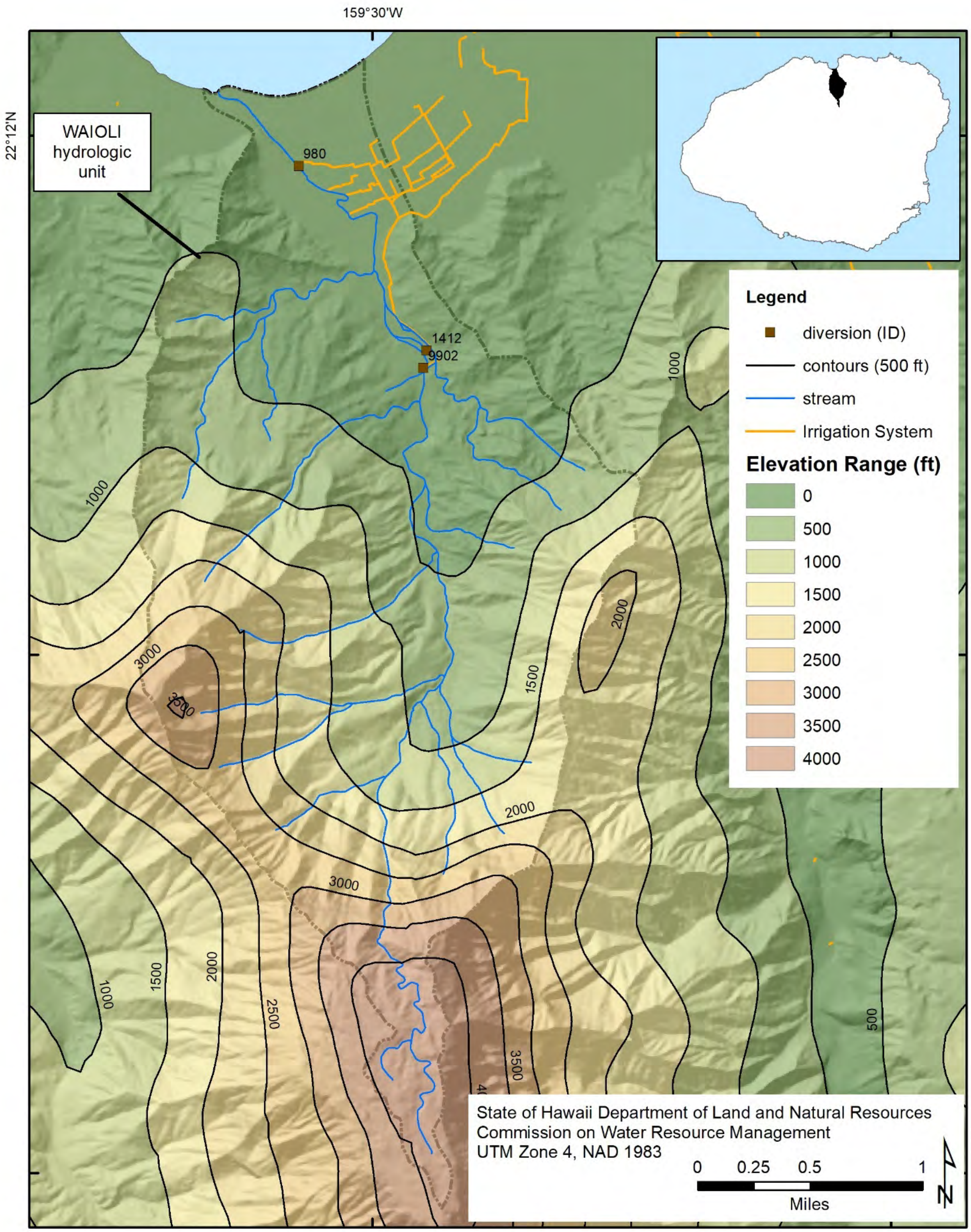


Figure 1-5. USGS topographic map of Waioli hydrologic unit. (Source: U.S. Geological Survey, 1996)

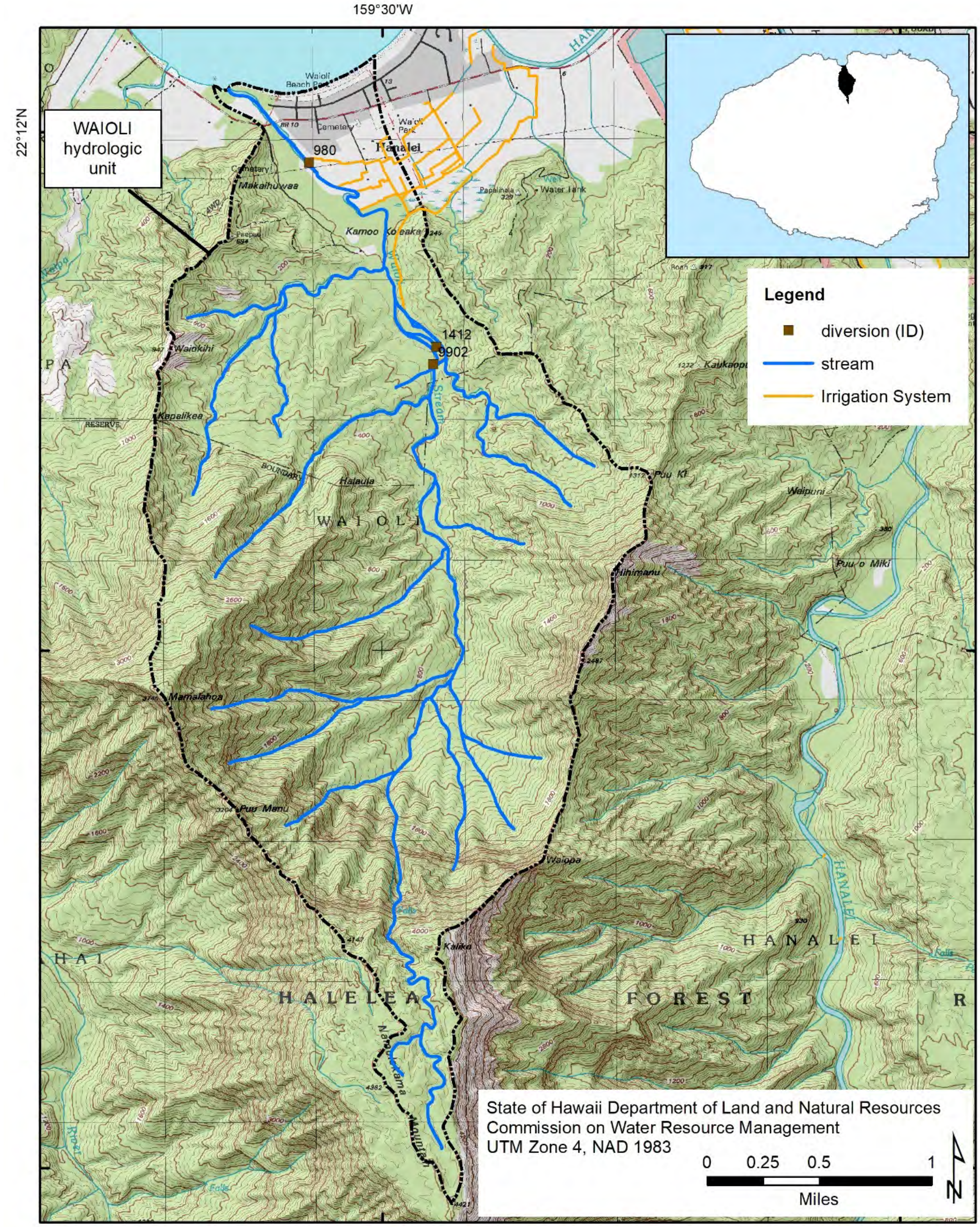
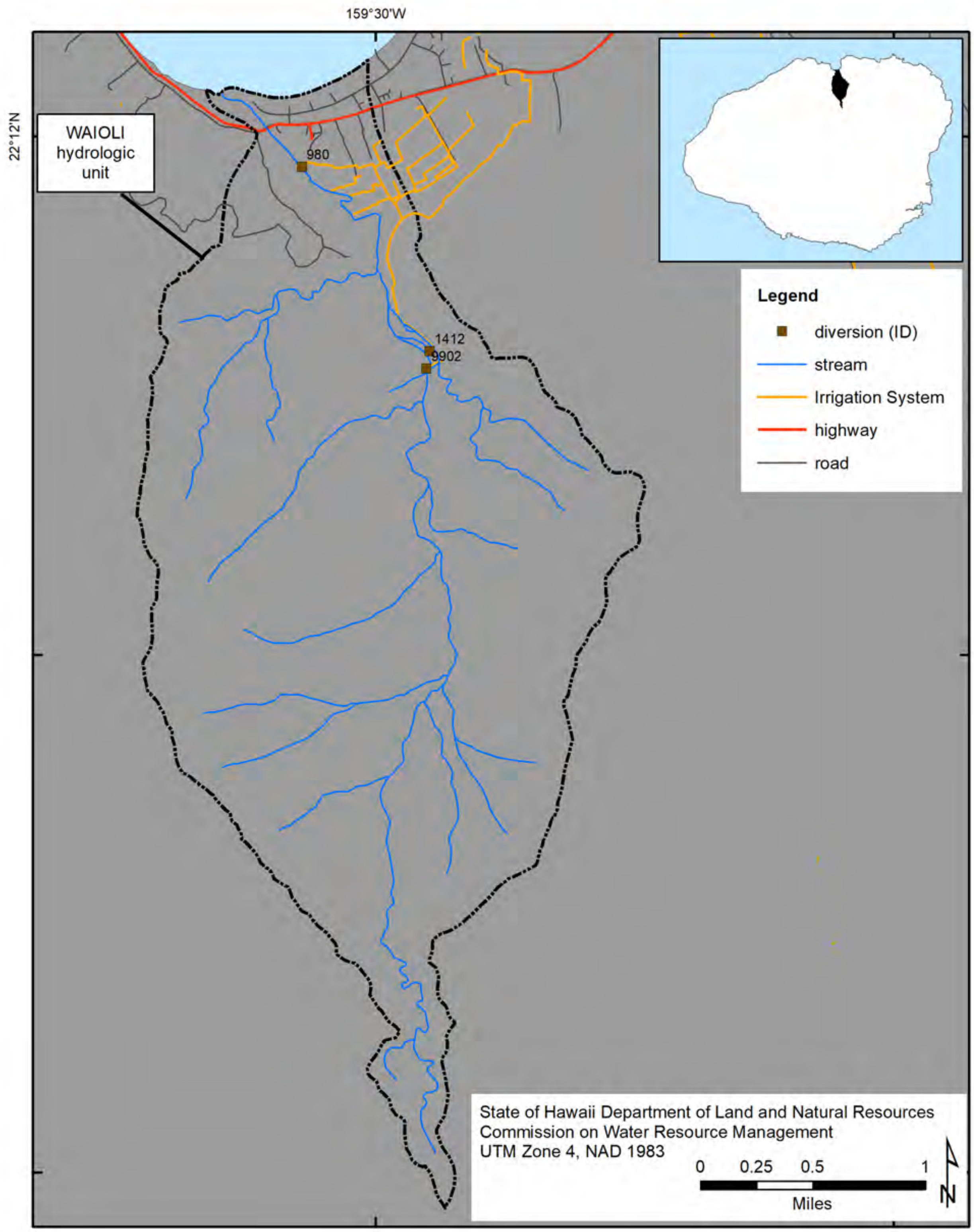


Figure 1-6. Major and minor roads for the Waioli hydrologic unit. (Source: State of Hawaii, Office of Planning 2015)



2. Watershed Characteristics

Geology

Kauai is the most geologically complex island of the main Hawaiian Islands, but subsurface geohydrologic information is not as well developed as in other areas of Hawai‘i (USGS SIR 99-4066). Waioli Stream drains an amphitheater-shaped watershed in the headwaters, transitioning to a narrower, v-shaped watershed through the middle reaches, and then opens up again closer to the coast with a broad flood plain typical of older Hawaiian watersheds. The north coast of Kauai is primarily composed of the shield-building stages of the Waimea Volcanic Series produced during the formation of the original Olokele Caldera, with the rejuvenated lavas of the Koloa Volcanic Series appearing primarily east of Hanalei. The Waioli hydrologic unit is composed of a single geologic formations: tholeiitic Waimea Canyon Basalt of the Napali Formation (Figure 3-2). The Napali Formation is a thick accumulation of many thin lava flows created during the shield-building phase of Kaua‘i and is highly permeable, but generally found in irregular north-south bands (Macdonald et al., 1960). Deeply buried dikes are likely to influence transmissivity and submarine groundwater discharge. The coastal plain and current shoreline are the result of higher sea levels between 1500 and 4000 years ago supporting reef development further inland. Baseflow in Waioli is supported by continuous groundwater discharge from thick layers of thinly-bedded basalts and associated breccia of the Napali formation in the Waimea Canyon Basalt, supporting mauka to makai flow 100 percent of the time. The different members of the Waimea Canyon Basalts likely have varying degrees of permeability due to localized differences in the thicknesses of lava flows. The generalized geology of the Waioli hydrologic unit is depicted in Figure 3-2.

Soils

The U.S. Department of Agriculture’s Natural Resources Conservation Service (formerly known as the Soil Conservation Service) divides soils into hydrologic soil groups (A, B, C, and D) according to the rate at which infiltration (intake of water) occurs when the soil is wet. The higher the infiltration rate, the faster the water is absorbed into the ground and the less there is to flow as surface runoff. Group A soils have the highest infiltration rates; group D soils have the lowest. In the Waioli hydrologic unit, soil types are dominated by Group D, which tend to have a high clay content with the highest potential for runoff (low infiltration rate) and are often shallow soils on top of impervious lava, composing 63% of all soils in the unit (U.S. Department of Agriculture, Soil Conservation Service, 1972). This is followed by the moderately deep to deep, well drained Group B soils supporting moderate infiltration, composing 32% of the unit (Figure 2-3). The highest elevation regions are composed of rough broken land and rough mountainous land soil groups accounting for the largest percentage of the watershed.

Rainfall

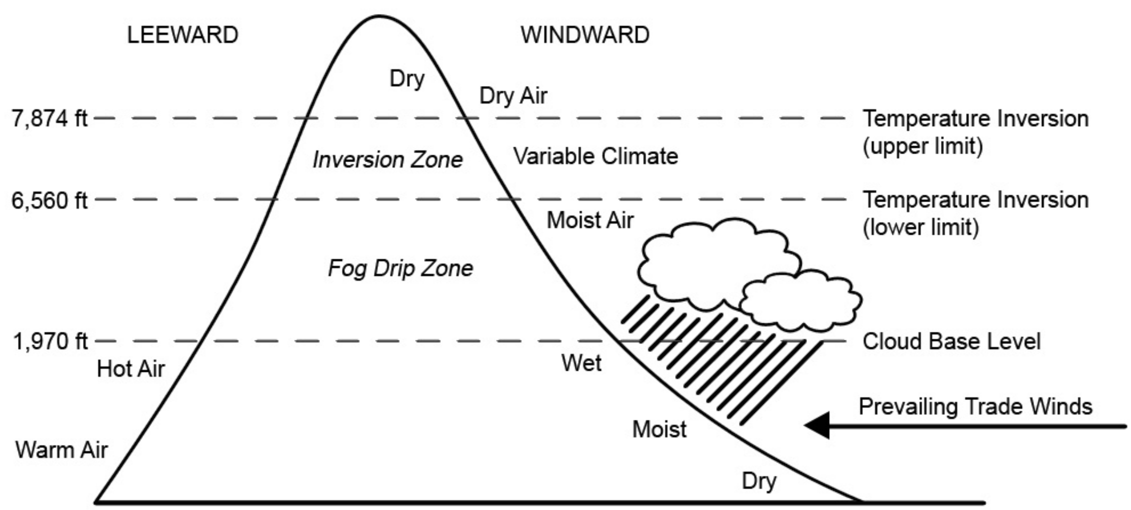
Orographic[1] rainfall is the driving force affecting the distribution of rainfall in Hawaii (Figure 2-3). Precipitation occurs when the prevailing northeasterly trade winds lift warm air up the windward side of Waialeale into higher elevations where cooler temperatures persist. As moist air cools, water condenses and the air mass releases precipitation. As a result, frequent and heavy rainfall is observed on the windward mountain slopes. Fog drip is a result of cloud-water droplets impacting vegetation (Scholl et al, 2002) and can contribute significantly to ground water recharge. The fog drip zone occurs below the elevation where cloud height is restricted by the temperature inversion. The temperature inversion zone typically extends from 6,560 feet to 7,874 feet, and thus the Waioli hydrologic unit sits completely below the inversion zone.

[1] 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.

A majority of the mountains in Hawaii peak in the fog drip zone, where cloud-water is intercepted by vegetation. In such cases, air passes over the mountains, warming and drying while descending on the leeward mountain slopes. Precipitation on Waialeale is influenced by its position relative to the trade winds. 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. The relatively round, conical shape of the Waialeale exposes all sides of the peak to wind and moisture.

The Waioli hydrologic unit is situated on the windward flank of Waialeale and as such receives substantial amounts of orographic rainfall (Figure 2-4). Near the coast, mean annual rainfall averages approximately 85 inches but the interior-most ridges receive at least 190 inches per year. The high spatial variability in rainfall is evident by the 100-inch variation in mean annual rainfall across the hydrologic unit.

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



Fog drip is also expected to contribute substantially to the water budget of the hydrologic unit. Shade (1999) used the monthly fog drip to rainfall ratios for the windward slopes of Mauna Loa on the island of Hawaii to calculate fog drip contribution to the water budget in windward East Maui. Using this same technique, the total monthly contribution of fog drip to the total water budget can be estimated (Table 2-1). On an annual basis, fog drip contributes approximately 25% to the total water inputs at elevations above 2000 ft.

Figure 2-2. Generalized geology of the Waioli hydrologic unit, Kauai. (Source: Sherrod et al., 2007)

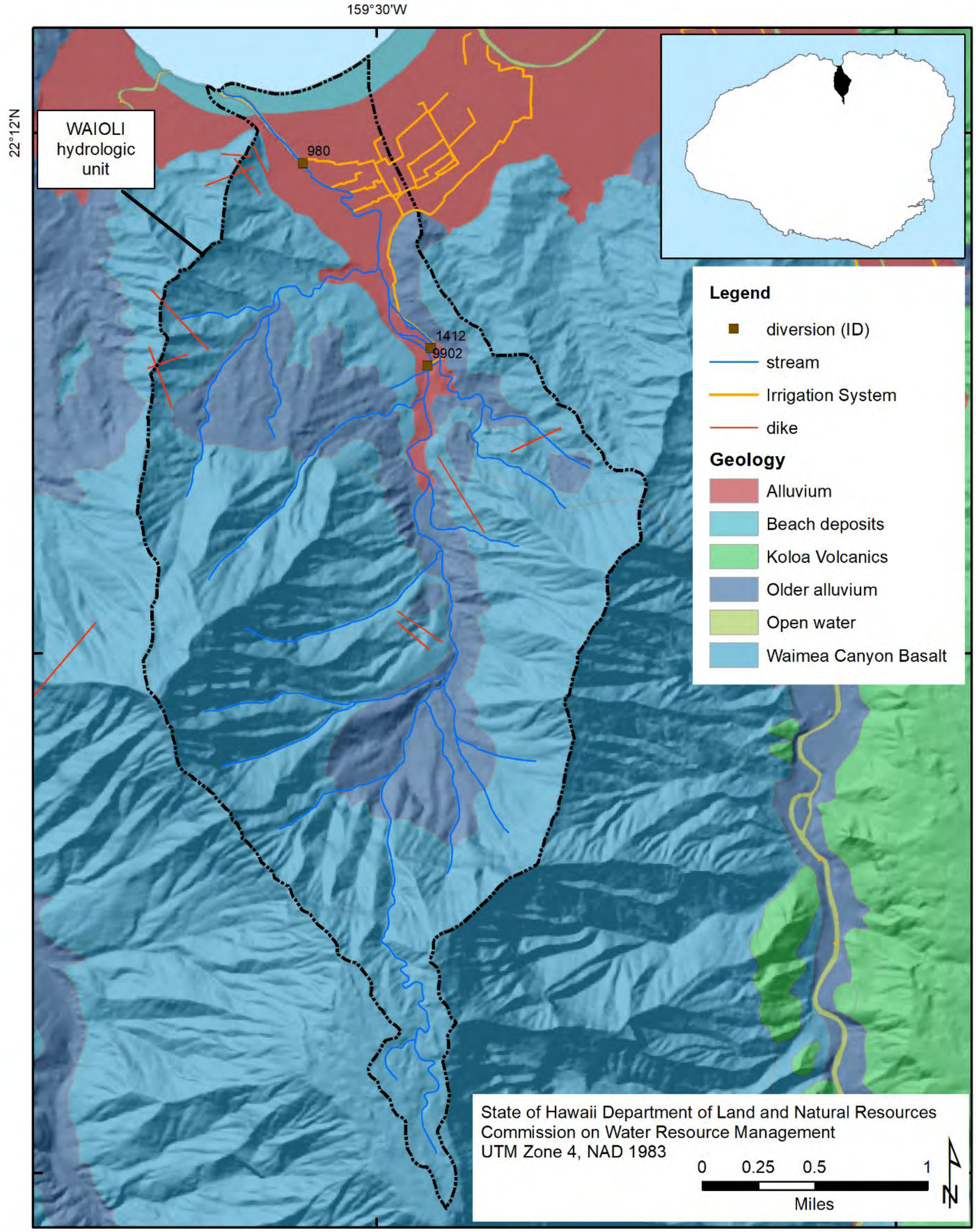
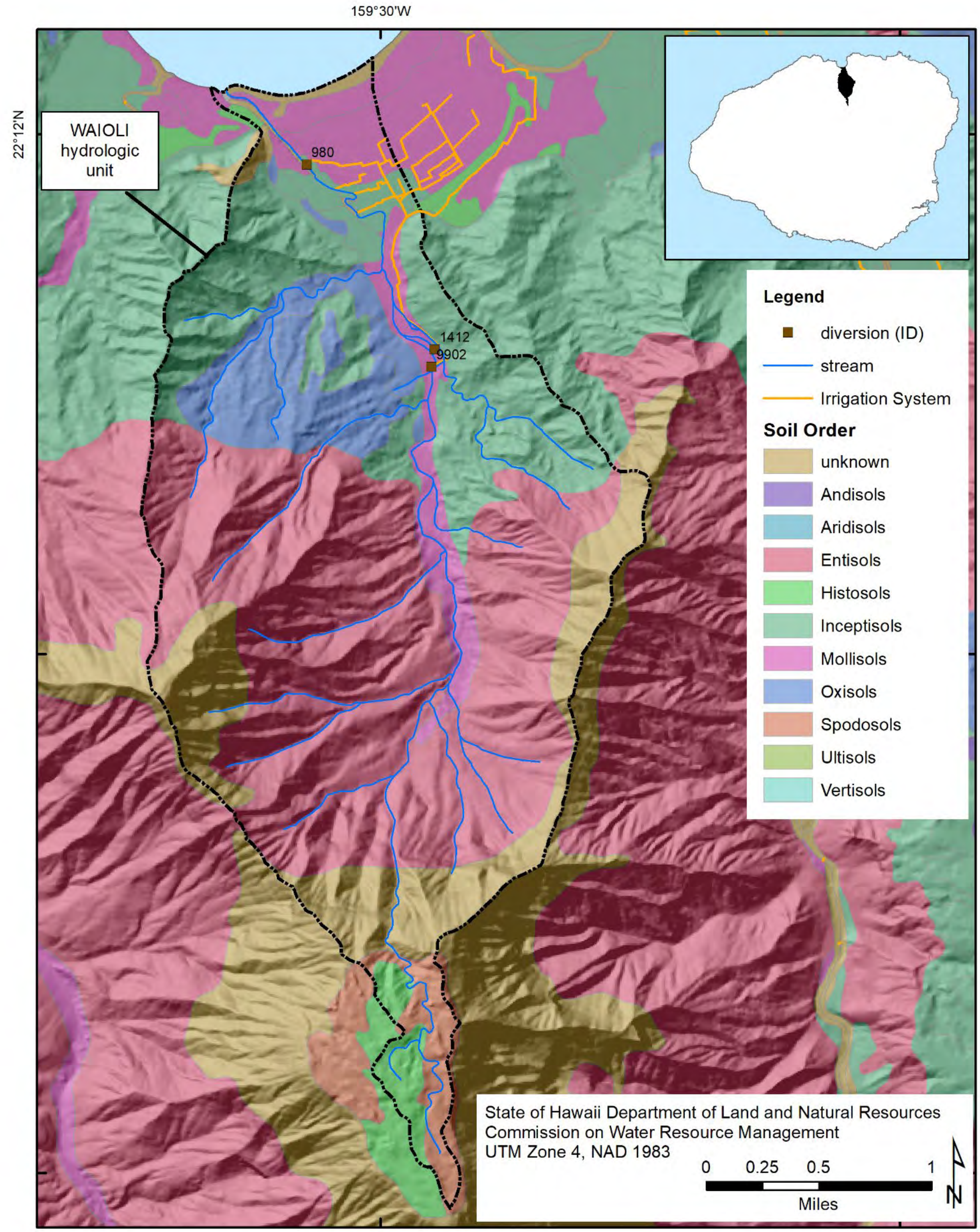


Figure 2-3. Soil classification of the Waioli hydrologic unit, Kauai. (Source: State of Hawaii, Office of Planning, 2015m)



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 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.

Table 2-1. Fog drip to rainfall ratios for the windward slopes of Mauna Loa on the island of Hawaii and approximate contributions to the Waioli hydrologic unit based on an elevation range of 2000-6000 feet and equivalent ratios.

Month	Ratio (%)	Mean Rainfall (in)	Contribution (in)
January	13	12.7	1.65
February	13	11.7	1.52
March	13	16.2	2.11
April	27	15.2	4.10
May	27	11.6	3.13
June	27	10.8	2.92
July	67	12.6	8.44
August	67	11.8	7.91
September	67	11	7.37
October	40	11.8	4.72
November	40	16.5	6.60
December	27	14.5	3.92

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 Waioli, average annual solar radiation ranges from 161.2-212.2 W/m^2 per day (Figure 2-5). It is greatest at the coast and decreases toward the uplands, where cloud cover is more of an influence (Giambelluca et al. 2014).

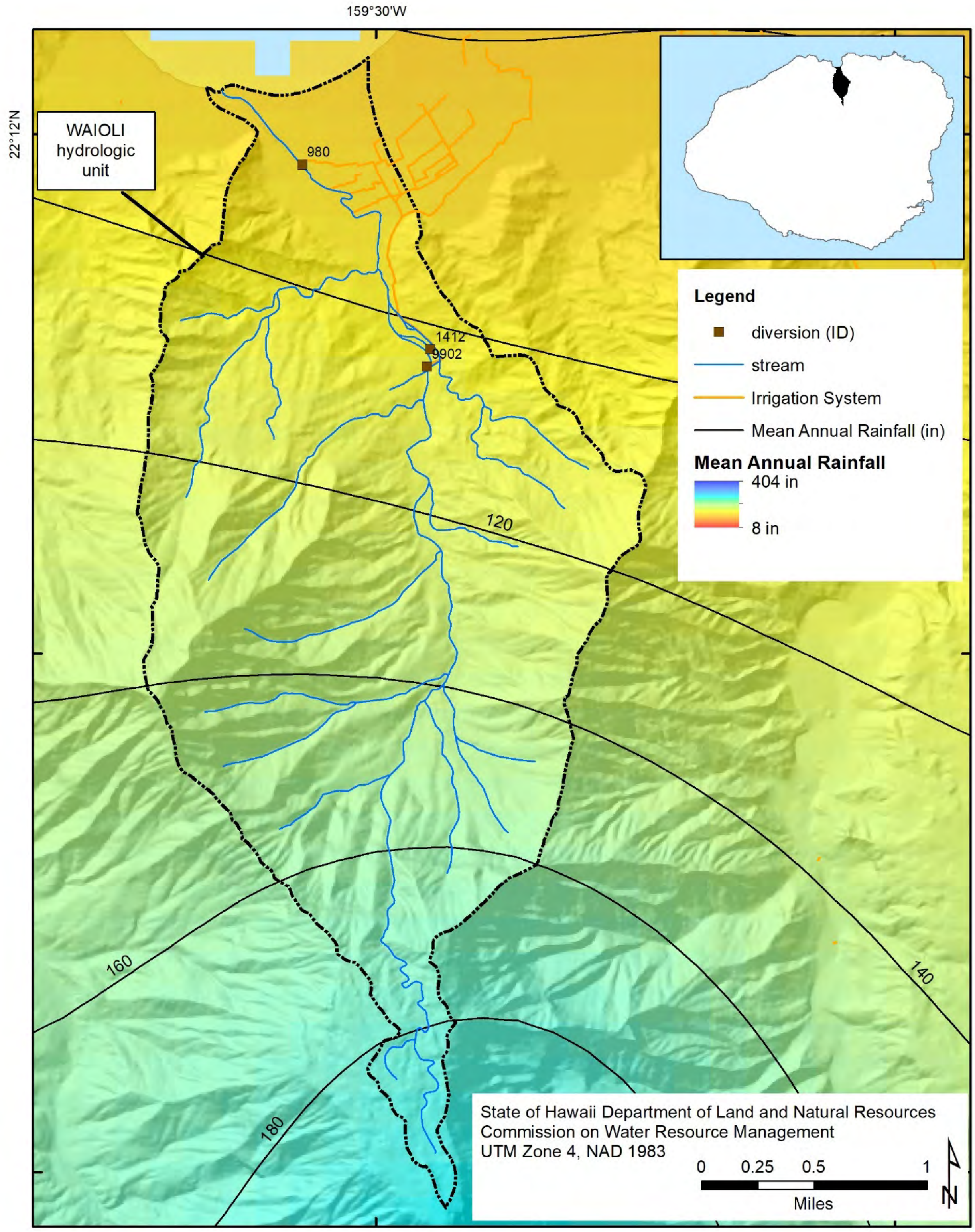
Evaporation

Evaporation is the loss of water to the atmosphere from soil surfaces and open water bodies (e.g. streams and lakes). Evaporation from plant surfaces (e.g. leaves, stems, flowers) is termed transpiration. Together, these two processes are commonly referred to as evapotranspiration, and it can significantly affect water yield because it determines the amount of rainfall 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[1], rainfall, humidity, wind speed, surface temperature, and sensible heat advection[2]. Higher evaporation rates are generally associated with greater net radiation, high wind speed and surface temperature, and lower humidity.

