North Shore Watershed Management Plan

O'ahu Watershed Management Plan

PUBLIC REVIEW DRAFT - NOVEMBER 2015

PREPARED FOR: HONOLULU BOARD OF WATER SUPPLY

PREPARED BY: GROUP 70 INTERNATIONAL

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GLOSSARY

NOTE: Terms in this Glossary may have different meanings in other jurisdictions.

Aquifer

A geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.[1]

Aquifer Sector Area

A large region with hydrogeological similarities. "Sectors reflect broad hydrogeological similarities yet maintain traditional hydrographic, topographic and historical boundaries where possible."[2]

Aquifer System Area

An area within a sector showing ground water hydraulic continuity.[2]

Continuous Stream

A type of perennial stream that flows to the sea year-round under normal conditions, including streams with diversions.[3]

Criteria

Measures or standards for judging or selecting among choices.[4]

Domestic Use

"any use of water for individual personal needs and for household purposes such as drinking, bathing, heating, cooking, noncommercial gardening and sanitation."[5]

Ground Water

"any water found beneath the surface of the earth, whether or not in perched, dike-confined or basal supply; in underground channels or streams; in standing, percolating or flowing condition; or under artesian pressure."[5]

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[1] USGS, Water Science Glossary of Terms, http://ga.water.usgs.gov/edu/dictionary.html#A

[2] Wilson Okamoto & Associates, Inc., March 1990, *Oahu Water Management Plan Technical Reference Document*, Department of General Planning City and County of Honolulu, p. 21.

[3] *Hawaii Stream Assessment: A Preliminary Appraisal of Hawaii's Stream Resources*, 1990, p. 9.

[4] American Planning Association Hawaii Chapter, 1999, *From the Ground Up: A Handbook for Community- Based Land Use Planning*, p. 97.

[5] Revised Ordinances of Honolulu Chapter 30: Water Management, §30-1.2 Definitions

GLOSSARY (continued)

NOTE: Terms in this Glossary may have different meanings in other jurisdictions.

Instream Flow Standard

"a quantity or 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."[6]

The amount of water required to protect instream uses such as to protect fish and wildlife habitat, aesthetic values, or traditional Hawaiian uses.[7]

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."[8]

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."[6]

Intermittent Streams

Streams that are normally dry during part of the year.[9]

Interrupted Streams

A type of perennial stream that flows year-round in the upper portions and intermittently at lower elevations under normal conditions. The interruption may be natural or man-made.[9]

Median Stream Flow

The flow at the gaging station that is exceeded 50% of the time.

Metered Consumption

The amount of water consumed by a specific user or system as measured by a water meter or aggregation of meters. Not all water infrastructure has a water meter, therefore making it difficult to determine the amount of water that is conveyed by that system.

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.'"[6]

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[6] HRS §174 C-3, State Water Code.
[7] *Oahu Water Management Plan.* 1992. p.11
[8] HAR §13-167-2.
[9] *Hawaii Stream Assessment: A Preliminary Appraisal of Hawaii's Stream Resources*, 1990, p. 9.

GLOSSARY (continued)

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Non-instream 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."[10]

Nonpotable Water
"water that does not meet State Department of Health drinking water standards."[10]

Palustrine Wetland
Shallow non-tidal freshwater areas that lack flowing water and are dominated by trees and shrubs.

Perennial Streams
Streams that normally have surface flow year-round, in all or part of their course, as opposed to intermittent streams.[11]

Potable Water
Fit or suitable for drinking.

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."[12]

Streams are considered separate entities when they have a separate mouth to the sea.[12]

Stream Channelization
Stream channelization is the realignment or lining of a natural stream channel for the purposes of flood or erosion control.

Stream Diversion
"the act of removing water from a stream into a channel, pipeline, or other conduit."[13]

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[10] Honolulu Board of Water Supply, 2004. *Definitions.* Available URL: http://www.hbws.org/cssweb/display.cfm ?sid=1415 [Accessed 6/17/14]
[11] *Hawaii Stream Assessment: A Preliminary Appraisal of Hawaii's Stream Resources*, 1990, p. 9.
[12] HAR §13-167-2.
[13] HRS §174 C-3, State Water Code.

GLOSSARY (continued)

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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, and reservoirs) and diffused surface water (that is, water occurring upon the surface of the ground other than in contained waterbodies). Water from natural springs is surface water when it exits from the spring into the earth's surface."[14]

Sustainable Yield

"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."[14]

Forced withdrawal rate of ground water that could be sustained indefinitely from an aquifer without affecting either the quality of the pumped water or the volume rate of pumping. Meant to be a guide for planning.[15]

Total Maximum Daily Loads

Calculations of the maximum amount of each pollutant that can enter a given water body without violating state water quality standards

Water or Waters of the State

"any and all water on or beneath the surface of the ground, including natural or artificial watercourses, lakes, ponds, or diffused surface water and water percolating, standing, or flowing beneath the surface of the ground."[16]

Water Management Area

"a geographic area which has been designated pursuant to chapter 13-171 as requiring management of the ground or surface water resource, or both."[16]

Designated by the Commission when it is determined that water resources in the area may be threatened by existing or proposed withdrawals or diversions of water.[17]

Water Pumpage

The volume of water pumped from a ground water source.

Watershed

An area of land that is defined by ridgelines and drains into a distinct stream or river.

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[14] HAR §13-167-2.
[15] *Oahu Water Management Plan.* 1992. p.3
[16] HAR §13-167-2.
[17] *Oahu Water Management Plan.* 1992. p.7

GLOSSARY (continued)

NOTE: Terms in this Glossary may have different meanings in other jurisdictions.

Water Source

"a place within or from which water is or may be developed, including but not limited to: (1) generally, an area such as a watershed defined by topographic boundaries, or a definitive ground water body; and (2) specifically, a particular stream, other surface water body, spring, tunnel, or well or related combination thereof."[18]

Water Withdrawal

The volume of water withdrawn from a ground or surface water source.

Wetlands

Areas that are regularly wet or flooded throughout most of the year and are often characterized by specific plant associations and soil types.

[18] HAR §13-167-2.

ACRONYMS

ADC	Agribusiness Development Corporation
ALISH	Agricultural Lands of Importance to the State of Hawai'i
ASEA	Aquifer Sector Areas
ASYA	Aquifer System Area
AWUDP	Agricultural Water Use and Development Plan
BAT	Best Available Technologies
BLNR	Board of Land and Natural Resources
BMP	Best Management Practice
BOC	Bureau of Conveyances
BWS	Honolulu Board of Water Supply
CAP	Conservation Action Plan
CFS	Cubic Feet per Second
CWA	Clean Water Act
CWB	Clean Water Branch
CWRM	State of Hawai'i Commission on Water Resource Management
CY	Calendar Year
CZM	Coastal Zone Management
DAGS	Department of Accounting and General Services
DAR	Division of Aquatic Resources
DBCP	1,2-dibromo-3-chloro-propane
DBEDT	Department of Business, Economic Development and Tourism
DDC	Department of Design and Construction
DFM	Department of Facility Maintenance
DHHL	Department of Hawaiian Home Lands
DLNR	State of Hawai'i Department of Land and Natural Resources
DMR	Dillingham Military Reservation
DOA	State of Hawai'i Department of Agriculture
DOCARE	Division of Conservation and Resources Enforcement
DOFAW	Division of Forestry and Wildlife
DOH	State of Hawai'i Department of Health
DOT	Department of Transportation
DP	Development Plan

ACRONYMS (continued)

DPP	Department of Planning and Permitting
DPR	Department of Parks and Recreation
DRA	Dillingham Ranch ʻĀina, LLC
DTS	Department of Transportation Services
ENV	Department of Environmental Services, City and County of Honolulu
EPA	United States Environmental Protection Agency
EPO	Environmental Planning Office
ESPC	Energy Savings Performance Contracting
ET	Evapotranspiration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FY	Fiscal Year
GAC	Granular Activated Carbon
GPAD	Gallons per Acre per Day
GPCD	Gallons per Capita per Day
GPD	Gallons per Day
GWCM	Ground Water Contamination Maps
GWMA	Ground Water Management Areas
HECO	Hawaiian Electric Company
HEER	Hazard Evaluation and Emergency Response
HEL	Highly Erodible Land
HFD	Honolulu Fire Department
HISC	Hawaiʻi Invasive Species Council
HISWAP	Hawaiʻi Source Water Assessment and Protection Program
HPD	Honolulu Police Department
HRS	Hawaiʻi Revised Statutes
HSA	Hawaiʻi Stream Assessment
HTA	Hawaiʻi Tourism Authority
HUD	Housing and Urban Development
HWP	Hawaiʻi Water Plan
IAL	Important Agricultural Lands

ACRONYMS (continued)

ICAP	Island Climate Adaptation and Policy
IFS	Instream Flow Standard
IIFS	Interim Instream Flow Standard
INRMP	Integrated Natural Resources Management Plan
IWS	Individual Wastewater Systems
KLOA	Kawailoa Training Area
KMWP	Ko'olau Mountains Watershed Partnership
KS	Kamehameha Schools
KTA	Kahuku Training Area
LID	Low Impact Development
LUC	Land Use Commission
MACZAC	Marine and Coastal Zone Advocacy Council
MAPS	Multi-Attribute Prioritization of Streams
MBR	Membrane BioReactor
MCBH	Marine Corps Base Hawai'i
MCL	Maximum Contaminant Level
MG	Million gallons
MGD	Millions of gallons per day
MLCD	Marine Life Conservation District
NARS	Natural Area Reserves System
NAVFAC	Naval Facilities Engineering Command
NB	Neighborhood Board
NDMA	N-nitrosodimethylamine
NEO	Nonpoint Education for Officials
NOAA	National Oceanic and Atmospheric Agency
NRCS	U.S. Department of Agriculture Natural Resources Conservation Service
NSCLT	North Shore Community Land Trust
NSF	National Science Foundation
NSRWWAP	North Shore Regional Wastewater Alternatives Plan
NSSCP	North Shore Sustainable Communities Plan
NSWC	North Shore Water Company
NSWMP	North Shore Watershed Management Plan

ACRONYMS (continued)

NTHP	National Trust for Historic Preservation
O&M	Operations and Maintenance
OCCL	Office of Conservation and Coastal Lands
OHA	Office of Hawaiian Affairs
OISC	O'ahu Invasive Species Committee
OP	Office of Planning
OR&L	O'ahu Railway and Land
ORC&D	O'ahu Resource Conservation and Development Council
ORMP	Ocean Resources Management Plan
OTEC	Ocean Thermal Energy Conversion
OWMP	O'ahu Water Management Plan
PCA	Potential Contaminating Activity
PICCC	Pacific Islands Climate Change Cooperative
PIRCA	Pacific Islands Regional Climate Assessment
PUC	Primary Urban Center
RISA	Pacific Regional Integrated Sciences and Assessments
ROH	Revised Ordinances of Honolulu
RWA	Rapid Watershed Assessment
SCP	Sustainable Communities Plan
SHPD	State Historic Preservation Division
SIMA	Surf Industry Manufacturers Association
SOEST	School of Ocean and Earth Science and Technology
SPAM	Stream Protection and Management
SWAP	Source Water Assessment Program
SWPP	State Water Projects Plan
SY	Sustainable Yield
T&E	Threatened and Endangered
TCE	Trichloroethylene
TCP	1,2,3-trichloropropane
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy

ACRONYMS (continued)

TPL	Trust for Public Land
TSS	Total Suspended Solids
UEM	Utilities & Energy Management
UH	University of Hawaiʻi
UH CTAHR	University of Hawaiʻi College of Tropical Agriculture & Human Resources
UIC	Underground Injection Control
US	United States
USACE	United States Army Corps of Engineers
USAG-HI	US Army Garrison Hawaiʻi
USANG	US Army National Guard
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WARMF	Watershed Analysis Risk Management Framework
WIS	Wahiawā Irrigation System
WKWS	Waialua-Kaiaka watershed Study
WMA	Water Management Area
WMP	Watershed Management Plan
WMWP	Waiʻanae Mountains Watershed Partnership
WOSWCD	West Oʻahu Soil and Water Conservation District
WPAA	Watershed Participatory Assessment and Action
WRPP	Water Resources Protection Plan
WRRC	Water Resources Research Center
WUDP	Water Use and Development Plan
WUP	Water Use Permit
WWTP	Wastewater Treatment Plants

ES EXECUTIVE SUMMARY

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ES.6 WATER USE AND PROJECTED DEMAND
ES.7 PROJECTS AND STRATEGIES
ES.8 IMPLEMENTATION OF THE NSWMP

ES.1 THE NORTH SHORE WATERSHED MANAGEMENT PLAN PURPOSE

The North Shore Watershed Management Plan (NSWMP) is a long-range, 20-year plan to the year 2035 for the preservation, restoration, and balanced management of ground water, surface water, and related watershed resources in the North Shore district, island of O‘ahu. The City and County of Honolulu Department of Planning and Permitting (DPP) and the Honolulu Board of Water Supply (BWS) have jointly prepared the NSWMP, in accordance with the State Water Code, the Hawai‘i Water Plan, and the City's Ordinance 90-62 that established the *O‘ahu Water Management Plan*. The NSWMP is one of eight district-specific plans that together will form the updated *O‘ahu Water Management Plan*.

The public review draft of the NSWMP is posted on the BWS website at www.hbws.org. After the public review period, support for the NSWMP will be requested from the Neighborhood Board #27. DPP and BWS will then finalize the NSWMP and the plan will be submitted for approval and adoption by the Honolulu City Council and the State Commission on Water Resource Management (CWRM), respectively.

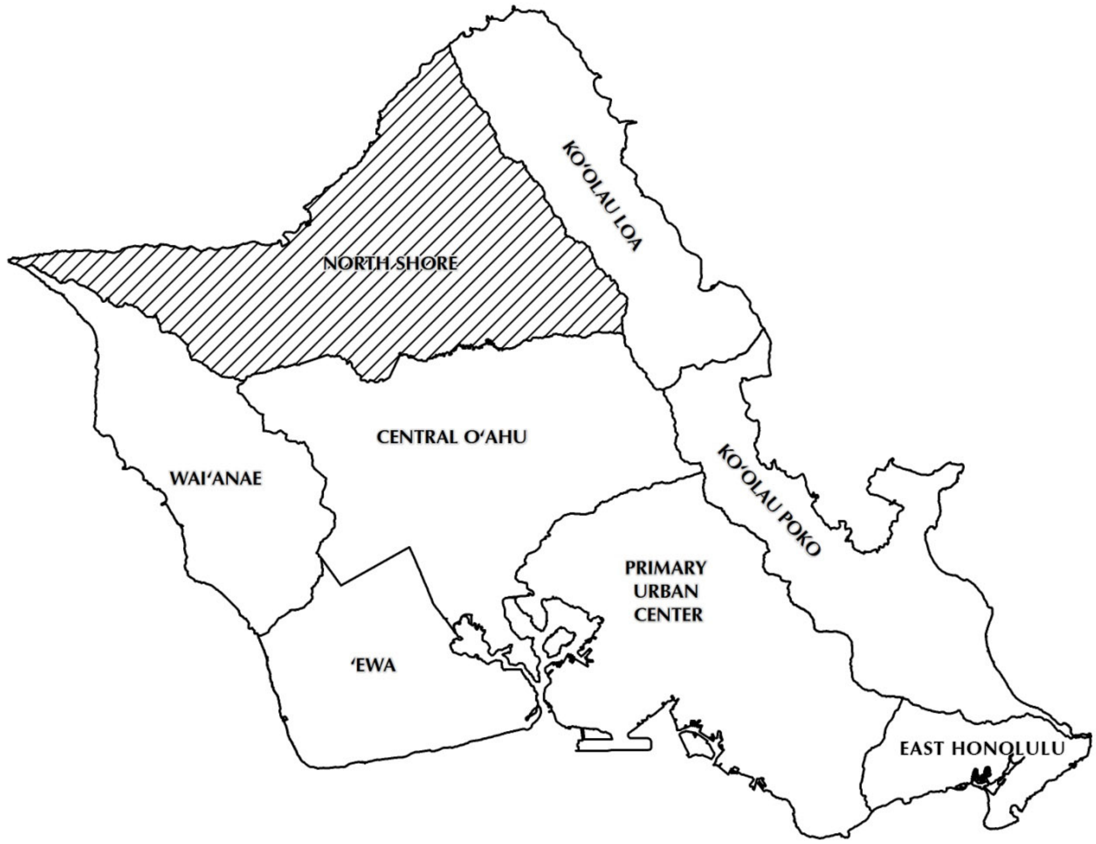


Figure ES.1 The Eight Districts of the Oʻahu Water Management Plan

This Executive Summary provides a brief synopsis of the planning process, major findings, and recommendations of the NSWMP.

The plan is presented in five chapters and a number of appendices:

Chapter 1. Oʻahu Water Management Plan Overview

Chapter 2. North Shore Watershed Profile

Chapter 3. Existing Water Use and Forecasts of Future Water Use and Demand

Chapter 4. Plan Objectives, Water Supply and Watershed Management Projects and Strategies

Chapter 5. Implementation of the NSWMP

ES.2 THE NSWMP AND THE NORTH SHORE SUSTAINABLE COMMUNITIES PLAN

The State Water Code requires that the County water use and development plans be consistent with County land use plans and policies. Thus, throughout the planning process for this plan, BWS and DPP have been mindful of the policies and guidelines of the *North Shore Sustainable Communities Plan* (NSSCP), which was first enacted in the year 2000. The NSSCP was revised and adopted in 2011, and thus the NSWMP reflects the policy changes that are included in the revised NSSCP.

The NSSCP provides a vision for the preservation, conservation, and enhancement of the region's natural and scenic resources, recreational opportunities, agricultural lands, and cultural and historical resources. This overarching vision for the district is the overall policy guide for the NSWMP as well.

ES.3 THE PLANNING PROCESS

At the outset of the planning process, BWS and DPP established several key guiding principles for the NSWMP. They directed that the Plan be:

- Community-based
- Environmentally holistic
- Reflective of ahupuaʻa management principles
- Action-oriented
- In alignment with State and City water and land use policies

In accordance with these overall guiding principles, the planning process for the NSWMP emphasized the importance of two complementary sets of studies and actions:

1. **Technical research work:** data collection and analysis, review of relevant plans and programs, creation of maps, charts and graphs, and statistical projections of future demands for potable and nonpotable water; and

2. **Stakeholder outreach and consultation:** individual interviews and small group meetings with community leaders, community groups and organizations, landowners, developers, public agencies, and elected officials; and general community meetings to provide a forum for the discussion of watershed issues and needed actions.

   As a result of the technical and community-based nature of the planning process, the conclusions and recommendations are based on both technical analysis and on the values and ideas of the many stakeholders.

ES.4 GOALS AND OBJECTIVES OF THE NSWMP

BWS and DPP established an overall goal and five supporting objectives for all of the watershed management plans:

GOAL: ***To formulate an environmentally holistic, community-based, and economically viable watershed management plan that will provide a balance between: (1) the preservation, restoration and management of O'ahu's watersheds, and (2) sustainable ground water and surface water use and development to serve present users and future generations.***

The five major objectives which are common to all of the watershed management plans for O'ahu are:

OBJECTIVE #1: PROMOTE SUSTAINABLE WATERSHEDS

OBJECTIVE #2: PROTECT AND ENHANCE WATER QUALITY AND QUANTITY

OBJECTIVE #3: PROTECT NATIVE HAWAIIAN RIGHTS AND TRADITIONAL AND CUSTOMARY PRACTICES

OBJECTIVE #4: FACILITATE PUBLIC PARTICIPATION, EDUCATION, AND PROJECT IMPLEMENTATION

OBJECTIVE #5: MEET FUTURE WATER DEMANDS AT REASONABLE COST

Each of the Watershed Management Plans developed **district-specific Sub-Objectives** under each of the major objectives. These Sub-Objectives were articulated based on the issues and values that emerged for the district from both the technical research work and the stakeholder consultation process.

Water Supply and Watershed Management Projects and Strategies that respond to and implement these Sub-Objectives were then developed into project and strategy descriptions for this NSWMP.

ES.5 SUMMARY PROFILE OF THE DISTRICT

North Shore is one of the eight planning districts of Oʻahu. This district is located on the windward side of the island, and stretches from Kaʻena Point in the west to Waialeʻe Gulch near Kawela Bay in the east, spanning a distance of about 20 miles. North Shore is 77,000 acres in size, and has a population of approximately 17,720 people (US Census, 2010).

The largest urbanized areas in the district are Haleʻiwa, Waialua, and Pūpūkea. A single Neighborhood Board provides opportunities for community dialogue on various local issues. Kamehameha Highway is the major arterial roadway serving these communities.

The North Shore district consists of 22 watersheds, which include: a portion of Kaluakauila, Manini, Kawaihāpai, Pahole, Makaleha, Waialua, a portion of Kaukonahua, Kiʻikiʻi, Paukauila, a portion of Poamoho, Helemano, ʻŌpaeʻula, Kawaiʻiki, Kawainui, Kawailoa, Anahulu, Loko Ea, Keamanea, Waimea, Kālunawaikaʻala, Pākūlena, and a portion of Paumalū (*Figure ES.2*).

There are eight perennial streams in North Shore. Three of these perennial streams are "stream systems," i.e. streams with two or more major tributaries that extend from different valleys and converge on a coastal plain. The median flows of these streams range from about 0.2 cubic feet per second (cfs) for Helemano Stream to 14.9 cfs for the Kiʻikiʻi System. These streams are important habitats for native fresh water species as well as important sources of water for local farmers.

A watershed is defined as a drainage basin that catches, collects, and stores water that travels toward the ocean via rivers, streams, or through subterranean springs or seepages. Watersheds and ahupuaʻa often have shared or similar boundaries. However, in North Shore, watershed boundaries do not line up exactly with ahupuaʻa boundaries due to the larger land areas of the ahupuaʻa in North Shore as compared to the watersheds.

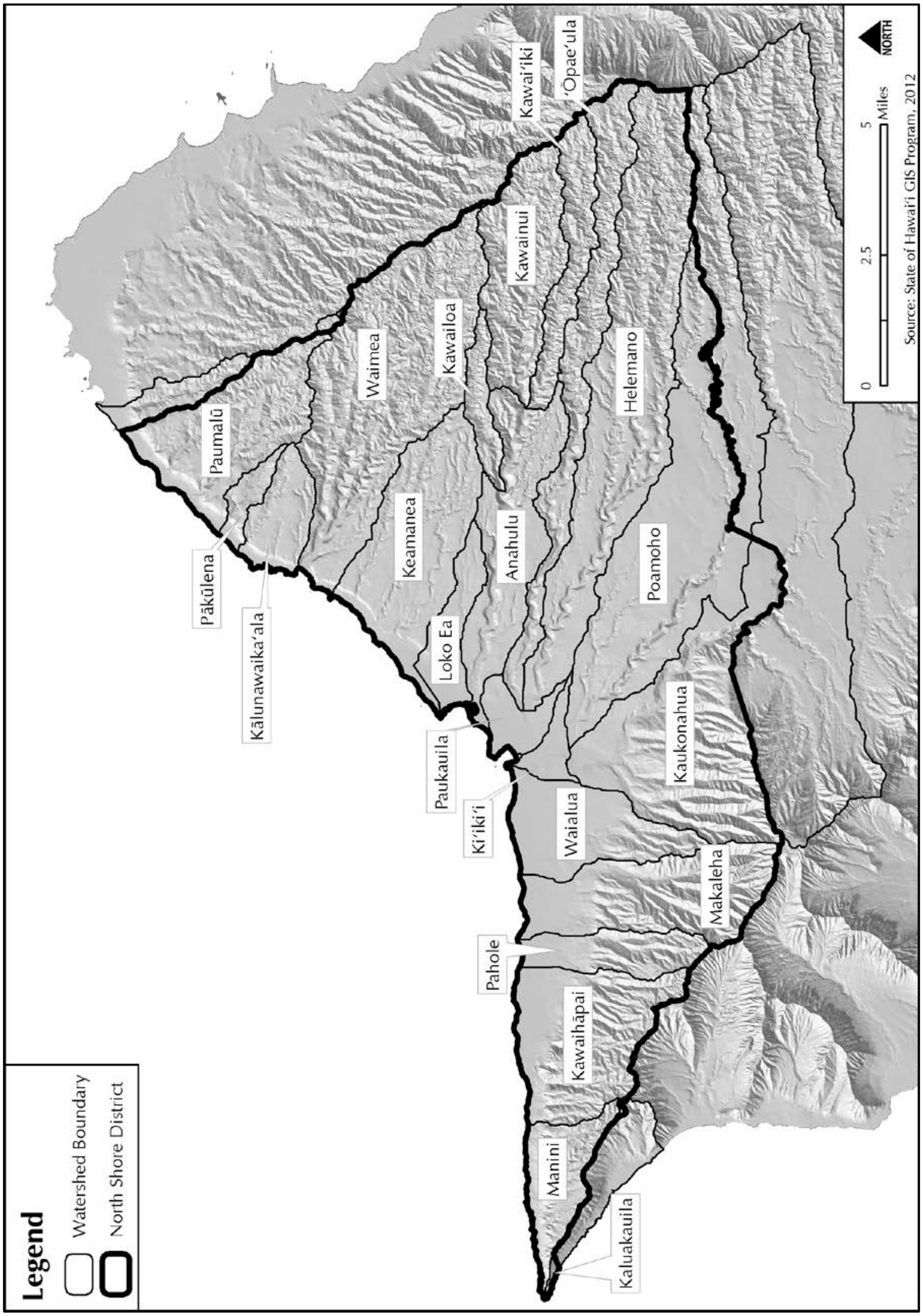


Figure ES.2 North Shore Watersheds

ES.6 WATER USE AND PROJECTED DEMAND

North Shore utilizes a combination of ground, surface, and recycled sources to meet its water demands.

Table ES.1 Current In-District Water Use by Source Type

Water Source	Estimated Amount (mgd)[1]
Surface Water	12.4[2]
Ground Water	6.8[3]
Recycled Water	3.9[4]
Total	22.1

[1] Million of Gallons per Day
[2] North Shore Primary Surface Water Use (2012) see *Table 3.5*
[3] Estimated amount is conservative as some users were non-reporting (2010)
[4] Reported averages from the Wahiawā and Schofield Barracks Wastewater Treatment Plants (2012)

The North Shore district overlays four Aquifer System Areas (ASYA) for ground water: the Mokulēʻia, Waialua, and Kawailoa ASYAs of the North Aquifer Sector Area, and a portion of the Wahiawā ASYA in the Central Aquifer Sector Area. The sustainable yield for each ASYA is as follows: Mokulēʻia – 8 million gallons per day (mgd), Waialua – 25 mgd, Kawailoa – 29 mgd, and Wahiawā – 23 mgd (total). From 2006 to 2010, the Board of Water Supply provided nearly 3 mgd of potable water to meet this district's needs. In addition, there are several small potable water systems. Ground water is also used for some agricultural needs where the Wahiawā Irrigation System (WIS) does not extend, where high quality water is needed, or when surface water quantities are limited such as during periods of drought.

Surface water from stream diversions brings water into the WIS from the North and South Forks of the Kaukonahua Stream, a portion of the Poamoho Stream, and ʻŌpaeʻula and Kawaiʻiki Streams. Dole Food Inc. and Kamehameha Schools owns and operates different portions of the WIS. Kamehameha Schools has improved and piped their portion of the system to minimize system losses. About 5,500 acres were occupied by diversified agriculture farms using WIS water in 2007. The WIS currently provides 9 mgd (from recent USGS gage readings) to diversified crops (including seed corn, pasture grass and tree crops) and to additional acreage of pineapple.

Future water demands were projected in low-, mid- and high-growth scenarios through the year 2035. The mid-growth demand scenario was selected as the most probable demand scenario as it is based upon the DPP's Socio-Economic Policy Projections and *Oʻahu Agriculture: Situation, Outlook and Issues* (2011) which was prepared as part of the City and County of Honolulu's General Plan update process. The DPP's Socio-Economic Policy Projections show an increase in population to approximately 10% by the year 2035. The greatest increase in the Mid-Growth Demand scenario is from a nearly 30% increase in agricultural acreage by the year 2035.

The ultimate demand scenario is a scenario that assumes the full build-out of residential units within the North Shore Sustainable Community Plan Community Growth Boundary, and irrigation of all the prime and unique agricultural lands outside of it. The ultimate demand scenario is for an unspecified time in the future as it reflects an end state that might occur based on land use plans, land use constraints and considerations of climate change impacts. The ultimate demand scenario is meant to test the foreseeable limits of supply and demand in the North Shore district to inform long range water resource management plans and policies on natural water resources, source augmentation and conservation efficiencies. The ultimate demand scenario is used for watershed planning purposes and is not tied to City and County of Honolulu Department of Planning population projections.

The **Water Use and Development** section of the plan is summarized as follows (*Table ES.2* and *Figure ES.3*):

- The most probable future growth “scenario” for North Shore is the SCP Policy or mid-growth scenario based on population projections developed by DPP. The DPP population projections show an increase in the district’s population by 10% from 2000 to 2035.
- BWS potable water supplied to the North Shore district in CY 2010 was 2.8 mgd. BWS potable water demand for the district projected to 2035 is 3.4 mgd for the most probable scenario. Existing BWS potable water sources and systems for the district are adequate to meet the current and future projected potable water demand.
- North Shore agriculture demand in 2010 was nearly 25 mgd. The most probable demand scenario for agriculture in 2035 is nearly 30 mgd. This is based upon an almost 30% increase in agricultural acreage by 2035, or about a 1% increase per year.

Table ES.2 Water Demand by Water System

Water System	2010 (mgd)	2035 (mgd)			Ultimate Scenario
		Low Scenario	Mid Scenario	High Scenario	
Domestic Water Systems					
Board of Water Supply	2.8	2.8	3.0	3.2	
Dole Foods	0.0	0.1	0.1	0.1	
North Shore Water Company	0.1	0.1	0.2	0.2	
Dillingham Airfield	0.1	0.1	0.1	0.1	
Total Domestic Water System	***3.0***	***3.1***	***3.4***	***3.6***	***5.5***
Agricultural System					
Total Agriculture	***24.2***	***26.1***	***29.3***	***32.7***	***72.7***
TOTAL	**27.2**	**29.2**	**32.6**	**36.2**	**78.2**

Note: See Appendix E for calculation methodology

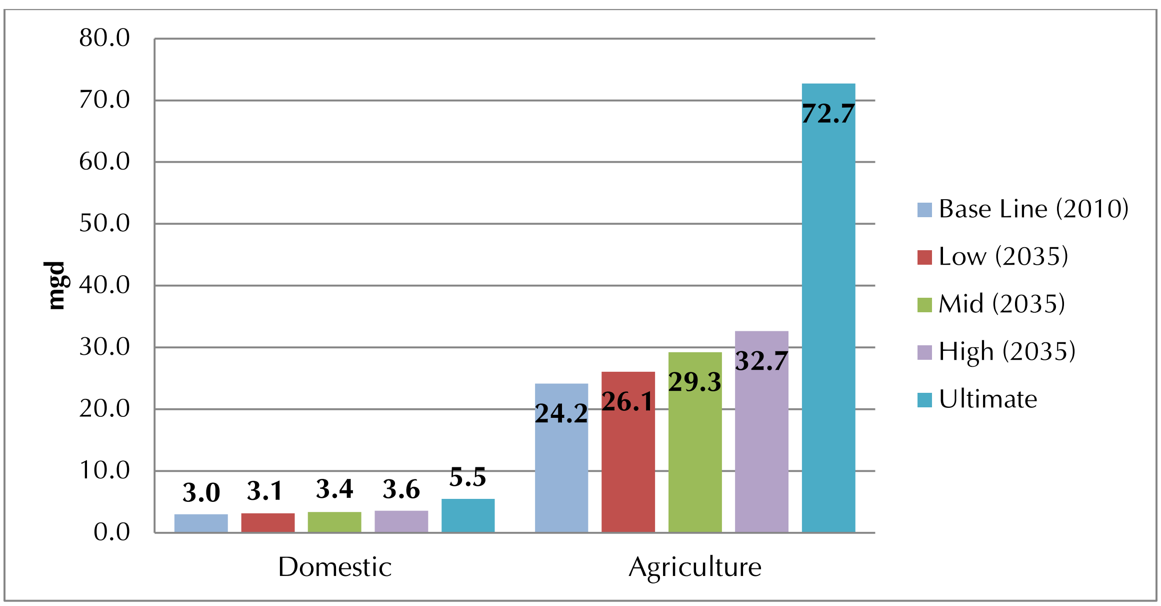


Figure ES.3 Water Demand By Water System

ES.7 SUMMARY OF DEMAND AND SUPPLY

Table ES.3 summarizes the most probable water demand scenario by water system with supply sources that may be used to meet the demands. The total demand is nearly 33 mgd by the year 2035.

The total supply to meet the demand is over 35 mgd. Ground water supply in *Table ES.3* is existing permitted well uses, and surface water supply is existing use via Kamehameha and Dole Food Inc. water distribution systems. The domestic water supply systems are supplied by ground water to meet current and future water demands. A mix of surface water and ground water are used to meet the current and future agricultural demands.

Based on the demand projections for the North Shore and known supply sources, the analysis shows there are adequate water supplies to meet the most probable demand scenario.

One water supply issue not captured in overall demand and supply comparisons of the most probable and ultimate demand scenarios is the availability of water supplies during dry periods and drought conditions. These may result from seasonal fluctuations or long term climate change impacts. Projects that address long term potential water supply issues are especially important and include ones that respond to 1) irrigation water system losses in Wahiawā Irrigation System, 2) agricultural water reliability, and 3) Wahiawā Reservoir water quality.

Table ES.3 Summary of North Shore Most Probable Demand Scenario and Supply

	2010	2015	2020	2025	2030	2035
DOMESTIC WATER SYSTEMS						
BWS Potable Water System Demand	2.81	2.80	2.89	2.94	3.00	3.01
BWS System - Permitted Ground Water Use[1]	3.75	3.75	3.75	3.75	3.75	3.75
Dole Potable Water System Demand	0.00	0.13	0.13	0.13	0.13	0.13
Dole - Permitted Ground Water Supply[1]	0.26	0.26	0.26	0.26	0.26	0.26
North Shore Water Company Potable Water System Demand	0.12	0.12	0.13	0.15	0.16	0.18
North Shore Water Company - Ground Water Supply[1]	0.15	0.15	0.15	0.15	0.15	0.15
US Army/State DOT Dillingham Airfield System Demand	0.06	0.06	0.06	0.06	0.06	0.06
Federal Systems - Ground Water Supply[1]	0.06	0.06	0.06	0.06	0.06	0.06
AGRICULTURE						
Agriculture Water Demand	24.15	25.17	26.19	27.21	28.23	29.25
Ag, Surface Water Supply						
KS Surface Water Supply	3.50	3.50	3.50	3.50	3.50	3.50
Dole Surface Water Supply[2]	8.90	8.90	8.90	8.90	8.90	8.90
Ag, Recycled Water Supply						
Wahiawā Waste Water Treatment Plant (R-1)[3]	-	-	-	1.60	1.60	1.60
Ag, Ground Water Supply						
KS Ground Water Supply[1]	3.21	3.21	3.21	3.21	3.21	3.21
Dole System - Ground Water Permitted Use[1]	1.41	1.41	1.41	1.41	1.41	1.41
State Ag Stations - Ground Water Supply[1]	0.03	0.03	0.03	0.03	0.03	0.03
Other Ground Water Supply[1]	12.80	12.80	12.80	12.80	12.80	12.80
Future Ground Water Permit(s)[4]	-	-	-	-	-	-
TOTAL WATER DEMAND	**27.14**	**28.27**	**29.40**	**30.48**	**31.57**	**32.62**
TOTAL WATER SUPPLY	**34.07**	**34.07**	**34.07**	**35.67**	**35.67**	**35.67**
Kalo Water Demand	1.00	1.50	1.50	2.00	2.00	2.50

Note: Water quantities are in million gallons per day (mgd)

1 CWRM Water Use Permit (WUP) Index (2010); permitted uses for fresh and brackish water wells. Existing unused sustainable yield is available for new wells subject to CWRM water use permit approval.

2 Existing surface water use with current level of losses; additional water demands need to be met through water conservation savings that means more efficient transport of water through the system.

3 Effluent from Wahiawā WWTP that will be used for Galbraith lands which are included in the overall agricultural demand beginning in 2025.

4 Future ground water permits for lands within the Dole WIS system should be granted after WIS system efficiency improvements that maximize existing supply sources have been implemented

ES.8 ULTIMATE DEMAND SCENARIO AND SUPPLY

Figure ES.4 and *Table ES.4* show the demands and supply sources for the ultimate scenario. The total estimated demand for municipal uses is 6 mgd, for agriculture about 73 mgd, and for kalo 10 mgd for a total of 88 mgd.

The supply sources for the ultimate scenario differ from those used to meet the most probable scenario. Due to the unbounded timeframe, it is assumed that all supplies may be more fully developed and distribution systems will have improved efficiencies. The ultimate scenario assumes that the distribution systems deliver water efficiently with minimal losses.

The ground water supply sources include the entire North Shore aquifer sustainable yields (62 mgd) with well development up to those amounts. For the Wahiawā aquifer, the currently permitted well amounts (totaling about 5 mgd) supplying the North Shore district and Galbraith lands are used.

For surface water supply, allowable surface diversions are used and based on declared uses in 1992 which equate to 33 mgd.

Recycled water from the Wahiawā Wastewater Treatment Plant (WWTP) is included as a supply as it may be used for irrigation of the Galbraith lands. The Schofield WWTP production is not included as it is expected that reuse of the increased 3 mgd output will not continue to be placed into the Wahiawā Irrigation System because the cost for that disposal might eventually be recovered by creating more localized uses in Central Oʻahu.

In total, these supply sources add up to 102 mgd which would be enough water to meet the ultimate scenario demand of 89 mgd. Chapter 3 provides more details on these supply sources.

Table ES.4 Ultimate Demand Scenario and Supply

DEMAND (all units in mgd)	
Domestic	**6**
Agriculture	**73**
Kalo	**10**
TOTAL DEMAND	**89**
SUPPLY (all units in mgd)	
Ground Water Sustainable Yields (Waialua, Kawailoa, Mokulēʻia aquifer systems)	62
Ground Water Permitted Uses (for North Shore wells in Wahiawa aquifer system)	5
Recycled Water (Wahiawā WWTP)	**2**
Surface Water (CWRM Diversion Listing)	**33**
TOTAL SUPPLY	**102**
Balance = Supply - Demand	**13**

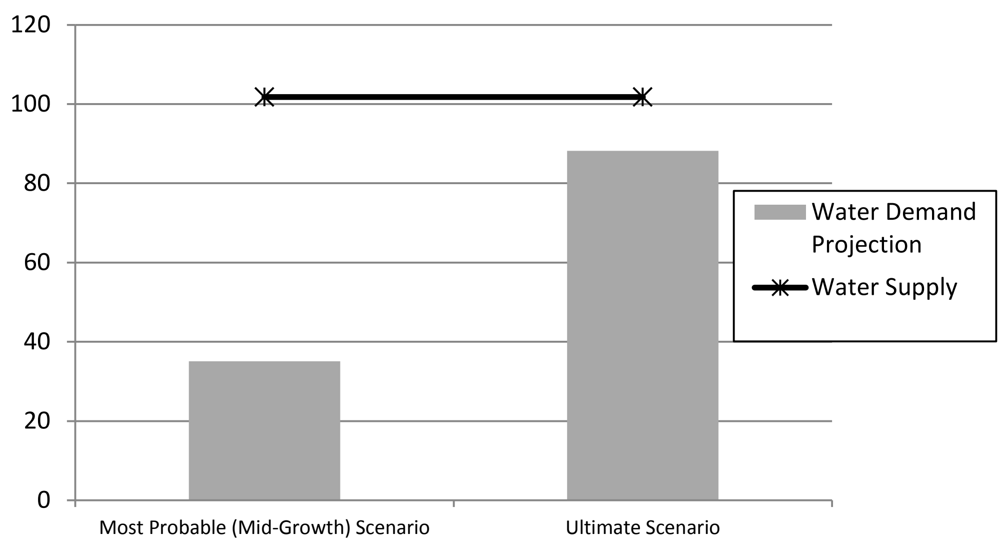


Figure ES.4 North Shore Demand and Supply: Most Probable and Ultimate Scenarios

ES.9 PROJECTS AND STRATEGIES

The NSWMP provides information on specific Water Supply and Watershed Management **"Projects with Champions,"** and more general information on **"Watershed Management Strategies."** The strategies are defined as important concepts that do not yet have "champion" entities that would organize and implement these concepts.

The Projects with Champions are **specific projects that are being planned and/or that are being implemented by a particular public agency or agencies or by a particular community group or non-profit entity.** Many land use and resource management plans present "projects" that are general ideas and conceptual by nature. For North Shore, however, there are many place-specific watershed management projects that are already ongoing.

The NSWMP presents information on a total of 16 projects with champions, which are grouped into five categories: 1) Surface Water, 2) Ground Water, 3) Land Management, 4) Cultural Resources/Traditional Practices, and 5) Water Supply. A **Watershed Management Projects Map** is included on the following page *(Figure ES.5).*

WATERSHED MANAGEMENT PROJECTS AND PROGRAMS WITH PROJECT CHAMPIONS

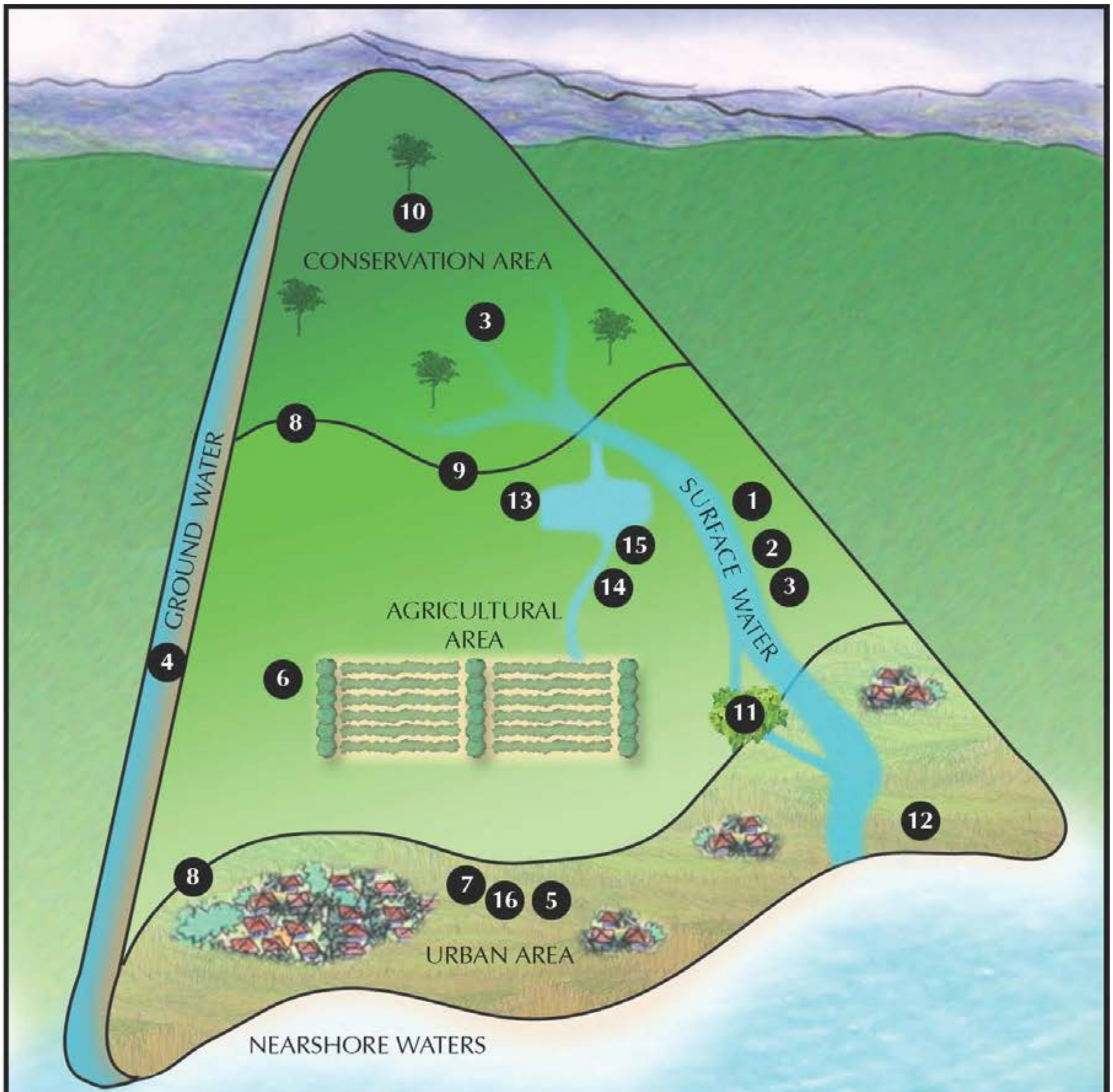
Surface Water Projects and Programs
1. Kaukonahua Stream TMDL Implementation
2. Measurable Instream Flow Standards
3. Waialua-Kaiaka Watershed Restoration Study

Ground Water Projects and Programs
4. Potable Wellhead Protection
5. Mokulēʻia Potable Water System Improvements

Land Management Projects and Programs
6. Agricultural Best Management Practices
7. Low Impact Development Techniques
8. Pūpūkea Paumalū Risk Management
9. Waimea Valley Conservation Action Plan
10. Koʻolau and Waiʻanae Mountains Watershed Partnerships

Cultural Resources/Traditional Practices Projects and Programs
11. Kalo Maintenance and Restoration
12. Kamehameha Schools Loko Ea Fishpond and ʻUkoʻa Marsh Restoration

Water Supply Projects and Programs
13. Wahiawā Reservoir Water Quality Improvements
14. Wahiawā Irrigation System Improvements
15. Agricultural Water Reliability: Water Storage, Back-up Wells, Stormwater Reclamation
16. BWS Conservation Programs



NORTH SHORE WATERSHED MANAGEMENT PROJECTS AND PROGRAMS WITH "PROJECT CHAMPIONS"

Surface Water
1. Kaukonahua Stream TMDL Implementation
2. Measurable Instream Flow Standards
3. Waialua-Kaiaka Watershed Restoration Study

Groundwater
4. Potable Wellhead Protection
5. Mokulē'ia Potable Water System Improvements

Land Management
6. Agricultural Best Management Practices
7. Low Impact Development Techniques
8. Pūpūkea Paumalū Risk Management
9. Waimea Valley Conservation Action Plan
10. Ko'olau and Wai'anae Mountains Watershed Partnerships

Cultural Resources / Traditional Practices
11. Kalo Maintenance and Restoration
12. Kamehameha Schools Loko Ea Fishpond and 'Uko'a Marsh Restoration

Water Supply
13. Wahiawā Reservoir Water Quality Improvements
14. Wahiawā Irrigation System Improvements
15. Agricultural Water Reliability: Water Storage, Back-up Wells, Stormwater Reclamation
16. BWS Conservation Programs

Figure ES.5 Watershed Management Projects Map

The NSWMP also presents basic information on 15 Watershed Management Strategies. "Strategies" are defined here as potential actions that would serve to implement the overall goal, objectives, and sub-objectives of the NSWMP, but that **do not currently have a project champion** or **are small in scope**. Many of these strategies could become Projects if/when an agency or organization decides to be the champion for that strategy. The Strategies are grouped into six categories: 1) Surface Water, 2) Ground Water, 3) Nearshore Water, 4) Land Management, 5) Cultural Resources/Traditional Practices, and 6) Water Supply.

WATERSHED MANAGEMENT STRATEGIES

Surface Water Management Strategies

A. Assess Stream Ecosystem Health
B. Implement Kaiaka Bay Watershed Flood Mitigation Projects and Planning
C. Conduct a Dredging Study and Systematic Maintenance of Key Areas

Ground Water Management Strategies

D. Implement Drought Mitigation Strategies
E. Improve Wastewater Treatment
F. Encourage Gray Water Reuse

Nearshore Water Strategies

G. Support Mālama Pūpūkea-Waimea Makai Watch
H. Designate Waialua Reef as a MLCD

Land Management Strategies

I. Restrict Off-Road Vehicles in Conservation Areas
J. Promote Pollution Prevention Awareness and Education

Cultural Resources/Traditional Practices Strategies

K. Record North Shore Oral History
L. Create North Shore Ahupuaʻa Boundary/Stream Markers

Water Supply Strategies

M. Repair and Replace BWS Pipelines
N. Incorporate Climate Change Plans and Initiatives into North Shore Water and Watershed Planning
P. Implement the Energy Savings Performance Contracting Strategy for Selected BWS Facilities

ES.10 IMPLEMENTATION OF THE NSWMP

Implementation of the North Shore Watershed Management Plan will be a long term, ongoing process involving many project champions from public agencies, non-profit entities, community groups, and private landowners and businesses. Chapter 5 provides plan implementation details.

Phasing and Funding of the 16 Projects with Champions is presented in the Implementation chapter. The projects are noted as being either "short term" – to be implemented within the next 5 years – or "long term" – requiring more than 5 years to implement. Funding for these projects will potentially be provided by various federal, state, and city programs and agencies, and by private foundations and businesses.

The Implementation chapter also provides a presentation and discussion of Priority Watersheds and Catalyst Projects.

A **"Priority Watershed"** is defined as a watershed that: (1) provides various opportunities to promote sustainable watersheds, and/or (2) needs protection or enhancement of water quality and quantity, and/or (3) provides many opportunities to protect Native Hawaiian rights and traditional customary practices, and/or (4) presents special opportunities for organizing and implementing important watershed management actions, and/or (5) provides significant ground water or surface water supplies to meet current and future demand.

A **"Catalyst Project"** is defined as a high priority project within a critical watershed that, when implemented, will provide energy, connectivity, information, and inspiration for other projects and programs within the watershed or district.

The selected Priority Watersheds and Catalyst Projects are discussed below:

- **Ki'iki'i and Paukauila Watershed Systems** – the majority of surface water sources and diversions for agricultural irrigation are within the Ki'iki'i and Paukauila Watershed System areas as well as major portions of the Wahiawā Irrigation Systems' currently irrigated agricultural fields. Also, these watersheds encompass the population centers and contain flood prone areas.

  Catalyst Project: Wahiawā Irrigation System (WIS) Improvements – Fund and complete repairs to improve the condition of the ditches in the Dole-owned portion of the WIS.

  Catalyst Project: Waialua-Kaiaka Watershed Restoration Study – Obtain Congressional funding for a feasibility study to determine appropriate flood control measures. Local community and local governments would then need to pursue structure relocations and flood proofing.

- **Anahulu Watershed System** – includes the Anahulu Stream, which historically provided sustenance to large numbers of Native Hawaiians.

  Catalyst Project: Kalo Maintenance and Restoration – Conduct research and identify potential lo‘i locations; encourage the kalo farmers to offer educational programs along with the farming practices to provide opportunities for learning about and access to native Hawaiian cultural practices. The water supply for kalo should be monitored over time to ensure availability.

- **Loko Ea Watershed** – contains ‘Uko‘a Marsh and Loko Ea Fishpond which are two important cultural resources within the Loko Ea Watershed that contributed to the abundance and wealth of Waialua.

  Catalyst Project: Kamehameha Schools Loko Ea Fishpond and ‘Uko‘a Marsh Restoration – Provide funding for continued conservation, restoration and education at Loko Ea Fishpond and ‘Uko‘a Marsh.

The NSWMP identifies a large number of Projects with Champions and Watershed Management Strategies that are important for water use and watershed health in North Shore. These projects and strategies require various levels of manpower and funding, and can only be implemented to the extent that resources are available from the private and public sectors of the community.

The Implementation chapter concludes with some thoughts on the need for a dedicated funding source that could provide ongoing financial resources for the implementation of important water supply and watershed management projects.

The proposed strategies and projects within this plan are the result of a comprehensive watershed analysis and stakeholder consultation process. The projects may involve various governmental agencies and non-governmental organizations. The implementation and funding of these projects are not the sole responsibility of the Board of Water Supply, City and County of Honolulu, or State of Hawai‘i. This Plan is intended to guide agencies and organizations in implementing the most important initiatives for North Shore watersheds and water resources; however, implementation will depend on budgetary priorities, the availability of grants, and partnering efforts over the long term.

1 O'AHU WATER MANAGEMENT PLAN OVERVIEW

1.1 AUTHORITY AND PURPOSE
1.2 O'AHU WATER MANAGEMENT PLAN FRAMEWORK
1.3 O'AHU WATER USE AND DEVELOPMENT PLAN UPDATE
1.4 PLAN IMPLEMENTATION

1.1 AUTHORITY AND PURPOSE

The Watershed Management Plans (WMPs) for O'ahu have been prepared in accordance with the requirements of the State Water Code and Revised Ordinances of the City and County of Honolulu, which established the "O'ahu Water Management Plan." The State Water Code, Chapter 174-C protects, controls and regulates the use of the State's water resources for the benefit of its people and the environment. Under the Code, the County is responsible for preparing the water use and development plan for the City and County of Honolulu. In response, Chapter 30 Revised Ordinances of Honolulu (ROH) Water Management, established the *O'ahu Water Management Plan* (OWMP), which has evolved into a framework of regional WMPs by City development plan district to plan for the management of all water resources within each watershed (*Appendices A and B*). The land use districts are shown in *Figure 1.1*.

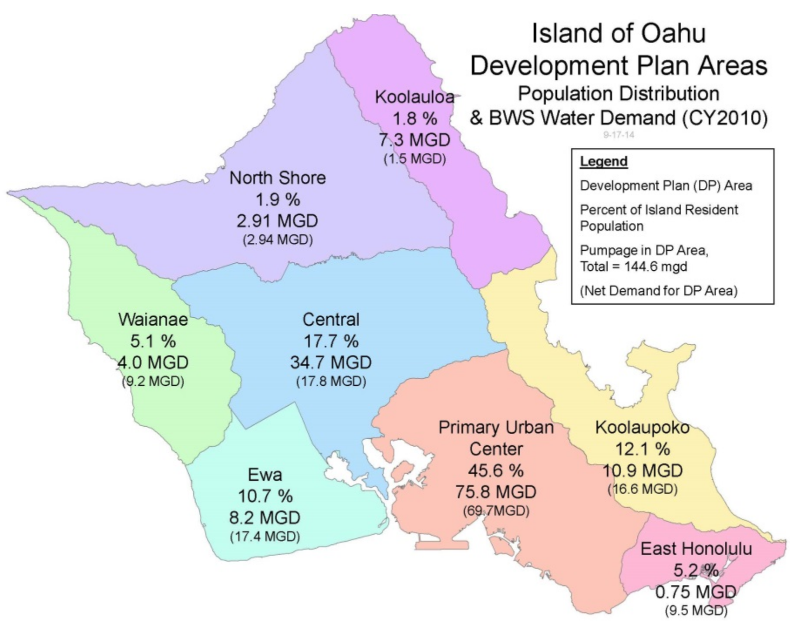


Figure 1.1 O'ahu Development Plan Areas

The State Water Code's Declaration of Policy recognizes the need for comprehensive water resources planning and establishes the Hawaiʻi Water Plan (HWP) as the guide for developing and implementing this policy. The HWP is intended to serve as a continuing long-range guide for the Commission on Water Resource Management (CWRM) in executing its general powers, duties, and responsibilities assuring economic development, good municipal services, agricultural stability, and environmental protection.

The HWP currently consists of five major components (plans) identified as the: 1) Water Resource Protection Plan, 2) Water Quality Plan, 3) State Water Projects Plan, 4) Agricultural Water Use and Development Plan, and 5) County Water Use and Development Plans.

The Water Code recognizes that the HWP must be *"continually updated to remain useful and relevant and further specifies that each county shall update and modify its water use and development plans as necessary to maintain consistency with its zoning and land use policies"* §174C-31(q) HRS.

WATER USE AND DEVELOPMENT PLAN (WUDP)

A separate WUDP is to be prepared by each of the four counties and adopted by ordinance. The objective of the WUDPs is to set forth the allocation of water to land use in that county. Administrative Rule §13-170-31 states that each WUDP shall include, but not be limited to:

(1) Status of county water and related land development including an inventory of existing water uses for domestic, municipal, and industrial users, agriculture, aquaculture, hydropower development, drainage, reuse, reclamation, recharge, and resulting problems and constraints;
(2) Future land uses and related water needs; and
(3) Regional plans for water developments including recommended and alternative plans, costs, adequacy of plans, and relationship to the water resource protection plan and water quality plan.

Additional guidelines for preparing the WUDPs are provided in Administrative Rule §13-170-32:

(4) Each water use and development plan shall be consistent with the water resource protection plan and the water quality plan.
(5) Each water use and development plan and the state water projects plan shall be consistent with the respective county land use plans and policies, including general plan and zoning as determined by each respective county.
(6) Each water use and development plan shall consider a twenty year projection period for analysis purposes.
(7) The water use and development plan for each county shall also be consistent with the state land use classification and policies.
(8) The cost of maintaining the water use and development plan shall be borne by the counties; state water capital improvement funds appropriated to the counties shall be deemed to satisfy Article VIII, section 5 of the State Constitution.

STATEWIDE FRAMEWORK FOR UPDATING THE HAWAI'I WATER PLAN

In February 2000, CWRM adopted the Statewide Framework for Updating the Hawai'i Water Plan (Statewide Framework). The objectives of developing and outlining a statewide framework for the Hawai'i Water Plan (HWP) are:

- To achieve integration of land use and water planning efforts that are undertaken by federal, state, county, and private entities so that a consistent and coordinated plan for the protection, conservation and management of our water resources is achieved;
- To recommend guidelines for the HWP update so that the plan and its component parts are useful to CWRM, other state agencies, the counties, and the general public;
- To develop a dynamic planning process that results in a "living document" for each component of the HWP which will provide county and state decision-makers with well formulated options and strategies for addressing future water resource management and development issues;
- To better define roles and responsibilities of all state and county agencies with respect to the development and updating of the HWP components;
- To describe and outline the techniques and methodologies of integrated resource planning as the basic approach that should be utilized in developing and updating the County WUDPs;
- To facilitate permitting and to identify potential critical resource areas where increased monitoring or baseline data gathering should proceed;
- To establish an overall schedule for phased updating of the HWP; and
- To outline an Implementation Plan for near-term and long-term actions.

The Statewide Framework includes the following recommended plan elements for the County WUDP update process:

- County-Specific WUDP Project Description
- Coordination with CWRM on Water Resource Management
- Stakeholder and Public Involvement
- Development of Policy Objectives and Evaluation Criteria
- Description of Water System Profiles
- Identification of Resource and Facility Options
- Development and Evaluation of Strategy Options
- Implementation Plan

The Statewide Framework further recommends integration of HWP components at the county level.

O'AHU WATER MANAGEMENT PLAN: 1990 ADOPTION TO PRESENT

The initial HWP, including all component plans, was adopted by CWRM in 1990. In compliance with the State Water Code, the City and County of Honolulu enacted the O'ahu Water Management Plan (OWMP) by Ordinance No. 90-62 and codified as Chapter 30, Articles 1, 2 and 3, Revised Ordinances of Honolulu (ROH), 1990, as amended. The OWMP serves as the WUDP for the City and County of Honolulu. The OWMP consists of policies and strategies, which guide the activities of the City and County of Honolulu and advises CWRM in the areas of planning, management, water development and use and allocation of O'ahu's natural water resources.

The 1990 OWMP described existing uses of water and contemplated future needs for the island of O'ahu. The plan highlighted regional water problems and identified major water development projects. It also described the quality of water required for the contemplated uses. Informational needs and data gaps identified in the plan included surface water availability and use and agricultural water demand projections.

CWRM deferred adoption of the 1992 OWMP update pending additional refinement of plan components. Subsequent updates were complicated because of rapid changes to the water resources situation on O'ahu with the closing of the sugar plantations and the resulting Waiāhole Ditch Contested Case in 1995.

In 1999, the Honolulu Board of Water Supply (BWS) began the integrated island-wide water planning effort to update the OWMP as recommended by CWRM. However, this approach was met with significant opposition by the public. One of the major concerns expressed by the public was that it is important to have equal focus on resource protection, conservation, and restoration as on water use and development. Communities also desired to be active participants in a community-based planning process. In addition, the communities consulted wanted assurance that there were sufficient water resources within their watersheds before island-wide regional water needs were discussed.

In August 2000, the Hawai'i Supreme Court announced their landmark decision that changed the way Hawai'i's water laws were interpreted. The court drew upon principles of the Public Trust Doctrine and the Precautionary Principle and have over time, identified four public trust uses of water that have priority over other water uses: 1) maintenance of waters in their natural state; 2) domestic water use; 3) the exercise of Native Hawaiian and traditional and customary rights, including appurtenant rights and 4) reservations of water for Hawaiian Home Lands (See Appendix B.5). In response to these Supreme Court decisions, BWS decided to expand the water planning approach to include these principles through a holistic watershed-based approach modeled after the Hawaiian concept of ahupua'a encompassing environmental, economic and social/cultural values. A planning framework for watershed protection and water use and development was established for updating the OWMP that is inclusive of various legal and planning documents with extensive community participation that guide the plan.

On March 17, 2004, CWRM approved the OWMP framework, scope of work and planning elements for regional watershed management plans as meeting the statutory and statewide framework provisions for updating the County WUDP.

The Honolulu City Council adopted the Waiʻanae and Koʻolau Loa WMPs on August 18, 2010, and the Koʻolau Poko WMP on August 15, 2012. These three of eight regional watershed management plans will, together with island-wide water management policies and strategies in Article 2 of Chapter 30 ROH, form the updated Oʻahu Water Management Plan. In areas where a regional watershed plan has not been adopted, Chapter 30, ROH and the Technical Reference Document for the OWMP, dated March 1990, shall serve as the County WUDP.

The Ordinance further states that in conjunction with BWS, the City Department of Planning and Permitting (DPP) shall be responsible for the preparation of the regional watershed management plans for the OWMP. The regional WMPs shall be adopted by ordinance and then submitted to CWRM for adoption. Each regional WMP shall be updated, at a minimum, in tandem with the respective Development Plans/Sustainable Communities Plans.

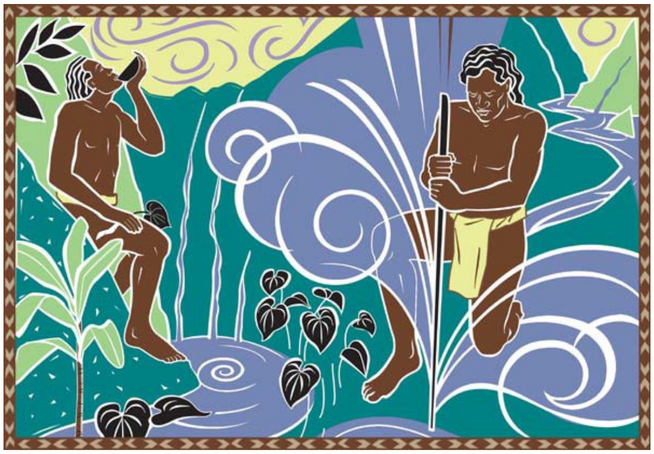
On March 16, 2011, CWRM adopted the Waiʻanae and Koʻolau Loa WMPs into the Hawaiʻi Water Plan. CWRM approved of the regional, watershed-based approach to water resource management as a viable methodology for the integration of HWP components within the County WUDP.

1.2 OʻAHU WATER MANAGEMENT PLAN FRAMEWORK

The OWMP consists of overall policies and strategies and regional watershed management plans, that will guide the activities of the City and County of Honolulu and will also provide advice to CWRM regarding the planning, management, conservation, use, development, and allocation of Oʻahu's limited surface water and ground water resources for the next 20 years to 2035.

The OWMP shall be consistent with relevant Federal, State, and City laws and policy documents, including:

- Federal Clean Water Act and Safe Drinking Water Act
- Hawaiʻi State Water Plan
- State Water Code
- Statewide Framework for Updating the Hawaiʻi Water Plan
- Hawaiʻi Supreme Court Decisions on the Waiāhole Ditch and the Waiʻola O Molokaʻi contested cases
- State land use classifications and policies
- City and County of Honolulu Chapter 30, ROH establishing the OWMP island-wide polices and strategies and regional WMPs.
- General Plan for the City and County of Honolulu and Development Plans and Sustainable Communities Plans for Oʻahu's eight land use districts
- City Zoning Designations
- BWS Mission of "Water for Life, Ka Wai Ola"



"Water for Life – Ka Wai Ola"

The resulting WMPs are built on the following key planning principles:

- Community-based
- Environmentally holistic
- Based on *ahupua'a* management principles
- Action-oriented
- In alignment with State and County water and land use policies.

The following graphic (*Figure 1.2*) illustrates the planning framework for the OWMP. The framework identifies the various legal and planning documents that guide the plan. Each of the eight WMPs by O'ahu General Plan land use districts will be organized within this framework and the island overview chapter will provide a consolidating mechanism to place each of the regions into the proper island-wide perspective.

The framework is meant to establish and guide the watershed management objectives and strategies specific to each region. The eight WMPs tie directly into the eight land use plans through common boundaries, vision and policies. A key denominator integrating land use and water planning is the maintenance of a healthy watershed. Land use plans and water use and development plans that support growth and existing communities on O'ahu must ensure that watersheds remain healthy through sustainable planning practices, watershed protection projects, and best management practices that minimize impacts.

Given these expressed inter-relationships between land and water, Chapter 30 ROH now requires that each regional WMP shall be updated, at a minimum, in tandem with the respective Development Plans/Sustainable Communities Plans. With each iteration, land use and water planning will become increasingly integrated in vision, policies, goals, and objectives, resource protection and management and infrastructure development to achieve a sustainable future.

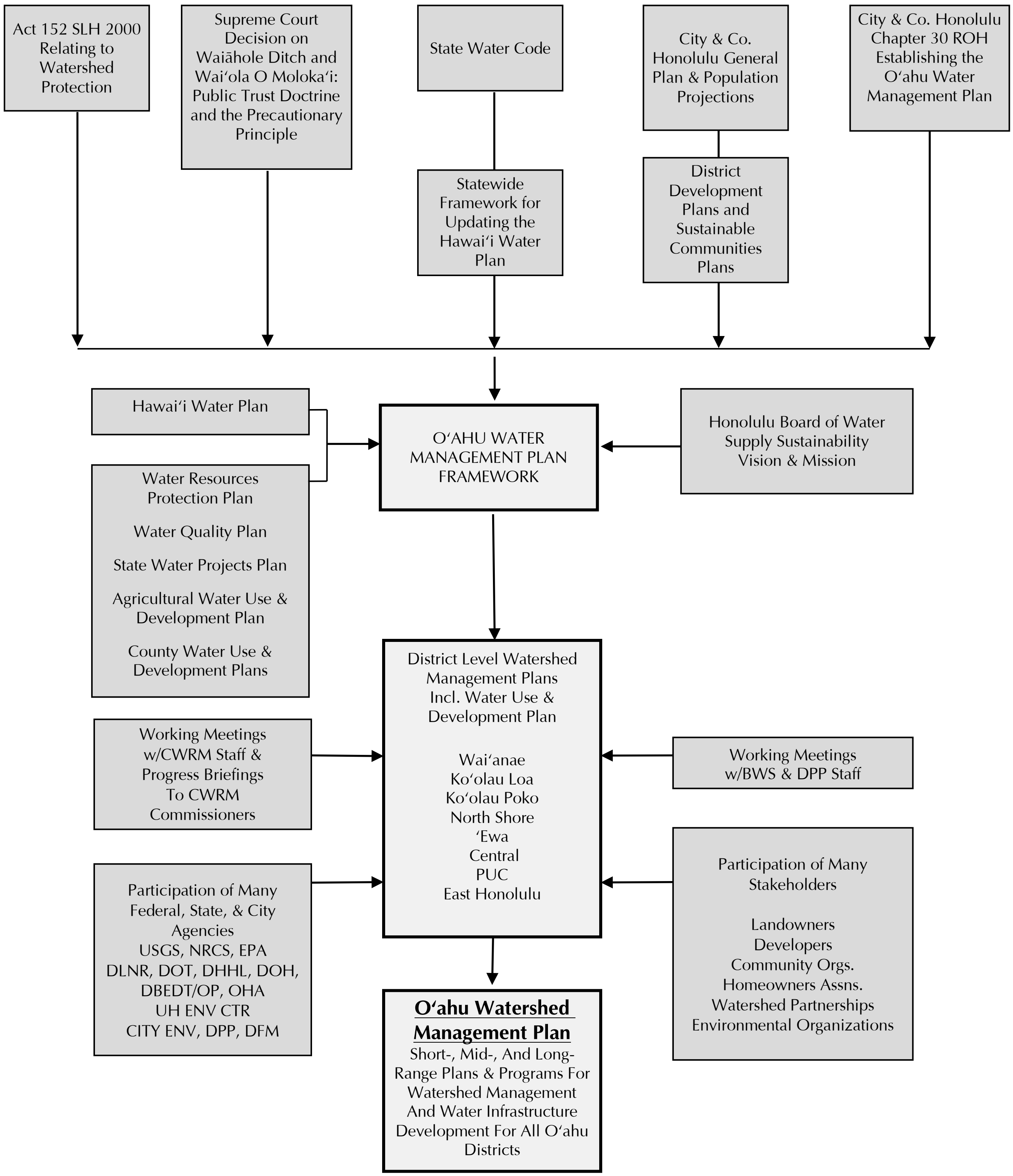


Figure 1.2 Watershed Management Plans for Oʻahu, County and State Level Planning Framework Diagram

Based on the planning principles and through a consultation process with community leaders, community groups, public agencies, landowners, and other stakeholders in the watershed management planning process, BWS then developed an overall statement of Goals and Objectives for the OWMP, as follows:

GOAL

To formulate an environmentally holistic, community-based, and economically viable WMP that will provide a balance between: (1) the preservation, restoration and management of O'ahu's watersheds, and (2) sustainable ground water and surface water use and development to serve present users and future generations.

OBJECTIVES

(1) Promote sustainable watersheds.
(2) Protect and enhance water quality and quantity.
(3) Protect Native Hawaiian rights and traditional and customary practices.
(4) Facilitate public participation, education, and project implementation.
(5) Meet future water demands at reasonable costs.

The WMP objectives were derived from an extensive stakeholder consultation process and reflect their values and thinking about water resources. These values and thinking were then consolidated into broad goals and objectives that apply island-wide thus providing the overall guidance, balance, and consistency for each of the eight district level WMPs. Each of the eight plans will define more specific sub-objectives, policies, strategies, and actions that reflect specific district conditions, issues, and needs and provide a balance among all five plan objectives under the OWMP Framework.

Objective 1. Promote sustainable watersheds

Sustainable watersheds are bio-diverse, renewable, and resource productive land and water ecosystems extending from the mountains to the coral reefs, that meet present needs without compromising those of future generations. In a sustainable watershed, there is a holistic interrelationship among watershed resources including geologic structures, soil characteristics, forest communities, endemic and indigenous animals, native and introduced species, ground water aquifers, streams and wetlands, reefs and near-shore waters, traditional and cultural practices, land use and land development. Healthy, sustainable watersheds should be the foundation for both land use and water resources management planning.

Sustainable watersheds can be achieved through the implementation of a comprehensive WMP that promotes a healthy watershed by emphasizing habitat and native species preservation, active forestry management practices, invasive species and pollution controls, resource conservation and demand-side management programs, low-impact development concepts and recycling.

Objective 2. Protect and enhance water quality and quantity

Water is essential to human life and to the health of the environment. As a valuable natural resource, it comprises marine, estuarine, wetlands, freshwater streams and ground water environments, across coastal and inland areas. Water has two dimensions that are closely linked - quality and quantity. Water quality relates to the composition of water as affected by natural processes and human activities. It depends not only on water's chemical condition, but also its biological, physical and radiological condition. Water quantity relates to the amount of renewable ground water supply or base stream flow existing on a sustainable basis. In a healthy environment, water quality and quantity supports a rich and varied community of organisms and protects public health. Water quality and quantity influence the way in which communities use the water for activities such as drinking, swimming, fishing, farming, gathering, or commercial purposes.

Drinking water systems are regularly tested for compliance with EPA Safe Drinking Water Standards and BWS criteria for system operations and resource monitoring. Watershed protection projects and programs will ensure that aquifers and streams are healthy and sustainable. Source water protection programs and the monitoring of hydrologic indicators of rainfall, stream and spring flows, and aquifer water levels will ensure consistently high source water quality.

BWS ensures the health of the ground water aquifers by monitoring the island-wide index and deep monitor wells for water levels and chlorides at the top and mid-point of the fresh water/sea water transition zone. Source water quality can be affected by sea water intrusion or up-coning brackish water especially during extended drought. Monitoring also ensures sufficient aquifer recovery during post-drought periods.

BWS, CWRM, University of Hawai'i and U.S. Geological Survey (USGS), are advancing research and analytical modeling tools to increase understanding of recharge and ground water aquifers and streams. The agencies work collaboratively to fund, construct and utilize 3-dimensional solute transport ground water modeling calibrated with new deep monitor wells in basal aquifers to:

- Evaluate individual source yields to prevent up-coning and salt water intrusion during normal rainfall and drought events.
- Optimize existing source pumpages to meet water system demands and avoid detrimental impacts to the aquifer's utility (quality and quantity); ensure adequate aquifer recovery after long drought periods.
- Evaluate aquifer sustainable yields as allocations and pumpage approach sustainable yield limits to ensure new sources are sustainable.
- Site and size new wells to develop remaining ground water and minimize impacts to adjacent and down-gradient sources and surface waters.

Objective 3. Protect Native Hawaiian rights and traditional and customary practices

Native Hawaiian water rights are set forth in the State Constitution, Section 221 of the Hawaiian Homes CWRM Act and Section 174C-101 of the State Water Code, providing for: a) Department of Hawaiian Home Lands water; b) traditional and customary gathering rights; and c) appurtenant water rights of kuleana and kalo lands. Native Hawaiian water uses also include cultural uses for spiritual/religious practices, kalo and other traditional agriculture, as well as adequate flows of fresh water into the nearshore water ecosystem.

The Hawai'i Supreme Court held that title to water resources is held in trust by the State for the benefit of its people and established the exercise of Native Hawaiian and traditional and customary practices as a public trust purpose, along with the maintenance of waters in their natural state, domestic water use, and reservation of water for Hawaiian Home Lands. Some of the objectives proposed for implementing the public trust purposes include the provision of adequate stream flows, riparian restoration, and control of alien species. These WMP objectives strive to ensure the availability of healthy and plentiful water resources.

Protecting Native Hawaiian rights and traditional and customary practices must be done in conjunction with setting measurable instream flow standards (IFS) for all perennial streams and stream segments, and balancing in-stream uses, domestic uses, and Native Hawaiian and traditional and customary uses with off-stream reasonable and beneficial uses. In developing those standards a precautionary order, consisting of instream studies such as stream hydrology and bio-assessments for habitat and gathering, is proposed. Studies of water for public trust purposes are also needed. Only after completing this evaluation of stream water can a determination of surface water availability for additional agricultural uses and urban nonpotable uses be accomplished.

Where practical, the WMP will identify the conversion of existing off-stream surface water uses to recycled water and implement conservation measures to create an opportunity for stream restoration. BWS will continue to develop new ground water sources that do not impact surface waters. However, if instream flow standards are established and surface water becomes available, surface water diversions and ground water development that may reduce surface water within the allowances granted by the measurable IFS may be pursued.