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

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

Figure 2-4. Mean annual rainfall isohyets (in) and rasterized mean annual rainfall for the Waioli hydrologic unit. (Source: Giambelluca et al., 2013)



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[3] and the cloud layer (Figure 2-6). 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). 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 summit causes increased evaporation, with pan evaporation rates of about 50 to 70 inches per year (Shade, 1999, Figure 26). For example, 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 evapotranspiration in the Waioli hydrologic unit averages 39.6 inches and ranges from 21.6 inches to 72.9 inches per year (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 93.2 percent of the land in Waioli as conservation (5.053 square miles) and 4.7 percent as agricultural (0.253 square miles) with 2.1 percent as urban (0.116 square miles) (State of Hawaii, Office of Planning, 2015d). The conservation district is located in the upper part of the hydrologic unit, whereas the agricultural and urban districts are located in the lower part of the hydrologic unit (Figure 2-7).

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

Figure 2-5. Mean annual solar radiation for the Waioli hydrologic unit, Kauai. (Source: Giambelluca et al., 2014)

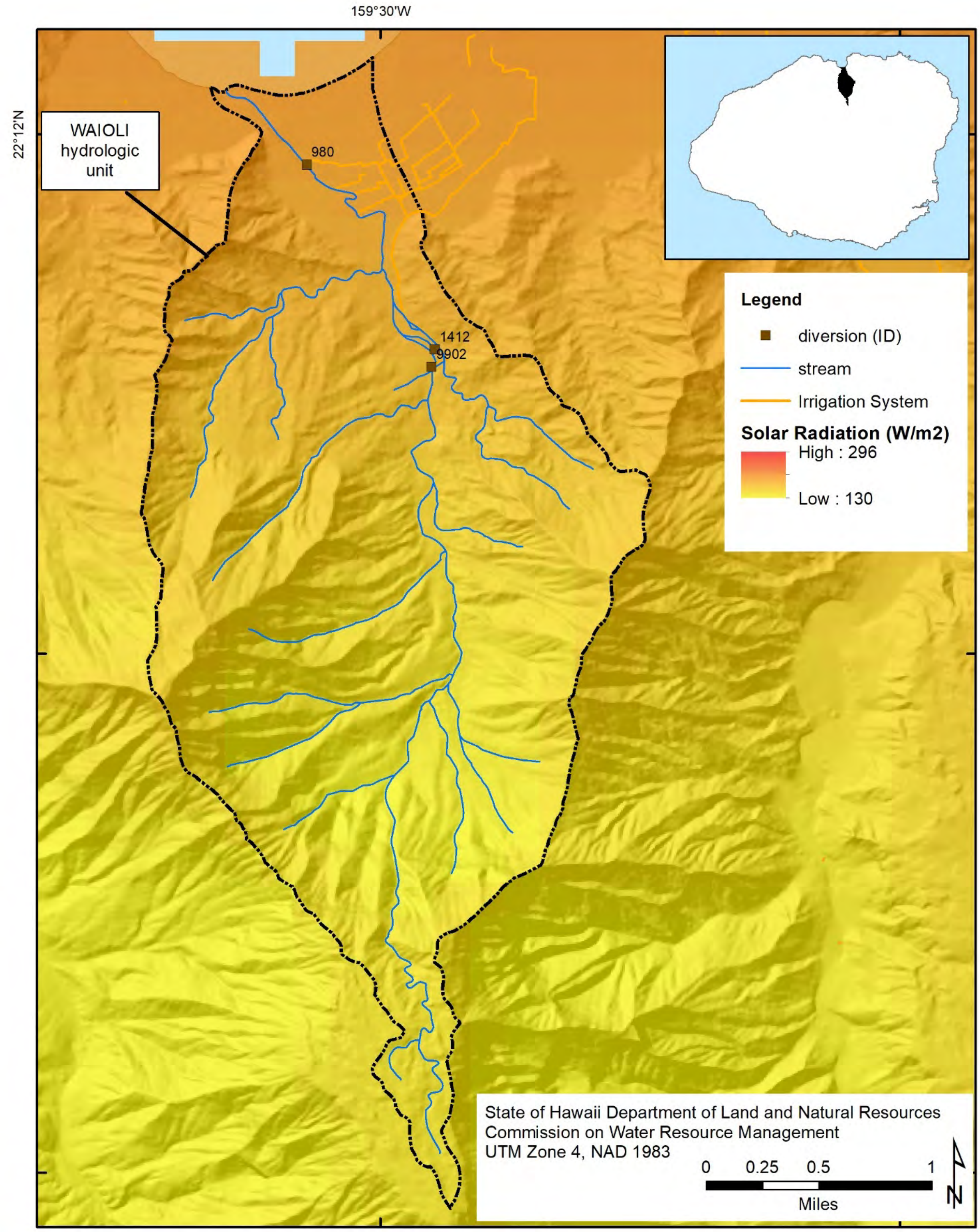


Figure 2-6. Mean annual potential evapotranspiration for the Waioli hydrologic unit, Kauai. (Source: Giambelluca et al., 2014)

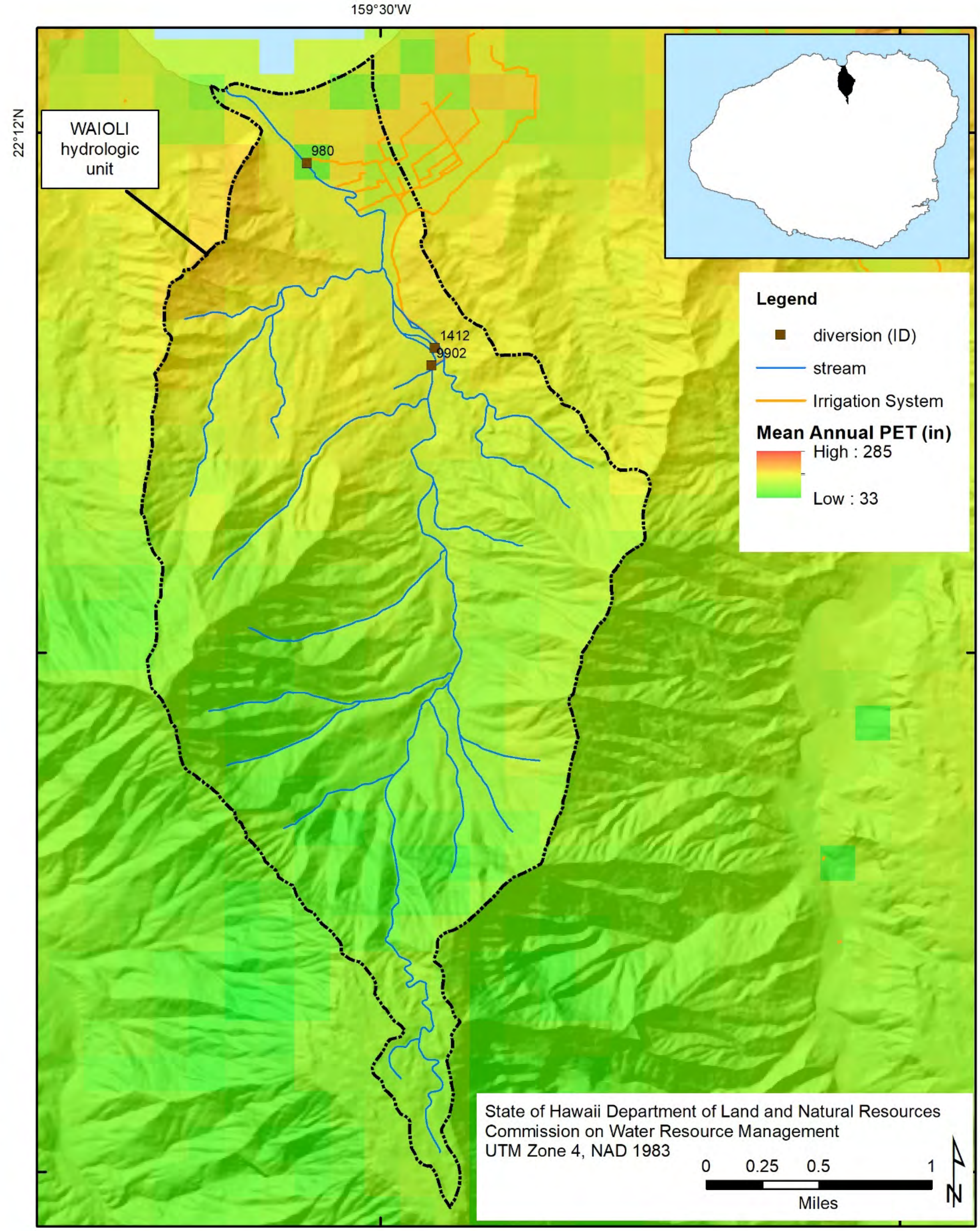
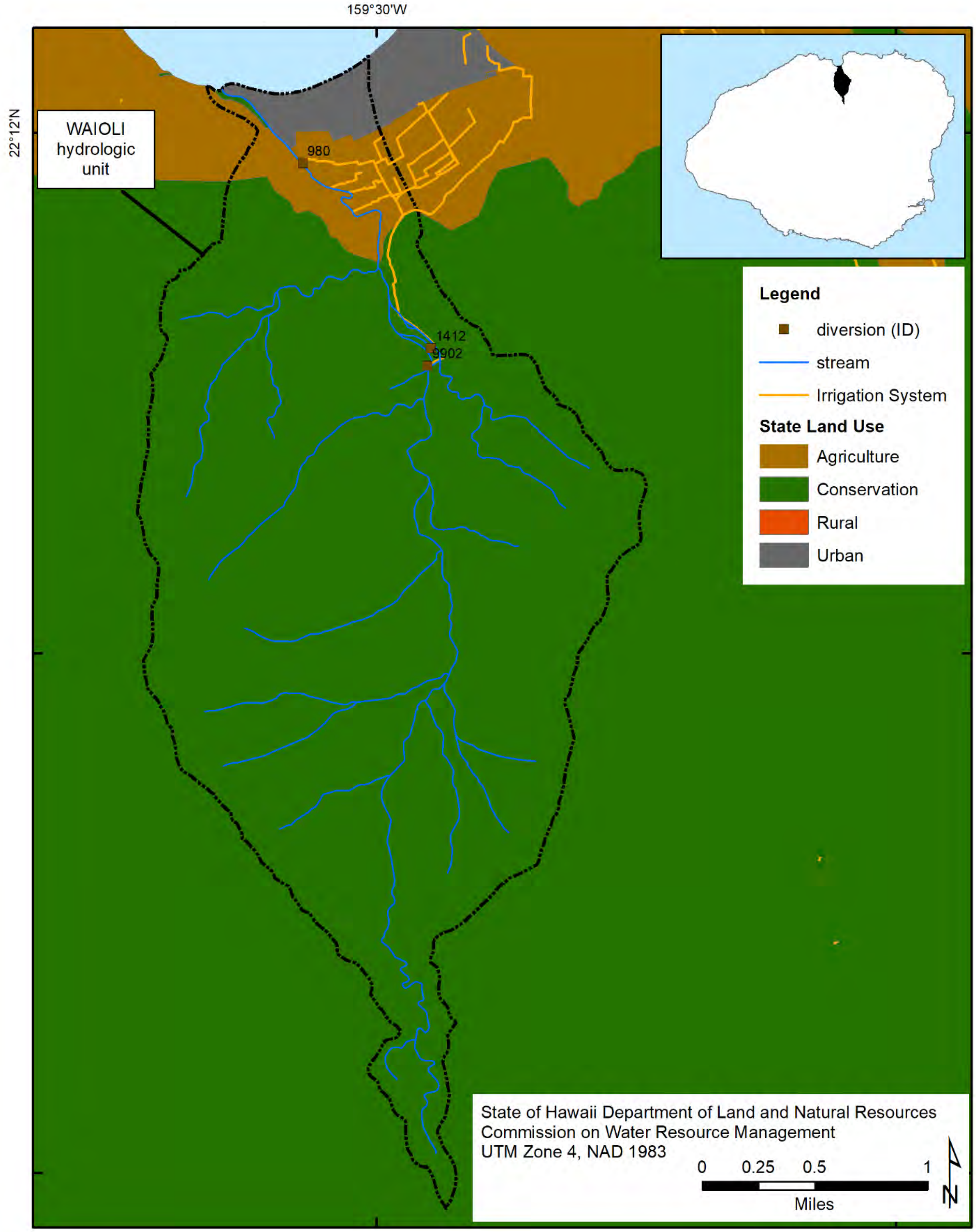


Figure 2-7. Current land use zoning in the Waioli hydrologic unit, Kauai. (Source: State of Hawaii, Office of Planning, 2015d)



Land Cover

Land cover for the hydrologic unit of Waioli 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 Waioli, e.g. forest, grassland, shrub land, with minor developed areas, cultivated areas, and bare land (Table 2-2; 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 2-3; Figure 2-9).

Based on the two land cover classification systems, more than half the Waioli hydrologic unit is composed of alien forest or alien shrubland, with only about a third of the hydrologic unit composed of native wet forest vegetation. Much of the lower elevation regions are in agriculture or grassland with more urban development.

Table 2-2. C-CAP land cover classes and area distribution in the Waioli hydrologic unit, Kauai. (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	3.701	68.2%
Scrub	Areas dominated by woody vegetation less than 6 meters in height	1.076	19.8%
Grassland	Natural and managed herbaceous cover	0.204	3.8%
Palustrine Scrub/Shrub Wetland	Includes tidal and nontidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity is below 0.5%	0.191	3.5%
Low Intensity Developed	Constructed surface with substantial amounts of vegetated surface	0.093	1.7%
Agriculture	Contains areas intensely managed for the production of annual crops	0.054	1.0%
Palustrine Forested Wetland	Included tidal and nontidal wetlands dominated by woody vegetation 5 meters in height or more	0.039	0.7%
Developed Open Space	Areas mostly managed grasses or low-lying vegetation planted for recreation, erosion control, or aesthetic purposes	0.023	0.4%
Medium Intensity Developed	Areas with a mixture of constructed materials and substantial amounts of vegetation	0.020	0.4%
Open Water		0.011	0.2%
Bare land	Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, gravel pits	0.007	0.1%
Unconsolidated Shore		0.006	0.1%

Figure 2-8. C-CAP landcover data for the Waioli hydrologic unit, Kauai. (Source: NOAA Coastal Change Analysis Program, State of Hawaii, Office of Planning 2015)

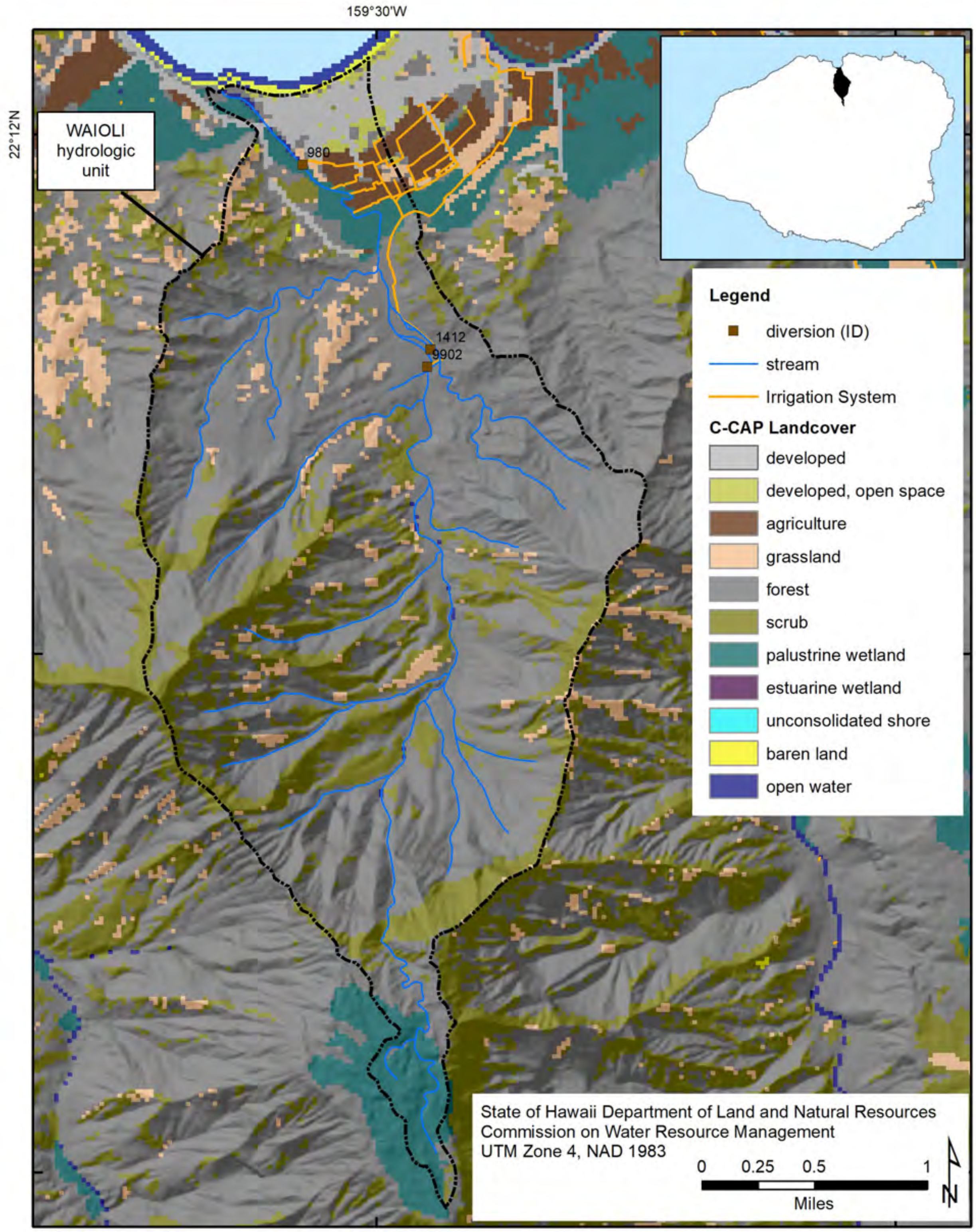


Figure 2-9. USGS GAP landcover analysis for the Waioli hydrologic unit, Kauai. (Source: USGS GAP Analysis, 2012)

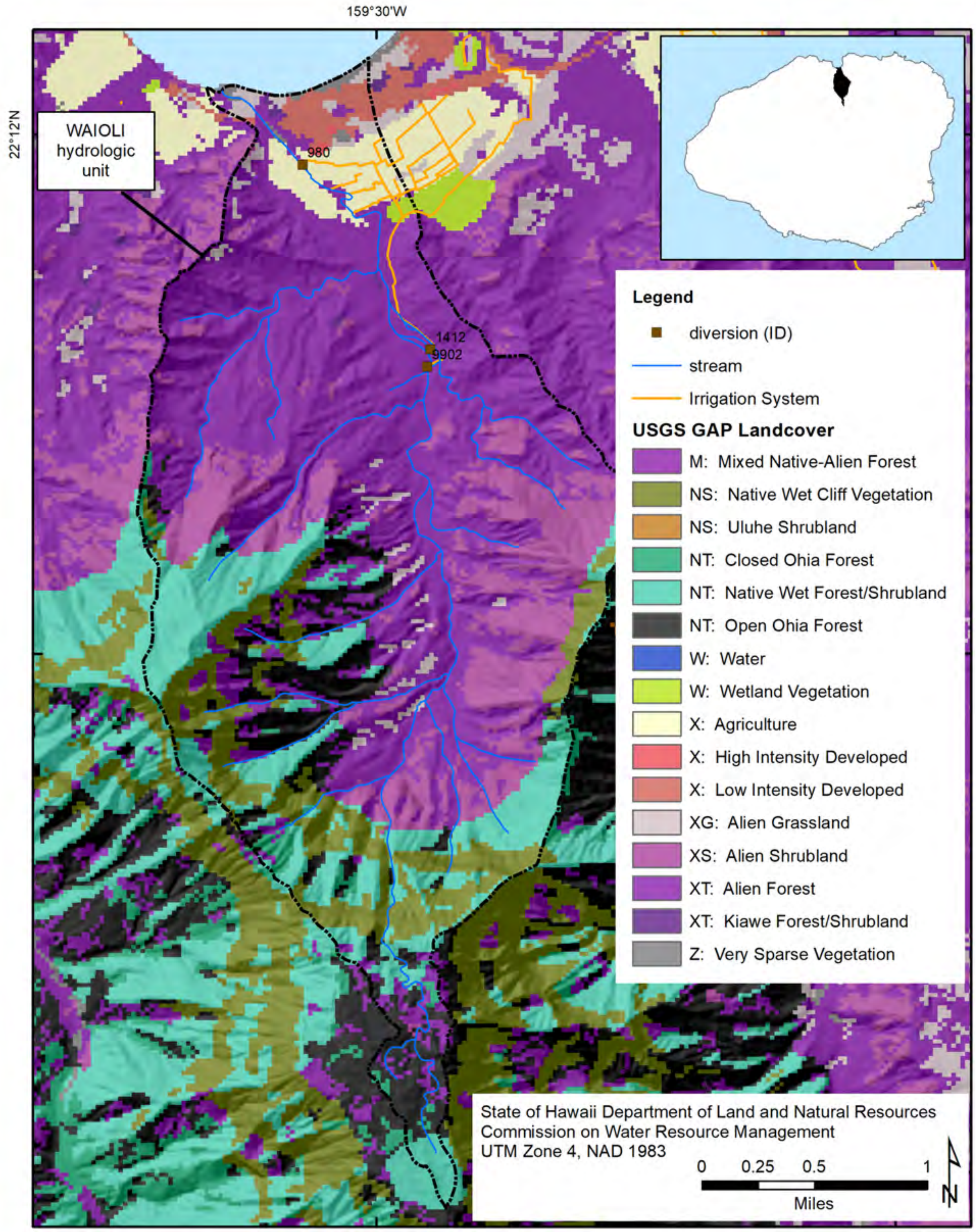


Table 2-3. HI-GAP land cover classes and area distribution Waioli hydrologic unit, Kauai. (Source: USGS, 2005)

Land Cover	Area (mi^2)	Percent of Unit
Alien Forest	2.592	47.80%
Alien Shrubland	0.766	14.13%
Native Wet Forest and Shrubland	0.721	13.30%
Native Wet Cliff Vegetation	0.519	9.58%
Open Ohia Forest	0.427	7.87%
Cultivated Cropland	0.134	2.48%
Alien Grassland	0.089	1.65%
Closed Ohia Forest	0.068	1.25%
Developed, Low Intensity	0.065	1.19%
Very Sparse Vegetation to Unvegetated	0.019	0.35%
Wetland Vegetation	0.010	0.18%
Kiawe Forest and Shrubland	0.007	0.12%
Developed, High Intensity	0.005	0.08%
Undefined	0.001	0.02%

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.

Peak floods in Waioli were only monitored by USGS from 1914-1931 (USGS station 16105000). The estimated 2-, 5-, 10-, 50-, and 100-year flood magnitudes at these stations is listed in Table 2-4. Where Waioli Stream crosses Kuhio Highway, the estimated 2-, 5-, 10-, 50-, and 100-year flood magnitudes are 2140, 3540, 4590, 7230, and 8460 cfs, respectively. 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 the lower reaches of the Waioli hydrologic unit along the stream channels as flood-risk zone A, (Figure 2-10).

Table 2-4. The magnitude of peak flows with specific recurrence intervals based on measured peaks flows at select monitoring locations in the Waioli hydrologic unit, Kauai. (Source: Oki et al., 2010)

station ID	station name	period of record	peak flood magnitudes (cfs)				
			2-year	5-year	10-year	50-year	100-year
16105000	Waioli Stream near Hanalei	1914-1931	1080	1380	1560	1920	2060

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.

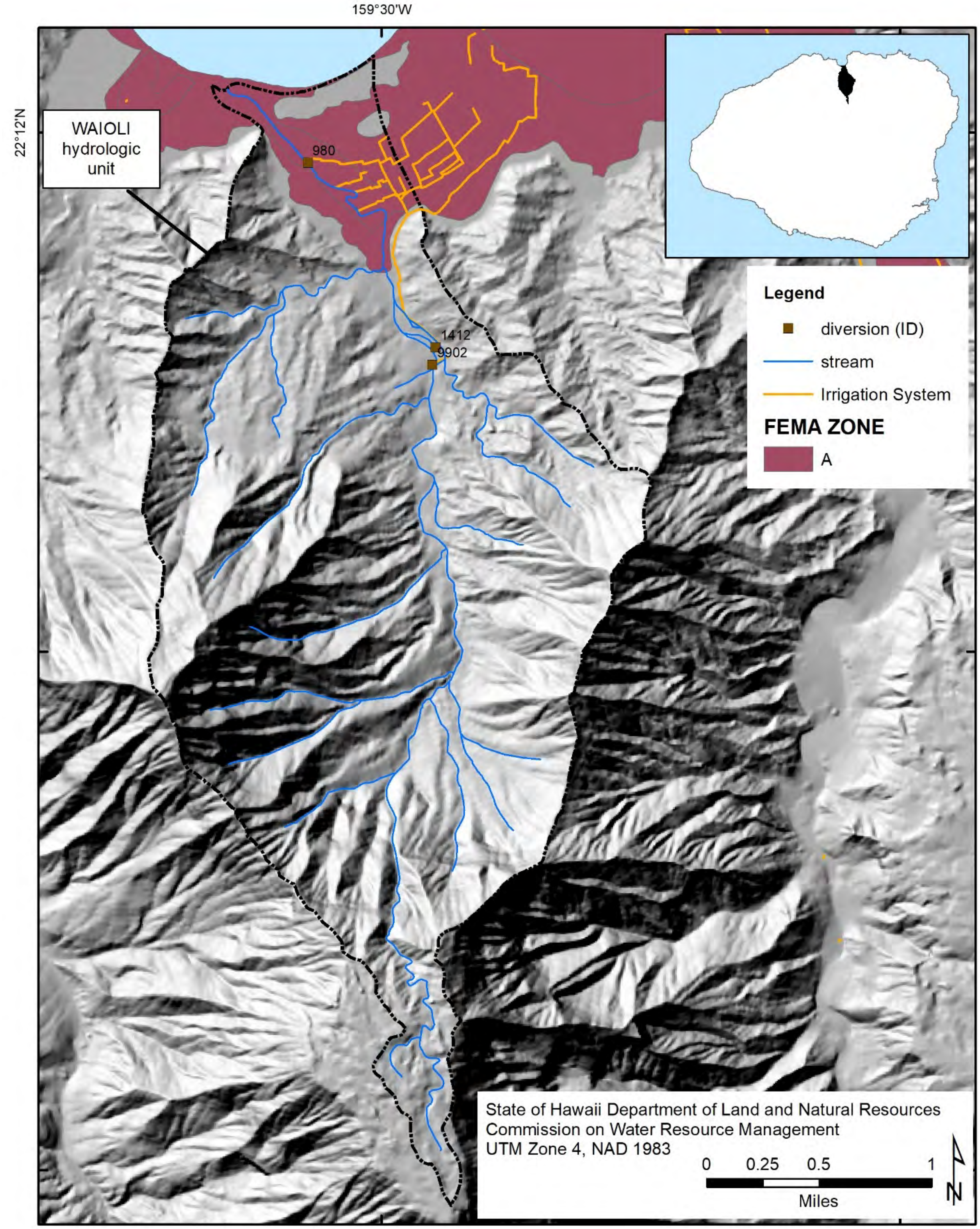
Droughts have affected the islands throughout Hawaii's recorded history. The most severe events of the recent past years are associated with the El Niño phenomenon. In January 1998, the National Weather Service's network of 73 rain gauges throughout the State did not record a single above-normal rainfall, with 36 rain gauges recording less than 25 percent of normal rainfall (State of Hawaii, Commission on Water Resource Management, 2005b). The most recent drought occurred in 2000-2002, affecting all islands, especially the southeastern end of the State. 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 2-2.

Table 2-5. 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

Based on the 12-month SPI, the Wailua, Lihue and Koloa regions have the greatest risk to drought impact on Kauai.