Objective 4. Facilitate public participation, education, and project implementation

Planning and managing our island's water and related resources involves a variety of stakeholders including end users, landowners, public and private water purveyors, and government agencies. A collaborative process can result in innovative planning and implementation that incorporates local knowledge and directly involves area residents. Public education of water resource issues can support collaboration with informed stakeholders. Directed water resource curriculum for schools will ensure that knowledge and respect for water resources will extend to future generations. Ultimately public participation will result in benefits to the water resources, water users and the related ecosystems.

Several watershed partnerships have been established in both conservation and urban areas with community groups, agencies and organizations with similar objectives. These partnerships pool funding, resources and initiatives toward common objectives of watershed health, education, project funding, and implementation.

Objective 5. Meet water demands at reasonable costs

Water is essential to all life. O'ahu's population relies on an abundant and reliable water supply for drinking, irrigation, agriculture, commercial and industrial use, and fire protection. O'ahu's residents are educated in watershed management practices; water conservation is not just a message, but a way of life. Efficient water systems promote public health and safety and deliver water to meet current and future demands at reasonable costs. Reasonable costs encompass a balancing of the other plan objectives and are not necessarily the lowest economic costs. Capital improvements and operations and maintenance costs should not place an unreasonable burden on water rate payers. Water systems are flexible yet secure to account for uncertainties, and are expanded concurrent with land use plans and growth forecasts. Withdrawal rates are precautionary with respect to the resource and are well within established sustainable yields and instream flow standards, which protect the long-term viability of the water resource and do not detrimentally, impact cultural uses and natural environments.

The allocation of water to land use considers a full range of alternative water sources. Water quality should be matched with appropriate use. Thus, high quality water is used for drinking and lower quality water, such as recycled water, is used for irrigation and industrial processes. New technology allows cost effective, diversified, drought proof water systems that develop ground water, surface water, recycled and seawater resources that meet water demands while balancing other plan objectives.

The following categories describe the primary water planning elements of this objective:

<u>Water Conservation</u>

- Improving distribution system efficiencies will reduce Operations and Maintenance (O&M) costs and reduce water loss. Infrastructure water loss and efficiency measures include leak detection and repair of existing pipelines and ditch systems and the renewal and replacement of water system facilities (pipelines, ditches, pump stations, reservoirs and treatment systems). Advanced corrosion protection systems will maximize the life of existing and new pipelines.

- Promoting demand-side management programs provides hardware and behavioral modifications on customer water use. Water conservation tips, public service announcements and specific programs tailored to distinct user categories will effectively reduce water use and defer development of new water sources.

- Educational programs promote conservation as a way of life that affects a generational change in thinking that starts with the education of our children. BWS has been promoting water conservation best practices in schools for over 40 years.

<u>Efficient Water Use and New Sources of Supply</u>

- New source development can be deferred with increases in system efficiency, which is more cost effective. New source options must balance economic costs with environmental, cultural and social values.

<u>Growth Projections</u>

- Improving water demand forecasting methodologies will ensure that new sources become available at the appropriate time. The level of accuracy will improve as the calibration of leading indicators and trends improve.

Drought Mitigation

- A diversified and sustainable water system can mitigate drought impacts. The State and O'ahu County Drought Plans have identified mitigation strategies and projects for water supply, agriculture and wildland fire prevention, to reduce the detrimental impacts of drought on water uses, the economy and the environment.

Operational Flexibility

- An integrated island-wide water system provides operational flexibility, water service reliability, and hydraulic efficiency. A flexible water system maintains level of service standards while allowing planned repair and maintenance. An important element of optimization integrates efficient operations of the existing water systems with sustainable aquifer pumpage levels.

Water System Reliability, Adequacy and Efficiency

- Water system reliability reflects the ability of the distribution system to consistently deliver water with minimal interruptions during normal and emergency conditions. Water systems are constantly improved to meet BWS Water System Standards providing standby pump capacity, infrastructure redundancy, treatment systems, enhanced security measures, drought mitigation, and disaster response.

- Adequate capacity reflects the ability to deliver an acceptable quantity and quality of water at a suitable pressure and overall responsiveness to customer needs and planned growth. As aging pipelines are replaced, capacity is added to improve fire protection, increase low pressure areas and reduce high pressure transients that could reduce pipeline design life. A diversified water supply system consisting of a combination of ground water, surface water, recycled water, desalinated water and seawater resources improves water system adequacy.

- Water System Efficiency reflects how well water is produced, delivered and used, and how energy is utilized. Efficiency is the ability to deliver water with a minimum of effort, expense or waste. Reliable water systems are energy efficient, have emergency power generation and are supplied with an increasing proportion of renewable energy supplies reducing reliance on imported oil. Elements of this objective include:

    - Reducing water system energy use per mgd produced.
    - Energy efficiency measures in pumping facilities include motors, variable frequency drives, lighting, heating, ventilation and use of photovoltaics.
    - Peak power load reduction using reservoirs and diesel generators to meet peak hour water demand results in lower electric bills.
    - Researching and supporting renewable energy systems such as H-Power, wind, solar, biofuels, OTEC and wave energy will help reduce water pumping power consumption from imported oil, mitigating some of the global energy uncertainties.

Planning for Uncertainty

- Maximize the ability to effectively plan and respond to uncertainties in water supply, forecasting water demand and climate change adaptation.

1.3 O'AHU WATER USE AND DEVELOPMENT PLAN UPDATE

The OWMP consists of island-wide water management policies and strategies and regional watershed management plans, which guide the activities of the City and County of Honolulu and advises the state CWRM in the areas of planning, management, water development and use and allocation of O'ahu's limited water resources. The island-wide policies and strategies listed in Article 2, Chapter 30 ROH, and restated below, apply to all City agencies *"in the performance of their powers, duties and functions as related to both public and private development."* The implementation of the strategies will carry out the policies.

Policy 1. Facilities for the provision of water shall be based on the general plan population projections and the land use policies contained in the development plans and depicted on the development plan land use maps.

Policy 2. System flexibility shall be maintained to facilitate the provision of an adequate supply of water consistent with planned land uses. The municipal water system shall be developed and operated substantially as an integrated island-wide water system.

Policy 3. Close coordination shall be maintained between federal, state and county agencies which are involved in the provision or management of water to ensure optimal distribution of the available water supply.

Policy 4. The quality and integrity of the water supply shall be maintained by providing for the monitoring and protection of the water supply in accordance with the requirements of the state water code.

Policy 5. The development and use of nonpotable water sources shall be maximized in a manner consistent with the protection of the ground water quality.

Policy 6. Water conservation shall be strongly encouraged.

Policy 7. Alternative water sources shall be developed wherever feasible to ensure an adequate supply of water for planned uses on O'ahu.

Strategy 1. Develop water resources in consonance with the general plan population projections and the land use policies contained in the development plans and depicted on the development plan land use maps. Priority shall be given to affordable housing projects shown on the development plan land use maps or processed under HRS Chapter 201E.

Strategy 2. Continue to safely develop the remaining available ground water in accordance with the requirements of the state water code.

Strategy 3. Use surface water more effectively and efficiently.

Strategy 4. Continue to refine the near and long-term projections of agriculture on the island to more accurately project the future net release of water currently committed to agricultural use.

Strategy 5. Maintain an ongoing water conservation program through the board, using such approaches as pricing, public information, educational programs, water-saving devices, and use restrictions and allocations.

Strategy 6. Develop and use nonpotable water sources, wherever feasible, for the irrigation of agricultural crops, parks and golf courses, landscaping and for certain industrial uses.

Strategy 7. Continue efforts to develop economical methods of demineralizing brackish water and desalting seawater.

Article 2 further states that *"based on the findings and projections in the OWMP, provisions for an adequate supply of water to meet island-wide needs for at least twenty years shall be addressed. This shall be determined after evaluating the anticipated demand for water use from municipal, agricultural, military and private users; the available remaining ground water which can be safely developed; the planned and proposed water source development projects; and alternative water development projects under way."* The following update provides this basis.

Water use and development on O'ahu is guided by the City's General Plan and the Development Plans and Sustainable Communities Plans for the eight land use districts. These community-based land use plans describe each community's vision of their future and provide land use and infrastructure policies and guidelines. An important aspect of the City's land use plans is the establishment of urban growth and sustainable community boundaries that separate urban and rural development from agricultural and conservation lands. These boundaries provide adequate area for urban and rural development, protect important agricultural and conservation lands and facilitate infrastructure master planning.

An essential component of the WMP is the development of region-specific watershed management projects and strategies that enhance ground water and surface water supplies, improve land management with respect to water, protect traditional and cultural practices and facilitate plan implementation. Each regional WMP will consist of about 30 to 40 watershed management projects and strategies derived from stakeholder consultation and the strategic plans and capital improvement programs of various Federal, State and City agencies, organizations, communities and watershed partnerships. These projects meet the five WMP objectives of balancing the protection of natural resources and the sustainable use of O'ahu's water supplies.

The following summary of O'ahu's water use and development provides the island-wide context to review and understand the eight regional WMPs. Together, the proposed regional watershed management plans update the OWMP as designed in the OWMP Framework.

As part of the process of initiating the update of the OWMP, and consistent with the guidelines set forth in the Statewide Framework for Updating the Hawai'i Water Plan, BWS has compiled information on existing and projected water demands and sources of supply for the municipal system; State, federal, and private water systems; and prime and unique agricultural lands. In summary, BWS has evaluated the adequacy of the supply to meet future potable and nonpotable water needs and through a combination of conservation, diversified water supply development and watershed protection strategies, the City can meet water demands through the 2035 planning period.

1.3.1 City and County of Honolulu Land Use Plans

The General Plan for the City and County of Honolulu is a comprehensive statement of objectives and policies, which sets forth the long-range aspirations of O'ahu's residents and the strategies of actions to achieve them. It is the overarching policy document of a comprehensive planning system that addresses physical, social, economic and environmental concerns affecting O'ahu. This planning system serves as the coordinating structure by which the City provides for the future growth on the island of O'ahu. The General Plan provides objectives and policy statements which will help the City achieve a desirable and attainable residential population distribution among the eight land use regions, directing the bulk of new growth and supporting infrastructure to the primary and secondary urban centers and the 'Ewa and Central O'ahu urban fringe areas to relieve developmental pressures in the remaining urban fringe and rural areas and to meet housing needs.

The City established regional Development Plans (DP) and Sustainable Communities Plans (SCP) for each of the eight land use planning regions of O'ahu. Each community-oriented land use plan is intended to help guide public policy, investment, and decision making over the next 20 years. Each plan responds to specific conditions and community values of each region. 'Ewa and the Primary Urban Center are "development plan" areas where growth and supporting facilities will be directed and be the policy guide for development decisions and actions needed to support that growth. The remaining six districts are "sustainable communities" plans, which are envisioned as relatively stable regions in which public programs will focus on supporting existing populations. Each land use district establishes a boundary to contain urban and rural development to protect agriculture and preservation zoned areas. These plans can be found on the City and County of Honolulu Department of Planning and Permitting's website at http://www.honoluludpp.org/.

1.3.2 Population Forecasts and Municipal Water Demand

Population forecasts are provided by DPP's land use model utilizing US Census Bureau and State Department of Business Development and Tourism data, development master plans and subdivision information. DPP provides the forecasts by transportation analysis zones (TAZ) and census tracts, which provide more discrete land use coverage information within each land use district.

BWS applies its water use data to DPP's population forecast data to derive BWS served populations, gallon per capita demands and water demand forecasts by land use district for long range planning of source development and water system infrastructure sizing. Note that with all long-range forecasts, a range of variation will occur due to uncertainties in changing economic climate, jobs, tourism, zoning, development starts, population distribution and water conservation.

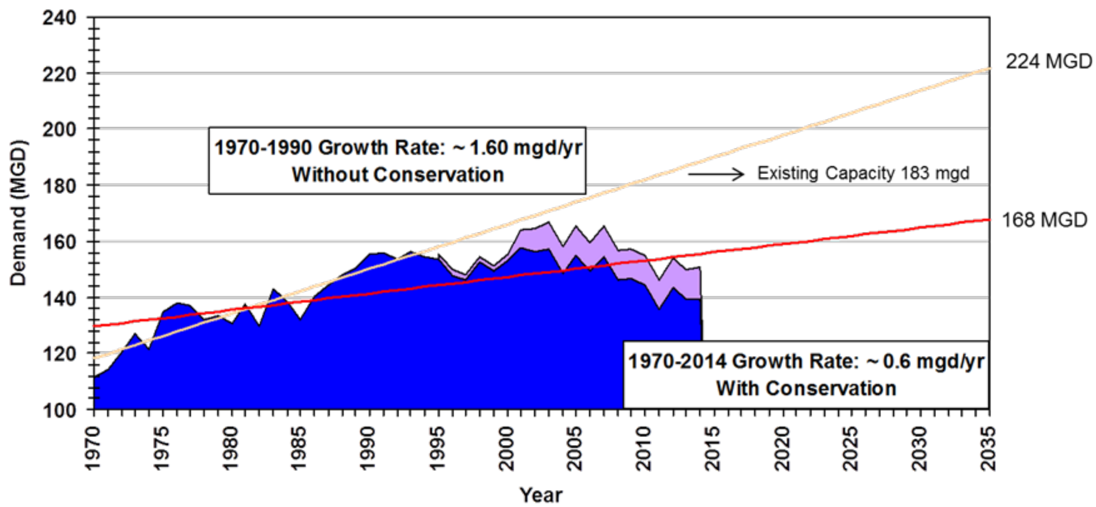


Figure 1.3 BWS Potable and Nonpotable Water Systems Demands: Actual 1970-2014 and Linear Projection to 2035

BWS water conservation programs starting in 1990 (in particular low flow toilets), Honouliuli recycled water in 2003 and the economic incentives associated with the increase in water and sewer rates over the last decade have significantly reduced potable water demand on O'ahu. In *Figure 1.3*, potable demand (blue) plateaued at about 155 mgd from 1990 to 2000 after steady growth from 1970 to 1990. Since 2004, potable water demand has decreased to 144.5 mgd in 2010 despite a resident population increase of over 115,000 people. Recycled and brackish nonpotable demands are shown in purple.

In *Figure 1.3*, potable demand growth rates are linearly projected to 2035 along two slopes of 1.60 mgd/year from 1970-1990 without conservation and 0.6 mgd/year from 1970-2014 with conservation amounting to 168 mgd in 2035. The trend with conservation can be considered as the BWS mid-growth scenario, while the 224 mgd trend without conservation will no longer be considered as a possible scenario. A trend line from 1990-2014 would show a decreasing trend to some future point, but is not provided because there is a saturation point at which additional conservation savings will only be realized at significant costs (see also *Figure 1.4*).

BWS applies the per capita demand model to forecast future water demands because population forecasts using the DPP land use model as described above are readily available. In *Table 1.1*, the Per Capita Demand is derived by dividing BWS potable water demand, which includes water loss, by the BWS served population. The served population accounts for visitors present, residents absent and deducts military and private water systems. The per capita demand is then multiplied by the projected served population to derive the potable water demand forecast.

Table 1.1 Oʻahu Population and Water Demand 2010, By Development/Sustainable Communities Plan Area

DP Area	Resident Population	% Resident Population	Residents Absent	Visitors Present	Defacto Population	Private/ Military	BWS Population Served	DP Area Demand (mgd)	Per Capita Demand (gpcd)
Waiʻanae	48,519	5%	2,667	1,349	47,201	6	47,195	9.251	196
ʻEwa	**101,520**	**11%**	**5,582**	**2,993**	**98,931**	**6,757**	**92,174**	**17.367**	**188**
Central Oʻahu	168,520	18%	9,264	493	159,749	18,822	140,927	17.762	126
PUC	435,118	46%	23,921	79,967	491,164	30,214	460,950	69.768	151
East Honolulu	49,914	5%	2,744	896	48,066	0	48,066	9.476	197
Koʻolau Poko	115,164	12%	6,331	293	109,126	632	108,494	16.508	152
Koʻolau Loa	16,732	2%	920	80	15,892	6,398	9,494	1.474	155
North Shore	17,720	2%	975	1,377	18,122	3,623	14,499	2.940	203
TOTAL	953,207	100%	52,404	87,448	988,251	66,452	921,799	144.546	

*Note: Population numbers are from DPP using 2010 census numbers.

Water conservation has a significant and beneficial effect on the per capita demand factors from 1990 to 2010 as shown in *Figure 1.4*. From 1990-2010, the per capita demand decreased 16.5% and through graphical trend analysis, BWS projects per capita demand to continue to decrease another 7.6% to 2040 as long as water conservation program goals are achieved.

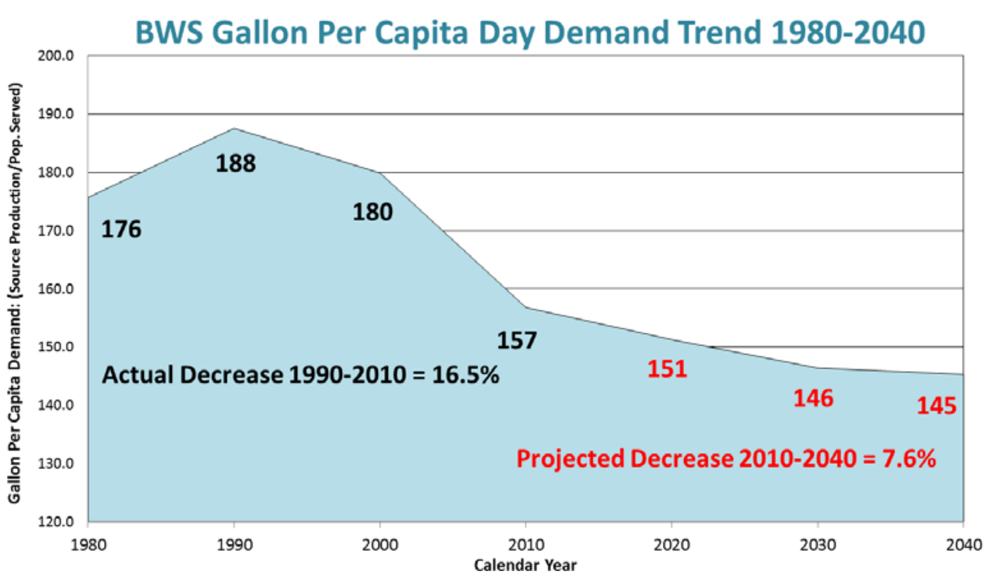


Figure 1.4 BWS Gallons per Capita Day Demand Trend 1980-2040

The following tables and descriptions highlight the BWS water demand forecasts by development plan districts for Oʻahu**.**

BWS served population for Oʻahu in *Table 1.2* is forecasted to increase 12.2% from 921,799 in 2010 to 1,049,905 in 2035 with the majority of the increase occurring in the Ewa, PUC, and Central Oʻahu districts. East Honolulu and Koʻolau Poko populations are expected to decrease.

Table 1.2 BWS Served Population by Year and DP Area

BWS Served Population by Year & DP Area									
DP AREA	**1980**	**1990**	**2000**	**2010***	**2015**	**2020**	**2025**	**2030**	**2035**
	Given Data (Served Pop.)				**Projected Data (Served Pop.)**				
Waiʻanae	32,724	37,801	41,731	47,195	48,041	48,887	49,733	50,578	51,424
ʻEwa	24,614	31,321	61,660	92,174	104,054	115,933	127,812	139,691	151,571
Central Oʻahu	77,354	105,917	124,455	140,927	144,880	148,834	152,788	156,742	160,695
PUC	435,671	466,297	447,114	460,950	466,278	471,606	476,933	482,261	487,589
East Honolulu	42,829	45,646	45,702	48,066	48,078	48,091	48,103	48,115	48,128
Koʻolau Poko	107,667	116,803	113,256	108,494	108,176	107,857	107,539	107,220	106,902
Koʻolau Loa	7,816	11,212	10,409	9,494	9,723	9,952	10,181	10,409	10,638
North Shore	11,798	14,725	14,438	14,499	14,819	15,139	15,459	15,778	16,098
TOTAL Oʻahu Island Population	**740,473**	**829,722**	**858,765**	**921,799**	**944,048**	**966,297**	**998,546**	**1,010,795**	**1,033,044**

* Residential Population by Traffic Analysis Zone (TAZ)

BWS gallon per capita demand for potable water is forecasted to slow its downward trend to 7.6% from 2010 to 2040 as water conservation capacity approaches saturation, *Table 1.3.* ʻEwa has the largest potential for water efficiency savings of 15% despite its dry climate because of the availability of recycled water for irrigation of large landscaped areas.

Table 1.3 BWS GPCD by Year and DP Area

BWS GPCD by Year & DP Area									
Calendar Year:	**1980**	**1990**	**2000**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
DP AREA	**Given Data (GPCD Rate)**				**Projected Data (GPCD rate)**				
Waiʻanae	235.30	239.40	223.79	196.00	197.16	191.19	185.40	179.79	174.34
ʻEwa	316.90	281.10	223.58	188.00	181.96	167.87	160.00	160.00	160.00
Central Oʻahu	148.70	141.80	155.96	126.00	134.86	132.74	130.65	128.60	126.58
PUC	177.00	190.00	170.98	151.00	150.14	145.38	140.77	140.00	140.00
East Honolulu	144.80	190.20	221.30	197.00	179.17	180.00	180.00	180.00	180.00
Koʻolau Poko	148.60	151.20	173.17	152.00	150.00	150.00	150.00	150.00	150.00
Koʻolau Loa	191.90	254.20	140.55	155.00	144.78	140.00	140.00	140.00	140.00
North Shore	194.90	216.60	194.97	203.00	202.73	202.83	202.93	203.03	203.14
TOTAL Oʻahu Island Gallon Per Capita	**175.70**	**187.57**	**179.91**	**156.81**	**155.93**	**151.53**	**147.82**	**146.94**	**146.44**

Assuming a continuation of conservation savings trends, the average day water demand, in *Table 1.4* is forecasted to increase by only 8 mgd from 144.5 mgd in 2010 to 153 mgd in 2035. The forecast which can be considered as the BWS low-growth demand scenario is a major reduction from the 52 mgd forecast from 2000. The largest water demand increase is expected in Ewa due to a population increase of about 80,400 people in 2035. Interestingly, PUC's water demand is expected to be stable or even decrease despite an increase of 26,000 people because per capita demand is decreasing. High rise transit oriented development uses much less water than a townhouse or single family residence which will reduce the per capita water demand.

Table 1.4 BWS Demand by Year and DP Area

BWS Demand by Year & DP Area									
Calendar Year	**1980**	**1990**	**2000**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
DP AREA	**Given Data (Demand)**				**Projected Data (Demand)**				
Waiʻanae	7.7	9.05	9.34	9.251	9.47	9.35	9.22	9.09	8.97
ʻEwa	7.8	10.60	15.30	18.418	18.93	19.46	20.45	22.35	24.25
Central Oʻahu	11.5	15.02	19.41	18.264	19.54	19.76	19.96	20.16	20.34
PUC	77.1	88.58	76.45	68.183	70.00	68.56	67.14	67.52	68.26
East Honolulu	6.2	8.68	10.11	9.507	8.61	8.66	8.66	8.66	8.66
Koʻolau Poko	16.0	17.66	19.61	16.507	16.23	16.18	16.13	16.08	16.04
Koʻolau Loa	1.5	2.85	1.46	1.517	1.41	1.39	1.43	1.46	1.49
North Shore	2.3	3.19	2.82	2.940	3.00	3.07	3.14	3.20	3.27
TOTAL Oʻahu Island Demand	**130.10**	**155.63**	**154.50**	**144.59**	**147.20**	**146.42**	**146.12**	**148.52**	**151.28**

Table 1.5 shows Oʻahu's ground water use as of 2010 totaling 229 mgd including the Waiāhole Ditch and the brackish ʻEwa Caprock aquifer. Municipal ground water use constitutes 76% of the total, with military, agriculture and irrigation and other uses taking up the remainder. Agriculture ground water use includes private wells and the Waiāhole Ditch but overall agriculture ground water use has decreased post-plantation owing to the availability and use of surface water and the slow rate of diversified agriculture growth.

Table 1.5 Oʻahu's Ground Water Use (2010)

Use Category	Water Used 12-Mo. MAV (mgd)	Percentage of Total Water Use
Municipal	146.358	6.5.5%
Military	23.242	10.4%
Agriculture*	23.082	10.3%
Irrigation**	16.679	7.5%
Domestic	0.50	0.2%
Industrial**	19.512	8.7%
Total	**229.373**	**100%**

* Includes Waiāhole Ditch
** Includes Ewa Caprock Brackish aquifer

Table 1.6 summarizes Appendix C by listing Oʻahu's largest permitted uses of fresh ground water by user including Waiāhole Ditch water uses but excluding saltwater and brackish caprock water uses in 2010.

Table 1.6 Oʻahu's Top Fresh Ground Water Users by Permitted Use May 2010

Owner	Permitted Use (mgd)	Owner	Permitted Use (mgd)
1. Honolulu BWS	172.98	9. State of Hawaiʻi	3.23
2. US Navy	29.00	10. Kalaeloa Partners, L.P.	2.89
3. Waialua Sugar	27.19	11. Campbell Estate	2.49
4. US Army	7.31	12. Monsanto	2.64
5. Agribusiness Dev. Corp.	6.49	13. Metropolitan Mortgages	2.60
6. Dole/Castle & Cooke	5.21	14. Coral Creek	2.19
7. KS/Bishop Estate	4.07	15. HRI/Laie Water Co.	2.08
8. Kunia Water Assoc, Inc.	3.96	16. Mokuleia Land	1.50

1.3.3 Department of Hawaiian Home Lands Demands

The Department of Hawaiian Home Lands (DHHL) owns lands in Mākaha, Waiʻanae, Lualualei, Nānākuli, Kalaeloa, Kapolei, Papakōlea, Mōʻiliʻili, Waimānalo and Haʻikū as shown in *Figure 1.5*. DHHL is currently compiling their Oʻahu master plan and their findings will be incorporated in future WMP's. DHHL projected water demands of 1.7 mgd (State Water Projects Plan 2003) are incorporated into the BWS municipal water demand forecasts using the population based per capita demand method. DHHL holds water reservations in the Waimānalo aquifer of 0.124 mgd and in the Waipahu-Waiawa aquifer of 1.358 mgd for their projects. DHHL will request that CWRM assign their reservations toward new or existing sources as their lands are developed. The State Water Projects Plan and DHHL demands are currently being updated by DLNR Engineering.

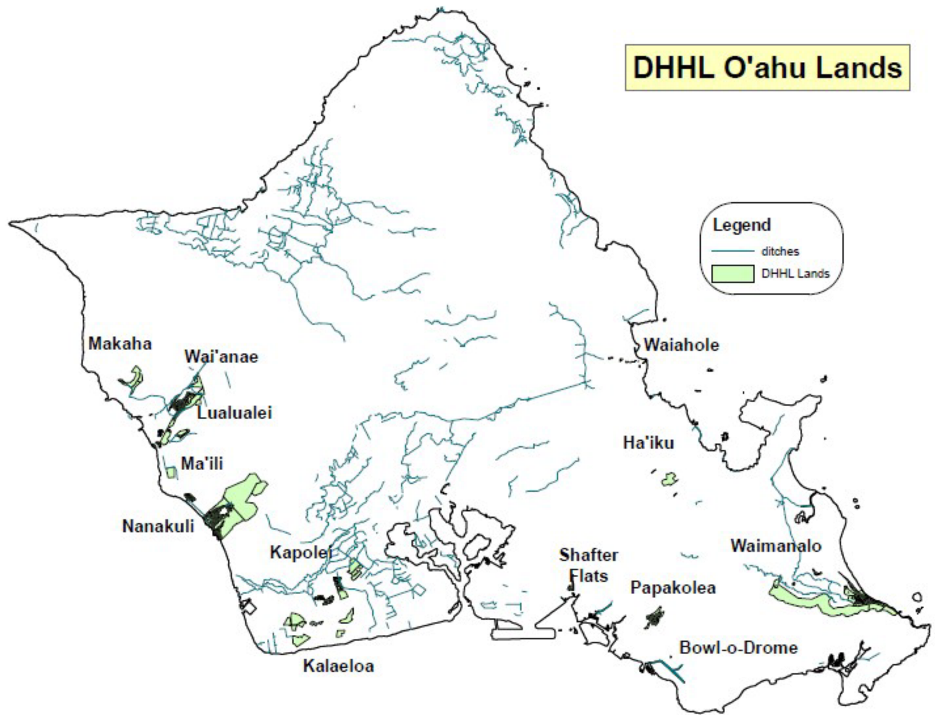


Figure 1.5 Department of Hawaiian Home Lands on O'ahu

1.3.4 State Water Projects Plan Water Demands

The State Water Projects Plan (SWPP), 2003, identified a total of 24.5 mgd of water demand for housing, commercial, industrial, institutional, and agricultural uses for State agencies on O'ahu to the year 2020. Approximately 51% of O'ahu's SWPP demand, or 12.5 mgd, is nonpotable use. The Department of Agriculture's demand of 7.6 mgd, the Department of Business Economic Development and Tourism's demand of 7.2 mgd and the University of Hawai'i's demand of 3.1 mgd comprise the largest water needs among State agencies.

The SWPP identified several water development strategies to meet their projected water demands including the use of existing State water system capacity; developing new water systems based on development master plans such as East Kapolei and Kalaeloa; utilizing existing BWS water credits from previous source development; and pursuing recycled and brackish water for nonpotable irrigation. These strategies constitute approximately 17.9 mgd or 73% of O'ahu's SWPP total. The remaining 6.7 mgd or 27% of State water demand can be obtained from BWS through the payment of Water System Facilities Charges. The BWS municipal water demand forecasts using the population based per capita demand method of assessing State and County land use plans can be assumed to incorporate most of the SWPP's demands except for State owned water systems. An accounting tying specific source names to projected State agency demands would be helpful in the next SWPP update.

The SWPP update should add stronger water conservation and water loss reduction strategies, which were largely absent in the 2003 SWPP. Leak detection and repair projects in aging State water systems, such as agriculture, could reduce new source development, reduce operating and maintenance costs and provide more capacity for drought mitigation. The SWPP is currently being updated and their findings will be incorporated in future WMP's.

1.3.5 Agricultural Water Demand

The State and City have adopted objectives and policies for the preservation of agricultural lands and for the long-term support of a viable agriculture industry on O'ahu. City land use plans have been adopted with growth boundaries in part to protect prime agricultural lands.

O'ahu's projected agricultural water demands have a wide variation and are uncertain yet important for water use planning because of the substantial quantities consumed for irrigation. Future water demand for agricultural crops depend on the type of crops cultivated, climate, and number of acres in cultivation. The *State Agricultural Water Use and Development Plan* (AWUDP, 2004) estimated a worst and best case range of 7.6 mgd and 30.4 mgd, respectively, of additional water demand for O'ahu based on population projections, partial replacement of imported produce with locally grown produce, and maintaining farm value growth in diversified agriculture.

Approximately 13 mgd of the projected best case agricultural demand was assumed to be assigned to private irrigation systems, with the remaining 17 mgd accommodated by the State's Waiāhole Ditch and Waimānalo irrigation systems. The AWUDP focused on maintaining existing State diversified agriculture systems and on transforming plantation water systems to serve diversified agriculture. *"With available farm lands and adequate irrigation water, a significant expansion of diversified agriculture is an attainable and economically worthwhile goal which can be achieved largely by: 1) replacing much of Hawai'i's imported produce with locally grown produce, 2) pursuing niche and off-season markets of fruits and vegetables for export, 3) growing new or Asian-based specialty crops for export, and 4) meeting increased demand from the tourism and cruise ship industries for fresh fruits and vegetables."*

The two irrigations systems studied on O'ahu are the Waiāhole Ditch and Waimānalo irrigation systems. The Wahiawā Irrigation System in Central O'ahu and North Shore was not included in the State AWUDP. Based on water metered data from the Lālāmilo system (South Kohala, Hawai'i Island), dry and wet season water use per acre varied between 2,500 gallons per day per acre (gpd/acre) to 4,600 gpd/acre. According to the AWUDP, an average of 3,400 gpd/acre is considered the best available estimate and a reliable value for use in planning and forecasting irrigation water demand for Hawai'i's diversified agriculture industry. It should be noted, that 3,400 gpd/acre is considered a practical consumptive water use rate which does not include irrigation system water loss.

Figure 1.6 shows the agricultural zoned lands on O'ahu with the four major irrigation systems: Waiāhole Ditch, Wahiawā, Waimānalo and Punalu'u. Existing stream diversions and distribution systems should be inventoried, leaks and evaporation losses reduced to a reasonable goal and water use verified. Diversion works should include control gates to maintain diverted flows at reasonable and beneficial use plus losses. The practice of diverting maximum stream flow and then releasing unused diverted water into downstream drainage systems or into different streams should be minimized. Improvements to existing ditch systems, such as lining or piping ditches, have the potential to reduce water loss and thereby provide water for the expansion of agriculture without adding new diversions. Cost and benefit considerations should be factored into the feasibility of these improvements and will affect implementation. Significant new surface water diversions require amendments to the IFS, but the studies and processes are cost prohibitive.

Kamehameha Schools has renovated their Punaluʻu and Kawailoa irrigation systems with cultural and eco-friendly stream diversion modifications and piped ditch systems to conserve and enhance the availability of stream water, *Figure 1.7*. The diversions include fish ladders on both stream banks and grated intakes to prevent debris and fish from entering the system. The ditch system was piped to reduce water loss and ditch maintenance and provide a pressurized irrigation system for farmers. The improvements keep unused water in the stream because as irrigation declines during the day or season, the pipe fills up to the intake and diverted flow reduces to zero.

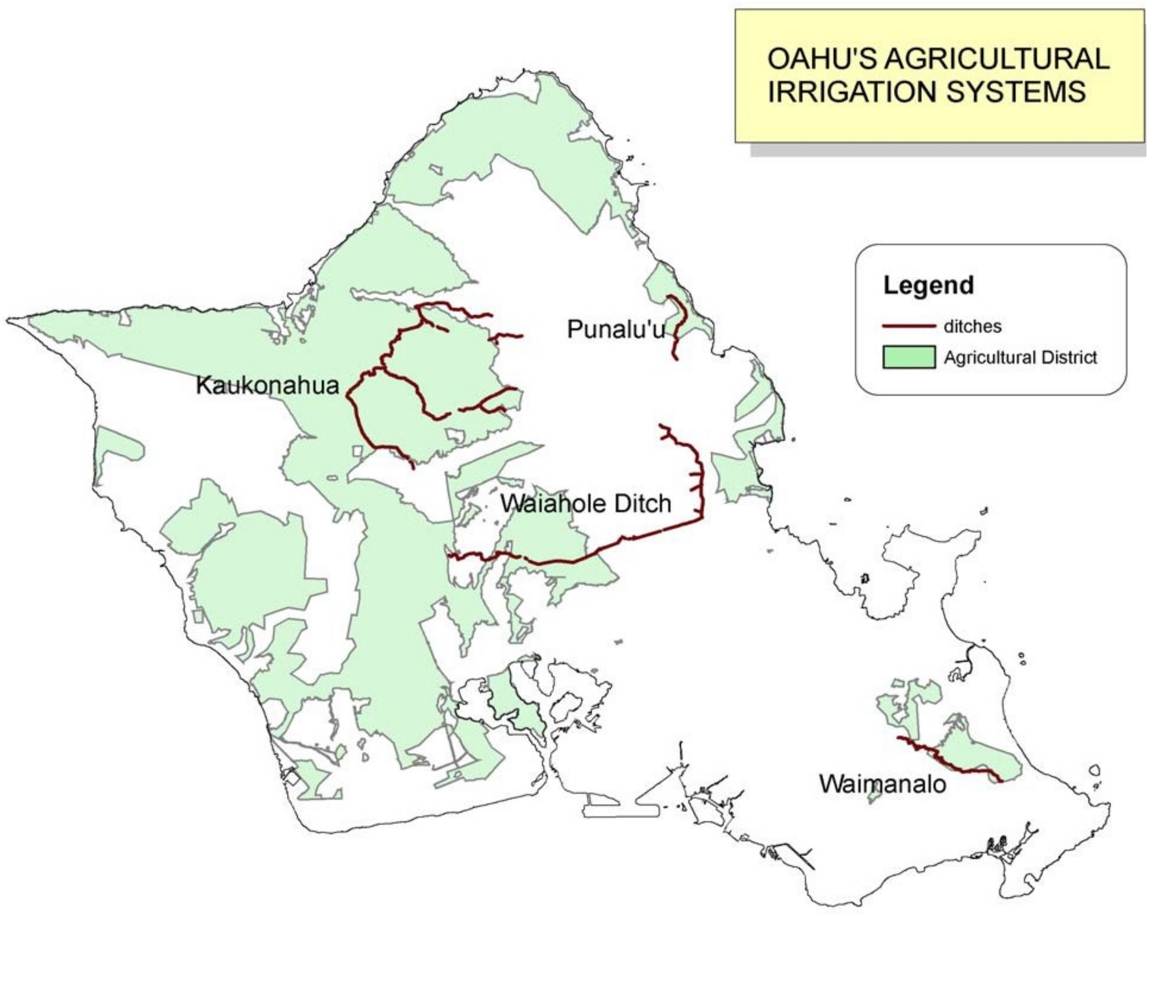


Figure 1.6 Agricultural Zoned Lands on Oʻahu

Figure 1.7 Punaluʻu Stream Diversion and Piped Ditch

There are large tracts of agricultural lands in the ʻEwa, Central Oʻahu, North Shore, Koʻolau Loa and Koʻolau Poko districts. The 2004 AWUDP estimated that of the 49,500 acres of prime agriculture lands on Oʻahu, 11,000 acres are in monocrop cultivation. The remaining 38,500 acres are idle and available for cultivation. *Table 1.7* lists the projected most probable water demands for each land use district compiled from the regional Watershed Management Plans and based on the projected use of agricultural lands within a 2030 and 2035 horizon.

Table 1.7 Oʻahu Agricultural Irrigation Water Demand

Land Use District	Existing Agricultural Irrigation Water Demand (mgd)	Projected Agricultural Irrigation Water Demand (mgd)*
North Shore	24.2	29.3
Central Oʻahu	15.8	15.7
ʻEwa	7.0	4.7
Koʻolau Loa	14.5	17.4
Koʻolau Poko	4.2	6.0
Waiʻanae	2.3	2.4
Total	**68.0**	**86.5**

* *Agricultural water demands are the most probable demand scenarios for agriculture from Watershed Management Plans for Koʻolau Loa (2030), Koʻolau Poko (2030), Waiʻanae (2030) and North Shore (2035). Central Oʻahu (2035) and ʻEwa (2035) are from calculations for watershed management plans under development. Loʻi Kalo water demand is not included.*

The total agricultural lands water demand of 86.5 mgd utilize 3,400 gallons per day per acre (gpd/acre) from the State AWUDP for low rainfall areas and 2,500 gpd/acre for high rainfall areas. Studies indicate that applied water demands for diversified agriculture in high rainfall areas such as Punaluʻu, Waiāhole, Kahaluʻu and Kāneʻohe, where rainfall exceeds 60 to 70 inches per year, requires less water and averaged 2,500 gpd/acre. Agricultural irrigation water demand is met with both ground and surface water supplies.

CWRM, in the Waiāhole Ditch contested case, allocated an average of 2,500 gpd/acre for large-tract Kunia farms allowing for some continuous proportions of fallow and cultivated lands. Small farms do not have the area to fallow their fields and will therefore have higher water demands per acre. Existing systems like the Waiāhole Ditch, Wahiawā, Kawailoa, Punaluʻu, Waimānalo and the ʻEwa Plantation irrigation systems already provide a portion of this total. Additional potable ground water supplies in these aquifer system areas could provide supplemental agricultural water supply especially during drought. Diversified agricultural water demands in Waiʻanae, PUC, East Honolulu and a portion of North Shore are largely incorporated into the municipal demand forecasts. Agricultural water use constitutes only 3% of BWS potable metered water use. Ground water development is more costly for agriculture than gravity and surface water sources and may compete with urban uses.

Traditional wetland kalo occurs in almost all districts but according to various studies, the variability of water demands is large, and inflows can range from approximately 100,000 gpd/acre to 300,000 gpd/acre with temperature as one of the key factors to prevent rot. While net consumptive use (evapo-transpiration and infiltration) averages approximately 50,000 gpd/acre (USGS, 2007), the additional water flow, which is returned to the stream, is needed to manage temperature and account for ditch losses. This plan therefore assumes 100,000 gpd/acre as the wetland kalo water demand estimate as presented in the Koʻolau Poko WMP in discussions with Waiahole kalo farmers. Kalo's high water use per acre and limited surface water supplies will limit the expansion and restoration of loʻi kalo but because it is important to preserve the remaining traditional kalo lands, the lower range of water demand will allow a greater amount of restoration. Water loss reduction strategies in *ʻauwai* and ditch systems (lining and piping) could provide additional water reducing the necessity of constructing additional stream diversions and potentially divert less stream water.

1.3.6 Ground Water Availability

The table of Sustainable Yield and Ground Water Use by Aquifer System Area was provided by CWRM and BWS for 2010 (*Table 1.8*). The table shows the seven aquifer sector areas and 26 aquifer system areas on Oʻahu with their associated revised sustainable yields adopted in August 2008 by CWRM, water use permits, water use in 2010 and the unallocated sustainable yields. CWRM reduced Oʻahu's sustainable yields by 39 mgd in 2008 from 446 mgd to 407 mgd. A complete listing of Oʻahu Water Use Permit Index is provided in *Appendix C,* and additional information on sustainable yields is included in *Appendix D, Overview of Oʻahu's Hydrogeology*.

Overall, there is available water on Oʻahu, in comparing permitted use that has been allocated and/or actual withdrawal to sustainable yield. A significant portion of the remaining untapped supplies exist in remote areas of the island where growth is limited, infrastructure does not exist or pumping may affect stream flows and will be subject to future measurable IFS. 2010 was a below normal rainfall year with the first half averaging 60% of normal rainfall. The 5-month moving average recovered to normal rainfall levels with heavy rains in November and December of 2010. Therefore, 2010 water use was higher than normal for both agriculture and urban sources. Ground water use increased by 4.5 mgd from 2009 to 2010, primarily due to the drier weather and some growth related increases in 2010.

Table 1.8 Sustainable Yield and Ground Water Use by Aquifer System Area (MGD)

Aquifer Sector	Aquifer System	Notes	Sustainable Yield (SY)	Water Use Permits Issued 2010	Unallocated Sustainable Yield	Water Use (2010)	SY Minus Water Use
Honolulu	Waiʻalae - East		2	0.79	1.21	0.124	1.876
	Waiʻalae - West		4	2.797	1.203	1.004	2.996
	Palolo		5	5.646	-0.646	6.289	-1.289
	Nuʻuanu	1	14	15.165	-1.165	15.232	-1.232
	Kalihi		9	8.761	0.239	5.424	3.576
	Moanalua	1	16	19.96	-3.96	17.143	-1.143
Total Honolulu			50	53.119	-3.119	45.216	4.784
Pearl Harbor	Waimalu		45	46.951	-1.951	35.524	9.476
	Waipahu-Waiawa		104	84.856	19.144	51.819	52.181
	ʻEwa-Kunia		16	15.457	0.543	12.143	3.857
	Makaiwa		0	na	na	0	0
Total Pearl Harbor			165	147.264	17.736	99.486	65.514
Central	Wahiawā		23	21.928	1.072	7.694	15.306
Total Central			23	21.928	1.072	7.694	15.306
Waiʻanae	Nanakuli	1,2, 4	2	na	na	0	2
	Lualualei	1,2, 4	4	na	na	0	4
	Waiʻanae	2	3	na	na	2.710	0.29
	Makaha	1,2	3	na	na	1.956	1.044
	Keaʻau	2,4	4	na	na	0	4
Total Waiʻanae			16			4.666	11.334
North	Mokulēʻia	1	8	8.025	-0.025	0.175	7.825
	Waialua	1	25	30.311	-5.311	3.276	21.724
	Kawailoa	1	29	1.614	27.386	0.425	28.575
Total North			62	39.95	22.05	3.876	58.124
Windward	Koʻolau Loa	1	36	18.589	17.411	17.853	18.147
	Kahana	1,4	15	1.101	13.899	0.36	14.64
	Koʻolau Poko	1,3, 4	30	10.312	19.688	10.227	19.773
	Waimānalo	1,4	10	1.631	8.369	0.699	9.301
Total Windward			91	31.633	59.367	29.139	61.861
Total Aquifer Sector			407	293.894	97.106	190.077	216.923
ʻEwa Caprock	Malakole	5	1,000 mg/L		-	4.513	-
	Kapolei	5	1,000 mg/L		-	0.747	-
	Puʻuloa	5	1,000 mg/L		-	1.374	-
Total ʻEwa Caprock			0	0	0	6.634	0
Waiāhole Ditch			15	12.991	2.009	7.068	15
Grand Total Fresh and Brackish			422	306.885	99.115	203.779	224.855

1 2008 Water Resource Protection Plan updates on sustainable yield.
2 Waiʻanae is not a designated water management area, therefore, there is no permitted use.
3 Waiheʻe Tunnel & Waiheʻe Inclined Wells are not included under 2010 Permitted Uses, but are included under Existing Water Use.
4 BWS Recoverable Yield expected to be lower due to economics, land constraints, small yields, etc. & regulatory actions involving instream flow standards.
5 Brackish Water. Managed by chloride limit of 1,000 mg/l for irrigation wells.
Excluded salt water wells
Source: CWRM and BWS Data. BWS footnotes.
Based on 2010 reported pumpage to CWRM.

In general, the Honolulu sector is fully allocated to the adopted sustainable yields. The Pearl Harbor, Wahiawā and North Shore sectors have a significant amount of unallocated sustainable yield, unused or released by the sugar plantations. The Windward sector's unused sustainable yields (Waimānalo, Koʻolau Poko and Kahana) may interact with streams due to dike influences and therefore, availability may be subject to amendments of the interim IFS. Waiʻanae's remaining water is small, in remote areas and also subject to interim IFS in dike areas.

Due to these land, economic, operational and environmental reasons, BWS has identified the concept of recoverable yield for its own municipal planning purposes. Recoverable yield is an estimate of the amount of ground water that could feasibly be developed for an aquifer system area and is slightly less than CWRM adopted sustainable yields. BWS has identified Waimānalo, Koʻolau Poko, Kahana, Keaʻau, Lualualei and Nānākuli aquifer system areas where recoverable yields are less than or equal to sustainable yields. The concept of recoverable yield allows BWS to plan and respond to uncertainties.

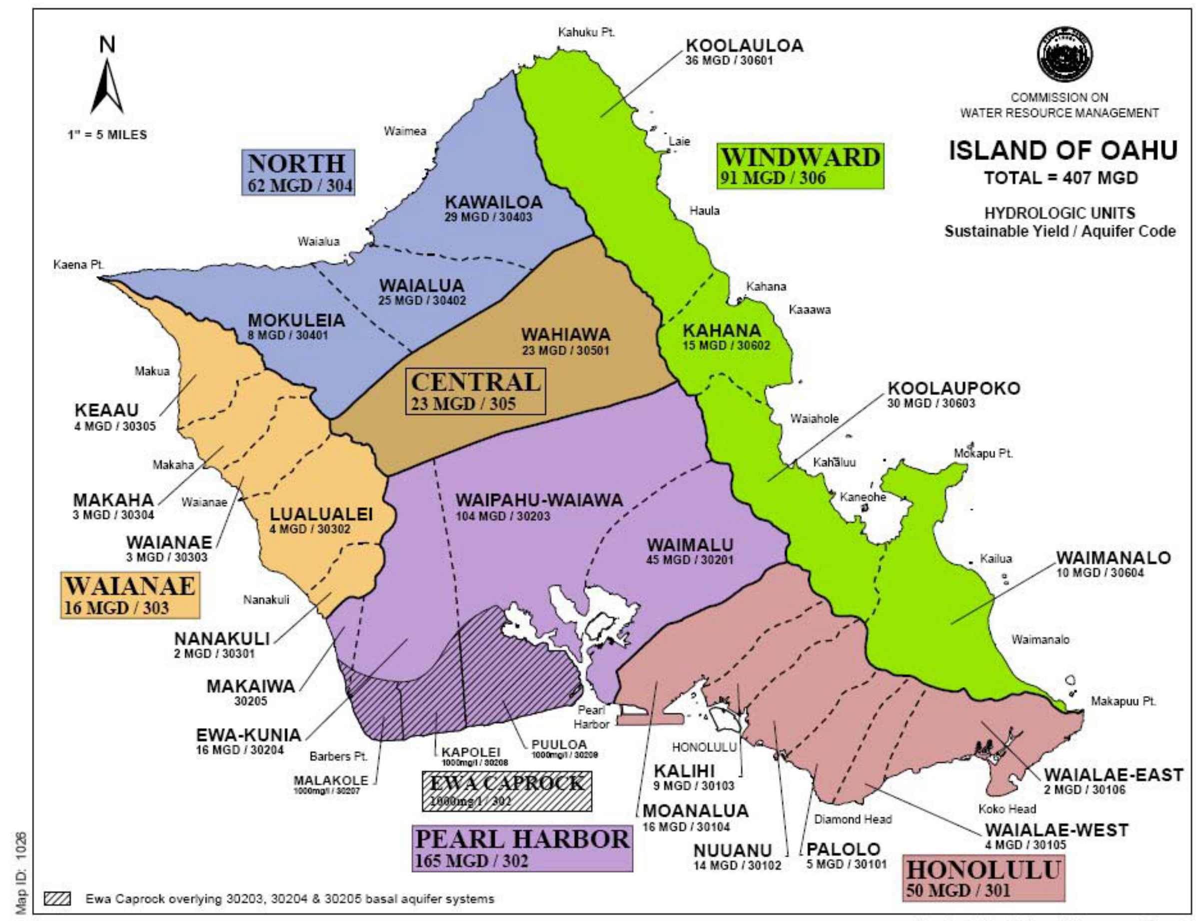


Figure 1.8 Oʻahu Aquifer System Areas

CWRM has adopted sustainable yields to protect ground water resources and regulate water use by water use permits. The following *Table 1.9* summarizes the available ground water by aquifer sector area accounting for the uncertainties of ground water/surface water interaction in dike formations in Windward and BWS operational experience in Waiʻanae.

Table 1.9 Summary of Available Ground Water by Aquifer Sector Area

Aquifer Sector	Sustainable Yield	Water Use Permits Issued (2010)	Unallocated Sustainable Yield (mgd)	Water Use 2010	SY minus Water Use
Honolulu	50	53	-3	45	5
Pearl Harbor	165	147	18	99	66
Central	23	22	1	8	15
Wai'anae	16	---	--	5	1*
North	62	40	22	4	58
Windward	91	32	59	30	18**
Waiāhole Ditch	15	13	2	7	8
Total	**422**	**307**	**99**	**198**	**171**

* Adjusted: Based on pumping operations and BWS assessed recoverable yields. Wai'anae & Makaha systems: (6 mgd SY – 5 mgd use)

** Adjusted: Ko'olau Loa system:(36 mgd SY – 18 mgd use). Excludes for planning purposes the balance of Kahana, Ko'olau Poko & Waimānalo systems per CWRM ruling due to possible surface water interactions in dike formations.

On O'ahu in 2010, a below normal rainfall year, about one-third or 109 mgd (307-198) of permitted use was unused. An estimate of available and recoverable ground water on O'ahu is approximately 171 mgd, based on CWRM revised sustainable yields for O'ahu minus water use in 2010, excluding the balance of the Kea'au, Lualualei, Nānākuli, Kahana, Ko'olau Poko and Waimānalo aquifer systems. Ground water use on O'ahu increased by about 8 mgd from 2009 to 2010 primarily due to the dry weather and water use variability.

1.3.7 Surface Water Availability

IFS are similar to sustainable yields for ground water, in that their establishment provides a management system that protects instream and cultural uses while allowing for possible non-instream water use. CWRM is tasked with setting IFS for Hawai'i's streams in accordance with the State Water Code. The code defines instream flow standards as "the quantity or 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."[1] These instream flow standards need to consider the best available information in assessing the range of present or potential instream and non-instream uses.

The current instream flow standards for O'ahu streams are called interim instream flow standards (IIFS) and are based on the *"amount of water flowing in each stream on the effective date of the standard without further amounts of water being diverted off-stream through new or expanded diversions"*. The effective dates are December 10, 1988 for Leeward O'ahu and May 4, 1992 for Windward O'ahu.[2] In the Waiāhole Contested Case Hearing, CWRM recognized that *"retaining the status quo (through the adoption of the* *previous interim standards) helped to prevent any future harm to streams while the scientific basis for determining appropriate instream flow standards is developed and an overall stream protection program put into place."* The stream flows and diversions were not quantified in the standard; however users of surface water and ground water were required to register their uses with CWRM.

CWRM amended the interim instream flow standards for four windward streams - Waiāhole, Waianu, Waikāne and Kahana have been established via the Waiāhole Ditch Combined Contested Case on July 13, 2006 *(Table 1.10)*.

Table 1.10 Amended Oʻahu Interim Instream Flow Standards

Stream	1960s Streamflow	Amended Interim Instream Flow Standard	Percent Increase
Waiāhole	3.9 mgd	8.7 mgd	124%
Waianu	0.5 mgd	3.5 mgd	600%
Waikāne	1.4 mgd	3.5 mgd	150%
Kahana	11.2 mgd	13.3 mgd	19%

The State Water Resources Protection Plan (WRPP) established surface water hydrologic units and provided an inventory of basic data for Oʻahu's streams. Table 3-22 of the WRPP lists 87 streams on Oʻahu, including the watershed area, number of diversions and stream gages. Diverted stream flows and their uses are not measured or reported and could not be included. The stream diversion inventory process continues and new information will be added to future WMPs. *Figure 1.9* shows Oʻahu's surface water hydrologic units.

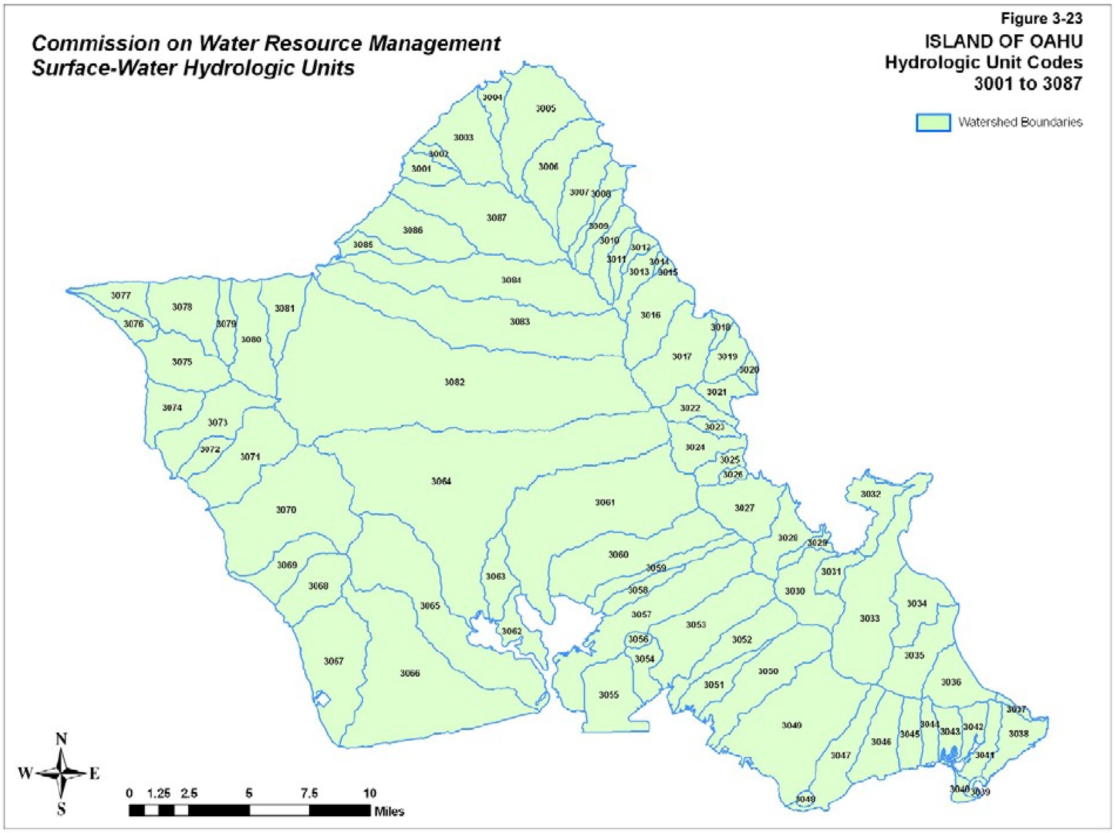


Figure 1.9 O'ahu Surface Water Hydrologic Units

The hydrogeology appendix describes the complexity of setting measurable IFS balancing hydrology with instream and non-instream uses. It is difficult to plan for additional non-instream uses of surface water without measurable IFS, because non-instream uses of surface water are an essential IFS component. Punalu'u Stream and irrigation system studies have cost over $500,000 and therefore, new diversions, while permit-able, are not cost effective unless a simpler methodology for setting measurable IFS is proposed. The planning approach to surface water availability then, is to plan within the diverted amounts existing when the status quo interim IFS were adopted, or as subsequently amended by CWRM. Additional surface water can be provided for non-instream uses through improvements in distribution system efficiency, leakage reduction, crop selection and through efficient irrigation techniques. Significant new stream diversions will require amendments to IFS. In general, a starting point for surface water availability assumes 50% of Q70, stream flowing 70% of the time. *Table 1.11* lists some of O'ahu's largest perennial streams.

Table 1.11 O'ahu's Largest Streams and Mean Flows (2004 and 2010)

Stream Name	USGS Stream Gage no.	Mean Flow 2004 / (MGD)	CFS Mean Flow 2010 (CFS / MGD)
Kaluanui	16304200	7.5 / 4.8	3.9 / 2.5
Punalu'u (above ditch)	16301050		19.0 / 12.3
Kahana	16296500	53.5 / 34.6	28.1 / 18.1
Waikāne	16294900	19.1 / 12.3	7.9 / 5.1
Waiāhole (Kamehameha Hwy)	16294100	55.0 / 35.6	26.3 / 17.0
Waihe'e	16284200	9.2 / 6.0	5.3 / 3.4
Kahalu'u	16283200	5.1 / 3.2	1.6 / 1.1
Ha'ikū	16275000	3.6 / 2.3	1.8 / 1.2
Kamo'oali'i - Kāne'ohe	16272200	17.5 / 11.3	-- / --
Makawao – Kailua	16254000	7.2 / 4.7	3.2 / 2.1
Mānoa (Kānewai)	16240500	5.9 / 3.8	8.2 / 5.3
Kalihi	16229000	9.2 / 6.0	4.0 / 2.6
North Hālawa	16226200	9.9 / 6.4	2.8 / 1.8
Waiawa	16216000	50.0 / 32.3	-- / --
Waikele	16213000	53.7 / 34.7	24.5 / 15.8
Mākaha	16211600	2.2 / 1.4	0.5 / 0.3
N. Kaukonahua	16200000	19.2 / 12.4	10.4 / 6.7
S. Kaukonahua	16208000	29.6 / 19.1	15.1 / 9.7
'Ōpae'ula	16345000	18.8 / 12.2	11.9 / 7.7
Kamananui - Waimea	16330000	24.7 / 16.0	12.9 / 8.3
Total		**400.9 / 259.2**	**187.4 / 120.9**

Source: USGS Data. Several USGS gages have been discontinued due to cost considerations.
Note: Q70 is less than mean stream flow.
2004 was an above normal rainfall year while 2010 was a below normal rainfall year which accounts for the large difference in total gaged stream flow.

1.3.8 Planned Source Development

New sources recently completed or in various stages of construction and potential potable sources that will provide for future water demands are listed in *Table 1.12*. Alternative potable and nonpotable sources such as recycled water and desalination are listed in *Table 1.13*.

Table 1.12 Existing and Potential Ground Water Resources of Potable Water

New Ground Water Sources	Estimated Yield (mgd)	Additional Permitted Use Required (mgd)	CWRM Water Management Area	Potential Development Plan Area(s) Served
1. Kahuku Wells Pump 3	1.0	0.4	Koʻolau Loa	Koʻolau Loa
2. ʻŌpana Wells *	1.0	0.654	Koʻolau Loa	Koʻolau Loa
3. Kaipapaʻu or Wailele Well (1)	1.0		Koʻolau Loa	Koʻolau Poko
4. Kaluanui Wells * (1)	1.5		Koʻolau Loa	Koʻolau Poko
5. Maʻakua Wells * (1)	1.0		Koʻolau Loa	Koʻolau Poko
6. Kūʻou Well III *	0.5		Koʻolau Poko	Koʻolau Poko
7. Waimānalo Well III *##	0.5	0.3	Waimānalo	Koʻolau Poko
8. ʻĀina Koa Well II	1.0		Waiʻalae-West	East Honolulu
9. Waiʻalae West Well	0.5	0.5		
10. Waiʻalae Nui Well *	0.7		Waiʻalae-West	East Honolulu
11. Nuʻuanu Tunnels MF Treatment Plant	0.2	Gravity Flow	Nuʻuanu	PUC
12. Wahiawā Well III	3.0	3.0	Wahiawā	Central
13. Waipiʻo Heights Wells III *	3.0	1.75	Waipahu-Waiawa	Central/PUC
14. Mililani Wells IV *	3.0	1.0	Waipahu-Waiawa	Central
15. Waiawa Wells I-I (2)	6.0	6.0	Waipahu-Waiawa	Central
16. Manana Well *	1.0	0.3	Waipahu-Waiawa	PUC
17. Kunia Wells III *	3.0		Waipahu-Waiawa	ʻEwa, Waiʻanae
18. Waipahu Wells II *	3.0	1.0	Waipahu-Waiawa	Central
19. Waipahu Wells III *#	3.0		Waipahu-Waiawa	PUC
20. Waipahu Wells IV *	3.0		Waipahu-Waiawa	ʻEwa, Waiʻanae
21. ʻEwa Shaft *	10.0	2.4	Waipahu-Waiawa	ʻEwa
22. Waipio Heights II *	2.0	1.0	Waipahu-Waiawa	Central
Total Potable Resources	48.9	18.3**		

Notes:

1 Potential transfer of existing permitted use from Punaluʻu Wells to optimize pumpage

2 Waiawa Water Master Plan, Revised Dec 14, 2004.

* Source already has an existing permitted use equal to or a portion of the estimated yield.

** Total does not include transfers of existing permitted use.

Includes 0.5 mgd water reservation for Department of Hawaiian Home Lands (DHHL)

0.124 mgd water reservation exists for DHHL in the Waimānalo WMA

Table 1.13 Existing and Potential Alternative Potable and Nonpotable Water Sources

Resource[1]		Minimum Estimate	Maximum Estimate	Development Plan Areas Served
Desalination (potable)				
1	Kapolei Brackish Desalination Plant	0.5	0.7	‘Ewa
2	Kalaeloa Seawater Desalination Plant	1.0	5.0	‘Ewa
Recycled Water				
4	Wahiawā WWTP R-1 (1)	2.0	2.0	Central (Galbraith)
5	Schofield WWTP R-1	2.0	4.0	Central (Kunia)
5	Honouliuli Recycled Water	12.0	20.0	‘Ewa
6	Wai‘anae Recycled Water (2)	1.0	1.0	Wai‘anae
7	Kahuku, Turtle Bay, Lā‘ie Recycled Water	0.8	2.6	Ko‘olau Loa
8	Waimānalo Recycled Water	0.7	1.0	Ko‘olau Poko
9	Ala Wai Golf Course MBR	0.25	0.5	PUC
10	Mililani WWTP MBR	1.0	2.0	Central
Nonpotable Water				
9	Waiāhole Ditch (3)	15.0	15.0	‘Ewa, Central
10	Wahiawā Reservoir (4)	8.5	16.0	North Shore, Central
11	Kalauao Spring	0.5	3.3	PUC
12	‘Ewa Brackish Basal Wells (5)	4.0	5.0	‘Ewa
13	Ko‘olau Loa Agricultural Wells (6)	6.3	12.6	Ko‘olau Loa
14	Punalu‘u Stream Irrigation System (7)	2.0	7.0	Ko‘olau Loa
15	Maunawili Ditch/Waimānalo I	0.4	1.4	Ko‘olau Poko
16	Kawailoa Irrigation System (8)	8.0	8.0	North Shore
17	Glover Tunnel – Makaha	0.55	0.55	Wai‘anae
18	Barbers Point NPW Well	1.0	1.0	Ewa
19	Waipio-Makalena NPW System	1.0	1.0	Central O‘ahu
	Total Alternative Resources	**68**	**109.1**	

Notes:
1 Wahiawā WWTP avg flow = 2 mgd, Schofield (Army) Avg flow = 2 mgd.
2 Wai‘anae WWTP effluent chlorides at 800-900 mg/l may constrain full expansion.
3 Waiāhole Ditch Min = 2009 CWRM permitted use. 2.43 mgd remains unpermitted.
4 Kaukonahua Streams minimum average month = 8.5 mgd, 2004 mean flow = 31 mgd, 2010 mean flow = 16 mgd. Wahiawā Reservoir storage capacity = 9,200 ac-ft or 3,066 mg.
5 Revised ‘Ewa Development Plan. EP2 (1 mgd), EP5&6 (2 mgd), EP10 (1-2 mgd).
6 Sustainable yield exists, but well sites have not been identified.
7 Effects of Surface Water Diversion and Ground Water Withdrawal on Streamflow and Habitat, USGS Report 2006-5153.
8 Approximately 80% is surface water and 20% is ground water sources

The following table summarizes *Tables 1.12* and *1.13* of planned potable ground water sources and alternative potable and nonpotable sources.

Resource	Quantity (mgd)
Ground Water – Potable	49
Desalination – Potable (minimum estimate)	1.5
Recycled Water (minimum estimate)	19.75
Ground Water – Nonpotable	36
Surface Water – Nonpotable	34
Total	**140**

Increases in potable and nonpotable demand are offset by water conservation, released agricultural ground water from the close of the sugar plantations, seawater desalination and the development of brackish and recycled irrigation water systems. Surface water is continuing to supply agriculture and although new stream diversions are not planned, additional water demands could be supplied by water loss control measures in ditch irrigation systems. Surface water will not be evaluated for municipal use until measurable IFS are set and water availability is determined.

Ground water will be developed utilizing available sustainable yield including released agricultural water for agricultural lands rezoned to urban use. Ground water supply evaluations will be conducted to refine available ground water estimates especially as permitted use approaches sustainable yields. New sources of supply will be developed in locations that do not impact streams or other sources.

Recycled water facilities in 'Ewa and Central O'ahu are planned for expansion to continue to off-set additional ground water development.

- BWS has been operating the 12 mgd Honouliuli Water Recycling Facility for over a decade to supply irrigation and industrial process water for 'Ewa. The recycled water distribution system can be supplemented with brackish water.
- The Army's Schofield WWTP produces about 2.0 mgd of R-1 recycled water and a distribution system within Schofield and to Kunia farms is planned.
- The City's Wahiawā WWTP is close to completion of its upgrade to produce 2.0 mgd of R-1 recycled water for the State Agribusiness Development Corporation's Galbraith Lands in Wahiawā.

In the mid-term, seawater and brackish water desalination plants will be constructed to provide for future demand and off-set additional ground water development and provide a cost competitive alternative to increasing inter-district transfers.

- The Kalaeloa Seawater Desalination Plant is currently planned for construction in the early 2020 timeframe and will bring an additional 1.0 mgd minimum of potable water supply to the ʻEwa districts. The plant will be capable of further expansion as needed.

- The Kapolei brackish water desalination plant in Kapolei Business Park is currently being master planned adjacent to a new operations base yard. The brackish desalination plant is expected to produce approximately 0.7 mgd of potable water supply for Kapolei.

1.3.9 Adequacy of Supply and Future Demand and Population Distribution

The 171 mgd of unused ground water available on Oʻahu in 2010 (*Table 1.6*), adjusted for recoverability, and the existing large agricultural irrigation systems [Wahiawā Reservoir (16 mgd), Maunawili Ditch (1.4 mgd), Punaluʻu Stream (7.0 mgd), Kawailoa (8 mgd) and the Waiāhole Ditch (15 mgd)] totaling 47 mgd are available to meet future urban and agricultural water demands beyond the 2035 planning horizon.

Existing stream diversions will continue to provide for agricultural uses, including kalo, and reduce the need for potable ground water, although supplemental wells are recommended as a drought mitigation strategy. No new stream diversions are planned for non-instream uses until interim IFS are amended to protect and support appurtenant rights, traditional and customary rights in the stream, estuary and nearshore water environments. However, water efficiency improvements in the stream diversion and ditch systems should provide additional surface water for additional agricultural irrigation.

Recycled water is planned to supply a minimum of 20 mgd for urban irrigation. Future seawater desalination could supply approximately 2 mgd of potable water for ʻEwa.

The City's General Plan directs the majority of future growth to ʻEwa and the Primary Urban Center, the two development plan areas where plans and infrastructure investment will support a total of 59% of Oʻahu's population. Adding Central Oʻahu, the total General Plan population increases to 76% in these three districts. Therefore, natural and alternative water supplies, such as ground water, storm water, recycled water and desalination as well as advanced water conservation and watershed management to sustain the natural water resources must be fully integrated. In the remaining five sustainable communities of Waiʻanae, North Shore, Koʻolau Loa, Koʻolau Poko and East Honolulu, little change in BWS water demand is expected throughout the planning horizon. The existing sources and infrastructure in these sustainable areas are adequate and therefore, additional transfers of water between these districts will be stable.

A summary graphic of O'ahu's population distribution based on the 2010 census, BWS potable water demand and water transfers is provided for the eight land use districts (*Figure 1.10*). This updated graphic from the 2000 graphic in previous WMP's shows a reduction in BWS water demand of approximately 10 mgd from 155 mgd to 145 mgd. The 2010 water demand and distribution in the BWS system will be referenced in establishing future regional watershed management plan scenarios.

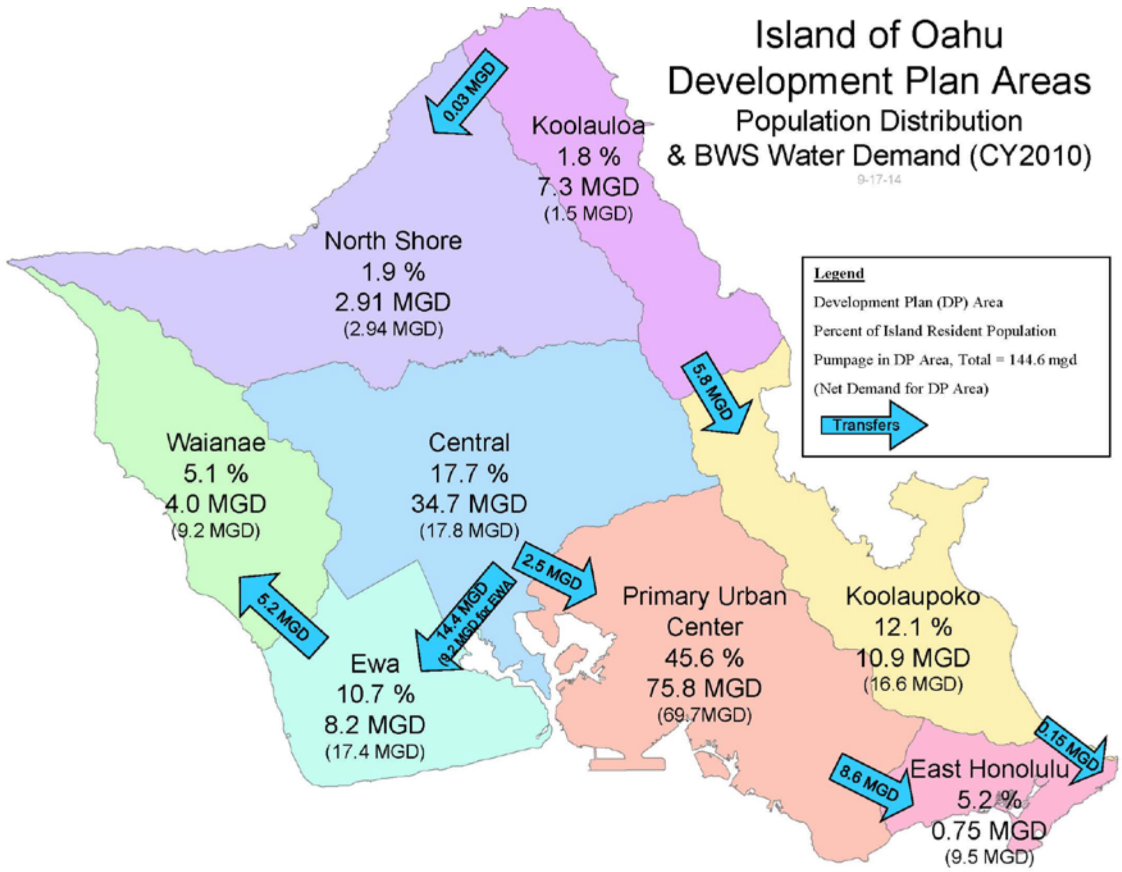


Figure 1.10 Population and Potable Water Demand Distribution 2010

A second summary graphic (*Figure 1.11*) of O'ahu's estimated population distribution and water demand based on DPP's 2035 forecast is the BWS low-growth demand scenario. Potable water demand is increasing by only 8 mgd from 145 mgd in 2010 to 153 mgd in 2035, anticipating continued decreasing trends in per capita water use. Water transfers in 2035 between land use districts are expected to decrease accordingly except between Central O'ahu and 'Ewa and PUC. Desalination is included in the 'Ewa district along with recycled water for irrigation that will be reducing the amount of additional potable water demand.

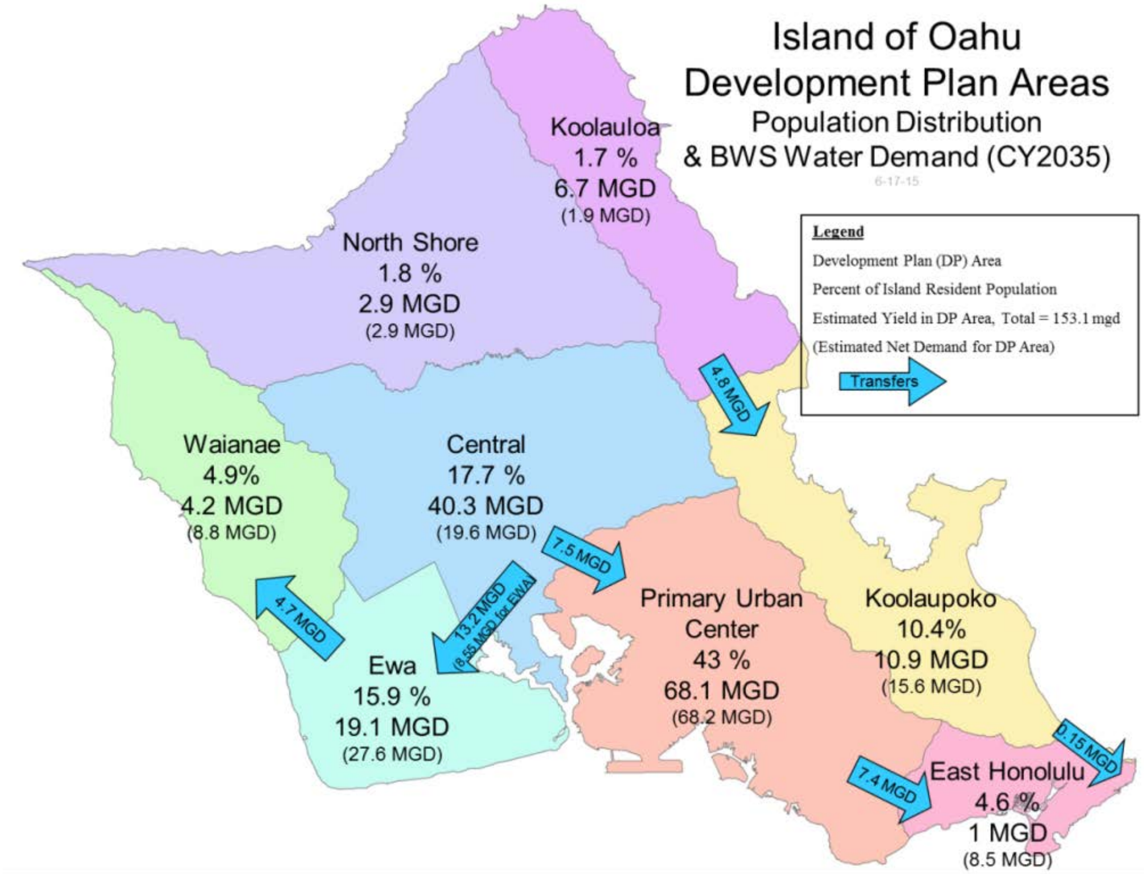


Figure 1.11 Estimated Population and Potable Water Demand Distribution 2035

The following findings summarize *Figures 1.10* and *1.11* Population Distribution and Potable Water Demand 2010 and 2035.