Figure 2-10. Federal Emergency Management Agency (FEMA) flood risk zone for the Waioli hydrologic unit, Kauai. (Source: FEMA, 2014)



3. 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 hydrologic characteristics of a stream are critical to determining the interim IFS recommendation. These characteristics indicate the effects of geology, climate, and soils on the flow of water in the stream. Of great importance is the concept of a gaining and losing stream reach. A gaining reach is typically interpreted as where the streambed intersects the underlying water table and groundwater contributes to streamflow as seepage or springs. On Kaua‘i, streams are generally gaining from their headwater reaches at high elevations all the way to the lower elevation reaches. Continuous mauka to makai flow is estimated to naturally occur 100-percent of the time in the main stem of Waioli Stream. Considerable groundwater gains occur from springs emanating from perched bodies and dike structures. The following is a summary of general hydrology and specific hydrologic characteristics for streams in the Waioli hydrologic unit.

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

Groundwater

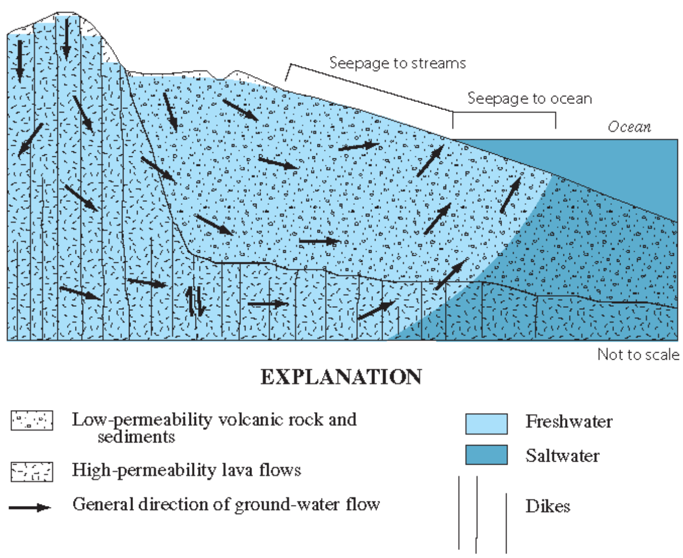
Groundwater is an important component of streamflow as it constitutes the base flow[5] of Hawaiian streams. When ground water is withdrawn from a well, the water level in the surrounding area is lowered. Nearby wetlands or ponds may shrink or even dry up if the pumping rate is sufficiently high (Gingerich and Oki, 2000). The long-term effects of groundwater withdrawal can include the reduction

[5] 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).

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 groundwater warrants a close look at the groundwater recharge and demand within the State as well as the individual hydrologic units.

In Hawaii, groundwater is replenished by recharge from rainfall, fog drip, and irrigation water that percolate through the plant root zone to the subsurface rock. Recharge can be captured in three major fresh ground water systems: 1) fresh water-lens system; 2) dike-impounded system; and 3) perched system. The fresh water-lens system provides the most important sources of ground water. It includes a lens-shaped layer of fresh water, an intermediate transition zone of brackish water, and underlying salt water. A vertically extensive fresh water-lens system can extend several hundreds or even thousands of feet below mean sea level. By contrast, a dike-impounded system is found in rift zones and caldera of a volcano, where low-permeability dikes compartmentalize areas of permeable volcanic rocks, forming high-level water bodies. On Kauai, dikes impound water to as high as 3,300 feet above mean sea level. A perched system such as the Alakai Swamp 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). A general overview of the ground water occurrence and movement in the Lihue Basin is described in Izuka (2006) and illustrated in Figure 3-1.

Figure 3-1. Diagram illustrating the ground water system of Lihue Basin, Kauai. Arrows indicate general direction of ground water flow (Source: Izuka 2006).



The hydrologic unit of Waioli lies almost completely within the Hanalei aquifer system. Groundwater is found in perched and dike-impounded structures of Koloa Volcanics as well as in the fresh water-lens system making up the basal aquifer in Waimea 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, during certain hydrologic conditions, there may be surface water-groundwater interactions, especially in the gaining reaches. A summary of the wells registered in the Waioli hydrologic unit is provided by Table 3-1 with their locations identified in Figure 3-2. As of 2019, the Hanalei aquifer's sustainable yield is estimated to be 35 mgd. The two wells in the Waioli hydrologic unit withdrawal a de minimus amount of water from the aquifer compared to its sustainable yield.

Table 3-1. Well number, name, owner, elevation, pump capacity (million gallons per day, mgd), and 10-year mean pumpage (mgd) for the Koloa Aquifer System, Kaua'i. [ABN = abandoned; AGR = Agriculture; UNU = unused; IRR = irrigation; MUNCO = municipal county; MUNPR = municipal private; DOM = domestic; NTBG = National Tropical Botanical Garden]

well number	well name	well owner	ground elevation (ft)	well depth (ft)	pump capacity (mgd)	2009-2018 pumpage (mgd)	water use
2-1130-001	McPeek Kosteletsky	Camille Kostelecky Trust	20	170	0.010	n/a	domestic
2-1130-002	Lot 41	Richard Henkels	18	165	0.058		

Streamflow Characteristics

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

The USGS has maintained only one monitoring location on Waioli stream at station 16105000 at an elevation of 550 feet from 1914 to 1932, and there are no currently active monitoring stations in the hydrologic unit (Figure 3-8). Historic data from this station are available in Table 3-2. Using a baseflow separation technique, median baseflow for the continuous record from 1914 to 1932 was 16 cfs (10.34 mgd). The mean annual flow measured at station 16105000 on Waioli Stream at 550 feet in elevation is provided in Figure 3-3. The Hawai'i Department of Health measured unregulated and regulated flow below East Waioli Ditch 12 times from 2001 to 2003 in conjunction with water quality samples at a lower elevation of 1 foot (downstream near the mouth) and at an upper elevation of 160 feet, which are presented in Table 3-3. These measurements were made on six different days as indicated. On 2/9/2019, CWRM staff made a measurement of 32.7 cfs (21.1 mgd) on Waioli Stream above the tributary inflow (~160 feet in elevation) on the right bank.

Table 3-2. Selected streamflow values for the period of record (1914-1932) for USGS station 16105000 at in the Waioli hydrologic. [cubic feet per second, cfs (million gallons per day, mgd)]

USGS station ID	Station	14-day Low Flow	Q_{30}	Q_{40}	Q_{50}	Q_{70}	Q_{80}	Q_{90}	Q_{95}
16105000	Waioli Stream nr Hanalei	8.5 (5.5)	37 (23.9)	23 (14.9)	20 (12.9)	15 (9.7)	13 (8.4)	11 (7.1)	10 (6.5)

Table 3-3. Unregulated (upper) and regulated (lower) flow measurements made by the Hawai'i Department of Health on Waioli Stream at an approximate elevation of 160 feet. [cubic feet per second, cfs and million gallons per day, mgd]

date	11/5/2001		7/8/2002		5/19/2003		7/21/2003		8/4/2003		9/22/2003	
location	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Time	7:58	11:05	7:50	8:40	10:30	9:30	10:00	11:07	9:20	10:10	9:05	9:50
cfs	33.8	23.7	29.0	30.1	76.6	61.8	4.7	13.8	34.5	11.9	8.9	16.0
mgd	21.83	15.31	18.73	19.44	49.48	39.92	3.04	8.91	22.29	7.69	5.75	10.34

Figure 3-2. CWRM aquifer systems and registered wells of the Waioli hydrologic unit, Kauai. (Source: CWRM, 2020)

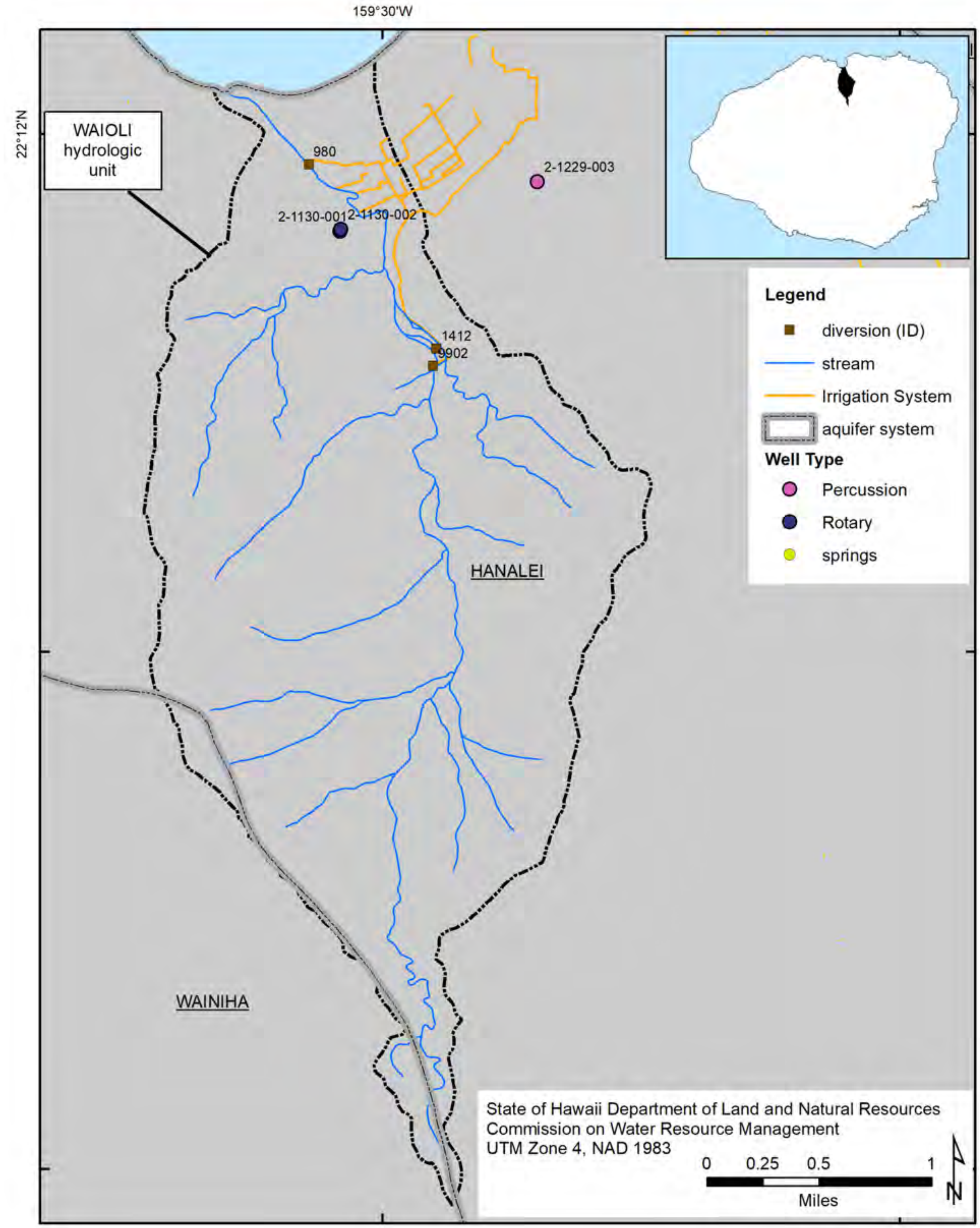
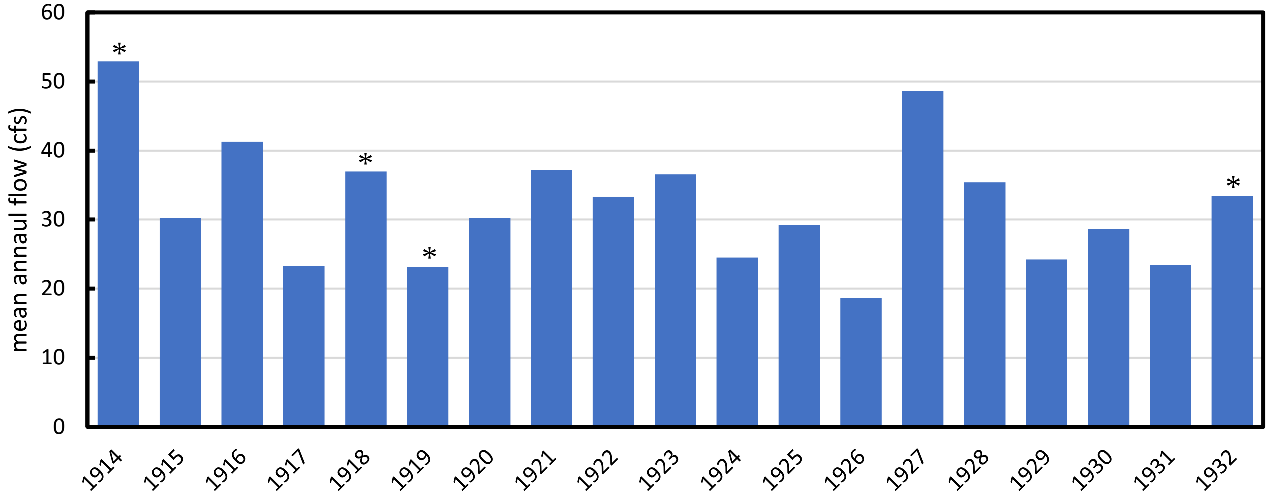


Figure 3-3. Mean annual flow in Waioli Stream at USGS station 16105000 from 1914 to 1941. (Source: USGS, 2020) [note: years with an asterisk indicate incomplete record]



Using miscellaneous flow measurements by the DOH, CWRM staff, and others, the MOVE.1 model can be utilized to estimate current (1984-2013) low-flow statistics based on the mean daily flow at USGS station 16108000 on Wainiha River as provided by Cheng (2016). The results of that model are found in Table 3-4. Results are consistent with historic data estimated assuming a small decline in rainfall between the 1914-1932 and 1984-2013 periods, which is supported by Frazier and Giambelluca (2017).

Table 3-4. Estimated low-flow streamflow values for the 1984-2013 climate for in the Waioli hydrologic. [cubic feet per second, cfs and million gallons per day, mgd]

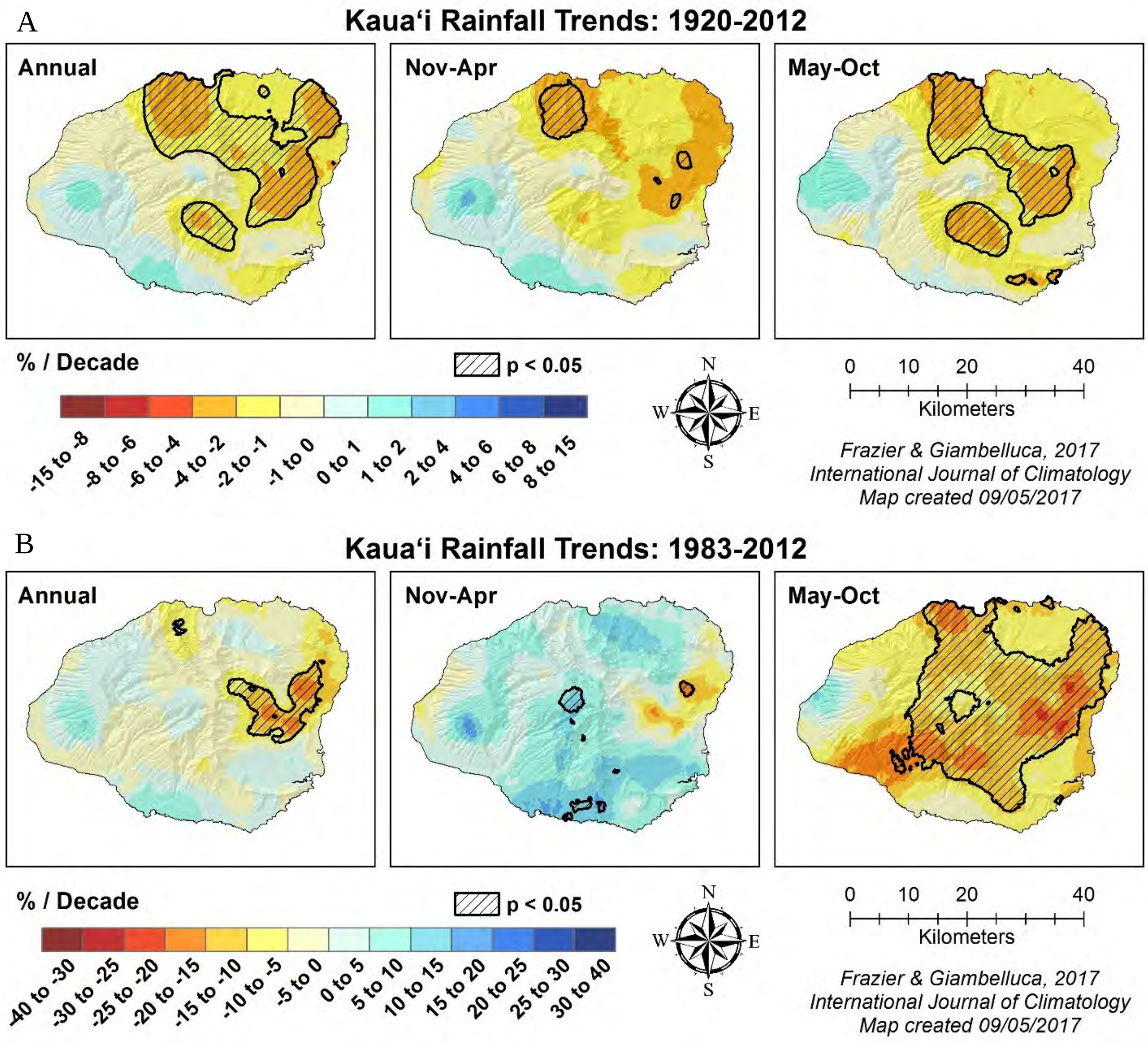
Station	Q_{50}	Q_{55}	Q_{60}	Q_{65}	Q_{70}	Q_{75}	Q_{80}	Q_{85}	Q_{90}	Q_{95}
Waioli Stream	20 (13.0)	18 (11.6)	16.6 (10.7)	15.6 (10.0)	14.3 (9.3)	13.3 (8.6)	12.4 (8.0)	11.5 (7.4)	10.6 (6.8)	9.4 (6.0)

Long-term trends in rainfall and streamflow

The climate has profound influences on the hydrologic cycle and in the Hawaiian Islands, shifting climate patterns have resulted in an overall decline in rainfall and streamflow. Rainfall trends are driven by large-scale oceanic and atmospheric global circulation patterns including large-scale modes of natural variability such as the El Nino Southern Oscillation and the Pacific Decadal Oscillation, as well as more localized temperature, moisture, and wind patterns (Frazier and Giambelluca, 2017; Frazier et al, 2018). Using monthly rainfall maps, Frazier and Giambelluca (2017) identified regions that have experienced significant ($p<0.05$) long-term decline in annual, dry season, and wet season rainfall from 1920 to 2012 and from 1983 to 2012. On Kauai, certain windward areas have experienced a significant decline in annual and seasonal rainfall from 1920 to 2012, including Waioli, and for most of the island from 1983-2012 (Figure 3-4).

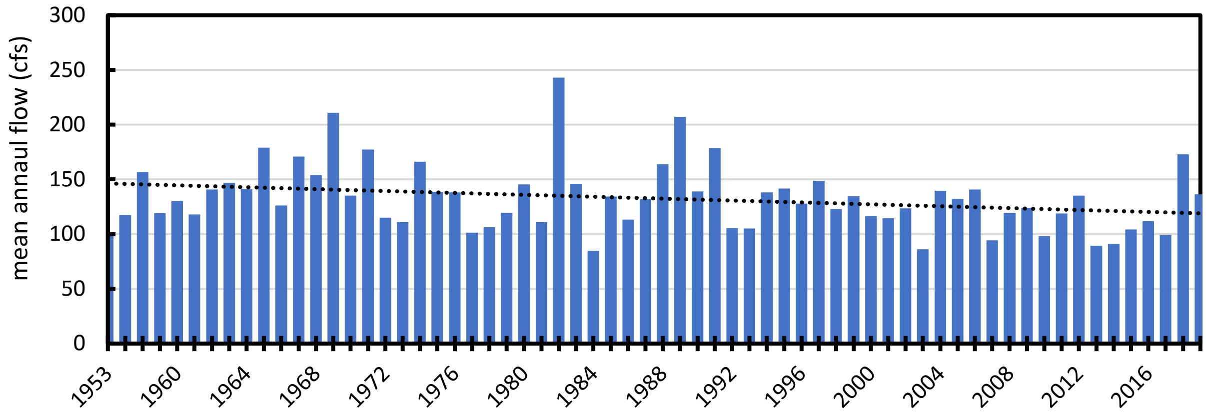
In a different study, the USGS examined the long-term trends and variations in streamflow on the islands of Hawaii, Maui, Molokai, Oahu, and Kauai, where long-term stream gaging stations exist (Oki, 2004). The study analyzed both total flow and estimated base flow at 16 long-term gaging stations, one of which is located in Wailua River (station 16068000). For the 90-year period 1913-2002, monthly mean base flows generally followed an increasing trend above the long-term average from 1913 to early 1940s, and a decreasing trend after the early 1940s to 2002 (Figure 3-5). Monthly mean total flows follow a similar pattern with the exception that the monthly mean total flow increased from mid-1980s to mid-1990s, and decreased from mid-1990s to 2002. Downward trends in the annual total low flow percentiles, TFQ_{75} and TFQ_{90}, were statistically significant at the 5 percent level of significance. This is consistent with the annual base flow percentiles (Oki, 2004).

Figure 3-4. Annual, wet season (Nov-Apr) and dry season (May-Oct) rainfall trends for the 1920-2012 (A) and 1983-2012 (B) periods, Maui. Hashed line areas represent significant trend over the period. (with permission from Frazier and Giambelluca, 2017)



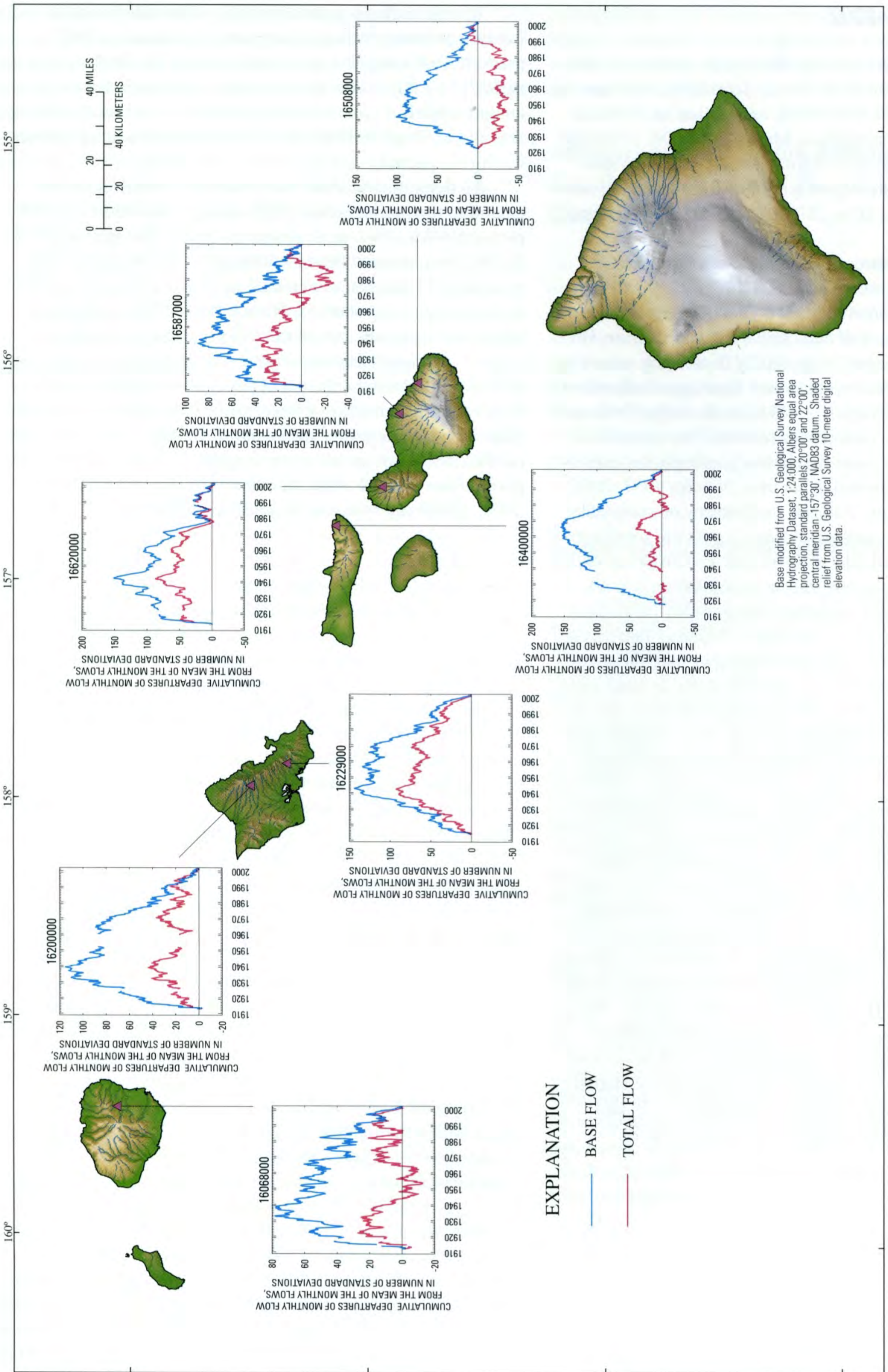
At a nearby long-term continuous gaging station on Wainiha Stream (USGS 16108000), which has been active almost continuously from 1952 to present day, trends in mean annual flow provide some context for the long-term decline in rainfall (Figure 3-5). Changing streamflow characteristics could pose a negative effect on the availability of drinking water for human consumption and habitat for native stream fauna (Oki, 2004).

Figure 3-5. Mean annual flow in Wainiha Stream at USGS station 16108000 from 1952 to 2019 and linear trend line. (Source: USGS, 2020)



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 3-7 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 groundwater contribution to streams.

Figure 3-6. Cumulative departures of monthly mean flow from the mean of the monthly flows, Hawaii. This data is based on complete water years from 1913 through 2002. (Oki, 2004, Figure 4)



4. Maintenance of Fish and Wildlife Habitat

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

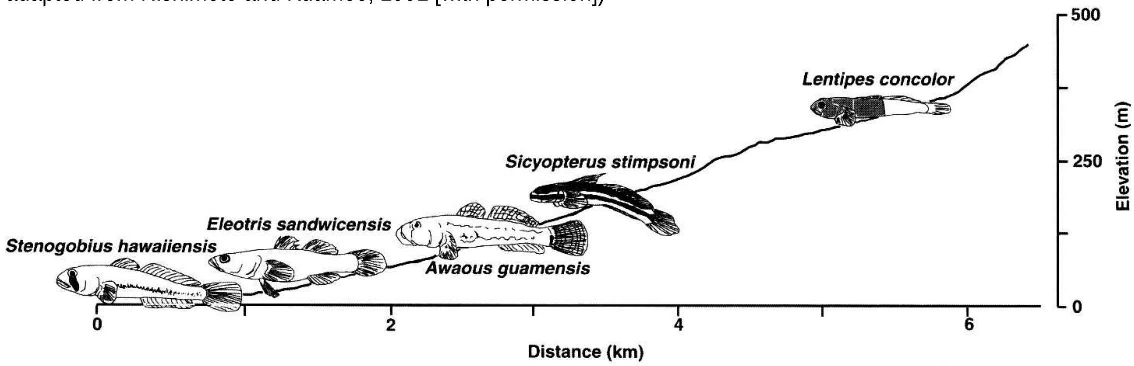
Table 4-1. List of commonly mentioned native stream organisms. (Source: State of Hawaii, Division of Aquatic Resources, 1993)

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

Hawaii’s native stream animals have amphidromous life cycles (Ego, 1956) meaning that they spend their larval stages in the ocean (salt water), then return to 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 stamineus* 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.

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.

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])



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 recommend that the Waioli stream be listed as a candidate stream for protection based on its diversity and blue ribbon recreational resources, but not based on its riparian, cultural, or aquatic resources.

DAR Atlas of Hawaiian Watersheds

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 atlases with more recent stream survey data collected statewide, and developing up-to-date reports for Commission use in interim IFS recommendations. A copy of the updated inventory report for Waioli is in Appendix A. The following is a summary of the findings.

- **Point Quadrat Survey.** In the Waioli watershed, stream surveys were conducted in 1965 by the Hawaii Department of Fish and Game and 1989 and 2000 by the Division of Aquatic Resources. Surveys focuses on the lower and middle reaches. There is a large estuarine environment that supports native species near the highway. A diversity of native fish species have been found in Waioli, including three of the five endemic stream species (Table 4-2).

- **Insect Survey.** The Waioli hydrologic unit did not meet the criteria as a biotic stream of importance for native insect diversity (>19 spp), but did meet the native macrofauna diversity (>5 spp.). In historic surveys, there was not an abundance of any native species. However, there was an absence of priority 1 introduced species. In 1988, the US Fish and Wildlife Service identified Waioli as a high quality stream.

- **Watershed and Biological Rating.** The Waioli watershed has a high rating for Kauai and medium rating statewide for land cover due to the high percentage of conservation land. There is some wetland and estuarine reaches giving the watershed a good rating for shallow waters on Kauai and statewide. However, the watershed rates medium for stewardship due to the extent of invasive species and biodiversity protection. Waioli Stream has a medium rating for stream size, a medium-high rating for wetness, and a medium high rating for reach diversity resulting in an above medium rating total watershed rating for Kaui and statewide. The watershed rated medium for number of native species found and high for introduced species for both Kauaʻi and statewide, resulting in a medium score for all species for total biological rating for the island and the state. These scores combined give the Waioli watershed an overall watershed rating of medium-high for Kauai and the state.

Table 4-2. Presence (P) of native aquatic biota in Waioli Stream identified by historic surveys at varying reach classifications.

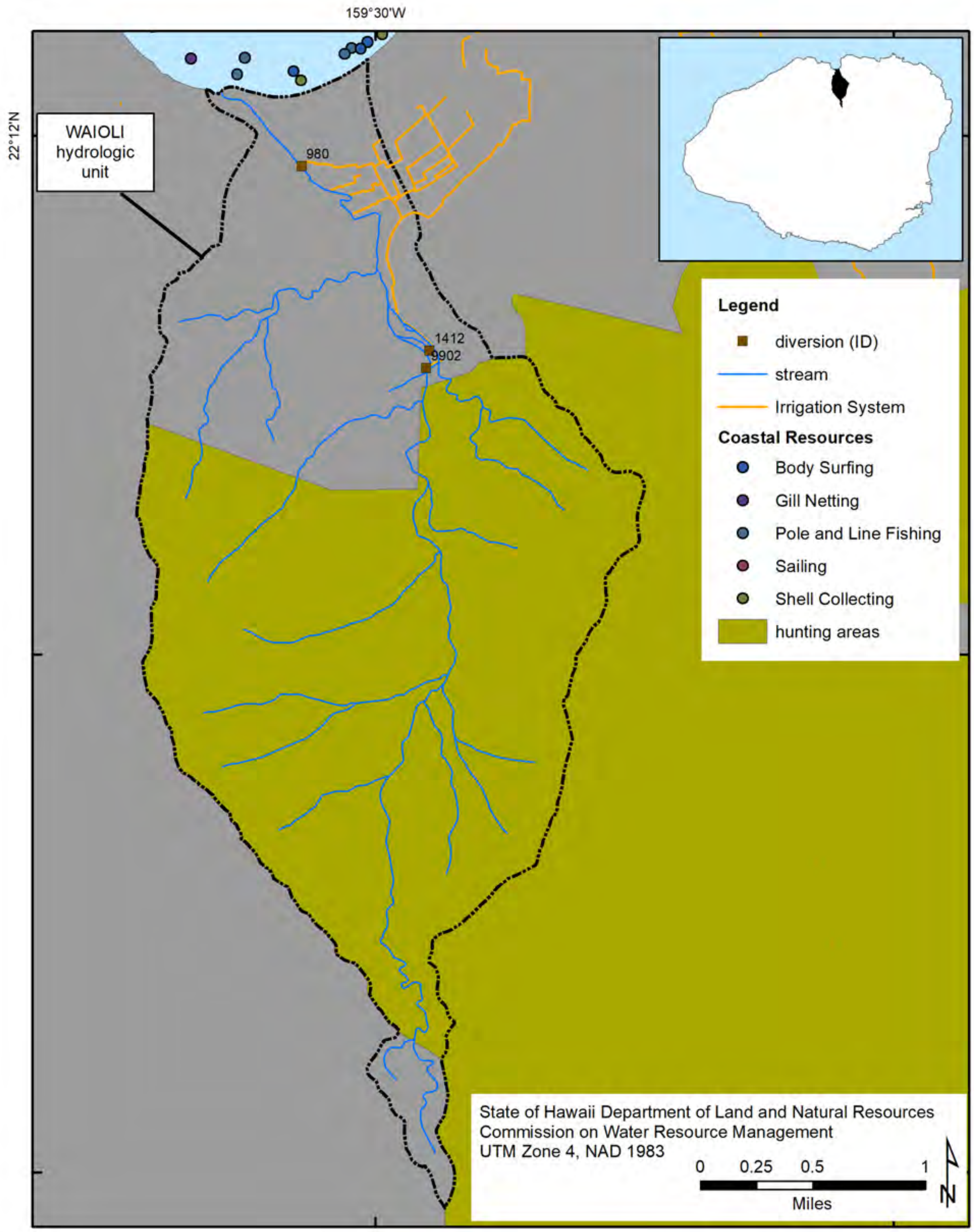
Species	Estuary	Lower	Middle	Upper
Atyoida bisulcata		P	P	
Macrobrachium grandimanus		P	P	
Awaous stamineus	P	P	P	
Stenogobius hawaiiensis				
Eleotris sandwicensis				
Sicyopterus stimpsoni		P	P	
Lentipes concolor				
Kuhlia sandvicensis			P	
Neritina granosa				
Neritina vespertina				

5. 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 Waioli hydrologic unit supports swimming, hiking, fishing, boating, hunting, and scenic views. Swimming, boating and fishing are common in larger pools of the middle and lower reaches, while hunting takes place in the upper reaches of the watershed. The Hawaii Stream Assessment identified nine recreational opportunities with three high quality experiences, giving it a regional ranking of outstanding for the Island of Kauai. Restoration of streamflow will increase the appeal of recreational opportunities. Coastal recreational features near the Waioli hydrologic unit are depicted in Figure 5-1. Body surfing, pole and line fishing, and gill netting are common along the shore.

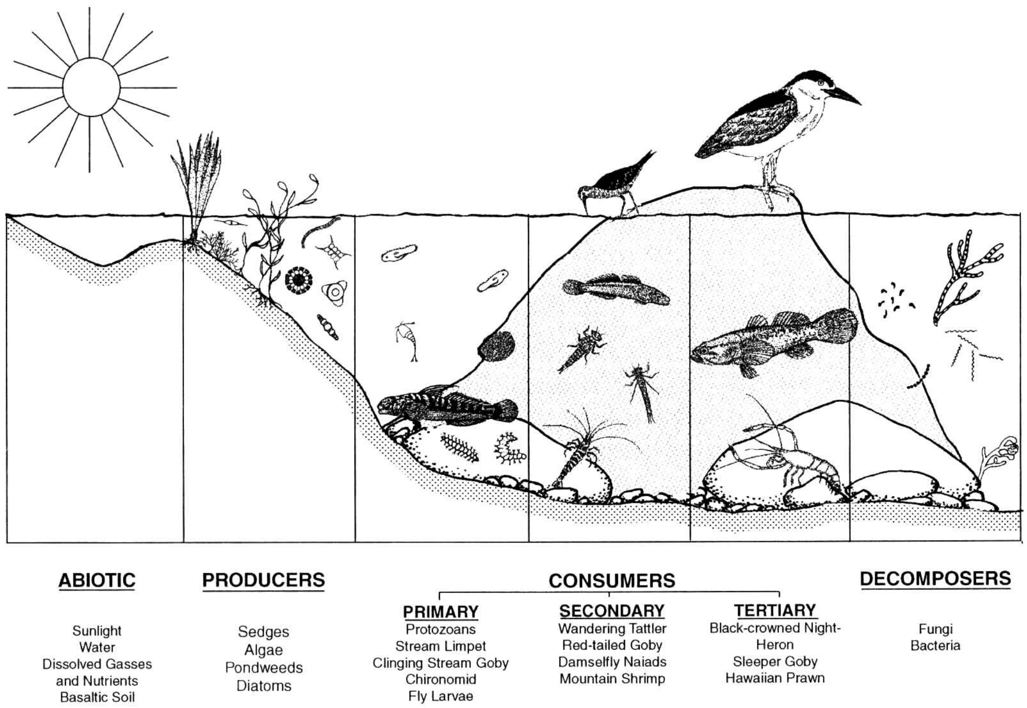
Figure 5-1. Coastal resources and public hunting areas for game mammals in the Waioli hydrologic unit, Kauai. (Source: State of Hawaii, Office of Planning, 1999, 2002b, 2002c, 2004a)



6. 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, riparian and stream vegetation, according to the State Water Code. Figure 6-1 provides a simplified ecosystem represented in a Hawaiian stream. The entire hydrologic unit, as it relates to hydrologic functions of the stream, could also be considered an ecosystem in a very broad context.

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



The Hawaiian resource-use concept of ahupuaa is closely related to the Western concepts of ecosystem maintenance. Native Hawaiians generally utilized natural resources within the limits of their ahupuaa; therefore, it was important to manage and conserve 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 Hawaii Stream Assessment indicated the presence of a palustrine wetland with 30% of the overall Lawai watershed remaining in native forest. The valley is being invaded by hau bush (*hibiscus tiliaceus*) and California grass (*Uroshloa mutica*), with feral pigs feeding on groundcover and uprooting the soil. The valley supports three species of threatened and endangered birds. The riparian resources of Waioli 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 Waioli hydrologic unit.

Category	Value
Listed threatened and endangered bird 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.	4
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.	0
Other rare organisms and communities: Many species that are candidates for endangered or threatened status have not been processed through all of the requirements of the Endangered Species Act. Also a number of plant communities associated with streams have become extremely rare. These rare organisms and communities were considered to be as indicative of natural Hawaiian biological processes as are listed threatened and endangered species.	none
Protected areas: The riparian resources of streams that pass through natural area reserves, refuges and other protected areas are accorded special protection from degradation. Protected areas were so designated because of features other than their riparian resources. The presence of these areas along a stream, however, indicates that native processes are promoted and alien influences controlled.	Forest Reserve, State Park
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.	30%
Detrimental organisms: Some animals and plants have a negative influence on streams. Wild animals (e.g., pigs, goats, deer) destroy vegetation, open forests, accelerate soil erosion, and contaminate the water with fecal material. Weedy plants can dramatically alter the nature of a stream generally by impeding water flow. Three species, California grass, hau, and red mangrove, are considered to have the greatest influence. The presence of any of these animals or plants along a stream course was considered a potentially negative factor, while the degree of detriment is dependent on the number of species present.	3 (Hau, California Grass, Pigs)

For the purpose of this section, management areas are those locales that have been identified by federal, state, county, or private entities as having natural or cultural resources of particular value. The result of various government programs and privately-funded initiatives has been a wide assortment of management areas with often common goals. Such designated areas include forest reserves, private preserves, natural area reserves, wildlife sanctuaries, national parks, historic landmarks, and so on. In Waioli, about 70 percent of the hydrologic unit falls within the Halelea Forest Reserve (Table 6-2).

Table 6-2. Management areas located within Waioli hydrologic unit. (Source: State of Hawaii, Division of Forestry and Wildlife, 2010).

Management Area	Managed by	Area (mi^2)	Percent of Unit
Halelea Forest Reserve	DLNR Division of Forestry and Wildlife	3.691	70.0%
The Halelea Forest Reserve was established by Governor's Proclamation in 1905 as Kaua'i's first forest reserve for protecting forest and watershed resources. The Halelea Forest Reserve consists of approximately 15,000 acres and is managed by the State Department of Land and Natural Resources (DLNR)'s Division of Forestry and Wildlife as a multi-use area that incorporates various, and often competing, public uses and benefits. The management goals of the Forest Reserve System include: 1) watershed protection; 2) protection of native ecosystems; 3) invasive species control; 4) recreation, including hiking, hunting, and fishing; 5) threatened and endangered species management; and 6) game animal management.			

In addition to the individual management area 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 as depicted near the Waioli hydrologic unit in Figure 6-3.

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

Management Area	Year Established	Total Area (mi^2)	Area (ac)	Percent of Unit
Kauai Watershed Alliance	2003	78.125	50,000	70.5%
The Kauai Watershed Alliance (KWA) is comprised of the County of Kauai Department of Water Supply, Hawaii State Department of Land and Natural Resources (Division of Forestry and Wildlife, Division of State Parks, Land Division), Kamehameha Schools; McBryde Sugar Company, Ltd; Grove Farm Company, Inc; Lihue Land Company; Kealia Ranch, LLC; B.A.Dyer; Princeville Development, LLC. The KWA is delineated into three primary management designations: with three Core 1 (highest priority) areas, seven Core 2 (second priority) areas, and various buffer areas (third priority). The management priorities of the KWA include: 1) ungulate management; 2) weed management; 3) KWA infrastructure; 4) Staff control to remove pest animals from upper watershed; and 5) Pest plant control, particularly of priority weed species such as *Psidium cattleianum*. As of 2013, 19.44 miles of fencing have been built, of which 4.43 miles are pig and deer fencing (8-foot) and 14.91 miles are pig (4-foot) fencing resulting in 21,084 acres of protected lands. Approximately 3.821 mi^2 of the Waioli hydrologic unit falls into the Kauai Watershed Alliance.				

A series of vegetation maps describing upland plant communities was prepared as part of a USFWS survey from 1976 to 1981 to determine the status of native forest birds and their associated habitats. Another important consideration of fish and wildlife habitat is the presence of critical habitat. Under the Endangered Species Act, the U.S. Fish and Wildlife Service is responsible for designating critical habitat for threatened and endangered species. Critical habitat for endangered or threatened birds, snails and plants that may occur in the Waioli hydrologic unit are identified in Figure 6-4. Though there are very few threatened or endangered Hawaiian species that are directly impacted by streamflow, the availability of surface water may still have indirect consequences for other species. For example, increasing streamflow reduces breeding habitat for introduced mosquitoes that transmit diseases to threatened and endangered native birds. In Waioli, the density of threatened and endangered plant species is medium at elevations above 1,200 feet and low to none at lower elevations (Figure 6-5). Approximately 61% of the unit is dominated by introduced species, while only 32% percent of the unit is dominated by native species.

Wetland Habitat

In 1974, the 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). Only 5.7 percent of the Waioli Hydrologic Unit is classified as wetlands (Figure 6-5). Palustrine wetlands are nontidal wetlands dominated by trees, shrubs, persistent emergent species, emergent mosses or lichens, or wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 percent. A total of 0.217 mi^2 (4.9 percent) of the hydrologic unit is classified as palustrine freshwater forested/shrub wetland.

Economic Value of Ecosystem Services

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 6-5. Following upon the results of the Oahu Koolau case study, some of the most valuable aspects of the forested areas are believed to be ecotourism, aesthetic pleasure, species habitat, water quality, and water quantity. Certain areas of Waioli provide critical habitat for native forest birds, endangered plants and invertebrates in Kauai.

Table 6-4. 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**	

Figure 6-2. Reserve areas for the Waioli hydrologic unit, Kauai. (Source: State of Hawaii, Office of Planning, 2007b; 2015n)

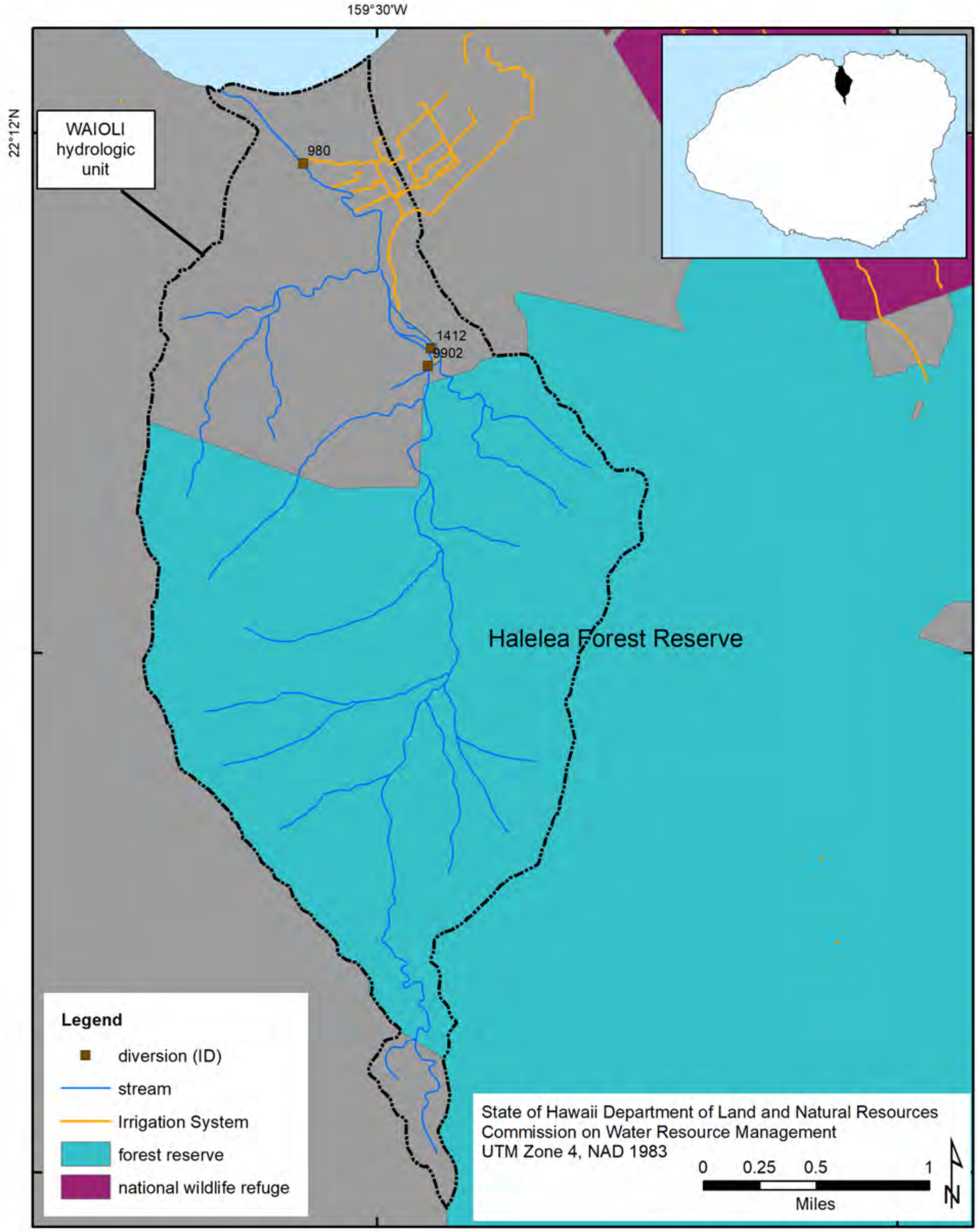


Figure 6-3. Extent of the Kauai Watershed Alliance in relation to the Waioli hydrologic unit, Kauai.

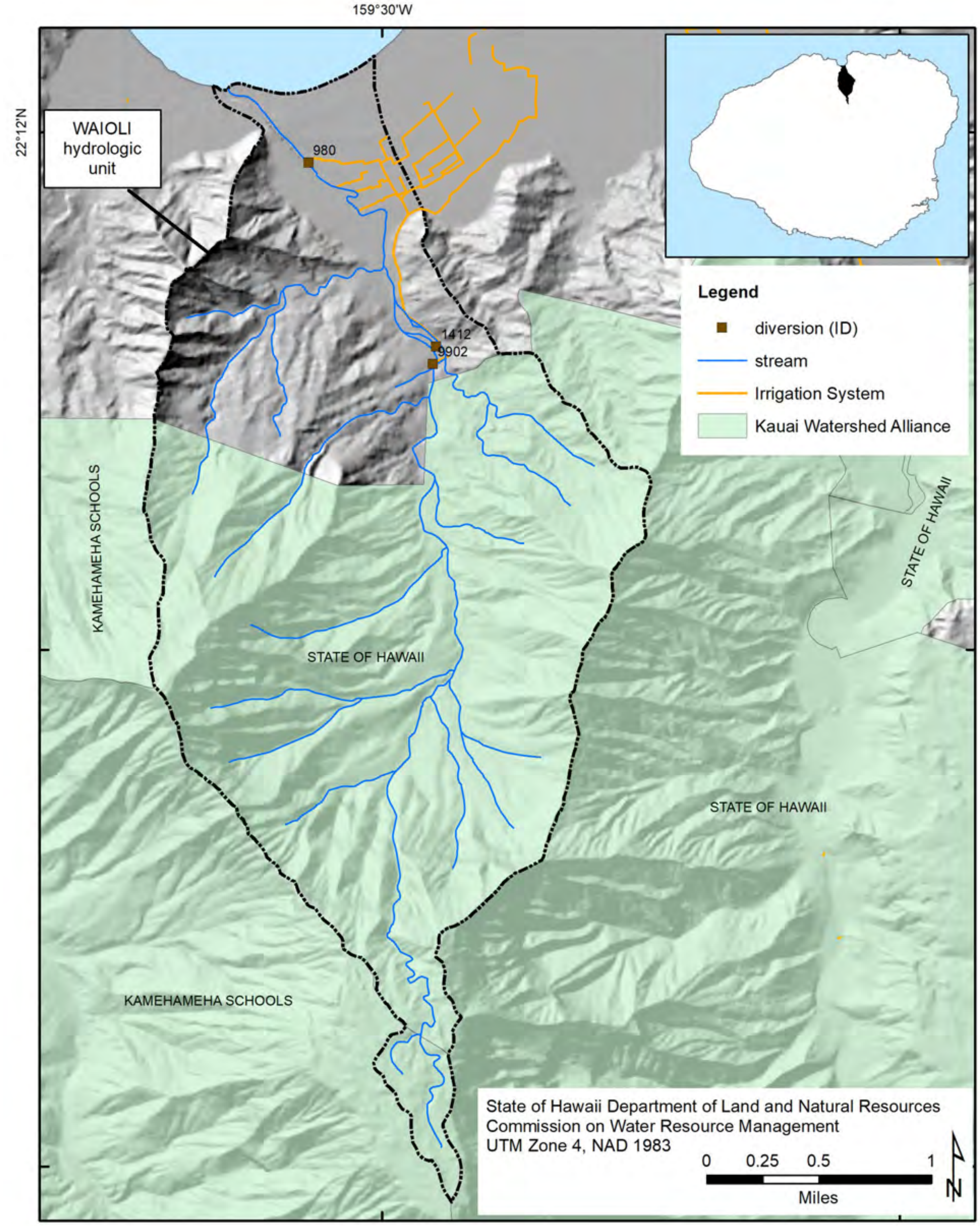


Figure 6-4. Distribution of critical habitat for particular endangered species including plants and snails in the Waioli hydrologic unit. (Source: Scott et al., 1986; State of Hawaii, Office of Planning, 1996; 2004b)

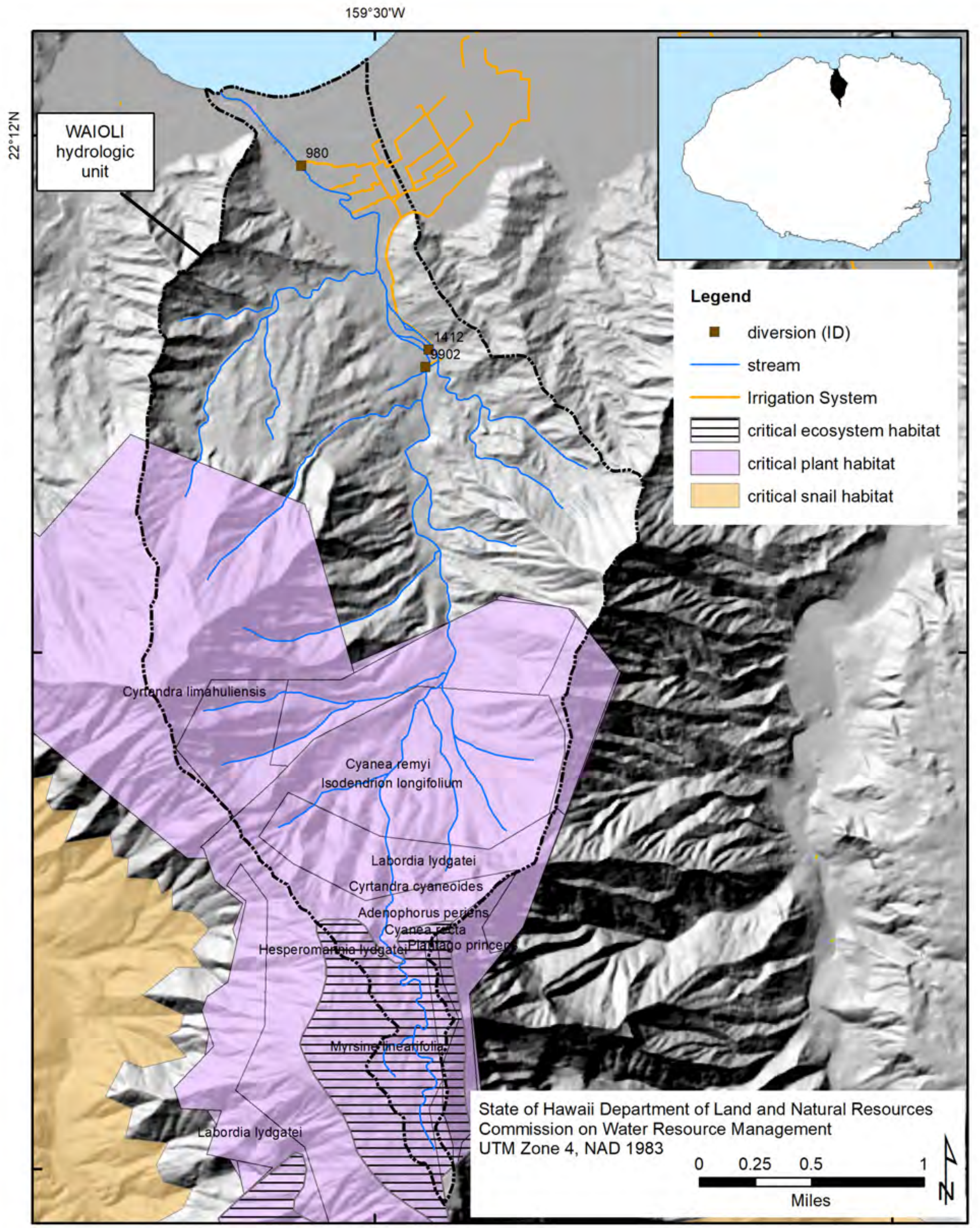


Figure 6-5. Density of threatened and endangered plants species in the Waioli hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015h)