- The Oʻahu General Plan directs growth to South Oʻahu, (ʻEwa, Central Oʻahu and PUC). The directed growth policy allows the remaining districts of Waiʻanae, North Shore, Koʻolau Loa, Koʻolau Poko and East Honolulu to be sustainable communities with limited growth.

- Projected increase in water demand for Oʻahu's eight land use districts of 8 mgd can be met with the current BWS water system. However, to realize this low forecasted demand, it is important that the following strategies be pursued:

  - Continue to advance water conservation programs of water loss control in distribution systems and on-site plumbing/irrigation systems, high efficiency toilets and water fixtures, economic incentives and education, etc.
  - Diversify water supplies through a combination of ground water, recycled water, storm water and desalination, which will preserve the natural ground water resource by providing drought proof water supplies and capture storm water to supplement irrigation. New potable ground water sources will be developed to distribute source withdrawals to reduce concentrated pumping in select large pump stations in anticipation of decreasing rainfall predicted by

some climate change models. Brackish 'Ewa Plantation wells will continue to be converted for urban irrigation in 'Ewa to reduce potable ground water use. New distributed recycled water systems including membrane bioreactor (MBR) scalping plants are planned.

- Promote green infrastructure and low impact development standards that reduce water use. Consider new policies that utilize recycled water to irrigate single family lots and dual water systems for toilet flushing in new construction
- Ensuring watershed protection projects are adequately funded and implemented to preserve native species and water supplies in a climate change future so that existing source capacities can be maintained

The BWS low-growth demand scenario of population and potable water distribution in 2035 is based on the best available estimates of supply and demand, analysis of decreasing water demand trends experienced since 1990 plus a significant commitment to advanced water conservation and alternative water development. New aquifer studies and climate change research will continue to refine estimates of sustainable yield and pumpage optimization plans will be adapted to avoid salinity and other water quality impacts.

The most conservative estimates of available remaining ground water sustainable yields, a reasonable accounting of uncertainties and climate change, planned ground water source projects, advanced water conservation and green infrastructure programs and alternative water source projects, such as recycled water, storm water and desalination, are used to accommodate future demands while also providing a comprehensive, watershed based suite of strategies, programs and projects to accommodate future growth and water demands within and beyond the 2035 planning horizon.

1.3.10 Uncertainties and Contingencies

Planning efforts have uncertainties due to assumptions made about existing conditions and future scenarios. Identifying these uncertainties provides an opportunity to plan for a practical range of contingencies. This section highlights the major uncertainties and contingencies of this watershed management plan. Many of the watershed protection projects and water supply options discussed in *Chapter 4: Plan Objectives, Water Supply and Watershed Management Projects and Strategies* and *Chapter 5: Implementation* incorporate contingencies designed to plan for uncertainties in supply and demand.

1.3.10.1 Ground Water Supply Uncertainties and Contingencies?

Ground water supply uncertainties and contingencies are presented in the this section and include the following topics:

- Estimating Sustainable Yield
- Recoverability of Sustainable Yield
- Climate Change
- Ground Water Contamination

The uncertainties are discussed followed by contingencies, or planning strategies to mitigate effects of the ground water supply uncertainties:

Estimating Sustainable Yield

Sustainable yields for all aquifer system areas have been adopted as part of the State Water Code's Water Resources Protection Plan and are used for resource management, protection and development. The current sustainable yields are based on the best available information of hydrologic factors but have acknowledged limitations in estimating rainfall distribution, vegetative transpiration, overland runoff, aquifer leakage to the ocean and to the brackish transition zone and recharge to the various dike, basal, perched and caprock aquifers.

Contingency for Estimating Sustainable Yield

- Periodically update information on rainfall, evapo-transpiration, runoff, leakage and recharge to reflect current hydrologic trends due to climate change.

- Evaluate and account for aquifer boundary conditions recognizing separate geological formations such as dike, basal, alluvial and caprock aquifers within each aquifer system area.

- Construct deep monitor wells in important basal aquifers to provide the ability to monitor water levels, freshwater lens and transition zone thickness and trends in response to pumping.

- Develop advanced numerical ground water models to improve sustainable yield estimates. CWRM with BWS, USGS and UH participating in various efforts, dedicated to monitoring key hydrologic indicators such as rainfall, evapo-transpiration, recharge, head, salinity, and transition zone trends, and also to reaffirming the adopted sustainable yields in key aquifer systems. The USGS is constructing a 3-dimensional solute transport ground water model of the Pearl Harbor aquifer system calibrated to deep monitor wells.

Recoverability of Sustainable Yield

Recoverability is the ability to feasibly extract ground water through wells or tunnels, up to the adopted sustainable yield. Recoverability is a major uncertainty due to surface and ground water interactions, presence of separate hydro-geological formations within an aquifer system area, extended drought, and well location and spacing constraints. There are also regulatory, political, financial and public acceptance uncertainties surrounding additional ground water development and regional transport of water with respect to environmental impacts, local water needs and available supply.

Contingency for Recoverability of Sustainable Yield

- Until interim IFS are amended, seek new ground water wells that do not impact surface waters. Develop long-term monitoring plans of stream and watershed indicators.

- Optimize well spacing and pump sizing on an aquifer system area basis to increase recoverability and avoid lens shrinkage, up-coning and seawater intrusion. Align water system infrastructure capital plans to more readily accommodate smaller wells spaced throughout the water system when practical.

- During severe, long-term droughts usually greater than 3 years, the full sustainable yield may not be recoverable. Dike source yields will likely drop below permitted use. BWS operational experience accounts for source yields in normal rainfall and drought years. The difference, approximately 14 mgd, is supplemented by the following drought mitigation strategies that will improve the water system's resilience to climate variability:

  - In non-drought years, ensure pumping does not exceed normal rainfall level estimates to preserve sufficient aquifer storage to meet maximum day demands during drought.
  - During drought years, reduce pumping to drought level estimates to protect the freshwater lens. Reducing pumping is difficult, as water demands will increase during drought, therefore:
    - Implement the BWS low ground water plan and other progressively increasing conservation measures to reduce water demands.
    - Develop additional ground water wells to supplement reductions in source yields due to severe drought.
    - Develop alternative, drought-proof water supplies such as recycled water, brackish and seawater desalination facilities.
    - Mandate dual water systems for new large developments to maximize nonpotable water use to conserve the potable water supply.

  - Ensure sufficient aquifer recovery during post-drought periods by reducing pumpage and implementing the applicable watershed protection projects for the most important and/or impacted watersheds.
- Regulatory, political, financial and public acceptance uncertainties can be addressed by environmental disclosure, cost benefit analysis, public outreach, education, alternative source analyses, and holistic watershed management and integrated resource planning.

Climate Change

Climate change is expected to cause more severe droughts and floods, and as global temperatures increase, sea water levels are expected to rise affecting coastal environments, brackish aquifers and stream estuaries. Rainfall data from 1990 to 2010 show decreasing rainfall of 12% on O'ahu (rain follows the forest). However, local climate models are mixed on the severity of future rainfall trends. The uncertainties introduced by climate change emphasize the importance of incorporating water system flexibility, conservation and alternative supplies in the range of planning options. *"Although most scientists worldwide agree that our planet's climate is warming, they recognize the uncertainty inherent in assessing climate change impacts. Uncertainties in projected greenhouse gas emissions, limitations of climate models, information loss when climate projections are downscaled to watershed resolution, and imperfections in hydrological models all contribute to the uncertainty."*[3]

Contingency for Climate Change on Rising Sea Levels and Decreasing/Variable Rainfall

Rising sea levels and rainfall variability are global issues, which may have long-term impacts for Hawai'i. A precautionary approach to adaptation and mitigating impacts of rising sea levels and rainfall variability is to 1) identify the water system's most critical vulnerabilities; 2) suggest how climate variability and extremes might aggravate those vulnerabilities, and 3) design a range of solutions covering the climate uncertainty. The following contingencies could be evaluated:

- Sea level rise models by UH Sea Grant anticipate a likely sea level rise of 3 feet by 2100. At this level, coastal inundation, retreat/fill, hardening and infrastructure damage are predicted. BWS freshwater wells will not be impacted because of the overlying caprock formation preventing seawater from entering into the basal aquifer. Basically, if sea level rises by 3 feet, the freshwater lens due to density differences will rise 3 feet which will not detrimentally affect source yields. In areas of thin caprock above mean sea level, such as in Pearl Harbor, constructed hydraulic barriers could prevent rising sea levels from intruding over the caprock into the freshwater aquifers. This solution is similar to Orange County California's Ground Water Replenishment System, recycled water hydraulic barrier injection system. However, the recycled water is treated by reverse osmosis to better than drinking water standards. In many systems in California, potable reuse has become the preferred strategy.
- Private brackish caprock wells near the coast may become more brackish or unusable increasing potable demand if converted and may need to be replaced with alternative supplies, such as recycled water
- Recycled water and seawater desalination provide drought proof water supplies and watershed management projects will ensure healthier forests that will capture a larger percentage of less rainfall, stabilizing recharge fluctuations and maintaining current aquifer sustainable yields.
- BWS has engaged UH and the Water Research Foundation in climate change research projects to increase our understanding of climate change impacts to freshwater supplies. Vulnerable water systems to severe drought and coastal inundation will be identified and resolved through the BWS capital improvement program.
- BWS is engaging UH in an aquifer storage and recovery study of storm water impoundment in Nu'uanu Reservoir No. 4. Impounded storm water could be treated and injected into the Kalihi and Nu'uanu aquifers to supplement natural recharge and sustain existing pumping stations down gradient.

Ground Water Contamination

Contaminants infiltrating into ground water and spreading through the aquifers places uncertainty in the amount of available water supply. Contamination from agricultural, underground fuel storage and distribution, and urban activities has previously occurred in Central O'ahu, Waialua, Red Hill, and Honolulu. Contamination could also result from purposeful human activities. The contamination can be mitigated, but treatment is very expensive and time consuming. If treatment is too costly, the well will be shut down and pump capacity will be permanently reduced. Replacement wells are also expensive. Therefore, prevention is the most cost effective measure against ground water contamination.

Contingency for Impacts from Ground Water Contamination

- Prevent ground water contamination from happening in the first place.
- EPA and DOH provide extensive regulatory guidelines to address contamination of drinking water. EPA has developed a list of Best Available Technologies (BAT) to remove various contaminants in drinking water and restore the drinking water source for public consumption.
- Conduct regular water quality samples and track trends of contaminants. If trends are rising toward the maximum contaminant level (MCL), initiate planning and engineering of the recommended BAT so that the treatment system is in place before the MCL is reached.
- Apply DOH Source Water Protection program guidelines to water systems such as conducting sanitary surveys, protecting source water delineation/capture zones above wells and best management practices for potential contaminating activities. Conditions for source water protection should be placed on land use plan approvals.
- Implement the water system vulnerability assessment recommendations and other security measures for well stations and other facilities.
- Seal old, unused wells with cement grout to prevent direct contamination to the aquifer and leakage from the aquifer. Well sealing could be regulated through the building permit application process.

1.3.10.3 Surface Water Supply Uncertainties

Surface water supply uncertainties and contingencies are presented in the this section and include the following topics:

- Amending Interim Instream Flow Standards
- Quantifying Stream Flows, Diversions and Use
- Drought Impacts on Surface Water

The uncertainties are discussed followed by contingencies, or planning strategies to account for surface water supply uncertainties:

Amending Interim Instream Flow Standards

The most significant uncertainty related to the availability of surface water is the lack of measurable IFS for the majority of streams on O'ahu. Other uncertainties relate to the complexity of stream studies (scientific, cultural, economic and environmental) and their potential cost. These uncertainties realistically mean that additional surface water is not available now or for the foreseeable future. The following is a range of possible outcomes:

- If there is additional water available after instream uses are met, water will be available for agricultural use.
- If no additional water is available, status quo instream and non-instream uses will be maintained.
- If there is insufficient water in the stream to meet the measurable IFS, water from existing non-instream uses will need to be returned to the stream, and alternative water sources for agriculture and urban uses may be needed.

Contingency for amending interim IFS

- CWRM identifies high natural quality streams to amend interim IFS using best available information.
- CWRM will be acting on the pending petitions for amending interim IFS and has developed a standardized measurable IFS methodology emphasizing practicality and consistency.
- Until measurable IFS are established, new stream diversions are not recommended in this plan, other than for traditional and cultural practices, such as kalo cultivation. Other surface water users should work within the existing diverted flows, applying conservation and water loss prevention strategies to increase system efficiencies.

Quantifying Stream Flows, Diversions and Use

There is a level of uncertainty in the amount of surface water flowing in O'ahu's streams and stream segments (low, mean, median and peak variations of flows), the number of diversions and diverted flows, and their associated use and non-use. On O'ahu there are 87 surface water hydrologic units containing approximately 232 stream diversions. In order to adequately protect streams and manage surface water use, streams need to be gaged, diversions structures must be inventoried and surface water use reported on a regular basis. As with ground water use, non-instream water use must be reasonable and beneficial, conserved or returned to the stream.

Contingency for inventories of stream flow, diversion and use

- Cooperative partnerships such as with USGS, will be expanded to jointly fund the gaging of important perennial streams.
- The 2006 Legislature appropriated $650,000 to conduct statewide field investigations to verify and inventory surface water uses and stream diversions and update existing surface water information. BWS hydro-geologists are conducting field surveys using CWRM survey protocols of stream diversions to supplement CWRM efforts.
- The stream permitting process is being revised to improve the acquisition of pertinent information, and a surface water use reporting system will be established.

Drought Impacts on Surface Water

Drought impacts instream uses and surface water availability, and is another uncertainty. Surface water is supplied by rainfall and ground water leakage as base flow, and is impacted more readily during drought than ground water. Extended drought can have dire implications, especially for agriculture, much of which relies solely on surface water for irrigation.

Contingency for Drought Impacts on Surface Water

- Alternative sources such as ground water and recycled water should be developed to mitigate drought impacts on agriculture. Barriers to recycled water especially for edible vegetable crops will need to be addressed.
- Water loss strategies will extend existing diverted flows. Agricultural crops could also be modified to use less water, markets permitting.
- Watershed forestation and protection projects will focus on critical watersheds to increase base flows and natural storage supplying streams.

A significant limitation to using surface water is its variability and lack of reliability especially during dry periods and drought. By increasing water storage, or by supplementing surface water with ground water, which is called conjunctive use, additional agricultural lands may be irrigated year-round cost effectively with minimal impact. *Figure 1.11* (*Seasonal Agricultural Water Use Supplementing Surface Water with Ground Water*) shows the seasonal relationship between surface water in conjunction with ground water for agricultural irrigation. During dry seasons and drought, when demand increases and limited stream water is available, ground water can supplement surface water, protecting instream uses. Surface water, which is more abundant during the wet season, can be economically used, allowing time for the ground water source to be replenished.

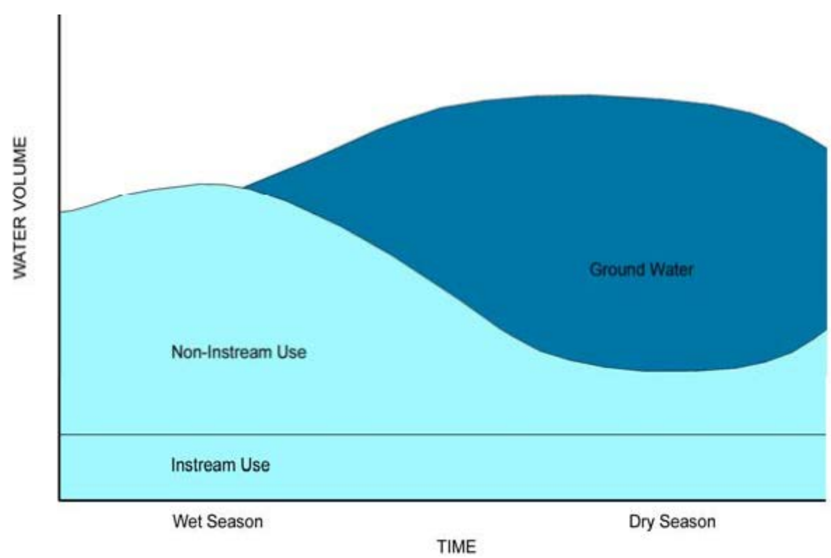


Figure 1.12 Seasonal Agricultural Water Use Supplementing Surface Water with Ground Water

1.3.10.5 Agricultural Water Demand Projection Uncertainties and Contingencies
Predicting agricultural water demands is challenging because of market uncertainties, variable regional crop type and associated water demand numbers, climate variability, etc. In addition, the general lack of metering agricultural water use severely hampers not only demand estimates but the protection and management of the water resource. Hawai'i's diversified agricultural production has increased in recent years.

Regional crop water demand uncertainties are related to crop types, operational variables for each crop type such as fallow periods and frequency of harvest, and local climatic conditions. Crop water demands are challenging because of the diversity of crops and of the relatively few crop numbers that are geographically specific or agreed upon.

Contingency for Agricultural Water Demands

CWRM funded a UH study to develop a crop water demand model that is now used to provide discreet water demands by specific crop type, climate and soil condition. The model allows CWRM to tailor water allocations to specific lands thereby assuring reasonable and beneficial water use.

1.3.10.6 Urban Water Demands Uncertainties and Contingencies
Predicting population growth depends on public policies in the Development and Sustainable Communities Plans and the fluctuating economic trends affecting the pace of urban growth. The urban growth and rural community boundaries provide essential guidance on discreet limits to urban growth to protect agricultural and conservation lands. A significant uncertainty is estimating water demands associated with urban growth concurrently with decreasing unit water demands that masks the true effect of water conservation programs.

Contingency Plans for Demand Projection Uncertainties

The following strategies can mitigate the uncertainties in demand forecasting:

- Compiling trend data to analyze the extent, causes and effects of decreasing per capita water demand to develop reliable and accurate water demand forecasts. Improved conservation measures and economic forces have slowed both urban and agricultural water demand growth extending existing supplies.

- Demand forecasts provide a range of possible future demands (low, mid and high) with associated water supplies. Adjusting the timing of water supply projects will accommodate changes in the rate of demand growth. If growth is slower or faster than predicted, projects can be deferred until needed or developed in a shorter timeframe. Regular updates of this plan will allow course corrections.

- With the integrated water resources strategies of watershed protection, advanced conservation, and sustainable diversified ground water and surface water supplies, and new technologies in recycled water and desalination using renewable energy sources, there should be sufficient water supply to accommodate variability in climate and domestic and agricultural water demand growth.

1.4 PLAN IMPLEMENTATION

The implementation of the watershed management plans will be accomplished by:

1. Guiding public investment in infrastructure through agency functional and facility plans, which are consistent with the sustainable communities and development plans and the WMPs of the City.
2. Including watershed and water supply projects in agency capital improvement programs for short-, mid- and long-term horizons that balance the five WMP objectives.
3. Incorporating major watershed management strategies and projects through the City's land use planning processes such as the Development Plans, Sustainable Communities Plans, special area plans, land use permitting process for private and public development, and through the Public Infrastructure Map.
4. Creating watershed partnerships of Federal, State and City agencies, landowners, organizations and communities who can pool resources toward common objectives, and creating groups that choose to assume the responsibility or obtain authorization to implement specific watershed projects.
5. Securing sufficient funding sources to support watershed and water supply projects through a combination of appropriations, grants, fees and dedicated funds. Each project is subject to annual budget approval and available funding.
6. Recommending approval, approval with conditions or denial of developments seeking water based on the adequacy and timing of planned water system infrastructure.

Water Allocation and System Development

The OWMP sets forth the allocation of water to land use by identifying new water supplies for the planned urban developments and agricultural lands as designated in O'ahu's sustainable communities and development plans. The land use plans and watershed management plans will be used as a guide for the review and approval of CWRM water use permit applications and water commitments and land use approvals by BWS and DPP. CWRM review of Stream Diversion Works Permits and Stream Channel Alteration Permits for new diversions of surface water can also use the plans for guidance. Water use permits are not required for domestic consumption of water by individual users (Chap. 174C-48(a) HRS). Regular updates of the regional land use plans and watershed plans will integrate land use and water planning and with iteration, will improve consistency and ultimately achieve healthy watersheds.

Adequate Facilities Requirement

All land use actions for developments requiring water, including domestic service, irrigation and fire protection from the BWS water systems are reviewed for adequacy of supply and level of service in compliance with *BWS Rules and Regulations, Chapter 1, Water and Water System Requirements for Developments and BWS Water System Standards.*

BWS issues water commitments based on an assessment of the adequacy of water supply and water system capacity. There are three categories of available water of which Category 2 currently applies island-wide:

1. Areas with Adequate Water Supply. BWS may issue advance water commitments to proposed developments in areas where the water system has adequate supplies to assume new or additional services.
2. Areas with Limited Additional Water Supply. BWS may restrict the issuance of advance water commitments to proposed developments in areas where the water system has limited additional supplies to assume new or additional services.
3. Areas with No Additional Water Supply. BWS shall not issue water commitments to proposed developments in areas where the water system has no additional supplies to assume new or additional services. The only exceptions shall be the issuance of a single 5/8-inch meter to proposed developments on existing single vacant lots.

BWS assists CWRM with permit reviews for new development. New ground water sources, both public and private, must comply with the State Water Code, Chapter 174C-51, Application for a Permit. Water Use Permits are required for sources of supply in designated water management areas. All areas except Wai‘anae are designated ground water management areas. Chapter 174C-49 Conditions for a Permit, establishes that the proposed use of water:

1. Can be accommodated with the available water source;
2. Is a reasonable-beneficial use as defined in Section 174C-3;
3. Will not interfere with any existing legal use of water;
4. Is consistent with the public interest;
5. Is consistent with state and county general plans and land use designations;
6. Is consistent with county land use plans and policies; and
7. Will not interfere with the rights of the Department of Hawaiian Home Lands.

Review of zoning and other development applications

Before zoning is approved for new residential, commercial and industrial development, the BWS will indicate to DPP that adequate potable and nonpotable water is available or recommend conditions that should be included as part of the zone change approval in order to assure adequacy.

Large developments requiring major new water system infrastructure

BWS requires new large developments to submit potable and nonpotable water master plans for review and approval, showing the necessary infrastructure to accommodate the development. The master plan should provide land use, site layout, phasing, water demands, and infrastructure including proposed source, storage, transmission and treatment facilities with hydraulic analysis. The master plan then guides the review and approval of construction plans, and the installation of infrastructure to be dedicated to

BWS in compliance with BWS Water System Standards. Applications for Water Service are contingent upon the fulfillment of these conditions.

Existing lot developments and small subdivisions

BWS capital program expands the water system to accommodate planned growth. Each application for water service is evaluated for system adequacy to provide domestic and fire protection services. Water System Facilities Charges, the BWS impact fees, are applied to all new developments requiring new or additional water service. If water system infrastructure is not adequate, the development can be denied or conditions to ensure adequacy are placed on the development before water service is approved.

BWS Capital Improvement Program

The OWMP is the long-range strategic water resource plan for the City and informs and guides the BWS long-range capital program plan of source, storage, transmission, treatment infrastructure by providing a watershed based evaluation of available sources of supply and water demand forecasts. The capital projects plan is an integral part of the BWS responsibility, authorized by City Charter as the public water system purveyor and water resource manager. The capital projects program is integrated with the BWS long-term financial plan and water rate structure. BWS is authorized by City Charter to set water rates to provide water supply for Oʻahu. The capital program accommodates water system expansion and infrastructure renewal and replacement as guided specifically by the strategies in Objective #5 meet demands at reasonable costs while balancing the other plan objectives.

In 2013, BWS initiated the BWS Water Master Plan, a 30 year infrastructure plan that evaluates the entire water system, identifies improvements and balances needs and costs. The benefits are that infrastructure needs are anticipated so that water is available when and where it's needed and capital projects are prioritized based on a comprehensive understanding of water resources from a holistic watershed perspective, most probable water demands accounting for conservation savings and the complexities of the water systems serving Oʻahu's residents such that BWS can provide safe, dependable and affordable water supply now and into the future.

ENDNOTES

1 State Water Code Section 174-C3

2 HAR Section 13-169-49 and 49.1

3 Miller, K. and Yates, D. 2006. *Climate Change and Water Resources: A Primer for Municipal Water Providers.* National Center for Atmospheric Research, American Waterworks Assoc. Research Foundation Publication

2 NORTH SHORE WATERSHED PROFILE

2.1 INTRODUCTION
2.2 METHODOLOGY
2.3 LAND AND WATER RESOURCES
2.4 TRADITIONAL PRACTICES AND CULTURAL RESOURCES
2.5 SETTLEMENT HISTORY
2.6 DEMOGRAPHIC CHARACTERISTICS
2.7 TRANSPORTATION
2.8 LAND USE
2.9 PREVIOUS RELEVANT PLANS
2.10 STAKEHOLDER CONSULTATION

2.1 INTRODUCTION

The North Shore Watershed Management Plan (NSWMP) is part of a comprehensive effort of the Honolulu Board of Water Supply (BWS) to plan for future water resource needs of the City and County of Honolulu, as mandated by the State Water Code. Over the years, BWS has recognized the importance of focusing on resource protection, conservation, and restoration, in addition to water use and development. A watershed approach was developed for this plan to understand the inter-relationships among the physical, biological, and human environments. Thus, in order to understand the resources and provide a context for water management, this plan includes a watershed profile with an overview of the terrestrial, land use, socio-economic, and water resources present in North Shore. This chapter provides a summary of the data collected and analyzed.

2.2 METHODOLOGY

The data collection and analysis process included identification of issues and needs, data gaps, and potential water resources management opportunities. The primary sources of data were previous studies, plans, and reports conducted by various agencies, organizations, and academics. These documents provided information on general watershed issues and specific topics within North Shore. Various individuals, agencies and organizations were then contacted to provide either follow-up details or updated information, and to identify natural resource values, issues, and needs.

2.3 LAND AND WATER RESOURCES

Known throughout O'ahu as being part of "the countryside," the rural North Shore is home to pristine white sand beaches and dramatic mountain views that frame expanses of agricultural lands. Encompassing approximately 77,000 acres[1] (120 sq. mi.), the North Shore district makes up 20% of O'ahu's land mass. The Ko'olau and Wai'anae Mountain Ranges form the eastern and the western boundaries of the district, respectively.

The North Shore district follows the same geographic boundaries as delineated in the North Shore Sustainable Communities Plan.

2.3.1 Ahupua'a and Watersheds

The North Shore district contains lands in the Waialua moku, as well as a portion of the Ko'olau Loa moku (*Figure 2.1*). The moku of Waialua encompasses lands from Ka'ena Point to Kāpaeloa at Waimea Bay. The portion of the Ko'olau Loa moku within the North Shore district extends from Kāpaeloa to Waiale'e Gulch near Kawela Bay. There are 19 ahupua'a in North Shore (*Figure 2.1*). These include: a portion of Keawa'ula, Ka'ena, Keālia, Kawaihāpai, Kikahi, Auku'u, Mokulē'ia, Kamananui, Pa'ala'a, Kawailoa, Lauhulu, Kuikuiloloa, Punanue, Kāpaeloa, Waimea, Pūpūkea, Paumalū, Kaunala and a portion of Waiale'e.

Traditional Hawaiian ahupua'a management operated under a holistic approach that recognized the interconnectedness between land and sea, the interactions among species, the rhythms of the seasons, and the impacts of overuse on resources. Resources were managed for the collective good of all living within the ahupua'a, based on the principle that activities in one part of the ahupua'a were tied to the health of all areas of the ahupua'a. Along with ecological/environmental inter-relationships, the ahupua'a concept embraced human activities such as the economic aspect (trade between mauka agriculture with makai fishing) as well as social/cultural values of kapu, kuleana, conservation, etc.

Adapted to the context of today's community needs and technology, the ahupua'a concept provides useful principles for guiding the use and management of the North Shore's resources.[1] This style of resource management requires greater collaboration among jurisdictional authorities as well as community involvement and stewardship. For this Watershed Management Plan, the ahupua'a concept is a holistic approach to land management that recognizes the ecological connections between land-based and marine-based natural resources and the dependent relationships between ecological functions, with a triple bottom line balancing environment, economy, and social/cultural values.

A watershed can be defined as an area of land where all water collects and drains into a common body of water. While watersheds and ahupua'a can have similar boundaries, in the North Shore district, watershed boundaries are not the same as the ahupua'a boundaries. The watersheds in North Shore typically have a smaller land area than ahupua'a. The North Shore district consists of 22 watersheds (*Figure 2.2*), which include: a portion of Kaluakauila, Manini, Kawaihāpai, Pahole, Makaleha, Waialua, a portion of Kaukonahua, Ki'iki'i, Paukauila, a portion of Poamoho, Helemano, 'Ōpae'ula, Kawai'iki, Kawainui, Kawailoa, Anahulu, Loko Ea, Keamanea, Waimea, Kālunawaika'ala, Pākūlena, and a portion of Paumalū.

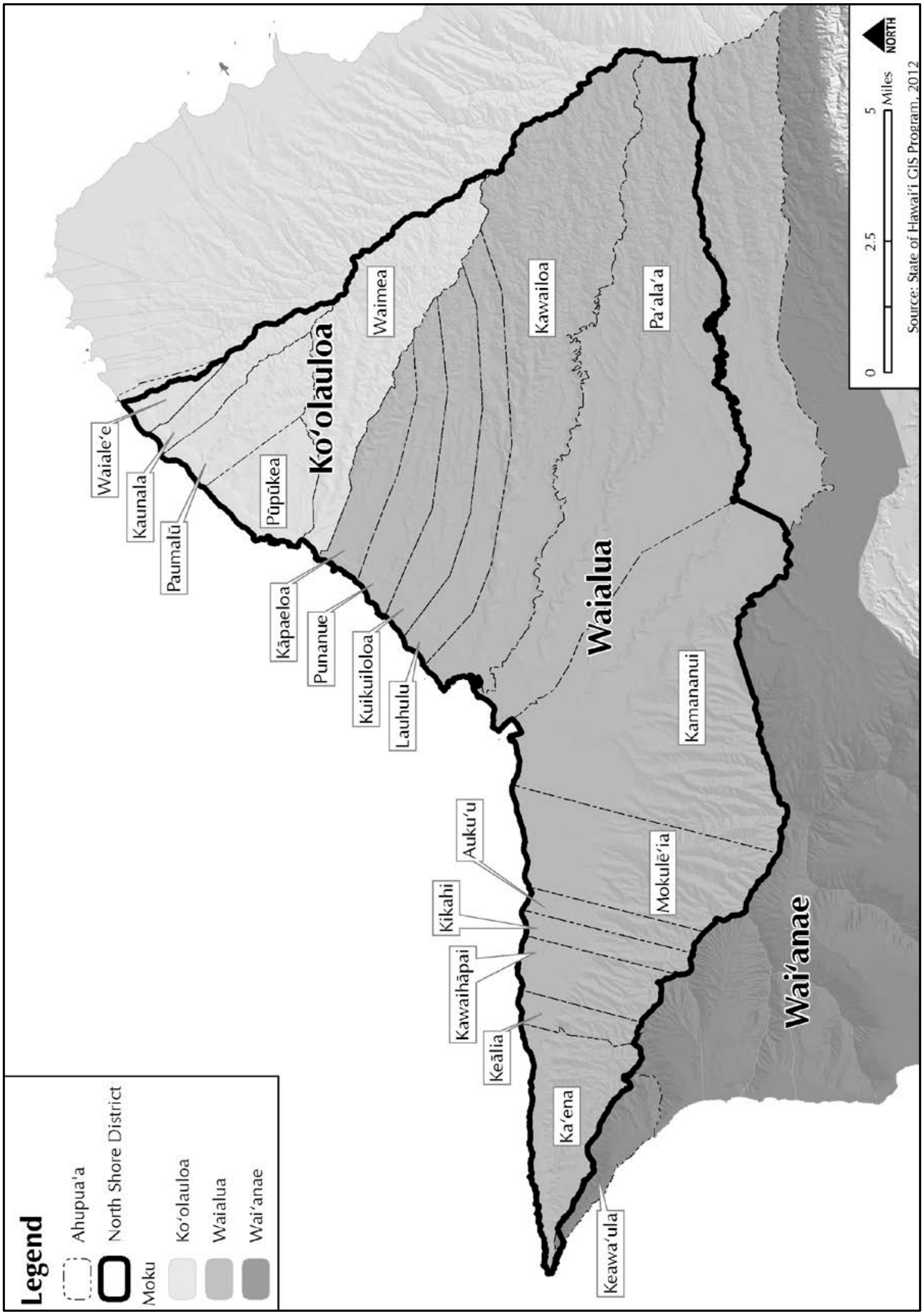


Figure 2.1 Ahupua'a of the North Shore District

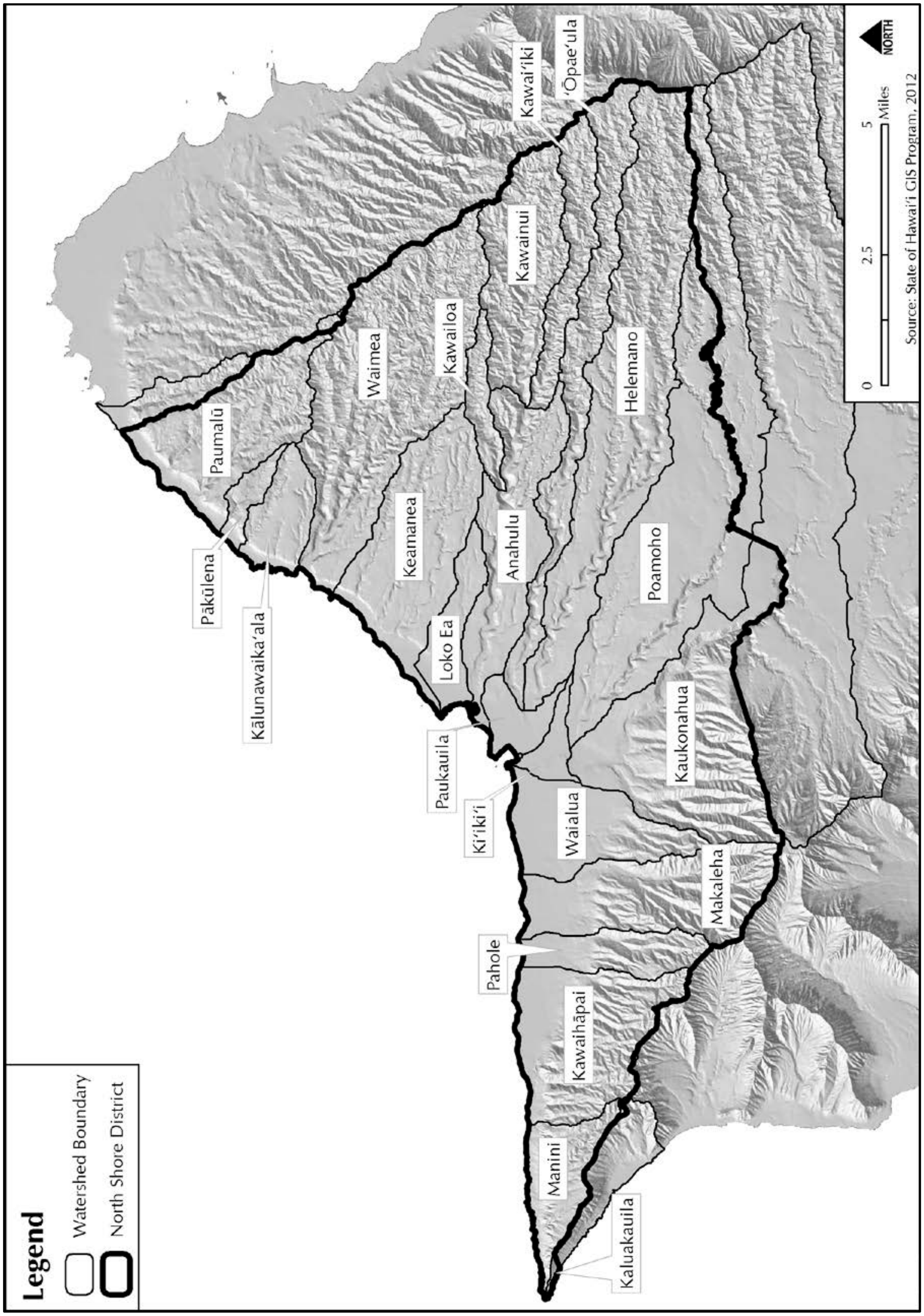


Figure 2.2 Watersheds of the North Shore District

2.3.2 Climate

The coastal areas and central plains of the North Shore have moderate to frequent rainfall (*Figure 2.3*). The highest annual average rainfall in the district (over 200 inches) occurs in the upper portions of the Koʻolau Mountain range. The coastal areas of Haleʻiwa and Mokulēʻia have the lowest annual average rainfall (31 inches).

Average temperatures vary by month and elevation, with the warmest month generally being August (mean temperature of 80.5° F) and the coolest month generally being February (72.0° F).[2] The prevailing trade winds come from the northeast and usually vary between 10 to 20 mph. The trade winds usually occur about 50% of the time between January and March and 90% of the time during June and through August.[3] In the winter, strong Kona winds associated with extra-tropical storms that track predominantly eastward from origins in the northwest Pacific produce large swell events, which can travel for thousands of miles until reaching the shores of Hawaiʻi. The recurrence of these high surf events control many natural beach processes like rip current formation, erosion, and reef growth.[4]

Hawaiʻi's climate is changing in measurable ways that are consistent with the predicted influence of global warming (*Figure 2.4*):

- Air temperature has increased by 0.08°F per decade over the period 1919 to 2006[5]
- A general downward trend in rainfall has been documented over the last century, with an even steeper decline by about 15% over the past 20 years - the likely cause of decreased base stream flow around the State
- Rain intensity has increased by approximately 12%
- Sea level has risen at approximately 0.6 inches per decade over the past century
- Sea surface temperatures have increased by 0.22°F per decade
- The ocean is acidifying (from rising carbon dioxide in the atmosphere that mixes with the seawater) at exactly the rate of chemical equilibration with the atmosphere.[6]

Because these trends are likely to continue, scientists anticipate growing impacts to Hawaiʻi's water resources and forests, coastal communities, and marine ecology.

One of the effects of climate change is an increasing rate of drought. Drought impacts surface water uses and agriculture first before ground water sources and urban uses. During droughts, soil moisture may be completely depleted in un-irrigated, fallow fields, causing dust storms and loss of top soils from wind erosion. Certain ground water sources, predominately dike sources are more susceptible to drought because dike aquifers store less water than basal aquifers.

Global warming and forest degradation can also change evapotranspiration rates. Evapotranspiration (ET) is the process of evaporation and plant transpiration returning water to the atmosphere, thus reducing the amount of water going into streams and ground water.[6] As global temperatures rise, the average annual ET may increase. Deforestation contributes to decreased ET, by reducing atmospheric moisture attracted by forest cover. In some cases, precipitation levels downwind from the deforested area are affected, as water is lost in runoff and returns directly to the oceans.[7]

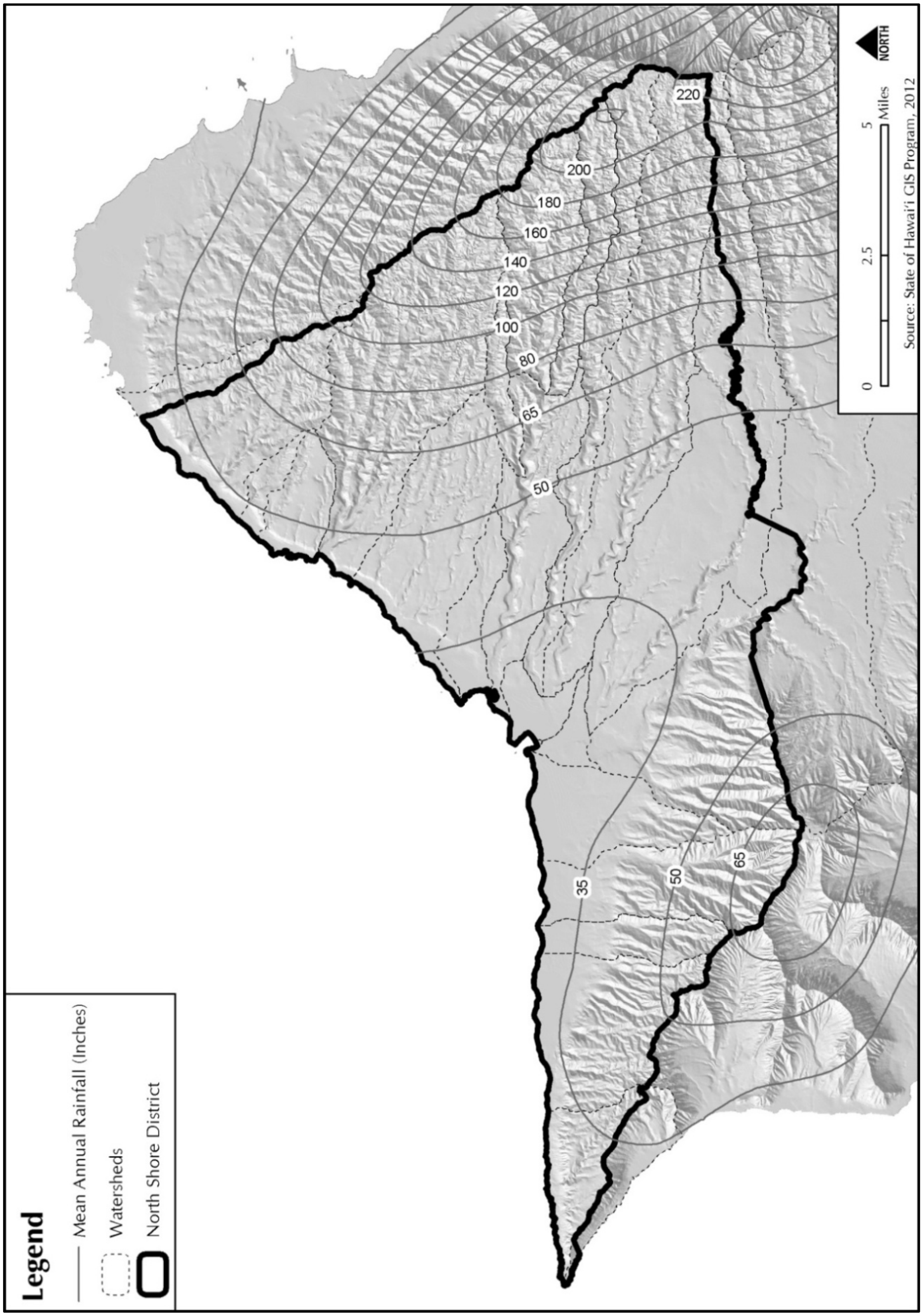


Figure 2.3 Mean Annual Rainfall (1978-2007) of the North Shore District
(Source: Online Rainfall Atlas of Hawaiʻi, 2012)

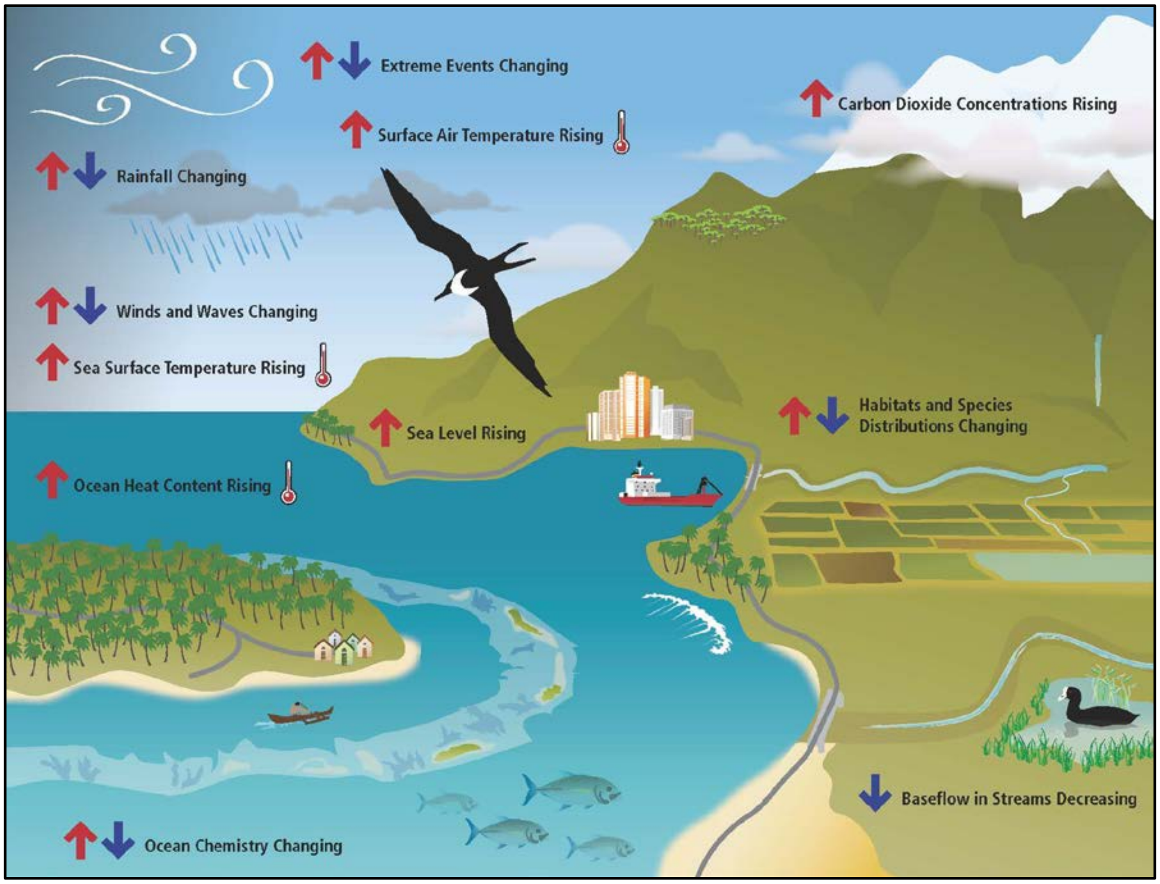


Figure 2.4 Indicators of Climate Change
(Source: Climate Change and Pacific Islands: Indicators and Impacts, 2012)

Water quality and quantity may be impacted due to salt water intrusion into fresh and brackish water aquifers and stream estuaries as sea level rises. Sea level rise could immerse more metallic pipeline infrastructure in seawater, increasing corrosion, main breaks, and replacement costs. As coastal communities retreat from the coast and increased population growth and migration from inundated Pacific islands occurs, development pressures will increase in agricultural and conservation zoned lands.

Increased urbanization may reduce prime ground water recharge areas (> 50″ annual rainfall) thereby affecting water supply. Climate change also: reduces aquifer recharge and available water supply due to more frequent and severe drought; changes rainfall patterns, such as thermal inversion effects; increases evaporation due to higher global temperatures, reducing recharge; and increases runoff if forest health declines.[9]

In July of 2009, the State Legislature established a Climate Change Task Force within the State Office of Planning to scope the impacts of global climate change trends in the State.[8] The Climate Change Task Force developed a framework that identified 15 areas of planning that are likely to be affected by climate change, including the potential impacts climate change may have on water supply, coastal zone management, storm and wastewater management, agriculture, natural resources/environmental protection, and flood control.[9] These impacts, including rising sea level, inundation, loss of property and open space, and severity of storms should be considered in North Shore planning efforts.[9]

While climate change is a problem on a global scale, simple, local actions can safeguard Hawai'i's declining water sources. Protecting forest watersheds is the most cost effective and efficient way to absorb rainwater and replenish ground water. Forests also reduce impacts from climate change by absorbing greenhouse gases and reducing flooding, erosion, and siltation of reefs and fisheries, while sustaining irreplaceable cultural and natural values.[10]

2.3.3 Geology

North Shore district covers a portion of the Schofield Plateau which lies between two extinct shield volcanoes: Wai'anae to the west and Ko'olau to the east.[11] Wai'anae volcano is the older of the two and consists of shield lavas overlain by a thick sequence of postshield-stage alkalic basalt.[12] The Wai'anae volcano is extensively eroded. Near Mokulē'ia, its slopes are gradual with small, narrow valleys, and ends in steep coastal cliffs at Ka'ena.[13] The range's Ka'ala summit rises to approximately 4,025 feet, which is the highest point on the island.[14]

The Ko'olau volcano consists of the eruptive products of the shield and rejuvenated stage lavas. The highest point of the Ko'olau Range is the Kōnāhuanui summit at approximately 3,150 feet, which lies outside the district.[11] The leeward slopes of the Ko'olau Range are characterized by wide ridges bordered by steep stream valleys. The relatively gradual slope allows for higher ground water infiltration rates.[15]

The northwest coast from Waiale'e to Hale'iwa is characterized by massive winter surf, long sandy beaches, rocky points, and patches of exposed beach rock. The beach rock is particularly exposed in the winter, when foreshore slopes steepen, and large quantities of sand are moved by high surf from the water's edge toward the back of the beach. Sand at the shoreline is mostly coarse grained and calcareous, a signature of the high energy waves that impact this coast in the winter.[16]

The Mokulē'ia shoreline extends west from Hale'iwa toward Ka'ena Point. This low lying coastal terrace faces due north with consistent trade winds blowing across it to the base of the northern Wai'anae Range. Nearly the entire coastline from Mokulē'ia to Ka'ena Point is fronted by broad wave-cut platforms of older limestone with small sandy beaches and vegetated dunes occurring in gaps along the shoreline. The coastal slope increases in steepness as the Mokulē'ia shoreline approaches Ka'ena Point. The point is composed largely of fossiliferous coral conglomerate with loose coral and basalt cobbles up to approximately 10 m above sea level, fronted by a dune field.[16]

2.3.4 Soils

The *United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) General Soil Map* describes soil associations, which are distinctive proportional patterns of soil landscapes that consist of one or more major soil series and at least one minor soil series. A soil association is named for the major soils. There are six general soil associations in the North Shore (*Table 2.1*).

Table 2.1 Soil-Type Associations in North Shore[11]

Soil-Type Association	General Extent	Soil-Type Association Description
Kaena-Waialua	Coastal lands, talus slopes and drainageways	Deep, gently sloping, poorly drained (Kaena series) to excessively drained soils (Waialua series) consisting of fine to coarse subsoil or underlying material
Rock Land-Stony Steep Land	Rocky and stony land (Along Ki'iki'i River, Paukauila River, and Anahulu River; also Ka'ena Point area)	Steep to precipitous, well-drained to excessively drained
Lolekaa-Waikane	Fans, terraces, and uplands area	Deep, nearly level to very steep and well drained soils that have dominantly fine-textured subsoil
Helemano-Wahiawa	North Shore uplands	Deep, nearly level to moderately sloping, well-drained soils consisting of fine subsoil
Tropohumults-Dystrandepts	Long narrow ridges and eastern side slopes of the Wai'anae Range	Gently to very steep sloping, well-drained soils underlain by soft weathered rock, volcanic ash or colluvium
Rough Mountainous Land-Kapaa	Gullies and along narrow western ridges of the Ko'olau Range	Very steep land broken by numerous drainageways with deep, well-drained, fine textured soils with moderately fine subsoil

Soil characteristics associated with watershed management include permeability, water capacity, and erosion level. Soil permeability is a general measure of how fast water can move downward in a particular soil. The majority of soils in the North Shore district are well-drained, meaning that permeability is moderate to rapid. The more permeable soils must be managed carefully to keep pesticides from reaching ground water. Removal of pesticides and other organics within the soil depends on the soil type, hydraulic loading rate, degree of pretreatment, and travel distance through the soil, vadose zone and aquifer.[17] Surface runoff is low from undisturbed areas except on the steepest slopes.[18] Other notable characteristics of Hawaiian soils include the ability of the soils to adsorb nitrate due to their unusual positive charge at low pH, and the ability to adsorb viruses.[19]

Water capacity is an estimate of the capacity of soils to hold water available for use by plants. North Shore has a high water capacity due to the dominating fine textured soils, also referred to as clay soils.[20] Clay soils have a higher water capacity than sandy soils. Pesticides move at a slower rate through finer textured soils containing more clay, and may be more likely to cling to these soils.

Susceptibility to wind erosion is low in clay soils, and susceptibility to water erosion is also low if the soil is aggregated with strong structure. Under proper soil moisture conditions, breaking up clods of soil with poor or weak structure will increase the surface area and facilitate aggregation. However, multiple tilling passes can cause soils to compact, resulting in the formation of a “plow pan” and platy structure. With decreased rates of infiltration, issues of surface runoff and soil erosion may arise.[21]

When the steeper areas throughout the North Shore are cleared and tilled, erosion becomes a significant concern. Historically, these steeper areas were used for plantation agriculture, both sugarcane and pineapple. Significant areas of former plantation lands on steep slopes have been removed from intensive agricultural production and, if used, are mainly dedicated to pasture. Pineapple cultivation continues in the Wahiawā area on more gently sloped lands. Cultivation of seed corn and other diverse crops including coffee is also expanding in these areas.[18]

For the large gently sloping agricultural lands including Kawailoa, Waialua and Mokulēʻia, water erosion is of less concern except for small localized areas on steeper slopes. Wind erosion can be a concern in certain areas, especially those lands close to the ocean which are subject to strong trade winds. These soils generally have moderate to low permeability. Surface runoff, ponding and occasional flooding can be a concern in some areas. Historically these areas were used for sugarcane as well as small areas of diversified vegetable crops. They now support a wide variety of annual and perennial crops including vegetables and flowers. Because of the predominance of shrink-swell clays, some of these soils become very sticky and difficult to manage when wet and form large cracks when dry.[18]

Both Haleʻiwa and Waialua are located in the lower watershed areas and affected by the accumulation of loosened soil from the upper elevations. This sedimentation can lead to clogged streams, an increased likelihood of flooding, and reduced downstream water quality.[22]

2.3.5 Regional Hydrology

The principle source of ground water recharge on O'ahu is rainfall. Fresh water, which percolates down through the ground into the saturated zone, does not mix well with the denser salt water present in the subsurface environment. This results in a lens-shaped fresh water body that rises where recharge occurs and thins where the fresh water discharges to the ocean.[23] A brackish water transition zone exists between the freshwater lens and the underlying saltwater. [24]

Three types of ground water systems have been identified in central O'ahu: (1) the Schofield High-level Water Body, (2) basal ground water, and (3) dike-impounded ground water. The Central O'ahu Schofield High-level Water Body is located beneath the Schofield Plateau. This water body is bound to the east and west by dike-impounded ground water (*Figure 2.5*) and to the north and south by basal ground water. The general hydrology of the island of O'ahu is described in *Appendix D – Overview of O'ahu Hydrogeology.*

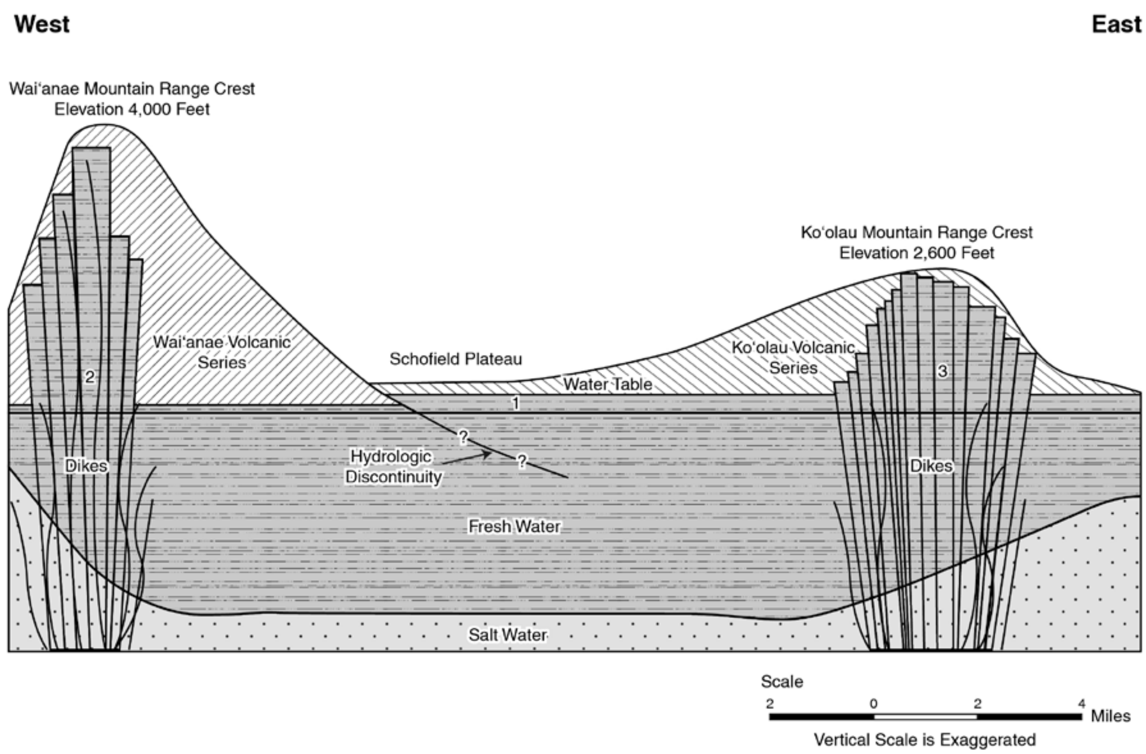


Figure 2.5 Cross Section of Central O'ahu
(Source: Public Health Assessment Schofield Barracks Wahiawā, Honolulu, County, Hawai'i. 2010)

The drainage divide of the Schofield Plateau runs roughly east-west. North of this divide, watercourses flow to the north and discharge into Kaiaka Bay at Haleʻiwa *(Figure 2.6)*. South of this divide, watercourses flow south and discharge into the West Loch of Pearl Harbor.[25] Ground water contamination that occurs mauka will move towards lower areas along the direction of ground water movement.

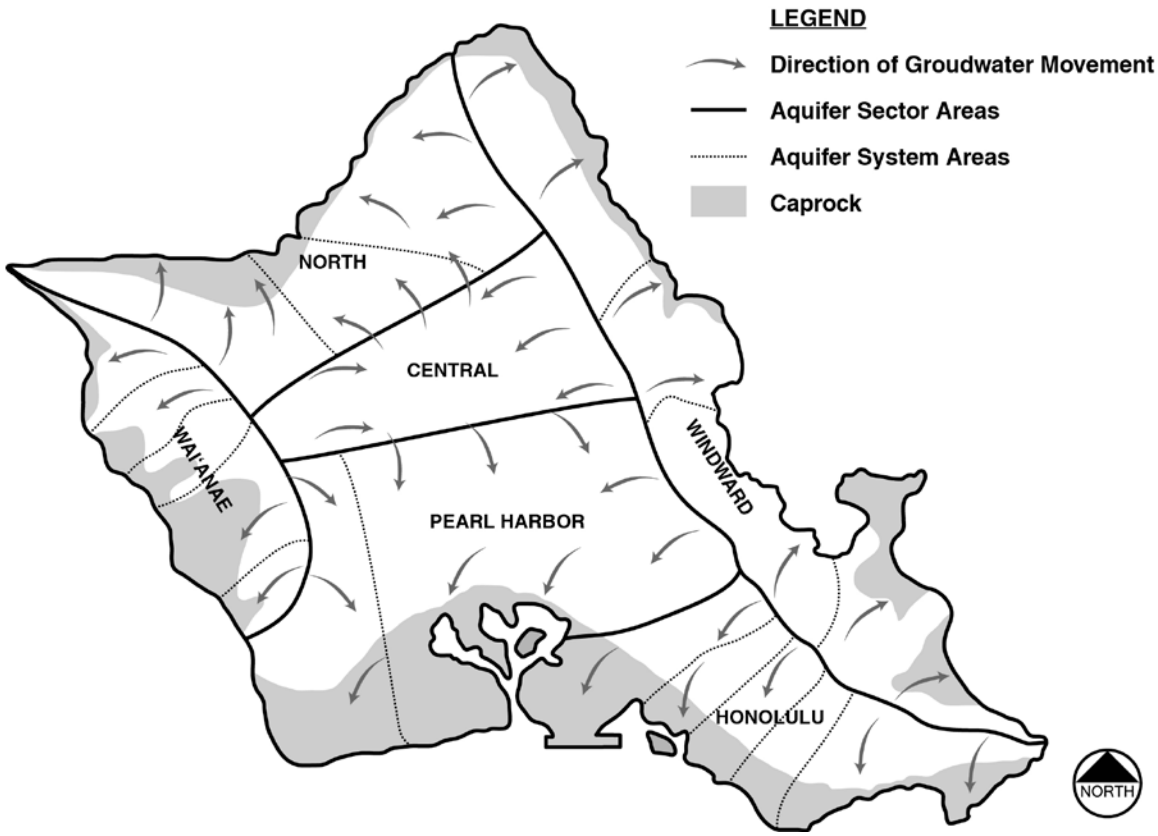


Figure 2.6 Ground Water Movement on Oʻahu

In the freshwater lens system along the coast, water is confined in the underlying aquifers by coastal-plain deposits known as caprock. Caprock borders the island along the coastal areas. In the North Aquifer Sector, the freshwater lens can range from more than 20 feet above sea level near Mokulēʻia, where the caprock is thick, to less than three feet above sea level near Haleʻiwa where the caprock is thin.

Discharge of the ground water occurs through springs and outflows to the ocean, and withdrawals from wells and shafts. Numerous springs can be found throughout the North Shore district near sea level.[26]

2.3.6 Ground Water

2.3.6.1 Ground Water Quantity

In North Shore, approximately 43% of precipitation ends up as ground water recharge, approximately 42% as evapotranspiration, and the remaining 15% as runoff. In addition to rainfall, fog drip and irrigation water also contributes to ground water recharge.[15] Recharge also occurs from adjacent dike-impounded water areas and from the Central Oʻahu Schofield High-level Water Body (*Figure 2.5*).

Ground water withdrawals from the freshwater lens through wells and shafts were computed for the ground water areas on Oʻahu from 1901 to 1980. Since 1940, withdrawals in the North Aquifer Sector area ranged from 20 to 60 million gallons per day and decreased in the 1990's when sugarcane cultivation ceased on the North Shore.[24] With the decrease in ground water use, there may be some thickening of the freshwater lens due to decreased withdrawal. However, recharge rates may also be less, due to the reduction in agricultural return irrigation, as a result of the transition from extensive, high-water use sugar cultivation to lower-water use diversified agriculture and biofuel crops.

The *State of Hawaiʻi Water Resource Protection Plan (WRPP)* divided the island of Oʻahu into six Aquifer Sector Areas (ASEA): Honolulu, Pearl Harbor, Waiʻanae, North, Central, and Windward. These sectors reflect broad hydrogeological similarities while maintaining hydrographic, topographic, and historical boundaries where possible. Aquifer System Areas (ASYA) are areas within an ASEA that exhibit ground water hydraulic continuity. The North Shore district overlays four aquifer systems: the Mokulēʻia, Waialua, and Kawailoa ASYAs of the North Aquifer Sector Area, and a portion of the Wahiawā ASYA in the Central Aquifer Sector Area. Mokulēʻia, Waialua, and Kawailoa are predominantly basal ground water, and Wahiawā is high-level ground water.

The Central Aquifer Sector (Wahiawa Aquifer System) is separate from the Pearl Harbor and North Aquifer Sectors because the water is high-level rather than basal. The existing pumping withdrawal from the system, which totaled 23 mgd, was set as the sustainable yield to maintain spillover of ground water into the Pearl Harbor and North Sectors, thus ensuring sufficient ground water availability in these Sectors to meet demand. The spillover was variably redistributed between the Pearl Harbor and North Aquifer Sectors based on the best available hydrogeologic information. Sustainable yield is *"the maximum rate at which water may be withdrawn from a water source without impairing the utility or quality of the water source".*[27] The sustainable yield of each ASYA is reported in *Table 2.2*.

Table 2.2 Aquifer System Areas in North Shore

Aquifer System Area	Sustainable Yield (mgd)
Mokulēʻia	8 mgd
Waialua	25 mgd
Kawailoa	29 mgd
Wahiawā*	23 mgd

* The Wahiawā ASA underlies both the North and Central Districts.

2.3.6.2 Ground Water Quality

Ground water quality is a special resource concern on O'ahu because nearly all drinking water comes from ground water sources. BWS, the State Department of Health (DOH), and the Federal Environmental Protection Agency (EPA) operate several monitoring and treatment programs to safeguard drinking water sources from contamination. *Table 2.3* contains information on some of the programs and their related findings in North Shore.

North Shore ground water quality is generally considered high, although agricultural and military activities have contaminated certain aquifers with pesticides, herbicides and solvents. BWS and the Army filter ground water to remove these contaminants in order to meet safe drinking water standards. The *BWS 2011 Consumer Confidence Report* found that the ground water provided to North Shore meets the Federal and State drinking water standards. This report is based on BWS and DOH regular monitoring of drinking water sources for traces of more than a 100 different types of natural and human-induced contaminants. Monitoring of certain types of contaminants such as coliform bacteria and trihalomethanes is conducted throughout the distribution system. Contaminants that may enter drinking water as a result of water flowing through the water delivery system, such as lead and copper, are tested both at the source and also at the consumer's tap.[28]

Known Issues

Seven Dole wells used for drinking water or irrigation supply have shown detectable levels of one or more chemical contaminants commonly found in solvents or pesticides, including trichloroethylene (TCE), 1,2,3-trichloropropane (TCP), 1,2-dibromo-3-chloro-propane (DBCP), atrazine, desethyl atrazine and lindane.

TCE is a solvent, used in military, urban and industrial areas.[29] TCP and DBCP are fumigants that were used to eliminate nematodes that attack pineapple roots, although their use has been discontinued since 1977. Atrazine and desethyl atrazine are widely used herbicides, however it has led several researchers to call for its ban because of its endocrine disruptor effects, possible carcinogenic effect, and epidemiological connection to low sperm levels in men.[30] Lindane was used as an insecticide, but was phased out of agricultural use by the EPA in 2007 due to concerns over its effects on human health and the environment.[31]

Four BWS wells used for drinking water have shown detectable levels of TCE, TCP, and DBCP. All reported levels are well below federal or state drinking water standards, and appropriate public health protection measures are implemented in those cases where water is used for human consumption.[18] BWS treats TCP and DBCP using granular activated carbon (GAC). About 60,000 lbs. of GAC will treat 1 mgd of pumped ground water. Carbon costs and management are a significant cost BWS incurs to provide safe drinking water to North Shore.

Fertilizers have been applied widely for agriculture in O'ahu dating back to 1900 or earlier. Concentrations higher than the natural soil background are anthropogenic, resulting from over a century of agricultural fertilizer application. Elevated concentrations of nitrate and phosphorus are highest in, and downgradient from, present and former agricultural lands. Nitrate is below drinking-water limits at all wells, with the maximum nitrate concentration of 5.24 mg/L - about half the EPA drinking water maximum concentration level of 10 mg/L.

Table 2.3 Ground Water Quality Protection Programs

Program (Agency)	Program overview	Program Activities in North Shore
Hazard Evaluation and Emergency Response – HEER (State DOH)	Compiles records of released hazardous substance at sites throughout the State.	Responses in FY 2009 were due to: soil contamination from oil, drum dumping, and alleged taro farm contamination from flood.
Ground Water Contamination Maps – GWCMs (State DOH)	Identify locations where organic and non-organic contaminants have been detected and confirmed in drinking water wells, select nonpotable wells, and fresh water springs throughout the State	1983 – 1985, 1993, 1997: Waialua Sugar (various) Irrigation Wells – DBCP & TCP 1987, 1982: Haleʻiwa Battery Irrigation Wells – Lindane and Atrazine 1992: Waialua Battery Drinking Water Wells – Atrazine and Desethyl Atrazine 2004: Haleʻiwa Drinking Water Wells – DBCP, TCE, & TCP 2005: Waialua Drinking Water Wells – TCE & TCP
Hawaiʻi Source Water Protection Program – HISWAP (State DOH)	Identifies potential contaminating activities of drinking water sources in Hawaiʻi.	Susceptibility analysis and delineation of wellhead protection areas.
Oʻahu Inactive Landfills Relative Risk Evaluation (BWS)	Evaluation of inactive landfill sites (mostly established prior to State and Federal waste laws).	Ten inactive landfills: 1 former military, 2 former municipal and 7 former agricultural landfills.
Underground injection control – UIC (State DOH)	The UIC line was established in HAR Chapter 23 to regulate injection wells (well defined as deeper than width) used for disposal. The UIC line was drawn at the 10,000 ppm chloride contour.	See *Figure 2.7*
Pass/No Pass Line (BWS)	Established in BWS Rules and Regulations Chapter III, Sec. 3-301, having the effect of ordinance. The line was determined from soil borings as areas of thick caprock overlying basal aquifers. Protects drinking water sources from contamination by ground disposal of wastewater, landfills, wastewater treatment plants, etc.	Through a 1988 inter-agency agreement, DOH regulates ground disposal of wastewater in consultation with BWS. See *Figure 2.7*

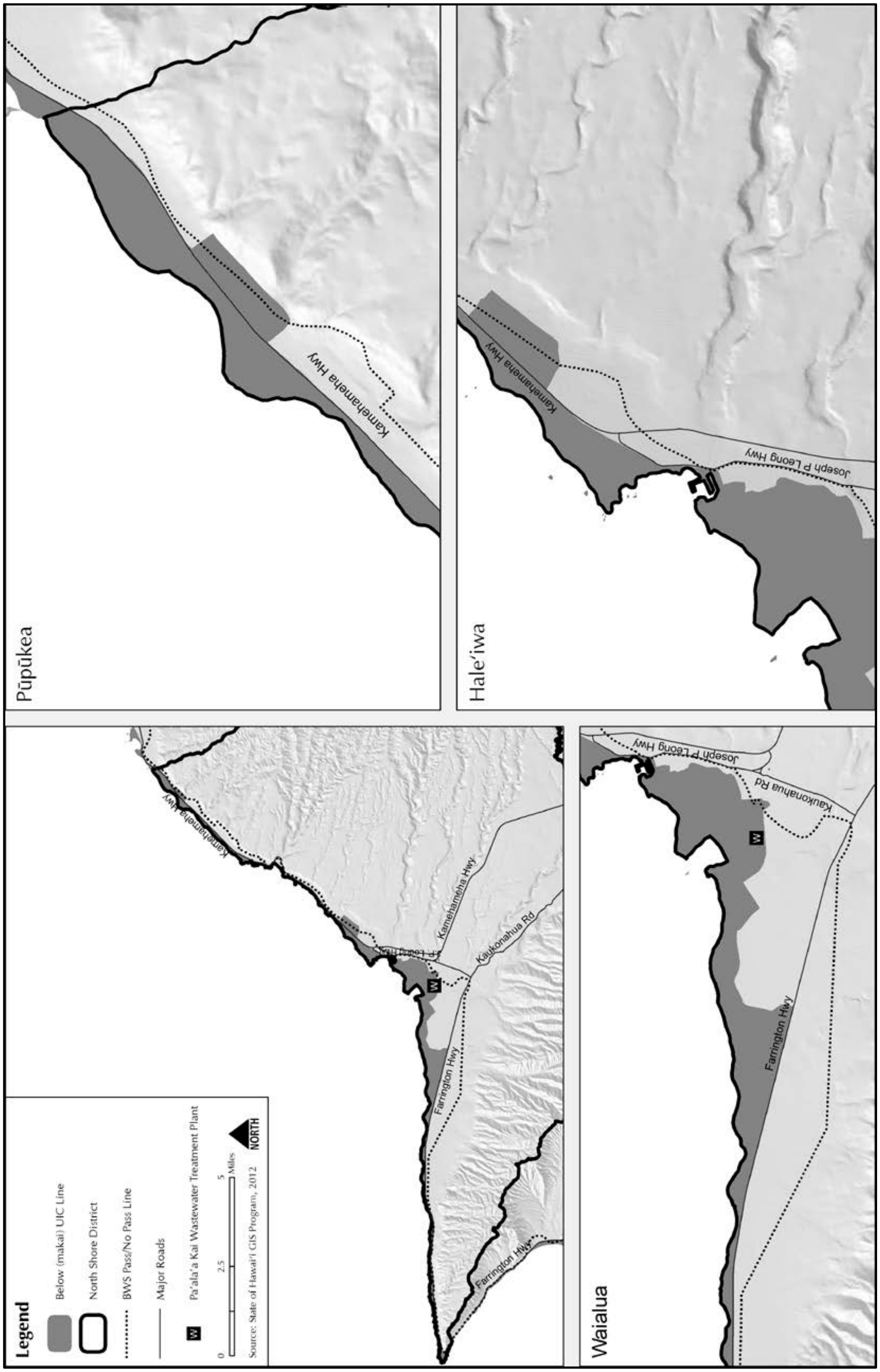


Figure 2.7 North Shore Pass/No Pass and UIC Lines

However, many orthophosphate concentrations were greater than the EPA recommended goal of 0.1 mg/L for avoiding nuisance plant growth (eutrophication) in moving waters. Ground water can discharge into streams. Nutrient concentrations were found to be higher in stream base flow than in storm flow by USGS National Water-Quality Assessment surface water studies, and the higher concentrations were attributed to discharge of nutrient-laden ground water. The organic compounds atrazine and desethyl atrazine also were higher in base flow than in storm flow, raising concerns about possible effects of organic compounds on aquatic organisms.[32] Discharging ground water also carries nutrients and chemicals into estuaries and nearshore marine waters. Nutrients are a particular concern with respect to coral reefs. The coral-reef ecosystem is highly nutrient-sensitive and can be degraded where excess nutrients promote excessive algal growth that displaces or interferes with the growth of healthy corals.[32]

Potential Issues

Ground water also has the potential for contamination from cesspools. The majority of the region handles its wastewater through the use of cesspools that may be more than 50 years old.[33] A study done by Parametrix, Inc. in 1992 estimated there were 3,152 cesspools in the North Shore, with about 40% of those in failing condition. Cesspools do not provide much, if any, treatment of wastewater prior to it flowing into the surrounding ground, and require pumping twice a year or more. Homes that discharge all wastewater directly into cesspools may experience cesspool failure as a result of overloading or clogging. Some homes have upgraded to septic tank/leach field systems.[34] Septic tank systems and cesspools are examples of Individual Wastewater Systems (IWS), or facilities which are used and designed to receive and dispose of no more than one thousand gallons per day of domestic wastewater. DOH prohibits an IWS within 1,000 feet of a potable drinking water well serving public water systems.