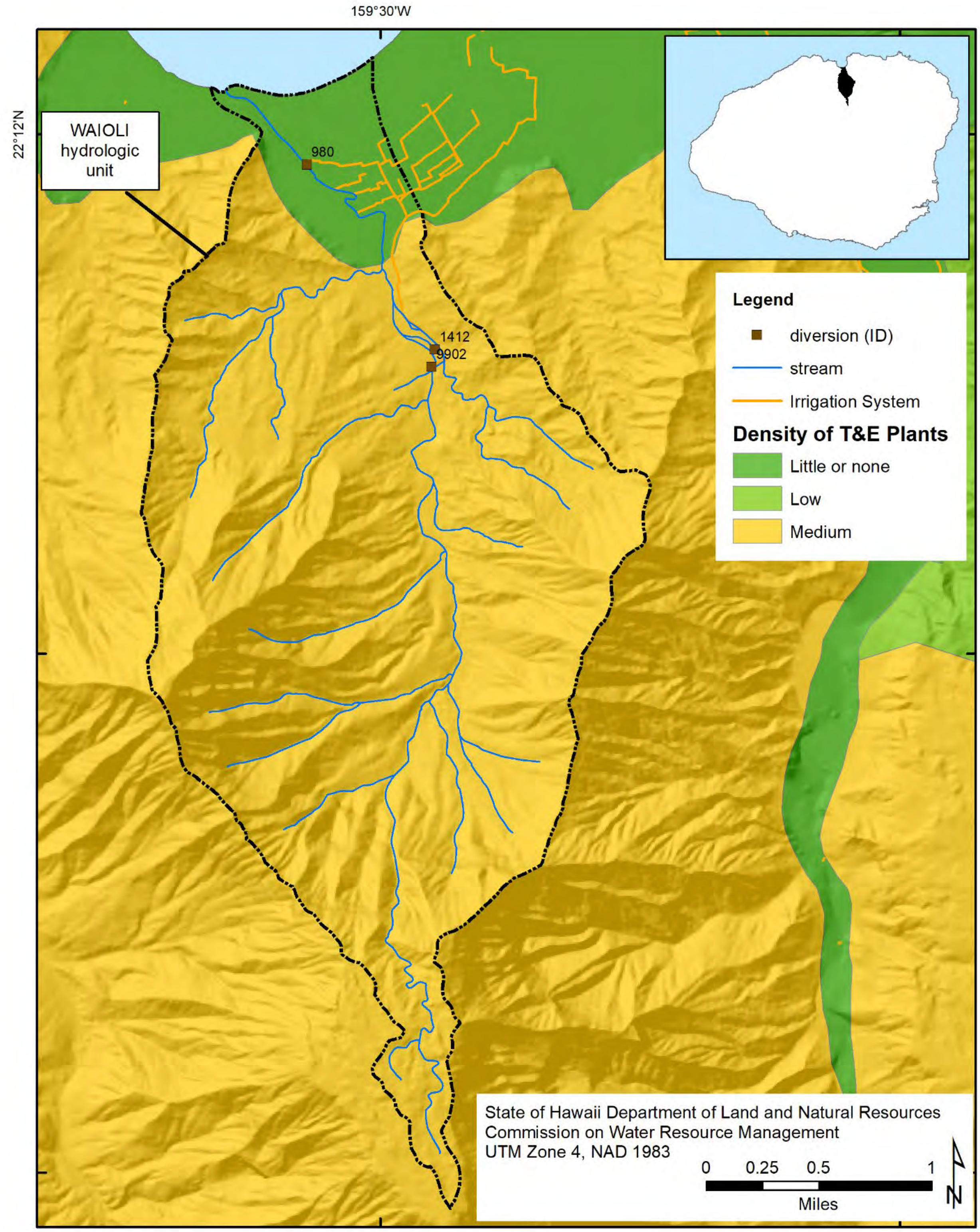
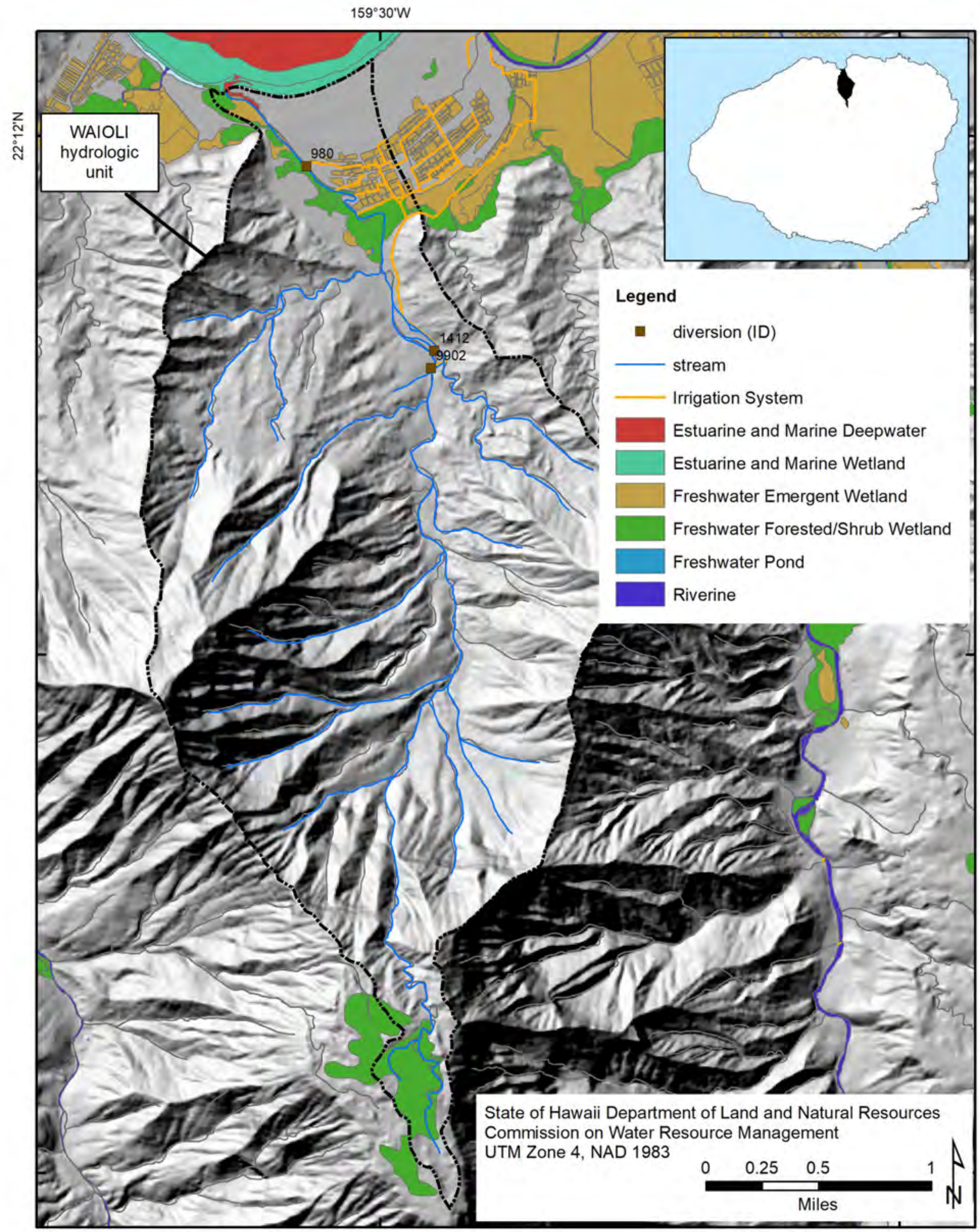


Figure 6-6. Designated wetlands by type in the Waioli hydrologic unit, Kauai. (Source: State of Hawaii, Office of Planning, 2015n)



7. 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. However, the points listed are not exhaustive and it is beyond the scope of this report to list all potential aesthetic values. The continual flow of water through the natural watercourse improves the aesthetic value of the stream.

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. Wailua State Park (including Opaekaa Falls, Wailua Falls, and Wailua Marina) is one of the most popular parks in the state with 888,100 visitors in 2007, 91 percent of which were out-of-state. The primary reason behind tourist visits to Kauai are for nature and scenery (71 percent) and relaxation (67 percent).

8. Maintenance of Water Quality

The maintenance of water quality is important due to its direct impact upon the maintenance of other instream uses such as fish and wildlife habitat, outdoor recreation, ecosystems, aesthetics, and traditional and customary Hawaiian rights. There are several factors that affect a stream's water quality, including physical, chemical, and biological attributes. The State of Hawaii Department of Health (DOH) is responsible for water quality management duties statewide. The DOH Environmental Health Administration oversees the collection, assessment, and reporting of numerous water quality parameters in three high-priority categories:

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

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

Sediment and temperature are among the primary physical constituents of water quality evaluations. They are directly impacted by the amount of water in a stream. The reduction of streamflow often results in increased water temperatures, whereas higher flows can aid in quickly diluting stream contamination events. According to a book published by the Instream Flow Council, "[w]ater temperature is one of the most important environmental factors in flowing water, affecting all forms of aquatic life (Amear et al, 2004)." While this statement is true for continental rivers, fish in Hawaii are similar, but their main requirement is flowing water. Surface water temperatures may fluctuate in response to seasonal and diurnal variations, but only a few degrees Celsius in natural streams, mainly because streams in Hawaii are so short. However, temperatures in streams with concrete-lined channels, and dewatered streams, may fluctuate widely due to the vertical solar contact. Surface water temperatures may also fluctuate widely due to water column depth, channel substrate, presence of riparian vegetation, and ground water influx. Surface water also differs considerably from ground water, generally exhibiting lower concentrations of total dissolved solids, chlorides, and other major ions, along with higher concentrations of suspended solids, turbidity, microorganisms, and organic forms of nutrients (Lau and Mink, 2006). Findings of a 2004 USGS National Water Quality Assessment (NAWQA) Program report identified land use, storm-related runoff, and ground water inflow as major contributors of surface water contaminants (Anthony 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. Areas with more exposed soil, tend to generate higher quantities of sediment.

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

Fresh waters are classified for regulatory purposes, according to the adjacent land's conservation zoning. There are two classes for the inland fresh waters. Class 1 inland waters are protected to "remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source." These waters are used for a number of purposes including domestic water supply, protection of native breeding stock, and baseline references from which human-caused changes can be measured.

Class 2 inland waters are protected for uses such as recreational purposes, support of aquatic life, and agricultural water supplies.

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

Land use affects water quality because direct runoff (rainfall that flows overland into the stream) can transport sediment and its chemical contaminants into the stream. According to the U.S. Environmental Protection Agency (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)."[6] 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

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

waters, and "recreational purposes, the support and propagation of aquatic life, and agricultural and industrial water supplies" are among the designated uses of Class 2 inland waters. This means that uses tied to the exercise of traditional and customary Hawaiian rights that are protected by the State Constitution and the State Water Code (Section 10.0, Protection of Traditional and Customary Hawaiian Rights), including but not limited to gathering, recreation, healing, and religious practices are also protected under the CWA and the WQS as designated and/or existing uses. Therefore, the Commission's interim IFS recommendation may impact the attainment of designated and existing uses, water quality criteria, and the DOH antidegradation policy, which together define the WQS and are part of the joint Commission and DOH obligation to assure sufficient water quality for instream and noninstream uses.

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

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

The sources for the 2014 Integrated Report are Hawaii's 2012 §303(d) list, plus readily-available data collected from any State water bodies over the preceding 6 years (State of Hawaii, Department of Health, 2014). 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 exceedance of WQS occurred. Waioli Stream did not appear on the 2012 List of Impaired Waters in Hawaii, Clean Water Act §303(d). The 2006 Integrated Report indicates that the current WQS require the use of *Enterococci* as the indicator bacteria for evaluating public health risks in the waters of the State; however, no new data were available for this parameter in inland waters. As mentioned in Section 5.0, Outdoor Recreational Activities, DOH maintains WQS for inland recreational waters based on the geo-mean statistic of *Enterococci*: 33 colony-forming units per 100 mL of water or a single-sample maximum of 89 colonies per 100 mL. This is for full-body contact (swimming, jumping off cliffs into waterfall pools, etc.). If

Enterococci count exceeds those values, the water body is considered to be impaired. DOH Clean Water Branch efforts have been focused on coastal areas (State of Hawaii, Department of Health, 2006, Chapter II, p.20). The marine recreational zone, which extends from the shoreline seaward to 1,000 feet from shore, requires an *Enterococci* geo-mean of less than 7 colony-forming units per 100 mL of water to protect human health (HAR 11-54-8.). The 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)." The distribution of Onsite Sewage Disposal Systems (OSDS) in and near the Waioli Hydrologic Unit is provided in Figure 8-1. There are a total of 98 OSDS in the Waioli Hydrologic unit, which probably contributes to stream and nearshore contamination of nutrients and bacteria.

The upper tributaries of the Waioli are classified as Class 1 inland waters from its headwaters to the boundary of the forest reserve as the surrounding land is in the conservation subzone "protective", while the middle reaches are not classified since they run through agriculture and rural zoned districts. The lowest reaches of the Waioli Stream are classified as a Class 2 inland water (Figure 8-2). It should be noted that there is no direct relationship between elevation and attainment of water quality standards. The proliferation of fecal bacteria in warm, moist soils inoculated by mammals and the high density of cesspools in developed areas contribute to high bacteria levels in the river. Restoration of flows in already gaining stream reaches do not impact the frequency of runoff events, which is the primary driver of pathogen loading in surface waters (Strauch et al., 2014).

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 Waioli hydrologic unit are Class A waters. Figure 8-2 shows the Waioli hydrologic unit, including inland and marine (coastal) water classifications.

The State of Hawaii Department of Health (DOH) maintains water quality standards (HAR 11-54) for recreational areas in inland recreational waters based on the geo-mean of *Enterococcus*, a fecal indicator: 33 colony-forming units per 100 mL of water or a single-sample maximum of 89 colonies per 100 mL. This is for full-body contact (swimming, jumping off cliffs, etc.). If *Enterococcus* exceeds those values, the water body is considered to be impaired. DOH also has a standing advisory for *Leptospirosis* in all freshwater streams. The marine recreational zone, which extends from the shoreline seaward to 1,000 feet from shore, requires an *Enterococci* geo-mean of less than 7 colony-forming units per 100 mL of water, to protect human health. Land-based sources of fecal pollution are common in the tropics, where high densities of animals and a warm, moist environment provide ideal conditions for the proliferation of bacteria (Strauch et al., 2014). Data collected by the State of Hawaii Department of Health available through the US Environmental Protection Agency's online database (STORET) are available in Table 8-1. As part of the Hanalei Bay Watershed Management study, the EPA monitored water quality in Waioli Stream from 2003 to 2005 (Table 8-2).

Table 8-1. Mean, standard deviation (SD), and sample size of various water quality parameters measured by the State of Hawaii Department of Health Clean Water branch from 2001 to 2003 at one downstream (elevation 1 ft a.s.l.) and one upstream (10 ft a.s.l.) site.

	Lower Waioli			Upper Waioli		
parameter	Mean	SD	n	Mean	SD	n
DO (%)	98.2	14.7	10	96.4	13.4	10
ORP (mg L^{-1})	285.8	44.8	8	325.0	34.8	8
pH	7.449	0.228	10	7.572	0.180	9
Salinity (mg L^{-1})	0.034	0.011	10	0.027	0.008	10
SpCond (μS cm^{-1})	0.0851	0.0109	10	0.0074	0.0082	10
Temp (°C)	20.4	1.0	10	20.0	1.0	10
Turbidity (mg L^{-1})	4.56	4.73	17	2.34	1.34	17

Table 8-2. Mean, standard deviation (SD), and sample size of various water quality parameters measured by the Environmental Protection Agency from 2003 to 2005 at one site near the mouth.

	Waioli at mouth		
parameter	Mean	SD	n
DO (mg L^{-1})	7.16	1.61	27
Enterococcus Bacteria (mpn)	1596.8	4096.3	24
pH	6.755	0.211	16
Total Suspended Solids (mg L^{-1})	12.1	16.7	28
Salinity (mg L^{-1})	1.22	3.36	29
SpCond (μS cm^{-1})	2147.9	5768.6	28
Temp (°C)	21.31	1.60	28
Turbidity (mg L^{-1})	13.1	22.8	28

Figure 8-1. Distribution of onsite sewage disposal systems (OSDS) in the Waioli hydrologic unit, Kauai. (Source: State of Hawaii Department of Health, 2020)

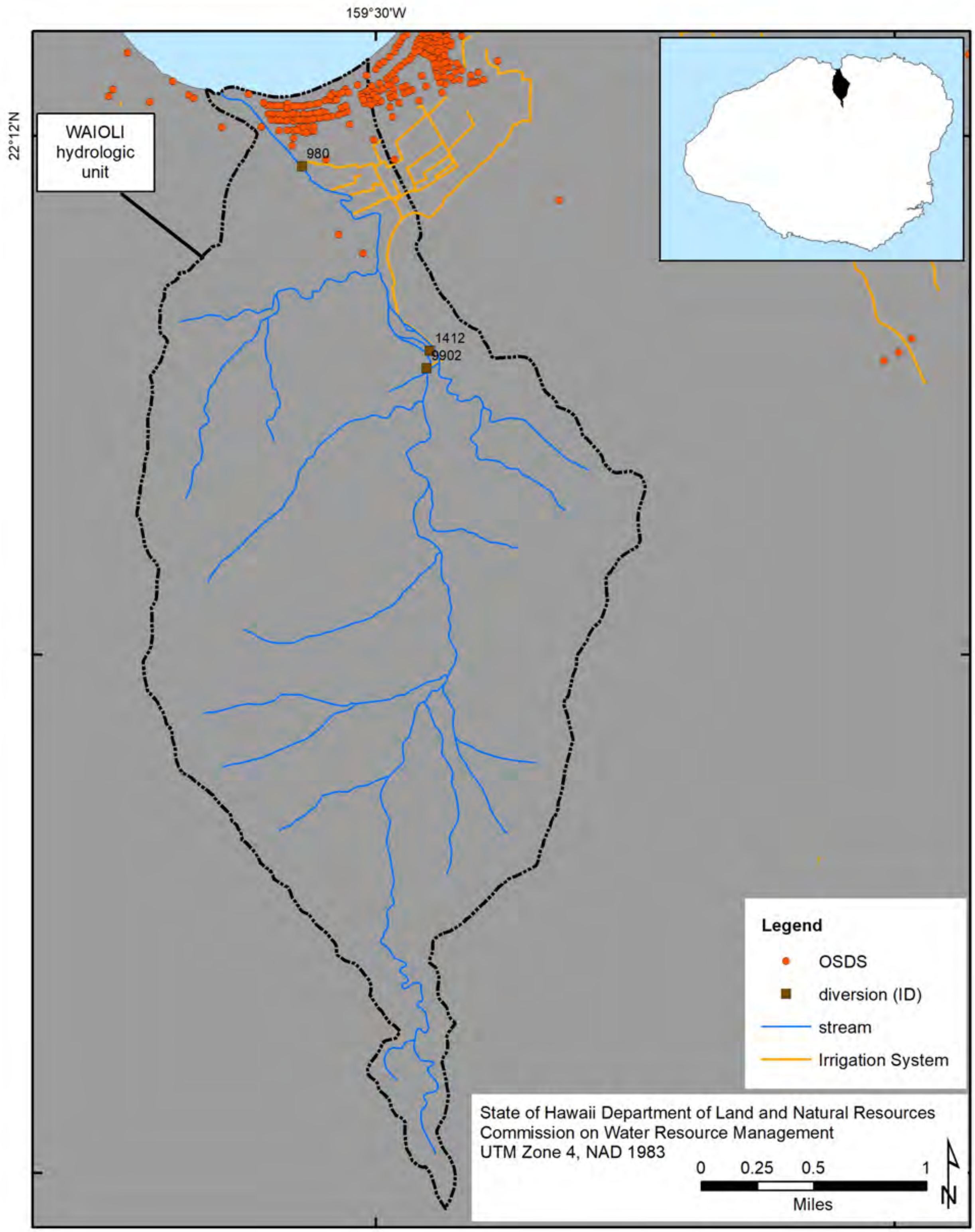
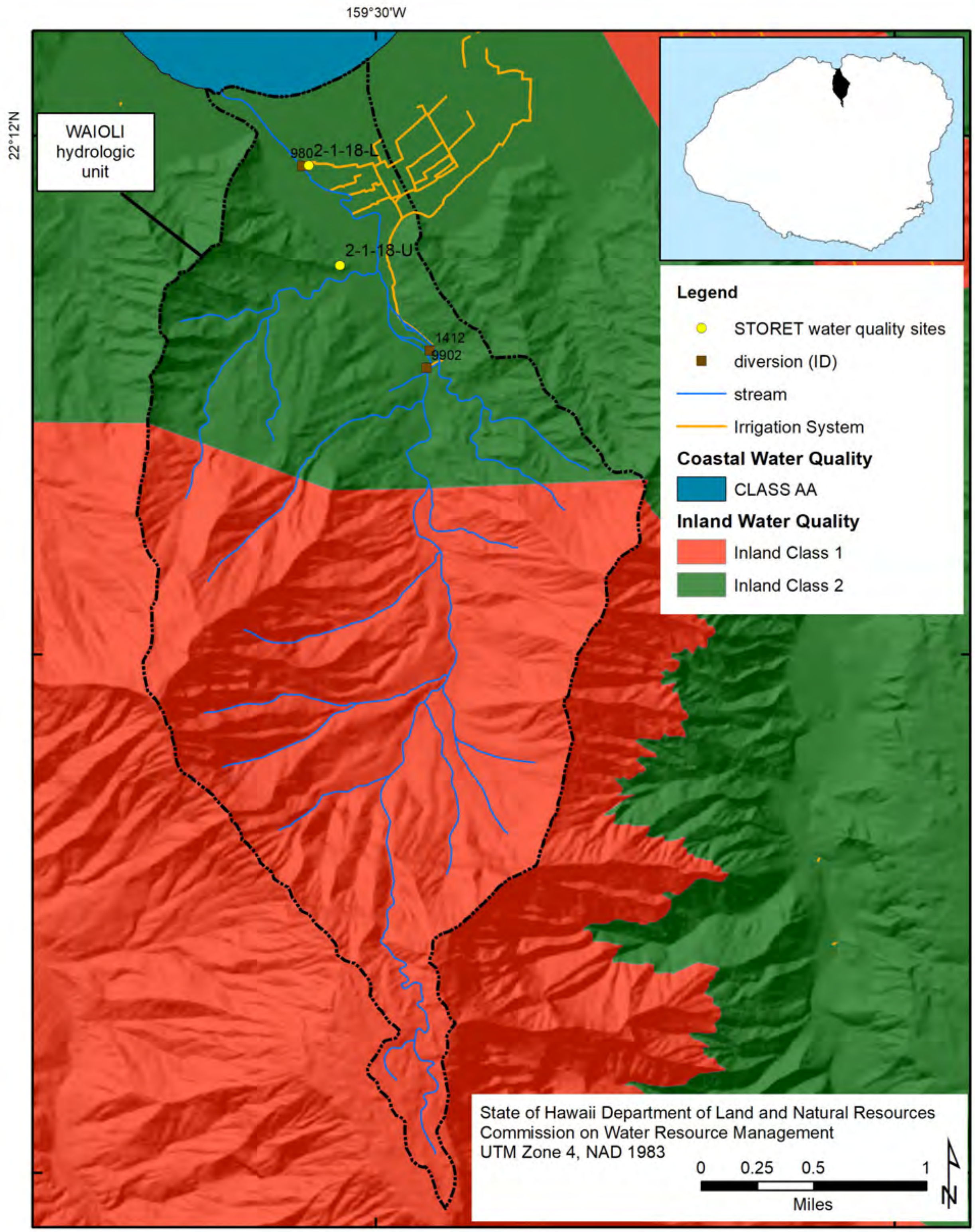


Figure 8-2. Water quality standards and DOH water quality sites for the Waioli hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015e; 2008). The classifications are general in nature and should be used in conjunction with Hawaii Administrative Rules, Chapter 11-54, Water Quality Standards.



9. 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.

A tributary of Waioli Stream is used for the conveyance of irrigation water diverted from the main stem of Waioli Stream at approximately 180 feet in elevation along the right bank. The start of the

10. 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."

Kānaka Maoli (Native Hawaiians) maintain traditional and customary rights to continue practices that have endured the many social, political, and economic changes since western contact and that Hawaiʻi continues to experience today. These subsistence, cultural, and religious practices are inextricably intertwined with natural resources and systems, the protection of which are codified in Hawaiʻi law and reaffirmed by our Constitution (Forman, 2015, p. 790).

In contrast to western property law, which upholds certain absolute rights of landowners, Hawaiʻi law limits a property owner's rights, such as the right to exclude, while safeguarding Native Hawaiian traditional and customary practices (Forman, 2015, p. 786). In the context of fresh water resources, the maintenance and restoration of instream flows plays an important role in protecting Native Hawaiian rights and practices, as they are closely connected to the health of stream resources (e.g., hīhīwai or wī, ʻōpae, ʻoʻopu) for gathering, recreation, kalo (*Colocasia esculenta* or taro) cultivation purposes, and more.

It is difficult to fully represent in words the depth of the Indigenous cultural aspects of streamflow, including traditions passed down from generation to generation regarding gathering, ceremonial and religious rites, and the central importance of water to everyday life in Hawaiʻi. Native Hawaiians have long had a "clear understanding that fresh water is the foundation of all life" and that continuous ma uka (inland) to ma kai (ocean) stream flow is "critical to providing fresh water for drinking, supporting traditional agriculture and aquaculture, recharging ground water supplies, and supporting productive estuaries and fisheries by both bringing nutrients from the uplands to the sea and maintaining a travel corridor through which native stream animals could migrate between the streams and ocean to complete their life cycles" (Sproat, 2015, p. 525–26). "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, 2001, p.II:8)."

Appurtenant Water Rights

The loʻi kalo in Waiʻoli are appurtenant, riparian, and traditional and customary Native Hawaiian uses of water and public trust purposes, which are protected by Hawaiʻi's Constitution and Water Code, HRS chapter 174C. Under Article XI, section 7 of Hawaiʻi's Constitution, the state has an obligation "to protect, control and regulate the use of Hawaiʻi's water resources for the benefit of its people." Accordingly, the Water Commission is responsible for setting "overall water conservation, quality and use policies," while also "assuring appurtenant rights." Thus, appurtenant rights have among the highest level of protection under Hawaiʻi law.

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).

Article XI, section 7 of Hawai‘i’s Constitution also protects existing riparian uses; or, the interests of people who live along the banks of rivers or streams to the reasonable use of water from that stream or river on the riparian land. Hawai‘i has a bifurcated system of rights, where anyone with riparian land retains riparian rights under the common law in non-designated areas. After an area has been “designated,” only those with existing riparian rights have preferential status (Sproat, 2015, p. 542).

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[7] 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

[7] 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.

water.[8] 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.[9] Once established, future uses are not limited to the cultivation of traditional products approximating those utilized at the time of the Mahele[10], as long as those uses are reasonable, and if in a water management area, meets the State Water Code's test of reasonable and beneficial use ("the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is both reasonable and consistent with the State and county land use plans and the public interest"). As mentioned earlier, appurtenant rights are preserved under the State Water Code, so even in designated water management areas, an unexercised appurtenant right is not extinguished and must be issued a water use permit when applied for, as long as the water use permit requirements are met.

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 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.

Native Hawaiians have relied on streams and springs to cultivate kalo long before the documented arrival of westerners in 1778. Wetland kalo requires a consistent supply of cool, fresh water flowing through the lo‘i to survive and thrive. Lo‘i receive stream water via carefully engineered open channels called ‘auwai, which transport water – sometimes great distances – from the stream to the lo‘i via gravity flow.

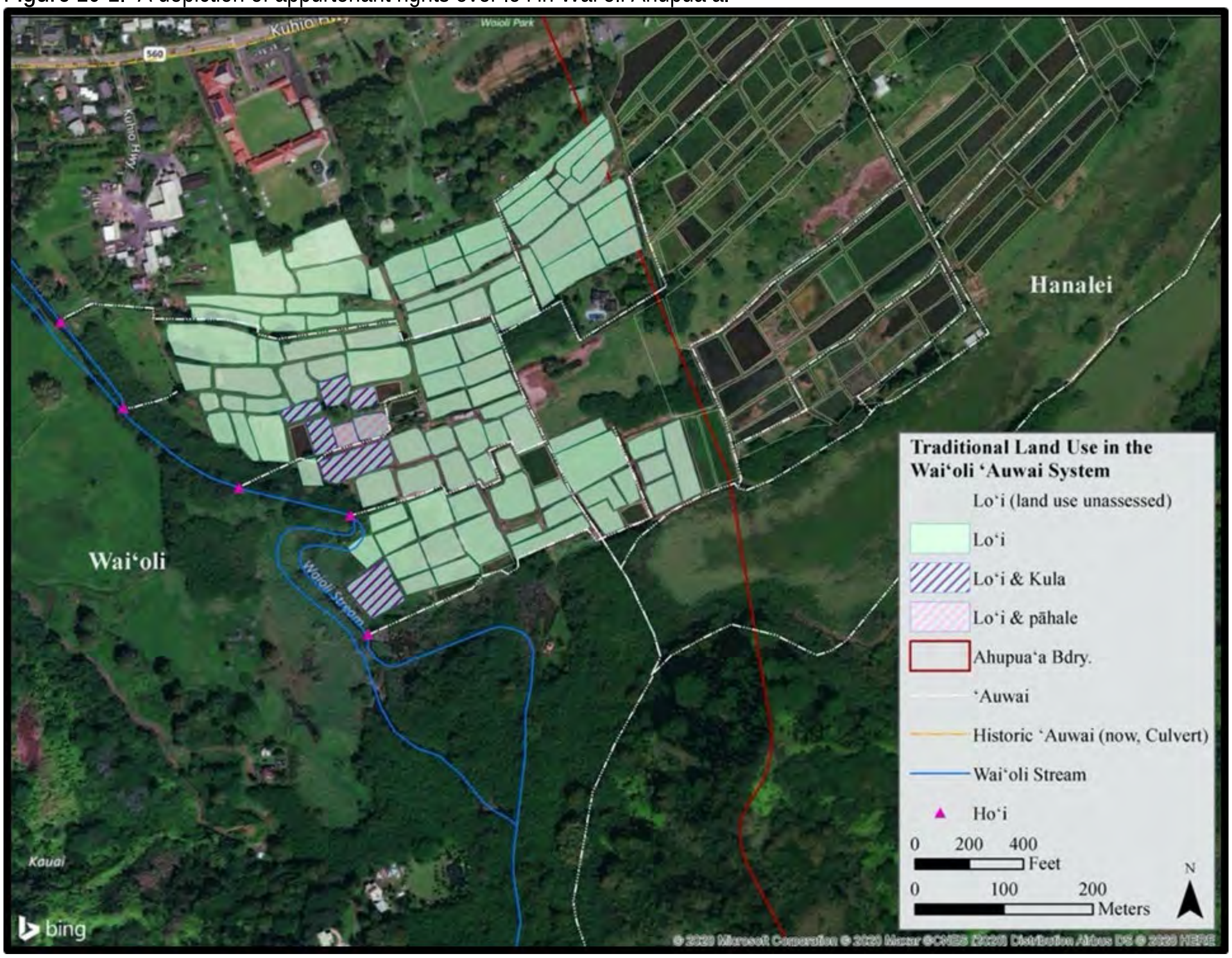
Kalo is the most culturally significant food plant in Hawai‘i and also one of Hawai‘i's highest yielding staple starch food crops, producing between 10,000 and 30,000 pounds per acre per annum under current wetland cultivation practices (State Senate, 2015). To cultivate this essential plant, Native Hawaiians engineered lo‘i and related agriculture irrigation in alluvial plains and valleys with sufficient stream resources, enabling them to transform vast areas into farmland to support the production of wetland kalo. They built complex irrigation ditches to direct and redirect water from free-flowing streams, and closely controlled water flow and circulation within the fields to prevent stagnation, keep water and kalo temperatures low, and prevent disease (Kurashima, 2019, p. 196). In a system of multiple lo‘i, water is either fed to individual lo‘i through separate ditches, or in the case of steeper slopes, water overflows and drains from one lo‘i to the next. Consistent ma uka to ma kai flow in streams is also necessary for native stream life, including ‘o‘opu, ‘ōpae, and hīhīwai (also known as wī), to reproduce.

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 ‘o‘opu, 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

[8] 54 Haw. 174, at 188; 504 .2d 1330, at 1339.
[9] 65 Haw. 531, at 554; 656 P.2d 57, at 72.
[10] *Peck v Bailey*, 8 Haw. 658, at 665 (1867).

color, locale, and growing conditions. The water needs of taro under wet conditions depend upon: 1) climate; 2) location and season (weather); 3) evaporation rate; 4) soil type; 5) ground water hydrology; 5) water temperature; and 6) agronomic conditions (crop stage; planting density and arrangement; taro variety; soil amendment and fertilization regime; loi drainage scheme; irrigation system management; and weed, pest, and disease prevalence and management).

Figure 10-1. A depiction of appurtenant rights over loʻi in Waiʻoli Ahupuaʻa.



Information relating to Pre-Contact Practices

Waiʻoli, which literally translates as "joyous waters," is an ahupuaʻa in the moku (district) of Haleleʻa. It was also called "the birthplace of rainbows" and was one of the most agriculturally productive regions on Kauaʻi (Handy, 1991, p. 419).

The Waiʻoli Valley Taro Hui and their ancestors have been cultivating kalo in Waiʻoli Valley since time immemorial. As a part of the background information reviewed by the Board of Land and Natural Resources for the February 28, 2020 Amendment to the Grant of Term for a Non-Exclusive Easement, the research conducted by the Office of Hawaiian Affairs ("OHA") established that this loʻi kalo irrigation system has been in existence since before the arrival of Westerners in Hawaiʻi. Moʻolelo, geneaological scholarship, Māhele documentation, and Native Testimony in support of Land Commission Awards in particular, establishes lo‘i use in Wai‘oli from the 1500s.[11]

While there is no written record of Wai‘oli prior to the advent and proliferation of writing in the Hawaiian Islands, mo‘olelo (oral histories) as well as mele and oli (songs and chants) were documented and distributed in the mid-1830s via Hawaiian Language Newspapers (nūpepa) (Nogelmeier, 2003, 107). Around the same time, nūpepa, as well as reports and journals, began to record the great extent of kalo cultivation in Wai‘oli. Various crops of both native and foreign origin were grown to sustain the resident population and, at the height of the whaling industry and the American Board of Commissioners for Foreign Missions, the various ships and mission ports scattered around the islands (Ka Nupepa Kuokoa 25 May 1865).

The Commission on Water Resource Management’s 1990 Hawai‘i Stream Assessment identified Wai‘oli Stream as one of only six throughout the pae ‘āina that historically supported more than fifty acres of kalo cultivation – the HSA’s largest category. Just as their ancestors did before them, members of the Hui actively manage and care for the traditional irrigation system that enables wetland kalo cultivation and nourishes the watershed and greater community.

Land Commission Awards

The Māhele records of the 1840s and 50s, including Land Commission Awards (LCAs), provide a wealth of information about Wai‘oli and its agricultural system as land transitioned to the fee-simple system and was redistributed from being the sole property of the King to a division of three categories: land belonging to the mō‘ī (monarch) as Crown Lands (one-third); land belonging to the ali‘i and konohiki (chiefs and managers of the ahupua‘a) (one-third); and land belonging to the common people (kuleana).

Kuleana are a type of LCA claimed by Kānaka Maoli tenants during the Māhele. Native tenants seeking a kuleana would submit testimony to explain the extent of their land claim, which would then be recorded in a Native Register; a witness would support a claim, which would then be recorded in the Native Testimony. Typically, the Native Register included how many ‘āpana (land parcels) the applicant was claiming, what type of property the ‘āpana was, and what if anything, was being cultivated.

Following the Māhele, the Wai‘oli Ahupua‘a was retained by the Government whereas the neighboring Hanalei ahupua‘a was retained by the Crown, excepting kuleana, Grants, and Kamehameha Deeds.[12] Within the Wai‘oli Lo‘i Kalo Irrigation System, there are LCAs, Government Grants, Crown lands and a few Kamehameha IV Deeds. Although many of these lands were cultivated and lived on by the same families for generations, it was after the 1840 Constitution, and during the Māhele, that a distinctly Kānaka Maoli, hybridized, fee-simple land tenure was established. The Hawaiian Kingdom enjoyed a phenomenal literacy rate early in history, and the detail and breadth of government documentation reflects this. A great many surveys, claims, documents, and testimonies were generated for all of the land parcels that were sold, awarded, exchanged, or gifted between 1840 and 1893.[13]

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[11] Mo‘olelo of Pīkoi and Lonoikamakahiki confirm that a Native population was living in the Wai‘oli area before the arrival of westerners in Hawai‘i. *No Lonoikamakahiki,* Ke Auokoa, 19 January 1871. According to Abraham Fornander, Kākuhihewa, who was a main character in these mo‘olelo, was born around 1540 and was the 15th Ali‘i‘aimoku of O‘ahu. Fornander 1880: 272-73. Esther Mookini puts Keawe’s birth, another main character in these mo‘olelo, some time in the 16th century. *Translation Makes Hawaiian Treasure Accessible,* Honolulu Advertiser & Star Bulletin, 20 January 1991.

[12] Kamehameha Deeds include lands sold from the Crown inventory by Kamehameha III & IV up until Crown lands became inalienable by the 1865 Act.

[13] Excepting the Crown lands which were held in the Crown inventory until they were made alienable and sold post-overthrow, Iaukea 1894.

A Cultural Impact Assessment for the Wai'oli Ahupua'a documented forty-one (41) Royal Patent Grants or grants of land sold from the Government body of land (prior to the illegal overthrow). There are fifty-five Land Commission Awards documented in the Buke Māhele for Wai'oli Ahupua'a.[14] A 2019 OHA report found that forty-one (41) kuleana awards had at least one (1) 'āpana that was lo'i, although that survey was not exhaustive (Tong 2019). Based on a thorough review of these and other documents, a significant majority of LCAs have more than one (1) 'āpana; some, up to six (6). Records from the Māhele indicate that, at that time, the system provided water to kuleana parcels, many of which were engaged in kalo cultivation (DLNR, Land Division, 2020).

The use of Wai'oli's lo'i kalo for subsistence and cultural purposes is recorded in Land Commission Awards as early as 1850. Interestingly, historical records also document the exchange or sale of products as a traditional and customary practice in this kalana (area). The claimants, their Land Commission Award(s), and one associated tax map key number are listed in Tables 11-1.

Research for the CIA's figures/tables was based solely on primary source archival materials in English and 'ōlelo Hawai'i and the use of ESRI ArcGIS software to contextualize the geospatial locations of historic maps and land features. Based on this research, the CIA estimated that, *at minimum*, 34.57 acres of the Wai'oli Lo'i Kalo Irrigation System was in lo'i between 1830-1860, with all the rights and access to water necessary to irrigate those fields. The documentation provided is contemporaneous with the use of lo'i on these same parcels today.

Historic maps establish that the 'auwai system was partly surveyed and recorded 147 years ago (Figure 10-1). This extremely early depiction confirms the existence of the mānowai and po'owai as well as the extent of the 'auwai system. When coupled with the Māhele claims (discussed above), this quantification of appurtenant rights for this acreage is reasonable based on an exhaustive survey of Māhele and other data.

All of this underscores the extent and interconnectedness of the Wai'oli Lo'i Kalo Irrigation System at the time of the Māhele as well as how little the system has changed over the last 170 years.

Land Commission Award claimants may also have legal access to utilize surface water to practice traditional and customary uses of water. The claimants, their Land Commission Award, and one associated tax map key number are listed in (Table 10-1).

[14] One of these LCA claims is crossed out in the Buke Māhele, at least two LCAs have duplicate helu (two numbers for the same award), and of course most LCAs have multiple 'āpana, ranging from 1-6 parcels.

Table 10-1. Land Commission Award (Land Award), Tax Map Key (TMK), current landowner, and claimant in the Lawai Hydrologic Unit, Kauai (Source: www.kipukadatabase.com, 2019)

TMK	Land Type	Awardee/ Grantee	Reference Date	Land Use	Source
455006009	Grant	Hanson, P.	1857	lo‘i	Gr2685
455007030	LCA	Helepalala	1844	1 lo‘i named Waiau	LCA, NR, NT,
455007004	LCA	Isaia	1851	2 lo‘i	LCA, NR, NT,
455007016	Grant	Johnson, E	1854	the lo‘i of Johnson	Grant, neighboring LCA (Kahookane)
455006008 (por)	Grant	Johnson, E	1855	“kalo lands”	neighboring LCA (A.B.C.F.M.) “surrounded by kalo”
455007010	Grant	Kaaloa, S	1856	2 lo‘i	Grant
455007003	LCA	Kahookane		the lo‘i [4] named Uhikiko	LCA, NR, NT
455007018	LCA	Kahooponopono	1820	2 lo‘i starting at the ‘auwai and the lo‘i of Nalimanui	LCA, NR, NT
455006007	LCA	Kawainui, Solomon	1851	1 lo‘i	LCA, Gr2402
455007005	LCA	Kawainui, Solomon	1840	1 lo‘i named Koele	LCA, NR, NT
455007016	LCA	Koenapuu	1848	kalo, beginning at the lo‘i of Mana	LCA, NR, NT
455007009	LCA	Kokokaia	1851	lo‘i	LCA
455007016	LCA	Kuaua	1841	1 lo‘i named Kamanui (ap1 is along the highway in Hanalei)	LCA, NR, NT
455007011	LCA	Kulou	1846	1 lo‘i beginning at the lo‘i named Paele	LCA, NR, NT
455007016	LCA	Mana	“...ever since until now 1848”	1 lo‘i named Kaumaunui	LCA, NR, NT
455007014	LCA	Nahau, D.	1851	1 lo‘i starting at the corner of Kaleikini‘s lo‘i	LCA, NR
455007032	LCA	Naiwi	1851	1 lo‘i	LCA
455007015	LCA	Nalimanui	1848	1 lo‘i in Waiau	LCA, NT
455006006	LCA	Nuku	1830	1 lo‘i named Puhaunui	LCA, NR
455007021	LCA	Nuku	1830	1 lo‘i	LCA, NR
455007016	LCA	Papa	1834	3 lo‘i bordered by the lo‘i of Pipiwai, Koi, Naiwi, Mareko	LCA, NR, NT
455007013	LCA	Pepee	1847	1 lo‘i named Kuloko	LCA, NR, NT
455007029	LCA	Waioni	1833	lo‘i in the ‘ili of Ukiuki	LCA, NR
455007033	LCA	Waioni	1833	lo‘i	LCA, NR
455006003	LCA	Nuku	1860	lo‘i & pāhale	LCA, NT, Gr2625
455006001	LCA	Kaleikini	1851	kalo & dry-land area	LCA, NT

Table 10-1. [continued]

TMK	Land Type	Awardee/ Grantee	Reference Date	Land Use	Source
455006022	LCA	Pepee	1860	lo‘i & pāhale	LCA, Gr1616 (c1860), Gr2684 (c1860)
455007006	LCA	Waioni	1833	ap2 lo‘i & kula	LCA, NR
455006002	LCA	Kokokaia	1860	lo‘i & pāhale	LCA, Gr1616
455006008	Grant	Wilcox, A	1857, 1860	“kalo lands” & kula	LCA387, LCA9070
455006008	LCA	A.B.C.F.M.	1855, 1857	lo‘i & house/Mission “bounded by kalo” “along kalo patch” “kalo corner”	Gr2403, 2625

Ahupuaa and Aha Moku Systems

In ancient Hawai‘i, moku (districts) were subdivided into ahupua‘a (approximating watersheds) for the purposes of taxation. Each ahupua‘a 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 bowl) (Handy, 1991).

Western concepts of ecosystem maintenance and watersheds are similar to the Hawaiian concept of ahupua‘a, and the Commission’s surface water hydrologic units often coincide or overlap with ahupua‘a boundaries.

In this case, however, the Hanalei Bay Watershed has been described as a kalana, a traditional Native Hawaiian land division term associated more with systematic biocultural resource management and community identity rather than governance (Winter et al., 2018). For centuries, Kānaka Maoli have managed natural and cultural resources within the larger Hanalei Bay Watershed as a single integrated system to maximize the cultivation of traditional crops and lifeways and to distribute water resources.

Within this kalana, the Wai‘oli Ahupua‘a shares stream resources with the ahupua‘a of Waipā and Hanalei. For instance, the muliwai of Wai‘oli Stream is located within the Waipā Ahupua‘a, and two (2) ho‘i (returns or outtakes) from Wai‘oli Stream return water to Hanalei River, all eventually terminating in Hanalei Bay. The ho‘i temper and distribute the overflow from floods, reducing the force and impact of floodwaters on Hanalei town (Kīpuka Kuleana, 2020). Wai‘oli’s Lo‘i Kalo Irrigation System, which was built centuries ago to be self-sufficient and allow for continuous stream flow, feeds lo‘i in both Wai‘oli and Hanalei. See Figure 11-5 – Ahupua‘a Boundary. Thus, the use of water for kalo irrigation is largely non-consumptive, instream, almost entirely within the Wai‘oli Watershed, and completely within the Hanalei Bay Watershed, consistent with the Indigenous tradition of this kalana.

Figure 10-2. Register Map 2625 depicting location of Wai‘oli Lo‘i Kalo Irrigation System.

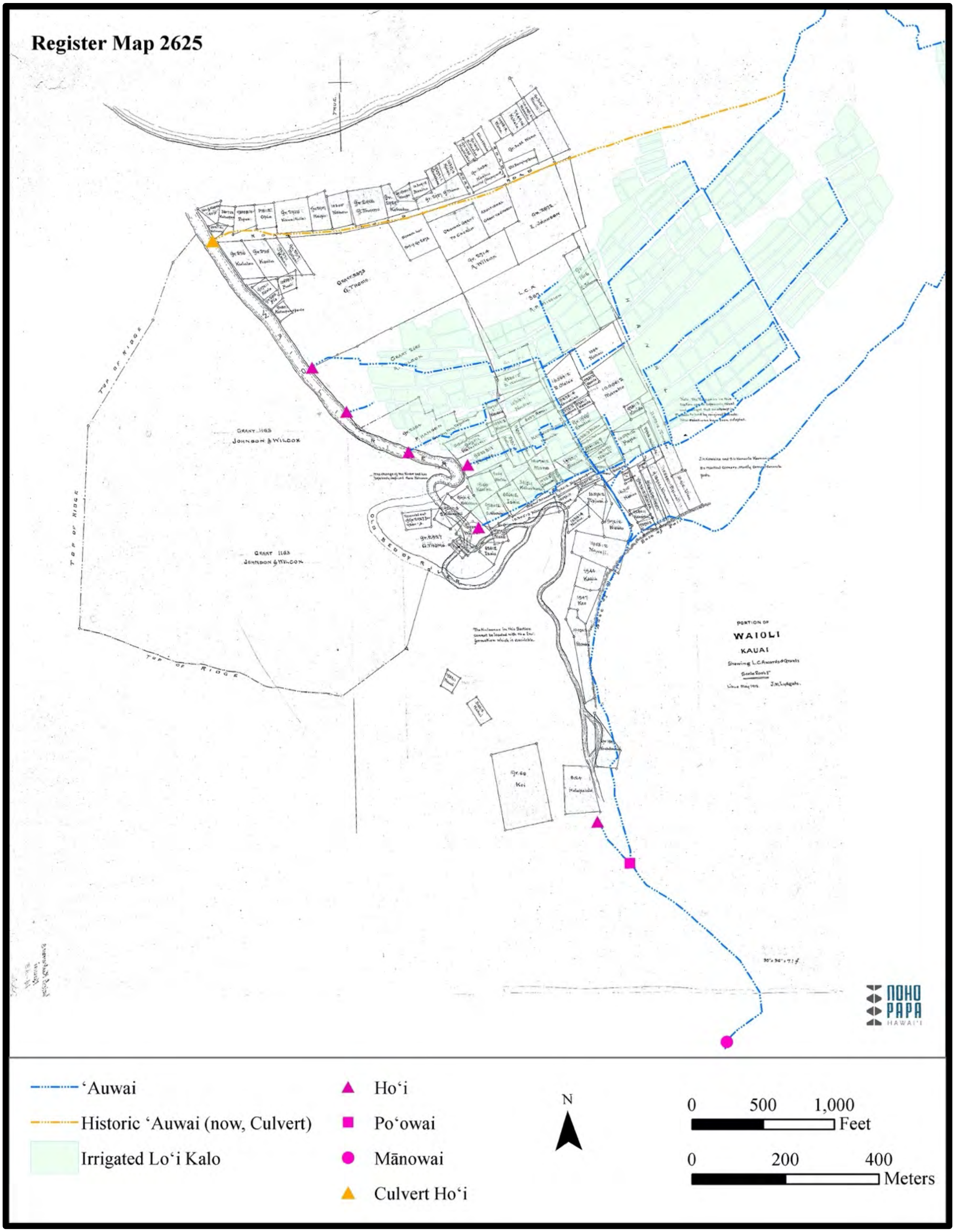


Figure 10-3. Detailed portion of Register Map 927, circa 1873. The red circle shows where a portion of the main ‘auwai flows along the base of the ridge.

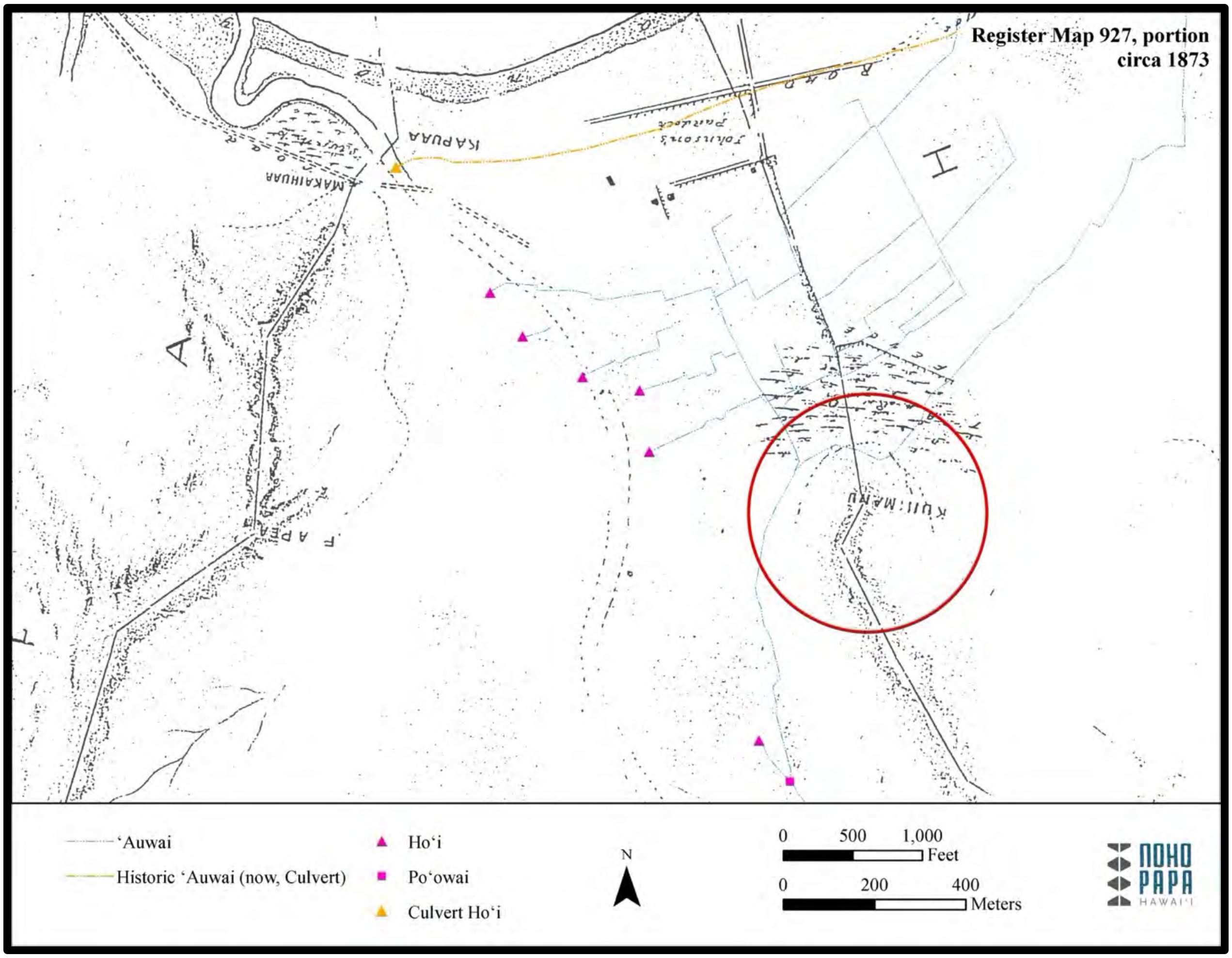


Figure 10-4. Photo taken in 1890-1892 from Kamoo Koleaka, looking out across the Waiʻoli Loʻi Kalo Irrigation System. [Source: Waiʻoli Mission Collection, negative in possession of David Forbes, photo circa 1890-1892. Also in the Bernice Pauahi Bishop Museum archives collection, Kauaʻi, Hanalei, pre-1900, folder 2, CP 96254]

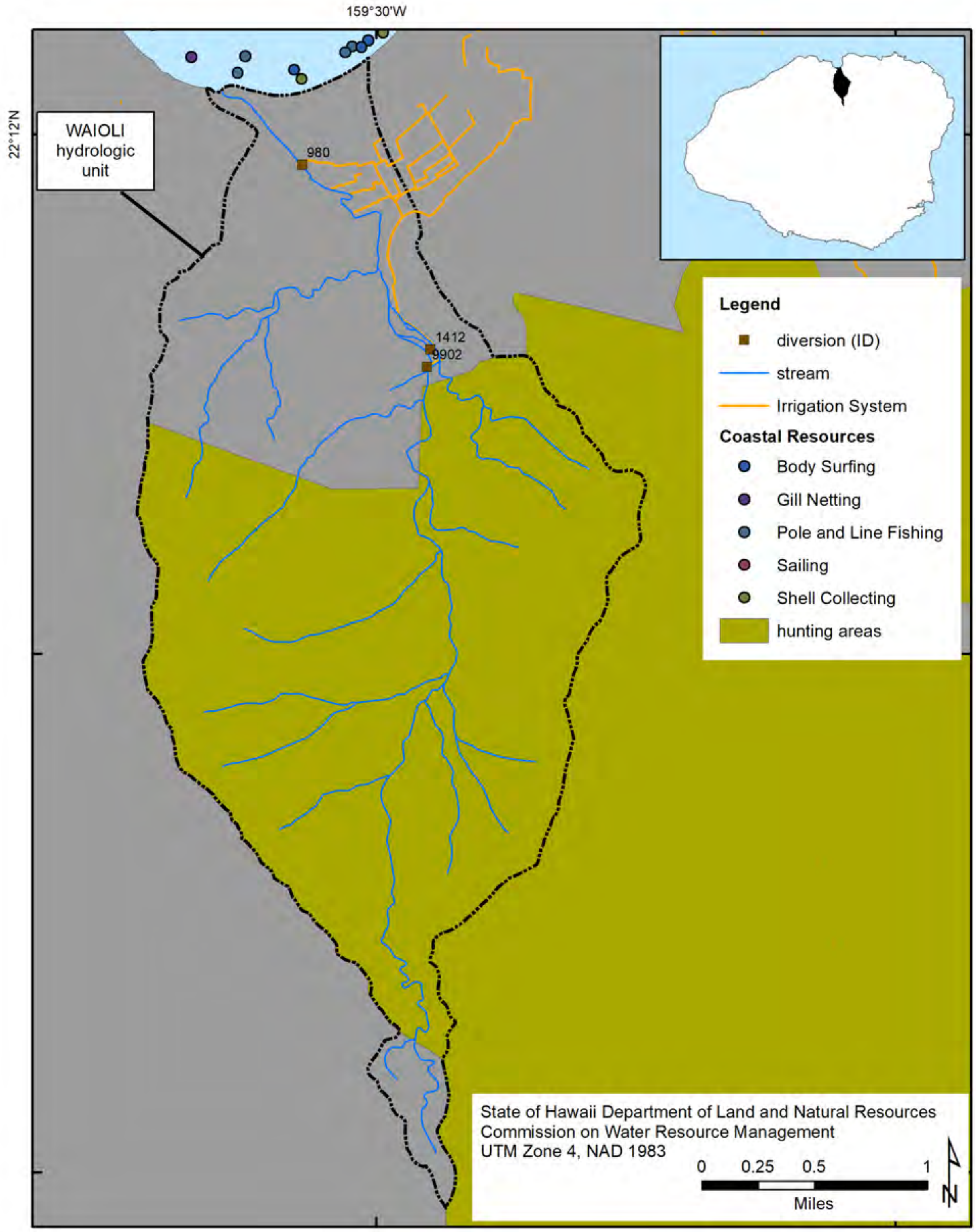
Traditional and Customary Practices

Traditional and customary Native Hawaiian practices are preserved and protected by the Hawaiʻi State Constitution, statutes and administrative regulations, and case law. Article XII, section 7 of the Hawaiʻi Constitution specifically addresses these 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." The Hawaiʻi Supreme Court declared in *Pele Defense Fund v. Paty* that "Native Hawaiian rights protected by article XII, § 7 may extend beyond the ahupuaʻa in which a native Hawaiian resides where such rights have been customarily and traditionally exercised in this manner." 73 Haw. 578, 620, 837 P.2d 1247, 1272 (1992). Moreover, traditional and customary Native Hawaiian rights do not need to be exercised continuously and can evolve as they adapt to modern society. *See, e.g., Pub. Access Shoreline Haw. v. Planning Comm'n.*, 79 Haw. 425, 441 n.26, 903 P.2d 1246, 1262 n.26 (1995); *Palama v. Sheehan*, 50 Haw. 298, 302, 440 P.2d 95, 99 (1968) (upholding the evolution of access from walking to vehicular). Moreover, the expansion of Native Hawaiian practices has been upheld, including changes in the items gathered as well as how those items are gathered. *See Pele Def. Fund v. Estate of James Campbell*, Civ. No. 89-089, 2002 WL 34205861 (Haw. 3d Cir. Aug. 26, 2002).

Hawaiʻi Revised Statutes ("HRS") section 1-1 codifies a "Hawaiian usage" exception to the common law. The Supreme Court has held that this provision "may be used as a vehicle for the continued existence of those customary rights which continued to be practiced and which worked no actual harm upon the recognized interests of others." *Kalipi v. Hawaiian Trust Co.*, 66 Haw. 1, 12, 656 P.2d 745, 751–52 (1982). HRS section 7-1, moreover, protects the right to gather certain enumerated items:

> Where the landlords have obtained, or may hereafter obtain, allodial titles to their lands, the people on each of their lands shall not be deprived of the right to take firewood, house-timber, aho cord, thatch, or ki leaf, from the land on which they live, for their own private use, but they shall not have a right to take such articles to sell for profit. The people shall also have a right to drinking water, and running water, and the right of way. The springs of water, running water, and roads shall be free to all, on all lands granted in fee simple; provided that this shall not be applicable to wells and watercourses, which individuals have made for their own use.

Figure 10-5. Cultural features, coastal activities, and hunting areas in the Waioli Hydrologic Unit, Kaua'i.



As another example, section 174C-101(c) of the Water Code similarly respects traditional and customary Native Hawaiian rights, including but not limited to, "the cultivation or propagation of taro on one's own kuleana and the gathering of hīhīwai [*Neritinu graposa* or freshwater snail], ʻōpae [*Halocaridina rubra* or shrimp], ʻoʻopu [Hawaiian freshwater goby], limu [seaweed], thatch, ti [*Cordyline terminalis* or lāʻī] leaf, aho cord, and medicinal plants for subsistence, cultural, and religious purposes."[15] HRS section 174C-101(d) declares that the "appurtenant water rights of kuleana and taro lands, along with those traditional and customary rights assured in this section, shall not be diminished or extinguished by a failure to apply for or to receive a permit under this chapter."

Today, the Waiʻoli Valley Taro Hui consists of fourteen (14) farms and sixteen (16) kalo farmers in Waiʻoli Valley, whose families have been living and working in this area for generations. In addition to kalo cultivation, these individuals are engaged in a variety of traditional and customary Native Hawaiian practices from the ma uka reaches of their watershed to the sea. Their rights and practices are representative of practitioners in this area. Several Hui members are also beneficiaries of the Department of Hawaiian Home Lands and 100% Native Hawaiian. The Hui's members are not only keenly familiar with this ʻāina (land; that which feeds) and their traditional and customary Native Hawaiian practices that have evolved over centuries, they also feel an obligation to ensure the responsible use of the land and its resources.

Despite the dramatic transformation of Kauaʻi's North Shore from a sleepy farming community into a bustling tourist destination, the exercise of traditional and customary Native Hawaiian rights has persevered and remains at the heart of community identity. For example, several farmers regularly hunt for feral pigs in the surrounding area, which is an important part of how the Hui manages the Waiʻoli Watershed and controls the invasive ungulate population. One farmer, whose family has been hunting in the area for three generations, first started this practice in Waiʻoli Valley when he was a child. The farmers never sell the meat, only share it with their families and friends, which is a recognized practice and way of life in Kauaʻi's Haleleʻa district.