Contaminants typically found in wastewater can migrate to the ground water where they can find their way to streams and near shore waters, posing potential health risks to terrestrial and aquatic environments, and human populations as well. During flooding events in the past, cesspools have backed up after three feet of water covered the low-lying areas of Otake Camp,[35] and Hale'iwa Elementary was shut down when rainwater flooded a nearby cesspool.[36] Environmental sampling and analysis data on soil and water in the North Shore region are very scarce, especially for identifying indicators of wastewater contamination. Aside from DOH nearshore marine water quality monitoring and sampling conducted by the UH CTAHR in 2007 in Ki'iki'i and Paukauila streams, no studies have been conducted to date to evaluate the presence and impacts of sewage contamination in the ground water and streams around Waialua and Hale'iwa Towns.[2]

In 2000, EPA banned large-capacity cesspools. DOH also banned the construction of new cesspools on O'ahu. In 2005, EPA regulations required all existing large capacity cesspools to be closed and replaced with an alternative wastewater system. Over the last few years, DOH has been slowly requiring upgrades for individual cesspools to individual wastewater treatment systems during home renovations in an effort to eventually eliminate all cesspools.[1] However, there are concerns that even septic systems will not adequately treat the water before release, as the soil in the Waialua and Hale'iwa area are not suitable for leaching effluent from the septic systems.[37]

The *North Shore Regional Wastewater Alternatives Plan* (2011) provides recommendations for ways to improve wastewater effluent in the North Shore area with possible reuse. With water reuse gaining popularity, people increasingly consider gray water from their residences as a resource to be separated from the wastewater stream and reused in their landscapes. Such reuse of gray water reduces the amount of wastewater entering sewers or IWSs, reduces demands to use potable water, and helps preserve limited water supplies.[38]

The BWS undertook a study in 2005 to assess if recycled water can be safely used on Hawaiian soils above potable aquifers. The results found that soils in Central O'ahu have sufficient retention times and soil carbon for complex organics such as N-nitrosodimethylamine (NDMA) and hormones to be filtered from the percolate prior to reaching ground water. Soil column studies indicate that antipyrine (used for ear infections) adsorbed little to the soil. In contrast, caffeine was found to initially adsorb to the soil, which was followed by degradation of the caffeine within 4 days by native microorganisms. Alkalinity, bicarbonate alkalinity, sulfate, nitrate-N, potassium and total organic carbon show significant differences in the applied water but not in the percolate water. Drawing from these finding, these constituents are effectively removed from the water by passing through the soil matrix. Therefore, the practice of recycled water irrigation in Central O'ahu is not of concern with respect to the contribution of these constituents to the potable water aquifer. The predominant source of selected metals (i.e., barium, iron, manganese, and nickel) measured in the percolate water may have been from the soil rather than irrigation water due to mobilization of the metals in the soil.[39] The final report found that the application of recycled water over the potable aquifer could be allowed, with the understanding that DOH reuse guidelines limit application rates below the consumptive evapotranspiration of the vegetative cover.[40]

The *O'ahu Inactive Landfills Relative Risk Evaluation* (2006) shows that there are ten old unlined dumps in the North Shore, which are a potential source for ground water degradation. These sites include two municipal landfills (Kawailoa (capped) and Waialua), seven agricultural landfills (California Packing Company Dump 1 and Hawaiian Pineapple Dumps 1, 3, 4, 5, 6 and 7), and one military landfill (Pūpūkea). Eight of these former landfills are located mauka of the DOH's Underground Injection Control (UIC) line. Hawaiian Pineapple Dump 3 lies within the 2-year and 10-year pumping period capture zones of two BWS Waialua wells, where the maximum concentration levels of TCE were exceeded. These wells are filtered with granular activated carbon. None of these landfills are within one mile of a drinking water well nor mauka of the No-Pass Line. The Inactive Landfill study conclusion found no indication that these former landfill sites are a threat to human health.

Two new potential landfill sites in upland Pūpūkea were recently ranked third and fourth out of 11 sites by a City Advisory Committee on Landfill Site Selection in 2012.[41] The potential Pūpūkea landfill locations are situated above Waimea Bay, a Marine Life Conservation District. Concerns were raised by residents of polluted runoff going into Waimea Bay, and increased traffic from dump trucks on an already congested Kamehameha Highway.[42] These two proposed sites are mauka of the DOH UIC line and the BWS No Pass line, but there are no drinking water wells in the vicinity or downgradient.

2.3.7 Surface Water

2.3.7.1 Streams

The *Hawai'i Stream Assessment* (HSA, 1990) lists six perennial streams in the North Shore district: Makaleha, Ki'iki'i, Paukauila, Anahulu, Loko Ea, and Waimea (*Figure 2.8*). The Hawai'i Watershed Atlas (2008) also considers Kawaihāpai and Pahole as perennial streams.[43] Three of these perennial streams, Anahulu, Paukauila, and Ki'iki'i, are "stream systems," i.e. streams with two or more major tributaries that extend from different valleys and converge on a coastal plain.

- The Anahulu System consists of Kawai'iki, Kawailoa, Kawainui and Anahulu Streams draining into Waialua Bay.
- The Paukauila System consists of 'Ōpae'ula, Helemano and Paukauila Streams draining into Kaiaka Bay.
- The Ki'iki'i System consists of Poamoho, the North and South Forks of Kaukonahua, and Ki'iki'i streams, also draining into Kaiaka Bay.

Several of the streams within the watershed are perennial in their upper reaches but intermittent in their lower reaches. This is primarily due to surface water diversions for agricultural use. The upper and middle reaches of each of the three stream systems have moderate slopes. The lower reaches traverse a low-lying and relatively flat coastal plain in the vicinity of Waialua and Hale'iwa towns, where stream flows slow down and become tidally influenced. Flooding in the lower reaches of the three stream systems occurs frequently due to heavy rainfall or high surf.[2]

Makaleha Stream and Ki'iki'i Stream are candidates for stream protection and meet blue ribbon criteria, according to the HSA. Blue ribbon resources stand out among the best in the resource area. The resource areas include Aquatic, Riparian, Cultural, and Recreational. Makaleha met a score of seven out of a possible ten for Riparian resources. The criteria for Riparian blue ribbon resources include threatened and endangered birds, water bird recovery habitat, rare plants and communities, protected areas, wetlands and native forest. Ki'iki'i is one of the statewide outstanding streams for Recreation. Recreational blue ribbon resources include camping, fishing, boating, nature study areas, parks, hiking, swimming, and scenic views. Recreational Resources are considered to be of statewide importance.[44]

The *Multi-Attribute Prioritization of Streams* (1998) lists potential heritage streams that were identified using the criteria set forth in the State's proposed Stream Protection and Management (SPAM) System rules, and exhibit *"high natural quality or that possess significant scenic value"* appropriate for preservation and protection. Waimea is listed as a Potential Heritage Stream; however, the SPAM rules were never adopted by CWRM. The proposed SPAM rules called for the establishment of a stream protection and management system providing for the adoption and management of heritage streams to protect biological resources of entire stream systems, including all tributaries.

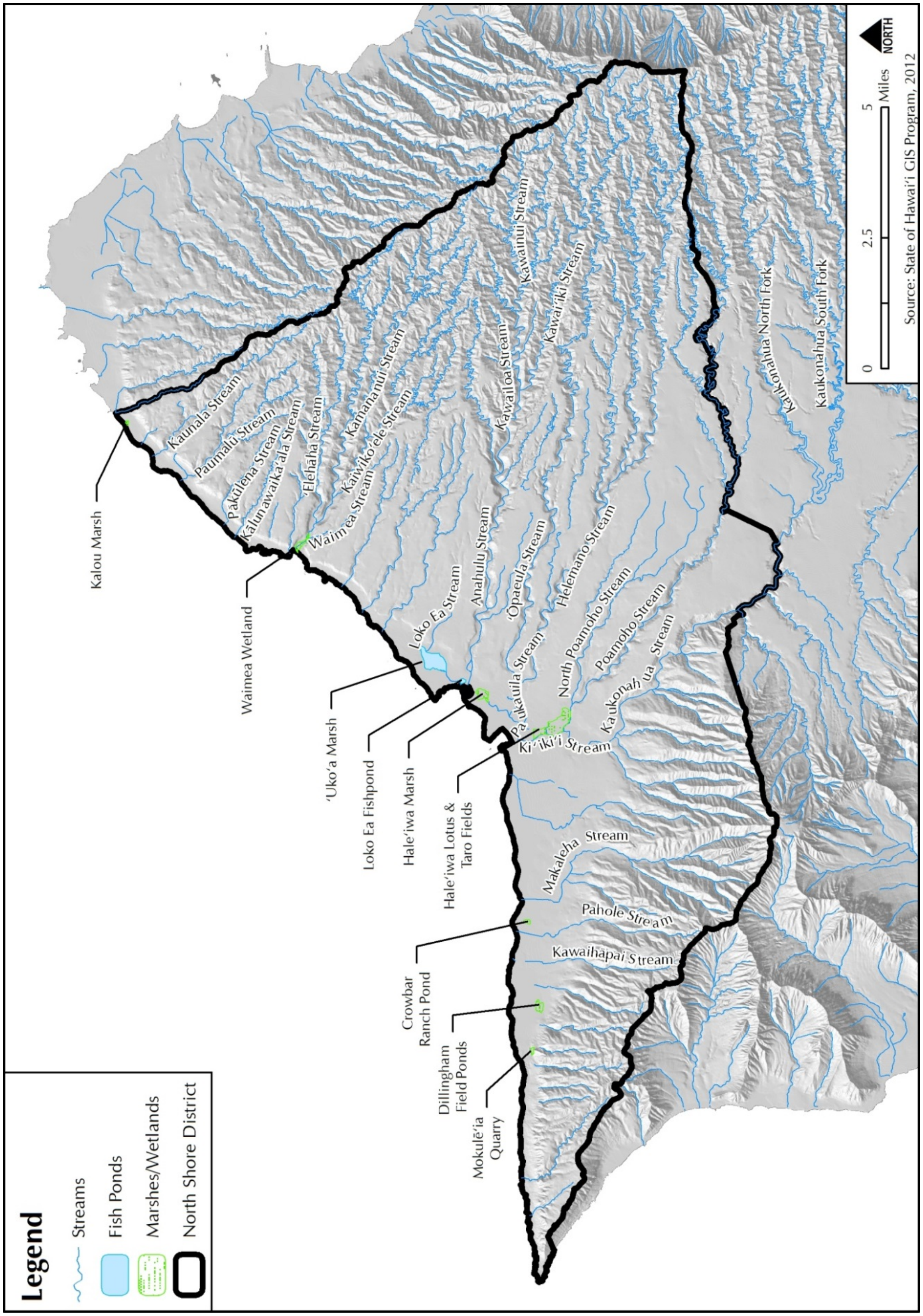


Figure 2.8 Streams, Wetlands and Fishponds of the North Shore District

In addition to these streams, the *North Shore Sustainable Communities Plan* (2011) mentions Kaiwikoʻele, Kamananui, ʻElehāhā, Kālunawaikaʻala, Pākūlena, Kaunala, and Paumalū as major streams in the North Shore. According to local knowledge, at one time there was a Polipoli stream in Mokulēʻia, but it had been filled due to Dillingham Airfield construction. Other streams were diverted around the airfield.

As part of the update of the WRPP, CWRM identified the need for a standardized coding system to delineate and codify Hawaiʻi's surface-water resources. The 2005 CWRM Surface-Water Hydrologic Units coding system is an important first step towards improving the organization and management of surface-water information that CWRM collects and maintains, by providing a practical approach to managing surface water information and allowing additional efforts to easily build upon or refer to this system. Through this effort, CWRM staff will be able to better coordinate and improve surface water data collection and utilization between agencies and stakeholders, leading to better statewide resource management measures. *Figure 2.9* delineates the CWRM hydrologic units and their codes for North Shore.

2.3.7.2 Stream Flow

Rainfall, runoff, and ground water seepage contribute to the flow of streams. Rain water may fall directly into the streams. Runoff may enter streams within minutes to days from the original rainfall event. Ground water seepage into streams may take months or even decades from the original rainfall event.

As part of the instream use protection program required by the State Water Code, CWRM is charged with establishing *"instream flow standards on a stream-by-stream basis whenever necessary to protect the public interest in waters of the State."* IFS are similar to sustainable yields for ground water, in that their establishment provides a management system that protects instream and cultural uses while allowing for possible non-instream water use. The Water Code defines instream flow standards as *"the quantity or 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."* These instream flow standards need to consider the best available information in assessing the range of present or potential instream and non-instream uses.

To date, measurable Interim IFS (IIFS) have been established for all or portions of 34 streams in Hawaiʻi. There are no streams with measurable IIFS on the North Shore. For other streams without measurable IIFS, CWRM adopted a "status quo" policy. IIFS were established based upon the amount of water flowing in each stream at the time the administrative rules governing the IFS designation were adopted in 1988 and 1989. Future diversions of stream water cannot be made without first amending the IIFS and obtaining a diversion permit from the CWRM.

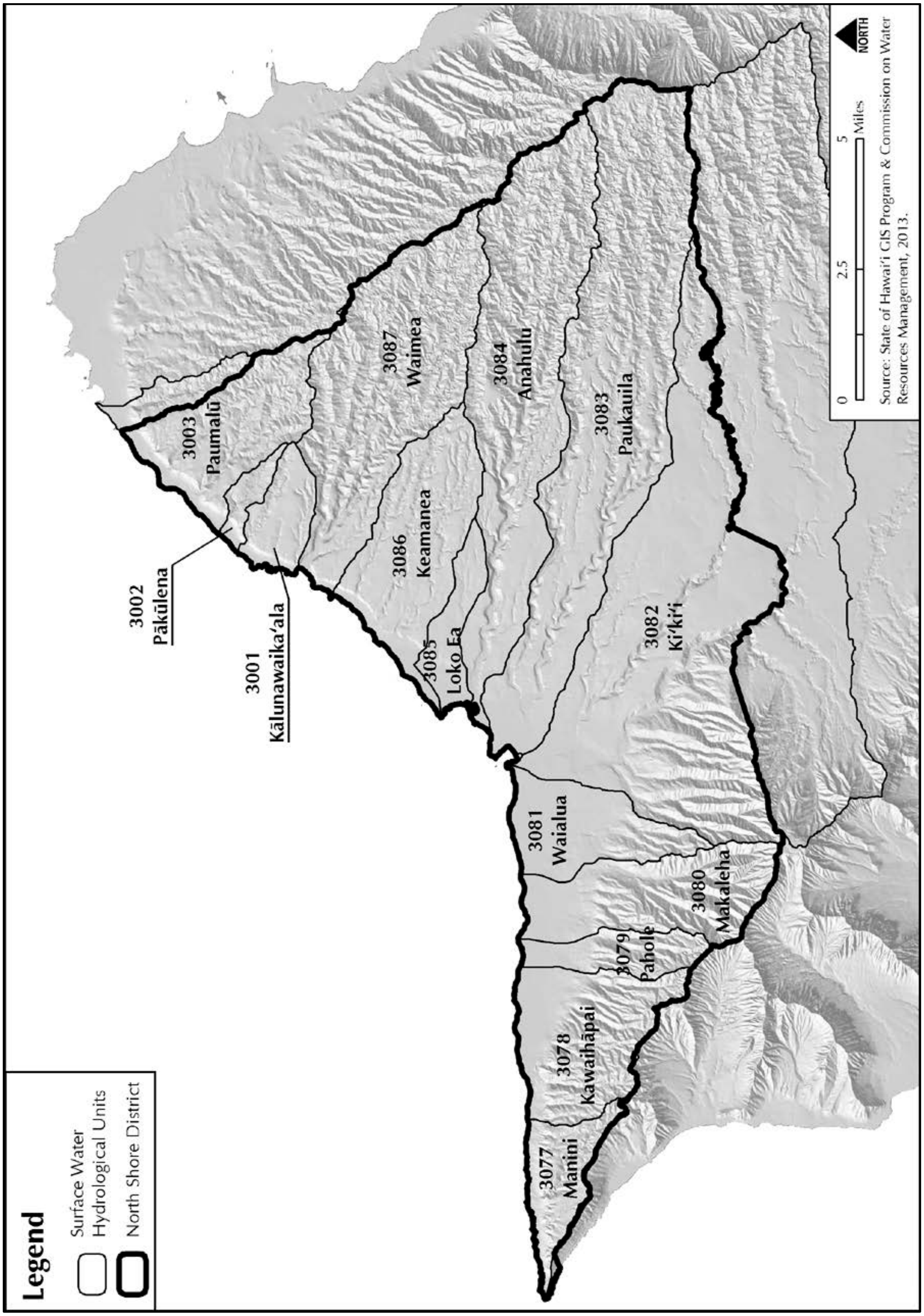


Figure 2.9 CWRM Surface Water Hydrologic Units

In Hawaiʻi, at least two types of stream flow are calculated for surface water resources planning purposes:

- **Average flow** is determined by dividing the sum of all stream flow measurements for a particular stream by the number of stream flow measurements taken.
- **Median flow** is the rate of discharge of a stream for which there are equal numbers of greater and lesser flow occurrences. In Hawaiʻi, due to the flashy characteristics of streams, especially during storm events, measurement of stream flows often times produces very large peak flows. These large peak flows may affect the calculation of the stream average flow, making it a less accurate measure of "normal" times.

Table 2.4 contains flow information for those streams with gaging stations in the North Shore district. When a stream has more than one gaging station, the largest average and median flows were used.

Table 2.4 North Shore Stream Flow

Stream Name	2010 Annual Median (cfs) / (mgd)	Median Flow (cfs) / (mgd)	Avg. Daily Flow (cfs) / (mgd)	Data Years
North Kaukonahua	6.3 / 4.1	7.7 / 5.0	16.3 / 10.5	1913-1990
South Kaukonahua	4.3 / 2.8	8.8 / 5.7	21.2 / 13.7	1957-1990
ʻŌpaeʻula	2.9 / 1.9	4.3 / 2.8	13.5 / 8.7	1959-1990
Kamananui	1.2 / 0.8	3.7 / 2.4	16.9 / 10.9	1960-1990
Kiʻikiʻi System	Not available	14.9 / 9.6	32.0 / 20.7	calculated based on multiple stream gages
Paukauila	Not available	4.5 / 2.9	24.3 / 15.7	calculated based on multiple stream gages
Waimea River	Not available	3.7 / 2.4	16.9 / 10.9	calculated based on multiple stream gages
Helemano	Not available	0.2 / 0.1	10.8 / 7.0	1967-1982

Source: 2010 Annual Median from USGS and all other from Hawaiʻi Stream Assessment: A Preliminary Appraisal of Hawaiʻi's Stream Resources Report R84. 1990

Information on a stream's base flow is also important. Base flow is the portion of stream flow that originates from ground water. It is therefore the amount of flow in streams during prolonged dry periods, when there are negligible contributions from rainfall and runoff.[45] A USGS stream survey study in 2004[46] found that downward trends in the median and lower total flows are consistent with the trends of decreased base flows over time. This corresponds to long-term decreases in rainfall, and is likely due to decreases in concurrent ground water storage and recharge.

The United States Geological Survey (USGS) operates and maintains most of the stream gaging stations in Hawai'i. There are currently four operating streamflow gages – three on Kaukonahua and one on Kamananui. At its peak, there were eight operating stream gages in North Shore between 1967 and 1971. Thus, in many instances, there are no data available for streams in North Shore.

2.3.7.3 Stream Modifications

Stream modifications are manmade alterations to natural stream channels and/or stream flow. Common stream modifications in the North Shore district are dam or reservoir construction and stream water diversion. Reservoirs and stream diversions may impact the water movement, morphology, and ecosystem of a stream. A stream diversion is defined in the State Water Code as *"the act of removing water from a stream into a channel, pipeline, or other conduit."*

In the North Shore, stream diversions provide agricultural water for both modern and traditional agricultural operations. Stream diversions from different eras in Hawai'i's history can still be found throughout the North Shore district. In ahupua'a such as Waimea and Anahulu, water has been diverted from the streams for many generations primarily for wetland kalo cultivation and inland fishponds. During the 19th century, Waialua Agricultural Company constructed extensive networks of irrigation ditches diverting ground and surface water over many miles. Agricultural reservoirs were also constructed over time to store water and increase its pressure before distribution to agricultural lands. The agricultural reservoirs may also function as flood control reservoirs.

2.3.7.4 Surface Water Quality

The Federal Clean Water Act (CWA) of 1972 establishes a regulatory framework for the nation's surface water quality protection. The CWA calls for a bi-annual surface water quality assessment in each state. Those surface water bodies found to be in violation of State standards must be reported pursuant to §303(d) of the CWA. The list of impaired water bodies is referred to as the 303(d) list, and contains information on the types of pollutants that are impairing the water quality of a stream. The 303(d) list also makes an assessment on the severity of the impairment and identifies priorities for Total Maximum Daily Load (TMDL) studies.

A TMDL identifies in much greater detail the causes of pollution and calculates the maximum daily amount of pollutant load that can enter water bodies without violating water quality standards. TMDL calculations are performed for both point and non-point source pollutants. Point source pollutants originate from identifiable sources such as industrial discharges, sewage treatment plants or municipal storm water drainages. Non-point source pollutants originate from many sources such as soil sediments, fertilizers, and insecticides that are carried by rainfall and move over and through the land. The calculated maximum pollutant loads are then divided and assigned among the identified sources of pollution.

For the 303(d) list, the State DOH assesses several types of water quality parameters including nutrients, turbidity, total suspended solids (TSS), bacteria, heavy metals, pesticides, herbicides and other potentially harmful substances. While there are many variations in terms of the sources of water quality degradation in streams, excess pollutants in North Shore streams mostly consist of nutrients and turbidity. The following is a brief overview of these two major sources of pollution.

- **Nutrients** in a water quality context refers specifically to nitrogen and phosphorous, two essential substances for the growth of aquatic biota. At an elevated level, nutrients cause accelerated growth of phytoplankton that leads to an increase in turbidity.
- **Turbidity** refers to the cloudiness of water. High levels of turbidity are considered unfavorable in a stream because it hampers sunlight from reaching the bottom of the stream, which in turn inhibits the growth of aquatic biota.

Table 2.5 lists the North Shore streams that were on the 2008/2010 303(d) list of impaired water bodies submitted by the State DOH to the EPA. DOH prioritization for TMDL studies is based on the severity of pollution in a stream, designated uses of water for that stream, and degree of public interest, among other factors. Those streams and water bodies that drain large watersheds and flow into the central Waialua and Kaiaka Bays are on the 303(d) list, while the peripheral Waimea, Loko Ea, Makaleha, Pahole and Kawaihāpai Streams are not. Although the North and South Forks of Kaukonahua and Wahiawā Reservoir are not physically within the North Shore district, they feed the Wahiawā Reservoir that brings irrigation water throughout the North Shore, or feed (lower) Kaukonahua Stream, and are therefore listed in *Table 2.5*. Some previously listed stream systems were updated as estuaries, or inland brackish water bodies. For the North Shore, this includes Kiʻikiʻi, Paukauila, and Anahulu. Anahulu Stream was listed as a medium TMDL priority on the 2004 303(d) list, but was downgraded to a low priority in 2006, and reduced from the whole stream to the estuary portion. Kawailoa Stream, previously listed at No Priority in the 2006 303(d) list, is now a Low Priority in the 2008/2010 303(d) list.

Table 2.5 North Shore Streams on the 2008/2010 303(d) List

District	Stream	TMDL Priority	Pollutant in Excess
North	Kawailoa	Low	Nutrients, Turbidity
North	Anahulu*	Low	Nutrients, Turbidity
North	ʻŌpaeʻula	Low	Nutrients, Turbidity
North	Helemano	Low	Nutrients, Turbidity
North	Paukauila*	Low	Nutrients, Turbidity
North	Kiʻikiʻi*	Low	Unknown
North	Poamoho	Medium	Nutrients, Turbidity
North	Kaukonahua	Medium	Nutrients, Turbidity
Central	N. Fork Kaukonahua	TMDL approved in 2010	Nutrients, Turbidity
Central	S. Fork Kaukonahua	TMDL approved in 2010	Nutrients, Turbidity
Central	Wahiawā Reservoir	High	Nutrients, Turbidity

* Estuary portion only

Excess pollutants in these streams on the 2008/2010 303(d) list mostly consist of nutrients and turbidity. Where these concentrations are high, they warrant concerns about decreased oxygen in the water, toxicity to fish, and accelerated eutrophication.[47] Nutrient loading may be derived from animal wastes and the use of fertilizers. In forested areas, sediment and particulate nitrogen and phosphorus can come from unstable stream embankments, shallow storm-induced landslides, and altered and denuded landscapes as influenced by vegetative cover and wildlife disturbance.[48]

The NRCS Local Work Group has identified sheet and rill soil erosion as a high priority resource concern.[18] Turbidity is thought to be the result of erosion occurring in mauka conservation lands, stream banks, and agricultural lands.[49] Erosion is also thought to be associated with cane haul roads and dirt bikes. The decrease in agricultural production that has occurred in recent years may be accompanied by reduced levels of maintenance on agricultural roads and ditches, leading to an associated rise in sedimentation and TSS discharges.[18] However, this can be disputed by the fact that unmaintained agricultural roads become overgrown with weeds over time, and would likely reduce sheet runoff from the road surface and reduce erosion-related sedimentation of streams.

Unlined irrigation ditches can result in erosion sediment in the irrigation system, so settling basins and filtration systems are utilized before irrigating fields. Settling basin dredging removes silt, which is then spread on adjacent cultivated fields. Lack of monitoring data throughout the North Shore district currently precludes any reliable estimates of sediment loading originating from agricultural lands as compared to other sources, such as the steep slopes of upland headwaters and lowland gulches.[18]

NRCS has defined three classes to assess the potential for water-induced soil erosion: Class 1 is defined as highly erodible land (HEL), while Classes 2 and 3 signify land which is potentially highly erodible and not highly erodible, respectively. Approximately half of the North Shore watershed is classified as HEL, largely due to the steeply sloping soils of the Koʻolau and Waiʻanae ranges. Farmers who grow agricultural commodities on HEL lands are required to maintain an approved conservation system in order to be eligible for certain USDA benefits and programs. Proposed conservation plans on Class 2 lands (potentially HEL) are required to complete a field check of slope-length and gradient to confirm the soil erosion classification.[16]

A TMDL study for the North and South Forks of Kaukonahua was approved by the EPA in 2010. When implemented, DOH TMDLs for total nitrogen and turbidity for the North and South Forks of Kaukonahua streams will result in the attainment of total nitrogen and turbidity criteria. Achieving these water quality objectives may involve closer identification of sediment source areas (e.g. shallow landslides, eroding stream banks, denuded/disturbed hillslopes), sediment transport pathways (e.g. denuded hillslopes, hardened drainageways), and appropriate repairs (e.g. stabilizing slopes and streambanks, establishing riparian buffers, diverting and detaining surface runoff).[48]

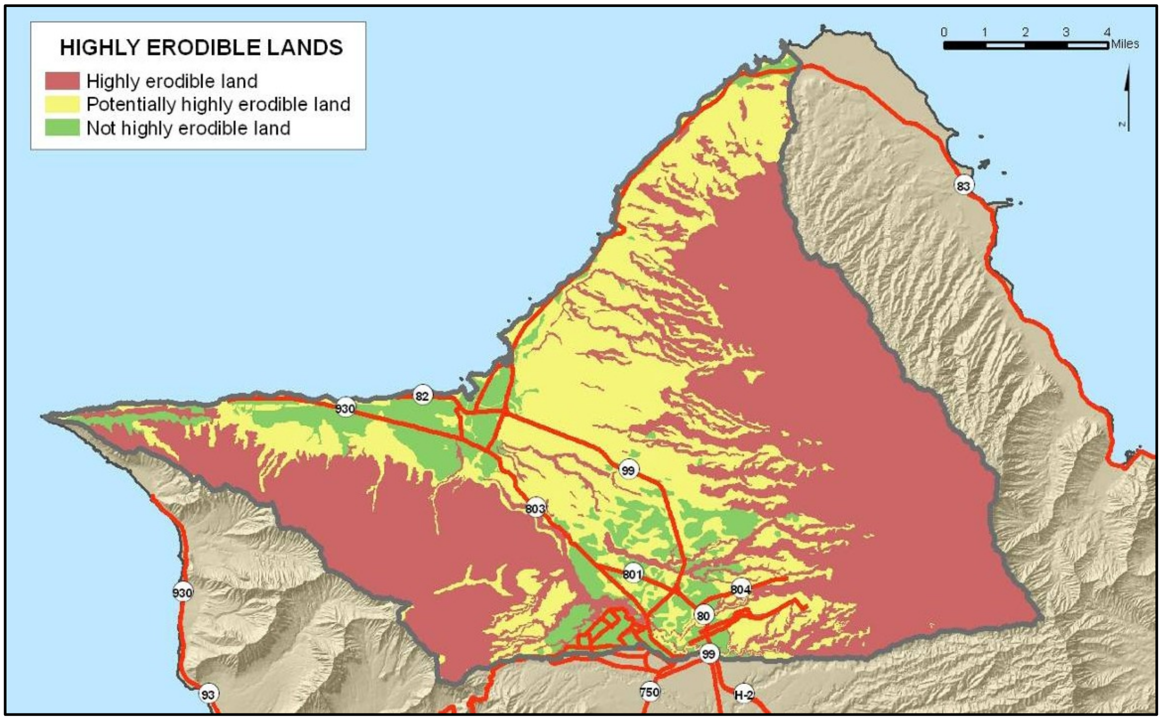


Figure 2.10 Highly Erodible Lands (HEL) of the North Shore (Source: Rapid Watershed Assessment North Shore Watershed, Oʻahu. 2009)

The extent to which this TMDL for the North and South Forks of Kaukonahua will contribute to the attainment of water quality standards downstream (in Wahiawā Reservoir, Lower Kaukonahua Stream, Kiʻikiʻi Estuary, and Kaiaka Bay) largely depends upon the manner in which Wahiawā Reservoir, its other pollutant sources (the Wahiawā WWTP, urban stormwater from municipal drainage systems, and polluted runoff/diffuse pollution from surrounding agricultural, military and urban lands), and the Wahiawā Irrigation System are operated and managed in the future.[48]

Water quality sampling of the Kiʻikiʻi and Paukauila streams in 2007 by the Kaiaka Bay Watershed Team revealed high levels of the toxic pollutants ammonium and nitrite. Inorganic nitrogen may exist in the free state as ammonium, nitrite, or nitrate. Sources of ammonia include releases of ammonia-rich fertilizer, livestock waste, improper disposal of ammonia-containing cleaning products, septic systems, sewage treatment plants, and food processing.[50] DOH does not test for ammonium in streams, only in marine waters. Nitrite, in itself a more toxic substance than nitrate, is tested for with a nitrite/nitrate test. However, because the maximum containment level recognized by the EPA for nitrate is ten times more than that for nitrite, the Kaiaka Bay Watershed Team questions the DOH policy of combining these two compounds into a single standard that is suitable only for nitrate. The high levels of the ammonium and nitrite pollutants reported in Kaiaka Bay Watershed Team's sampling, if confirmed, could be of considerable harm to plants and animals as well as to humans if ingested.[51]

Although various theories exist for the causes of poor water quality, options and actions available for remediation are limited. However, certain precautions can be undertaken, such as limiting additional loading of nutrients into streams by curtailing further sewage discharge, reducing animal water discharge into the North Shore's water systems, and seeking better control of soil erosion on the highly erodible lands of the district.[37]

Numerous studies have been conducted on the water quality of Lake Wilson (Wahiawā Reservoir). The primary water quality concerns are dissolved oxygen, nutrient levels, turbidity, and bacteriological and toxic inputs, which have been associated with algal blooms and fish kills. In the 1960s and 1970s, major fish kills in the lake were a result of little or no dissolved oxygen existing in the reservoir, especially during the summer months when the reservoir water level was low. The demand for irrigation water is greatest during the summer months when drawdown from the reservoir has been known to interfere with the re-oxygenation capacity of the water. Consequently, low dissolved oxygen levels were contributing factors to anoxia of the fishes.[52]

The Wahiawā WWTP has been discharging treated effluent into Lake Wilson since 1927. Between 1986 and 1992 ten fish kills in the immediate vicinity of the Wahiawā WWTP discharge were believed to be caused by toxic substances from the WWTP.[53]

In 2002, heavy rains caused an estimated 9,000 gallons of raw sewage to overflow at the Wahiawā WWTP, spilling into storm drains and Lake Wilson.[36] High nutrient loading of phosphorus and nitrogen in the WWTP effluent and storm water runoff can result in eutrophication or the excessive and undesirable growth of algae. Excessive algal growth can produce low oxygen in the water. High nutrient concentrations in the lake were associated in 2002 and 2003 with the explosive growth of the floating aquatic fern *Salvinia molesta,* which covered approximately 90% of the lake's surface within a few months. The *Salvinia* infestation posed the threat of a massive fish kill and human health concerns, and required intensive mechanical removal.[2]

The Schofield WWTP discharges 2.6 mgd of high quality R-1 water into the Wahiawā Irrigation System (WIS), but due to the discharge of R-2 water into the Wahiawā Reservoir by the Wahiawā WWTP (1.8 mgd), irrigation water from the WIS is considered R-2 quality. The use of R-2 water is limited to irrigating crops such as seed corn, trees and orchard crops (e.g., papaya and coffee), and crops that are processed sufficiently to kill pathogens.[54] Prohibited crops include root crops and those that would expose their edible parts to the water (e.g., vegetables). Vegetable crops on the North Shore are irrigated with ground water or with water from the other ditch systems, whose water does not mix with water from the WIS.[55]

The WWTP currently conducts tertiary treatment of its effluent. The effluent is characterized as R-2 recycled water quality by DOH. Wahiawā WWTP's effluent water quality will improve to R-1 status after the construction of the Membrane BioReactor (MBR) plant.[56] Once the Wahiawā WWTP upgrades their recycled water to R-1 quality, several other conditions will need to be met in order for DOH to consider Wahiawā Reservoir water unregulated. Additional information regarding the Wahiawa and Schofield WWTP's can be found in 3.1.3 Recycled Water Availability and Use.

2.3.7.5 Stream Biotic Resources

The ability of a stream to sustain aquatic life reflects the condition of a stream's chemical and physical characteristics. Therefore, in Hawai'i, the presence or lack of aquatic species in a stream is indicative of a stream's overall health, as introduced non-native aquatic species tend to better tolerate degraded stream conditions. Native aquatic species found in the North Shore district's streams are listed in *Table 2.6*.

Native freshwater species possess several unique characteristics that make them a good indicator of a stream's ecological health. These characteristics include: (1) Native freshwater species that are uniquely adapted to the "flashy" characteristics of Hawai'i's streams and are dependent upon streams with large flow volumes for their reproductive success; (2) Native freshwater species that have an amphidromous (migrating between streams and ocean environments) life cycle. Native aquatic species lay eggs in fresh water; their larvae drift downstream into the ocean and mature; juveniles leave the ocean and return to fresh water environments, swimming upstream to live their adult lives. This life cycle requires an unimpeded connection between the upper reaches of a stream and the ocean; (3) Native freshwater species require well-oxygenated water and are sensitive to a changing environment.

The Atlas of Hawaiian Watersheds (2008) assigns a standardized score from one to ten with one being the lowest and ten being the highest for the biological resources of the streams. The biological resource rating is a combination of the Native Species Rating, Introduced Genera Rating, and All Species Rating. None of the North Shore streams that were rated by the Atlas of Hawaiian Watersheds received a rating higher than 5 on a 10 point scale *(Table 2.7).* Kaukonahua and Ki'iki'i received a rating of 2. Five streams were not ranked due to lack of data. Comparatively, the majority of O'ahu streams score lower than 5 for biological resources.

Department of Land and Natural Resources (DLNR) Division of Aquatic Resources (DAR) Stream Biotic Importance Criteria are also used to assess the biological resources in North Shore's streams. DAR uses the following stream characteristics when determining a stream's existing biological importance *(Table 2.7).*

- 19 or more different types of native insect species can be found in the stream
- 5 or more different types of native macrofauna can be found in the stream
- Absence of priority 1 introduced species in streams
- Abundance of any native species in streams
- Presence of candidate endangered species in streams
- Endangered Newcomb's Snail habitat

Table 2.6 North Shore Native Aquatic Species*

Common Name	Hawaiian Name	Scientific Name
Crustaceans		
Mountain shrimp	ʻŌpae kalaʻole	Atyoida bisulcata
Hawaiian prawn	ʻŌpae ʻoehaʻa	Macrobrachium grandimanus
Fish		
Freshwater goby	ʻOʻopu nakea	Awaous guamensis
Threadfin Shad	no known Hawaiian name	Dorosoma petenense
Hawaiian Sleeper	ʻOʻopu akupa	Eleotris sandwicensis
Smooth Cornetfish	Nunu peke	Fistularia commersonii
Hawaiian Flagtail	Aholehole	Kuhlia sandvicensis
Freshwater goby	ʻOʻopu ʻalamoʻo	Lentipes concolor
Striped mullet	ʻAmaʻama	Mugil cephalus
Bigeye Scad	Akule	Selar crumenophthalmus
Freshwater goby	ʻOʻopu napoili	Sicyopterus stimpsoni
Freshwater goby	ʻOʻopu naniha	Stenogobius hawaiiensis
Insects		
Green Darner Dragonfly	Pinao	Anax junius
Hawaiian Campsicnemus	no known Hawaiian name	Campsicnemus bicoloripes
True fly	no known Hawaiian name	Dasyhelea hawaiiensis
Caddisfly	no known Hawaiian name	Hydroptila sp.
Case-Making Hawaiian Aquatic Moth	no known Hawaiian name	Hyposmocoma sp.
Upland Damselfly	Pinao	Megalagrion hawaiiense
Crimson Hawaiian Damselfly	Pinao	Megalagrion leptodemas
Blackline Hawaiian Damselfly	Pinao	Megalagrion nigrohamatum nigrolineatum
Oceanic Hawaiian Damselfly	Pinao	Megalagrion oceanicum
Pacific Hawaiian Damselfly	Pinao	Megalagrion pacificaum
Hawaiian Pond Bug	no known Hawaiian name	Microvelia vagans
True fly	no known Hawaiian name	Procanace bifurcata
Hawaiian Saldid Bug	no known Hawaiian name	Saldula exulans
Hawaiian Shore Fly	no known Hawaiian name	Scatella cilipes
Hawaiian Shore Fly	no known Hawaiian name	Scatella clavipes
Hawaiian Midge	no known Hawaiian name	Telmatogeton sp.
Snails		
No common name	Pipiwai	Clithon cariosus
No common name	Hapawai	Neritina vespertina
Sponges		
Freshwater sponge	no known Hawaiian name	Heteromeyenia baileyi

* Source: Atlas of Hawaiian Watersheds & Their Aquatic Resources (2008).

In general, the biotic resources of the streams in the North Shore are severely degraded. Important biological resources found in these streams are summarized in *Table 2.7.*

Table 2.7 North Shore Stream Aquatic Resources

Watershed	Stream Biological Rating[a]	Important Biological Resources Found in Streams[b]
Anahulu	5	Native Microfauna Diversity, Presence of Candidate Endangered Species
Waimea	5	Native Microfauna Diversity
Pahole	4	Presence of Candidate Endangered Species
Makaleha	4	Absence of Priority 1 Introduced Species
Paukauila	3	Presence of Candidate Endangered Species
Loko Ea	3	Absence of Priority 1 Introduced Species
ʻĀweoweo (Waialua)	3	Absence of Priority 1 Introduced Species
Laniākea (Keamanea)	3	Absence of Priority 1 Introduced Species
Kawailoa (Keamanea)	3	Absence of Priority 1 Introduced Species
Kiʻikiʻi (Kiʻikiʻi, Poamoho, Kaukonahua)	2	Presence of Candidate Endangered Species
Kawaihāpai	NR	Unranked Due to No Data
Kaʻalaea (Keamanea)	NR	Unranked Due to No Data
Kālunawaikaʻala	NR	Unranked Due to No Data
Pākūlena	NR	Unranked Due to No Data
Paumalū	NR	Unranked Due to No Data

[a] Source: Atlas of Hawaiian Watersheds & Their Aquatic Resources (2008). Scoring is from zero to ten with zero being the lowest and ten being the highest.
[b] Based on stream's attainment of DLNR DAR stream Biotic Importance Criteria.

2.3.7.6 Flooding

The North Shore is subject to flooding from high waves, tsunamis, and rainstorms. High, wind-generated waves caused by unusual storm conditions can result in flooding along the shoreline. Tsunamis, also known as tidal waves, have also caused extensive flooding and damage along coastal regions. See *Figure 2.11* for the tsunami evacuation zone for the Haleʻiwa/Waialua area. Rainstorm-generated floods are the most common of the three natural causes due to the region's natural topography and the inadequate capacity of existing drainageways. Most rainstorm floods occur between November and May as the result of large-scale storm systems.[18]

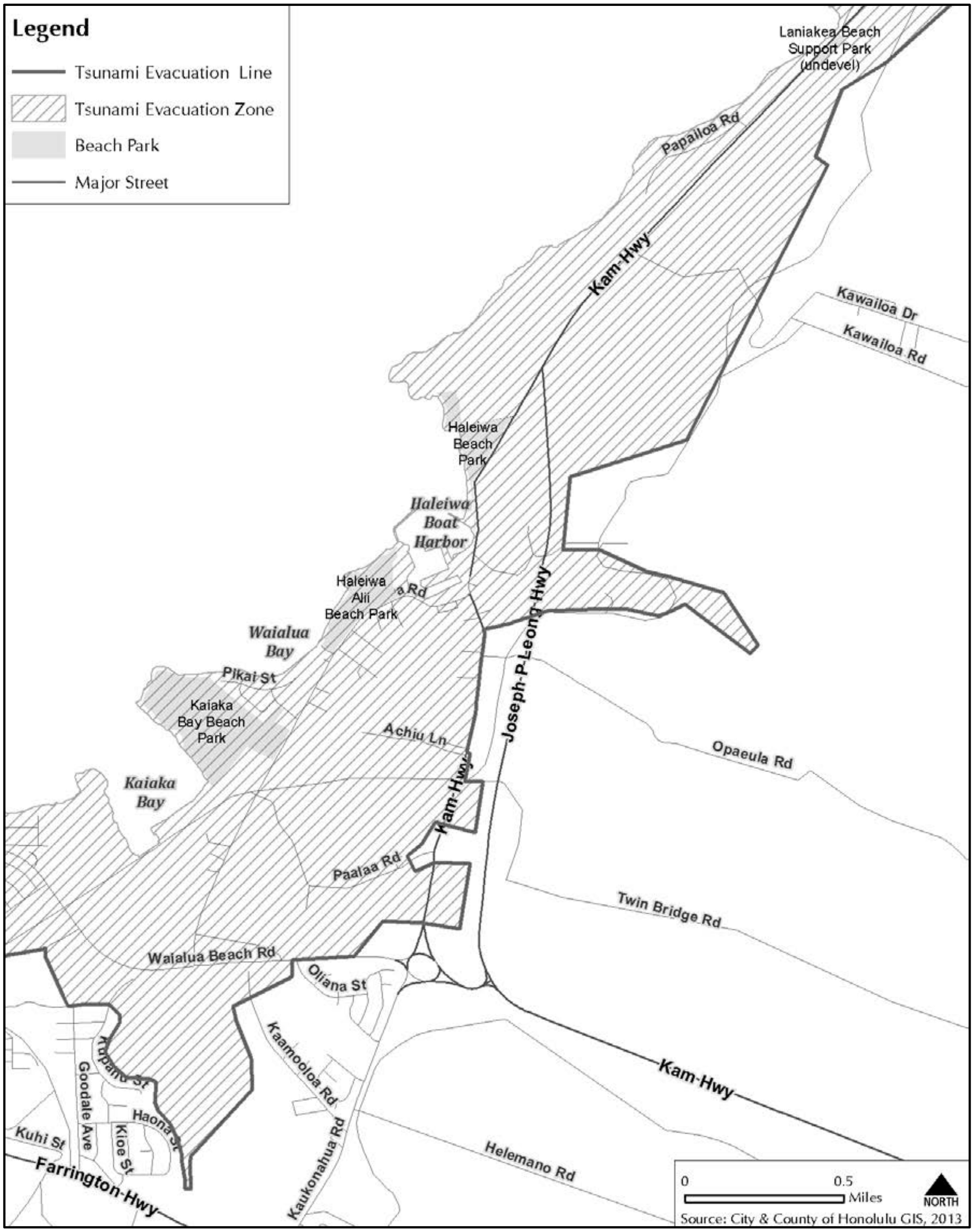


Figure 2.11 Tsunami Evacuation Zone for the Haleʻiwa/Waialua Areas

Figure 2.12 shows an area along Kaukonahua, Kiʻikiʻi and Anahulu streams that is Flood Insurance Rate Map (FIRM) Zone A and Zone AE, a 100-year flood inundation zone. Along the ocean shoreline is an inundation area, mainly Zone VE, which indicates coastal flooding that may have wave action. Modifications to natural drainage patterns and activities that increase storm runoff from the mauka areas – including stream channelization, increased erosion and sedimentation, and debris buildup/blockage to restrict stream flow – further compound flood hazards in this area.[1] Inland beyond the coastal flood area is Zone X, an area of 100-year flooding, and Zone X500, an area of 500-year flooding.

The FIRM zones help to identify areas that are less desirable to develop due to the chance of flooding and higher insurance rates. The area along Kiʻikiʻi Stream and to the east toward Haleʻiwa is such an area, due to its low elevation and its designation as a 100-year flood zone.[57]

The Wahiawā Reservoir can prevent, reduce, and delay flooding that occurs due to excessive rain events, although it was originally designed for irrigation purposes. In some events, in addition to tremendous rainfall in the coastal areas, the Wahiawā Reservoir overflows the spillway, allowing mauka rain-related water volumes to flow to the sea. When the spillway is overflowing, the dam no longer serves as a flood control device, and essentially stream flow volumes due to rainfall will flow unimpeded as if no dam existed.

A Limited Visual Dam Safety Inspection of Wahiawā Dam in 2006 by the US Army Corps of Engineers (USACE) classified the dam as a high hazard, based on its location and the potential for loss, not the structural integrity of the dam itself. Should the dam fail, lives could be lost and there would be extensive economic loss to community, industry or agriculture.[58] Overtopping of the dam would result in flooding of a large portion of the communities of Waialua and Haleʻiwa.[59] An agreement to lower the reservoir water level by ten feet to reduce the risk of future flooding, was reached by Dole Food Company and DOH, and is now in effect.[57] Dole has an Emergency Action Plan on file with USACE, and continues to monitor, conduct routine maintenance and contract third-party inspections as required.[60]

In response to resident concerns regarding the consequences of a break in the dam, a simulation study was carried out by the Kaiaka Bay Watershed Project Team in 2007. The model estimated that it would be 40 minutes from the time of the dam break to arrival in the North Shore populated areas of Waialua and Haleʻiwa. This dam break modeling analysis refines the evacuation zone in the Dam Emergency Action Plan, helping Civil Defense coordinate and address an emergency event.

Recently completed or ongoing drainage system studies to address the community's concerns about flooding in the Waialua-Haleʻiwa area include: (1) Haleʻiwa Road Drainage Improvements Engineering Study and (2) Kaukonahua Stream Dredging Study (from Otake Camp to Kaiaka Bay).[1] Dredging has occurred at the Paukauila Stream mouth, the State is working with the residents and owners of Kaukonahua Stream to develop a routine maintenance program for clearing channel debris and sediments (including field inspections after a major flood event), and also working with landowners to re-vegetate fallow lands. A possible contributor of sedimentation into the streams is lands left vacant after sugarcane and pineapple went out of production.[61]

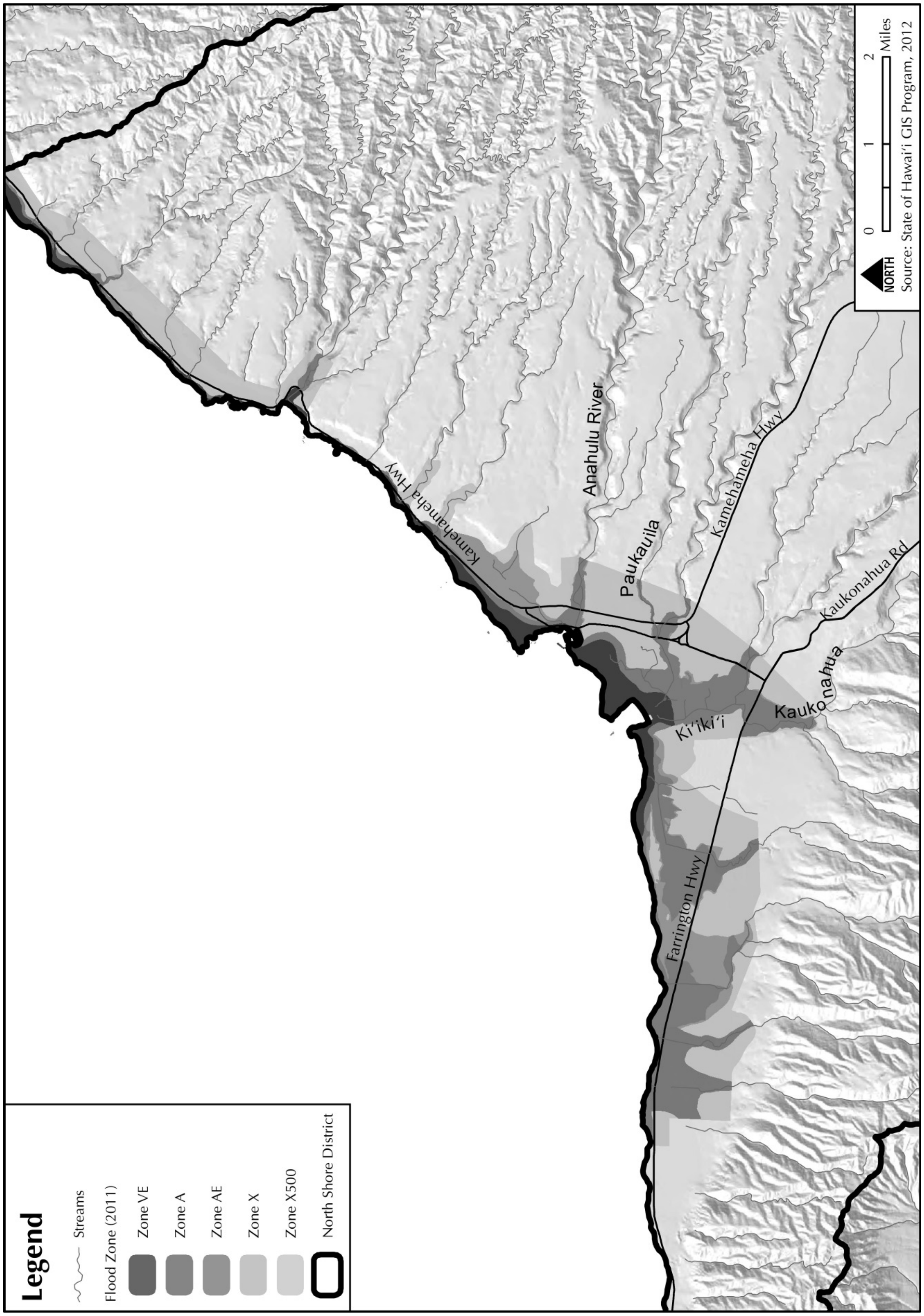


Figure 2.12 North Shore Flood Zones

2.3.8 Wetlands

Wetlands are areas that are regularly wet or flooded throughout most of the year and are often characterized by specific plant and soil types. Wetlands provide habitat for fish, birds, and other wildlife as well as serve two major hydrological functions - (1) as an interceptor for runoff that lessens the impact of flooding; and (2) as a sediment and pollutant absorber that traps sediment and pollutants in runoff. From an aesthetic point of view, wetlands provide recreational, education, and research opportunities.

The USACE, the U.S. Fish and Wildlife Service (USFWS), and the EPA as well as State and County agencies have responsibilities for the protection and management of wetlands. The major wetland areas on the North Shore include: ʻUkoʻa Marsh, Loko Ea Fishpond, Haleʻiwa Marsh, Taro and Lotus Fields, Kalou Marsh, Waimea Wetland and Estuary, Crowbar Ranch Pond, Dillingham Field Ponds, and Mokulēʻia Quarry (*Figure 2.8*).

ʻUkoʻa Marsh was formerly a fishpond and is part of what was previously a much more extensive wetlands area around Kawailoa Road north of Haleʻiwa town and south of the former Kawailoa Landfill. This wetland complex is the third largest existing wetland on Oʻahu.[62] ʻUkoʻa Marsh is described as shallow, from 0.9 to 1.2 m deep, and at one time some 0.9 miles long and up to 0.2 miles wide, with an open water area or pond. The waters of ʻUkoʻa emanate from streams originating in the upper mauka lands and where springs emerge from bedrock lavas.[63] Records from 1883 indicate that ʻUkoʻa fishpond was believed to have a subterranean connection with the ocean since the waters of the pond would be adversely affected during the presence of strong offshore conditions and stormy weather.[64]

Water from ʻUkoʻa pond was formerly pumped for sugarcane irrigation[65] and possibly to supply the OR&L trains.[63] At one time the pump house pumped 10 mgd of water from a well dug nearby on the Kawailoa mountainside to irrigate the sugar cane fields above.[66] Over time, erosion from intensive sugar cultivation carried soil into the pond.[64]

The landowner, Kamehameha Schools (KS) is working with groups such as Ducks Unlimited, The Nature Conservancy (TNC), and USFWS to control predators and expand habitat to protect the Hawaiian Stilt and the Gallinule. Plans are underway for restoration of the pond to utilize the area for ecotourism at ʻUkoʻa Marsh.[63]

Loko Ea Fishpond used to be connected to ʻUkoʻa via an open water channel extending about one mile south. This channel still exists and some water flow still remains during heavy rains, but it is overgrown with vegetation. Loko Ea Fishpond drains approximately 2.1 square miles of low-lying coastal lands and wetlands north of Anahulu River into Waialua Bay.[2] Loko Ea is a 10-acre brackish inland pond connected to the sea by a short channel and water control gates.

The pond is on Kamehameha Schools land, and has been under restoration since 2007. It is currently used for educational purposes.

The *Haleʻiwa Marsh, Taro, and Lotus Fields* wetland area is a cultivated marsh with a majority of the area supporting taro and lotus. This natural marsh, fed by surface water from perennial streams and ground water discharge from the Koʻolau aquifer, was divided into over 150 separate water impoundments prior to WWII for the production of aquatic food.[65] Uncultivated areas have been overgrown with invasive non-native vegetation.[62] The marsh is spring-fed, and running water can sometimes be heard beneath the vegetation. In the central and northeastern sections, the vegetation overlies mucky brown soil with standing water one to two feet deep. Surrounding the marsh are trees and shrubs. Nearby residents use the edge of the marsh for various aquatic gardens.[65]

Kalou Marsh is in the Waialeʻe Ahupuaʻa, within the University of Hawaiʻi Agricultural Experiment Station. Once known as Kalou Fishpond, this site is listed in the Hawaiʻi Register of Historic Places.[65] The marsh is a spring-fed pond which drains into the sea via a culvert through the sand dunes along the shore. It is an inland pond, approximately one acre in size and supports a total of 15 acres of wetland habitats.[62] A retaining wall borders the marsh, and a fence was installed around a portion of the perimeter. Previously used to grow taro, water from this marsh was used to irrigate pastures during the late 1980s. The marsh is in poor condition because of inadequate maintenance and is currently only a fraction of its former size. Parts of the northeastern section of the pond have been previously bulldozed and much of the pond has become overgrown.[65]

The ephemeral *Waimea Wetland and Estuary* along the lower portion of Waimea River provides only a marginal water bird habitat because of frequent fluctuations in water level and the encroachment of grasses. During the summer the river is frequently cut off entirely from the ocean by a sand bar; the dry weather flow enters entirely by seepage through the beach. The river is also subjected to continuing human disturbance associated with the Waimea Beach Park and Waimea Valley. Dogs, cats, and mongoose are common in the area and presumably inhibit bird nesting along the river.[65] With vigilant predator control and constant management of the habitat, Hiʻipaka, LLC is helping almost a dozen of the Common Hawaiian Moorhen population to endure.

Crowbar Ranch Pond is a small man-made pond located near the entry road to the Dillingham Ranch ʻĀina property. The pond was created to handle runoff upland of the property. It has since become a decorative feature of the nearby equestrian facility,[67] and provides a good habitat for a number of coots. The area is predominantly pasture land of open to semi-open grassy areas.[65]

The *Dillingham Field Ponds* on the Haleʻiwa Coastal Plain are ephemerally flooded pastures that have exposed underlying ground water. The primary grazing area at Dillingham Air Field includes extensive mudflats that flood after heavy rains.

Mokulēʻia Quarry is a former rock quarry which discontinued operations in the 1970s. The removal of rocks exposed ground water which now forms the wetland.[65]

Various species of endangered water birds, such as the ʻAlae ʻula or Hawaiian (Common) Moorhen (*Gallinula chloropus sandvicensis*), the ʻAlae keʻokeʻo or Hawaiian Coot (*Fulica americana alai*), the Āʻeo or Hawaiian Stilt (*Himantopus himantopus knudseni*) and the Hawaiian Duck or Koloa (*Anas wyvilliana*) can be found at North Shore wetlands. The coots and stilts utilize the wetlands primarily as feeding areas, but the coots may also nest there on occasion. The ʻAukuʻu or Black-crowned Night Heron *(Nycticorax nycticoras hoactli),* an indigenous resident water bird protected by state law, is likely to be found roosting in trees bordering the wetlands, or feeding in open water areas. The Pueo, or Hawaiian Owl (*Asio flammeus sandwichensis*), another endangered species, can be seen flying over the wetlands to forage.[63] *Table 2.8* lists the endangered water birds and in which wetlands they have been found.

Table 2.8 Endangered Species Found Within North Shore Wetlands*

	ʻUkoʻa Marsh	Loko Ea	Haleʻiwa Marsh, Taro and Lotus Fields	Kalou Marsh	Waimea Wetland and Estuary	Crowbar Ranch Pond	Dillingham Field Ponds	Mokulēʻia Quarry
Hawaiian Moorhen/ʻAlae ʻula (Galllinula chloropus sanvicensis)	X	X	X	X	X	X	X	
Hawaiian Duck/Koloa Maoli (Anas wyvilliana)	X	X		X	X	X	X	X
Hawaiian Coot/ʻAlae Keʻokeʻo (Fulica alai)	X		X	X		X	X	X
Hawaiian Stilt/Āʻeo (Himantopus mexicanus knudseni)	X	X	X			X	X	
Hawaiian Owl/Pueo (Asio flammeus sandwichensis)	X						X	
Black-crowned Night Heron/ʻAukuʻu (Nycticorax nycticorax hoactli)**	X	X	X		X	X	X	X

* Sources: Ecologically Sensitive Wetlands on Oʻahu: Ground Water Protection Strategy for Hawaiʻi (1989); Final Environmental Assessment Haleiwa Regional Park Skateboard Facility (2002); Strategic Plan for Wetland Conservation in Hawaiʻi (2006); North Shore Information (2008); Final Environmental Assessment: Intersection Improvements Dillingham Ranch Agricultural Subdivision (2008).)

** Not an endangered species, however an indigenous resident water bird protected by State law

2.3.8.1 Bogs

O'ahu is unique in that it is the only main Hawaiian island which does not have extensive bog habitats. Most true bogs and bog-like areas, like Mt. Ka'ala, are formed by collapsed calderas creating an impervious, saucer-shaped layer that holds water.[68] Geologically, bogs are characterized by impermeable substrate which limits water drainage. This accumulation of water makes the bog environment severely acidic thus limiting vigorous growth of plants. Hawaiian bogs house both bog-specific plant species, specially adapted to the bog environment, and plant species found throughout the Hawaiian rainforest that become dwarfed in the bog environment.[64]

Kamehameha Schools owns a large portion of the Army's Kawailoa Training Area in the Ko'olau Mountains. O'ahu's only true bog - Lehua Mahanoe bog[64] - was discovered here in 1993 by Joel Lau and Samuel Gon III. A true bog receives its water only from rain, without seepage from any surrounding wetland. There are many rare and three endangered species within the Kawailoa bog's stunted vegetation. The area has been fenced to protect the bog from pigs, the greatest threat to this unique resource. Pigs can devour and trample native species within the bog, as well as spread weedy species such as Strawberry Guava *(Psidium cattelianum)* and Koster's Curse *(Clidemia hirta)*.[69]

The cloud forest of Mt. Ka'ala, the highest peak in the Wai'anae Mountains, is home to a 70-acre immature bog on the summit plateau (4,000 feet), filled with rare and uniquely Hawaiian endangered plants and animals. A boardwalk passes through the Mt. Ka'ala Natural Area Reserve, providing a window into the forest for hikers and an important access trail for conservationists.[70] Its perimeter is also fenced to keep it free of feral pigs.[71]

2.3.9 Nearshore Waters

North Shore's nearshore waters are heavily used by residents for recreational and commercial activities. Three major embayments make up the nearshore waters of North Shore: Waimea Bay, Waialua Bay, and Kaiaka Bay *(Figure 2.13).* These bays can also be considered coastal plain estuaries.

Waimea Bay ("sacred water" or "red water") drains the 'Elehāhā, Kauwalu, Kamananui, Kaiwiko'ele and Waimea Streams of the Waimea watershed. The area of the watershed is 13.6 square miles.[72] Waimea Bay is famous for the largest, most dangerous and spectacular surf in the world, where waves can reach heights of thirty feet and more during the winter months.[73] This makes this beach the home of popular surfing competitions.[74] During the summer, the waves of Waimea subside making the waters suitable for swimming, snorkeling, SCUBA diving, and fishing.[75]

Waialua Bay is a coastal plain estuary that receives freshwater influence from Anahulu Stream and its tributaries (Kawai'iki and Kawainui streams), and is bounded by the rocky limestone outcrops of Kaiaka Point to the west and Pua'ena Point to the east.[3] At Waialua Bay, Anahulu River has a drainage area of 16 square miles and a 100-year peak discharge of 16,200 cubic feet per second. Freshwater leakage through the caprock into Anahulu River and into the bay is estimated to be 4.79 mgd.[52]

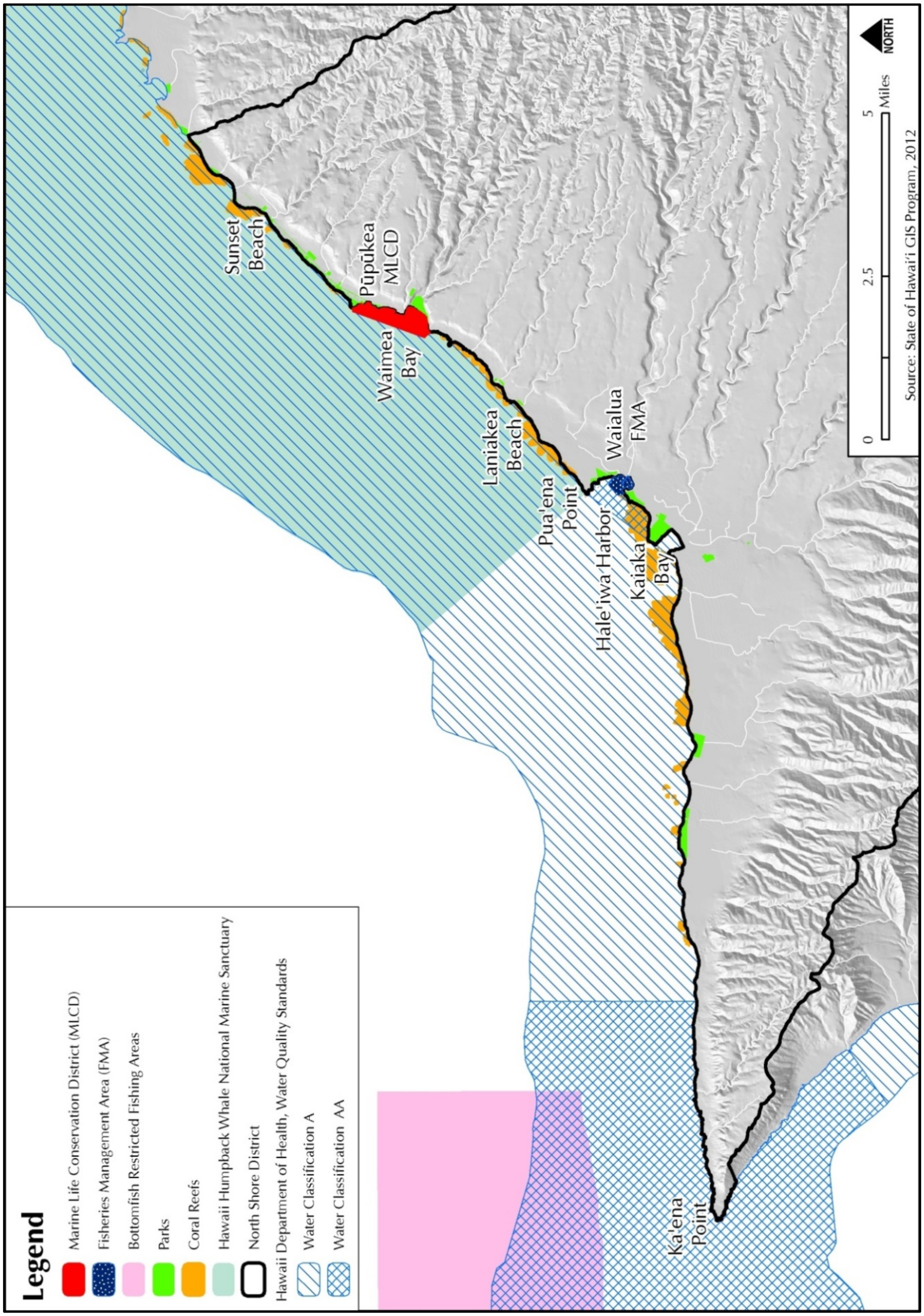


Figure 2.13 Nearshore Marine Resources of the North Shore

To accommodate its many uses, the State regulates portions of Waialua Bay for recreational and commercial activities. The Haleʻiwa Ocean Recreation Management Area designates zones for various recreational water sports to *"reduce conflicts among ocean water users, especially in areas of high activity"* (Hawaiʻi Administrative Rules §13-256-1). The various zones include dedicated areas for: A & C – Swimming and Bathing; B – Surfing and Bodysurfing; D – Commercial Thrill Craft; and E & F – Recreation Thrill Craft (*Figure 2.14*).[76]

When *Haleʻiwa Harbor* was built, Anahulu Stream was diverted to the east side of the Harbor, which has drastically altered the coastline of the bay. An L-shaped mole was constructed between the stream and harbor to serve as channel protection for the stream and as a breakwater for the harbor,[3] and provides 64 berths and 26 moorings for vessels.[2] The offshore bathymetry is dominated by two pronounced troughs or canyons associated with the Paukauila and Anahulu Stream drainages that extend towards shore. During the winter, this is a high wave energy coastline, directly exposed to the North Pacific Swell.[3]

Kaiaka Bay ("shadowy sea") is the marine receiving water for the entire Kiʻikiʻi Stream System (including Lower/Upper Kaukonahua Stream, Wahiawā Reservoir, and Poamoho Stream), as well as the adjacent Paukauila Stream System (ʻŌpaeʻula and Helemano Streams). These waters drain from both the Koʻolau and Waiʻanae mountains, and include 80 square miles of the Kaukonahua, ʻŌpaeʻula, Helemano, Poamoho, and Paukauila watersheds. Kaiaka Bay serves as a critical habitat for endangered marine species and has been shown to contain rich and diverse coralline and microalgae species diversity that are vulnerable to the impacts of streambank erosion.[61] Freshwater leaking through caprock into ʻŌpaeʻula, Helemano, Poamoho, and Kaukonahua streams and Kaiaka Bay amounts to an estimated seven mgd.[52]

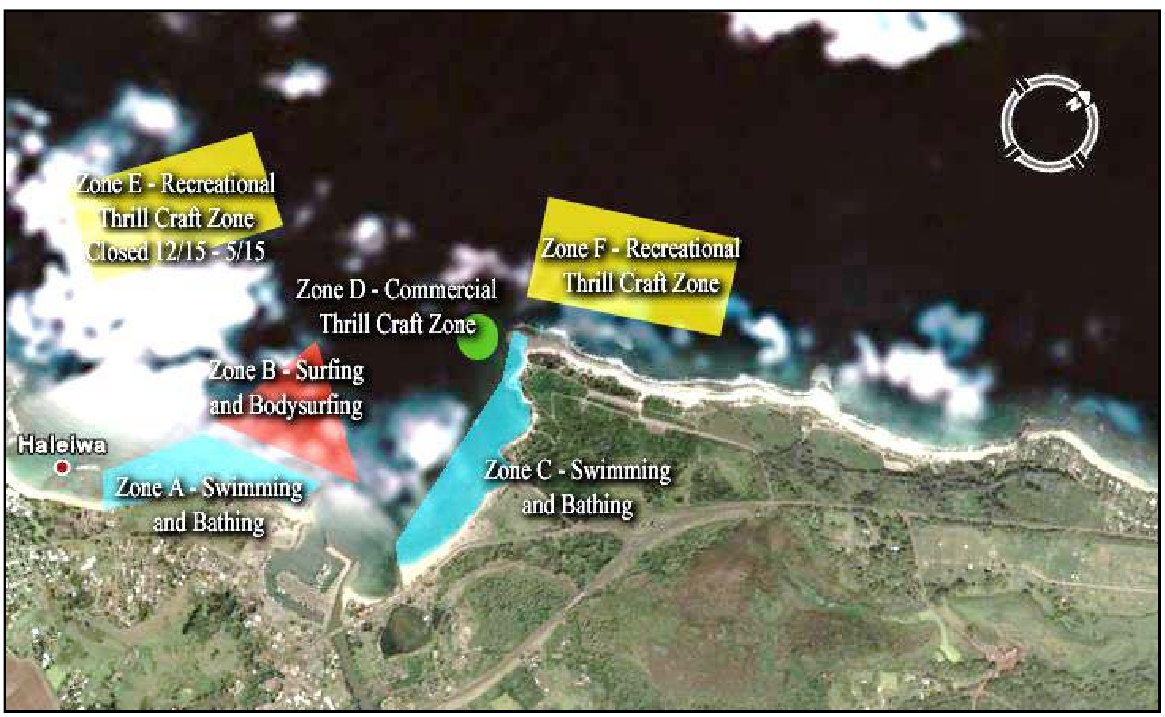


Figure 2.14 Haleʻiwa Ocean Recreation Management Activity Zones

2.3.9.1 Nearshore Water Quality

Hawai'i's Water Quality Standards classify marine waters as either Class AA or Class A.

- *Marine Waters Class AA:* these waters shall 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. The uses to be protected in this class are oceanographic research, the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, compatible recreation, and aesthetic enjoyment.
- *Marine Waters Class A:* for recreational purposes and aesthetic enjoyment. Other uses are permitted as long as they are compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters.

Waialua Bay is rated as a Class AA water body. Areas surrounding Ka'ena Point are also listed as Class AA. Remaining ocean waters are classified as Class A (*Figure 2.13*).

Kaiaka Bay and Waialua Bay were classified by DOH as water quality limited segments in the 1998 Hawai'i Unified Watershed Assessment. The bays are currently listed on the State's 303(d) list of threatened and impaired waters due to excessive levels of total nitrogen, nitrate-nitrite nitrogen, chlorophyll a, ammonium nitrogen, and turbidity exceeding the maximum allowable levels.[77]

Runoff generated in the upper reaches of the watershed impact the coastal communities of Waialua and Hale'iwa. Kaiaka Bay directly receives runoff from major drainages and has very turbid conditions. Excessive amounts of nutrients applied in agricultural production, landscaping, and gardening can become detrimental to water quality at the coast and in nearshore waters. The urbanized areas concentrate waste and build impervious surfaces that also contribute to negative water and ocean quality.[78]

The major sources of pollutants discharging into the Kaiaka and Waialua embayments are household cesspools, injection wells from treatment plants, and sediments from drainage basins.[79] Although cesspool effluent is discharged into the ground water, it may seep into surface water bodies and eventually reach the coastal waters.[77] Sediment deposition occurs along much of the coast after heavy rains, causing reduced downstream water quality, increased likelihood of flooding,[78] and discoloration of nearshore waters for extended periods of time.[2] Excessive sediment smothers and kills coral tissue and reduces light levels and food supplied to the coral by symbiotic algae.[80]

2.3.9.2 Marine Ecosystems and Fisheries

Significant amounts of coral reef habitat occur in the nearshore waters off the coast of the North Shore district (*Figure 2.13*). According to residents, the reef has declined dramatically over the past 30 years from a flourishing ecosystem and fish nursery to a dead reef system with cloudy and turbid conditions.[22] It is possible that the doubling of population from 1970 to 2000 (*Table 2.11*) also doubled the amount of land-based pollutants in the area.[18]

However, much of the seafloor in the North Shore is exposed to high waves and storms, and is characterized not by lush coral thickets but by fossil reefs that grew many thousands to tens of thousands of years ago. The bottom of the seafloor is a smooth limestone pavement called the insular shelf, composed of dead fossilized coral and their algal partners. For all Hawaiian shores that experience the North Swell, the reef was last alive about 5,000 years ago. This was about the time researchers think this extraordinary, large swell associated with strong El Nino years began hitting the Hawaiian Islands. Although these huge wave events only occur every few decades, the immense stress for the reef surface deters widespread coral growth on those exposed shores. Currently, most of the coral colonies are approximately the same size – meaning that they are about the same age. The age of these corals probably dates back to the last large wave event in 1998, when their predecessors were wiped out and reset the age of the seafloor back to 5,000 years ago. These corals are likely to live only until the next large swell arrives.[80]

Because of the North Pacific Swell, coral cover on the North Shore is relatively low and consists mainly of encrusting species that are wave resistant. The most common corals are lobe coral (*Porites lobata)*, cauliflower coral (*Pocillopora meandrina),* and mushroom coral *(Actinodiscus punctate).* Encrusting corals such as crater coral (*Leptastrea purpurea)*, leaf coral *(Pavona varians)* and blue rice coral (*Montipora flabellate)* are found throughout the area. Rare corals such as ringed rice coral (*Montipora studeri)* and invasive corals such as snowflake coral *(Carijoa riisei*) have also been noted in the area.[85]

Marine life that can be found in the North Shore nearshore waters includes: shellfish (ʻopihi, pipipi, pu ʻole, ʻopae), seaweed (limu kohu), sea cucumber (loli), nudibranchs, sea urchin (wana, hāʻukeʻuke, haʻukeʻuke ʻulaʻula, hāwaʻe), eel (puhi, puhi kāpā, puhiʻoniʻo), goatfish (kūmū, moano, weke pueo), surgeonfish (palani, maʻiʻiʻi, ʻapi, pualu) and other reef fish (humaumau, puʻu olaʻi, kala, nakea, nenue, humuhumu-nukunuku-a-puaʻa, hīnālea lau-wili, hinalea ʻaki-lolo, manini, kihikihi, awela, kikakapu, ʻaha, ʻopule, āholehole), Spotted Eagle Ray, and Monk Seal.[89,81,82,84]

In 1983, the State of Hawaiʻi designated Kalua o Māua (Three Tables) and Shark's Cove as a marine protected area, called the Pūpūkea Marine Life Conservation District (MLCD). This is one of three on Oʻahu and one of 11 in the State of Hawaiʻi administered by DLNR DAR. This MLCD recognizes the importance of this area as a center for marine recreation, conservation, and fishery replenishment.