Hui members also gather cultivated and uncultivated resources in the ma uka portions of Waiʻoli and along the kuāuna (banks or borders of a kalo patch) for a range of practices, including lāʻau lapaʻau (traditional Hawaiian medicine), making lei, and subsistence. For example, noni (*Morinda citrifolia* or Indian Mulberry) and the sap from kukui (*Aleurites moluccanus* or candlenut tree) nuts are relied on to maintain health or recover from illness, while ti leaves are used to make skirts for hula and to cook food in their respective imu (underground oven).

Additionally, Hui members frequent Hanalei Bay and Waiʻoli Stream, which both serve as a habitat for a range of native stream animals, including ʻoʻopu nakeʻa (*Awaous guamensisī* or freshwater goby), ʻoʻopu naniha (*Stenagobius hawaiiensis* or Naniha goby), ʻōpae kalaʻole (*Atyoida bisulcate* or spineless shrimp), ʻōpae ʻoehaʻa (*Macrobrachium grandimanus* or Hawaiian prawn), and hīhīwai or wī (*Neritina granosa*). The farmers and their extended ʻohana have long fished and gathered in these waters with nets, poles, and kahe (a ramp-like structure made from bamboo)—some of which they make themselves. And, just as they provide kalo for the people of Kauaʻi, Hui members help to feed those who fish and gather alongside them by sharing their catch (Vaughan, 2018). Although fishing, hunting, and gathering are prevalent subsistence practices, it is important to note that the Hui also perpetuate religious and spiritual traditions. For example, several members highlighted the significance of pule (prayer), while others gather fresh water for hoʻokupu (offering). A summary of these practices is provided in Table 10-2.

[15] The correct diacritical markings were added to this quotation, along with the respective scientific and common names in brackets.

Of course, the lives of the Hui members, some of whom are fourth- and fifth-generation farmers, revolve around the needs of their kalo, the cultivation of which is a cultural practice that has fed Waiʻoli Valley and its people since time immemorial. Their loʻi kalo irrigation system fosters an impressive range of kalo varieties that are enjoyed throughout Hawaiʻi, including many Indigenous ones, such as: ʻElepaio Hāuliuli, ʻEleʻele Mākoko, ʻEleʻele Naioea, Kapaaloa, Kaiala, Kaikea, Kaiuliuli, Lehua Maoli, Lehua Palaʻiʻi, Lauloa ʻEleʻele ʻŌmaʻo, Lauloa Palakea ʻEleʻele, Lauloa Palakea Papamū, Lihilihimolina, Manalauloa, Manaulu, Manini Kea, Manini ʻOwali, Manini Uliuli, Maui Lehua, Nihopuʻu, Paʻakai, Piko Keʻokeʻo, Uahiapele, and Moi.

Kalo grown by Hui members plays a major role in Kauaʻi's agricultural food system and beyond, as it is shared with a wide range of individuals and groups, including schools, community non-profits, and small and large poi mills across the pae ʻāina (archipelago). The Hui's ability to continue cultivating kalo depends on an Indigenous system of interconnected fields and flowing water from Waiʻoli Stream that has nourished the Waiʻoli plain for hundreds of years. Because they have always shared one loʻi system, Hui members and their families have longstanding knowledge of how to use water responsibly for the collective survival of all farmers who depend on the watershed, and the health of the greater community. These efforts, which include regular maintenance of the traditional irrigation system, loʻi, and nearby streams, ensure a healthy water system for the farms and for all those who value the waters that emanate from Waiʻoli Valley.

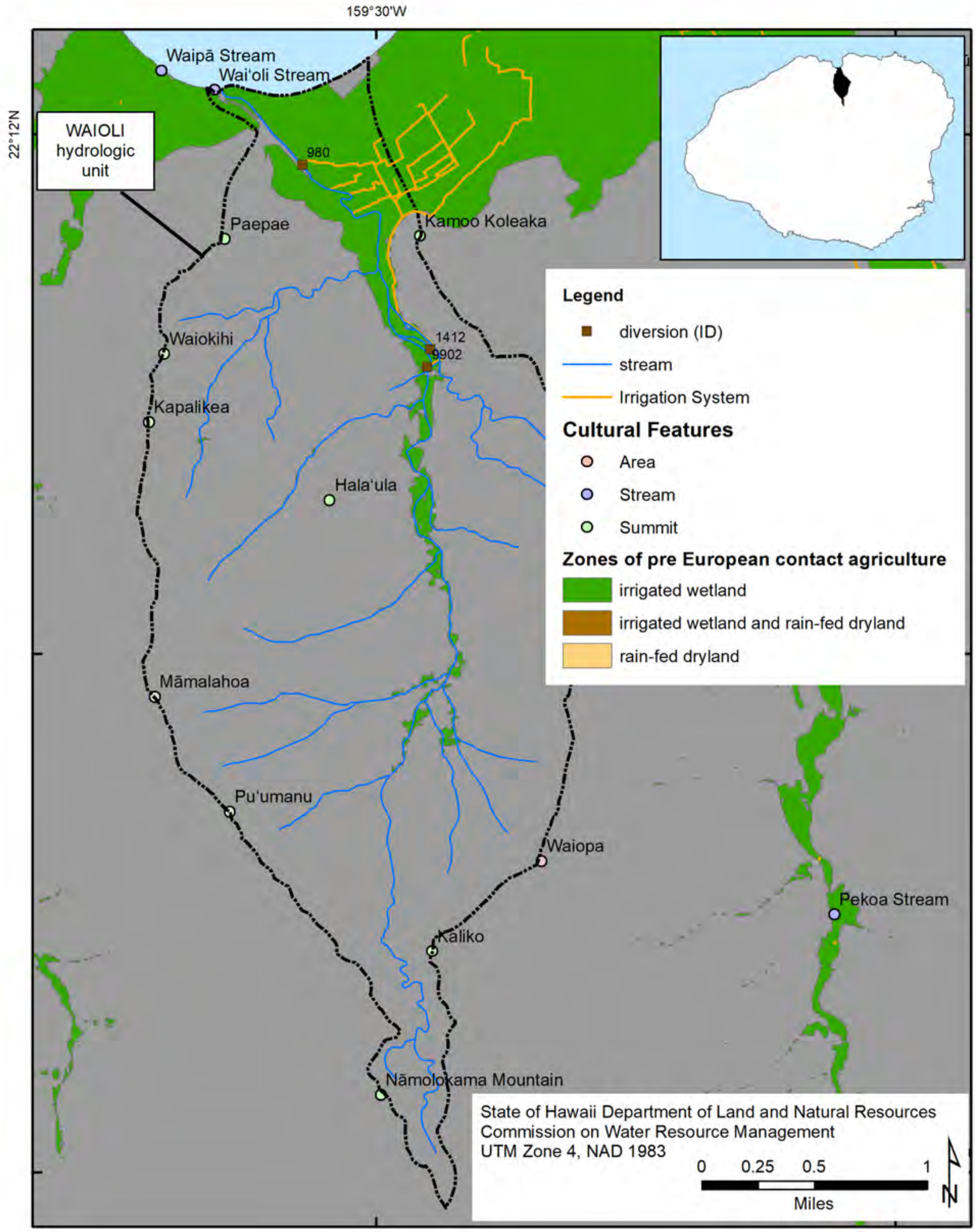
Like their ancestors before them, Hui members are also proud of the fact that they are passing on their generational knowledge and cultural practices to their own children and grandchildren in Waiʻoli, nearby Hanalei, and Wainiha. Some farmers sell their kalo, but for them it is a lifeway and generational practice specific to this ʻāina and stream, which they hope will survive the transition through the current legal system. As one Hui member noted, "Farming kalo is much more than a job, it is our way of life and how we connect to our ancestors. It is an important cultural practice that we want to pass down to our children and the generations to come." Indeed, Hui members are actively involved in the community and have provided numerous opportunities for people to learn about traditional methods of kalo cultivation. The Hui is also coordinating with DHHL beneficiaries on educational opportunities to perpetuate traditional and customary Native Hawaiian practices. In this regard, the loʻi kalo system does not simply nurture kalo cultivation, it facilitates traditional and customary Native Hawaiian practices – including, but not limited to, hunting, gathering, and fishing— as well as respect for ancient norms and values that are inextricably connected to this ʻāina and wai (fresh water).

When the Hui's way of life was threatened by severe flooding in 2018, they persisted and remained committed to kalo cultivation in the face of adversity. The adoption of numeric interim instream flow standards will ensure that this traditional and customary Native Hawaiian practice will continue to benefit current and future generations in Kauaʻi's rapidly changing North Shore community.

Table 10-2. Inventory of traditional and customary practices and resources dependent on the Wai‘oli Lo‘i Kalo Irrigation System [Note that this table is based on the results of interviews from the Cultural Impact Assessment, and representative of Hui members’ traditional and customary practices, albeit not an exhaustive list]

Traditional Cultural Practice	**Cultural Resource**	**Area/Location in Wai‘oli System**
Fishing	‘o‘opu	‘auwai (irrigation ditch)
		in stream
	wī	in stream / ma uka
	prawn	‘auwai and in stream
	‘ōpae	muliwai (stream mouth)
	‘anae (mullet)	stream
	Samoan crab	
	hinana (young ‘o‘opu)	muliwai
Gathering & Fishing	‘ohe (bamboo) to make trap	ma uka
Gathering	pōhaku (rock) to make papa ku‘i ‘ai (poi board)	ma uka along stream
	wai, for ho‘okupu, i.e., for Makahiki	ma uka
	maile	
	mokihana	
Gathering & Lā‘au Lapa‘au (Hawaiian medicine)	‘ōlena (turmeric)	ma uka & along lo‘i kūauna (border)
	koali	Wai‘oli
	kukui	ma uka
	noni	ma uka & along kuāuna
	nīoi (Hawaiian chili pepper)	along kuāuna
	lā‘ī (ti leaf)	along kūauna & Wai‘oli
Lei	palapalai (hay-scented fern)	ma uka
	nā‘ū (native gardenia)	
	hāpu‘u	
Preparing/eating food	pepeiao	
	‘uala (sweet potato)	along kuāuna
	mai‘a (banana)	
	‘ulu (breadfruit)	
	kō (sugar cane)	
Hunting	pua‘a (pig)	ma uka

Figure 10-6. Cultural features and the estimated extent of pre-contact agriculture.



11. Other Public Trust Uses of Water

IMPACT TO HAWAIIAN HOME LANDS

The Department of Hawaiian Home Lands (DHHL) does not have any land holdings in or near Waioli which would benefit from either instream flow standards or the use of water through the East Waioli Ditch.

IMPACT TO MUNICIPAL WATER SUPPLY

The Waioli Stream does not provide water for the County of Kaua‘i Department of Water Supply municipal system, nor does it provide water for any private drinking water systems.

12. 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.

In most cases, water is diverted from the stream channel via a physical diversion structure. Diversions take many forms, from small PVC pipes in the stream that remove relatively small amounts of water, to earthen auwai (ditches), hand-built rock walls, and concrete dams that remove relatively larger amounts of water. Water is most often used away from the stream channel and is not returned; however, as in the case of taro fields, water may be returned to the stream at some point downstream of its use. While the return of surface water to the stream would generally be considered a positive value, this introduces the need to consider water quality variables such as increased temperature, nutrients, and dissolved oxygen, which may impact other instream uses. Additionally, discharge of water from a ditch system into a stream may introduce invasive species.

In addition to the amount of water currently (or potentially) being diverted offstream, the Commission must also consider the diversion structure and the type of use, all 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.

The East Waioli Ditch has supported lo‘i kalo since pre-contact. During the registration phase following the passage of the State Water Code (1988-1989), 20 registrants filed paperwork identifying their use of water as an end use of East Waioli Ditch (Table 12-1). Two users also registered use of the Sin Wai Tai ditch, which is a branch of the East Waioli Ditch that supports lo‘i kalo production in Hanalei. Because many farmers lease land from other landowners (i.e., from WILCOX C&G) who also registered the use of water, its difficult to know exactly how many acres were in cultivation during the registration process. However, it is likely that approximately 113 acres were claimed to be in 1989. This is supported by data indicated that 101 acres were in production in 2015.

In addition to the users identified in Table 12-1, the registration KOBAYASHI H identified 37 acres of lo‘i kalo production from the West Waioli Ditch, whose intake is further downstream from the East Waioli Ditch.

Table 12-1. Registered users of off-stream water use for the East Waioli Ditch.

File reference	Registrant	Area (acres)	Primary Use	Instream use	Appurtenant right claim	notes
WILCOX C&G	Carol and Gaylord Wilcox	44	Taro, flowers, landscape	No	No	Parcel is leased for taro
YAGIHARA SH	Scott Yagihara	1.75	Taro	No	No	
WATARI H	Hideo Watari	6	Taro	No	Yes	Additional 6 acres leased from Waioli Corporation; 13.5 acres leased from USFWS in Hanalei
WAIOLI CORP	Barnes Riznik	30	Taro	No	No	
TASAKA K	Kenichi Tasaka	--	Taro	No	No	Incomplete declaration
TASAKA B	Bobby Tasaka	9.5	Taro	No	No	
TAI HOOK W	Wilbert Tai Hook et al.	--	Taro	No	Yes	Also irrigates 7 acres of taro from Hanalei River and unknown amount in Wainiha
SPECER CHK	Charles Spencer	0.237	Taro	No	Yes	Also irrigates 7 acres of taro from Hanalei River
SAY P	Paul Say	7	Taro	No	No	Parcel is leased for taro
REYES J	John Reyes	2.06	Taro	No	Yes	
OMO P	Patrick Omo	2.98	Taro	No	No	
MITSUI MM	Mike Mitsui	11	Taro	No	No	
MIIKE D	Donald Miike	7.9	Taro	No	No	Registration says East Waioli Ditch from Hanalei Stream
MASADA FARM	James Masada	3.5	Taro	No	Yes	
KAONA FARM	Clarence Kaona	3.53	Taro	No	No	
HARAGUCHI T	Tomio Haraguchi	6.57	Taro	No	No	
GARMA N	Norbert Garma	10.28	Taro, fish pond	No	No	End user of Sin Tai Wai Ditch from Waioli Stream
DAWA	Mrs. Dawa	1.75	Taro	No	No	
ANDRADE C	Carlos Andrade	--	Taro	No	No	No known acreage
ANDERSON GA	George Anderson	8.81	Taro, fish ponds	Yes	No	End user of Sin Tai Wai Ditch

Water Leaving the Waioli Hydrologic Unit in Ditch Systems

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 per 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.

In many locations, measuring or monitoring the amount of water diverted from the stream is logistically and physically challenging. In Waioli, very few measurements have been made of the amount of water flowing into the East Waioli Ditch and ‘auwai system (Table 12-2).

In 2007, the Commission initiated a contract for the purpose of conducting statewide field investigations to verify and inventory surface water uses and stream diversions, and update existing surface water information (Figure 12-1). Priority 1 Areas, under this contract, include all east Maui streams that are part of the pending Petition to Amend Interim Instream Flow Standards. Data from this study, along with information collected from Commission staff site visits, and information extracted from the original registration files are included in Table 12-3.

Table 12-2. Off-stream water use measurements for the East Waioli Ditch. (Source: Gingerich, 2012, CWRM site visits)
[Flows are in million gallons per day (mgd)]

location	Date	Measurement (mgd)	Flow (Percentile) at USGS 16103000 Hanalei River
Ka01 total (A+C+D)	8/8/2005	5.10	85.8 (
Ka01 total (A+C+D)	9/21/2005	5.13	260 (
Below Intake on Waioli Trib	2/9/2019	10.07	284

Table 12-3. Registered diversions in the Waioli hydrologic unit, Kauai.
[Source of photos are denoted at the end of each description; CWRM, Commission on Water Resource Management;Chevrons ( ) indicate general direction of natural water flow to and out of diversions; Arrows ( ) 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.1412	EAST WAIOLI DITCH	5-6-002:001	unknown	Yes	Yes	Yes	Yes

Photos. a) Downstream view of Waioli tributary from above the diversion (CWRM, 2019); b) Diversion intake on right bank (CWRM, 2019); Downstream view of Waioli tributary and intake from right bank (CWRM, 2019); Po‘owai (diversion intake) on Waioli Tributary on right bank (CWRM, 2019)

a)

b)

c)

d)

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
DIV.9902	EAST WAIOLI DITCH	5-6-002:001	unknown	Yes	Yes	Yes	Yes

Photos. a) Upstream view of Waioli Stream above the historic mānowai that diverted flow into a tributary on the right bank (CWRM, 2019); b) inflow from temporary mānowai from Waioli Stream to Waioli tributary (CWRM, 2019); c) view of historic mānowai from right bank (CWRM, 2019); d) view of historic mānowai from left bank on Waioli Stream (CWRM, 2019)

a)

b)

c)

d)

Current Agricultural Demands

As agricultural commodities changed substantially with the closure of large-scale pineapple and sugarcane in the 1980s-2000s, the HDOA funded an updated baseline study of agricultural land use (ALUM) for 2015. Agriculturally zoned land occupies about 5% of the Waioli hydrologic unit. Based on the 2015 Department of Agriculture Baseline Agriculture Survey (Perroy et al., 2015), the only agriculture taking place in the Waioli hydrologic unit is the cultivation of taro (Table 12-4, Figure 12-2). The HDOA is currently in the process of developing agricultural incentives based on classifications of Important Agricultural Lands. The burden of maintaining a non-potable water system can be more easily supported by large private landowners which have divested interests across their assets. Water from the East Waioli ditch system was used historically for the cultivation of taro and small diversified agriculture both in and outside of the Waioli hydrologic unit (Table 12-5). The ditch services several private and/or cooperative taro farmers in Waioli and Hanalei region. The HSA identified Waioli as one of six watersheds supporting at least 50 acres of lo‘i kalo. During the mid 1800s, at least 34.57 acres of lo‘i were in active cultivation as described in Section 10. Some of the water diverted from Waioli Stream to supply these lo‘i was returned through ho‘i to Waioli Stream, while a smaller portion flowed to Hanalei Bay through other ho‘i into Hanalei River. In 2005, 0.69 mgd out of 4.89 mgd (14%) and 0.63 mgd out of 4.83 mgd (13%) was discharged into Hanalei River. Flow returning to the stream of origin supports additional instream uses.

Table 12-4. Crop category, total land area and percent of unit for agriculture in the Waioli hydrologic unit. (Perroy et al., 2015)

Crop Category	Total Land Area (mi^2)	Acres	Percent of Unit
taro	0.049	31.36	0.9%

In 2005 and 2006, OHA funded a USGS study to make a sequence of flow measurements at various locations in ‘auwai and lo‘i complexes throughout the state (Gingrich et al., 2007). One of the locations choosen was the East Waioli ditch and lo‘i complex. Data from that study are presented in Table 12-6, with locations identified in Figure 12-1.

Table 12-5. Crop category, acreage, estimated irrigation demand, and water demand by crop supplied by the East Waioli Ditch based on the 2015 baseline agricultural survey. (Source: Perroy et al., 2015)

Crop Category	Acreage	Consumptive Irrigation Demand (gad)	Crop Water Demand (mgd)
Taro[a]	101.12	13,400	1.355

[a]assumes no flow through reuse of water

Table 12-6. Complex and lo'i measurements, area (acre), and calculated water use (gallons per acre per day; gad) by location in the East Waioli Ditch. (Source: Gingerich et al., 2007)

location	Date/time	Area (acre)	Measurement (mgd)	Water Use (gad)
Ka01A-CI	8/8/2005 08:50	32.89	4.2	130,000
	9/21/2005 11:47	32.89	4.2	130,000
Ka01B-CI	8/8/2005 10:00	2.98	0.36	120,000
	9/21/2005 12:46	2.98	0.55	180,000
Ka01C-CI	8/8/2005 11:32	5.46	0.54	100,000
	9/21/2005 12:11	5.46	0.38	70,000
Ka01D-CI	8/8/2005 15:05	4.18	0.15	36,000
	9/21/2005 15:10	4.18	0.25	60,000
Ka01B-LI	8/8/2005 14:00	0.21	0.076	370,000
	9/21/2005 13:37	0.21	0.047	230,000
Ka01C-LI	8/8/2005 10:30	0.16	0.028	170,000
	9/21/2005 12:55	0.16	0.019	120,000

Figure 12-1. East Waioli Ditch lo'i complex ditch flow measurement locations (Source: Gingerich et al., 2007)

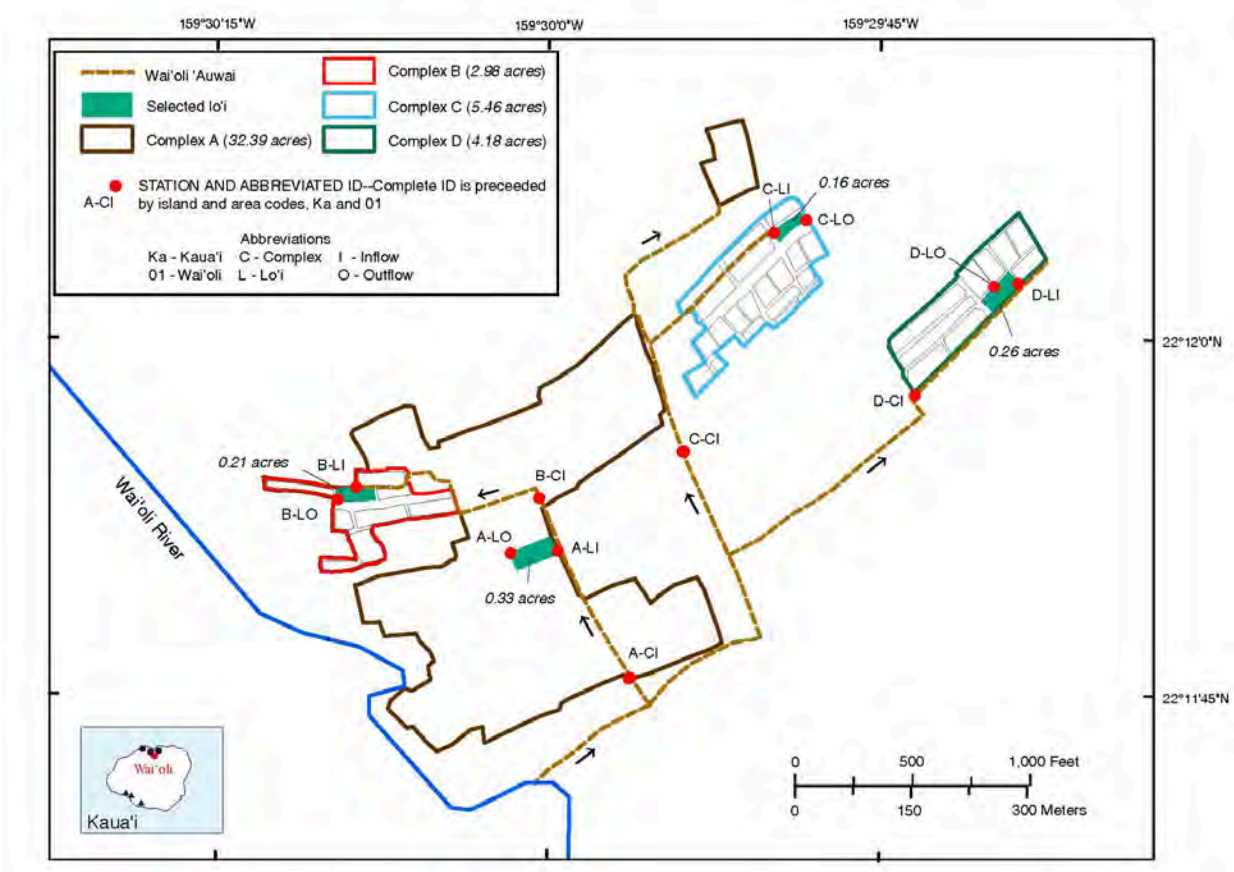
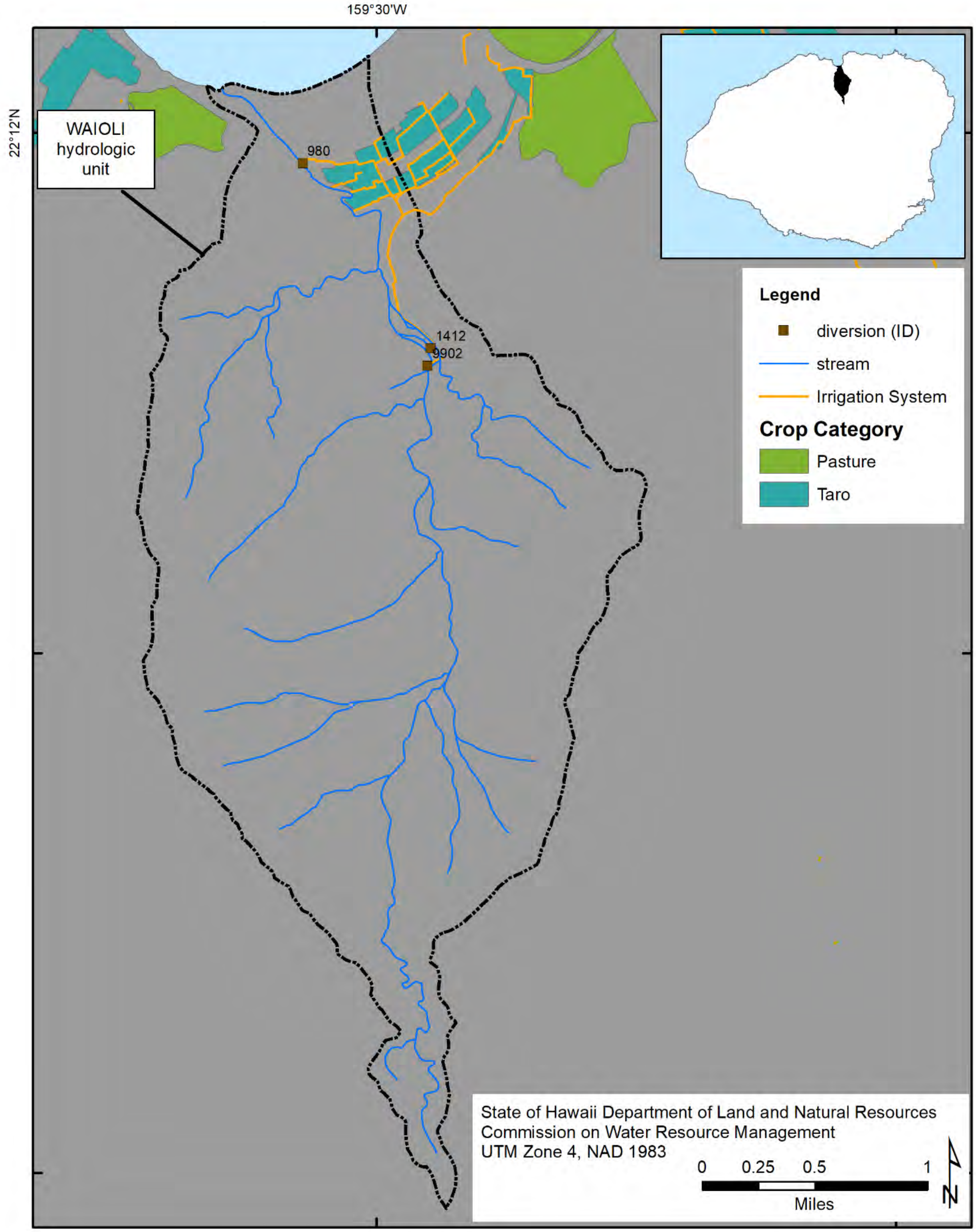


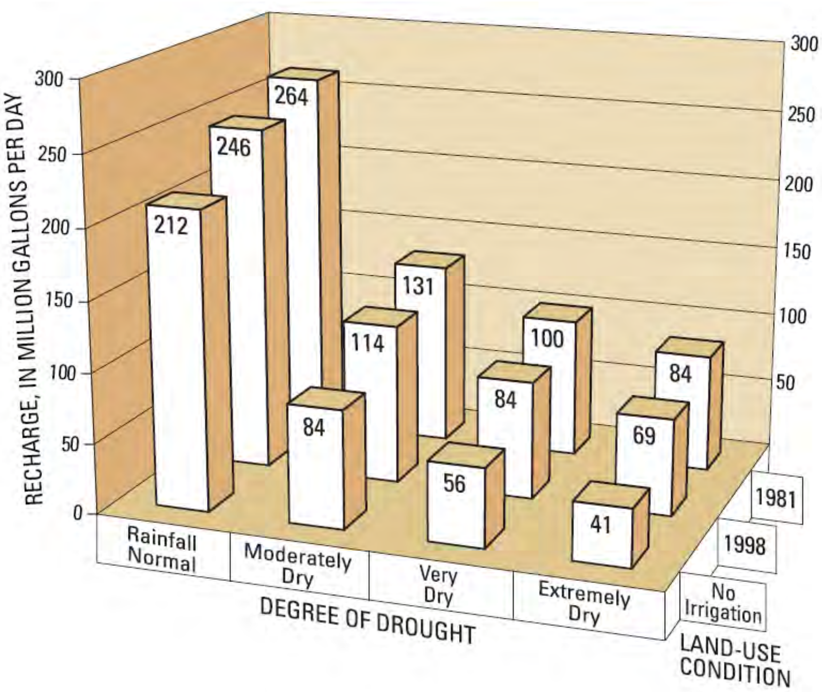
Figure 12-2. 2015 Baseline Agricultural Land Use map for the Waioli hydrologic unit, Maui. (Source: (Perroy et al. 2016)



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 groundwater recharge because it affects the amount of water available for irrigation. The effects of irrigation water on groundwater recharge can be analyzed using the water budget equation[16]. Engott and Vana (2007) at the USGS conducted a study that estimated each of the water budget components for west and central Maui using data from 1926 to 2004. Components of the water budget include rainfall, fog drip, irrigation, runoff, evapotranspiration, and recharge. 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 (Figure 12-3). Droughts, or periods of lower than average rainfall, have been shown to drastically decrease groundwater recharge. 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).