To aid the MLCD in its purpose of conserving and replenishing marine species, the State expanded the reserve in 2003 to cover Waimea Bay, increasing the MLCD to over 100 acres and about a mile of coastline.[83] It includes the submerged lands and overlying waters from Waimea to Kulalua Point. Waimea Bay, Three Tables Cove, Shark's Cove, Pūpūkea Beach Park, and the Pūpūkea Tide Pools are all within the protected area. The Pūpūkea MLCD has an extremely complex overall bathymetry and provides an outstanding natural laboratory for the study of the ecology of high wave impact environments.[84]

Divers, bathers and shoreline fishermen are increasingly using Pūpūkea for recreation and sustenance fishing.[85] Various user groups in the area have expressed concerns for the level of activity that is occurring at the site and the safety of all users due to the mix of ongoing activities.[85]

Before a rule change in 2002, fish stocks appeared to be depleted at the MLCD because of virtually unrestricted fishing activity. However, fish counts done by University of Hawaiʻi (UH) and TNC have found that there are many more fish now than before the rule change.[86] Under current regulations, only shore fishing and seasonal akule and ʻōpelu fishing are allowed in Waimea Bay, and limited limu (seaweed) gathering is allowed. Otherwise, any take of the protected resources in the MLCD is prohibited, including fishing at Shark's Cove or Three Tables, using a spear gun, collecting marine life (including shells), fishing, gathering ʻopihi, and damaging or removing coral.[87] The use of nets is currently allowed in the northern portion of the MLCD.[85] Many community members feel that allowing commercial netting in the MLCD is detrimental. There is also a significant amount of poaching in the MLCD which the non-profit group Mālama Pūpūkea-Waimea is working hard to suppress, with help from the Division of Conservation and Resources Enforcement (DOCARE) Mauka-Makai program.[86]

Pūpūkea MLCD also lies within the boundaries of the Hawaiian Islands Humpback Whale National Marine Sanctuary (*Figure 2.13*), which stretches from Puaʻena Point westward around Oʻahu's coast. The Sanctuary was created by Congress in 1992 to protect humpback whales and their habitat in Hawaiʻi, and includes some of the shallow (less than 600 feet) waters surrounding the main Hawaiian Islands.[2]

The Waialua Bay (Haleʻiwa Harbor) Fisheries Management Area is that portion of Waialua Bay bounded by lines drawn 100 yards seaward of and parallel to the Haleʻiwa Harbor Breakwater and the Haleʻiwa Beach Groin, and inland ten yards downstream of and parallel to the Anahulu Bridge. Fishing and harvesting aquatic life is prohibited in this area, except as indicated in the following permitted activities:

- To take any legal size fish in season with one line, or one rod and line, with no more than two hooks;
- To take crabs with not more than ten nets, provided the nets are not more than two feet in diameter;
- To take shrimp for bait with a hand net provided that the net is not more than three feet in any dimension;
- Commercial Marine licensees with a Bait License may take nehu, iao, and other authorized baitfish for bait purposes;
- Licensed pond owners or operators may take young mullet (pua) or other small fish for stocking their fishpond.[88]

Kaʻena is noted as an excellent fishing ground.[89] A Bottomfish Restricted Fishing Area lies just off the coast of Kaʻena Point. It is unlawful for any person to take or possess bottomfish while in a vessel that is drifting or anchored within this area, except in times of emergency. Bottomfish species covered by these rules include: a) ʻulaʻula koaʻe or onaga (*Etelis coruscans*); b) ʻulaʻula or ehu (*Etelis carbunculus*); c) kalekale (*Pristipomoides sieboldii*); d) ʻopakapaka (*Pristipomoides filamentosus*); e) ʻukikiki or gindai (*Pristipomoides zonatus*); f) hapuʻu (*Epinephelus quernus*); and g) lehi (*Aphareus rutilans*). These species are often referred to as the "Deep 7."

Deeper waters off the North Shore are home to Pacific Blue Marlin (Aʻu), Striped Marlin (Naiaragi), Shortbill Marlin (Hebi), Wahoo (Ono), Dolphin Fish (Mahi Mahi), Yellowfin Tuna (Ahi), Big Eye Tuna (Ahi Poʻonui) and Skipjack Tuna (Aku).[90]

2.3.10 Terrestrial Ecosystems

O'ahu is home to some of the world's most endangered tropical dryland forests – the island contains less than 0.2% native dry forest (1.7 km^2) with less than 30% protected in reserves (0.5 km^2).[91] 45% of the 68 native tree and shrub species identified in the dry forest region are threatened.[92]

Since the arrival of the first human settlers on the islands over 1,600 years ago, Hawai'i's forests have changed dramatically. Prior to human contact, the forest resources of North Shore consisted of montane, lowland dry and mesic forests; woodland; and shrub land. Significant changes to terrestrial ecosystems in Hawai'i began in the 19th century when cattle and other introduced livestock were allowed to range relatively freely throughout the islands.[93]

Unchecked cattle grazing caused the loss of biodiversity and soil erosion in many places throughout Hawai'i. Subsequent reforestation programs were counterproductive, as many of the plant species that were planted were non-native and replaced native forest cover. Currently, researchers estimate that over 90% of the original dry and mesic forest cover has disappeared in Hawai'i, leaving native forests only on mountain ridges and summits.[92]

The North Shore district, like most of the state of Hawai`i, has lost many of its native ecosystems, and those that remain are threatened by invasive species, development, natural disasters, and climate change. Based on data compiled by TNC, approximately 29% of the North Shore district has retained its native-dominated ecological systems. The remaining area, mainly in the lowland and coastal portions of the watershed where most anthropogenic activity occurs, is dominated by non-native ecosystems.[18]

TNC has rated the ecological viability of the native-dominated systems using an assessment methodology based on three criteria: ecosystem size, condition, and landscape context. Analysis of the viability data suggests 19% of the land within the North Shore district has fair ecosystem viability, and 9% has poor viability. None of the native-dominated land within the North Shore watershed received an assessment rating of good or very good.[18]

2.3.10.1 Critical Habitats

A critical habitat is defined as an area *"with the physical and biological features essential to the 'conservation' of a threatened or endangered species, and that may require special management considerations or protection"*.[94] There are more than 25 USFWS-designated critical habitat areas in the North Shore district, supporting a total of 36 threatened and endangered (T&E) plant species and several animal species. These critical habitat areas overlap with each other and are generally found on the summits of both the Ko'olau and Wai'anae mountains. *Table 2.9* lists examples of T&E species of the North Shore in addition to the endangered species found within wetlands listed in *Table 2.8*.

Table 2.9 Examples of Threatened and Endangered Species in North Shore*

Common Name	Hawaiian Name	Scientific Name
Flora		
Achyranthes	ʻAhinahina	Achyranthes splendens var. rotundata
Hawaiʻi alectryon	Māhoe	Alectryon macrococcus var. macrococcus
No known common name	No known Hawaiian name	Alsinidendron obovatum
Lavaslope centaury	ʻĀwiwi	Centaurium sebaeoides
No known common name	Kaʻena ʻAkoko	Chamaesyce celastroides var. kaenana
Herbst's sandmat	ʻAkoko	Chamaesyce herbstii
No known common name	Hāhā	Cyanea spp.
Sticky flatsedge	Puʻukaʻa	Cyperus trachysanthos
Mountain cyrtandra	Haʻiwale	Cyrtandra dentata
Delissea	ʻOhā	Delissea spp.
Sickle Island spleenwort	no known Hawaiian name	Diellia falcata
No known common name	Mehamehame	Flueggea neowawraea
Brackenridge's rosemallow	Maʻo hau hele	Hibiscus brackenridgei
Maui island-aster	No known Hawaiian name	Hesperomannia arbuscula
Kaʻala rockwort	Kuluʻī	Nototrichium humile
Carter's panicgrass	No known Hawaiian name	Panicum faurier var. carteri
Kaʻala phyllostegia	No known Hawaiian name	Phyllostegia kaalaensis
Dwarf naupaka	Naupaka	Scaevola coriacea
Oʻahu schiedea	Maʻoliʻoli	Schiedea spp.
Oʻahu riverhemp	ʻOhai	Sesbania tomentosa
Oʻahu cowpea	No known Hawaiian name	Vigna o-wahuensis
Koʻolau eugenia	Nīoi	Eugenia koolauensis
Fauna		
Hawaiian monk seal	ʻIlio-holo-I-ka-uaua	Monachus schauinslandi
Hawaiian hoary bat	ʻOpeʻapeʻa	Lasiurus cinereus semotus
Green sea turtle	Honu	Chelonia mydas
Hawksbill turtle	ʻEa	Eretmochelys imbricata
Hawaiian Flycatcher	Oʻahu ʻelepaio	Chasiempis sandwichensis ibidis
Bristle-thighed Curlew	Kioea	Numenius tahitiensis
Dark-rumped Petrel	Uau	Pterodroma phaeopygia sandwichensis
Newell's Shearwater	ʻAʻo	Puffinus auricularis newelli
Black-footed Albatross	Kaʻupu	Phoebastria nigripes
Oʻahu tree snail (41 taxa)	Pupu kani oe	Achatinella spp.
Picture-wing fly (6 taxa)	No known Hawaiian name	Delphinia spp.

* Sources: Kapuna Watershed Protection Project Pahole Natural Area Reserve Final Environmental Assessment (2003).Final Environmental Assessment Replacement, Repairs and Improvements Haleiwa Boat Harbor, Job No. B76DO70A (2005); Kaʻena Point Ecosystem Restoration Project (2009); North Shore Existing Conditions Draft (n.d.).

The statewide Natural Area Reserves (NARS) is based on the concept of protecting native ecosystems, as opposed to single species, nonetheless many threatened and endangered plants and animals benefit from the protection efforts through NARS.[95] NARS were created to preserve land and water areas that support relatively pristine natural communities and geological sites. Hiking and nature study are allowed in the NARS.[96] NARS currently consists of 20 reserves comprised of approximately 123,431 acres on five islands, managed by the DLNR Division of Forestry and Wildlife (DOFAW).

Three NARs are located within the North Shore: Ka'ena Point, Mt. Ka'ala, and Pahole. The Ka'ena Point NAR is designated critical habitat for seven endangered species of plants,[89] and is home to a growing population of rare and endangered coastal plants and seabirds. The endangered Hawaiian monk seal and green sea turtle are also regularly found resting along the shoreline.[97] The Pahole NAR in the Wai'anae Mountains above Mokulē'ia has been designated as critical habitat for the 'elepaio and for 25 threatened and endangered plants.[97] The Mount Ka'ala NAR in the Wai'anae Mountains above Waialua protects 219 native taxa, 76 of which are rare.[2] The North Shore NARS are named in the table below along with a general notation of the protected species.[18]

Table 2.10 North Shore Natural Area Reserves and their Protected Species

Reserve Name	Reserve Type	Acres	General Wildlife Concerns
Ka'ena Point	Coastal Dune System	12	Threatened & Endangered coastal plants and seabirds
Pahole	Dry and mesic forest	658	Forest birds, Threatened & Endangered forest plants, tree snails
Mount Ka'ala	Dryland to wet shrub forest	1,100	Forest birds, bog species

2.3.10.2 Ecosystem Threats

Invasive non-native plant species, feral ungulates and other non-native animals, human activities, aquatic pollutants and wildfire have been identified as the most damaging factors to Hawai'i's watersheds.[15] On the North Shore, native vegetation is extremely fragmented and invasive non-native vegetation is common along the ridges and in the valleys. The presence of invasive species in the streams and waterways also impacts native aquatic species.

The O'ahu Invasive Species Committee (OISC) identified several invasive species within the North Shore district. Target species include pampas grass, miconia, and coqui frog.[98] Strawberry guava is another invasive species that forms dense thickets, replacing native Hawaiian plants and damaging the watershed. Feral pigs and goats are a major concern in North Shore as they are found throughout the district. They both erode soils and cause biodiversity loss. Even in small numbers, feral pigs may cause great harm in ecologically sensitive areas.[15]

Other harmful mammals in the North Shore district include feral cats (*Felis catus*), dogs (*Canis familiaris*), mongoose (*Herpestes aruopunctatus*), and rats (*Rattus rattus, R. exulans*), all of which are a major cause of mortality among endemic and common native bird populations.[99]

The presence of avian malaria-carrying mosquitoes at elevations below 3,000 feet means that most native forest birds are restricted to higher elevations.[18] Similar to feral pigs, rats have also been observed in the district's forested areas, feeding on parts of native plants as well as native plants' fruits and seeds, which prevent these plants from thriving and reproducing. Rats also pose a threat to human health, as rat urine is the primary source of leptospirosis in surface water.[15]

Fire, as evidenced by the Waialua fires on the slopes of the Wai'anae Mountains in 2007 and 2010, can have a destructive force with lasting impacts. The 2007 fire burned 6,700 acres of land.[100] Initially, there is a loss of natives and introduced species; then, the bare ground without intervention is re-vegetated with the robust introduced species out-competing the native species.[64] In the interim, rains will wash the topsoil down into the ocean. Arsonists are the primary reason for the fires. Other causes include fireworks, road flares, cigarettes, and possibly dirt bikes without spark suppressors in the exhaust.[101] Recreational hiking may also impact forests. Hikers may unintentionally facilitate the spread of disease, invasive plants, or small pests. As these threats spread, the health and function of native ecosystems will suffer.

Various agencies and groups are working to protect the North Shore's natural resources. These include DLNR/DOFAW, U.S. Army, the O'ahu Invasive Species Committee (OISC), the Ko'olau Mountains Watershed Partnership (KMWP), and the Wai'anae Mountains Watershed Partnership (WMWP) (*See Figure 2.14*).

DLNR/DOFAW: The NARS are managed by the DLNR/DOFAW. Specific activities for the North Shore NARS include: monitoring and removal of rodent predators within the Ka'ena Point Predator Proof Fence, and predator suppression outside the fence as well; active participation in the DLNR Ka'ena Point Stewardship Group; monitoring of seabird populations at Ka'ena Point; ungulate removal from all fenced units within Pahole and Ka'ala NARS; boardwalk replacement at Ka'ala NARS; maintenance of lower Ka'ala access road; and even the monitoring and removal of feral goats in the adjacent upper Mokulē'ia Forest Reserve to reduce the potential for goat ingress into the NAR.[95] Additional information on the North Shore Forest Reserves and hunting areas can be found in section 2.8.3 Preservation Land Use.

U.S. Army: The Army's natural resources management program for the various training areas is guided by the Integrated Natural Resources Management Plan (INRMP), which was required by the Sikes Act for each military installation with significant natural resources. The ecosystem management program on O'ahu has a commitment to preserve, protect and enhance natural and cultural resources and lands upon which the quality of training ultimately depends.

A portion of the U.S. Army's Kahuku Training Area (KTA) and a majority of Kawailoa Training Area (KLOA) are within the North Shore's northern Ko'olau Mountains. The U.S. Army also manages the Dillingham Military Reservation (DMR), located just east of Ka'ena Point.[102] Natural resource management activities differ by training area. On KTA, the Army engages in incipient weed control of species such as *Melochia umbellata* and fountain grass, and control of established weeds around such rare plant populations as *Eugenia koolauensis*. Activities in KLOA focus on the protection of pristine habitat through fencing projects like that at 'Ōpae'ula, rare species management and monitoring, fire management, ungulate control and weed control of species such as *Leptospermum scoparium* and strawberry guava.

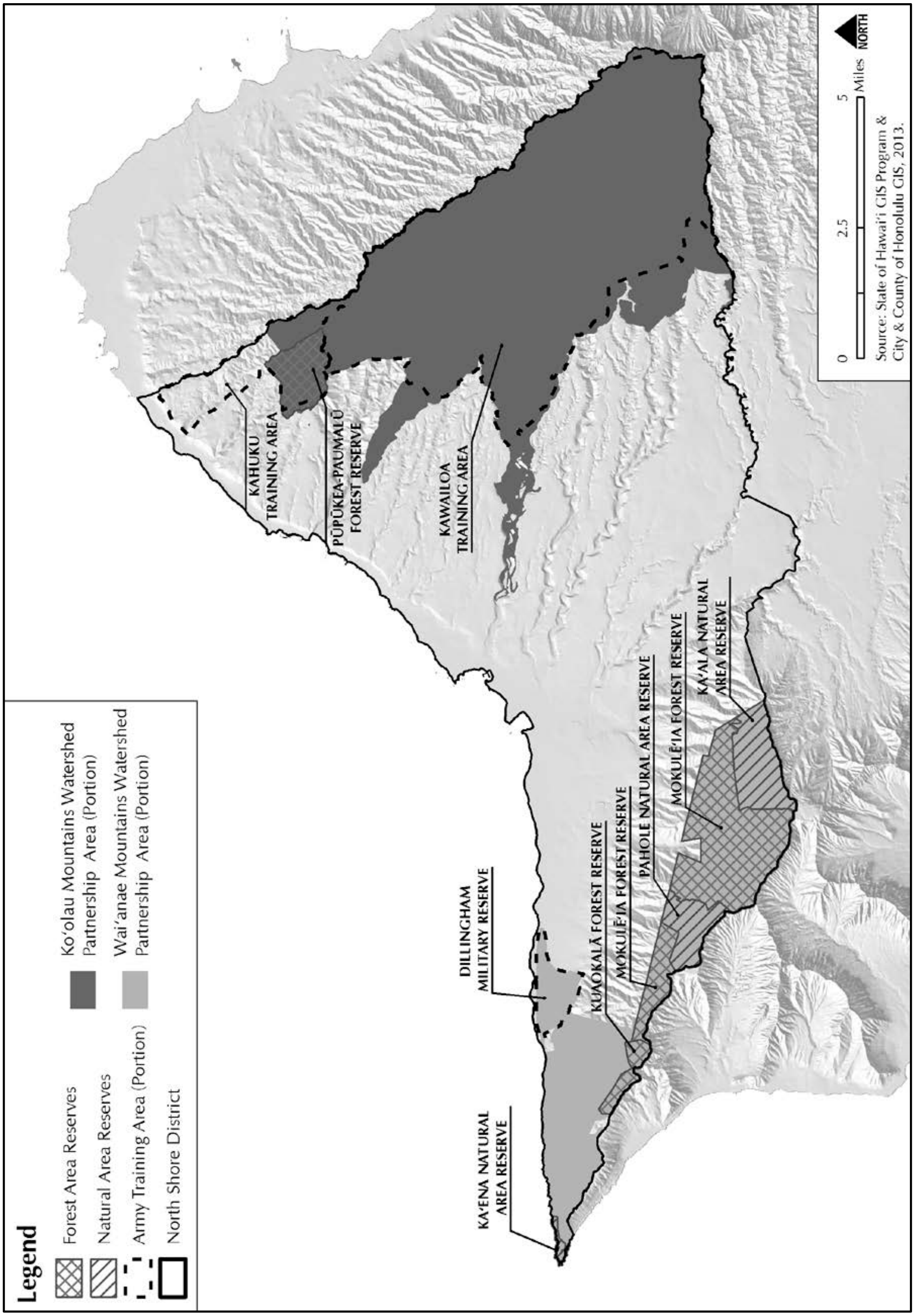


Figure 2.15 North Shore Ecosystem Management Areas

In KLOA, the U.S. Army has banded together with Kamehameha Schools (the landowner), USFWS, and DOFAW under a KMWP agreement. The parties formed a task group to undertake fencing of a 150-acre area of the ʻŌpaeʻula watershed to protect a sensitive native ecosystem from feral ungulate threat. The pilot project provided baseline information and regulatory protocols to gage future watershed work in the Koʻolau Mountains.[15]

Habitat within DMR is highly disturbed with very little of the native flora surviving, however small stands of native forest and shrubland can still be found on the cliffs of the Waiʻanae Range in the southwest portion.[103] Most of the Army's management at DMR is conducted within these small stands of the only known example of extremely dry closed canopy forests of the native soapberry *Sapindus Oʻahuensis* or lonomea. The maʻoliʻoli (*Schiedea kaalae*) is the only endangered plant known at DMR.[104]

Koʻolau Mountains Watershed Partnership: The KMWP area covers approximately 111,407 acres. KMWP partners for the North Shore include DLNR, Dole Food Co., Hiʻipaka, LLC (dba Waimea Valley), and Kamehameha Schools. The KMWP has participated in the following activities for the North Shore: finalized an ungulate management plan; goat removal from the Northern Koʻolau population; pig removal from the ʻŌpaeʻula fence exclosure; obtained high resolution aerial imagery for 39,000 acres of priority watershed; and surveyed weeds.[105] KMWP is also planning on expanding established fencing exclosures in areas such as the Upper Helemano drainage of the ʻŌpaeʻula fencing project, and Upper Kawaiʻiki Drainage.

Waiʻanae Mountain Watershed Partnership: The WMWP area covers 144,000 acres in the Waiʻanae Mountains. WMWP partners for the North Shore include DLNR and U.S. Army Garrison Hawaiʻi. These and other groups work together to cooperatively develop and implement management strategies for the Waiʻanae Mountains, mauka to makai. The WMWP has participated in the following activities for the North Shore: aerial imagery weed mapping and control;[106] meetings and community outreach on feral goat control; coordination of the Kaʻena Point Advisory Group; native plant seed collection and propagation; and assistance with Pahole weed control trials.[105] Future projects include watershed resource protection fences, native forest restoration in priority watershed areas, feral ungulate management and invasive weed control.[107]

Oʻahu Invasive Species Committee: OISC works to prevent new invasive species infestations and to eradicate incipient, high-threat species before they become widespread. Historical or episodic management includes, but is not limited to: monitoring, surveying, control of coqui frog, west nile virus, long-thorned kiawe, and false ʻawa. OISC also surveys and controls Pampas grass (Cortaderia selloana and C. jubata) and Fountain grass (Pennisetum setaceum).[108] OISC is another organization that partners with private, government, and non-profit organizations and individuals.[109] For the North Shore, OISC, Bishop Museum, the Hawaiʻi Department of Agriculture (DOA), and Oʻahu Army Natural Resources Program staff cooperatively developed a detailed map of *Chromolaena odorata* boundaries in KTA, an invasive weed infestation (dubbed the "next clidemia"). This map will be the first step in creating a comprehensive plan for addressing this highly invasive species.[110] In addition, OISC is partnering with Waimea Botanical Gardens to survey and control several plant target species.

2.4 TRADITIONAL PRACTICES AND CULTURAL RESOURCES

Hawaiʻi nui a kea
Loaʻa Oʻahu he wohi
He wohi na Ahukinialaʻa
Na Laʻamealaʻakona, he wahine

Oʻahu begotten of wohi rank
A chief of Ahu kini a Laʻa
Of Laʻamealaʻakona, a woman

This genealogical account of the chiefly birth of Oʻahu communicates not only the godly creative forces that gave birth to the Hawaiian archipelago but more importantly, describes the familial relationship shared between the Hawaiian people and their beloved lands.

The birth of the Hawaiian archipelago is credited to Papa and Wākea. Wākea, the upper province of the sky, is symbolic of the region from which sunshine and rain descend to fertilize the earth. Papa, the warm upper layer of earth, is where fertilized seeds await maturity to spring into life. Papa and Wākea are also credited as being the first parents of human life on earth. Through the birth of Hāloa, born from Wākea's own daughter, the first living child was named for "the long stalk" (hā loa), manifest as the original kalo that grew from the place where an earlier stillborn child, Hāloanakalaukapalili, was buried beside their house.

Thus, Papa and Wākea are the first parents of human life on earth as well as the plant life and animal life that feed upon it. These origins define the responsibility that rests with future generations to care for the elder Oʻahu, born of chiefly parents.

2.4.1 Traditional Cultural Practices

"Hawaiians, more than any of the other Polynesians, were a people whose means of livelihood, whose work and interests, were centered in the cultivation of the soil. The planter and his life furnish us with the key to his culture."[111] Understanding how Hawaiians worked with their surrounding environment to produce food provides keys to understanding their culture as a whole. These customs and practices distinguish Hawaiians as a people and their continued existence in an island environment.

Major aspects of Hawaiian lifestyle are embodied in customs and practices surrounding the cultivation of food including community life, family life, spirituality, stewardship, and the use of natural and cultural resources. Thus, to the Hawaiian mind, the natural elements - land, water, and ocean - form the basis of subsistence, cultural and religious beliefs, customs, and practices. ʻOhana living, or the presence of multiple generations in the extended family, ensured that ancestral knowledge of practices, customs, and traditions was passed down from generation to generation. Legends and chants that record the names of winds, rains, and prominent environmental features are sources of ancestral knowledge. Culturally prescribed behavior such as aloha ʻāina, and its companion expression of conservation through mālama ʻāina, ensure the sustainability of resources for present and future uses. The activities that are central to traditional and customary practices are dependent upon having access to and being able to care for and use natural and cultural resources of the land, ocean, air, and water.

Basic principles of Hawaiian stewardship and the use of natural and cultural resources recognize the ahupuaʻa as the most common unit of resource management. Geographically, an ahupuaʻa is typically a wedge-shaped land section that encompasses an area of land from the mountains to the sea. Mountain ridges also typically defined the boundaries of most ahupuaʻa. The land area of individual ahupuaʻa depended upon the availability of natural resources in that area.

Fresh water was one of the most coveted natural resources because of its life giving force, hence the origin of the saying wai ola "water is life." Hawaiians viewed water as a symbol of wealth and prosperity.[111] Thus in most instances, drier regions were split into larger ahupuaʻa to compensate for the relative lack of fresh water, while water rich regions were divided into smaller ahupuaʻa.[111] Healthy stream flow from mauka to makai provided drinking water, supported self-sustaining food cultivation activities including agriculture and aquaculture, and helped to create estuaries with abundant fisheries. Because water was viewed as a life force with spiritual connotations, water was not viewed as a resource that could be commoditized or privately owned; instead it was managed as a resource for the benefit of the entire community.[112]

Culturally, the concept of ahupuaʻa management recognized the interdependency and interconnectedness among the natural elements of land, air, water, and ocean as well as between people and place. Spiritually connected to their natural surroundings, Hawaiians depended on both the land and sea for survival. The system of ahupuaʻa management reinforced an extensive set of traditional practices and spiritual beliefs to protect the ahupuaʻa's natural resources from degradation and to ensure that the quality and quantity of these resources remained in abundance for future generations.[113]

Traditional practices varied throughout the different areas of an ahupuaʻa. The following section outlines how Hawaiians viewed the different sections of an ahupuaʻa and the associated traditional and customary practices associated with these areas. While this discussion is not meant to be exhaustive, it touches upon some of those elements necessary for traditional and customary practices.

WAO

The uppermost mauka regions of an ahupuaʻa were known as wao. The word wao refers to a place that is wild and distant and not often visited by man. Wao consisted of the upper forested mountain areas of an ahupuaʻa up to the mountain peaks or ridgelines. There are several divisions within the wao. The wao laʻau is the inland forested region. The wao kanaka, are the areas of the wao most accessible to man. In both the wao laʻau and wao kanaka, Hawaiians gathered koa wood for various uses such as canoes, utensils, and spears. Other resources were also gathered such as lau hala for thatch and mats, mamaki tree bark for kapa, and kukui nuts for oil. Above the wao laʻau and wao kanaka at the highest elevations of the ahupuaʻa was the wao akua – forest of the gods. These areas were seldom accessed by Hawaiians and were considered extremely sacred, as the wao akua were thought to be the realm of the gods and possessed both good and evil supernatural elements. Use of the land and resources in the wao was very limited as Hawaiians did not reside in this region of the ahupuaʻa and accessed these mountain forests only for gathering essential resources.[111] Today, these areas on the North Shore are primarily known as the conservation areas and may still be used for traditional gathering purposes (subject to landowner approval).

KULA

Below the wao, is the kula area. Kula consisted of the areas in the ahupuaʻa of sloping land between mountain and sea. Most kula consisted of great stretches of pili grass, a material which was used in the construction of hale. The areas of the kula closer to the ocean were called ko kula kai and those areas closer to the mountains were called ko kula uka. Cultivation of crops took place in the kula, although at a smaller scale when compared to the kahawai (fresh water) areas of the ahupuaʻa, as the kula areas were not the prime areas for crop cultivation. Kula areas in most ahupuaʻa on all islands are characterized by red dirt. Sugar cane and sweet potato grew well in this type of soil. Trees also existed in the ko kula uka regions, although the trees in this region were not as tall or dense as the trees found in the wao. The ko kula uka region provided Hawaiians with medicinal plants and herbs as well as wood for various uses.[111] The North Shore contains vast acreage of kula lands which are the primary agricultural lands today.

KAHAWAI

Kahawai literally means "the place of having fresh water" which most often included areas of land in close proximity to streams that flowed along valley floors. Thus, the kahawai areas of an ahupuaʻa were of prime importance to Hawaiians for this was where the most intensive cultivation of food crops took place. Unlike the red soils of the kula areas, the soils of the kahawai areas consisted of dark soils good for wetland kalo cultivation. It is in this region of the ahupuaʻa that the majority of loʻi terraces and ʻauwai existed. Hawaiians constructed their main dwellings in the kahawai areas or maintained temporary shelters there during periods of extensive cultivation.[111] The kahawai lands on the North Shore were the primary means that supported an estimated population of more than 300,000 at the time of Cook's arrival.[114]

KO KAHA KAI

The ko kaha kai areas consist of the coastal lands of the ahupuaʻa. The word kaha was used to refer to areas that were near the shore but were not good for planting. Activities that took place in this area were associated with the sea, including fishing, navigation, and housing canoes. In addition to these activities, fishing villages also existed in the ko kaha kai of some ahupuaʻa.[111] The ko kaha kai are places where people have more recently settled in the North Shore.

KAI

To Hawaiians, the kai (ocean) was an integral part of the ahupuaʻa. Fishing and gathering limu were some of the most common activities associated with this area of the ahupuaʻa. Hawaiians named different areas of the sea for their varied characteristics. Kai pualena referred to the areas where streams entered the sea. Puʻeone (literally heaps of sand) indicated the areas of the sea closest to land, including inshore dunes and outer sandbars. The portion of the sea inside the reefs where lagoons existed was called kai kohola. The poʻina nalu, also called kai poʻi (literally sea breaking) was the area further out from shore where waves break. Kai ele referred to the dark sea and kai uli referred to the deep blue sea.[111] The extraordinary poʻina nalu of the North Shore are what draw many locals and visitors to this area of Oʻahu.

2.4.2 Cultural Resources

The North Shore has numerous cultural resources and wahi pana. The concept of wahi pana is a cultural interpretation of spatially defined areas. Wahi pana are sacred sites or significant places such as heiau, shrines, churches, prominent pōhaku or stones, burial caves or grounds, geographic features, and natural features and phenomena associated with deities or significant natural, cultural, or historical events.[115] The following paragraphs describe known wahi pana on the North Shore.

2.4.2.1 Fishponds

The North Shore lands are known for their rich abundance of water and fishponds. Native Hawaiians cultivated loʻi kalo near streams, planted dry land gardens, and constructed fishponds which provided food to the kuaʻāina (country people), and the aliʻi (chiefs), entrusted with the protection and sustainable productivity of these resources.[115] The political importance of the district was grounded in the system of agricultural and aquacultural production, notably the extensive taro irrigation complexes of the well-known royal fishponds ʻUkoʻa and Loko Ea in Kawailoa Ahupuaʻa.[116]

ʻUkoʻa and *Loko Ea* are two important cultural resources for food production that contributed to the abundance and wealth of Waialua which was known as ʻāina momoma (fattened land). In pre-contact times, these royal ponds were linked to aliʻi who controlled production from the adjacent ahupuaʻa and socio-political center, Kamananui. Ruling chiefs who lived near the center of the island and the famous birthing stones of Kukaniloko in Wahiawā were also fed by the fish of ʻUkoʻa fishpond.[117]

ʻUkoʻa and Loko Ea Fishponds are linked to three ʻaumakua (ancestral deities) that are considered guardians and protectors for the pond areas. These guardians brought blessings of abundant fish and health to the people, and preserved the welfare of the ʻohana (families) of Waialua. These deities include the shark god Niukala, and the eel god Puhiʻula, but the most famous was the large moʻo (lizard) named Laniwahine.[118] Historical accounts indicate that there was a kapu of extracting the white ʻanae, which was considered as belonging to Laniwahine.[64] The distinguishing feature of the pond was its ample fish stock; comprised of a distinctive school of ʻanae and āholehole whose skin colorings emulated the markings of various types of other fish species. The mullet of ʻUkoʻa were full of fat when, as in all such ponds, the native guardian of the pond was remembered; at other times the fish had thin bodies and heads like wood, or sometimes disappeared altogether.[119]

2.4.2.2 Natural Features and Phenomena Associated with Deities or Significant Events

Kalua o Māua, also known as Three Tables due to the table-like reef outcropping, was an important area within the Pūpūkea MLCD for the gathering of water in ancient times. One of the flat outcroppings is named after a woman who was known as Kaluamāua. Tradition says that whenever you saw Kaluamāua "floating" (the exposed table-like reef tops) you would find fresh water bubbling up from the ocean bed there. In times of drought, water was retrieved from these underwater freshwater springs by diving for it and collecting it in gourds.[120]

Mary Kawena Pukui, a recognized Hawaiian cultural expert, explains the legend of Kawaihāpai, an ahupuaʻa in the Mokulēʻia area:

> *A drought once came there in ancient times and drove out everyone except two aged priests. Instead of going with the others, they remained to plead with their gods for relief. One day they saw a cloud approaching from the ocean. It passed over the house to the cliff behind. They heard a splash and when they ran to look, they found water. Because it was brought there by a cloud in answer to their prayers, the place was named Kawaihāpai (the carried water) and the water supply was named Kawaikumu'ole (water without source).*[121]

2.4.2.3 Heiau

An important element of the Waialua moku's cultural landscape is its strong connective force to the traditional understandings of spiritual realms and forces linked to physical sites. The overall concentration of archaeological sites throughout the moku indicate that Waialua was viewed as an important area to invoke and sustain mana (spiritual force and energy) for purposes of political and social order.[115] The presence of no less than eleven heiau (religious site or temple), several of which were luakini (sacrificial) class and therefore associated with ruling chiefs, testifies to the importance of the Waialua moku in the Hawaiian culture.[116]

Heiau Kupopolo stands near the beach on the Hale'iwa side of Waimea River. Measuring 266 feet long and 116 feet wide, and with at least three terraces, Kupopolo is considered a relatively large heiau and is relatively intact with internal features which include petroglyphs, upright stones, and a possible shrine.[122] During the reign of Kahāhana, who became ruler of O'ahu in 1773, Waimea's presiding priest was Kaopulupulu. In one legend, Kahahana asked his priest to determine whether the gods approved of him, and whether the island of Kaua'i would surrender if he invaded its shores. Kaopulupulu requested that a temple be built where he could get a signal and *"speak to the great chief Kekaulike (of Kaua'i) through the thoughts of the great akua Mahuka."* Heiau Kupopolo was built on the beach of Waimea Bay; however, when Kaopulupulu used it, he received no answer from Kaua'i. It was thought the temple was in the wrong location. Because no sign came, he called on the people to build a second temple high upon the cliffs. This was to become Heiau Puu o Mahuka. From the temple, Kaopulupulu sent out thought waves, and the answer quickly returned - Kaua'i wished for peace.[123] A partnership between Kamehameha Schools and the University of Hawaii's Department of Anthropology establishes a North Shore field school at Kupopolo Heiau, allowing archaeology students to survey the historically significant heiau.

Pu'u o Mahuka is the largest heiau on O'ahu, covering almost two acres. The highest of the three walled enclosures may date to the 17th century, with the lower two enclosures perhaps added during the 18th century.[124] The name is translated as "hill of escape". Located in Pūpūkea, this site is situated on a pali with a commanding view of Waimea Bay.[125] From this vantage point, signal fires were used to provide visual communications with another heiau at Wailua on the island of Kaua'i, nearly 100 miles away. Traditionally, food offerings were presented to the gods, but it is reported that human sacrifices may have also been offered here, perhaps marking success in war.[126] The high priest Hewahewa conducted religious ceremonies here, until the traditional religion was abolished in 1819. Pu'u o Mahuka Heiau was declared a National Historic Monument in 1962, in recognition of its importance to Hawaiian culture and history. The 4-acre property was placed under the jurisdiction of Hawai'i State Parks.[124]

Hale o Lono heiau is dedicated to Lono, the god of agriculture, harvests, weather, sports, and medicine. The site, located in Waimea Valley, was excavated, identified, and restored during an effort begun by Waimea Valley archaeologist Rudy Mitchell in 1985 and the first phase of restoration was completed in 1988. It is estimated that the Hale O Lono Heiau was built between 1470 AD and 1700 AD.[127]

Ke Ahu O Hapu'u (also the name of the bluff), located on the southern point of Waimea Bay, is an ancient heiau. The hapu'u is a type of sea bass. Once there lived two Kahuna who were also lawai'a or fishermen. One day they both went fishing in the bay and, after many tries, they came up empty. Time after time, they dropped their 'upena (net) but did not catch any i'a (fish). Ready to call it a day, on the last try they pulled in their net and found a pohaku (stone) and one fish. They threw back the fish and also the stone, which was the size of a human head. Later that night, they both had a moe-uhane (dream). The next morning, one of them said, "Last night I had dream." The other man said, "I too had a dream. I dreamed that the stone said he was cold and asked me to pull him out of the ocean." To their surprise, they had dreamed the same dream. The next day, they went fishing and retrieved the stone. They began to build a heiau in honor of the sacred pohaku. In the dream the stone said that his body was in Waialua. They retrieved the wooden body from Waialua (it was a large piece of drift wood in the form of a human body) and united it with the stone head. As a reward for their building the temple in his honor, Kāne Aukai brought an abundance of fish to the Waimea district. For many years, Waimea was famous for its multitude of fish species. The temple is still standing and is visited to this day by local fishermen, who leave offerings before fishing.[120]

2.4.2.4 Prominent Pōhaku or Stones

Kaiaka Bay Beach Park, a large 53-acre park, is on the north point of Kaiaka Bay. The beach park is the site of a legendary pedestal, or balancing, rock called Pōhaku o Lāna'i, which was said to have floated ashore from the distant land of Kahiki.[128] This large limestone formation stands alone near the edge of the bay, and is said to have been used as a lookout by fishermen in the region. When fish were sighted, the stone was beaten with a wooden mallet, and the resulting hollow sound was sufficient to gather together the fishermen of the village.[116] The beach and bay are used primarily for fishing and surfing.[128]

The ancestral belief is that Kaiaka Beach Park (Pua'ena) serves as a "leina a ka 'uhane" (spirit leap). This is an area of the physical realm where the souls of the departed pass on into the afterlife. Spirits of the recently departed leapt into the sea from an uplifted limestone rock and were met by ancestors who guided them safely to the land of spirits.[117] This site has an associative linkage, both in name and cultural function, to Ka'ena Point which is also a famous leina.[64] This leina has been described as a *"small rectangular platform of basalt cobbles, with scattered coral on the surface."* Its possible religious function is suggested by its size, the presence of coral, upright stones along the edge of the platform, and its vantage point.[89]

Pōhaku o Kaua'i marks the endpoint of a series of partially submerged rock outcrops that form the westernmost extent of O'ahu at Ka'ena Point. According to several recorded traditions, this rock formation was once part of Kaua'i.[89] Early Hawaiians used Ka'ena Point for fishing and feather collecting. Today, people of various cultures visit Ka'ena Point for fishing, hiking, bicycling, and other recreational and educational activities.[129]

2.5 SETTLEMENT HISTORY

2.5.1 Pre- Contact to Contact (1779)

In 700 AD, with the expanding Hawaiian settlement of the islands north from Hawai'i Island, O'ahu and the North Shore region became home to ancient Hawaiian communities that thrived at ocean/land/river junctures such as the Anahulu River and Waimea Valley. Such locations were ideal for the traditions and culture of the Hawaiians' symbiotic existence with nature, and were well suited to fishponds and the farming of taro and other staple foods. The North Shore is still highly regarded today for its fishing and agriculture.[130]

The district of Waialua is rich in legends, stories, proverbs, and myths. As can be expected from a place with the word "wai" in its name, water resources were abundant in Waialua. There were many springs, streams, tributaries, pools, shorelines, and nearshore areas that were named, indicating their importance. Additionally, there were several fishponds, watch towers to assist in nearshore fishing, and areas associated with sharks.[2]

Waialua can be literally translated as "two waters" and may refer to the two large stream drainages (Anahulu and Helemano-Poamoho-Kaukonahua) that were once used to irrigate extensive taro fields in the ahupua'a of Kamananui, Pa'ala'a, and Kawailoa (the more populous ahupua'a on the eastern side of the district).[131] In the pre-contact period, villages in the Waialua district were concentrated along the coast and the well-watered valleys of the ahupua'a on the eastern side of the district. The population of these ahupua'a had been estimated at 6,000 to 8,000 people before Western contact.[132]

In Kamananui, it was likely that sweet potato and bananas were planted at home sites along the ridge and near taro patches at the bottom of the gulch. The remains of *"the longest irrigation ditch of which there is any memory"* among native Hawaiians is located at Kamananui.[2] The intake was from Kaukonahua Stream, and could be traced as far as the intersection of the Mokulē'ia, Hale'iwa, and Honolulu roads[133] (this could possibly be near what is now known as Weed Circle). In general, the ahupua'a of Kawaihāpai, Keālia, and Mokulē'ia, on the western side of the district, were more arid, and were not as well-watered.[131] However, Kawaihāpai Stream, at one time, provided the water for several lo'i, which extended to Keālia.[121] These western lands were famed for their warm climate, cooling breezes, plant resources, and especially, marine resources.[131]

The significance of the district of Waialua and the ahupua'a of Kawailoa in the consciousness of native Hawaiians are suggested in the numerous traditions associated with the district and ahupua'a. Waialua is the site of a significant event in the consolidation of chiefly power in the islands. For the 28 generations from Hulihonua (the first man in the ancient Hawaiian past) to Wakea, no man was made chief over another. Kapawa was the first chief to be set up as a ruling chief. This was at Waialua, O'ahu; and from then on, the group of Hawaiian Islands became established as chief-ruled kingdoms.[119]

Prior to the close of the 11th century, the ahupua'a of Waimea was given to the kahuna (priest) of O'ahu by Kamapua'a, O'ahu's ruling chief of the time. Waimea Valley remained home to the kahuna nui (high priest) of O'ahu for over 600 years. The last was Hewahewa, the Chief Kahuna under the reign of Kamehameha.[130]

2.5.2 Contact (1779) to 1850

The first Westerners to land on O'ahu came ashore at Waimea Bay in 1779, aboard Captain Cook's ship and briefly anchored to replenish freshwater supplies after Cook's death on Hawai'i Island. The crew recorded that the area around Waimea River was *"well cultivated and full of villages and the face of the country is uncommonly beautiful and picturesque".*[130]

Beginning in the early 1800s, the sandalwood trade initiated economic and cultural transformations in Waialua Moku. It was the strict monopoly of the ali'i (chief) beginning with Kamehameha.[116] Among these ali'i, Ke'eaumoku Cox was the Hawai'i Island chief who had been given control of Waialua by Kamehameha. Diaries and journals of the western entrepreneurs on O'ahu record the early 19th-century sandalwood-based trade that intruded upon the established mores and customs of the Waialua population.[119] The demands put on the maka'āinana (commoners) to harvest wood for trade caused many taro fields to become fallow.[116]

After the death of Kamehameha in 1819, leadership of the Islands fell into the hands of Ka'ahumanu, the third of Kamehameha's wives. Together, Ka'ahumanu and Hewahewa brought an end to the ancient kapu system of Hawai'i. Hewahewa then retired to Waimea Valley.[130] As the sandalwood trade collapsed in the 1830s, Protestant missionaries began to establish their presence in Waialua.[116]

The first Western settlement came in 1832, when Protestant missionaries arrived to the Waialua district. Aboard the Thaddeus, the Emerson family anchored at Waialua Bay at the mouth of the Anahulu River, where the Anahulu (or Hale'iwa) Bridge is found today. They went on to establish an Emerson House and a Protestant church in the heart of the village and Hewahewa became a regular visitor to the church. Today, that church is known as the Queen Liliu'okalani Protestant Church, named after Hawai'i's last queen who vacationed in Hale'iwa at the royal summer home and worshiped at the church.[130] The first missionary census of the district, in 1831-32, recorded 2,640 people in Waialua, probably down 20 to 30% from the first decade of the century.[131]

During this time, whaling enterprises were emerging to fill the sandalwood void at Waialua. The islands became a victual (providing food supplies and provisions) and layover base in the mid-Pacific.[119] Between 1830 and 1850, the demands of the ali'i on the maka'āinana were severe. The missionary, John Emerson, commenting on the burdensome taxes on the people, wrote that the ruling chiefs *"get hungry often and send a vessel to Waialua for food quite as often as it is welcomed by the people."*[132] Supplies of produce and fresh and salted beef were in demand; and a trade in hide and tallow was also developing. As had happened during the years of the sandalwood trade, authority to commandeer valued goods from the commoners of Waialua was vested in the chiefs. The variety as well as amount of things being appropriated from Waialua by the ruling chiefs is impressive. *"The [letters of Gideon La'anui] speak of ocean fish taken in sweeps as well as great quantities of fish shipped from the old royal ponds of 'Uko'a and Loko Ea, of dry cooked taro (pa'i'ai) as well as poi, of sweet potato, breadfruit, shrimp, goats and pigs, timbers of different kinds, chickens, oranges and lemons - and often cash money."*[119]

Sugarcane was first cultivated at Waialua earlier in the century by the missionary John Emerson who grew sugarcane on his land from as early as 1836. He *"made his own molasses, grinding a few bundles of cane in a little wooden mill turned by oxen, and boiling down the juice in an old whaler trypot"*. This sugarcane plantation later passed through several hands, including the Levi and Warren Chamberlain Sugar Company (established 1865), Halstead & Gordon, and the Halstead Brothers.[116]

Cattle grazed on the lowlands in Waialua as early as the 1840s. Gideon La'anui had amassed a herd of 100 cattle by the time of his death in 1849. Other chiefs also had small herds, and the Protestant mission had at least 250. The main cause of destruction to the gardens of the native Hawaiians, however, were caused by the cattle ranches established in the uplands of Pa'ala'a and Kawailoa on land leased by the ali'i to foreigners, especially Robinson and Co., who leased the Helemano lands of upper Pa'ala'a, and Louis Gravier, who leased the Paukauila lands of Pa'ala'a. The cattle not only ranged over the upper pasture land, but also ran into and over the lowland sweet potato fields and coastal wetland taro patches. Many fences and walls were built during this period to a keep the cattle out, but the Hawaiians had little recourse for the damages caused by these animals.[116]

The human population continued to decline in the first part of the nineteenth century, and by 1848, the population was down to 1,616 persons. Much of this decline was due to a high death rate from newly introduced diseases, such as smallpox, typhus, and venereal diseases.[131] With the death of Hewahewa in 1848, whose bones remain at Waimea Valley, the rule of the kahuna nui came to a close. In the same year, the ancient kahuna land system was overthrown in a great land division known as the "Great Mahele". This western land system of land titles and deeds signaled the start of private land ownership in Hawai'i.[130]

2.5.3 1850-1900

During the Great Mahele, two descendants of missionaries, William Emerson and John T. Gulick, were the first foreigners to buy land in Mokulē'ia and Kawaihāpai. Over the next few years, Emerson continued to buy land from the original grantees or later owners until he owned a total of 2,605 acres in Waialua.[131]

In 1850, the first road from Honolulu to Waialua was built. With dwindling whale ship arrivals during the 1860s, the populaces of districts like Waialua, which had been dependent on the victualing trade, migrated to Honolulu and other parts of O'ahu. The whaling industry in the Pacific Ocean reached its peak in 1859. Prices for whale oil collapsed five years later.[116]

Following the death of Victoria Kamāmalu in 1866, Pa'ala'a Ahupua'a, along with her many other land holdings, was passed on to successive members of the ali'i, eventually becoming part of the Princess Bernice Pauahi Bishop Estate (i.e. Kamehameha Schools).[116]

The ponds and coastline in Waialua were used for salt making. Thomas Thrum noted that salt-making was a money-making enterprise for land-owners, usually the ali'i, and was a major item of export up to the 1880s, with a peak around 1870. He noted *"The enterprise was carried on very much after the ancient method of earth saltpans as described by Cook and Ellis. Waialua had a section of several acres at Paukauila, devoted to salt making, by a hui or company of adjoining kuleana holders, on the earth pan or vat process"*.[116]

In the latter half of the 1800s, Chinese immigrants began to cultivate rice in areas where taro had once thrived. A market for rice in California had developed as increasing numbers of Chinese laborers began immigrating there since the mid-19th century. Similarly, as Chinese immigration to the islands also accelerated, a domestic market opened.[116] By 1876 there was still a considerable amount of former taro land available for rice farming. At Waialua, about three hundred acres of swamp land were reclaimed for rice farming.[116] The high demand for rice land brought disused taro patches into requisition - especially because water rights were attached to them.[131] In 1892, 180 acres were under rice cultivation in Waialua. These rice fields extended from Kamananui Ahupuaʻa, across Paʻalaʻa Ahupuaʻa, to Kawailoa Ahupuaʻa.[116]

The diaries of Robert Perkins, an entomologist and ornithologist, reveal that Kawailoa and Waialua had become a favorite haunt of hunters in the 1890s:

> *At this time Waialua was much visited by sportsmen of Honolulu, as great numbers of golden plover were scattered over the forehills and along the coast. The native wild duck was common on the ponds and there were a good many pheasants amongst the lantana on the plains, but still more on the dry forehills below the forest and within this, before the trees became continuous or dense. Thick forests, no doubt, once came down at least to 700 feet, for there were many traces of fires, some very old and some comparatively recent. Great herds of wild pigs may sometimes be seen crossing the flats between the gulches, where they chiefly hide. I counted 42 in one lot, of different sizes, from the largest boar with great tusks to pigs only half grown...*[119]

Western entrepreneurial interests altered the Paʻalaʻa landscape. The Oʻahu Railway and Land (OR&L) Company, organized by Benjamin Dillingham in 1889, connected outlying areas of Oʻahu to Honolulu, and would later wrap around Kaʻena Point and along the north shore to Kahuku.[67] In 1897, Dillingham purchased the Kawailoa Ranch in Mokulēʻia. The ranch included over 2,000 head of cattle and over a hundred horses and mules on 10,000 acres of land. Dillingham also leased additional property in Mokulēʻia, including the Gaspar Silva Ranch, the James Gay Estate, and other lands in the area that he could secure. Dillingham's plan was to later sublease or sell the land at a profit, as the lands had potential for being developed into large-scale sugar plantations. He anticipated the land would become valuable once extensive irrigation systems were in place, and once the OR&L railroad was constructed.[67] During the last decade of the 19th century, the railroad would reach from Honolulu to Pearl City in 1890, to Waiʻanae in 1895, to Waialua in 1898, and to Kahuku in 1899.[116]

The development of a railroad system also spurred the development of large-scale sugar farming in Waialua.[116] The Waialua Agricultural Company was established in 1898 by J. B. Atherton, E. D. Tenney, B. F. Dillingham, W. A. Bowen, H. Waterhouse and M. R. Robinson, and was incorporated by the company Castle & Cooke. They bought the Halstead Brother's land and mill and began to buy or lease the adjacent lands, much of which was owned by native Hawaiians. They acquired many of the former irrigated taro lands in order to control the water rights of the region.[116]

By the end of 1898, the first cane crop, grown on 300 acres and harvested in 1899, produced 1,741 tons of sugar.[2] Land for a new railroad that would carry cane from the fields to the mill began to be surveyed in 1898, and by 1908 the new railroad connected the plantation lands in Waialua, Helemano, and Kawailoa.[116]

The sugar companies needed laborers, so Chinese, Japanese, Korean, Portuguese, Norwegian, Scotsmen, and later Filipino, were conscripted to work. The Asians were industrious and many soon left their sugar jobs to go into business for themselves, starting laundries, vegetable and meat markets, tailor shops, barbershops, restaurants, a post office, and others.

Capitalizing on the increasing numbers of visitors to the north shore of O'ahu who journeyed on his railroad, Dillingham opened the two-story grand Victorian Hale'iwa Hotel at Waialua Bay in 1899. The hotel was built on land leased from the Bernice Pauahi Bishop Estate (where Hale'iwa Joe's restaurant stands today). The hotel's name, Hale'iwa, translates as "home of the frigate bird" ('iwa), but as the 'iwa is a poetic symbol for an attractive person, so the figurative meaning of the name is "home of attractive people". The name eventually was used to identify the entire area above the bay and the "town" there, which at that time comprised of only the hotel, a church, and a courthouse. Eventually the area became the town of Hale'iwa.[116] With the opening of the Hale'iwa Hotel, the business climate expanded and tourism began to play a hand in the area. Many of the early business families and their original business buildings still remain in Hale'iwa town today. Some of the town's buildings are protected landmarks.[130]

2.5.4 1900-1950

Oral histories depict the changing composition of Waialua with the sugar industry and tourism. There are stories that describe the water in Anahulu Stream and Hale'iwa Bay as clearer and more productive than today; early interactions between locals and tourists on the North Shore; the social activity that centered around Hale'iwa Hotel and it prestigious guests, including Queen Emma and Charles Bishop; and the commercial side of Hale'iwa town in the early 1900s.[116]

Dole Food Company's pineapple growing and processing operation was established by James Dole as the Hawaiian Pineapple Company in 1901.[134] In 1913, Dole invested in a new machine that could peel and core thirty-five pineapples every minute. With a fully mechanized outfit, Dole's business boomed.[135]

Innovations in agricultural operations, including mechanical loading of harvested cane, hydroelectric power, and irrigation reservoirs and wells, helped to increase sugar production dramatically.[2] Some of the area's first ditches to control water flow were built in Waialua around 1902. Between 1900 and 1906, four surface water collection systems were constructed, giving the Waialua sugar plantation the largest water storage capacity in the state of Hawai'i. As a result of these efforts, sugar production increased from less than 5,000 tons to 20,000 tons from 1900 to 1905.[136] The Ito Ditch, built after 1911, diverted water to the Mokulē'ia sugarcane fields. The Waialua Agricultural Company was famous for its system of flume irrigation. The portable concrete flumes were set around the fields in a herringbone pattern and water was released to the field by small tin gates.[116] Mechanical loading of harvested cane began to replace manual labor using self-propelled machines in

1920. Later, the Waialua plantation would co-generate electricity and sell it to local communities, contributing a small percentage to Hawai'i's energy production.[136]

Waialua Agricultural Company, later named Waialua Sugar Company in the 1970s, continued to expand during the first decades of the 20th century, eventually operating on more than 12,000 acres, including a large portion of Kawailoa Ahupua'a which was leased from the Bishop Estate. Kawailoa became the site of one of the three camp units (the other two were Helemano and Waialua) into which the plantation was divided. Kawailoa Camp comprised of housing, social and recreational facilities for the workers of the adjacent fields and their families.[119]

Into the 20th century, rice continued to be cultivated in the Waialua district, and other areas within the Hawaiian Islands. However, it declined steadily during the decades leading up to World War II.[116] The marked-off fields shown on a 1919 U.S. War Department map are probably abandoned rice fields, constructed in the former taro land area where Pa'ala'a and Kawailoa Hawaiians once planted taro. Rice farming went into a steady decline for several decades before phasing out almost completely just before the beginning of World War II. By the early twentieth century, the main government road had been paved and improved. The 1919 map also shows other, unimproved (dirt, gravel, or macadamized) roads crossing the main road, which would become Kamehameha Highway and Kaukonahua Road. The bridge over the Anahulu River, now called "the Rainbow Bridge" was completed in 1921.[116]

A 1929 U.S. Geographical Survey map depicts increasing habitation and infrastructure density with a solid row of houses adjacent to Kamehameha Highway. Improved side streets lead to other housing clusters, especially near the beach. The former taro land area west of Hale'iwa is marked as small fields; it was probably too swampy at this stage to develop for housing. The 1929 map also shows one of the camps ('Ōpae'ula Camp 2) in the inland section of Waialua set up by the Waialua Agricultural Company for their sugar field workers. Unimproved roads and railroad tracks lead to these camps and to the upland sugarcane fields. By 1943, Hale'iwa is a maze of railroad tracks, irrigation ditches, pumps, reservoirs, camps, and other facilities constructed by the Waialua Agricultural Company. Schools and fire stations were built near the Waialua Mill, and the working population moved away from the Hale'iwa area to Waialua town near the mill.[116]

The Hale'iwa Hotel continued to operate in the first decades of the 20th century. It closed in 1928, but reopened in 1931 as the Hale'iwa Beach Club. It was taken over by the U.S. Army in the 1930s, serving as a center for recreational activities by military personnel in Hale'iwa during World War II.[116] At this time, the Hale'iwa Hotel and the associated golf course were utilized by the U.S. military.[116] The Hale'iwa Hotel closed and was torn down in 1952.[119]

Beginning in the late 1920s, portions of Kawailoa were developed for military operations as the United States expanded its armed presence in the Hawaiian Islands.[116] What would subsequently evolve into the Hale'iwa Auxiliary Airfield at Pua'ena began as a gunnery range in 1928. By November 1941, military facilities consisted of a small tent city, and the airstrip was more like a country road than a regular runway. During the Japanese attack on December 7th, 1941, two pilots took off from Hale'iwa Field and succeeded in shooting down two Japanese planes. Following the United States' entrance into World War II, Haleʻiwa and the surrounding area was subjected to major infrastructure improvements associated with military activity. A major runway was constructed from Puaʻena Point, extending to the present-day Kawailoa Drive. Military records indicate the construction of bunkers, housing and storage buildings, as well as improvements to the Haleʻiwa Auxiliary Field facilities. These improvements in turn created the demand for labor, services, and associated construction, which led to a further increase in population.[118]

By 1946, Robert P. Patterson, Secretary of War of the United States, executed a "Declaration of Taking," which stated that the land of Mokulēʻia, Aukuʻu, Kawaihāpai, Keālia, and Kaʻena, Waialua, Oʻahu, Territory of Hawaiʻi; Mokulēʻia Ranch and Land Company, Limited, et al. *"is taken... to provide for a military airfield, an ordnance storage area, and related military purposes incident thereto. The said land has been selected by me for acquisition by the United States for use in connection with such purposes, and for such other uses as may be authorized by Congress or by Executive Order, and is [r]equired for immediate use."* Several of the native Hawaiian families, who had retained their small plots of land through the 19th and early 20th centuries, now lost lands through this confiscation.[67]

The OR&L railway continued to operate during the war to transport military equipment and other goods, but announced the Company's decision to discontinue service in 1947, when shipping by truck became more economically feasible.[116] The Waialua Agricultural Company slowly made the change to truck transportation, until the last railroad line was closed in 1952.[67] The monocrop industry (sugarcane and pineapple) was the major contributor to Hawaiʻi's economy during the first half of the twentieth century, but by the late 1950s air travel began to create a new, more lucrative industry – tourism - which did not require the arduous labor of agriculture.[8]

2.5.5 1950-Present

During peak sugar production in the 1970s, over 120 fields averaging 100 acres in size produced 80,000 tons of sugar per year. Other historical land uses include pineapple production on 2,100 acres of land owned by the George Galbraith Estate and leased to the Del Monte Fresh Produce and Castle and Cooke.[2]

Waialua Sugar Company was one of the largest sugarcane plantations in the state of Hawaiʻi.[134] The influx of workers into the region caused significant population increase in the area. Before the initiation of large-scale sugar cultivation, the population in 1896 was 1,349 persons. By 1900, this had jumped to 3,285 persons, with an increase to 6,083 in 1910, to 8,397 in 1940, and to 9,171 in 1970. Historic maps and aerial photographs indicate that from 1953 to 1978, the density of housing complexes increased along the coast and Kamehameha Highway, but still avoided the former swampy taro lands.[116]

On a 1953 map, the initial draining of the former taro lands is depicted, as a reservoir with a pipeline is west of Haleʻiwa.[116] The Haleʻiwa Small Boat Harbor was completed in 1966.[116] Haleʻiwa Aliʻi Beach Park, the area formerly used as a golf course, was developed in 1969 after the land had been transferred from the Bernice Pauahi Bishop Estate to the City and County of Honolulu.[116] In 1984, the City established the Haleʻiwa Historic, Scenic, and Cultural District, mandating preservation rules and construction constraints for Haleʻiwa Town.[116]

In 1985, Castle & Cooke merged with the FlexiVan Corp. to become the Dole Food Company. In 1991, Dole Food Company's subsidiary, Waialua Sugar Company, produced 8% of the sugar in Hawaiʻi, but in the next few years the plantation became unprofitable.[116] International competition resulted in a dramatic decline in large-scale agriculture in Hawaiʻi. Waialua Sugar Company, the last sugar plantation on Oʻahu, closed in 1996.[2]

With increasing globalization of agriculture, an economic need to diversify agriculture arose and culminated in the mid-1990s. With the closure of the sugarcane plantation and in response to a growing consumer demand for high quality Hawaiian grown products, Dole initiated a program of diversified agriculture to assist displaced workers while expanding the local market with new products. Crops were selected and planted to take advantage of new, emerging markets and products included papaya, mango, seed crops, tropical flowers, sunflowers, and specialty crops such as coffee and cacao.[134] Del Monte ceased their pineapple operations in Poamoho in 2004, leaving Dole Food Co. as the sole remaining pineapple grower on the island.[2] Pineapple, along with diversified agriculture, continues along the North Shore today.[137]

Today, Haleʻiwa and Waialua, the region's two rural towns, still feature a country atmosphere with low-density residential structures and low-rise buildings, including housing, retail establishments, restaurants, and surf shops.[1] Rural residential communities include Mokulēʻia, Kawailoa, and Sunset/Pūpūkea.[1] Haleʻiwa Town is a prime destination for tourists and surfers from all over the world.[116]

2.6 DEMOGRAPHIC CHARACTERISTICS

Following World War II and the resultant tourism boom on Oʻahu, the North Shore has experienced a steady increase in population. In 1970, the North Shore's population was about 9,200 people, accounting for 1.5% of Oʻahu's total population. By 2000, the North Shore's population doubled to nearly 18,400 people, about 2.0% of the island-wide population.[1]

Table 2.11 North Shore Population[138]

	1970	1980	1990	2000	2010
North Shore	9,200	13,061	15,729	18,380	17,720
Oʻahu	630,528	762,565	836,231	876,156	953,207
% of Oʻahu	1.5%	1.7%	1.9%	2.1%	1.9%

Visitor studies also indicate that the North Shore's permanent residents share their area with an estimated average of 6,731 visitors on any given day. Surveys conducted by the Department of Business, Economic Development and Tourism (DBEDT) in 2003 and 2005 show that 51% of all visitors to Oʻahu visit the North Shore during their stay (or 2,423,446 visitors per year).[92]

Table 2.12 presents population and housing characteristics for North Shore. In 2010, the average household size was slightly smaller in North Shore (2.93 persons per household) than for O'ahu as a whole (2.95 persons per household). There were approximately 6,632 total housing units in North Shore, of which 13.0% were vacant.

Table 2.12 2010 North Shore Population and Housing Characteristics[139]

	Population	Persons per Household	Housing Units	Total Vacant Units	Housing Vacancy Rate
North Shore	17,720[‡]	3.05	6,678	868	13.0%
O'ahu	953,207	3.06	336,899	25,941	7.7%
% of O'ahu	1.7%	n/a	2.0%	3.3%	n/a

The 2010 Census reported 6,678 housing units in North Shore, an increase of 0.5% from 2000 (at 6,648 housing units). In comparison, O'ahu as a whole increased its housing stock (of 315,988 in 2000) by about 6.6% during the same time period.

2.7 TRANSPORTATION

This section describes the existing road, transit, and bikeway network on the North Shore.

The only major road arterial on the North Shore is Kamehameha Highway, a two-lane thoroughfare which links North Shore communities with Central O'ahu and Ko'olau Loa. It is a scenic highway which traverses the coastline from Hale'iwa through the communities of Kawailoa, Waimea, Pūpūkea, and Sunset Beach. Segments of Kamehameha Highway along the North Shore are sometimes closed during periods of high surf and flooding when roads are hazardous to travelers, or as a result of rock slides.[1] Hale'iwa Bypass, also known as the Joseph P. Leong Highway (Route 83), connects Kamehameha Highway east of Weed Circle to Kamehameha Highway north of Hale'iwa Beach Park.[140]

North Shore residents regularly experience "bottleneck" traffic congestion at Waimea and near Laniākea on weekend days and during periods of high surf. While congestion along Kamehameha Highway has been historically limited to the winter months when spectators travel slowly through the area to observe the high surf, traffic delays in the vicinity of Hale'iwa Town and Laniākea Beach have become frequent occurrences throughout the year.[1]

Traffic in the area could lead to environmental concerns. Working residents who run errands on the weekends feel that it is not worth it to travel to the dump, due to its location on Kamehameha Highway.[22] This could lead to dumping in illegal areas - a constant, bigger problem. For Dole Foods, it costs $20,000 to clean up metals four times a year, even with Aloha 'Āina.

Traffic regularly grinds to a halt as beach-goers stream across the road to view sea turtles at Laniākea. During high surf, waves and sand sometimes wash onto the highway. To alleviate congestion, a proposed North Shore bypass or highway realignment would jog inland and run parallel to the current Kamehameha highway through pasture and agricultural land, mostly owned by Kamehameha Schools. The City and County of Honolulu (City) acquired a three-acre parcel of land mauka of Kamehameha Highway to build parking and restrooms at Laniākea. If the road were moved inland of that parcel, beach-goers could access the shore without walking across the highway. An expanded beach park would also allow the shoreline to move with the seasons without threatening the highway.[141]

Minor arterials on the North Shore include Kaukonahua Road and Farrington Highway. Kaukonahua Road is a narrow two-lane roadway which goes from Wahiawā north to Thompson Corner and continues as Farrington Highway past Waialua and Mokulēʻia to Kaʻena Point. Numerous local streets, including Haleʻiwa Road, Goodale Avenue, Waialua Beach Road, and Pūpūkea Road, serve the residential communities.[1]

Kamehameha Highway, except for the segment from Weed Junction to Haleʻiwa Beach Park, Haleʻiwa Bypass, Farrington Highway, and Kaukonahua Road from Thompson Corner to Weed Junction, are under State jurisdiction. Except for former cane haul roads, most of the remaining streets in the North Shore district are under City jurisdiction.[1]

The City and County of Honolulu's TheBus system currently has four bus routes serving the North Shore district. The Haleʻiwa Park-and-Ride is located at the Waialua Community Association Facility in Haleʻiwa. The North Shore has a total of two miles in bike routes along the Joseph P. Leong Highway (Haleʻiwa Bypass Road), and seven miles in bike paths along Waialua Beach Road. An additional 59 miles of lanes, paths, and routes are proposed for the North Shore district in the Draft Oʻahu Bike Plan (2009). These bikeways are proposed along Kamehameha Highway, Farrington Highway, Kaukonahua Road, and throughout Haleʻiwa Town.[1]

Dillingham Airfield in Mokulēʻia is the only public airport facility located on the North Shore. The U.S. Army owns the field, but it is used jointly by the U.S. Army and the State of Hawaiʻi. The airfield consists of one 5,000-foot-long runway, hangars and tie-downs for smaller aircraft, facilities for air-taxi services, and storage. The airport services general aviation demands for small aircraft including civilian-powered flights, sailplane/glider flights, and parachute activities, as well as military flights. Air traffic is limited to daytime operations as a condition of the lease Department of Transportation has with the Army.[1]

The Haleʻiwa Boat Harbor is the only recreational boat harbor facility in the North Shore district. The facility is managed by the DLNR, Division of Boating and Ocean Recreation.[1] It is currently undergoing $2 million in improvements, including a new comfort station/office, repair revetment, and roadway and parking improvements.[1]

2.8 LAND USE

State land use is differentiated into four broad categories: Urban, Rural, Agriculture, and Conservation. More than half of the land in North Shore is designated Agriculture. Conservation lands make up approximately 40% of North Shore lands, which primarily encompass the mountainous ridges and upper valleys of the Koʻolau and Waiʻanae Mountain Ranges and the Mokulēʻia area. Urban lands account for just two percent of the land area in the district. There are no State Land Use District "Rural" lands in North Shore. *Table 2.13* displays the acreage and percentage of total North Shore lands that are in each State Land Use District and *Figure 2.16* illustrates the State Land Use Designations in North Shore.

Table 2.13 State Land Use Designations in North Shore

Land Use	Acres	% of Total
Agriculture	45,874	60%
Conservation	29,194	38%
Urban	1,563	2%
TOTAL	76,631	100%

At the City and County level, the two largest zoning districts in the North Shore district are Agriculture and Preservation, which comprise 97% of the total land area. *Table 2.14* displays the City and County Zoning acreage and percentage of total North Shore lands, and *Figure 2.17* illustrates this zoning.

Table 2.14 City and County Zoning in North Shore

Zoned Use	Acres	% of Total
Agriculture	42,441	55%
Preservation	31,887	42%
Country	1,029	1.3%
Residential	853	1.1%
Military/Federal	321	0.4%
Industrial	75	0.1%
Apartment	25	0.03%
TOTAL	76,631	100%

2.8.1 Land Ownership

There are eight landowners that own 500 or more acres in North Shore (*Table 2.15*).[142]

Table 2.15 North Shore Large Landowners

Landowner	Acres
Kamehameha Schools/Bishop Trust Estate	25,331
Dole Food Inc./Castle & Cooke	23,727
State of Hawaiʻi	10,787
Pioneer Hi-Bred International Inc.	3,160
Dillingham Ranch ʻĀina LLC	2,739
U.S. Federal Government	2,092
Hiʻipaka LLC	1,875

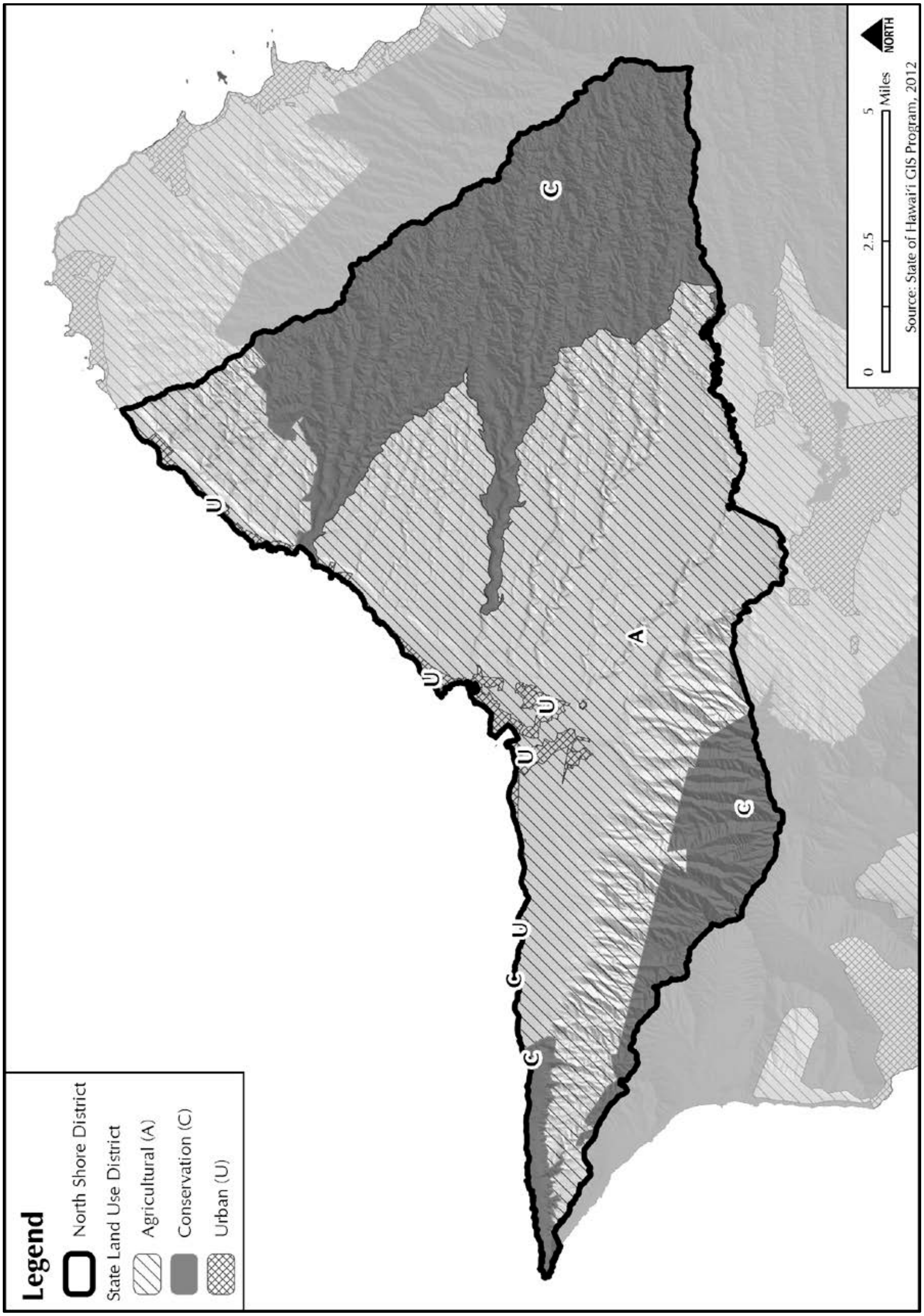


Figure 2.16 North Shore State Land Use Districts

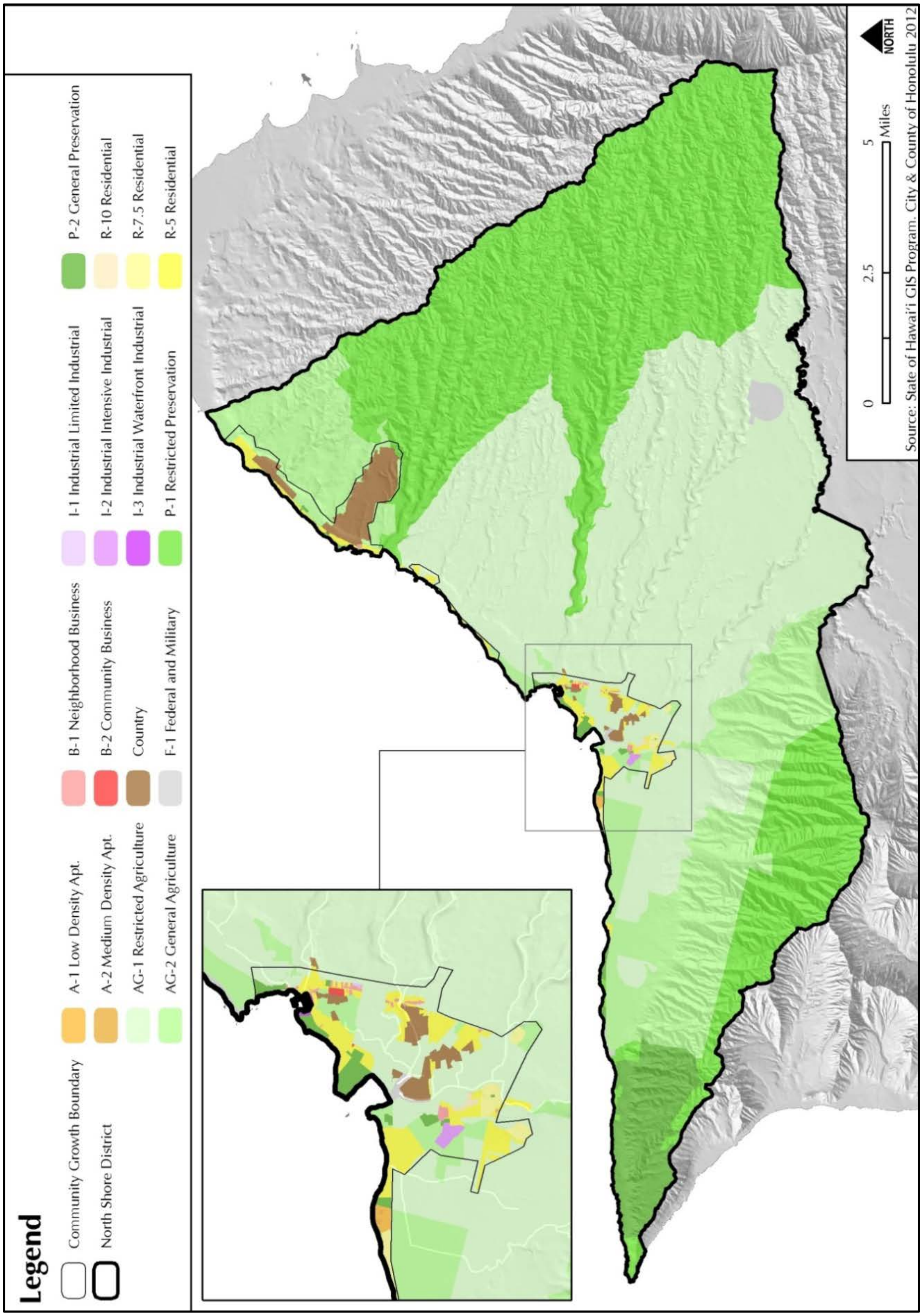


Figure 2.17 City and County of Honolulu Zoning Districts

Together these landowners own approximately 90% of North Shore's approximately 77,000 acres. The remaining 10% of land in the district is owned by various small private landowners.

Dole is currently offering for sale 16,000 acres of agricultural and conservation land. The State of Hawai'i recently bought 520 acres of agricultural land in the North Shore district plus an adjoining 1,200 acres in the Central district from Galbraith Estate.[143]

2.8.2 Agricultural Land Use

Agricultural lands help to define the North Shore's rural character, and is a major contributor to the North Shore's economy, providing jobs and economic opportunities for area residents. Agricultural products grown on the North Shore are sold throughout O'ahu. Agriculture from the North Shore is valuable for providing food for the island's population, and reducing O'ahu's dependency on imported foods.[92]

Of the approximately 27,000 acres of land in the North Shore zoned as "Agriculture" by the State, approximately 19,000 acres are considered "Prime", 2,275 acres are considered "Unique", 4,800 acres are considered "Other", and 290 acres are considered "Unclassified" in the Agricultural Lands of Importance to the State of Hawai'i (ALISH) Soil Ratings adopted by the State Board of Agriculture in 1977 *(Figure 2.18).* The following describe each of the ALISH zoning categories:

- **Prime** agricultural land is land best suited for the production of food, feed, forage and fiber crops. The land has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops economically when treated and managed, including water management, according to modern farming methods. Sugarcane was previously grown on these lands.
- **Unique** agricultural land is used for the production of specific high-value food crops. The land has the special combination of soil quality, growing season, temperature, humidity, sunlight, air drainage, elevation, aspect, moisture supply, or other conditions, such as nearness to market, that favor the production of a specific crop of high quality and/or high yield when the land is treated and managed according to modern farming methods. Some examples of such crops in the North Shore are coffee, taro, and non-irrigated pineapple.
- **Other** important agricultural land is of state-wide or local importance for the production of food, feed, fiber and forage crops, yet they exhibit properties such as seasonal wetness, erodibility, limited rooting zone, slope, flooding, or droughtiness that exclude them from the Prime or Unique agricultural land classifications. These lands can be farmed satisfactorily by applying greater inputs of fertilizer and other soil amendments, drainage improvement, erosion control practices, flood protection and produce fair to good crop yields when managed properly.
- **Unclassified** lands are not considered for classification as agricultural lands of importance to the State of Hawai'i if they are: 1) Developed urban land over 10 acres; 2) Natural or artificial enclosed bodies of water over 10 acres; 3) Forest reserves; 4) Public use (parks and historic sites) lands; 5) Lands with slopes in excess of 35%; and 6) Military installations, except undeveloped areas over 10 acres.

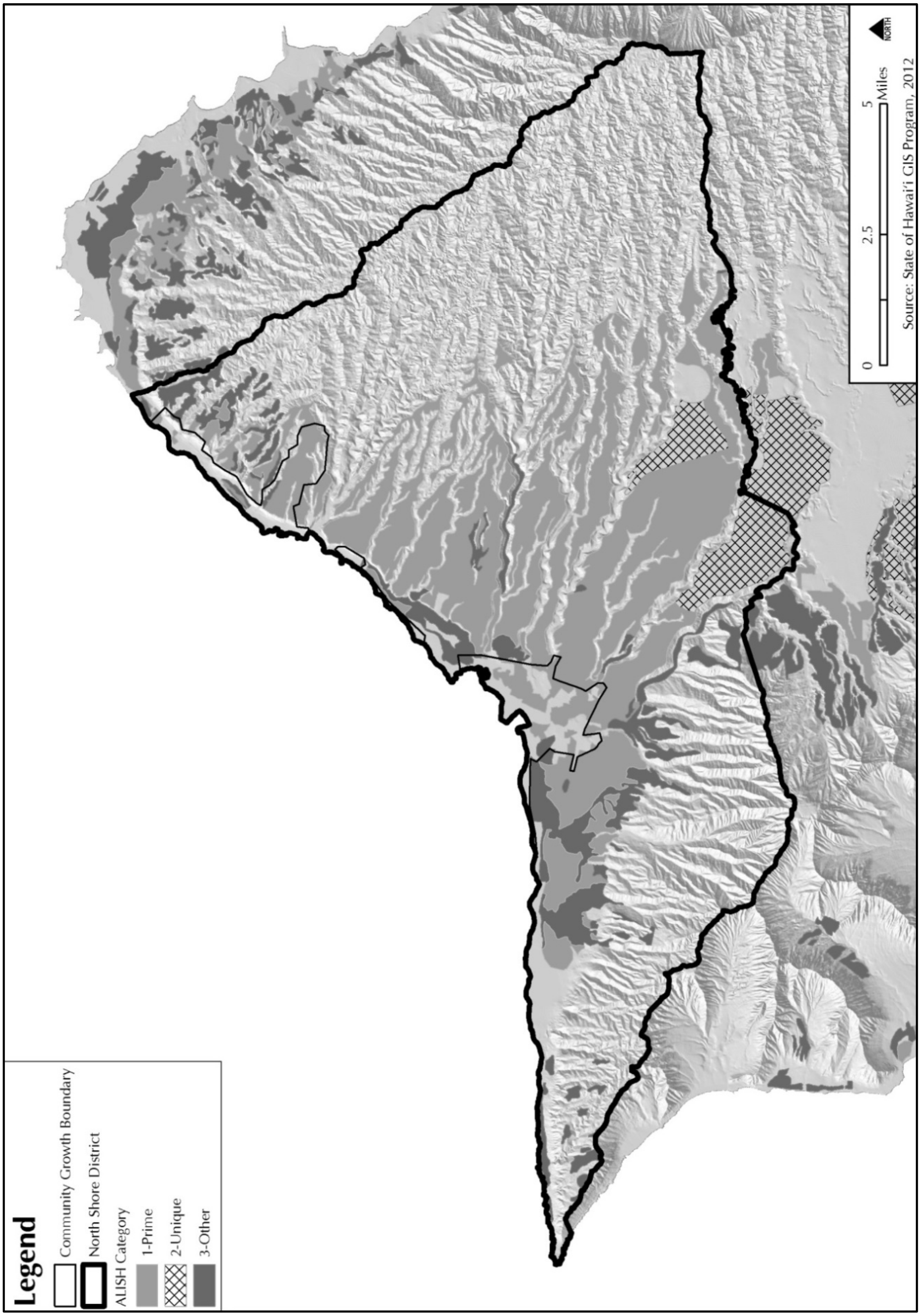


Figure 2.18 North Shore Agricultural Lands of Importance to the State of Hawai'i

North Shore agricultural lands extend north from Helemano Plantation towards Mokulēʻia and Sunset Beach, to the areas bordering Haleʻiwa and Waialua Towns. The most productive agricultural lands are located near or below the Wahiawā Irrigation System. Less productive lands include some of the Mokulēʻia, Kemoʻo and Waimea fields and fields in the foothills of the Koʻolau Mountain Range.[1] This is in part due to less water availability from the Wahiawā Irrigation System in those areas.

The identification and designation of Important Agricultural Lands (IAL) was first proposed at the 1978 Constitutional Convention and subsequently approved by voters in the same year. Enacted as Article XI, Section 3, of the Constitution of the State of Hawai`i, the State is required to conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally suitable lands. Act 233, SLH 2008, which provides incentives for designation of important agricultural lands, became effective on July 1, 2008, and triggered the commencement of the process to identify, map, and designate important agricultural lands throughout Hawaiʻi. Landowners were given a July 2011 deadline to suggest parcels for the designation. Castle and Cooke Homes Hawaiʻi, Inc. petitioned for 679 acres in 3 geographically separate properties for Central Oʻahu and North Shore for the predominant agricultural uses of diversified vegetable and fruit crops, flowers, and foliage.[144]

The City and County of Honolulu Department of Planning and Permitting is currently in Phase I of identifying IAL for Oʻahu. Phase I includes information gathering, meetings of an IAL Technical Advisory Committee, operationalizing IAL criteria, and preliminary draft IAL maps. Funds are being requested for Phase II which, depending on funding, will include public review and adoption of the IAL maps and county IAL incentives.[145]

A healthy agricultural industry continues to generate economic opportunities that are appropriate to North Shore's open space and rural qualities. Economic incentives to support the industry, including tax or other incentives or measures, have been enhanced and strengthened. These have helped to maintain productive agricultural lands, facilitate conversion from plantation crops to diversified agriculture, and promote long-term leases or sale of lands for farming.[1]

Dole Food Company is the largest agricultural landowner in the North Shore with approximately 23,000 acres, and owns much of the North Shore's irrigation water infrastructure, including ditches, reservoirs, dams, wells, and diversions. Dole is the last company on Oʻahu that continues to produce approximately 2,5000 acres of pineapple. Dole also produces coffee and cacao on approximately 200 acres, and leases its remaining lands for agricultural uses.

Farmers who lease lands from Dole farm vegetables, orchards, and seed corn. Waialua Farmer's Cooperative and other small farmers near Waialua High School grow asparagus, onions, potatoes, and tropical flowers. Large farms have orchards in Waialua where they grow papaya, banana, lychee, and mango. Other Dole tenant uses include ranching.

Kamehameha Schools owns approximately 9,000 acres of agricultural lands across five ahupuaʻa (Kawailoa, Lauhulu, Kuikuiloloa, Punanue and Kāpaeloa) and a portion of the Paʻalaʻa Ahupuaʻa. Current tenants and their crops include: Alluvion Inc. (tropical flowers), Mays Wonder Garden (hydroponic lettuce), Kawailoa Ranch Co. (horse boarding), Kawailoa Farms (vegetables), and Twin Bridge Farms (asparagus).[146] Twin Bridge Farms is home to Hawaiʻi's only commercially-grown asparagus, and Mays Wonder Garden is Hawaiʻi's largest and most modern lettuce farm, which is fast becoming the island's premier supplier of hydroponically grown lettuce.[147]

Plans for the area include encouraging additional diversified agriculture in the lower portions of the property, investigating opportunities for alternative energy development such as solar, wind, and hydro-power in the mid-regions, and stewarding the forested uplands.[2]

Pioneer Hi-Bred International grows seed corn on lands they own as well as lands they lease from Dole and Kamehameha Schools. Corn grows at a lower elevation, and the quantity of water use for farming corn is high per acre. Corn is not planted edge to edge so that there is some isolation to keep from cross-breeding. Leaving land fallow is part of the planting schedule. Pioneer also grows produce, wheat, and rice. Seed corn is a labor-intensive endeavor that involves hand pollination. Growing seed corn requires small plots in isolated areas, with limited intensity (1.25 crops/acre/year). Although seed companies are currently a major agricultural producer in Hawaiʻi, there is the possibility that other parts of the world may become more competitive for seed corn production.[148]

University of Hawaiʻi's College of Tropical Agriculture and Human Resources (CTAHR) has a *Livestock Experiment Station in Waialeʻe*, makai of Kamehameha Highway. The Experiment Station is an animal research and demonstration facility, owned by the State of Hawaiʻi. Waialeʻe covers 135 acres of which about 65 acres are fenced and 35 acres have the potential to be irrigated. The facility consists of an office space, staff cottages, slaughterhouse, feed storage/mixing facility and an animal housing for pigs, poultry, swine and cattle. Additional facilities include grazing pastures and an experimental waste to biogas conversion demonstration.[149]

CTAHR also runs the 53-acre *Poamoho Research Station* for research activities in tropical fruit trees, entomology, termites, cover crops, vegetable breeding, papaya breeding, post-harvest techniques, and taro. Some of the crops grown include tomato, corn, papaya, macadamia nut, avocado, green bean, mustard cabbage, bulb onion, eggplant, pineapple, sweet potato, banana, lychee, and mango.

Small-scale commercial forestry and ranching, including free range cattle, was initiated at the upper elevations where intensive cultivation of crops is not feasible. Other small ranches raise chickens (also known as broilers), turkeys, eggs, etc.

Dillingham Ranch is a historic 2,700 acre property located in Mokulēʻia. The ranch has an equestrian center featuring the Mokulēʻia Polo Field, grazes about 140 head of cattle, grows various palms and coconut trees, is available as a filming location, and offers various activities for guests.[150]

The 216-acre *Pūpūkea Ranch* overlooks Waimea Bay. Previous to acquisition in 2001 by Preservation Partners, the ranch was an agricultural property with pineapple and papaya as the main crops. Preservation Partners are now clearing out invasive plants and trees in order to selectively re-establish native Hawaiian flora and fauna.[151]

Sunset Ranch is located above Waimea Valley, and is one of the largest private estates on O'ahu (approximately 30 acres). It has recently been protected by a conservation easement in partnership with the North Shore Community Land Trust and The Trust for Public Land. The ranch is primarily dedicated to equine operations, including a riding trail, riding field, horse stables and indoor riding arena. Sunset has a fruit tree farm, and is planning a Hawaiian plant nursery as well as a state-of-the-art aquaponics facility.[152]

Aquaculture occurs at specific sites in Mokulē'ia, Waialua, Hale'iwa and Kawailoa. Hawai'i Fish Company Inc., is a multi-species aquafarm formed in 1978. It is Hawai'i's largest tilapia farm with a pond eight acres large and over 100 feet deep, fed by cool natural springs.[153]

North Shore is home to O'ahu's largest certified organic farm – Poamoho Organic Produce in Waialua. Several other small farms on the North Shore feature organic products. As diversified agriculture continues to develop and adapt to changing market conditions, other suitable agricultural crops and uses may be introduced in the future.

Kalo is grown at several small farms, including Ku'u Home Kula'iwi, Kamananui Farm and Education Center, and Na Mea Kupono Lo'i Kalo. Many of the kalo farms primarily provide community education.

With the sugar plantation closures in the 1990s, displaced sugar workers began farming diversified agriculture. Southeast Asian immigrants began farming in the late 1970s and their numbers have increased through to the present time. There are challenges relative to this shift in the farming population. Many of the former plantation workers do not have farming skills, and the immigrant farming population is unfamiliar with the U.S. regulatory environment.[154] There are gaps in training opportunities and education for these farmers, resulting in ill-advised and unnecessary pesticide use, and large areas of bare ground fallow fields.[154]

2.8.3 Preservation Land Use

The forested *mauka* areas of the watershed are mostly in forest reserve. Forest reserves are multi-use land areas that are meant to provide a variety of public uses and benefits, serving as wildlife refuges and recreational areas.[92] The State Department of Land and Natural Resources develops management goals for each of the reserves that reflect the resources it contains.[92] The North Shore district includes three forest reserves: Mokulē'ia, Kuaokalā, and Pūpūkea-Paumalū (*See Figure 2.14*).

The Mokulē'ia Forest Reserve surrounds Pahole Natural Area Reserve and also supports the endangered O'ahu 'elepaio as well as various species of rare, threatened and endangered plants. Mokulē'ia Forest Reserve occupies approximately 3,341 acres, to the east and west of Pahole Natural Area Reserve.[155] Hiking, bicycling, 4-wheeling, hunting and camping are allowed on the trails and firebreak roads.[156] At Kuaokalā Forest Reserve, there are public hunting areas for game mammals and game birds in the Kuaokalā Game Management Area. Hiking, bicycling, and camping are allowed along Kuaokalā Trail.[156] A majority of the Pūpūkea-Paumalū Forest Reserve is within the Army's Kahuku Training Area (KTA). Public hunting is allowed in the Reserve, while Army hunting is allowed at the nearby Kahuku Hunting Area.[157] On December 15, 2011, 64.8 acres were withdrawn from the

Pūpūkea-Paumalū Forest Reserve by Governor Neil Abercrombie through Executive Order 4395. This acreage was part of a land exchange between DLNR and the Boy Scouts of America, involving the exchange of private lands in Waikele, O'ahu, for public lands located on the islands of O'ahu, Kaua'i, and Hawai'i.[158]

2.8.4 Recreational Land Use

The North Shore is known for its numerous beach parks, world famous surf spots, and abundant mauka and makai resources. The North Shore is a place for rest and recreation that offers opportunities to enjoy the country atmosphere, numerous white sand beaches, and mountain areas. Mauka areas provide opportunities for hiking, camping, hunting, and horseback riding. Coastal waters, beaches, and parks are linked by walkways and bicycle routes. Maintenance and improvements to existing beach parks, additional access to the shoreline, and acquisition of beach right-of-ways continue to be a priority.[1]

Table 2.16 North Shore Parks

Owner	Park	Acreage
Private	Waimea Valley	1,875.0
	Pu'uiki Beach Park	10.0
	Subtotal	1,885.0
State	Pūpūkea-Paumalū State Park Reserve	1,144.0
	Ka'ena Point State Park	779.0
	Pu'u o Mahuku Heiau State Monument	5.7
	Subtotal	1,928.7
City & County	Kaiaka Bay Beach Park	52.8
	Mokulē'ia Beach Park	38.5
	Pūpūkea Beach Park	36.6
	Makaleha Beach Park	27.7
	Waiale'e Beach Park	25.7
	Waimea Bay Beach Park	22.2
	Hale'iwa Ali'i Beach Park	19.3
	Sunset Beach Park	17.7
	Hale'iwa Beach Park	15.7
	Chun's Reef Beach Support Park	3.0
	Laniākea Beach Support Park	3.0
	Banzai Rock Beach Support Park	2.3
	Sunset Beach Support Park	2.1
	Kahawai Beach Community Park	1.5
	'Āweoweo Beach Park	1.4
	'Ehukai Beach Park	1.2
	Sunset Point Beach Park	0.9
	Kawailoa Beach Park	0.4
	Subtotal	**272.0**
	Grand Total	**4,085.7**

North Shore has approximately 4,000 acres of park lands. *Table 2.16* lists North Shore's parks and their corresponding acreages. Waimea Valley is a cultural and ecological park owned by Hi'ipaka, LLC. This cultural park accounts for 46% of all park land in the district, while State parks account for approximately 47% of park land in the district, with beach and shoreline parks accounting for the remainder. Pūpūkea-Paumalū State Park Reserve (28% of all park lands) was acquired in 2007 by Federal, State, and City governments, community organizations, and private individuals, who managed to successfully raise funds to purchase the property for the benefit of the public. This scenic viewshed is now permanently protected and is directly makai of the Pūpūkea Marine Life Conservation District. Trust for Public Land was instrumental in the acquisition of this land as well as Waimea Valley. There are no golf courses within the North Shore district, and none are planned.

2.8.5 Residential and Commercial Land Use

The North Shore Sustainable Communities Plan's Community Growth boundary directs the development of new housing units to areas in and around Hale'iwa and Waialua. The intent is to preserve open space and agricultural lands while providing access to accommodate existing and future housing needs with a mix of housing types.

The North Shore Sustainable Communities Plan supports commercial activity in the towns of Hale'iwa and Waialua while retaining their historic and "country town" character.[92] Within the next 10 to 20 years, Kamehameha Schools is planning a plantation-style Town Center infill development in Hale'iwa, consistent with the rural residential designation in the North Shore Sustainable Communities Plan. No other major development of housing and commercial uses is planned in the North Shore region.

2.8.6 Military Land Use

On the North Shore, the U.S. Army owns and leases the Helemano Military Reservation, with housing, related community facilities and operational uses. The Kawailoa and (a portion of) the Kahuku Training Areas are in the North Shore district and are used for maneuver training activities. Kawailoa Training Area is the largest training area on O'ahu, and can support small infantry maneuvers, helicopter training, and mountain and jungle warfare training.[159] Kahuku Training Area is primarily used for tactical maneuver and warfare training. Kahuku Training Area's non-military land is used for recreation - specifically hiking, biking, and hunting.

Dillingham Military Reservation, also known as Dillingham Army Airfield, was initially established as Kawaihāpai Military Reservation in 1927, then redesigned as Mokulē'ia Airfield and fully utilized after the outbreak of World War II. Following World War II the airfield was inactivated in 1948. Today, the Army reservation is used for small unit maneuvers of platoon and squad size, including para-drop and night vision goggle exercises. Helicopters also use the site for training for both day and night tactical flight operations. The runways are jointly used by civilian planes and commercial gliders and are leased to the State of Hawai'i.[160] Other public recreation/non-military uses include parachuting, sky diving, hang gliding, and hiking.[161]

2.8.7 Industrial Land Use

The Waialua Sugar Mill site, approximately 75 acres, has been reinforced as the industrial center for the region. Approximately 40 businesses are located in and around the Old Sugar Mill, in Waialua Shopping Center, and along Farrington Highway. In addition to industrial uses that support the agriculture industry, other industrial uses include boat and car repair, surfboard manufacturing and repair, manufacturing of crafts and island products, clothing and souvenir manufacturing, wholesale activities, and warehousing.[1]

2.9 PREVIOUS RELEVANT PLANS

The Hawai'i State Water Code requires that the County Water Use and Development Plans incorporate the Hawai'i Water Resources Protection Plan, Hawai'i Water Quality Plan, State Water Projects Plan, Agriculture Water Use and Development Plan, and county land use plan. This section provides a brief summary of these plans, which are indicated by an asterisk mark (*). There have been several other notable water use or watershed management related planning efforts that have previously occurred statewide or on the North Shore that are relevant to this planning process. These plans are presented beginning with the most recent.

2013 Update of the Hawai'i Water Reuse Survey and Report
State of Hawai'i Commission on Water Resource Management (2013)
This report is an update of the original 2004 Water Reuse Survey and Report. Findings in the update show the annual volume of recycled water beneficially reused in Hawai'i has not substantially increased since then. Current recycled water usage is described for each County. Traditional use of recycled water has been for golf course irrigation; however with the availability of higher quality water, industry use has grown and the number of landscape irrigation projects has increased. The use of recycled water for agricultural irrigation has great potential for expansion. Obstacles can delay or prevent water reuse projects from being implemented, but they are not insurmountable. Setting the price of recycled water should encourage its use and should not be more expensive than other water sources. Public acceptance is a critical component for the success of all water reuse projects, and it is highly recommended that a proactive and concerted effort be placed on educating the community, politicians, administration officials, and local farmers about the safety of recycled water and the reasons why water reuse projects need to be developed.

The North Shore Greenprint
Trust for Public Land (2012)
In 2009 the North Shore Community Land Trust (NSCLT) began a visioning process aimed at conserving the heritage of the North Shore. NSCLT partnered with The Trust for Public Land (TPL) to develop a Greenprint for guiding voluntary land conservation with willing landowners. The Greenprint is based on local and regional conservation priorities. During the Greenprint process, NSCLT and an inclusive steering committee, with information gleaned from existing and past efforts as well as public information-gathering sessions, identified the lands on the North Shore that are most important for meeting multiple land conservation objectives. The plan includes a detailed set of color-coded maps and action strategies.

North Shore Regional Wastewater Alternatives Plan
City and County of Honolulu Department of Environmental Services (2012)
The North Shore Regional Wastewater Alternatives Plan (NSRWWAP) was intended to update and revise previous wastewater planning efforts for the region. This planning effort attempted to first understand the values of the North Shore community, and then develop technical wastewater treatment alternatives that are consistent with these values. As a result, a decentralized system of treatment and disposal is proposed. Decentralized systems lend themselves to rural, spread-out, communities particularly where the geography makes it difficult to collect and treat at centralized facilities.

North Shore Sustainable Communities Plan*
City and County of Honolulu Department of Planning and Permitting (2011)
The plan includes geographic boundaries and policies that support the role of diversified agriculture and commercial activity in the towns of Haleʻiwa and Waialua while retaining their historic and "country town" character. The plan also sets forth the policies and guidelines for North Shore parks and recreational opportunities. The Open Space and Natural Environment section emphasizes an integrated approach to resource management that highlights the Native Hawaiian concept of ahupuaʻa, seeking to preserve valued natural features, agricultural lands, and recreational areas.

Oʻahu Agriculture: Situation, Outlook and Issues
City and County of Honolulu Department of Planning and Permitting (2011)
This report provides an assessment of (1) agronomic resources on Oʻahu, (2) the current situation and outlook for agriculture, and (3) issues affecting agricultural land. Topics analyzed also include supply, use and availability of farmland; economic contribution; and agricultural trends. The material covers food crops, seed crops, flowers and nursery products, biofuel crops, commercial forests, aquaculture, and livestock activities.

Waialua-Kaiaka Watershed Study
Townscape, Inc. (2010)
The purpose of the Waialua-Kaiaka Watershed Study (WKWS) is to provide guidance to the City and County of Honolulu on how to improve the surface water quality of Waialua Bay, Kaiaka Bay, and their tributaries so that they meet their respective State water quality standards. In order to make proposed water quality improvement actions eligible for Clean Water Act §319 non-point source grants, the City followed US EPA guidance in developing a watershed plan. ENV's Phase I of the WKWS included a general watershed analysis and calibration of a Watershed Analysis Risk Management Framework (WARMF) water quality model for Kaukonahua and Poamoho Streams. The following additional phases will continue the effort to develop a complete Waialua-Kaiaka Watershed Plan: Phase II - Data Collection; Phase III - Water Quality Model; and Phase IV - Watershed Plan. Once the Waialua-Kaiaka Watershed Plan is complete, ENV and other partners may seek funding to implement water quality improvement actions.

Rapid Watershed Assessment – North Shore Watershed
US Department of Agriculture Natural Resources Conservation Service (2009)
This Rapid Watershed Assessment (RWA) was compiled by the US Department of Agriculture Natural Resources Conservation Service (NRCS) to assist local land managers, planners, and others in evaluating opportunities to implement conservation and resource protection measures within the North Shore watershed. This document is the first component of a two-part assessment, which includes a Watershed Profile and Assessment of Conservation Opportunities. This Watershed Profile gives an overview of geographic and social attributes in the watershed, and summarizes current natural resource conditions that are particularly relevant to management of agricultural and natural lands. A synopsis of NRCS-backed activities completed between 2005 and 2007 provides an indication of resource protection progress as well as prospects for future partnerships in various land-use categories.

Hawai'i Water Resource Protection Plan*
State of Hawai'i Commission on Water Resource Management (2008)
CWRM is responsible for the preparation of the Water Resource Protection Plan (WRPP), which is a key component of the Hawai'i Water Plan. The objective of the WRPP is to protect and sustain ground and surface water resources, watersheds, and natural stream environments statewide. Such protection requires a comprehensive study of occurrence, sustainability, conservation, augmentation, and other resource management measures. One of the key components in the 2008 version of the WRPP is the identification of hydrologic units and their characteristics, including the quantity and quality of available resources, and requirements for beneficial in stream uses and environmental protection. This plan is currently being updated.

Kaiaka Bay Watershed Participatory Assessment and Action Project
Yost, Russell (2008)
The Watershed Participatory Assessment and Action (WPAA) Project identified numerous community concerns, some of which were not anticipated at the outset of the project. Although some issues and concerns were provided a solution, others were too complex, poorly understood or required costly implementation. For example, concerns such as waste and water quality concerns were identified, but causes, controls, and community evaluation of corresponding best management practices could not be identified. The project alerts the community to several important issues dealing with flooding, water pollution, sediment and siltation, and human waste management, all of which have contributed to the reduced quality of the waters in Hale'iwa and Waialua and, ultimately, to reduced quality of life of the community. Highlights of project results include 1) the establishment of a standing committee of the North Shore Neighborhood Board to work at a watershed-level to address the multiple community concerns and issues of flooding, water quality, waste management and reduction in hazards; and 2) increased awareness by the community of flooding hazard, poor water quality, and the importance of education as a best management practice.

Assessment of the Wahiawa Irrigation System
State of Hawai'i, Agribusiness Development Council (2007)
The Agribusiness Development Corporation (ADC), which is administratively attached to the State of Hawai'i Department of Agriculture (DOA), was tasked with evaluating whether the State via the ADC should take over the privately owned Wahiawa Irrigation System (WIS), including Lake Wilson. This study involved a review of the ownership, legal rights, obligations, and liabilities of the various parties involved with the WIS; an inventory of the existing infrastructure; an evaluation of the condition of the system; an estimate of the cost of making necessary major repairs; and an assessment of the water and sediment quality in Lake Wilson.

Agricultural Water Use and Development Plan*
State of Hawai'i Department of Agriculture (2004)
The major objective of the Agricultural Water Use and Development Plan (AWUDP) is to develop a long-range management plan that assesses state and private agricultural water use, supply, and irrigation water systems. The plan is intended to be a master irrigation inventory plan which identifies system rehabilitation needs and prioritizes system repair. Agricultural lands are extensive and can require significant quantities of water to maintain productivity. The AWUDP is intended to promote the agricultural self-sufficiency of the State and maintain once important agricultural water systems. This plan is currently being updated.

State Water Projects Plan*
Department of Land and Natural Resources Engineering Division (2003)
The purpose of the State Water Projects Plan (SWPP) is to provide a framework for planning and implementation of water development projects to meet projected demands for State projects over a 20-year planning horizon. The objective of the SWPP is to review current and future state water projects to ensure orderly authorization and development of the state's water resources. Each State department is surveyed to inventory existing and proposed State sponsored projects, associated water requirements by island and hydrologic unit, and proposed sources to meet the demand. Agency plans for future source development should be coordinated with DLNR and integrated within the County Water Use and Development Plans. This plan is currently being updated.

Hawai'i Water Quality Plan*
State of Hawai'i Department of Health (1990)
The Water Quality Plan outlines the regulations, standards, and resource management policies that define the quality to be maintained in ground and surface water resources and includes federal/state/county goals, objectives, and policies related to water quality. The plan also identifies water quality monitoring requirements and enforcement provisions.

DOH is currently undertaking numerous program efforts which will contribute to the update of the Water Quality Plan. Such programs include the Source Water Assessment Program (SWAP), and various other water quality management and water pollution control efforts, including the identification of impaired water bodies and the development and implementation of TMDLs. Results of these ongoing program efforts, such as SWAP, will be incorporated in an updated Water Quality Plan. The Water Quality Plan, together with the WRPP, establishes the overall protection framework for our State's water resources. This plan is currently being updated.

2.10 STAKEHOLDER CONSULTATION

2.10.1 Goals and Objectives of the Consultation Process

The Stakeholder Consultation process emphasized a community-based approach through extensive discussion and consultations with residents, community leaders, community organizations, landowners, business owners, public agencies and elected officials. Interested and active public and private stakeholders provided valuable insights during the course of the planning process regarding:

- Defining aspects of North Shore that people value
- Defining key water use and watershed related issues in North Shore
- Developing policies, actions, and strategies for this plan
- Evaluating proposed policies, actions, and strategies

The stakeholder consultation process included small group and individual one-on-one "talk story" meetings with elected officials, community groups and individual community members, and community meetings. Community meetings to date have included the following topics: 1) Preliminary Watershed Analysis; and 2) Water Use and Development in the North Shore. The North Shore and the Wahiawa-Whitmore Village neighborhood boards were also updated periodically of the plan's process and content. Board of Water Supply staff also met with government agencies at the City, State, and Federal level.

The Board of Water Supply also hosts a Watershed Management Plan web page that includes information on the North Shore Watershed Management Plan and its development.

2.10.2 Stakeholder Identification

Stakeholders represented a broad range of community members, organizations, and public agencies that are interested in, are affected by, or could affect activities related to the development of the North Shore Watershed Management Plan. Three resources were used to identify potential stakeholders: 1) Database of past participants in previous North Shore planning projects; 2) referrals from community members, agencies and elected officials; 3) relevant reports and news articles.

During initial outreach meetings, stakeholders were asked "Who else should we talk to?" This process identified additional community members that should be consulted. Government agencies and elected officials also helped to identify stakeholders both within the North Shore community as well as within other agency departments or divisions.

2.10.3 Consultation Process

The initial consultation process involved small group and individual meetings and telephone communication with elected officials, various community organizations, landowners, government agencies, and respected individuals in North Shore's communities. The purpose of these meetings was to inform people about the plan and the planning process, to identify community values and issues, and to clarify information. A summary of the community values and issues is included at the end of this chapter.

COMMUNITY ORGANIZATIONS AND INDIVIDUALS

From October 2011 to March 2013, a total of 21 small group and individual meetings were conducted that involved approximately 27 individuals. *Table 2.17* displays the community organizations, individuals, and landowners that were consulted during this process.

Table 2.17 Community Stakeholders Consulted

Ali Fares, UH Mānoa, Natural Resources & Environmental Management Dept.	Kamehameha Schools
Antya Miller, North Shore Neighborhood Board	Koʻolau Mountains Watershed Partnership
Aqua Engineers	Oʻahu Invasive Species Committee
Bob Leinau, Mālama Pūpūkea-Waimea	Pioneer Hi-Bred International, Inc.
Dillingham Ranch ʻĀina, LLC	Reed Matsuura, Councilmember Ernie Martin's Office
Dole Foods, Inc.	Ronald Rickman, US Geological Society
George Galbraith Trust	Russell Yost, UH Mānoa, Department of Tropical Plant and Soil Sciences
Hawaiian Botanical Society	Sustainable Hawaiʻi LLC
Hiʻiaka, LLC	Thomas Shirai, North Shore Neighborhood Board
HPC, LLC	Tom Giambelluca, UH Mānoa, Water Resources Research Center
Jake Ng, North Shore Neighborhood Board	Waiʻanae Mountains Watershed Partnership

ELECTED OFFICIALS

The Board of Water Supply notified North Shore and neighboring district's elected officials about the plan and planning process and met with some of them, including:

- City Councilmember Ernie Martin
- State Senator Donovan Dela Cruz
- State Senator Clayton Hee
- State Representative Marcus Oshiro
- State Representative Richard Fale
- State Representative Lauren Matsumoto

GOVERNMENT AGENCIES
The Board of Water Supply verified information with ten government agencies at the Federal, State, and City and County levels. These agencies included:

Federal Agencies

- Natural Resources Conservation Service (NRCS)
- Naval Facilities Engineering Command (NAVFAC) Hawaiʻi, Utilities & Energy Management (UEM) Division Potable Water Branch
- U.S. Army Corps of Engineers, Honolulu District
- U.S. Army Garrison Hawaiʻi

State Agencies

- Commission on Water Resources Management (CWRM)
- Department of Agriculture (DOA)
- Department of Health (DOH) Environmental Planning Office
- Department of Transportation (DOT)
- Division of Forestry and Wildlife (DOFAW)

City & County Agencies

- Department of Environmental Services (ENV)
- Department of Planning and Permitting (DPP)

2.10.4 Summary of Community Values

The following is a summary of North Shore community-identified values and principles which relate to their watersheds and water resources. Many of these key values were previously identified in the Sustainable Communities Plan process conducted from 2007 to 2009, and through the Trust for Public Land and the North Shore Community Land Trust's Greenprinting process conducted in 2011.

Protect Ground and Surface Water Sources
Clean, abundant water sustains community, health, and agriculture; therefore it is important to protect the quality of the aquifers, drinking water, and watershed areas. Protecting water sources also safeguards the ocean for marine life and world-class recreation. The quality of the North Shore's ground, surface, and nearshore waters is vital for ensuring public health, providing outdoor recreation, sustaining the integrity of ecological systems, and maintaining general environmental quality.

Promote a Diversified Agricultural Industry
A healthy agricultural industry continues to generate economic opportunities that are appropriate to North Shore's open space and rural qualities. The success of diversified agricultural operations on former sugar plantation land is evidence of the region's potential for cultivating locally consumed food crops. North Shore residents support the preservation of agricultural lands.

Maintain the Community Growth Boundary to Protect Agricultural, Open Space, and Natural Resources

The North Shore is characterized by vast tracts of agricultural lands, open spaces, and natural and cultural resources. To protect these resources from development, the Community Growth Boundary was established to guide development and preserve open space and agricultural areas. The Community Growth Boundary serves as a valuable tool to guide resource management, future development, or redevelopment.

Enhance the Region's Recreational and Educational Potential

The North Shore is known for its numerous beach parks, world famous surf spots, and abundant mauka and makai natural resources. These resources are important to quality of life and the visitor-based economy. While promoting expanded access and recreational opportunities to coastal and mauka resources, it is critical to protect the resources from overuse.

Provide Adequate and Appropriately-Sized Public Infrastructure, Facilities, and Services

Adequate infrastructure and public facilities and services are needed to provide potable and nonpotable water, wastewater, and drainage. Additional resources to upgrade and adequately maintain existing infrastructure systems and public facilities need to be provided. Adequate infrastructure is necessary for drainage systems to mitigate storm runoff and regional flood hazards, ensure continuous runoff, and protect the quality of coastal waters.

Preserve and Protect Cultural and Historic Resources

Heritage sites on the North Shore are reminders of the region's rich history and the ongoing work of cultural practitioners today. Preserving significant plantation era and other historic features in Hale'iwa Town, Waialua Town, the Waialua Mill, and other sites, as well as protecting Native Hawaiian cultural and archaeological sites, are important in retaining the area's unique identity and country character. Historic site restoration and interpretive programs should be integrated into the development of parks and shorelines and mountain access systems, to help enhance appreciation of these resources.

Provide Critical Habitat Protection for Endangered and Threatened Native Species

Protection of native flora and fauna are critical to the overall health of the North Shore's ecosystems. There are many Federal Threatened and Endangered species in the North Shore, including plants, snails, forest and water birds, stream species, coral and marine life. Some of these are declining species, and some are species of concern that have not yet made the Threatened and Endangered Species list.

Adapt the Ahupua'a Concept as a Framework for Land Use and Natural Resource Management

Traditional Hawaiian life was based on the ahupua'a system of land management. Defined by the natural geographic formations such as mountain ridges, gulches and streams, ahupua'a were complete ecological and economic production systems that provided all the resources to sustain the community living within the ahupua'a. Adapted to the context of today's community needs and technology, the ahupua'a concept provides useful principles for guiding the use and management of the North Shore's resources. In keeping with this approach, the planning and implementation of land use decisions and land-based actions considers related effects on coastal waters and the nearshore environment. On a broader scale, there is a need to recognize the connection between the North Shore and its neighboring regions (i.e., Central O'ahu, Ko'olau Loa and Wai'anae), and the many ways that events and activities occurring in one region may affect the others.

Integrate Principles of Sustainability into Decision-Making Processes
A community that successfully manages change will flourish and prosper in the future. For the North Shore, this means ensuring that planned growth and development respects and adheres to the principles of sustainability. The North Shore's principles of sustainability have promoted the long-term health of the land and community resources for both current and future generations of residents:

- Protect the environment, natural resources, existing flora and fauna, and where appropriate, open spaces and view planes.
- Use resources so they are not depleted, permanently damaged or destroyed.
- Avoid pollution and exceeding the limits of existing infrastructure systems.
- Respect the cultural, social and physical resources that shape residents' sense of community and rural quality of life.
- Honor the process of change. Make no decisions without first understanding the effects such change will have on the land and community resources.
- Strive for balance between economic prosperity, social and community well-being, and environmental stewardship. Adopt a multidisciplinary approach acknowledging the importance of our community capital in land use and infrastructure planning decisions.

2.10.5 Summary of Water Use and Watershed Related Issues and Strategies

The following is a summary of water use and watershed management related issues that were identified in the North Shore by community members and/or government agencies. Listed below these issues are **preliminary strategies (**suggested by either community members or agencies) that align with the values previously discussed.

A. Ground Water Quality

Contaminants that infiltrate into ground water can spread through the aquifers. This contamination can be mitigated, but treatment is very expensive and time consuming. If treatment is too costly, the well will be shut down and pump capacity will be permanently reduced. Replacement wells are also expensive. Therefore, prevention is the most cost-effective measure against ground water contamination. One potential source of ground water contamination that is of concern is ill-advised and unnecessary pesticide use and applications of agricultural by-products that may be the result of gaps in farmer training and education.

Suggested Strategies to address issue:

- Track land uses, permissible activities, and characterize chemicals, fertilizers and recycled water applied on all agricultural lands above drinking water wells.
- Implement agricultural Best Management Practices (BMPs) including soil and water conservation.

B. Surface Water Quality and Biota

Most of North Shore district streams are on the 2008/2010 303(d) list for impaired water bodies, primarily due to nutrients and turbidity. These indicators of pollutants could be caused by erosion, animal wastes, fertilizers, and human waste. High levels of stream contaminants accelerate eutrophication, decrease oxygen in the water, are toxic to fish, and could be of considerable harm to other organisms including humans if ingested.[51] Total Maximum Daily Loads (TMDL) are needed to guide actions to reduce contaminants.

In general, the biotic resources of the streams in the North Shore are severely degraded. None of the North Shore streams that were rated by the Atlas of Hawaiian Watersheds received a biological resource rating higher than 5 on a 10 point scale. Kaukonahua and Kiʻikiʻi received a rating of 2.

Suggested Strategies to address issue:

- Implement TMDL study recommendations for North and South Kaukonahua Streams.
- Provide public awareness and education outreach to reduce polluting behaviors.
- Integrate Low Impact Development (LID) concepts into existing and future developments to minimize run-off water quantity and improve water quality.
- Conduct Biological Assessments of stream ecosystem health for selected streams (e.g. Anahulu, Waimea).

C. Erosion and Sedimentation

When the steeper areas are cleared and tilled, erosion becomes a significant concern. Erosion is also associated with cane haul roads and dirt bikes. Wind erosion can be a concern in certain areas, especially those lands close to the ocean which are subject to strong trade winds. In forested areas, sediment can come from unstable stream embankments, shallow storm-induced landslides, and altered and denuded landscapes as influenced by non-native vegetative cover and feral pigs or other ungulates.

Lower watershed areas are affected by the accumulation of loosened soil from the upper elevations. This sedimentation can lead to clogged streams, an increased likelihood of flooding, and reduced downstream water quality. Lack of monitoring data currently precludes any reliable estimates of sediment loading originating from agricultural lands as compared to other sources, such as the steep slopes of upland headwaters and lowland gulches.

Suggested Strategies to address issue:

- Implement strategies from the Waialua-Kaiaka Watershed Area Study including:
  - Recommended BMPs for crop lands, orchards, rangeland and pastures.
  - Strawberry guava biocontrol
- Provide feral pig management planning and implementation techniques.
- Restrict off-road vehicles in ecologically sensitive areas.
- Develop and implement a risk management plan for Pūpūkea-Paumalu that identifies, evaluates, reduces and prevents wildfire, drainage, erosion, and rock falls.
- Measure and evaluate suspended sediment characteristics in streams to identify sediment source

D. Irrigation Water Quality and Quantity

The provision of high quality water for irrigation purposes is of concern for many farmers in the North Shore district. Surface irrigation water is less expensive than pumping ground water, however the Wahiawā Irrigation System (WIS) is old, in need of repairs, and experiences a high level of system water losses. A system of maintenance and possibly piping for the ditches is necessary, and should include a system to monitor and clear debris.

Lake Wilson supplies water to the WIS. The Lake Wilson water is made up of approximately 20 mgd from the streams, and approximately 2 mgd from the Wahiawā WWTP's effluent. Therefore, the entire Wahiawā Irrigation System supply is considered R-2 recycled water. The Wahiawā WWTP has been discharging treated R-2 effluent into Lake Wilson since 1927. The use of R-2 water is limited to irrigating crops such as seed corn, trees and orchard crops (e.g., papaya and coffee), and crops that are processed sufficiently to kill pathogens.[162]

Once the effluent draining into the Wahiawā Reservoir and Irrigation System is deemed unregulated the water can be used to irrigate many crop types and might slightly decrease agricultural demand on ground water.

The entire State experienced periods of drought from 2000 to 2010. The most recent drought period began in summer of 2008 and officially concluded on O'ahu and Kaua'i in December 2010, according to the National Weather Service.[163] During droughts, soil moisture may be completely depleted in un-irrigated, fallow fields.[164] A prolonged amount of rain is needed before recovering from several years of extremely dry conditions.

The United States Geological Survey (USGS) operates and maintains most of the stream gaging stations in Hawai'i. There were eight operating stream gages in North Shore between 1967 and 1971. There are currently four operating streamflow gages – three on Kaukonahua and one on Kamananui. Many streams have no stream gages. The lack of data limits the ability to accurately do surface water irrigation planning, biological stream health assessments, and flood mitigation.

Suggested Strategies to address issue:

- Improve the water quality of Wahiawā Reservoir
- Identify Wahiawā Irrigation System (WIS) water losses, make improvements to minimize water losses, and address the potential of supplying Galbraith Lands.
- Assess water storage options, mechanism for back-up well allocation and use, and potential stormwater reclamation projects.
- Support the formation of the Farmer's WIS User Association for the best use and maintenance of the Wahiawā Irrigation System.
- Implement high priority recommendations from the City and County of Honolulu Drought Mitigation Strategies for agriculture.
- Re-activate or install additional USGS stream gage stations and data collection funding.

E. Flooding

Flooding is a major community issue in Waialua and Haleʻiwa. These low-lying areas are the most vulnerable to flooding due to the watershed's large size and the number of streams and gulches that converge at the shoreline (including Kiʻikiʻi Stream, Paukauila Stream and the Anahulu River). During high-peak discharges, flood waters overtop the streambanks, inundating the low-lying residential and agricultural lands. Modifications to natural drainage patterns (e.g. increased erosion and sedimentation, debris buildup/ blockage) restrict stream flow and further compound flood hazards in this area. The Wahiawā Reservoir can prevent, reduce, and delay flooding that occurs due to excessive rain events. When the spillway overflows, the dam no longer serves as a flood control device, and stream flow volumes due to rainfall will flow unimpeded as if no dam existed. Blockage of bridge openings by debris restricts flow, causing flood waters to back up and inundate low-lying areas. Many residents feel that there have been too many studies and not enough action to alleviate flooding issues.

Suggested Strategies to address issue:

- Support suggested projects from the Kaiaka Bay Watershed Participatory Assessment and Action Project such as:
  - Construct wetlands, storage ponds, and other flood mitigation works
  - Conduct a feasibility study regarding long term flood mitigation strategies
  - Gather information on additional dams at key locations for flood mitigation
- Conduct dredging studies to estimate the cost and efficiency of approaches for mitigating floods. Support strategies for the systematic maintenance/dredging of key areas.
- Develop a Waialua-Kaiaka watershed restoration study to identify all water resource problems in the watershed and evaluate possible solutions.
- Develop and implement a drainage master plan for Pūpūkea-Paumalū that identifies the risks due to flooding and recommends hazard mitigation actions and strategies. Include a drainage study based on the topographic survey and research on previous flooding.

F. Nearshore Water Quality

Sediment deposition occurs along much of the coast after heavy rains, causing reduced downstream water quality and discoloration of nearshore waters for extended periods of time.[2] In addition to sedimentation, effluent discharged from household cesspools and excessive amounts of nutrients applied in agricultural production and landscaping can be detrimental to water quality in nearshore waters.

Significant amounts of coral reef habitat occur in the nearshore waters off the coast of the North Shore district. A large amount of sediment has accumulated on the reef. According to residents, the reef has declined dramatically over the past 30 years from a flourishing ecosystem and fish nursery to a dead reef system with cloudy and turbid conditions.[22] Making a preserve of the reef system off Waialua Beach Road might hold responsible those that contribute to further deterioration and also might enable this reef system to rejuvenate itself for future recreation and as a source of income for local fishermen.

Before a rule change in 2002, fish stocks appeared to be depleted at the Pūpūkea Marine Life Conservation District (MLCD) because of virtually unrestricted fishing activity. However, fish counts done by University of Hawaiʻi (UH) and TNC have found that there are many more fish now than before the rule change.[86] The use of nets is currently allowed in the northern portion of the MLCD.[85] Many community members feel that allowing commercial netting in the MLCD is detrimental. There is also a significant amount of poaching in the MLCD which the non-profit group Mālama Pūpūkea-Waimea is working hard to suppress with the Division of Conservation and Resources Enforcement (DOCARE) Mauka-Makai program.[86]

Suggested Strategies to address issue:

- Support the implementation of Low Impact Development techniques.
- Implement Agricultural Best Management Practices (BMPs) including soil and water conservation.
- Implement the North Shore Regional Wastewater Alternatives Plan strategies, such as:
    - Upgrade cesspool systems
    - Injection wells or reuse for neighborhood clusters
    - Upgrade existing wastewater systems
    - Small WWTF for larger commercial and residential areas.
- Designate a natural reserve/reef preserve off of Waialua Beach.
- Support the Mālama Pūpūkea-Waimea educational outreach at the Pūpūkea MLCD, including the Makai Watch Program.

G. Invasive Non-native Species

Invasive non-native plant species, feral ungulates and other non-native animals have been identified among the most damaging factors to Hawaiʻi's watersheds, causing soil erosion and biodiversity loss. Non-native animals such as mongoose and feral cats are major cause of mortality among endemic and common native bird populations. The presence of invasive species in the streams and waterways also impacts native aquatic species.

Suggested Strategies to address issue:

- Support the Waimea Valley Invasive Species Control & Native Forest Restoration and Native Hawaiian Damselfly Habitat Creation programs.
- Support the Koʻolau Mountains Watershed Partnership and the Waiʻanae Mountains Watershed Partnership.

H. Wildfires

Fire, as evidenced by the Waialua fires on the slopes of the Waiʻanae Mountains in 2007 and 2010, can have a destructive force with lasting impacts. Initially, there is a loss of natives and introduced species; then, the bare ground without intervention is re-vegetated with introduced species out-competing the native species.[64] In the interim, rains erode soil which runs off down into streams and ultimately nearshore waters.[101] Climate change may increase wildfire risk due to greater fluctuations in periods of rain and drought.

Suggested Strategies to address issue:

- Implement high priority recommendations from the City and County of Honolulu Drought Mitigation Strategies for Wildland Fire and Environment.
- Coordinate and plan for the relocation and construction of the Waialua Fire Station.

I. North Shore History & Native Hawaiian Practices

Ahupuaʻa management by Native Hawaiians involved information acquired during a relationship with the ʻāina that developed over hundreds of years. Much of the knowledge and information may be lost with the passing of older generations and elders. Continuing Hawaiian practices and utilizing ancient knowledge will provide an opportunity for sound decision making in resource management while preserving the legacy and traditions of its people and places.

Suggested Strategies to address issue:

- Conduct North Shore Oral History Studies to utilize local knowledge in resource management while preserving the legacy and traditions.
- Support kalo restoration projects within the community.
- Support restoration programs for ʻUkoʻa Marsh and Loko Ea Fishpond with educational and ecosystem components.
- Identify and mark the traditional ahupuaʻa boundaries and streams of the North Shore to educate and raise public awareness about Hawaiian traditional land boundaries and stream locations.

J. Climate Change

Hawaiʻi's climate is changing in ways that are consistent with the influence of global warming. Air temperature has increased and a general downward trend in rainfall has been documented over the last century. There will be an increased water demand with the higher temperatures. Less rainfall equates to less surface and ground water recharge. There has been increased severity and frequency in droughts and flooding, with an increase in wildfire risk as well. Because these trends are likely to continue, scientists anticipate growing impacts to Hawaiʻi's water resources and forests, coastal communities, and marine ecology. These impacts of climate change should be considered in North Shore planning efforts.

Suggested Strategy to address issue:

- Implement the Hawaiʻi Ocean Resources Management Plan, A Framework for Climate Change Adaptation in Hawaiʻi, and other initiatives for long-term planning.

K. Potable Water Systems

Potable water usage, treatment, and delivery are essential for residents and visitors to the North Shore. To ensure adequate access to clean, fresh water for drinking and domestic use, it will be necessary to maintain an efficient delivery system while encouraging consumer conservation of the limited potable water resource.

The Mokulēʻia water system is owned and operated by the North Shore Water Company, which has issues with water delivery and is not sized for fire protection.

Suggested Strategies to address issue:

- Support the programs and strategies developed within the BWS Conservation Program.
- Support the BWS Capital Program projects in the North Shore.
- Promotion of gray water reuse techniques to the extent allowable.
- Conduct a Mokulēʻia Potable Water Long-Term Plan to provide reliable and clean water delivery to Mokulēʻia customers and meet fire protection requirements.

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3 WATER USE & PROJECTED DEMAND

3.1 WATER AVAILABILITY AND USE
3.2 WATER SUPPLY SYSTEMS
3.3 PROJECTING FUTURE WATER DEMAND
3.4 MOST PROBABLE WATER DEMAND SCENARIO
3.5 ADEQUACY OF SUPPLY TO MEET DEMAND

3.1 WATER AVAILABILITY AND USE

A combination of ground, surface, and reclaimed water supply the North Shore district's water needs *(Table 3.1).*

Table 3.1 Current In-District Water Use by Source Type

Water Source	Estimated Amount (mgd)[1]
Surface Water	12.4[2]
Ground Water	6.8[3]
Recycled Water	3.9[4]
Total	22.1

[1] Million of Gallons per Day
[2] North Shore Primary Surface Water Use (2012) see *Table 3.5*
[3] Estimated amount is conservative as some users were non-reporting (2010)
[4] Reported averages from the Wahiawā and Schofield Barracks Wastewater Treatment Plants (2012)

The North Shore district is linked to the Central O'ahu district for water availability *(Figure 3.1)*. Surface and recycled water comes from sources in the both the North Shore and Central districts. Multiple stream diversions feed into the Wahiawā Aquifer System. Recycled water from the Central O'ahu's Wahiawā Waste Water Treatment Plant (WWTP) enters the Wahiawā Reservoir, and recycled water from Schofield Barracks enters the Wahiawā Irrigation System below the Reservoir. The Wahiawā Aquifer System provides water for agricultural irrigation on the North Shore.

Ground water comes from various North Shore facilities owned and operated by City, State and Federal agencies as well as private water purveyors.

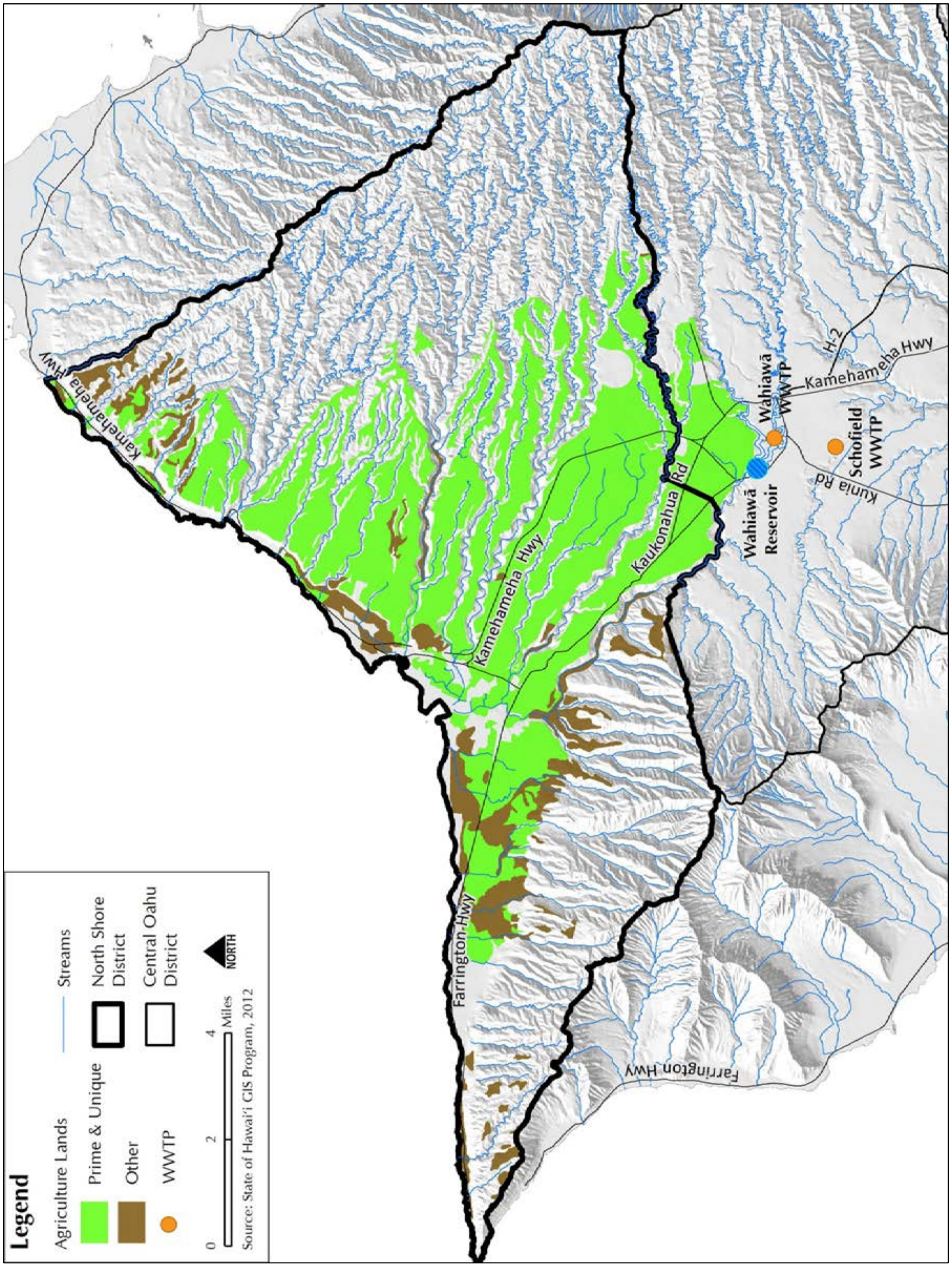

Figure 3.1 North Shore and Central Districts Locations and Surface Water Connections

3.1.1 Ground Water Availability and Use

The estimate of available ground water is referred to as the sustainable yield. The State Water Code defines sustainable yield as 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 (CWRM)"*.[1] Extracting amounts of ground water greater than the sustainable yield may irreparably damage the aquifer. Sustainable yield numbers are only estimates and should not be considered exact amount of ground water that can be safely utilized. *Figures 3.2 and 3.3* illustrate the sustainable yield of North Shore district's four aquifer system areas (ASYAs). The majority of available ground water is in the Kawailoa and Waialua aquifer systems.

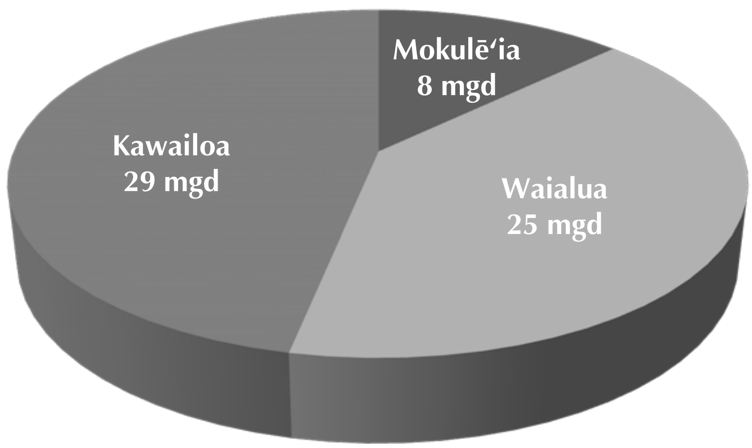

Figure 3.2 North Shore Aquifer Sector Sustainable Yields

The North Shore district overlays the North Shore aquifer sector and part of the Wahiawā aquifer system. Both the North Shore aquifer sector (which includes the aquifer systems of Kawailoa, Waialua, and Mokulēʻia) and the Wahiawā aquifer system are designated ground water management areas (GWMA). A water management area is defined by the State Water Code as *"a geographic area which has been designated as requiring management of the ground or surface water resource, or both"*.[2] Within a GWMA, ground water resources could be threatened by existing or proposed water withdrawals, therefore, any use of ground water, with the exception of domestic consumption by individual users, requires a water use permit from CWRM.

Table 3.2 shows the permitted ground water uses and the reported ground water pumpage by aquifer system areas for BWS, State and Federal agencies, and private water users. This table also shows the sustainable yield and available yield for each aquifer system area. Available water is the difference between the sustainable yield and the current permitted uses in the aquifer system area. The Waialua system area is the most heavily utilized by BWS and private users for municipal supply and agricultural irrigation, respectively. And, as seen in *Figure 3.4*, State and Federal systems account for very little of the ground water withdrawals in the district.

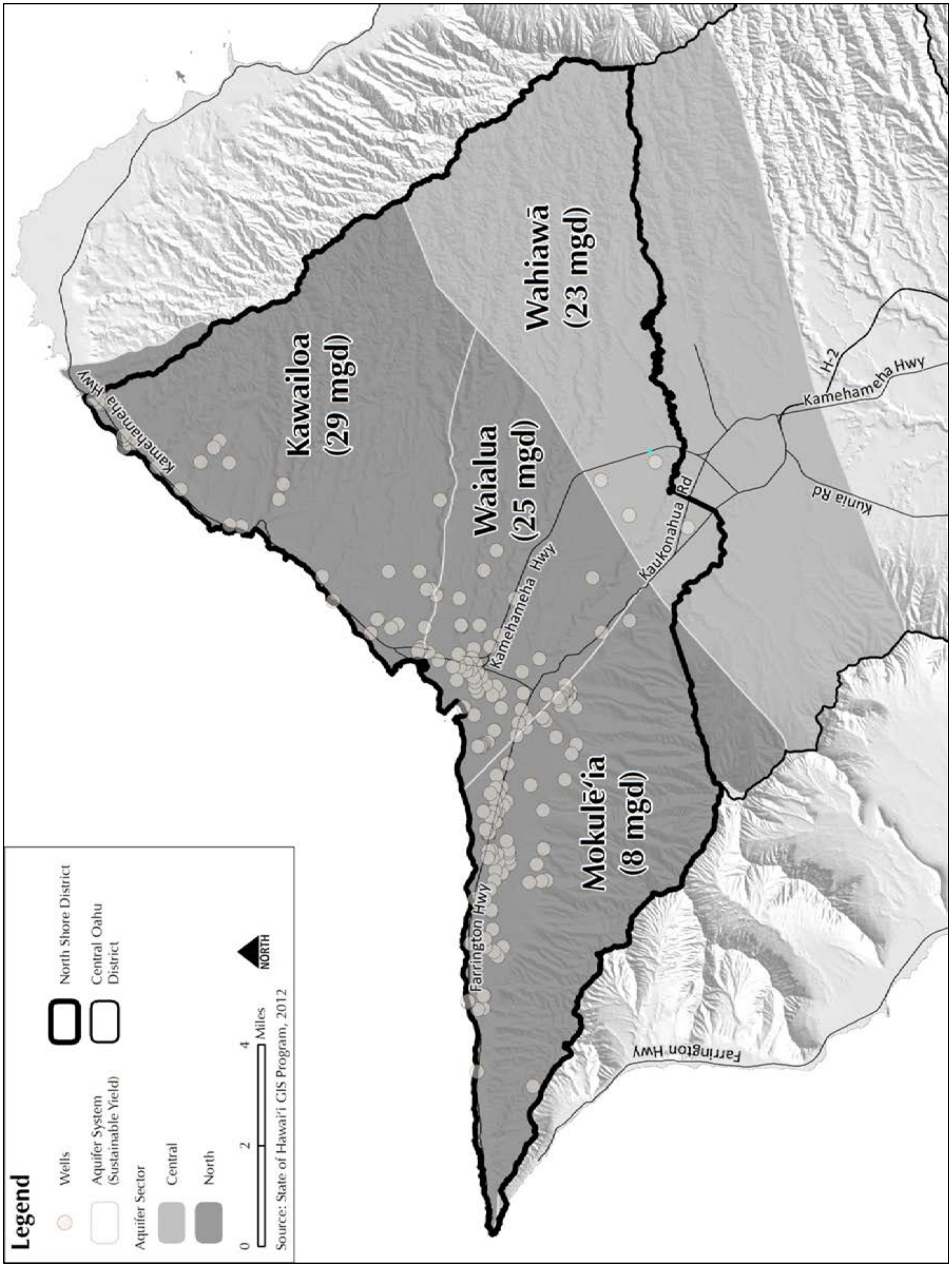

Figure 3.3 North Shore Aquifer Sector & System Areas and Sustainable Yields

Table 3.2 Ground Water 2010 Production by Producers

Aquifer System Area	BWS		State[1]		Federal[2]		Private		Total		SY[3] (mgd)	Available Yield (mgd)[4]
	WUP[5] (mgd)	Pumpage[6] (mgd)	WUP[5] (mgd)	Pumpage[6] (mgd)	WUP[5] (mgd)	Pumpage[6] (mgd)	WUP[5] (mgd)	Pumpage[6] (mgd)	WUP[5] (mgd)	Pumpage[6] (mgd)		
Mokulēʻia	-	-	-	-	0.073	0.081	6.991	0.151	7.064	0.232	8	0.936
Waialua[7]	3.000	2.626	-	-	-	-	6.750	2.956	9.75	5.582	25	15.250
Kawailoa[7]	0.339	0.192	0.326	0.112	-	-	0.538		1.914	0.304	29	27.086
TOTAL	**3.339**	**2.818**	**0.326**	**0.112**	**0.073**	**0.081**	**14.579**	**3.769**	**18.728**	**6.118**	**62**	**43.272**
Wahiawā[8]	4.270	3.280	-	-	6.092	3.788	12.301	0.843	22.663	7.911	23	0.337

1 State Uses: Kawailoa has the UH Waialeʻe Research Station & OHA's (Hiʻipaka LLC) Waimea Valley (unused); UH Poamoho Research Station uses potable water from Schofield Barracks.

2 Federal Uses: Mokulēʻia has USAF Kaena Point well & US Army/DOT Airport well. Helemano Military Reservation uses water from the Central Oʻahu district.

3 Based on SY estimates reported in the Water Resource Protection Plan (August 2008).

4 Available Yield = Sustainable Yield – Total Permitted Use;

5 CWRM Water Use Permit (WUP) Index (2012); permitted uses are for fresh and brackish water wells.

6 Pumpage as reported for 2010, however, with some users non-reporting. Waialua aquifer system area pumpage from the October 10, 2012 water revocation and allocation of water use permits CWRM submittal.

7 The BWS Kawailoa and Waialua pumpage is a five year average (2006-2010); Waialeʻe II Well is in the Koʻolau Loa district.

8 Wahiawā Aquifer System wells in the North Shore district include: 3103-01 Galbraith Estate Del Monte #5, 3203-01 Helemano Pump 25, and 3203-02 Waialua Sugar Pump 26 with a total WUP of 5.162 mgd and pumpage of 0.661 mgd. The remaining usage is for Kunia.

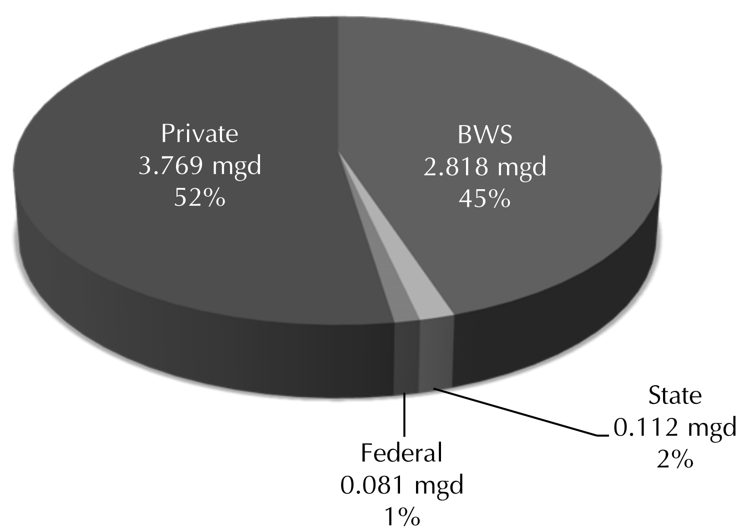

Figure 3.4 North Shore District Ground Water Withdrawals by Producer

In August 2008, CWRM adopted the updated Water Resource Protection Plan (WRPP) which revised the sustainable yield for all North Sector aquifer system areas to account for ground water spillover from the Wahiawā AYSA. The revised sustainable yields also account for the decrease in recharge from the cessation of irrigation from large-scale sugar cultivation that provided significant aquifer recharge. The sustainable yield for Mokulēʻia ASYA went from 12 mgd to 8 mgd, Waialua ASYA went from 40 mgd to 25 mgd, and Kawailoa AYSA went from 39 to 29 mgd. This is a more than 30% reduction in sustainable yield.

The Mokulēʻia, Waialua, and Kawailoa aquifer system area sustainable yields were reduced causing Mokulēʻia and Waialua to have an over-allocation of water permits in 2010 by 0.025 million gallons per day (mgd) and 5.887 mgd, respectively, although the aquifers are not over-pumped. Kawailoa had only 1.614 mgd allocated out of 29 mgd; most likely due to its high salinity levels which cause poor well yields and make it costly to develop water sources. In 2012, Waialua aquifer permits were revoked or partially revoked for non-use for a period greater than 4 years. There are requests for use of the wells as back-up to surface water usage which are still pending.

3.1.2 Surface Water Availability and Use

On the North Shore there are 21 watersheds with 8 perennial streams (per the 1990 Hawaiʻi Stream Assessment) which contribute to surface water availability. Some of these streams have diversions that provide irrigation water via the Wahiawā Irrigation System for North Shore agriculture.

Below in *Table 3.3* is a listing of available USGS stream data for North Shore and North and South Kaukonahua streams. Stream gage data has been generally available for the streams and/or tributaries that supply water for agricultural needs. There are many smaller streams without available stream data. Also, stream gages only measure flow from stream segments above the gage. In 2004 rainfall year was above normal while 2010 rainfall was below normal which may be a significant factor in the differences in total gaged stream flow.

Table 3.3 Mean Streamflow for Gaged Streams

Stream Name	Mean Flow 2004		Mean Flow 2010	
	(cfs)	(mgd)	(cfs)	(mgd)
N. Kaukonahua	19.2	12.4	10.4	6.7
S. Kaukonahua	29.6	19.1	15.1	9.7
ʻŌpaeʻula	18.8	12.2	11.9	7.7
Kamananui	24.7	16.0	12.9	8.3
Total	92.3	59.7	50.3	32.4

Source: USGS Stream Data

Another way of looking at available stream water is stream diversion data. CWRM maintains a database of surface water use consisting of stream and spring diversions. The CWRM database of stream diversions lists eleven reported stream diversions in North Shore and for Kaukonahua stream (*Table 3.4* and *Figure 3.5*). However, this database was populated based on surface water users' voluntary reporting conducted between 1989 and 1992; therefore, the data is outdated, incomplete, and does not provide an exact amount of available surface water. The stream diversion data does, however, provide a more useful estimate than the stream flow data, as it captures the streams and tributaries used to supply agricultural needs, such as Kaukonahua Stream diversions that supply Wahiawā Reservoir.

Table 3.4 North Shore District & Kaukonahua Stream Diversions
(1989-1992 Declared)

STREAM	MGD
Kaukonahua	25.542
Poamoho	2.665
Helemano	2.031
ʻŌpaeʻula	1.287
Kawaiʻiki	0.784
Kawainui	0.530
Unnamed Spring	0.110
Kalou Pond	0.022
Unnamed	0.006
Unnamed	0.006
Unnamed Spring	0.001
TOTAL	**32.984**

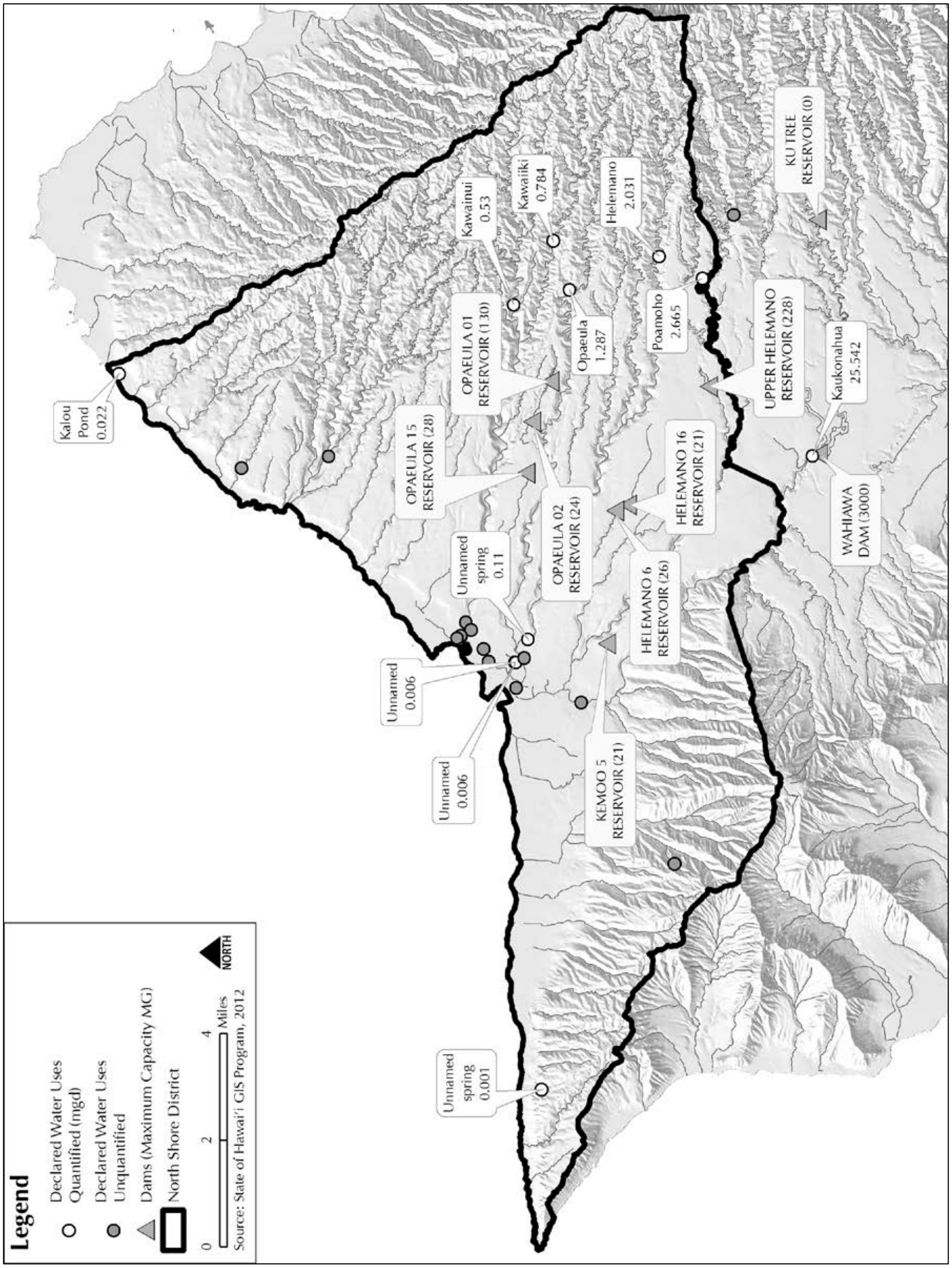

Figure 3.5 Declared Water Use (1989-1992 Declared) and Reservoirs

The primary users of surface water diversions on the North Shore are Dole Foods as operator of the Wahiawā Irrigation System and Kamehameha Schools. A USGS gage was installed below the Wahiawā reservoir in 2012 that records the water flowing into the Wahiawā Irrigation System. The average water flow is about 8.9 mgd. The other primary user of water is Kamehameha Schools which has two diversions on ʻŌpaeʻula and Kawaiʻiki Streams that supply 3.5 mgd of water into their portion the Wahiawā Irrigation System. This totals 12.4 mgd of available surface water (*Table 3.5*). There are also some smaller users of surface water but in very small quantities primarily for small areas of taro cultivation.