Figure 12-3. 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

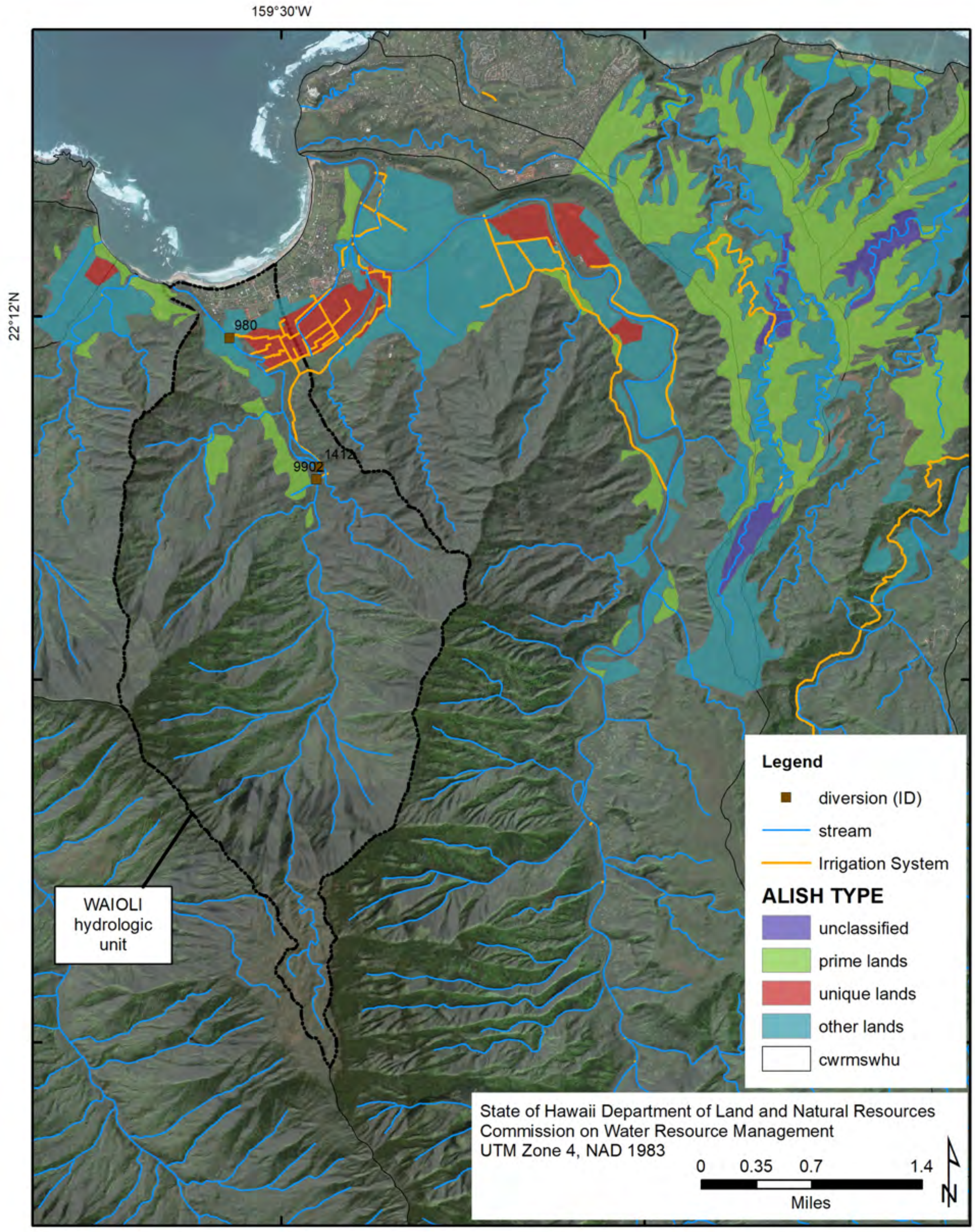
In 1977, the Agricultural Lands of Importance to the State of Hawaii (ALISH) were completed by the State Department of Agriculture (HDOA), with the assistance of the Soil Conservation Service (SCS), U.S. Department of Agriculture, and the University of Hawaii College of Tropical Agriculture and Human Resources. Three classes of agriculturally important lands were established for Hawaii in conjunction with the SCS in an effort to inventory prime agricultural lands nationwide (Figure 14-4). Hawaii's effort resulted in the classification system of lands as: 1) Prime agricultural land; 2) Unique

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

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. The ALISH was intended to serve as a long-term planning guidance for land use decisions related to important agricultural lands.

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. The Waioli hydrologic unit has 1.24 square miles of prime agricultural land (2.29%), 0.06 square miles of unique agricultural land (1.11%), and 0.109 square miles of land designated as "other" (2.01%) based on the ALISH dataset. There are approximately 0.228 square miles of unique agricultural lands and 0.154 square miles of other agricultural lands directly dependent on water from the East Waioli Ditch.

Figure 12-4. Agricultural Lands Important to the State of Hawai'i (ALISH) classification for the Waioli and neighboring hydrologic units. (Source: State of Hawai'i Department of Agriculture, 1977)



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14. Appendices

Appendix A Wai‘oli, Kaua‘i, Hawai‘i. June 2008. DAR Watershed Code: 21018
State of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources.

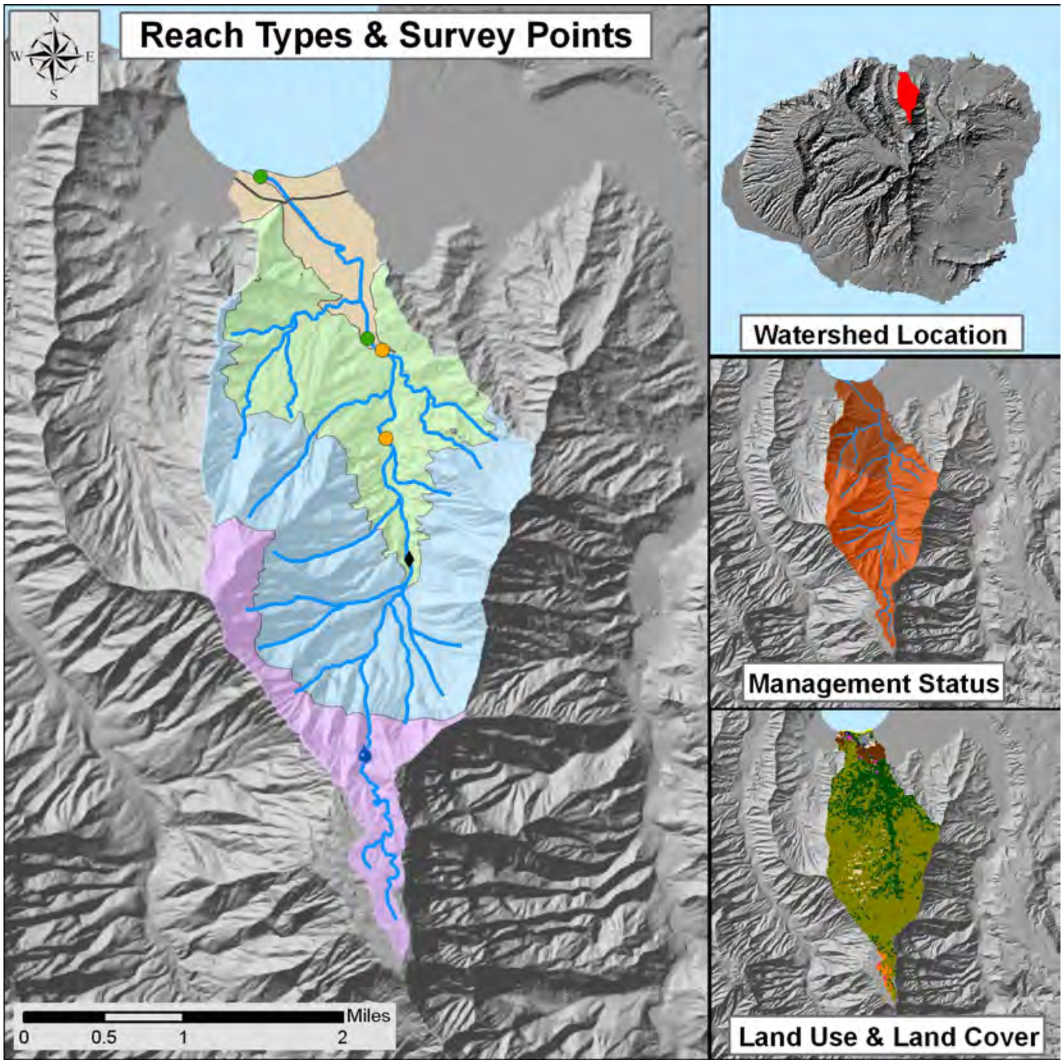
APPENDIX A

State of Hawai‘i, Department of Land and Natural Resources, Division of Aquatic Resources

Atlas of Hawaiian Watersheds & Their Aquatic Resources
Wai‘oli, Kaua‘i

DAR Watershed Code: 21018

Wai‘oli, Kaua‘i



WATERSHED FEATURES

Wai‘oli watershed occurs on the island of Kaua‘i. The Hawaiian meaning of the name is “joyful water”. The area of the watershed is 5.5 square mi (14.2 square km), with maximum elevation of 4409 ft (1344 m). The watershed's DAR cluster code is not yet determined. The percent of the watershed in the different land use districts is as follows: 5.9% agricultural, 92.5% conservation, 0% rural, and 1.7% urban.

Land Stewardship: Percentage of the land in the watershed managed or controlled by the corresponding agency or entity. Note that this is not necessarily ownership.

Military	Federal	State	OHA	County	Nature Conservancy	Other Private
0.0	0.0	69.9	0.0	0.0	0.0	30.1

Land Management Status: Percentage of the watershed in the categories of biodiversity protection and management created by the Hawaii GAP program.

Permanent Biodiversity Protection	Managed for Multiple Uses	Protected but Unmanaged	Unprotected
0.0	0.0	69.9	30.1

Land Use: Areas of the various categories of land use. These data are based on NOAA C-CAP remote sensing project.

	Percent	Square mi	Square km
High Intensity Developed	0.1	0.00	0.01
Low Intensity Developed	0.8	0.04	0.11
Cultivated	2.8	0.15	0.40
Grassland	1.6	0.09	0.23
Scrub/Shrub	67.5	3.70	9.57
Evergreen Forest	24.9	1.36	3.53
Palustrine Forested	0.2	0.01	0.03
Palustrine Scrub/Shrub	1.5	0.08	0.21
Palustrine Emergent	0.3	0.01	0.04
Estuarine Forested	0.0	0.00	0.00
Bare Land	0.2	0.01	0.04
Unconsolidated Shoreline	0.0	0.00	0.00
Water	0.2	0.01	0.03
Unclassified	0.0	0.00	0.00

STREAM FEATURES

Wai‘oli is a perennial stream. Total stream length is 15.8 mi (25.4 km). The terminal stream order is 3.

Reach Type Percentages: The percentage of the stream's channel length in each of the reach type categories.

Estuary	Lower	Middle	Upper	Headwaters
0.0	0.0	43.2	43.5	13.3

The following stream(s) occur in the watershed:
Wai‘oli

BIOTIC SAMPLING EFFORT

Biotic samples were gathered in the following year(s):

1965 1989 2000

Distribution of Biotic Sampling: The number of survey locations that were sampled in the various reach types.

Survey type	Estuary	Lower	Middle	Upper	Headwaters
DAR Point Quadrat	0	0	1	0	0
HDFG	0	0	2	0	0
Published Report	1	1	0	0	0

BIOTA INFORMATION

Species List

Native Species

Crustaceans *Atyoida bisulcata*
Macrobrachium grandimanus

Fish *Awaous guamensis*
Gobiid sp.
Kuhlia sandvicensis
Kuhlia sp.
Sicyopterus stimpsoni

Native Species

Insects *Megalagrion sp.*

Introduced Species

Crustaceans *Macrobrachium lar*

Fish *Xiphophorus helleri*

Species Size Data: Species size (inches) observed in DAR Point Quadrat Surveys.

Scientific Name	Status	Minimum Size	Maximum Size	Average Size
Macrobrachium lar	Introduced	2	2	2.0

Species Distributions: Presence (P) of species in different stream reaches.

Scientific Name	Status	Estuary	Lower	Middle	Upper	Headwaters
Atyoida bisulcata	Endemic		P	P		
Macrobrachium grandimanus	Endemic		P	P		
Sicyopterus stimpsoni	Endemic		P	P		
Megalagrion sp.	Endemic			P		
Awaous guamensis	Indigenous	P	P	P		
Gobiid sp.	Indigenous			P		
Kuhlia sandvicensis	Indigenous			P		
Kuhlia sp.	Indigenous			P		
Macrobrachium lar	Introduced			P		
Xiphophorus helleri	Introduced			P		

HISTORIC RANKINGS

Historic Rankings: These are rankings of streams from historical studies. "Yes" means the stream was considered worthy of protection by that method. Some methods include non-biotic data in their determination. See Atlas Key for details.

Multi-Attribute Prioritization of Streams - Potential Heritage Streams (1998): No

Hawaii Stream Assessment Rank (1990): Substantial

U.S. Fish and Wildlife Service High Quality Stream (1988): Yes

The Nature Conservancy- Priority Aquatic Sites (1985): No

National Park Service - Nationwide Rivers Inventory (1982): No

Current DAR Decision Rule Status: The following criteria are used by DAR to consider the biotic importance of streams. "Yes" means that watershed has that quality.

Native Insect Diversity > 19 spp.	Native Macrofauna Diversity > 5 spp.	Absence of Priority 1 Introduced
No	Yes	No
Abundance of Any Native Species	**Presence of Candidate Endangered Species**	**Endangered Newcomb's Snail Habitat**
No	No	No

CURRENT WATERSHED AND STREAM RATINGS

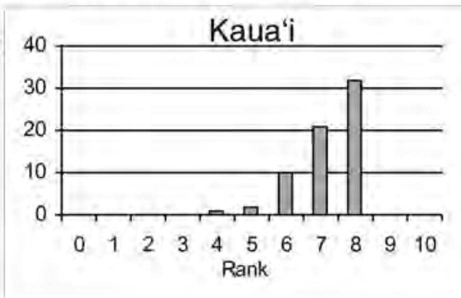
The current watershed and stream ratings are based on the data contained in the DAR Aquatic Surveys Database. The ratings provide the score for the individual watershed or stream, the distribution of ratings for that island, and the distribution of ratings statewide. This allows a better understanding of the meaning of a particular ranking and how it compares to other streams. The ratings are standardized to range from 0 to 10 (0 is lowest and 10 is highest rating) for each variable and the totals are also standardized so that the rating is not the average of each component rating. These ratings are subject to change as more data are entered into the DAR Aquatic Surveys Database and can be automatically recalculated as the data improve. In addition to the ratings, we have also provided an estimate of the confidence level of the ratings. This is called rating strength. The higher the rating strength the more likely the data and rankings represent the actual condition of the watershed, stream, and aquatic biota.

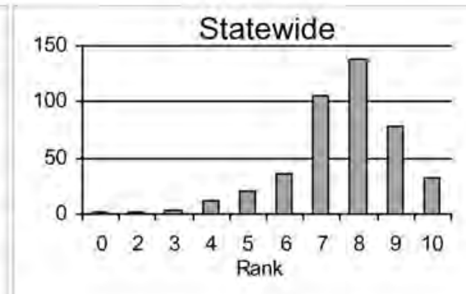
WATERSHED RATING: Wai‘oli, Kaua‘i

Land Cover Rating: Rating is based on a scoring sytem where in general forested lands score positively and developed lands score negatively.

Watershed Rating

8

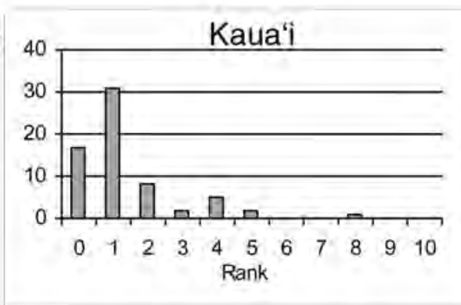


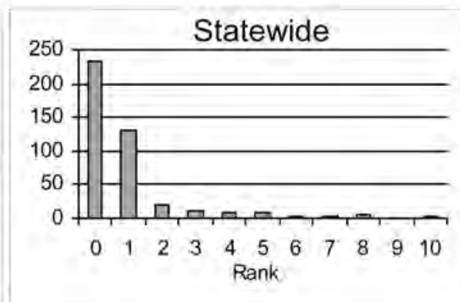


Shallow Waters Rating: Rating is based on a combination of the extent of estuarine and shallow marine areas associated with the watershed and stream.

Watershed Rating

2

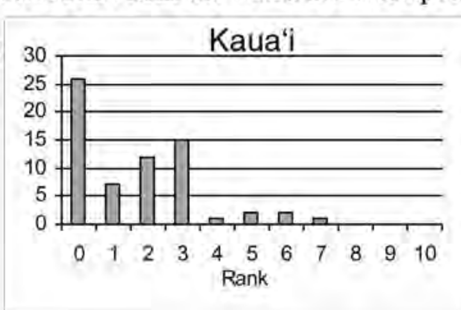


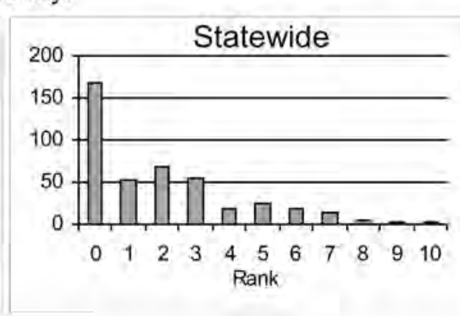


Stewardship Rating: Rating is based on a scoring system where higher levels of land and biodiversity protection within the watershed score positively.

Watershed Rating

2



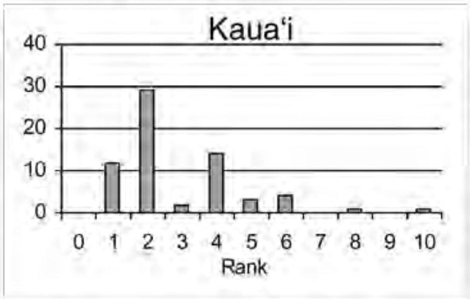


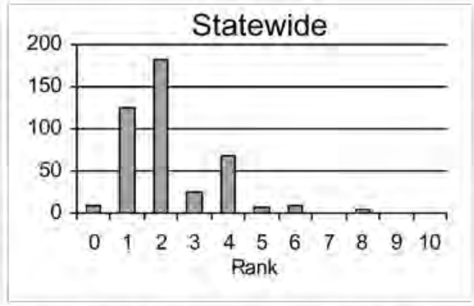
WATERSHED RATING (Cont): Wai‘oli, Kaua‘i

Size Rating: Rating is based on the watershed area and total stream length. Larger watersheds and streams score more positively.

Watershed Rating

4

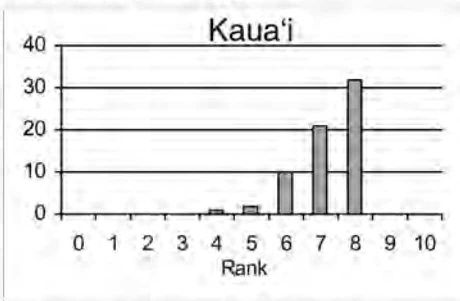


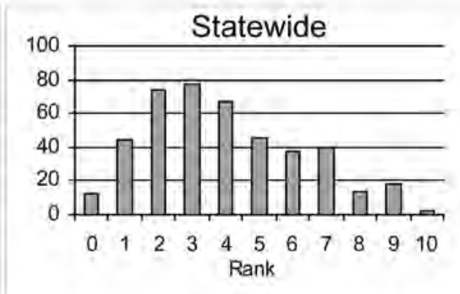


Wetness Rating: Rating is based on the average annual rainfall within the watershed. Higher rainfall totals score more positively.

Watershed Rating

7

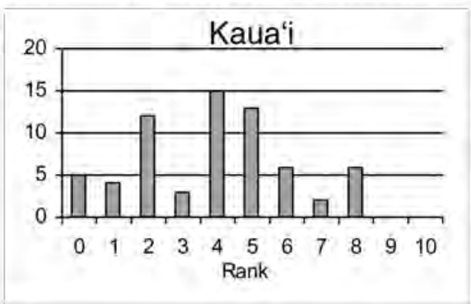


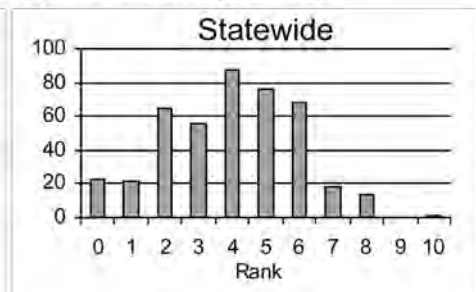


Reach Diversity Rating: Rating is based on the types and amounts of different stream reaches available in the watershed. More area in different reach types score more positively.

Watershed Rating

6

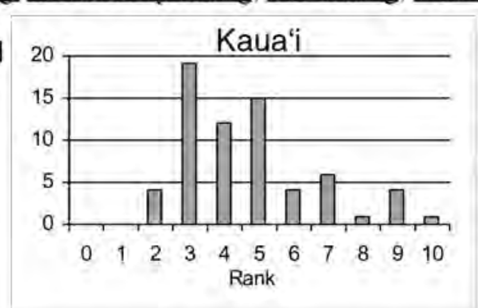


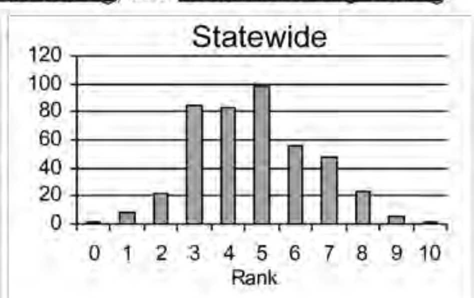


Total Watershed Rating: Rating is based on combination of Land Cover Rating, Shallow Waters Rating, Stewardship Rating, Size Rating, Wetness Rating, and Reach Diversity Rating.

Watershed Rating

7



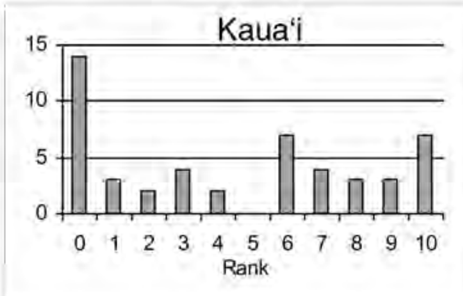


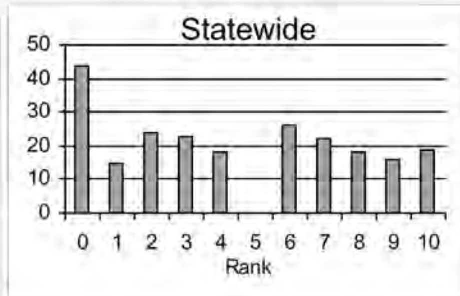
BIOLOGICAL RATING: Wai'oli, Kaua'i

Native Species Rating: Rating is based on the number of native species observed in the watershed.

Stream Rating

6

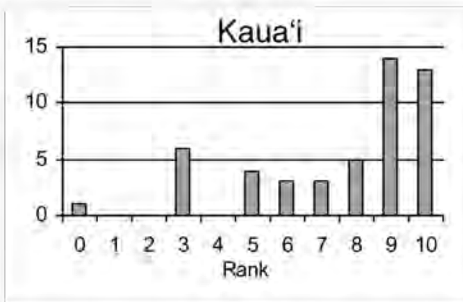


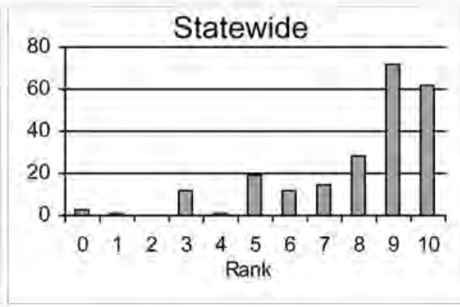


Introduced Genera Rating: Rating is based on the number of introduced genera observed in the watershed.

Stream Rating

9

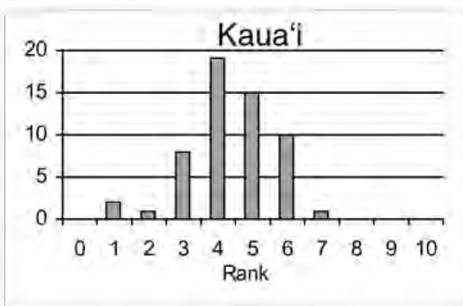


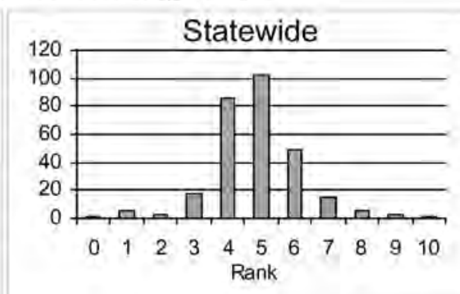


All Species' Score Rating: Rating is based on the Hawaii Stream Assessment scoring system where native species score positively and introduced species score negatively.

Stream Rating

5

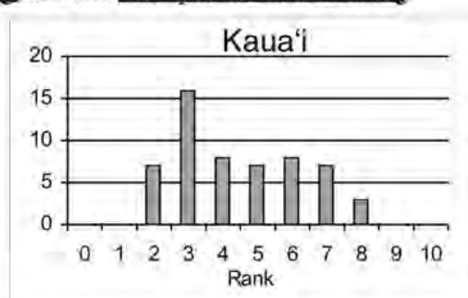


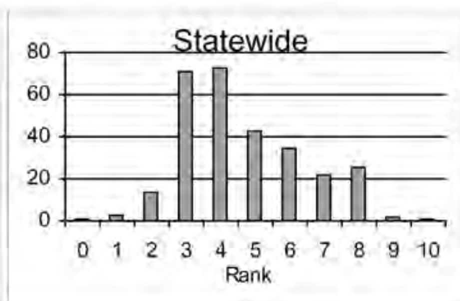


Total Biological Rating: Rating is the combination of the Native Species Rating, Introduced Genera Rating, and the All Species' Score Rating.

Stream Rating

6



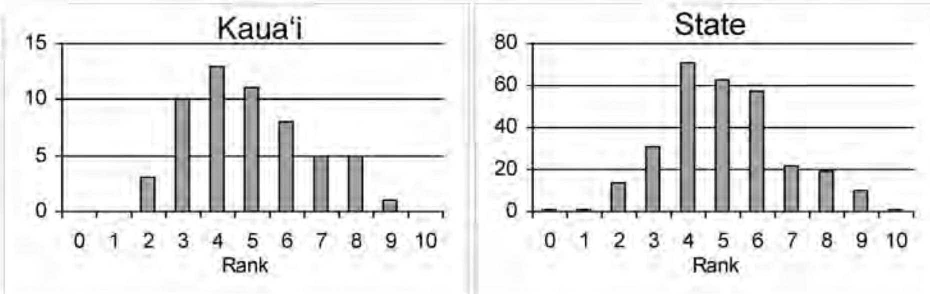


OVERALL RATING: Wai‘oli, Kaua‘i

Overall Rating: Rating is a combination of the Total Watershed Rating and the Total Biological Rating.

Watershed Rating

7

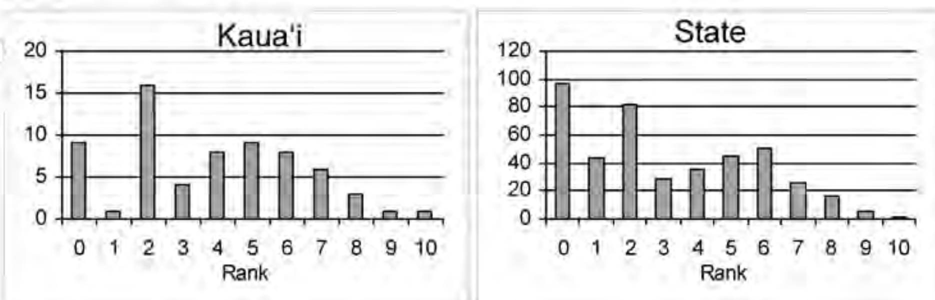


RATING STRENGTH: Wai‘oli, Kaua‘i

Rating Strength: Represents an estimate of the overall study effort in the stream and is a combination of the number of studies, number of different reaches surveyed, and the number of different survey types.

Information Rating

5



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