Table 3.5 North Shore Primary Surface Water Use

Stream	Flow/Usage (mgd)
Wahiawā Ditch *(includes diversions from Kaukonahua & Poamoho Streams)*[1]	8.9
ʻŌpaeʻula and Kawaiʻiki Stream Diversions[2]	3.5
TOTAL	**12.4**

1 USGS gage #16210100 below Wahiawa Ditch; data from October 2012 to December 2014

2 Kamehameha Schools, email correspondence 2012

There are currently 25 operating reservoirs in the North Shore district. Only dams that meet a certain size criteria (dam height greater than 25 feet and volume of the reservoir greater than 50 acre feet) are regulated under DLNR's Dam Safety Program *(Figure 3.5 and Table 3.6).* The Dam Safety Program currently regulates the following reservoirs in the study area: Helemano 6 and 16; Upper Helemano (Tanada); ʻŌpaeʻula 1; Kemoʻo 5; Wahiawā and Ku Tree. Ku Tree Reservoir has been dry since 1983, but sits along the Kalakoa Stream which feeds into the South Fork of the Kaukonahua Stream.[1] Ku Tree Reservoir will be breached at a later date when funding is available; it was drained in 1983 and has remained empty since then. Helemano 16 will also eventually be decommissioned and removed. It has been drained and currently remains empty.[1] Helemano 11, ʻŌpaeʻula 2 and 15 were recently decommissioned.

Table 3.6 North Shore State Regulated Dams

Reservoirs	Owner	Reservoir Capacity (MG)
Wahiawā Reservoir	Dole Foods	3,000
Ku Tree Reservoir*	US Army	300
Upper Helemano Reservoir	Castle & Cooke	228
ʻŌpaeʻula 01 Reservoir	Kamehameha Schools	130
Helemano 06 Reservoir	Dole Foods	26
Helemano 16 Reservoir*	Dole Foods	21
Kemoʻo 5 Reservoir	Dole Foods	21
	TOTAL	**3,726**

* Planned for decommissioning and not currently in use

Additional currently operating North Shore reservoirs that are not regulated by DLNR include Helemano 2A and 10; ʻŌpaeʻula 5 and 8; Kemoʻo 2A and 8; Kawaihāpai; Ranch 1, 4, 10A, 10B; and Kawailoa 3, 7, 8, 9, 11, 14, 15, 18.

3.1.3 Recycled Water Availability and Use

Recycled water is wastewater that has been treated to remove solids and other chemical impurities. When treated to levels specified by the Department of Health, recycled water can be used for nonpotable uses such as landscape and agriculture irrigation. Currently there are two wastewater treatment plants in Central Oʻahu producing recycled water available for irrigation – the Wahiawā and Schofield Wastewater Treatment Plants. There is one wastewater treatment plant on the North Shore, Paʻalaʻa Kai; however, it is not producing recycled water. The *Table 3.7* summarizes the three major wastewater treatment plants affecting the North Shore.

Table 3.7 Wastewater Treatment Plants in North Shore & Central Oʻahu

Wastewater Treatment Plant	Wastewater Treated	Current Recycled Water Use (2013)
Wahiawā	1.6 mgd[1]	Yes
Schofield	2.3 mgd[1]	Yes
Paʻalaʻa Kai	.09 mgd[2]	No

1 2013 Update of the Hawaiʻi Water Reuse Survey and Report.

2 Wastewater treated in FY 2012 as reported on the City's Department of Environmental Services' website.

In order to use the recycled water, the infrastructure for distribution must be constructed which can have considerable costs. There are also ongoing costs associated with the distribution of recycled water. Wastewater treatment plants tend to be downstream of the waste flow and distribution from them is typically pumped up and requires electric costs. It is most economically feasible to use the water in close proximity to reduce the infrastructure and operating costs. Also, there is an economy of scale with current technologies to make the recycled water cost effective, and producing recycled water from existing small treatment plants is very costly.

The Wahiawā Wastewater Treatment Plant produces approximately 1.6 mgd effluent that is classified as R-2 and can be used in limited ways on crops. The R-2 effluent empties into Wahiawā Reservoir which serves as the reservoir for the Wahiawā Irrigation System. The Wahiawā Irrigation System is the primary source of irrigation water for North Shore agricultural lands. Reservoir water not used for irrigation remains in Kaukonahua Stream.

Wahiawā Wastewater Treatment Plant's effluent water quality will be improved after the construction of the Membrane BioReactor (MBR) plant.[3] This project resulted from a lawsuit by Dole Food Company against the City and County of Honolulu because the Wahiawā Wastewater Treatment Plant's effluent was reducing the quality of the irrigation water. However, even with the construction of the MBR plant, the Wahiawā Reservoir irrigation water will not yet be rated R-1 due to State regulations. The first condition of the regulations will be met with the production of R-1 water with an MBR plant. The second requirement of the regulations is a direct pipeline for the primary use of the R-1 water. The third requirement is sufficient wet weather storage to hold the untreated water for treatment for plant upsets. The direct pipeline and wet weather storage do not exist, and when achieved will direct the Wahiawā Wastewater Treatment Plant produced recycled water for nearby nonpotable water demands.

The Schofield Wastewater Treatment Plant treats all wastewater processing for Helemano Military Reservation, Wheeler Army Airfield, Schofield Barracks, and Schofield Barracks East Range. Aqua Engineers owns the facility and operates the treatment plant located south of Wheeler Army Airfield (*Figure 3.1*). In 2007, Aqua Engineers, Inc. upgraded the Schofield Wastewater Treatment Plant with an MBR and ultraviolet disinfection processes to obtain R-1 effluent. The capacity of the plant is 4.2 mgd. Current flows for the Wastewater Treatment Plant are approximately 2.3 mgd.[4]

Currently the Army pays Dole to take their effluent at a rate of $550,000 per year. This agreement was established in 1994 to promote diversified agriculture in the North Shore, and at the time, the water was R-2 quality. The plant has since upgraded to produce R-1 water. The Army would like to reuse the R-1 water for irrigation at Schofield Barracks and Wheeler Army Airfield; however, the infrastructure to deliver the water for landscaping and recreational fields has not yet been installed. Funding was granted through a congressional appropriation to construct a pipeline to the Leilehua Golf Course. Even after installing infrastructure, this would use up to 1 mgd of R-1 water on base, leaving about 1.3 mgd of R-1 water flowing to North Shore agriculture.[5]

Under development is a *Central O'ahu Non-Potable Water Master Plan* to evaluate the potential of Schofield WWTP recycled water use in the Central O'ahu area. R-1 recycled water could be used for Ag irrigation in Kunia.

In North Shore district, the Pa'ala'a Kai Wastewater Treatment Plant services 314 homes in the Pa'ala'a Kai subdivisions. Pa'ala'a Kai has a current flow of .09 mgd, with a capacity of 0.14 mgd. The effluent from the facility is discharged into injection wells as the wastewater treatment plant does not currently have recycled water treatment capacity. The North Shore Wastewater Alternatives Plan recommends that the Pa'ala'a Kai Wastewater Treatment Plant be upgraded (and slightly expanded) to produce an R-1 quality effluent which will facilitate reuse, and also expand the collection system to allow a few adjacent parcels to connect to the system.

Throughout the North Shore, there are also 31 private wastewater treatment systems serving various condominium complexes, and reuse is limited due to their locations.[6]

3.2 WATER SUPPLY SYSTEMS

This section discusses the various water systems that supply water to the North Shore. These systems include:

3.2.1 Domestic Water Systems

3.2.2 Agricultural Water Systems

3.2.1 Domestic Water Supply Systems

Domestic water supply systems provide high quality drinking water to North Shore residences and businesses. The largest domestic water supply system on the North Shore is the Board of Water Supply System. Two smaller private systems are owned by Dole Foods and North Shore Water Company. There is also a domestic water system at Dillingham Airfield that is on US Army lands and operated by State Department of Transportation (DOT).

The Helemano Military Reservation potable water system is discussed in the Central O'ahu Watershed Management Plan as water is supplied from outside of the North Shore district.

3.2.1.1 Board of Water System

BWS provides most of the water for most residential and business uses in North Shore with the exception of Mokulē'ia and portions of Waialua which are served by private water companies. Municipal water uses consist of residential, commercial, City, and State water users. The BWS system also supplies 0.23 mgd, or 8% in 2010, of total water supplied for agricultural needs, mostly for farms along the highway that do not have access to the Wahiawā Irrigation System and also for agricultural processing.

The BWS delivery of potable water in North Shore is via the North Shore Water System which transmits water over a distance of approximately 16 miles from Crozier Drive in Waialua to the end of Turtle Bay Resort. There is one boosted system to Pūpūkea. The BWS North Shore Water System is supplied by five wells (one of which is inactive) and seven reservoir tanks. In North Shore, BWS has water supply sources in the Waialua, Hale'iwa, Waiale'e, and Kawela areas.

Figure 3.6 illustrates the main features of BWS Systems and other potable systems in the North Shore.

The BWS North Shore water system consists of the Waialua – Hale'iwa 225 system and the Kawela 228 system. The systems are interconnected for service reliability over 16 miles of transmission mains extending from Waialua to Turtle Bay Resort. The water service zones extend from sea level to the 125' elevation. The boosted Pūpūkea Highlands water system extends mauka to the Pūpūkea 892' reservoir. There are five well stations: Waialua, Hale'iwa, Waiale'e I & II and 'Ōpana. Waialua and Haleiwa wells have water treatment plants that use activated charcoal to remove agriculture pesticides, (1,2,3-trichloropropane (TCP) used in pineapple cultivation) from ground water. All wells use chlorination for disinfection. Sunset Beach well was taken out of service and disconnected due to high levels of bacteria from cesspools.

North Shore water system is not interconnected to the Wahiawā, Wai'anae or Windward water systems.

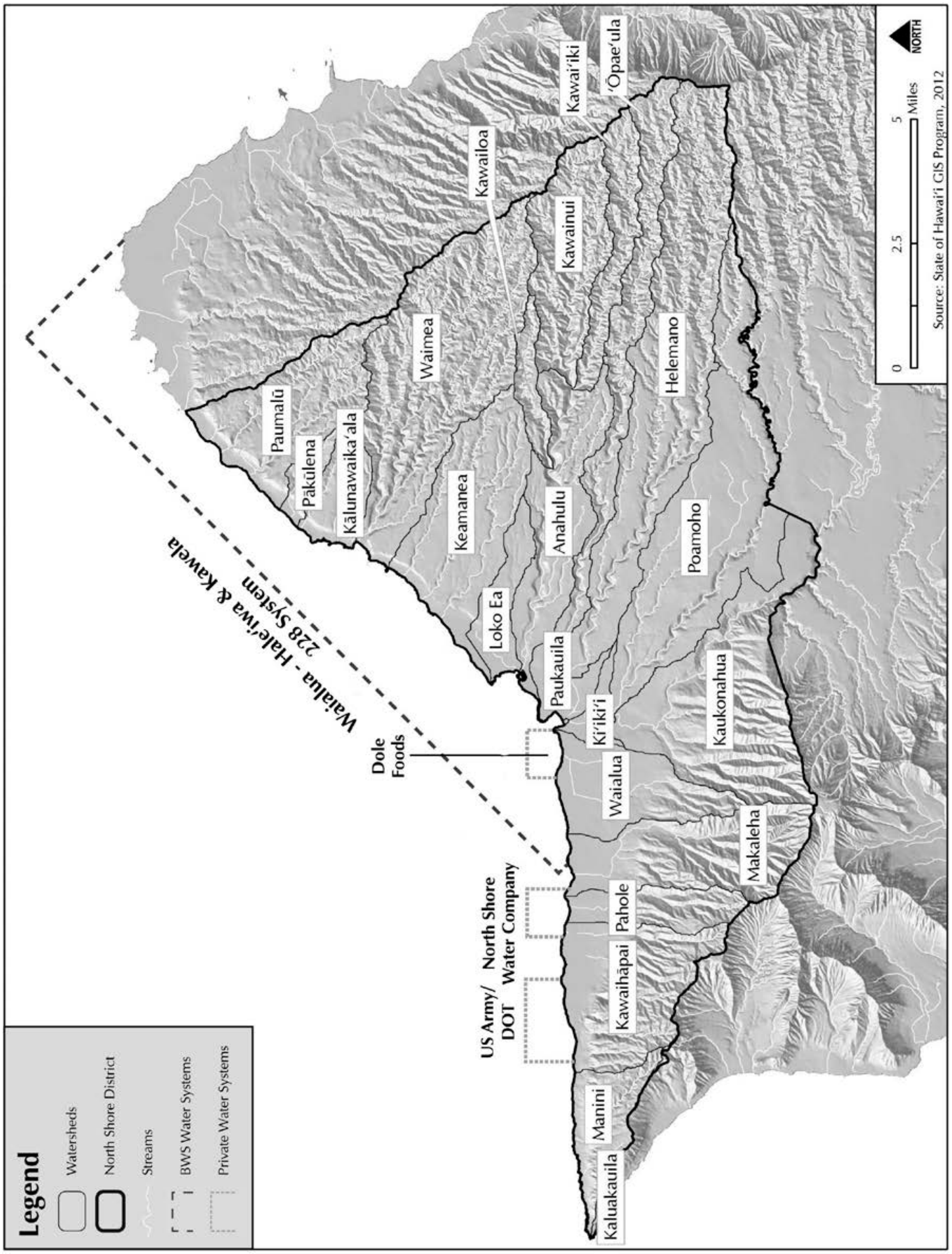

Figure 3.6 Potable Water Systems in North Shore

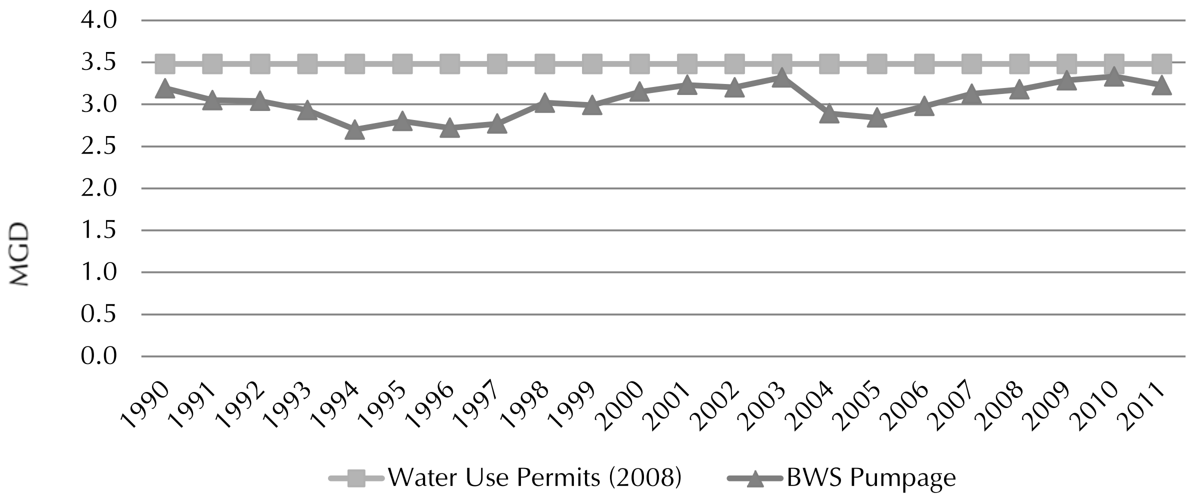

Figure 3.7 Waialua and Kawailoa Aquifer BWS North Shore Water System Water Use Permits and Ground Water Pumpage (CY 1990-2011)

Figure 3.7 above illustrates BWS ground water pumpage on North Shore between the years 1990 to 2011. BWS ground water production has been fairly consistent over this 22 year period. The highest BWS ground water production occurred over the last five years and may be attributed to both increases in population and the addition of agricultural users to the BWS system. BWS ground water pumpage has been within BWS' total permitted ground water withdrawals of 3.750 mgd. *Table 3.8* shows the permitted uses of BWS wells in North Shore for 2012. Prior to 2012, the permitted use for the Waialua Well was 1.730 as is reflected in *Figure 3.7* above. BWS withdrawals averaged 3.32 mgd for the 5-year period from 2007 to 2011 *(Table 3.9).*

Table 3.8 BWS Waialua and Kawailoa Aquifer Sources Permitted Use (2012)

BWS Water Sources	Water Use Permit (mgd)
Hale'iwa Wells	1.000
Waialua Wells[1]	2.000
Total Waialua Aquifer	*3.000*
Waiale'e Well I	0.339
Waiale'e Well II	*0.411*
Total Kawailoa Aquifer	*0.750*
TOTAL[2]	**3.750**

1 Prior to 2012 the permitted use was 1.730

2 Turtle Bay was required to develop a water source, and 'Ōpana well came online in 2013 and is not included in this total.

Table 3.9 BWS North Shore Water Pumpage (CY 2007-2011)

	2007	2008	2009	2010	2011	5-Yr Average
Total BWS Pumpage (mgd)	**3.13**	**3.18**	**3.29**	**3.33**	**3.23**	**3.32**

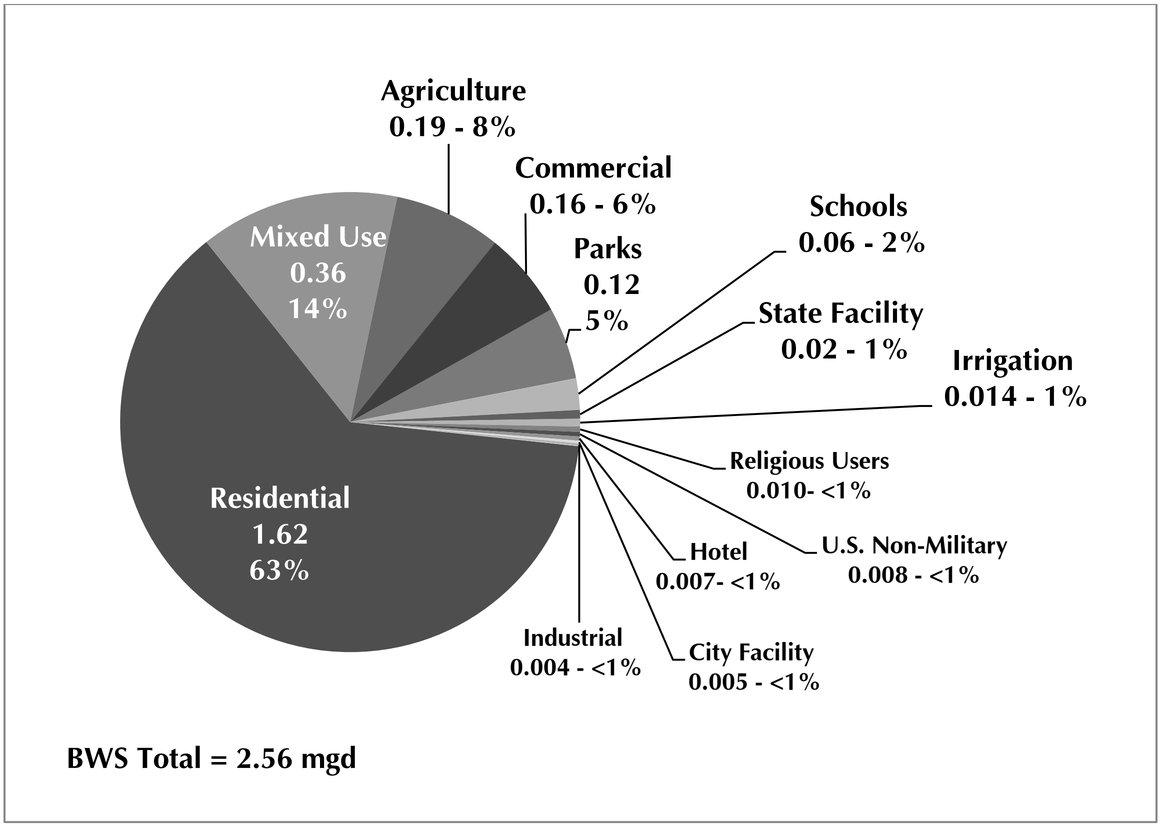

Figure 3.8 North Shore BWS Water Consumption by Sector (CY 2010)

Figure 3.8 illustrates the breakdown of water consumption for various BWS water use sectors on North Shore in 2010. The largest user of BWS water in North Shore was the residential sector with an average use of about 1.6 mgd. Mixed-use facilities were the second largest consumers of BWS water in the district, consuming 0.36 mgd. The agricultural and commercial sectors were the third and fourth largest consumers, respectively, of BWS water in the district. The agricultural sector consumed 0.19 mgd and the commercial sector 0.15 mgd. The daily average for all BWS metered users in the entire district was 2.56 mgd. This 2.56 mgd is water used and does not account for any system water losses. The BWS North Shore pumpage sources serve a slightly larger area than North Shore consumption; actual system water losses are about 17%.

Table 3.10 illustrates BWS water use in 2010 based on CWRM's water use categories.

Table 3.10 BWS Water Use by CWRM Categories in North Shore

CWRM Water Use Category		**2010**	
	BWS Metered User Type	**(mgd)**	**(%)**
Domestic Residential			
	Residential	**1.62**	**63.2%**
Domestic Non-Residential			
	Mixed Use, Commercial, Parks, Schools, State Facility, Irrigation, Religious Users, US Non-Military Facilities, Hotel, City Facility, Industrial	**0.75**	**29.2%**
Agriculture			
	Agriculture	**0.19**	**7.6%**
	TOTAL	**2.56**	**100%**

Source: BWS metered categories for 2010 usage

Table 3.11 illustrates the 2010 top individual users of BWS water in the district. Dole Foods was the largest single consumer of BWS water on the North Shore; the water was distributed to Dole Foods potable residential water users. BWS water is a back-up system for Dole, and this amount of water is not expected to be needed in the future. The next largest users are parks, including Waimea Valley Park, and a school.

Table 3.11 Largest BWS Water Users in the North Shore District 2010

Customer	**Average 2010 Consumption**
Dole Food Company	0.359 mgd
Division of Parks and Recreation (Haleʻiwa Aliʻi Beach Park)	0.045 mgd
Hiʻipaka LLC (Waimea Valley Park)	0.035 mgd
Department of Education (Waialua High/Intermediate)	0.028 mgd

<u>BWS Water Conservation Programs</u>

The BWS has actively promoted water conservation since its inception in 1929. The BWS "Water Conservation Program" is currently organized as follows *(Table 3.12):*

- Public Education and Outreach

- Leak Detection, Repair and Maintenance
- Large Water User Programs
- Regulation
- Alternative Source Development, Recycling & Conservation Alternatives

The principal elements of these five program clusters are summarized in *Table 3.12*. Specific programs within each of these categories that have been major contributors to water conservation savings are summarized below.

Public Education and Outreach

The primary objective of public education and outreach is to influence consumer water use habits. A variety of programs target homes, schools and businesses including Public Service Announcements, features in the newspaper, water saving tips, xeriscape demonstrations, detect-a-leak week, educational booths, water waste hotline, and a water conservation poster and poetry contest that has been held for more than 35 years.

Large Water User Programs

The large water user programs target organizations and businesses with high levels of water consumption. These organizations often have the capacity to facilitate change from within the organization or agency. During droughts, BWS reminds the top 100 water users on their system to conserve water. Additionally, existing agreements with City and State agencies target parks, schools, golf courses, roadway landscaping, and other governmental facilities to be more efficient in their water use. In 2013, the State DLNR CWRM developed the Hawaiʻi Conservation Plan to facilitate water conservation by State agencies and others, and in 2014 released its Hawaiʻi Water System Audits and Water Loss Control Manual.

Leak Detection, Repair, and Maintenance

Water loss audits are a measure of water distribution efficiency that can also indicate potential targets for specific water conservation measures. The Board of Water Supply recently began a targeted conservation program by identifying and fixing system water losses to reduce water lost between production from the ground and delivery into homes. A portion of water loss is due to leakage; other causes of water loss can be from pipes, main breaks, hydrant flushing operations, illegal unmetered water taps, and meters requiring calibration.

On the mainland, municipal water loss averages between 10-15%. On Oʻahu, the island-wide BWS goal is to reduce water loss to less than 10%. North Shore water loss was an estimated 17% in 2010. While over the target water loss percentage, the actual water loss is not large because the North Shore system is a small system compared to the overall BWS system. The BWS program for leak detection repair and maintenance includes 23,000 feet of water mains replacement for the North Shore which will help to lower the system loss percentage.

Table 3.12 BWS Conservation Programs

PUBLIC EDUCATION & OUTREACH	LEAK DETECTION, REPAIR & MAINTENANCE	LARGE WATER USER PROGRAMS	REGULATION	ALTERNATIVE SOURCE DEVELOPMENT, RECYCLING & CONSERVATION ALTERNATIVES
• **Schools** –Educational Material –Curriculum Development –Annual Poster & Poetry Contests –Hawai'i State Science Fair • **Tours** –Fred Ohrt Museum –Halawa Xeriscape Garden –Nu'uanu Watershed –Water Recycling Facility –Waihe'e Tunnel • **Workshops on Water Conservation Gardening & Rain barrel catchments** • **General Outreach** –Water Conservation Calendar –Water Matters Newsletter –Summer Conservation Media Campaign –Speakers' Bureau –NHB Liaison –BWS Website, Social media • **Water Conservation Information/Complaints** • **Communications** –News Releases/Advisories on Water Emergencies/ High Water Usage –Water Conservation/ Education Publications –Water Waste Hotline • **Special Events** –Fix-A-Leak Week –Water Conservation Week –Halawa Xeriscape Garden Open House & Unthristy Plant Sale –Community Events	• **Leak Detection and Repair** (within BWS distribution system and storage facilities) • **Pipeline Corrosion Protection Program** • **Flow Transmitter Maintenance** • **Repair and/or Replacement** of Water distribution mains and service line leaks, valves & fire hydrants • **Enforcement** of unauthorized use of water • **Meter Maintenance Program** • **Meter-Reading/Water Bill Monitoring** (Identify high water use due to undetected leakage; report seepages, leaks, or other signs of possible water leaks) • **Water Audits and Water Loss Control Program:** development of internal water use efficiency practices and programs • **Cathodic Protection** Monitoring and Maintenance –flow transmitter maintenance –pipeline corrosion programs • **QUINCI:** Quality Infrastructure Conservation Initiative	• **Visitor Industry** –Conservation Education –Linen Reuse Placard • **Government Agencies** –Conservation Partnership Projects • **Business/ Commercial** –Conservation Education –Low-Flow Fixture Incentives –Restaurant placard, water served only upon request –Cooling Tower conductivity meters and softening systems –Rebates for Water Efficient Appliances • **Irrigation Systems** Submetering, On-site Weather Stations, Moisture Controllers, Sprinkler Heads	• **BWS Rules & Regulations** –Governing wasteful water use practices (Empowering department to discontinue water service) –Use of nonpotable water for irrigation of large landscaped areas, golf courses, parks, highways, school playgrounds –Restaurant water service, water served only upon request –Restricted irrigation program (Applicable to periods of low rainfall and high consumption) • **BWS Low Ground Water (Drought) Plan** • **County Legislation** requiring low-flush toilets, and low-flow showerheads and faucet fixtures • **Conservation Rate Structure (Inverted Block Rate)** • **New Construction Regulations** –Dual Water Systems –High Efficiency Fixtures –Green Infrastructure –Rain Barrel Catchments	• **Nonpotable Water System Standards and Master Plans** • **Grey Water Reuse** • **Nonpotable Source Development** –Caprock –Brackish –Surface Springs • **Water Recycling** –Honouliuli Water Recycling Facility –Mililani MBR –Ala Wai Golf Course MBR Scalping Plant • **Desalination Plants** –Kalaeloa Seawater –Kapolei Brackish Water • **Research & Studies** –Nu'uanu Stormwater impoundment aquifer storage and recovery –Evapo-transpiration Study –Evaluation of New Water Conservation Efficiency Measures

3.2.1.2 Dole Foods Domestic Water System

Dole Food, Inc. domestic water system serves residential customers and the Waialua Sugar Mill. The fire hydrants were upgraded in the industrial area when the mill closed, and Dole is currently upgrading the line and pump. Aqua Engineers services this closed system, which is on all the time. The Mill Camp currently has a BWS emergency tie-in which is currently in use until Dole completes system repairs. Dole would like to turn its system over to BWS, however it would need to be upgraded to meet current standards before BWS could consider accepting the system.

3.2.1.3 North Shore Water Company System

The North Shore Water Company (NSWC) is owned by Dillingham Ranch ʻĀina, LLC (DRA), and operated by Aqua Engineers. The NSWC also provides domestic water to customers in Mokulēʻia (including Mokulēʻia Beach Colony and Camp Mokulēʻia). NSWC bought the water system assets of Mokulēʻia Water, LLC in fiscal year 2008.

Customers receiving water from Mokulēʻia Water Company in the past were affected numerous times by water contaminated with high levels of fecal bacteria. The Department of Health has been identified as the agency to take the lead on this issue to find a solution. The NSWC would like to transfer the system to BWS. The existing private water transmission system serving Mokulēʻia was built in the 1930's, and is in need of replacement/upgrades to address water contamination issues and meet current fire protection standards. BWS has indicated that the private owner would need to upgrade the system to meet current standards before the BWS could consider accepting the system.

3.2.1.4 US Army/State DOT Dillingham Airfield Water System

The Dillingham Airfield water system in Mokulēʻia is a Department of Health public water system 338, owned by the United States (US) Army. The State Department of Transportation (DOT), Airports Division leases the Dillingham Airfield facilities from the US Army. A private contractor maintains and operates the water system. The source for the water system is the US Army-owned well with a permitted water allocation of 0.055 mgd. The water is also provided to the US Air Force Kaʻena Point Satellite Tracking station per an agreement from Dillingham Airfield with its transfer from the US Air Force to US Army in 1975.[7] The US Air Force has a well near Kaʻena Point with a permitted amount of 0.018 mgd; however, it is not currently used.

3.2.2 Agricultural Water Systems

3.2.2.1 Dole Foods, Inc.

Dole's wells are covered by six water use permits and ground water not used for the potable water system is used: 1) as back-up water for periods when surface water cannot be reliably provided; 2) for agricultural crops that need a higher quality of water than the Wahiawā Irrigation System can provide (e.g. root crops and plants with exposed edible areas); or 3) for processing harvested crops. Of the six water use permits, three were revoked and the remaining three were recommended for reduction with the overall amount being reduced from nearly 23 mgd to 1.67 mgd[8]. On the back up well issue, current CWRM policy precludes the granting of two water use permits from different aquifers (and different water management areas) for the same end use. CWRM has considered using the "water emergency" provisions of the Code (174-62(g) HRS) to address emergency situations, but to date, no process has been established.

3.2.2.2 Wahiawā Dam and Irrigation System

Wahiawā Dam and Irrigation System (WIS) was built in 1906 by Waialua Agricultural Company, with the ability to provide approximately 50 mgd of water to 12,000 acres of sugarcane fields and 5,000 acres of pineapple fields in Waialua and Haleʻiwa. Approximately 8,100 acres can be irrigated under the current WIS configuration. These lands are among the most productive agricultural lands in the State of Hawaiʻi. Of the 8,100 acres, about 5,500 acres were occupied by diversified agriculture farms using WIS water in 2007. The WIS currently provides 9 mgd (from recent USGS gage readings) to diversified crops (including seed corn, pasture grass and tree crops) and to additional acreage of pineapple. The Wahiawā Irrigation System Economic Impact Study found that the WIS is the sole factor making agricultural production possible in the area.

The WIS consists of the Wahiawā Reservoir, the Wahiawā Dam, and an irrigation ditch system extending 30 miles. Portions of land underneath and around the Wahiawā Reservoir are owned by Sustainable Hawaiʻi LLC and leased to Dole. The WIS extends downhill from Wahiawā Reservoir to fields in Mokulēʻia, Waialua, Haleʻiwa, and near Waimea Bay *(Figure 3.9)*. The system is supplied by water from diversions on the North and South Forks of the Kaukonahua Stream, and a portion of the Poamoho Stream via the Poamoho Tunnel which brings that water to Kaukonahua. Other diversions on other lands feed water into other portions of the system. The Kemoʻo Ditch system, a branch of Wahiawā Reservoir Ditch, transports water to Waialua. Above Haleʻiwa, the Wahiawā Reservoir Ditch is joined by three other ditch systems:

- Helemano Reservoir Ditch, which collects irrigation water in Upper Helemano Reservoir (Tanada Reservoir) from the upper reaches of Poamoho and Helemano streams;
- ʻŌpaeʻula Ditch, which collects irrigation water into ʻŌpaeʻula Reservoir from the upper reaches of ʻŌpaeʻula and Kawaiʻiki streams;
- Kamananui/Kawainui Ditch, which collects water from the upper reaches of Kawainui Stream.

Dole Food Inc. owns and operates the Wahiawā Reservoir Ditch, Kemoʻo Ditch, and Helemano Reservoir Ditch. Kamehameha Schools owns the ʻŌpaeʻula and Kamananui/ Kawainui Ditches.[9] As noted above, Dole Foods Inc. has nonpotable wells that provide back-up to the surface water system.

Dole also has ground water sources for agricultural uses; however, they are used mainly as back-up supply during dry periods to allow for continued irrigation.

3.2.2.3 Kamehameha Schools Surface and Ground Water

The current sources of water for the Kamehameha Schools (KS) agricultural lands are on-site irrigation wells and stream diversions. Kamehameha School's surface water irrigation system was developed by Waialua Agricultural Company in 1898. This system is the primary irrigation water source for 2,000 acres currently in cultivation. Three surface water diversions which provide about 3.5 mgd are located in the mauka conservation area of Kawailoa and supply water from the Kawaiʻiki Stream, the ʻŌpaeʻula Stream, and Kawainui Stream via the old Waialua Sugar Irrigation System, including the ʻŌpaeʻula Ditch and

Kamananui/Kawainui Ditch, extending from ʻŌpaeʻula Stream to Waimea Bay. About 2 mgd of Wahiawā Reservoir water (via ʻŌpaeʻula Gulch siphon) is purchased at bulk rate from Dole Food Inc. to supplement supply when there is insufficient rainfall.

Kamehameha Schools also has two water use permits. One water use permit 895 is for well numbered 3506-003 and 3506-004 for 1.66 mgd. The other water us permit is for the ʻŌpaeʻula battery of wells for 1.552 mgd. The wells will provide high quality ground water for crops and supplement the surface water system. Kamehameha Schools has instituted an irrigation system maintenance and improvement program with substantial upgrades to infrastructure, stream diversions and wells, totaling more than $10 million.

3.2.2.4 Dillingham Ranch

Two active wells on DRA's property deliver water to sustain the day-to-day operation of the Ranch.

3.2.2.5 University of Hawaiʻi Waialeʻe Research Station

The University of Hawaiʻi (UH) College of Tropical Agriculture and Human Resources owns and operates the Waialeʻe Livestock Research Station water system. The system is located in the Kawailoa aquifer system. The water system is supplied by two well sources. Both sources supply brackish nonpotable water.

3.2.2.6 University of Hawaiʻi Poamoho Research Station

The University of Hawaiʻi Poamoho Agricultural Research Station is in the North Shore district; however, its potable water source is from Schofield Barracks. The water for its 20 plus acres of crops comes from the Wahiawā Irrigation System.

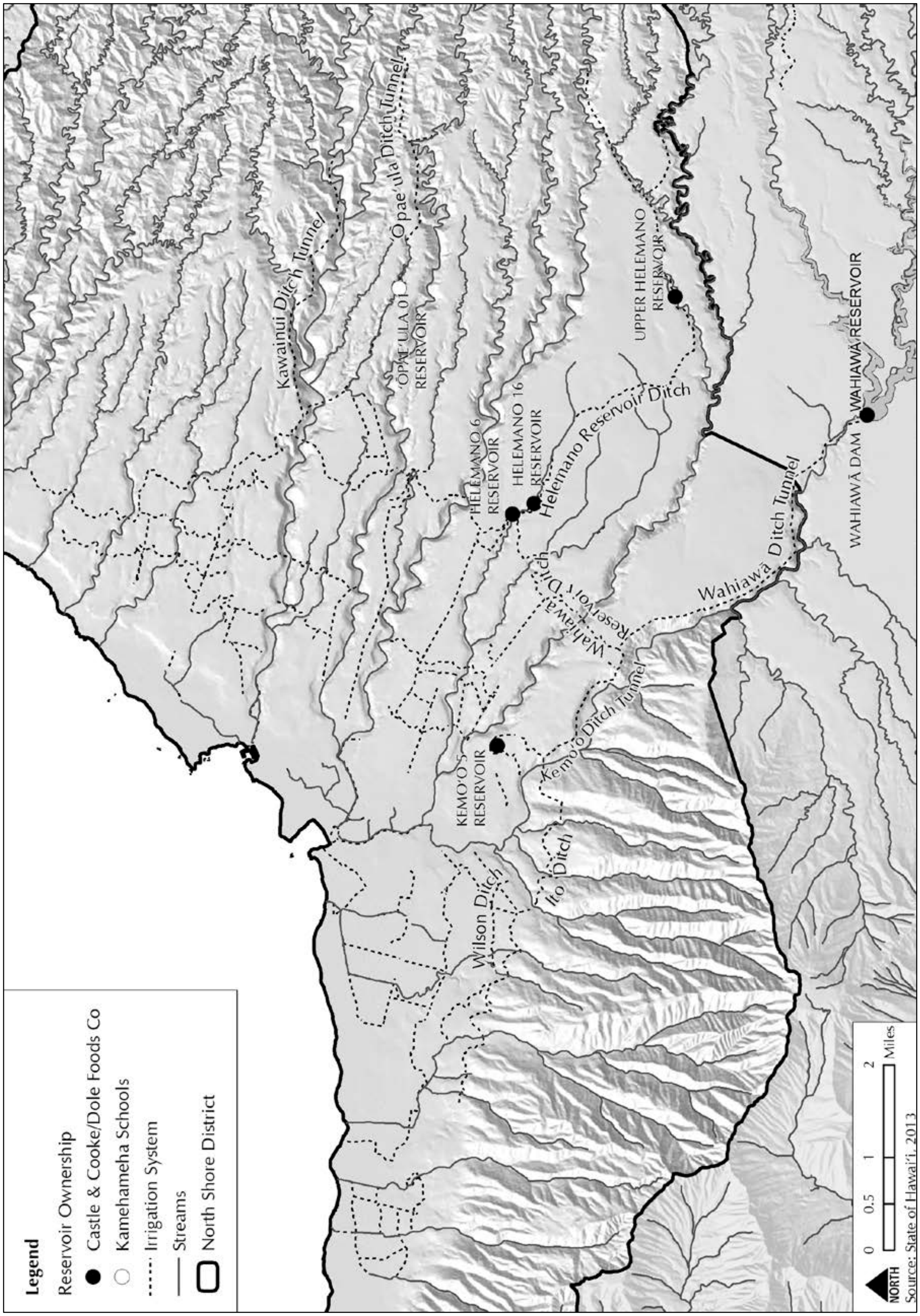

Figure 3.9 North Shore's Wahiawā Irrigation System and Related Ditch Systems

3.3 PROJECTING FUTURE WATER DEMAND

In planning for the North Shore's future water needs, water demand was projected for domestic and agricultural uses to the year 2035. These projections provide an estimate of how much water might be needed over the next twenty years and indicate when increased demand may require upgrades to infrastructure. The projections also provide guidance for future land and water use decision making.

Existing use is based on data from 2010, when available. The base year of 2010 was chosen as it corresponds to 2010 US Census population statistics. BWS existing use is from 2010 metered consumption records and U.S. Census figures were used to determine the population served. The year 2010 was a below normal rainfall year and as a baseline year provides more conservative numbers for planning purposes than a year with normal rainfall. When 2010 data was not available, other available water use information was used.

3.3.1 Water Demand Scenarios

The Statewide Framework for Updating the Hawai'i Water Plan (2000) requires that each County Water Use and Development Plan develop three water demand scenarios: a base case scenario based on the most likely assumptions, a high-growth scenario, and a low-growth scenario. The base case scenario is the mid-growth scenario which is grounded on City policies as presented in the North Shore Development Plan (approved by the City Council in 2011). A low-growth scenario will reflect slower growth in urban development and a high-growth scenario will reflect a faster rate of urban growth than the City and County policies. An ultimate-growth scenario was created to identify a point in the future where the North Shore district is "built out" and water becomes a potentially limiting factor.

3.3.1.1 Low-Growth Scenario

For the low-growth scenario, the amount of housing added to the North Shore remains limited and includes infill and small developments. The population grows at a rate of about half of that anticipated by the 2035 population projections, perhaps due to an economic downturn.

In this scenario, the City's rail project has been constructed and more people to choose to live in town (the Primary Urban Core) over the North Shore which reins in housing and population growth on the North Shore. Farmland remains available in other areas of O'ahu, and North Shore irrigated agriculture expands at a very modest rate.

3.3.1.2 Mid-Growth Scenario (Base Case Scenario)

The mid-growth scenario is based on the socio-economic projections for population for the North Shore district, as projected by the City and County of Honolulu. This scenario reflects the North Shore Development Plan vision which identifies limited growth and the preservation of open space and agricultural lands. Agriculture expands due to the loss of farmland in other parts of the island due to development pressures and increased needs for local food production.

3.3.1.3 High-Growth Scenario

The high-growth scenario reflects a future where population growth experienced on the North Shore between 1990 and 2010. These higher than DPP projected growth rates might result from a very robust economy where growth is occurring around the island.

With this growth in population comes increased need – and desire – for locally grown food. The North Shore's growing conditions and land and water availability continue to make it a desirable agricultural region.

3.3.1.4 Ultimate-Growth Scenario

The ultimate-growth demand scenario illustrates a development scenario for the North Shore at some point in the future. This scenario provides a level of demand used to consider if there will there be enough water to supply future potential agricultural and residential demands. In this scenario, development is "maxed out" and agricultural lands captures all the possible lands that might reasonably be irrigated.

The ultimate demand scenario for the North Shore reflects a "full build-out" of developable land within the community growth boundary and for agricultural reflects the maximum amount of agricultural lands in production and irrigated outside of the community growth boundary. The agricultural ultimate growth scenario might be triggered by demand for large scale crops such as with biofuels. The ultimate demand scenario is used for watershed planning purposes and is not tied City and County of Honolulu Department of Planning population projections.

3.3.2 Summary of Water Projection Scenarios

Table 3.13 summarizes the discussion on the assumed future water demand by each water use sector and for the low, mid, high, and ultimate-growth scenarios.

Table 3.13 North Shore Water Demand Projections Scenario Assumptions

Water Use Sector	Baseline Data (2010)	2035 Growth Scenarios			Ultimate Growth Scenario
		Low-Growth	Mid-Growth	High-Growth	
Domestic	17,720 persons	+900 persons less than DPP Policy Projections	+1,800 persons based on DPP Population Projections	+3,000 persons based on historic population trends	+ 800 acres is developed within the Community Growth Boundary
Diversified Agriculture	6,000 acres	+500 acres based on DPP ag jobs projections	+ 1,500 acres Based on O'ahu Outlook (2011) report	+ 2,500 acres or 50% of ALISH lands outside of Community Growth Boundary	+ 13,200 acres
Pineapple	2,500 acres	2,500 acres Status quo	2,500 acres Status quo	2,500 acres Status quo	
Kalo	10 acres	10 acres Status quo	25 acres Modest expansion	45 acres Robust expansion	100 acres

3.3.3 Water Demand Methodology and Assumptions

Water demand was estimated for domestic and agricultural systems. The assumptions used in projecting water demands for these systems are described below.

3.3.2.1 Domestic Water Systems

The domestic water systems on the North Shore supply residential, commercial, industrial, government, and agricultural uses. A "per capita" approach was used to calculate domestic water demand, whereby the average water demand is divided by population (i.e., water demand per capita).

Water Demand ÷ Population Served = Per Capita Water Demand

The per capita demand for the North Shore in 2010 was 203 gallons per capita per day (gpcd). The per capita demand from 1980 to present and projected to 2040 in *Figure 3.10* shows a fairly constant demand that is close to the 2010 per capita demand of 203 gallons per capita per day. This per capita demand is applied to population projections through the planning horizon (2035) to estimate future water demand.

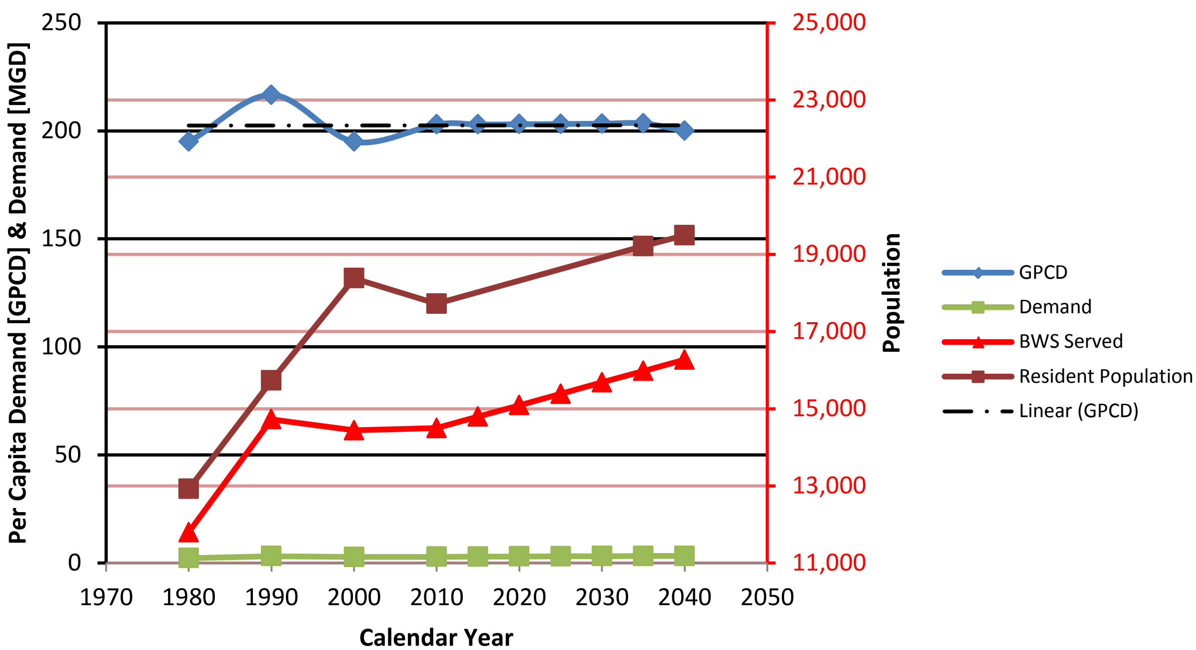

Figure 3.10 North Shore Gallons per Capita per Day Trend

The City and County of Honolulu's population projections for the year 2035 (September 2009) for North Shore are based on the land use policies in the *North Shore Sustainable Communities Plan*, the City and County of Honolulu's long-range land use plan for the district. The North Shore SCP calls for limited population growth and limited future development in the district.

City's population projections for North Shore show a population share of 1.9%, of the total O'ahu population, which is close to the General Plan's guidance for the North Shore population of 1.7% of O'ahu's population. The 1.9% is slightly higher than the General Plan percentage; however, the percentage has been higher than General Plan guidance since the 1990s (Chapter 2, *Table 2.11*).

The City's projections are used for the calculation of domestic water demand for the mid-growth scenario. The low-growth scenario assumes that only half of the projected DPP population increase occurs by 2035. The high-growth scenario assumes the North Shore historic population trend from 1990 to 2010 which results in the North Shore having 2% of O'ahu's population by the year 2035.

3.3.2.2 Diversified Agriculture, Pineapple, and Kalo

Future agricultural activity in North Shore may increase significantly, given that there are large areas of unutilized agriculture lands and a major variable of future water demand. The Galbraith lands, including those just outside the North Shore district in Central O'ahu district, are included in this watershed management plan.

To project agricultural water use, agricultural activities were categorized into three major types: diversified agriculture, pineapple, and wetland kalo. Each agricultural activity was assigned a different water use coefficient per acre. *Table 3.14* presents the water use coefficients used to project demands (in gallons per acre per day (gpad), the type of coefficient, and the data source(s) that the coefficients were based upon.

Aerial photo analysis (using 2008 aerial imagery) and *O'ahu Agriculture Situation, Outlook and Issues* (2011) were used to estimate the amount of agricultural lands currently in diversified agriculture and pineapple. The 2008 aerial photo analysis provided a snapshot in time and showed approximately 7,200 acres in cultivation *(Figure 3.11).* The 2011 *O'ahu Agriculture Situation* report listed a total of 8,500 acres in cultivation with a breakdown of 6,000 acres in diversified agriculture and 2,500 acres in pineapple. Between 2006 and 2011, Kamehameha Schools has been adding additional agriculture leases. Follow-up with Dole Foods confirmed the pineapple acreage, existing and future. The 8,500 acres listed in the O'ahu Agricultural Situation report are understood to be the most current and accurate.

While pineapple lands are assumed to be constant through 2035, the diversified agricultural lands are estimated to vary considerably amongst the scenarios. The low-Growth scenario for diversified agriculture is set based on the City and County of Honolulu's projections (September 2009) for agricultural jobs on the North Shore. There is a projection for a 9.5% increase in agricultural jobs on the North Shore by 2035 (increasing from 210 in 2009 to 230 in 2035). This increase is applied to the irrigated agriculture acreage for a 9.5% increase.

Table 3.14 Agricultural Water Use Coefficients

Agricultural Activity	Water Use Coefficient (gpad)	Type of Water Coefficient	Data Source
Diversified Agriculture	3,400	Average per acre water use for Diversified Agriculture activities NOTE: does not include irrigation system water losses	The State Agricultural Water Use and Development Plan (2004)
Pineapple	1,600	Average per acre water use for pineapple averaged assuming that an average of 80% of the land was kept in crop and 20% was kept fallow.	Oʻahu Agriculture: Situation, Outlook and Issues (2011)
Loʻi Kalo	100,000 to 300,000	Per acre water inflow into loʻi kalo system	Available kalo water use studies[1]

[1] Available kalo water use studies include USGS 2007 *Report on Water Use in Wetland Kalo Cultivation in Hawaiʻi*; Office of Planning 1995 *Preliminary Assessment of Potential Water Demand for Economic and Instream Uses in the Waiāhole-Kualoa Region*, and the *Agricultural Water Use and Development Plan* produced by the State DOA, Penn, D.C. 1997 dissertation on *Water and Energy Flows in Hawaiʻi Taro Pondfields*, Watson, L. J. 1964 *Observations made with respect to irrigation and growth of taro at certain patches at Waiāhole and Kahaluu*, and Miles, K. 1931 *Report on study of water requirements of taro in Hanapēpē Valley*, cooperative study by the Territory of Hawaiʻi and McBryde Sugar Company: ʻEleʻele, Hawaiʻi.

The mid-growth scenario for agriculture is based on the Oʻahu Outlook (2011) report that notes that 1,500 acres of agricultural lands in ʻEwa and Central Oʻahu are likely to be displaced by proposed development and will need to be relocated. For the mid-growth scenario, 1,500 acres of additional agricultural lands on the North Shore are assumed by 2035.

The ALISH system identifies three classes of agriculturally important lands: "Prime," "Unique," and "Other" *(Figure 3.11)*. The Prime and Unique lands on the North Shore are suitable for diversified agriculture and pineapple. Lands categorized as "Other" by the ALISH system are most likely to be used for un-irrigated pasture due to location, topography, and limited availability. *Figure 3.11* shows the existing agriculture from the 2008 aerial overlaid with ALISH categories of Prime, Unique and Other lands. The mid-growth scenario assumes 46% of the total ALISH Prime and Unique lands are cultivated and irrigated.

For the high-growth scenario, an even greater level of additional agriculture on the North Shore is assumed. Fifty percent (50%) of the "Prime" and "Unique" ALISH rated lands are assumed to be in production in this scenario with North Shore serving as the major agricultural producing area on Oʻahu.

In the ultimate scenario, all of these ALISH rated lands are assumed to be in production.

Current kalo production was estimated based on conversations with farmers and landowners. There are currently about 10 acres of kalo in production in areas in flat lowland areas. There are a couple acres in Waialua, several acres in the low area around ʻUʻkoa Marsh, and ¼acre in Waimea Valley. The water supply for most of the plot is springs.

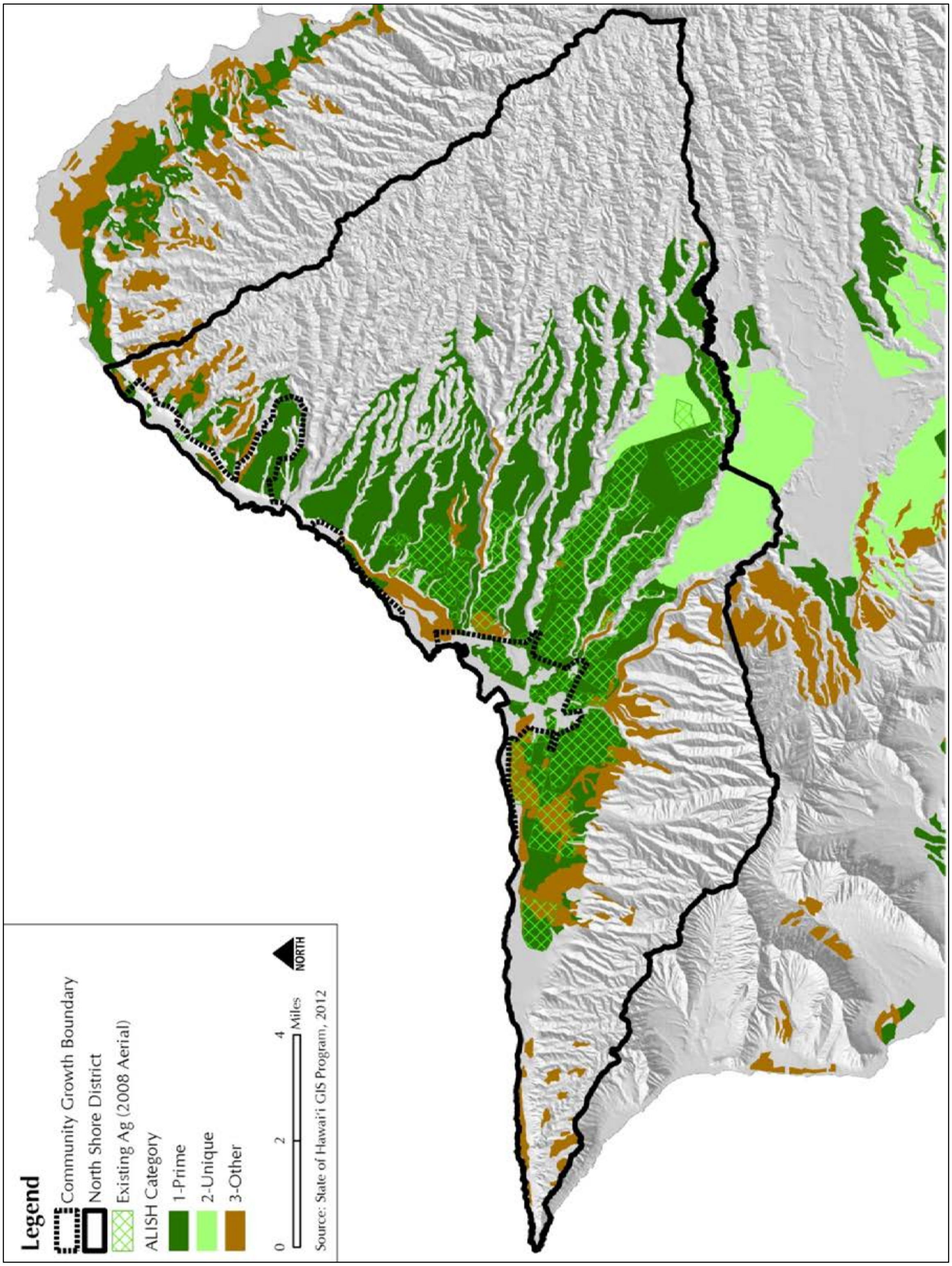

Figure 3.11 ALISH Ratings and Existing Agriculture

Mid-growth scenario projected expansion of an additional 15 acres is predominately through Kamehameha Schools plans to expand loʻi kalo at two locations (ʻUkoʻa and Anahulu areas), and through the Dole lands for sale that were previously used by HPC Foods (formerly Honolulu Poi Company which produces Taro Brand products) which may return to loʻi kalo production. ʻUkoʻa Marsh loʻi kalo would be spring fed, and Anahulu and Dole lands loʻi kalo would utilize stream water.

Previous studies on the amount of water needed to support healthy kalo fields document a wide range of inflow volumes (See Appendix E). These studies, as well as discussions with several kalo farmers, indicate that a general range of 100,000 to 300,000 gpad of inflow is needed. 100,000 gpad was selected as an acceptable demand which assumes modern water efficiency management practices such as lined or piped auwai, metered water use and hydrologic monitoring on-site weather stations, etc.

3.3.4 Water Demand Scenarios Summary

Water demand is estimated for domestic and agricultural systems and is summarized in this section. Domestic water systems demand increases slightly by 2035 under low, mid and high scenarios and nearly doubles from the 2010 usage under the ultimate scenario. The agricultural water demand, in particular, diversified agricultural demand, is projected to be the dominant future water use in all scenarios, and is an especially large demand in the ultimate scenario. *Table 3.15* shows the North Shore water demand by water systems. *Figure 3.12* illustrates the future water demand by water use systems for the water use scenarios.

Table 3.15 Water Demand by Water System

Water System	2010 (mgd)	2035 (mgd)			Ultimate Scenario
		Low Scenario	Mid Scenario	High Scenario	
Domestic Water Systems					
Board of Water Supply	2.8	2.8	3.0	3.2	
Dole Foods	0.0	0.1	0.1	0.1	
North Shore Water Company	0.1	0.1	0.2	0.2	
Dillingham Airfield	0.1	0.1	0.1	0.1	
Total Domestic Water System	***3.0***	***3.1***	***3.4***	***3.6***	***5.5***
Agricultural System					
Total Agriculture	***24.2***	***26.1***	***29.3***	***32.7***	***72.7***
TOTAL	**27.2**	**29.2**	**32.6**	**36.2**	**78.2**

Note: See Appendix E for calculation methodology

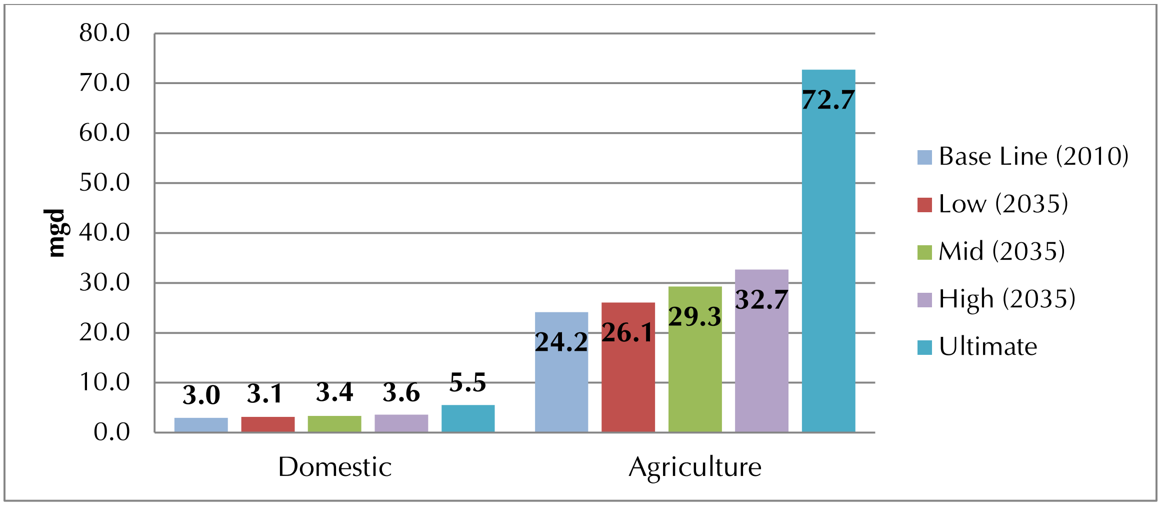

Figure 3.12 Water Demand By Water System

The State CWRM uses different water use categories to classify water demand. The following table *(Table 3.16)* shows North Shore projected water use according to CWRM water use categories. *Table 3.10* was used to assign the percentages for the CWRM water use categories.

Table 3.16 Water Use by CWRM Water Use Categories

Water Use	2010 (mgd)	2035 (mgd)			Ultimate Scenario
		Low	Mid	High	
Domestic	**2.8**	**2.9**	**3.1**	**3.3**	**5.5**
Residential	1.9	2.0	2.1	2.3	
Non-residential	0.9	0.9	1.0	1.0	
Agriculture	**24.4**	**26.3**	**29.5**	**32.9**	**72.7**
Ag (Ag area)	24.2	26.1	29.3	32.7	
BWS Ag (Urban area)	0.2	0.2	0.3	0.3	
TOTAL	**27.1**	**29.2**	**32.6**	**36.2**	***78.2***

Note: See Appendix E for calculation methodology

3.4 MOST PROBABLE WATER DEMAND SCENARIO

The mid-growth demand scenario is the most probable water demand scenario and serves as the basis for planning future water supply development options. The mid-growth domestic demand includes planned development in the SCP and small scale lodging. The agricultural mid-growth demand scenario shows a modest increase due to expansion of existing farming and potential relocation of agriculture lands from ʻEwa and Central Oʻahu per *Oʻahu Agriculture* (2011). This most probable water demand scenario selection does not rule out the possibility that one of the other demand scenarios could take place in the future. Flexibility in water supply options is a key consideration in meeting future needs.

3.5 ADEQUACY OF SUPPLY TO MEET DEMAND

This section discusses the implications of the water demand projections on water supply analysis. The major uncertainties and assumptions are made explicit and then the contingencies and implications are presented based on the analysis of current and future water use for both domestic and agricultural water use. To plan for water supply projects, the most probable water demand scenario has been matched to a water system with existing water supply sources *(Table 3.17)*. The implications and possible contingencies needed are also discussed below.

3.5.1 Domestic Water Supply

Uncertainties are inherent in water demand projections. A number of scenarios are used to provide a range of possible outcomes. For domestic water demand, the greatest uncertainties are related to economic markets for housing. The building of additional housing will likely depend on market timing especially for larger potential development.

The domestic water demand should have ample water supply for each system, BWS and private systems. The exception is the current North Shore Water Company which includes demand for an additional 91 units agricultural subdivision. This demand could likely be met using existing Dillingham Ranch permitted wells with an associated supply system extension or new system for the subdivision. This new development may provide an opportunity to create a water supply reservoir tank to provide increased pressure for the North Shore Water Company System and the ability to extend fire hydrant coverage.

Water conservation and efforts toward more efficient water system distribution could potentially help meet future projected demands as well.

3.5.2 Agricultural Water Supply

Economic markets impact the agricultural sector and the types of crops grown. For example, if biofuels (crops grown for producing fuels for vehicles or power production) were to become economically viable on O'ahu, most agricultural lands on the island would likely be put into production. Water costs, water availability, and water quality also affect the amount of agricultural water demand. Because water costs for surface water have historically been the lowest (versus the cost of electricity to pump ground water), the assumption was made that surface water, where available would be used before ground water. Water quality was not assumed to be a limiting factor to allow for the possibility that in the future, Wahiawā Reservoir water might be used for all types of irrigation.

For the most probable scenario, the various supply sources appear to be able to provide water to meet overall demand. However, there are situations in which demand may not be easily met such as under extended dry periods or drought when existing surface water may not provide enough water. Surface waters are very susceptible to weather conditions, and there is limited storage on the North Shore. Supply sources may also not be available for certain lands e.g. a farm outside of the Wahiawā Irrigation System service area might need to use ground water for irrigation needs.

Table 3.17 Most Probable Scenario Demand & Supply Summary

	2010	2035
DOMESTIC WATER SYSTEMS		
BWS Potable Water System Demand	2.81	3.01
BWS System - Permitted Ground Water Use[1]	3.75	3.75
Dole Potable Water System Demand	0.00	0.13
Dole - Permitted Ground Water Supply[1]	0.26	0.26
North Shore Water Company Potable Water System Demand	0.12	**0.18**
North Shore Water Company & Dillingham Ranch - Ground Water Supply[1]	0.15	**0.15**
US Army/State DOT Dillingham Airfield System Demand	0.06	0.06
Federal Systems - Ground Water Supply[1]	0.06	0.06
AGRICULTURE		
Agriculture Water Demand	24.15	29.25
Ag, Surface Water Supply		
KS Surface Water Supply	3.50	3.50
Dole Surface Water Supply[2]	8.90	8.90
Dole System - Future Water Conservation[3]	-	
Ag, Recycled Water Supply		
Wahiawā Waste Water Treatment Plant (R-1)[4]	-	1.00
Ag, Ground Water Supply		
KS Ground Water Supply[1]	3.21	3.21
Dole System - Ground Water Permitted Use[1]	1.41	1.41
State Ag Stations - Ground Water Supply[1]	0.03	0.03
Other Ground Water Supply[1]	12.80	12.80
Future Ground Water Permit(s)[5]	-	-
TOTAL WATER DEMAND	**27.14**	**32.62**
TOTAL WATER SUPPLY	**34.07**	**35.07**
Kalo Water Demand	1.00	2.50

1 CWRM Water Use Permit (WUP) Index (2010); permitted uses for fresh and brackish water wells.

2 Existing surface water use with current level of losses; additional water demands need to be met through water conservation savings that means more efficient transport of water through the system.

3 Ag water conservation from Wahiawā Irrigation system improvements needed to meet add'l demands.

4 Effluent from Wahiawā WWTP that will be used for Galbraith lands which are included in the overall Ag demand.

5 Future ground water permits for lands within the WIS system should not be granted until WIS system improvements have been made and that supply source maximized.

Below are some specific descriptions of North Shore agricultural supply issues.

Wahiawā Irrigation System Improvements: Most farmers on the North Shore irrigate with surface water from the Wahiawā Irrigation System or the Kamehameha Schools irrigation system. Aging infrastructure will require more investment and rates will need to be increased. The ability for farmers to pay higher water rates will significantly affect the success of North Shore agriculture into the future. However, water system reliability is needed to ensure continual agriculture investment and growth. With current agricultural demands by Wahiawā Irrigation System users, there is ample water supply available to meet demands with the current water system of stream diversion, storage and wells and its associated water losses. Kamehameha Schools has made extensive water system improvements to their portion of the Wahiawā Irrigation System ensure a high quality and quantity of water is available for irrigation of their lands. However, as water demands for diversified agriculture increase, the Wahiawā Irrigation System may not be able to deliver the available water, unless improvements are made to decrease water losses on the rest of the system. In effect, reducing water losses becomes the water bank for future agriculture and is the most cost effective strategy.

Instream Flow Standards: Only a portion of the streams on the North Shore have stream flow data. In the future, more information on stream flows is needed to better estimate the availability of stream water for agricultural uses and stream biota. Surface water uses (agricultural and instream) cannot practically be planned for until measurable instream flow standards are set. Once the measurable instream flow standards are set it might be possible to expand the amount of stream-irrigated agriculture in North Shore. Until measureable instream flow standards have been determined for diverted streams on the North Shore, existing diversions should be used as efficiently as possible to provide for the return of water to the streams or aquifers.

Irrigation Water Availability: Most agriculture on the North Shore is dependent on surface water due to its low cost. However, it is susceptible to drought which is problematic for crops that require continued irrigation. The ability to access ground water during these periods is critical. Increased water storage might also need to be explored. At a minimum, no net loss of existing storage is an important plan goal.

The above issues are addressed through various projects described in Chapter 4 and this Chapter, the ability of the local water supply resources to meet the North Shore water demands is discussed further in Chapter 5.

ENDNOTES

1 State of Hawai'i, Hawai'i Revised Statutes §174C-3.

2 State of Hawai'i Commission on Water Resource Management, 2008. *Water Resource Protection Plan.* Prepared by Wilson Okamoto Corporation.

3 Pobuck, Jack. Capital Improvement Projects Program Coordinator, City and County of Honolulu Department of Environmental Services. Email Communication, November 18, 2011.

4 State of Hawai'i Department of Land and Natural Resources Commission on Water Resource Management, 2013. *2013 Update of the Hawai'i Water Reuse Survey and Report*. Prepared by The Limtiaco Consulting Group.

5 Staff Submittal, February 15, 2012. *Request to Authorize the Chairperson to Enter Into a Contract Agreement to Develop a Central O'ahu Non-potable Water Master Plan.* Commission on Water Resource Management. Available URL: http://hawaii.gov/dlnr/cwrm/submittal/sb201202D1.pdf [Accessed May 11, 2012]

6 City and County of Honolulu, 2012. *North Shore Regional Wastewater Alternatives Plan*. Prepared by Brown and Caldwell.

7 US Air Force Space Command, 2013. *Draft Environmental Assessment Addressing the Repair, Upgrade, or Replacement of the Dillingham waterline for Ka'ena Point Satellite Tracking Station, O'ahu, Hawai'i.* Prepared by HDR.

8 Commission on Water Resource Management, 15 February 2012. Staff Submittal – Hearing to Review and Partially and/or Completely Modify or Revocate Water Use Permits in the Waialua Ground Water Management Area, O'ahu.

9 City and County of Honolulu Department of Environmental Services, 2010. *Waialua-Kaiaka Watershed Study Final Report.* Prepared by Townscape, Inc.

4 PLAN OBJECTIVES, WATER SUPPLY AND WATERSHED MANAGEMENT PROJECTS AND STRATEGIES

4.1 OVERALL GOAL, OBJECTIVES, AND SUB-OBJECTIVES OF THE NSWMP
4.2 WATERSHED MANAGEMENT PROJECTS, PROGRAMS AND STRATEGIES
4.3 WATERSHED MANAGEMENT PROJECTS AND PROGRAMS WITH "PROJECT CHAMPIONS"
4.4 WATERSHED MANAGEMENT STRATEGIES

4.1 OVERALL GOAL, OBJECTIVES, AND SUB-OBJECTIVES OF THE NSWMP

In order to provide planning consistency, all of the O'ahu Watershed Management Plans share the same general goal and the same five major objectives. More detailed sub-objectives, derived from an analysis of watershed issues and stakeholder values, reflect the unique resources and needs of each planning district.

The overall goal of the O'ahu Watershed Plans is: *"To formulate an environmentally holistic, community-based, and economically viable watershed management plan that will provide a balance between: (1) the preservation, restoration and management of O'ahu's watersheds, and (2) sustainable ground water and surface water use and development to serve present users and future generations."*

The five major objectives that are common to all of the O'ahu Watershed Management Plans are:

1. Promote Sustainable Watersheds
2. Protect and Enhance Water Quality and Quantity
3. Protect Native Hawaiian Rights and Traditional and Customary Practices
4. Facilitate Public Participation, Education, and Project Implementation
5. Meet Future Water Demands at Reasonable Cost

More detailed information further describing the objectives can be found in Chapter 1.2, O'ahu Water Management Plan Framework, and on pages 4-9 to 4-13.

The sub-objectives for the North Shore then provide the planning framework for organizing North Shore specific water supply and watershed management projects and programs. The five major objectives and corresponding sub-objectives are listed below.

OBJECTIVE #1: PROMOTE SUSTAINABLE WATERSHEDS

Sub-Objective 1.1: Remove invasive species and increase areas of healthy native forests. The diversity of plant types in native forests can enhance ground water recharge. Invasive plants and animals can affect the level of ground water recharge and increase soil erosion and sediment runoff. Very noxious weeds should be monitored and controlled. Fencing and then replanting as needed with native plants would mitigate erosion and run-off in threatened areas. Support of on-the-ground programs by the US Army, Ko'olau Mountains Watershed Partnership, and the Wai'anae Mountains Watershed Partnership are vital for forest protection.

Sub-Objective 1.2: Protect and restore wetlands and streams for ecological, cultural and recreational values. The North Shore is blessed with numerous streams and large wetland areas. Community members value North Shore streams and wetlands for their ecological, cultural, and recreational values. However, various scenarios can result in stream sediments impacting fishponds and wetlands: Hawai'i's natural geology and vegetation, episodic soil creep coupled with intense rain events, and streams that have been altered to irrigate agricultural lands. As a result, the stream, fishpond and wetland natural functions have been diminished. Community groups in partnership with government agencies and landowners have initiated several projects associated with protecting and restoring these resources.

Sub-objective 1.3: Collaborate with responsible agencies to identify and implement measures to alleviate flooding issues. Local flooding problems are a threat to public health and safety in many areas. There is a need for local drainage and flood mitigation plans for flood-prone areas in the North Shore district. The Kaiaka Bay watershed project contributed to the formation of the North Shore Neighborhood Board's Flood/Emergency/Watershed Committee, and it should continue to meet and work on these issues.

OBJECTIVE #2: PROTECT AND ENHANCE WATER QUALITY AND QUANTITY

Sub-Objective 2.1: Recognize the connection between land and sea and improve stream water, ground water, and coastal water quality. The water quality of surface and nearshore waters is connected as water flows through agricultural and urban areas into the ground water or ocean. Efforts that help to improve environmental quality of land areas will improve the conditions of water resources.

A wide variety of land use measures can help to improve the water quality of stream, ground and coastal waters. For example, sediment in stream water can be reduced with riparian buffers, agricultural road improvements, and other best management practices. Ground water quality is best maintained by preventing contamination in the first place, and coastal water quality can be improved through additional wastewater management techniques.

Sub-objective 2.2: Maintain and improve the water quantity of ground water and surface waters. The drinking water for the North Shore district is sourced from ground water. Withdrawal rates should continue to be within established sustainable yields, which protect the long-term viability of the water resource. Surface water is the main source of irrigation water, and a consistent quantity is necessary for crop irrigation.

OBJECTIVE #3: PROTECT NATIVE HAWAIIAN RIGHTS AND TRADITIONAL CUSTOMARY PRACTICES

Sub-Objective 3.1: Provide support to place-based natural and cultural resources management and Native Hawaiian cultural educational programs in North Shore. There are many educational programs that emphasize natural and cultural resource management based upon Native Hawaiian values and principles. These programs and the creation of more like-minded educational opportunities should be supported.

Sub-Objective 3.2: Restore and utilize kalo lands and fishponds for food production and cultural educational use. North Shore was historically known for its food abundance, which was attributed in part to the development of extensive lo‘i complexes and the development of numerous fishponds. These resources should be restored and utilized where feasible for future food production and cultural educational programs.

OBJECTIVE #4: FACILITATE PUBLIC PARTICIPATION, EDUCATION, AND PROJECT IMPLEMENTATION

Sub-Objective 4.1: Increase public awareness and educational efforts of watershed management. People may engage in behavior that can be harmful to the environment because they are not aware of the consequences human actions can have on natural resources. Efforts to increase public awareness can help to change an individual or group’s behavior and result in actions that are more environmentally sensitive.

Sub-Objective 4.2: Promote public participation in planning of watershed management projects and programs. Successful watershed management projects and programs embrace public participation in order to include local knowledge and support.

Sub-objective 4.3: Foster community/government partnerships to help with plan implementation. Community groups, agencies and organizations often have overlapping watershed objectives. By forming partnerships, funding and resources can be combined and maximized to work toward common objectives. Where the groups differ on objectives, the partnership can provide a forum for discussing diverse interests and problem solving strategies.

OBJECTIVE #5: MEET FUTURE WATER DEMANDS AT REASONABLE COSTS

Sub-Objective 5.1: Ensure adequate and cost-effective agricultural water supplies and promote water conservation and delivery efficiency. Fixing losses within the irrigation systems would save water and provide water for more extensive farming and/or return to streams.

Sub-Objective 5.2: Maintain and improve potable water system reliability, adequacy and efficiency. A reliable water delivery system can minimize the frequency, magnitude and duration of water shortages and ensure a consistent supply of high quality water to customers.

Sub-Objective 5.3: Integrate renewable energy and energy efficiency within the water delivery systems. Water and energy conservation go hand in hand in preserving the water supply and reducing Hawai'i's dependence on imported fuels. Saving water saves energy, and is a sustainable conservation behavior that can be incorporated into the everyday life of the public. As a large user of energy to provide water, Board of Water Supply (BWS) also has a responsibility to conserve energy and integrate renewable energy where feasible.

Sub-Objective 5.4: Adapt to and plan for drought, climate change and sea level rise. Community members expressed concern about the impacts of climate change and sea level rise to the aquifer. The question was posed, "What can we be doing now that we wish we would have done in 100 years?" North Shore land use planning and infrastructure should take into account potential changes in climate such as longer periods of drought and more frequent storm events, as well as potential impacts of sea level rise.

4.2 WATERSHED MANAGEMENT PROJECTS, PROGRAMS & STRATEGIES

Various watershed management projects, programs and strategies are needed to meet the NSWMP objectives and sub-objectives. The following pages provide information on specific Water Supply and Watershed Management **"Projects with Champions,"** and more general information on **"Watershed Management Strategies."** The "strategies" are defined as important concepts which do not yet have "champion" entities that would organize and implement these concepts or are smaller scale initiatives.

The Projects with Champions are primarily **specific projects that are being planned and/or that are being implemented by a particular public agency(s) or by a particular community group or non-profit entity.** Many land use and resource management plans present "projects" that are more or less generic ideas. For North Shore, however, there are many place-specific watershed management projects that are already ongoing. The NSWMP thus focuses on these real projects.

The NSWMP presents information on a total of 16 projects with champions, which are grouped into five categories: 1) Surface Water, 2) Ground Water, 3) Land Management, 4) Cultural Resources/Traditional Practices, and 5) Water Supply.

WATERSHED MANAGEMENT PROJECTS AND PROGRAMS WITH "PROJECT CHAMPIONS"

Surface Water Projects and Programs

1. Kaukonahua Stream TMDL Implementation
2. Measurable Instream Flow Standards
3. Waialua-Kaiaka Watershed Restoration Study

Ground Water Projects and Programs

4. Potable Wellhead Protection
5. Mokulēʻia Potable Water System Improvements

Land Management Projects and Programs

6. Agricultural Best Management Practices
7. Low Impact Development Techniques
8. Pūpūkea Paumalū Risk Management
9. Waimea Valley Conservation Action Plan
10. Koʻolau and Waiʻanae Mountains Watershed Partnerships

Cultural Resources/Traditional Practices Projects and Programs

11. Kalo Maintenance and Restoration
12. Kamehameha Schools Loko Ea Fishpond and ʻUkoʻa Marsh Restoration

Water Supply Projects and Programs

13. Wahiawā Reservoir Water Quality Improvements
14. Wahiawā Irrigation System Improvements
15. Agricultural Water Reliability: Water Storage, Back-up Wells, Stormwater Reclamation
16. BWS Conservation Programs

The NSWMP also presents some basic information on 15 Watershed Management Strategies. "Strategies" are defined here as potential actions that would serve to implement the overall goal, objectives, and sub-objectives of the NSWMP, but that **do not currently have a project champion** or **are much smaller in scope** than a Project. Many of these strategies could become "Projects" if/when an agency or organization decides to be the champion for that strategy. The Strategies are grouped into six categories: 1) Surface Water, 2) Ground Water, 3) Nearshore Water, 4) Land Management, 5) Cultural Resources/ Traditional Practices, and 6) Water Supply.

WATERSHED MANAGEMENT STRATEGIES

Surface Water Management Strategies

A. Assess Stream Ecosystem Health
B. Implement Kaiaka Bay Watershed Flood Mitigation Projects and Planning
C. Conduct a Dredging Study and Systematic Maintenance of Key Areas

Ground Water Management Strategies

D. Implement Drought Mitigation Strategies
E. Improve Wastewater Treatment
F. Encourage Gray Water Reuse

Nearshore Water Strategies

G. Support Mālama Pūpūkea-Waimea Makai Watch
H. Designate Waialua Reef as a Marine Life Conservation District

Land Management Strategies

I. Restrict Off-Road Vehicles in Conservation Areas
J. Promote Pollution Prevention Awareness and Education

Cultural Resources/Traditional Practices Strategies

K. Record North Shore Oral History
L. Create North Shore Ahupuaʻa Boundary/Stream Markers

Water Supply Strategies

M. Repair and Replace BWS Pipelines
N. Incorporate Climate Change Plans and Initiatives into North Shore Water and Watershed Planning
O. Implement the Energy Savings Performance Contracting Strategy for Selected BWS Facilities

A **Watershed Management Projects Map** is included on the following page. The map graphically illustrates the area of the watershed for "projects and programs with champions" in North Shore.

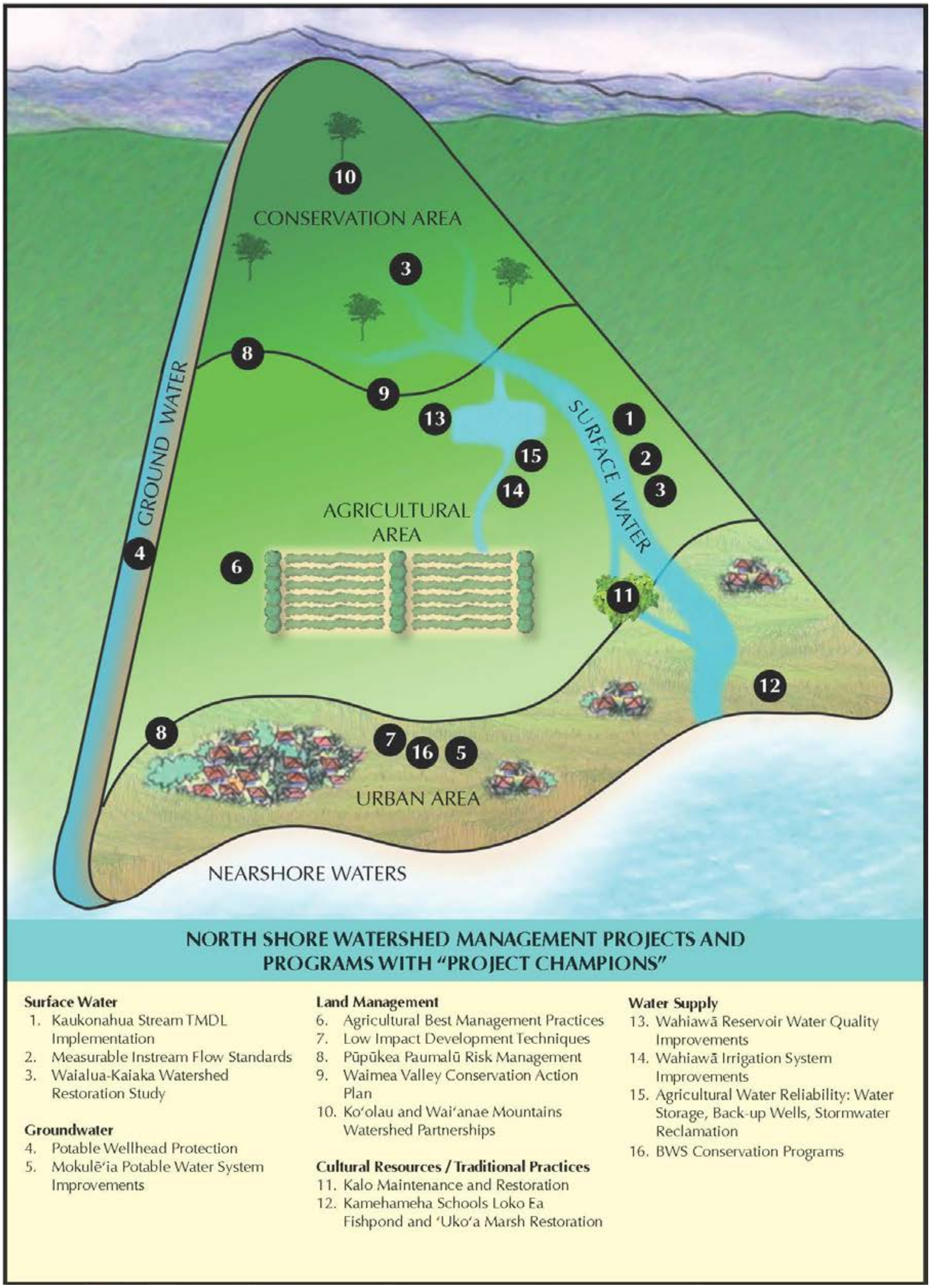

Figure 4.1 Watershed Management Projects Map

The following tables present a summary of the projects and programs organized according to:

- Watershed Management Plan 5 Major Objectives;
- Important Community and Agency Values or Issues documented during the stakeholder consultation process (See Chapter 2.10 "Stakeholder Consultation");
- North Shore Specific Projects and Strategies listed by Sub-Objective.

Watershed Projects and Strategies can help accomplish more than one objective and sub-objective and may be listed multiple times in the table.

OBJECTIVE #1: PROMOTE SUSTAINABLE WATERSHEDS

Sustainable watersheds are bio-diverse, renewable, and resource productive land and water ecosystems extending from the mountains to the coral reefs, that meet present needs without compromising those of future generations. In a sustainable watershed, there are holistic interrelationships among watershed resources including geologic structures, soil characteristics, forest communities, endemic and indigenous animals, native and introduced species, ground water aquifers, streams and wetlands, reefs and near-shore waters, traditional and cultural practices, land use and land development. Healthy, sustainable watersheds should be the foundation for both land use and water resources management planning. Sustainable watersheds can be achieved through the implementation of a comprehensive WMP that promotes a healthy watershed by emphasizing habitat and native species preservation, active forestry management practices, invasive species and pollution controls, resource conservation and demand-side management programs, low-impact development concepts and recycling.

Community or Agency Value or Issue	Sub-Objective (Policies)	**Project**/Strategy
Protect & expand healthy native forests ——— *Control the spread of invasive non-native species* ——— *Reduce wildfire susceptibility* ——— *Provide critical habitat protection for endangered and threatened native species* ——— *Improve surface water quality and stream biota* ——— *Adapt the Ahupuaʻa Concept as a framework for land use and natural resource management*	1.1 Remove invasive species and increase areas of healthy native forests	**9. Waimea Valley Conservation Action Plan** **10. Koʻolau & Waiʻanae Mountains Watershed Partnerships** D. Implement Drought Mitigation Strategies (wildfire prevention) I. Restrict Off-Road Vehicles in Conservation Areas
	1.2 Protect and restore wetlands and streams for ecological, cultural & recreational values	**1. Kaukonahua Stream TMDL Implementation** **6. Agricultural Best Management Practices** **9. Waimea Valley Conservation Action Plan** **12. Kamehameha Schools Loko Ea Fishpond and ʻUkoʻa Marsh Restoration** A. Assess Stream Ecosystem Health
Alleviate flooding impacts	1.3 Collaborate with responsible agencies & landowners to identify and implement measures to alleviate flooding issues	**3. Waialua-Kaiaka Watershed Restoration Study** **7. Low Impact Development Techniques** **8. Pūpūkea Paumalū Risk Management** B. Implement Kaiaka Bay Watershed Flood Mitigation Projects and Planning C. Conduct a Dredging Study & Systematic Maintenance of Key Areas

OBJECTIVE #2: PROTECT AND ENHANCE WATER QUALITY AND QUANTITY

Water is essential to human life and to the health of the environment. As a valuable natural resource, it comprises marine, estuarine, wetlands, freshwater streams and ground water environments, across coastal and inland areas. Water has two dimensions that are closely linked - quality and quantity. Water quality relates to the composition of water as affected by natural processes and human activities. It depends not only on water's chemical condition, but also its biological, physical and radiological condition. Water quantity relates to the amount of renewable ground water supply or base stream flow existing on a sustainable basis in perpetuity. In a healthy environment, water quality and quantity supports a rich and varied community of organisms and protects public health. Water quality and quantity influence the way in which communities use the water for activities such as drinking, swimming, fishing, farming, gathering, or commercial purposes.

Community or Agency Value or Issue	Sub-Objective (Policies)	**Project**/Strategy
Protect ground and surface water sources *Prevent erosion and sedimentation* *Reduce ground water contamination potential* *Improve nearshore water quality*	2.1 Recognize the connection between land and sea and improve stream water, ground water, and coastal water quality 2.2 Maintain and improve the quantity of ground water and surface waters	**1. Kaukonahua Stream TMDL Implementation** **2. Measurable Instream Flow Standards** **3. Waialua-Kaiaka Watershed Restoration Study** **4. Potable Wellhead Protection** **5. Mokulē'ia Potable Water System Improvements** **6. Agricultural Best Management Practices** **16. BWS Conservation Programs** A. Assess Stream Ecosystem Health D. Implement Drought Mitigation Strategies E. Improve Wastewater Treatment F. Encourage Gray Water Reuse H. Designate Waialua Reef as a MLCD J. Promote Pollution Prevention Awareness & Education

OBJECTIVE #3: PROTECT NATIVE HAWAIIAN RIGHTS AND TRADITIONAL CUSTOMARY PRACTICES

Native Hawaiian water rights are set forth in the State Constitution, Section 221 of the Hawaiian Homes Commission on Water Resource Management (CWRM) Act and Section 174C-101 of the State Water Code, providing for: a) Department of Hawaiian Home Lands water; b) traditional and customary gathering rights; and c) appurtenant water rights of kuleana and kalo lands. Native Hawaiian water uses also include cultural uses for spiritual/religious practices, kalo and other traditional agriculture, as well as adequate flows of fresh water into the nearshore water ecosystem.

Community or Agency Value or Issue	Sub-Objective (Policies)	**Project**/Strategy
Preserve and protect cultural and historic resources ——— *Adapt the Ahupua'a Concept as a framework for land use and natural resource management* ——— *Enhance the region's recreational and educational potential*	3.1 Provide support to place-based natural and cultural resources management and Native Hawaiian cultural educational programs in North Shore 3.2 Restore and utilize kalo lands and fishponds for food production and cultural educational use	**2. Measurable Instream Flow Standards** **9. Waimea Valley Conservation Action Plan** **11. Kalo Maintenance and Restoration** **12. Kamehameha Schools Loko Ea Fishpond and 'Uko'a Marsh Restoration** H. Designate Waialua Reef as a MLCD K. Record North Shore Oral History L. Create North Shore Ahupua'a Boundary/Stream Markers

OBJECTIVE #4: FACILITATE PUBLIC PARTICIPATION, EDUCATION, AND PROJECT IMPLEMENTATION

Planning and managing our island's water and related resources involves a variety of stakeholders from end users, landowners, public and private water purveyors, and government agencies. A collaborative process can result in innovative planning and implementation that incorporates local knowledge and directly involves area residents. Public education involving water resource issues can support collaboration with informed stakeholders. Directed water resource curriculum for schools will ensure knowledge and respect for water resources will extend to future generations. Ultimately public participation will result in benefits to the water resources, water users and the related ecosystems.

Community or Agency Value or Issue	Sub-Objective (Policies)	**Project**/Strategy
Enhance the region's recreational and educational potential ——— *Integrate principles of sustainability into decision-making*	4.1 Increase public awareness and educational efforts of watershed management	**12. Kamehameha Schools Loko Ea Fishpond and ʻUkoʻa Marsh Restoration** **16. BWS Conservation Programs** L. Create North Shore Ahupuaʻa Boundary/Stream Markers J. Promote Pollution Prevention Awareness & Education
	4.2 Promote public participation in planning of watershed management projects and programs	**8. Pūpūkea-Paumalū Risk Management** G. Support Mālama Pūpūkea-Waimea Makai Watch
	4.3 Foster community/ government partnerships to help with plan implementation	**3. Waialua-Kaiaka Watershed Restoration Study** **10. Koʻolau & Waiʻanae Mountains Watershed Partnerships** B. Implement Kaiaka Bay Watershed Flood Mitigation Projects and Planning

OBJECTIVE #5: MEET FUTURE WATER DEMANDS AT REASONABLE COSTS

Water is essential to all life. O'ahu's population relies on an abundant and reliable water supply for drinking, irrigation, agriculture, commercial and industrial uses, and fire protection. O'ahu's residents are educated in watershed management practices; water conservation is not just a message, but a way of life. Efficient water systems promote public health and safety and deliver water to meet current and future demands at reasonable costs. Reasonable costs encompass a balancing of the other plan objectives and are not necessarily the lowest economic costs. Capital improvements and operations and maintenance costs should not place an unreasonable burden on water rate payers. Water systems are flexible yet secure to account for uncertainties, and are expanded concurrent with land use plans and growth forecasts. Withdrawal rates are precautionary with respect to the resource and are well within established sustainable yields and instream flow standards, which protect the long-term viability of the water resource and do not detrimentally impact cultural uses and natural environments.

Community or Agency Value or Issue	Sub-Objective (Policies)	**Project**/Strategy
Promote a diversified agriculture industry	5.1 Ensure adequate and cost-effective agricultural water supplies and promote water conservation and delivery efficiency	**6. Agricultural Best Management Practices** **13. Wahiawā Reservoir Water Quality Improvements** **14. Wahiawā Irrigation System Improvements** **15. Agricultural Water Reliability: Water Storage, Back-up Wells, Stormwater Reclamation**
Provide adequate and appropriately-sized public infrastructure, facilities, and services ——— *Maintain & improve potable water systems*	5.2 Maintain and improve potable water system reliability, adequacy and efficiency	**5. Mokulē'ia Potable Water System Improvements** **16. BWS Conservation Programs** F. Encourage Gray Water Reuse M. Repair and Replace BWS Pipelines
Integrate principles of sustainability into decision-making	5.3 Integrate renewable energy and energy efficiency within the water delivery systems	**16. BWS Conservation Programs** O. Implement the Energy Savings Performance Contracting Strategy for Selected BWS Facilities
Prepare for climate change & sea level rise effects	5.4 Adapt to and plan for drought, climate change & sea level rise	**14. Wahiawā Irrigation System Improvements** **15. Agricultural Water Reliability: Water Storage, Back-up Wells, Stormwater Reclamation** D. Implement Drought Mitigation Strategies N. Incorporate Climate Change Plans into NS Planning

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4.3 WATERSHED MANAGEMENT PROJECTS AND PROGRAMS WITH "PROJECT CHAMPIONS"

This section provides two- to three-page descriptions of each **"Project with Champion"** and summarizes the project's problem statement, general background, preliminary scope, champion(s), partner(s), and estimated cost. The general background section further describes the problem as well as details the effort made to address the problem to date. Estimated costs are rounded order of magnitude except where provided by an existing document or study.

1. Kaukonahua Stream TMDL Implementation

PROBLEM STATEMENT

Kaukonahua streams are on the State of Hawaiʻi 2008/2010 303(d) list for impaired water bodies. The North and South Forks of Kaukonahua were listed primarily due to nutrients and turbidity. The sources of the sediments and nutrients could be caused by erosion, animal wastes, use of fertilizers, and human waste. High levels of stream nutrients and sediments may accelerate eutrophication, decrease oxygen in the water, be toxic to fish, and be of considerable harm to other organisms as well as to humans if ingested. Total Maximum Daily Loads (TMDL) studies for North and South Forks of Kaukonahua Streams have been completed but not implemented. The implementation of TMDLs is needed to address the contaminants.

GENERAL BACKGROUND

Section 303(d) of the Clean Water Act requires states across the nation to identify water bodies not meeting applicable water quality standards. For these polluted waterbodies, states are required to develop TMDLs. TMDLs represent the maximum amount of point and nonpoint source pollutants that can enter a waterbody without violating the water quality standards. The State Department of Health (DOH) is developing TMDLs for high priority water bodies. The TMDL process identifies activities that may help to reduce pollutant loads, improve water quality, and increase the ability of a waterbody to support its legally protected uses. TMDLs were calculated for a total of four water body/pollutant combinations: turbidity and total nitrogen for North Fork Kaukonahua, and turbidity and total nitrogen for South Fork Kaukonahua. Although these streams are outside of the North Shore district, they contribute to the water quality downstream in Wahiawā Reservoir, Lower Kaukonahua Stream, Kiʻikiʻi Estuary, and Kaiaka Bay.

Kaukonahua Stream

PRELIMINARY SCOPE

DOH is not recommending any particular mandates for the North and South Forks of Kaukonahua Stream at this time. Instead, they advocate that public and private landowners, when regulating and managing their own lands may be the most viable group for supporting implementation activities. DLNR, DOH, City and County of Honolulu, and other State government regulators and managers can also exert their influence across land ownership boundaries to enable and promote implementation activities.

Many of these agencies and landowners are already in the process of implementing activities that will help to bring North and South Fork Kaukonahua streams within prescribed TMDL levels. Current activities include:

- Documentation of the overall strategic and tactical approach for managing water quality (completed by the City & County of Honolulu's Department of Environmental Services in 2010 with the Waialua-Kaiaka Watershed Study)
- Vegetation management efforts
- Feral ungulate control
- Application of DLNR's Conservation Value Classification to management guidelines
- Erosion and sedimentation management measures
- Stream flow and sediment monitoring of Kaukonahua Stream
- Coordination with other participants in the Ko'olau Mountains Watershed Partnership.

Additional implementation activities recommended by the TMDL study include:

- Develop a comprehensive implementation strategy and detailed implementation plan that meets EPA requirements. Sufficient funding was not available to develop a complete plan, therefore Department of Environmental Services decided to phase the plan and seek partnerships and additional funding to complete subsequent phases. Once the plan is completed and approved, proposed actions may be eligible for Clean Water Act (CWA) §319 non-point source grants.
- Identify uses and conservation practices below the Forest Boundary and address them in future watershed planning
- Develop a Waste Load Allocations implementation plan and a Waste Load Allocation monitoring plan for the North Fork Kaukonahua Stream
- Implement Waste Load Allocations for the North Fork Kaukonahua Stream TMDLs
- Form a regionalized water quality monitoring program.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

City Department of Environmental Services*, DLNR, US Army, US Navy, Dole, EPA, DOH Environmental Planning Office Clean Water Branch, CWRM, Land Use Commission, State Office of Planning Coastal Zone Management, USGS.

ESTIMATED COST

- Comprehensive implementation strategy and detailed plan: $60,000
- Develop and implement Waste Load Allocation monitoring plan: $50,000
- Regionalized water quality monitoring program: $850,000

REFERENCES

City and County of Honolulu, Department of Environmental Services. 2010. *Waialua-Kaiaka Watershed Study.*

State of Hawai'i Department of Health. 2009. *Total Maximum Daily Loads (TMDLs) for the North and South Forks of Kaukonahua Stream, O'ahu, Hawai'i.*

Wakumoto, Randall. Civil Engineer, City and County of Honolulu Storm Water Quality Branch. September 24, 2013. Personal Communication.

2. Measurable Instream Flow Standards

PROBLEM STATEMENT

Studies are needed to revise the "status quo" interim instream flow standards (IIFS) to advance resource planning and decision-making for better management of the district's surface water resources. The precautionary first step is to understand and protect the public trust uses of stream waters. If water is determined available for other non-instream uses, then such quantities may be available for allocation. Every gallon not used should stay in the stream.

GENERAL BACKGROUND

Instream flow standards (IFS) protect the public interest in the waters of the State. IFS are defined by the State Water Code as the *"quantity or 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."* Currently, interim instream flow standards have been set, and are generally based on the *"amount of water flowing in each stream on the effective date of the standard (1988 for Leeward O'ahu and 1992 for Windward O'ahu) without further amounts of water being diverted off-stream through new or expanded diversions"* (see the O'ahu Water Management Plan Overview). CWRM has developed a methodology and is working towards establishing measurable IFS based upon best available information, along with input from interested parties and agencies.

Setting IFS is a collaborative process where CWRM, with input from interested parties and agencies, must determine and weigh present or potential instream values with present or potential non-instream uses, while protecting the public interest and avoiding or minimizing the impact on existing uses. This includes the economic impact of restriction of such uses [174C-71(1)(E)]. Stream flows should be expressed in terms of variable flows of water necessary to protect fishery, wildlife, recreational, aesthetic, scenic, or other beneficial instream uses.

Decisions regarding establishing IFS in North Shore will also need to be made in light of the Public Trust Doctrine. The four public trust purposes identified by the Hawai'i Supreme Court are: (1) maintenance of water in its natural state; (2) domestic water use of the general public (particularly drinking water); (3) the exercise of Native Hawaiian and traditional and customary rights, including appurtenant rights; and (4) reservations of water for Hawaiian Home Lands. The Precautionary Principle, in cases where there is a lack of scientific certainty, also applies.

Because of its prime agricultural land and the presence of many perennial streams, the North Shore district has traditionally been one of the important agricultural production areas of O'ahu. Expanding farming activities will largely depend on the efficient use of existing diversions for water availability. IFS should be established to identify the availability of surface water for stream health in addition to current and future kalo/agricultural activities in North Shore (see Chapter 3 Water Use and Projected Demand).

PRELIMINARY SCOPE

Stream hydrology, existing and potential instream uses as well as existing and potential non-instream uses should be considered when establishing the IFS. Studies, surveys, and other methods of collecting best available information are the first step in the process to establish the IFS. CWRM often relies on hydrologic studies conducted by the USGS, which is largely dependent upon the presence of long-term USGS stream gage stations in the study area along with the availability of project funding. At present, there are only four operating streamflow gages in North Shore – three on Kaukonahua stream and one on Kamananui stream.

Studies that should be conducted to support the establishment of an IFS include:

- Monitoring and recording stream flow
- Biological assessment of streams and nearshore waters
- Conducting a kuleana lands inventory survey to identify kuleana lands where their landowners may have appurtenant rights
- Conducting a survey of traditional and customary practices, including the exercise of gathering rights in streams and nearshore waters

CWRM has only established measurable IFS for selected streams on O‘ahu and Maui. CWRM cannot establish IFS for all streams in North Shore in the near term due to its limited staff and resources. Prioritization for establishing IFS for North Shore streams should be based on the following suggested criteria:

- Perennial streams (Kawaihāpai, Pahole, Makaleha, Ki‘iki‘i, Paukauila, Anahulu, Loko Ea, and Waimea)
- Streams with the most stream diversions (Anahulu, Paukauila)
- Streams that currently have a significant amount of water being diverted (Kaukonahua)
- Streams located in areas that have high potential for future expansion of agricultural activities that will require additional water supplies (Anahulu)

The North Shore Watershed Management Plan working group expressed a priority for Waimea Stream.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

CWRM*, BWS, USGS, DLNR Department of Aquatic Resources, Natural Area Reserves System Commission, DOH, DOA, and UH Cooperative Fishery Unit, UH WRRC, USACE, USFWS, SHPD, Bureau of Conveyances, and Landowners.

ESTIMATED COST

Each stream is expected to cost:

- $350,000 to study the characteristics of stream flow and stream fauna
- $75,000 for non-instream use study
- $40,000 for an oral history and archival/historical research on Native Hawaiian water rights and community involvement

REFERENCES

HRS §174C-71; State of Hawai‘i Commission on Water Resource Management, Hawai‘i Water Plan: Water Resource Protection Plan (June 2008); Personal communications with CWRM.

3. Waialua-Kaiaka Watershed Restoration Study

PROBLEM STATEMENT

The Paukauila and Kiʻikiʻi watersheds flood frequently, impacting residents and businesses, and draining City, State, and Federal resources. There is a lack of holistic hydrologic information for use in planning adequate flood-control measures to reduce and prevent the loss of life and property due to flooding in the Waialua and Haleʻiwa areas.

GENERAL BACKGROUND

The watersheds above Waialua and Haleʻiwa include the streams and tributaries of Kaukonahua, Poamoho, Helemano, and ʻŌpaeʻula, which drain approximately 51,500 acres from both the Koʻolau and Waiʻanae mountain ranges. During high-peak discharges, flood waters overtop the streambanks, inundating the low-lying residential and agricultural lands of Waialua and Haleʻiwa. Flooding occurs frequently at locations like Otake Camp, Cane Haul Road, and the Haleʻiwa Shingon Mission. Modifications to natural drainage patterns, including erosion and sedimentation, can restrict stream flow and further compound flood hazards in this area. Blockage of bridge openings by debris restricts flow, causing flood waters to back up and inundate low-lying areas.

In 1976, the United States Army Corps of Engineers (USACE) completed a report on a Small Flood Control Project for the Waialua-Haleʻiwa area. It was determined that Federal participation was not warranted at the time due to lack of economic benefits. In 2004, the State looked at another approach to involve the USACE by focusing on ecosystem restoration with incidental flood control benefits. The State requested the USACE to investigate the restoration of Kaiaka Bay (Waialua/Wahiawā watershed) under Section 206, Water Resources Development Act of 1996, Aquatic Ecosystem Restoration Projects Authority. The federally-financed preliminary plan found that the drainage area would require numerous and comprehensive erosion control and sediment basin features which would be excessively costly with respect to the Federal statutory limit for a Section 206 project. It was determined that the USACE was not to proceed with the feasibility stage at this time.

Continued community and political concern prompted the USACE to look at a third alternative to address the flooding situation in the Waialua-Haleʻiwa area. Under Section 209, Flood Control Act of 1962, a watershed study can be larger in scope than the previous Section 205 (Small Project Flood) and Section 206 (Small Project Ecosystem Restoration) studies, and allows for more funding. Appropriations to fund a Waialua-Kaiaka Watershed Study have been requested since 2006 without success. The most recent appropriation request for the Waialua-Haleʻiwa Master Drainage Plan (2003, Hawaiʻi State Legislature) also failed.

Concurrently, flood control measures have been explored by agencies and researchers at University of Hawaiʻi at Mānoa including the use of berms, reservoirs, wider and straighter stream channels, and the creation of dams and floodwater storage basins. After a major flooding of Otake Camp in 2002, DLNR considered dredging Kaukonahua Stream, constructing retention basins, elevating all structures above baseline elevations to a height of six to twelve feet, and relocating homes to higher grounds.

Past projects and studies have determined that:

- The lack of national economic development benefits does not warrant Federal involvement.
- Structure relocation, elevation, and acquisition are by far the most readily achievable solutions.
- Otake Camp is in a flood zone and will be flooded by frequent storms.
- Floodplain elevations and floodway limits were revised for Paukauila and Kaukonahua Streams in 2011.
- In 2013, the City produced a Flood Insurance Study that selected Anahulu, Helemano, Kaukonahua, Kiʻikiʻi, ʻŌpaeʻula, Poamoho, and Paukauila streams for detailed study, which concluded that there are presently no flood-control improvements in this area capable of containing larger floods.

PRELIMINARY SCOPE

The primary purpose of the Waialua-Kaiaka Watershed Restoration Study is to identify all water resource problems in the watershed and evaluate possible solutions in a coordinated fashion. These include flooding, ecosystem degradation, land use practices, urban development, etc. The scope of the study will include an initial problem identification report, a system evaluation report, and an implementation plan. The community wishes for the following plan objectives:

- Identify the major drainage basins and delineate basin boundaries;
- Identify the hydraulic capacities and associated levels of protection afforded by the existing major drainage systems;
- Evaluate the flood mitigation capabilities of Wahiawā Dam;
- Evaluate the restoration of Ku Tree Dam as a flood control measure;
- Evaluate additional potential detention basin locations and aquifer recharge capabilities;
- Identify possible downstream flood mitigation measures;
- Document areas most affected by heavy flooding and houses that repeatedly flood;
- Look at various ways to elevate, relocate, retrofit, and floodproof insurable houses;
- Recommend buy-out and relocation scenarios, if needed by non-Federal agencies;
- Identify needs and opportunities to reduce stormwater pollution loading, and to protect or enhance natural resource areas that are affected by stormwater drainage;
- Identify capital improvement projects that will reduce existing drainage problems and provide flood protection under ultimate development conditions; and
- Identify the criteria to plan, design, maintain, and monitor storm drainage facilities.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

US Congress*, USACE, FEMA, National Flood Insurance Program, ENV, DLNR Engineering, DPP, DFM, North Shore Neighborhood Board #27, Community, UH Mānoa, NRCS

ESTIMATED COST

- $300,000 for USACE initial reconnaissance phase study
- $3 million for the feasibility study if federal participation is warranted

REFERENCES

Chow, Derek. Chief, USACE Civil & Public Works Branch. September 20, 2013. Personal communication.

Department of Land and Natural Resources, 2002. *Flood Plain Analysis of Proposed Stream Dredging at Paukauila Stream, Island of O'ahu.* Prepared by US Army Corps of Engineers Honolulu District.

Department of Land and Natural Resources, 2002. *Flood Plain Analysis of Kaukonahua Stream Island of O'ahu.* Prepared by US Army Corps of Engineers Honolulu District.

Department of Land and Natural Resources, 2003. *North Shore Paukauila Streambank Erosion and Riparian Area Community Project: Annual Report to the Twenty-Second Legislature Regular Session of 2004.* Prepared in response to Senate Concurrent Resolution 223, Senate Draft 1, Regular Session of 1995.

House of Representatives, State of Hawai'i. 2003. *HB No. 1323 - Making an appropriation for a Waialua-Haleiwa stormwater drainage master plan.*

US Army Corps of Engineers. 2004. *Wahiawā/Waialua Ecosystem Restoration Project Island of O'ahu, Hawai'i, Preliminary Restoration Plan (PRP)* – Tab C.

A resident surveys the flooding to his home in Waialua, near Poamoho Stream

4. Potable Wellhead Protection

PROBLEM STATEMENT

Potable ground water resources of the North Shore district serve the entire North Shore population. It is important to protect ground water sources from potential contamination caused by land use activities and from seawater intrusion.

GENERAL BACKGROUND

The most significant potential threats to potable water sources are microbiological and chemical contamination from land use activities. In 1996, the reauthorization of the Safe Drinking Water Act required states to develop assessments of drinking water sources, including documentation and evaluation of existing conditions, potential problem locations, and local protection opportunities.

The State of Hawai'i Department of Health has complied with the federal act by sponsoring the University of Hawai'i Water Resources Research Center compilation of the Source Water Assessment Program (HISWAP, 2004). The report contains four elements including:

(1) Delineating zones of influence around drinking water sources where contaminants may reach the water supply;

(2) Identifying activities in the area that may contribute to microbiological or chemical contaminants;

(3) Evaluating the susceptibility of drinking water sources to contamination from these activities; and

(4) Increasing public awareness and providing access to water assessment information.

The HISWAP defines source water "susceptibility" as "*the potential for a Public Water System to draw water contaminated by inventoried potential contaminating activities (PCA) at concentrations that would pose concern.*" Relative susceptibility was determined using a numerical scoring system. In the State SWAP report, susceptibility scores for ground water sources on O'ahu ranged from 0 to 2,119, with higher scores indicating greater susceptibility to contamination. By comparison, scores for North Shore sources ranged from 62 to 128. This indicates that, on an island-wide scale, North Shore's sources have a low potential for contamination. Because treatment of contaminated wells is expensive, every effort should be made to prevent contamination. BWS Rules and Regulations establish the Pass/No-Pass Zones (Chapter 2) to protect the potable aquifer from contamination caused by cesspools, landfills, wastewater treatment plants and other waste disposal activities. In addition, DOH requires sanitary surveys to ensure that water system facilities are maintained and improved to prevent contamination from surface influences.

BWS potable water sources that serve the North Shore district are located in Waialua, Hale'iwa, and Waiale'e. These sources are located mauka of urban areas but are located within the State Agricultural District where agricultural activities take place. The Waialua and Hale'iwa Wells are also located near major roads, with the Waialua Wells located near a few residential parcels. The Waiale'e Wells are near a utility station, power plant, residential parcel, cesspool, and septic tank. Other Federal and private potable water sources are located in Mokulēʻia (near an airport and pasture lands) and Waialua (near agricultural, industrial and residential activities).

Thirteen wells in the North Shore watershed used for drinking water or irrigation supply have shown detectable levels of one or more chemical contaminant commonly found in solvents or pesticides, including carbon tetrachloride, TCP, DBCP and atrazine. Most reported levels are below federal or state drinking water standards, and appropriate public health protection measures are implemented in those cases where water is used for human consumption.

PRELIMINARY SCOPE

Establish a source water protection program and implementation plan that will:

- Track land uses, site permissible activities, and address characterization of chemicals, fertilizers and recycled water applied on agricultural lands above drinking water wellheads as part of a comprehensive source water protection program.
- Establish best management practices for land use management.
- Work to remove or mitigate existing PCAs from source water capture zones.
- Apply DOH Source Water Protection program guidelines to water systems such as conducting sanitary surveys, protecting source water delineation/capture zones above wells and best management practices for potential contaminating activities.
- Continue to apply the BWS Pass/No-Pass Zone rules and regulations for new developments to protect potable aquifers, meaning no injection wells above the Pass/No-Pass Line.
- Convert all cesspools in the vicinity of potable drinking water wells to septic tanks and leach fields to improve biological treatment before ground disposal.
- Establish “acceptable land uses” within source water capture zones and require new developments to conform either through agreements or changes to the zoning code to protect the water capture zones.
- Place conditions for source water protection approvals on land use.
- Site new potable wells above existing urban and agricultural activities. Ensure pumping operational procedures that will prevent seawater intrusion.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

DOH,* USGS, DOA, CWRM, BWS, Landowners

ESTIMATED COST

Individual source area protection plan/studies could range from $50,000 to $100,000

REFERENCES

National Association of Counties, 2000. *Counties Protecting Drinking Water Through Partnering*.

State of Hawaiʻi Department of Health Safe Drinking Water Branch, 2004. *Hawaiʻi Source Water Assessment Program Report*. Prepared by Water Resources Research Center University of Hawaiʻi at Mānoa.

State of Hawaiʻi Department of Health, 1990. *Hawaiʻi Ground Water Protection Strategy.*

5. Mokulēʻia Potable Water System Improvements

PROBLEM STATEMENT

The aging North Shore Water Company (NSWC) system has had past issues with contamination and the inability to provide ample water pressure for fire protection. The lack of fire protection limits expansion by Camp Mokulēʻia and other users. The NSWC would like to turn the water system over to BWS. However, BWS must be able to ensure system integrity and the ability to supply water. Therefore, the current system would need to be upgraded before BWS could accept the system.

GENERAL BACKGROUND

The NSWC, wholly owned by Dillingham Ranch ʻĀina, LLC (DRA), delivers potable water to 120 customers in Mokulēʻia along Farrington Highway from approximately 2,000 feet west of Mahinaʻai Street to Camp Mokulēʻia, including Mokulēʻia Beach Colony and Camp Mokulēʻia. Water is supplied from a well on DRA lands. NSWC assumed ownership of Mokulēʻia Water, LLC in 2007.

The water system was built in the 1930's, and is in need of replacement and/or upgrades to meet current fire protection standards. The water pressure in the NSWC system is inadequate for supplying a fire hydrant, and water tankers have to drive back through residential neighborhoods to a city hydrant when fighting fires in Mokulēʻia. Currently, the Honolulu Fire Department does not have a water tanker stationed in this area, and it takes at least 40 to 55 minutes for tankers from other areas to reach the Mokulēʻia/Kaʻena Point area. In 2001 there was also an issue with water contamination from high levels of fecal bacteria due to an equipment failure.

This City fire hydrant is over one mile away from the nearest Mokulēʻia residence

There is interest from NSWC and the residents served by the NSWC system to transfer the entire system to BWS. There is also broader community interest in having water provided to Mokulēʻia Beach Park. BWS has indicated that the system would need to be upgraded to meet current BWS standards before BWS could consider acquiring the system. The BWS position is that before it can accept dedication of an existing private water system, they must be able to ensure system integrity and ability to supply water. The condition, size, and locations of the 50 to 60 year-old pipes that comprise the water system are unknown. A rough "ballpark" construction cost for a new water system sized to meet the requirements of the BWS Water System Standards along Farrington Highway to Camp Erdman, that connects to the BWS Waialua system, was estimated to be approximately $30 million in 2006.

Subsequently, an engineering study was conducted by the City and County of Honolulu Department of Design and Construction (2007) regarding the feasibility of providing public water to Mokulēʻia Beach Park and installing fire hydrants along the main extension in accordance with Board of Water Supply Water System Standards. The City and County of Honolulu, NSWC, and DRA expended funds to support this study. The project was determined at the time to be not feasible by BWS with issues regarding unit fixture counts.

NSWC is working to find a solution, and has been pursuing a rate increase that would be used to improve the current system.

PRELIMINARY SCOPE

Goals for upgrading the system include providing: 1) reliable and clean water delivery to Mokulēʻia customers, 2) adequate water pressure to provide for fire protection requirements, and 3) an affordable solution to local and island-wide residents.

Options to consider:

- BWS provides a line to a bulk meter to serve residential uses. Currently the termination of the Board of Water Supply system is approximately one-half mile in the Waialua direction (east) of the bulk water meter. This could then involve the creation of an association who would be the BWS customer. Flow beyond that meter to individual residences would be private and billed by the created association.
- Camp Mokulēʻia's requirements for fire protection cannot easily be met with a residential system unless there is storage capacity added. If they had a mechanism to store ample water onsite for fire protection, the requirement could be met.
- With an agricultural subdivision on DRA mauka lands, related infrastructure improvements, such as a storage reservoir tank, could be utilized by the NSWC as well.
- A partnership between DRA and BWS may be able to provide funding for the reservoir tank.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

NSWC*, BWS, DRA, DOH

ESTIMATED COST

- $30 million to update entire system
- Less than $30 million for line to bulk meter and additional storage capacity

REFERENCES

Clifford P. Lum, Board of Water Supply Manger and Chief Engineer. July 24, 2007. *Letter addressed to The Honorable Donovan M. Dela Cruz, Honolulu City Council.*

Dillingham Ranch ʻĀina, LLC. 2008. *Intersection Improvements Dillingham Ranch Agricultural Subdivision Draft Environmental Assessment.* Prepared by R.M. Towill Corporation.

Honolulu Councilmember Donovan Dela Cruz. July 31, 2007. *Letter addressed to Michael Dailey, President Mokulēʻia Community Association.*

Smith, Clifford R., Senior Vice President, KW Commercial Investment Group (aka Dillingham Ranch ʻĀina, LLC). September 17, 2012. In-person meeting.

6. Agricultural Best Management Practices

PROBLEM STATEMENT

Agricultural lands are the dominant land use in the North Shore district with uses ranging from row crops (ex. pineapple, corn) and orchards to pasture of rangelands. Agricultural practices can cause a variety of impacts on the environment. For example, soil erosion is the main cause of high turbidity and suspended solids in streams of the district as well as in nearshore waters, particularly after storm events. In addition, fertilizers and pesticides are potential sources of ground and surface water contaminants.

GENERAL BACKGROUND

The North Shore has been in large-scale agricultural production since the late 1800's. At present, 60% of the land in the district is designated as State Land Use Agriculture.

Erosion, sedimentation, and soil contamination continue to be issues for the North Shore. When the steeper areas of land throughout the North Shore are cleared and tilled, erosion is a significant concern. Open land areas with minimal vegetative cover and open field roads can contribute to altered drainage patterns and soil erosion. Wind erosion can also be a concern in certain areas, especially for lands close to the ocean subject to strong trade winds. Accumulations of loosened soil from upper elevations gather in the lower elevations, where there is a blockage or large settlement area. This sedimentation can lead to clogged streams, an increased likelihood of flooding, and reduced downstream water quality.

Irrigation of crops can cause water loss due to mismatched delivery systems or system losses. Irrigation methods can cause inadvertent wasting as can the lack of system maintenance. Agricultural practices can also affect the mauka conservation lands by providing avenues for invasive plants and animals.

Agriculture activities are probably the most significant anthropogenic source of ground water contamination. Fertilization and pesticide application are the main agricultural activities that can cause degradation of ground water quality, with contaminants potentially infiltrating into ground water and spreading through the aquifers. One potential source of ground water contamination that is of concern is unnecessary pesticide use that may be the result of gaps in farmer training and education.

The Natural Resource Conservation Service (NRCS) works with private landowners to develop conservation plans to improve natural resource conditions of crop lands, pastures, and grazed ranges. Between 2005 and 2007, NRCS helped farmers implement 190 conservation practices on the North Shore. BMPs that have been implemented in some crop areas include: sediment basins, cover crop (around coffee plants, orchards, certain row crops), field strip-cropping (growing crops in strips across the general slope), drip irrigation, soil management, fences in rangelands, brush management, prescribed grazing in rangelands, and enhancement of pest and soil management in pastures.

PRELIMINARY SCOPE

NRCS identified North Shore district priority resource concerns, which include: Insufficient Irrigation/Plant Health, Sheet and Rill Soil Erosion, Noxious and Invasive Plants, and Declining Threatened & Endangered Species. While the priority NRCS concerns may guide a strategy for recruiting landowner participation, the site-specific conditions determine the ability to address all, some, or none of the priority concerns in the conservation plan.

The following BMPs are likely to be implemented on the North Shore to alleviate the priority resource concerns. Those practices with an asterisk (*) may be most effective in addressing concerns:

- Irrigation water management and drip irrigation*
- Nutrient and pest management*
- Fences*
- Brush management*
- Conservation crop rotation
- Contour farming
- Field border
- Vegetative barrier
- Tree/Shrub Establishment
- Prescribed Grazing Wetland Enhancement
- Wetland Wildlife Habitat Enhancement
- Cover Crop
- Firebreak

NRCS's ability to provide timely technical assistance is affected by funding and staffing levels. In the 2009 North Shore Rapid Watershed Assessment, NRCS provided initial estimates of installation quantities and associated costs for specific conservation measures having strong potential to be implemented over the next five years. NRCS estimated that with the appropriate levels of funding approximately 1,600 acres of croplands, orchards, pastures, and rangelands on the North Shore could undergo conservation treatment, representing about 9% of the amount of land used for those crops.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

USDA/NRCS*, O'ahu RC&D*, UH Cooperative Extension Service, West O'ahu Soil and Water Conservation District, UH CTAHR, DOA, CWRM, ENV, Farmers

ESTIMATED COST

Over $4.0 million: Cost-share by private landowners $1.5 million, NRCS $2.5 million.

REFERENCES

City and County of Honolulu Department of Environmental Services. 2010. *Waialua-Kaiaka Watershed Study Final Report.* Prepared by Townscape, Inc.

USDA NRCS, 2009. *Rapid Watershed Assessment, North Shore Watershed, O'ahu, Hawai'i.*

7. Low Impact Development Techniques

PROBLEM STATEMENT

The activities of residential and commercial areas have the potential to pollute surface waters with trash, debris, and chemical contaminants that leach into the water, pose health threats, and degrade aquatic habitat both in the streams and nearshore waters. Integrating Low Impact Development (LID) concepts into existing and future developments will help to minimize run-off water quantity and improve water quality.

GENERAL BACKGROUND

Low impact development (LID) is an approach to land development that works with the existing natural conditions of a place to manage stormwater as close to its source as possible, thus reducing the amount of polluted runoff from entering into storm drains or streams. This is accomplished by allowing rainwater runoff from impervious surfaces (e.g. roofs, driveways, walkways, and parking lots) the opportunity to be absorbed rather than running off into streams or storm drains. These design strategies reduce the amount of polluted runoff infiltrating into natural waterways.

Future development or re-development in the district should incorporate LID elements into their designs. Common LID design elements include rain gardens, rain barrels, pervious concrete (a.k.a. porous pavement), bioretention areas, and bioswales. As a secondary benefit LID also contributes to ground water recharge as more stormwater is trapped on land and is absorbed into the ground. Educational demonstration LID projects, such as rain gardens, should also be encouraged.

Green space is often desired for aesthetic reasons. However, it also performs an important ecological function. Pervious green spaces can reduce stormwater volumes and peak runoff rates, and remove pollutants from stormwater. Compact development that concentrates human impacts and maximizes green space can help to minimize effects of pollutants. A University of Connecticut study for the Nonpoint Education for Officials program indicated that at 10% impervious cover, the system may begin to lose sensitive stream elements. At 11-25% impervious cover, streams are impacted and will likely experience degradation. The percentage of impervious cover is an indicator of stream quality and will help in watershed management.

As one of the most rural areas of Oʻahu, the North Shore contains few municipal drainage systems. Only Waialua, Haleʻiwa, and Pūpūkea have small community storm drainage systems.

The region's perennial streams, intermittent drainages, and community drainage channels all intersect with Kamehameha Highway. Along the way, these waterways are prone to receiving waste and pollutants from human activities on adjoining lands and from roadways. Depending on location, the streams and drainage channels in North Shore collect debris and pollutants from stormwater runoff or from people directly dumping rubbish and debris into streams and storm drainage canals. In a coastal community such as North Shore, these types of pollutants can affect nearshore water quality and community health and safety in places where people fish, surf, and swim.

PRELIMINARY SCOPE

The scope of this project could include the following actions:

- Minimize the amount of impermeable surface in developed areas using methods such as alternative parking lot surfaces.
- Implement LID practices in the building code and subdivision standards, as outlined in the amended DPP Rules Relating to Storm Drainage Standards.
- Encourage compact development with green space for stormwater infiltration.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

ENV*, DPP, DOH Stormwater Quality Branch, BWS, DFM, Landowners, Businesses, Schools

ESTIMATED COST

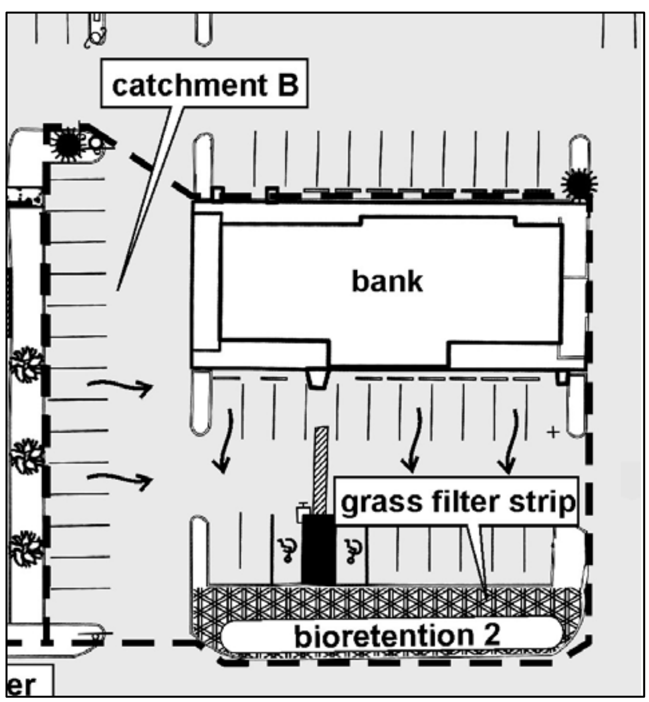
$200,000 for developer and contractor educational efforts

REFERENCES

City and County of Honolulu Department of Planning and Permitting. 2000. *Rules Relating to Storm Drainage Standards.* Amended, Effective June 1, 2013.

Dr. Clausen, Jack, et. al. 2003. *Nonpoint Education for Municipal Officials Impervious Surface Research Report.* University of Connecticut.

North Carolina State University. 2008. *Protecting Transylvania County Watersheds through Education about Land Use Change Impacts on Water Quality, and Low Impact Development.*



A Low Impact Development design example

8. Pūpūkea Paumalū Risk Management

PROBLEM STATEMENT

The Pūpūkea Paumalū area provides many opportunities for education, recreation, public safety, and natural and cultural resource restoration activities; however there are risks associated with physical features that need to be mitigated.

GENERAL BACKGROUND

In 2007, the Pūpūkea Paumalū bluff, and part of the coastal plain it overlooks, was permanently protected from development through the concerted efforts of Federal, State, and City governments, community organizations, and private individuals, who managed to successfully raise funds to purchase the property for the benefit of the public. The North Shore Community Land Trust initiated a Long-Range Resources Management Plan to document the community's vision for Pūpūkea Paumalū and to help define and describe projects, programs, and initiatives that will help move the property toward achieving that vision.

The Long-Range Resources Management Plan proposes various projects in order to support planned activities and avert potential risks to safety and property. Some of these projects - such as those that manage the risks of wildfire, drainage, erosion, and rock falls, which are discussed in this project - will also benefit the overall watershed.

The Pūpūkea Paumalū property is adjacent to homes on the makai side. It is important to manage the unique hazards related to living in wildland interface areas. Besides causing loss of life, wildfires can significantly alter landscapes and pose serious post-fire hydrologic consequences. Post-fire storms can threaten downstream communities with flooding, debris flows, and altered long-term water quality and quantity. Long-term solutions to mitigating the threat of catastrophic fire include improving prevention, suppression, reducing hazardous fuels, restoring fuel-adapted ecosystems, and promoting community assistance.

Significant soil erosion occurs on much of the mauka property due to the presence of moderately to severely erodible soils, steep slopes, and lack of ground cover. The roads and trails are in relatively good condition, but some maintenance is needed to address erosion and overgrowth. Erosion control activities such as establishing vegetative ground cover may be needed to reduce sediment runoff to the nearshore waters. Surface runoff has reportedly caused flooding problems in the lowland area between Pākūlena and Kālunawaikaʻala Streams.

A steep bluff separates makai from mauka, generally separating the City and State owned parcels. Portions of this bluff have been identified as potential rock-fall areas, with at least one rock-fall occurring in the last ten years. This area may require mitigative action.

PRELIMINARY SCOPE

The primary task for this project is to develop and implement a risk management plan for Pūpūkea-Paumalū that identifies, evaluates, reduces, and prevents wildfire, drainage, erosion, and rock falls.

Phase I – Planning

- Survey the property and identify and categorize potential hazards, such as wildfires.
- Develop a risk management plan that identifies, evaluates, reduces, prevents, and/or controls the potential for injury or loss of resources associated with use of the property.
- Include recommended primary planning studies such as engineering, modeling, and geotechnical services.

Phase II - Implementation of Recommended Actions

- ***Community Wildfire Protection Plan:*** Develop a community wildfire protection plan that preplans fire suppression facilities and procedures, prescribes active prevention measures, and develops community awareness and prevention education. The plan should work cooperatively with stakeholders, such as landowners and neighbors, to develop appropriate actions.
- ***Drainage Master Plan:*** Develop and implement a drainage master plan for the makai parcel that identifies the risks due to flooding and recommends hazard mitigation actions and strategies. Include a drainage study based on the topographic survey and research on previous flooding.
- ***Erosion Mitigation:*** Identify and mitigate erosion problem areas by planting native vegetation or by using other methods.
- ***Rock Fall Study:*** Conduct a rock fall study of the steep cliff faces to determine the potential for rock falls, identify appropriate mitigation, and recommend policies to ensure public safety.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

Community Wildfire Protection Plan: North Shore Community Land Trust.
Drainage Master Plan: City Department of Parks and Recreation, USACE.
Erosion Mitigation: DLNR State Parks, Hui Mālama o Pūpūkea-Waimea, NOAA, NRCS.
Rock Fall Study: DLNR State Parks.
General: US Army National Guard, US Navy Construction Battalion.

ESTIMATED COST

$100,000 - $500,000 for each study. Cost for implementation of recommendations will be dependent upon the findings of each study. Operations and maintenance costs may include maintenance of risk management features and programs and will be dependent upon the actions recommended in the planning phase.

REFERENCES

North Shore Community Land Trust, 2010. *Pūpūkea-Paumalū Long-Range Resources Management Plan.*

9. Waimea Valley Conservation Action Plan

PROBLEM STATEMENT

While Waimea Valley is managed for its cultural and natural resources, there are concerns with maintaining these resources to share with current and future generations. The ephemeral Waimea Wetland and Estuary along the lower portion of Waimea Stream provides only a marginal water bird habitat because of frequent fluctuations in water level and encroaching grasses. The presence of invasive species in the streams and waterways impacts native aquatic species of the fairly biologically diverse Waimea Stream. The stream is also subjected to continuing human disturbance associated with Waimea Beach Park and Waimea Valley Park visitors. Non-native animals such as dogs, cats, and mongooses are common in the area and presumably inhibit bird nesting along the river. The diverse lowland mesic forest native plant ecosystem in the Valley is also at risk due to feral ungulates and invasive weeds.

GENERAL BACKGROUND

Waimea Valley consists of 1,875 acres of cultural treasures and numerous endangered species, ranging from native waterfowl to endangered plants. Hiʻipaka LLC (dba Waimea Valley) was created in 2007 by the Office of Hawaiian Affairs to hold title and manage Waimea Valley. Waimea Valley currently has six educational programs whose objectives include placed-based education of the Waimea Ahupuaʻa.

Waimea Valley's Conservation Action Plan (CAP) covers land and resources that extend from the coast up to approximately 1,000 feet above sea level. Many different micro-habitats compose this diverse mesic (50 to 75 inches of annual rainfall) lowland ecosystem. Lowland mesic forests are some of the most diverse and threatened ecosystems in the Hawaiian Islands.

Work directed by the CAP began in 2011. Aerial imagery was used to identify and select the three most viable High Priority Areas. The Waimea Valley Native Forest Restoration Project (a mauka 15 acre site) was identified, and management practices implemented. Exclosure fencing around this site was recently installed to prevent ungulates from entering the area. Over 4,000 plants were planted as part of the Kalaheʻe Ridge Community Restoration Project, as well as over 4,000 plants planted in an estuary pilot project.

Waimea Valley is currently working with other members of the Koʻolau Mountains Watershed Partnership (including BWS) to continue to better address and control invasive species that pose a threat to watershed function. Three ongoing projects are focused on native forest restoration and estuary restoration.

In the estuary, additional traps were set, increasing ʻAlae ʻula predator control efforts by 11%. These efforts have increased the annual percentage of ʻAlae ʻula chicks reaching maturity to a success rate of greater than 30% averaged over a five-year period. Through vigilant predator control efforts and constant management of the habitat, Waimea Valley is helping almost a dozen of the Common Hawaiian Moorhen population to endure.

Waimea Valley is partnering with Oʻahu Invasive Species Committee (OISC) to survey and control several plant target species throughout Waimea Valley. The implementation of weed monitoring, mapping, and de-accessioning protocol is in progress. Waimea Valley is currently focused on finalizing the High Priority Areas and setting up management plans for those areas. They also recently received funding to write a Forestry Stewardship Plan with DLNR DOFAW.

PRELIMINARY SCOPE

The following are additional CAP actions Hiʻipaka will pursue to continue protection of the Valley:

- Continue to remove weeds and out-plant area-specific natives.
- Prepare management plans for the High Priority Areas.
- Increase the hunting effort towards ungulate removal by 50% in and around High Priority Areas.
- Prevent the establishment of new invasive plant or animal species in Waimea Valley.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

Waimea Valley*, KMWP, OISC, OHA, Center for Plant Conservation

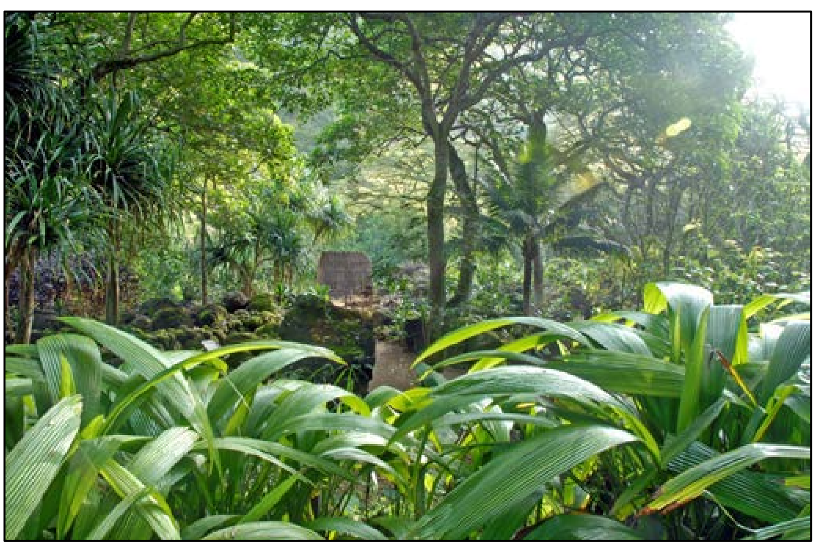
ESTIMATED COST

- Control priority weeds and replant with native plants: $5,000 to $10,000/acre
- Prepare three management plans: $90,000
- Increase the hunting effort: $5,000/yr
- Conduct biological surveys and work with the legislature and DOA to address the spread of invasive species: $50,000/yr

REFERENCES

Pezzulo, Richard. Executive Director, Waimea Valley. May 8, 2013. Email communication.

Waimea Valley, Hiʻipaka LLC. n.d. *Waimea Valley Conservation Action Plan.*



Cultural and Natural Management at Waimea Valley

10. Koʻolau & Waiʻanae Mountains Watershed Partnerships

PROBLEM STATEMENT

Management and maintenance responsibilities of Hawaiʻi's watersheds are fragmented among various government agencies, private landowners, and community organizations. This makes stewardship activities difficult, as jurisdictional responsibilities do not allow for holistic planning. EPA and the USDA suggest a watershed approach for water resource management that relies on three components: a geographic focus, continuous improvement based on sound science, and partnership/stakeholder involvement. Since watersheds transcend political and other socially constructed boundaries, collaboration among interested parties is necessary.

GENERAL BACKGROUND

Watershed partnerships in Hawaiʻi are *"voluntary alliances of public and private landowners committed to the common value of protecting large areas of forested watersheds for water recharge and other values."* Currently, more than 750,000 acres of important watershed areas lie within the management areas of the 10 existing partnerships: East and West Maui watersheds, Koʻolau Mountains watershed, Waiʻanae Mountains watershed, Lanaʻi Hale watershed, East Molokaʻi watershed, Leeward Haleakala watershed, ʻOlaʻa-Kilauea, Kauaʻi watershed, and the Kohala Mountain watershed. The large partnership areas encompass only the upper forested Conservation District.

Most of the partnerships coordinate actions among their members, who typically consist of Federal, State, and local agencies. Each watershed partnership develops a management plan to direct their focus, identify priorities, and outline actions and time frames for enactment. On-the-ground projects have focused on such issues as alien species control, native species outplanting, threatened and endangered species protection, and fencing projects. Partnerships can develop and maintain a "data bank" which includes historical and current information.

PRELIMINARY SCOPE

Watersheds can benefit from combining the responsibilities and efforts of community, landowners, and agencies with a mandate for managing specific watershed elements into a cooperative organization that can comprehensively address watershed issues for the region. North Shore has two such watershed partnerships: the Koʻolau Mountains Watershed Partnership (KMWP) and the Waiʻanae Mountains Watershed Partnership (WMWP).

The KMWP consists of private landowners and public agencies who interact throughout the Koʻolau Mountains. This organization focuses on efforts in approximately 102,000 acres of forested areas including the North Shore conservation district. KMWP partners for the North Shore include DLNR, Dole Food Co., Waimea Valley, and Kamehameha Schools. The KMWP has participated in the following activities for the North Shore: planning for ungulate management; goat removal from the Northern Koʻolau population; pig removal from the ʻŌpaeʻula fence exclosure; obtained high resolution aerial imagery for 39,000 acres of priority watershed; and invasive weed control workshops. KMWP will continue to develop island-wide invasive species control workshops and to expand established fencing exclosures in the Upper Helemano and Upper Kawaiʻiki Drainage.

The WMWP area covers 144,000 acres in the Waiʻanae Mountains. WMWP partners for the North Shore include DLNR and US Army Garrison Hawaiʻi. These and other groups work together to cooperatively develop and implement management strategies for the Waiʻanae Mountains, mauka to makai. The WMWP has participated in the following activities for the North Shore: aerial imagery weed mapping and control; meetings and community outreach on feral goat control; coordination of the Kaʻena Point Advisory Group; native plant seed collection and propagation; and assistance with Pahole weed control trials. Future projects include watershed resource protection fences, native forest restoration in priority watershed areas, feral ungulate management and invasive weed control.

Partnership programs may address North Shore district watershed issues, including polluted runoff, stream and ʻauwai clearing and management, management of feral pigs and other invasive species, and the need for measurable instream flow standards. Funding for watershed projects conducted by partnership programs is an ongoing need. The number of projects that could be implemented and are needed within the watershed exceeds the amount of available funding. Also, the available funding sources are not guaranteed from year to year, making it difficult to plan for ongoing multi-year programs. Funding is also critical in ensuring that a capable, continuous staff is available to perform field work and develop effective collaborative programs.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

Koʻolau Mountains Watershed Partnership, Waiʻanae Mountain Watershed Partnership, US Army, Natural Resources Conservation Service, West Oʻahu Soil and Water Conservation District, Landowners, North Shore Neighborhood Board #27, Individual Community Associations

ESTIMATED COST

- Fencing: Approx. $75,000 to 100,000/mile
- Invasive species control: $300,000/year
- Gather existing information and survey areas on threats and resources: $83,000
- Stabilize exposed soil areas: $5 to 10,000/acre
- Develop management strategies and policies: $6 to 12,000
- Water monitoring program: ~$10,000/stream gage; ~$20,000/year to maintain sediment gage; costs vary with conditions
- Land monitoring: $40,000/year
- Public education and outreach: $90,000/year

REFERENCES

Hawaiʻi Association of Watershed Partnerships. 2013. *Waiʻanae Mountains Watershed Partnership.* Available URL: http://hawp.org/partnerships/waianae-mountains-watershed/ [Accessed February 25, 2013]

Koʻolau Mountains Watershed Partnership. 2002. *Koʻolau Mountains Watershed Partnership Management Plan.*

Miyata, Yumi. Executive Director, Waiʻanae Mountain Watershed Partnership. February 25, 2013. Email communication.

11. Kalo Maintenance and Restoration

PROBLEM STATEMENT

Active kalo (taro) cultivation in North Shore is quite fairly limited despite an historical record of kalo cultivation throughout the region. There are lo'i (paddies) kalo systems that are no longer functioning that could be restored, and existing lo'i kalo whose cultivation should be maintained.

GENERAL BACKGROUND

Kalo *(Colocasia esculenta)*, well known throughout Polynesia, Asia, and Indonesia, is one of the oldest known cultivated crops in the world. Kalo has long been integral to the agricultural, nutritional, and spiritual traditions of Hawaiians. In Hawai'i, a sophisticated system of terraced farming was and continues to be used. These wetland agricultural systems consist of irrigation channels and irrigated terraces. They ranged in size from small plots which could be farmed by families, to large complex structures which required coordinated community efforts. Remnants of these agricultural systems may be found in some areas of the North Shore watersheds.

Today, kalo is an important crop to the many cultures represented in Hawai'i, thus creating a large demand. Fifty years ago, there were 14 million pounds of taro grown on thousands of acres, and poi cost 13 cents a pound at the market. This is in contrast to today's prices where poi can cost more than $6 a pound.

Wetland kalo farming is not without its obstacles. Disputes over water rights can engage parties in legal battles for years. Farmers' concerns include soil loss, invasive pests, kalo pathogens, kalo rot, weed control, crop damage by feral pigs, lack of infrastructure to meet water needs, lack of land to meet production demands, farmland conversions to nonagricultural uses, and potential increases in regulations on farms (e.g., Endangered Species Act, Clean Water Act).

A number of springs in the low-lying areas of Waialua and Hale'iwa have made ideal areas for growing kalo as well as other wetland crops such as lotus root which require a paddy environment. Most of these kalo growing areas are small scale farms run by families. The larger Dole acreage mauka of the Leong Bypass was also previously used by HPC Food for growing kalo, which utilized stream water as the irrigation source. Waimea Valley has a very small lo'i that is stream fed.

The most likely area for possible kalo expansion is the Kamehameha Schools land along Anahulu Stream. Kamehameha Schools recently purchased most of the remaining inholdings for complete ownership of the stream corridor. The Anahulu Stream corridor or gulch is known for its abundance of post-contact archaeological sites, and abundant foods food production for native Hawaiians.

The impetus for kalo recovery, restoration, and renewal in North Shore is embedded in the cultural significance of the practice. Many practitioners have moved into the educational aspect of kalo cultivation, coupling labor with education and the art and technology of agriculture, while teaching Hawaiian culture.

In addition to lo'i expansion, existing kalo farming on the North Shore needs to be maintained, which means ensuring available water sources will be available into the future. Presently, the water sources for growing kalo are limited to spring sources. Springs or artesian wells are ground water that surfaces in low lying areas. While they are connected to ground water, springs are administered by the State Commission on Water Resource Management as surface water. Extra monitoring and care is needed to ensure well withdrawals in the vicinity of springs do not adversely affect the water sources for lo'i kalo.

PRELIMINARY SCOPE

To support the expansion of kalo, both land and water sources are needed. Many of the springs in the makai area of North Shore are already being utilized for growing kalo or other wetland crops (e.g. lotus root). While some spring sources may be expanded, most expansion will need to be in areas where stream water can be provided. The most feasible area for such expansion is the Anahulu Stream corridor, where Kamehameha Schools has committed to restoring traditional practices in the area.

The following tasks are needed:

- Conduct archaeological and archival research to understand the history of the area and potential cultural sites.
- Identify potential water sources and request water use as needed. Note: both springs and stream waters are considered diversions and require coordination with Commission on Water Resource Management.
- Identify potential farmers with skills and interest to be matched up with available parcels.
- Encourage kalo farmers to offer educational programs along with the farming practices to provide opportunities for learning about and accessing native Hawaiian cultural practices.
- Monitor springs for water supply where they supply lo'i kalo.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

Kamehameha Schools*, CWRM, Existing Farmers, Natural Resources Conservation Service, Hawai'i Farm Bureau Federation, University of Hawai'i College of Tropical Agriculture and Human Resources.

ESTIMATED COST

- Monitoring water levels – $20,000 annual cost for stream gage installation, maintenance and data collection
- Additional $20,000 annually for data quality check and reporting
- Project costs for lo'i restoration projects can start around $100,000.

REFERENCES

Conversations with North Shore kalo farmers, October 2013.

Gima Craig, *Demand Makes Poi Shortage Possible.* Available URL:
http://starbulletin.com/2004/05/16/news/ story6.htm [Accessed September 19, 2012]

Hayworth, Phil, *No Mo' Poi?,* Midweek Magazine, March 16, 2005.

University of Hawai'i CTAHR website. Available URL:
http://www.ctahr.hawaii.edu/ctahr2001/ [Accessed September 19, 2012]

Uyehara, Kimberly, *Conservation Practices for Native Wildlife Habitat on Wetlands Taro Farms,* USDA, NRCS, Tropical Technology Consortium, August 2, 2004.

12. Kamehameha Schools Loko Ea Fishpond and ʻUkoʻa Marsh Restoration

PROBLEM STATEMENT

The cultural and ecological importance of fishponds and their role in the ahupuaʻa and watershed system have diminished over time. Historically fishponds provided not only food, but also had important ecological functions such as buffering the effects of flooding.

GENERAL BACKGROUND

The ponds of ʻUkoʻa and Loko Ea were considered bountiful sources of choice fish, and as such were considered favorite locales of the ruling aliʻi. These ponds served as abundant sources of food (including ʻanae and āholehole) for native Hawaiians since the time of Kakuhihewa in the 16th Century. The waters emanate from streams originating in the upper mauka lands and from lower springs. However, records from 1883 indicate that ʻUkoʻa fishpond was believed to have a subterranean connection with the ocean since the waters of the pond were adversely affected during the presence of strong offshore conditions and stormy weather.

Over time, the erosion from intensive sugar cultivation carried soils into ʻUkoʻa pond, causing siltation and other changes in the pond.. Originally a fishpond, ʻUkoʻa is now managed as a marsh by Kamehameha Schools for its wetland ecosystem functions. A wetland management plan was completed in 2010, and predator control fence was constructed around ʻUkoʻa to facilitate the recruitment of native water bird species. Kamehameha Schools has engaged Pono Pacific to manage the wetland area for ecosystem functions. An archaeological field survey was completed on the lands surrounding the marsh and fishpond, and the cultural features around ʻUkoʻa Marsh are now managed separate from the ecosystem functioning portion of the marsh.

Kamehameha Schools leased Loko Ea Fishpond out over the years to various families who continued its operation as a fishpond. In 2007, Kamehameha Schools took back control over operations and now partners with Mālama Loko Ea Foundation to steward and maintain the site and offers place-based education opportunities to school and community groups. Work days were established as a first step to clean up the site, and the fishpond house was renovated as a result. The overall goal of the work days is to restore the fishpond to a healthy, functioning, and productive ecosystem. Water quality issues continues to be a concern, as a cesspool is located on the adjacent Jameson's by the Sea restaurant property.

PRELIMINARY SCOPE

Support programs for ʻUkoʻa Marsh to restore ecosystem functionality and for Loko Ea Fishpond with restoration and educational components.

<u>ʻUkoʻa Marsh</u>

Continue the conservation/wetland management of the Marsh including:

- invasive species control
- predator control
- litter prevention
- possible silt dredging

There may be opportunities for student interns at Pono Pacific to learn more about the wetland management of ʻUkoʻa Marsh.

<u>Loko Ea Fishpond</u>

- Continue the fishpond work days
- Continue educational programs
- Develop a preservation plan to guide future efforts at the fishpond to restore the fishpond and increase its productivity
- Assess water quality issues and needed mitigation measures

An opportunity for a path between Loko Ea and ʻUkoʻa Marsh is also being researched by Kamehameha Schools.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

Kamehameha Schools*, Mālama Loko Ea Foundation, Pono Pacific

ESTIMATED COST

More than $500,000 for the efforts at both locations

REFERENCES

Fronda, Kalani, Senior Land Asset Manager, Kamehameha Schools. October 2013. Materials and conversation.

Volunteers at Loko Ea

13. Wahiawā Reservoir Water Quality Improvements

PROBLEM STATEMENT

The provision of high quality surface water for irrigation purposes is a concern for many farmers in the North Shore district, as surface irrigation water is less expensive than ground water. New FDA food safety rules require high quality irrigation water for certain crops. The water quality of the Wahiawā Reservoir and Irrigation System can be improved by redirecting R-1 recycled water out of the reservoir and directly to agricultural fields. The reservoir water will then be considered unregulated surface water for agricultural irrigation, fishing and recreational uses.

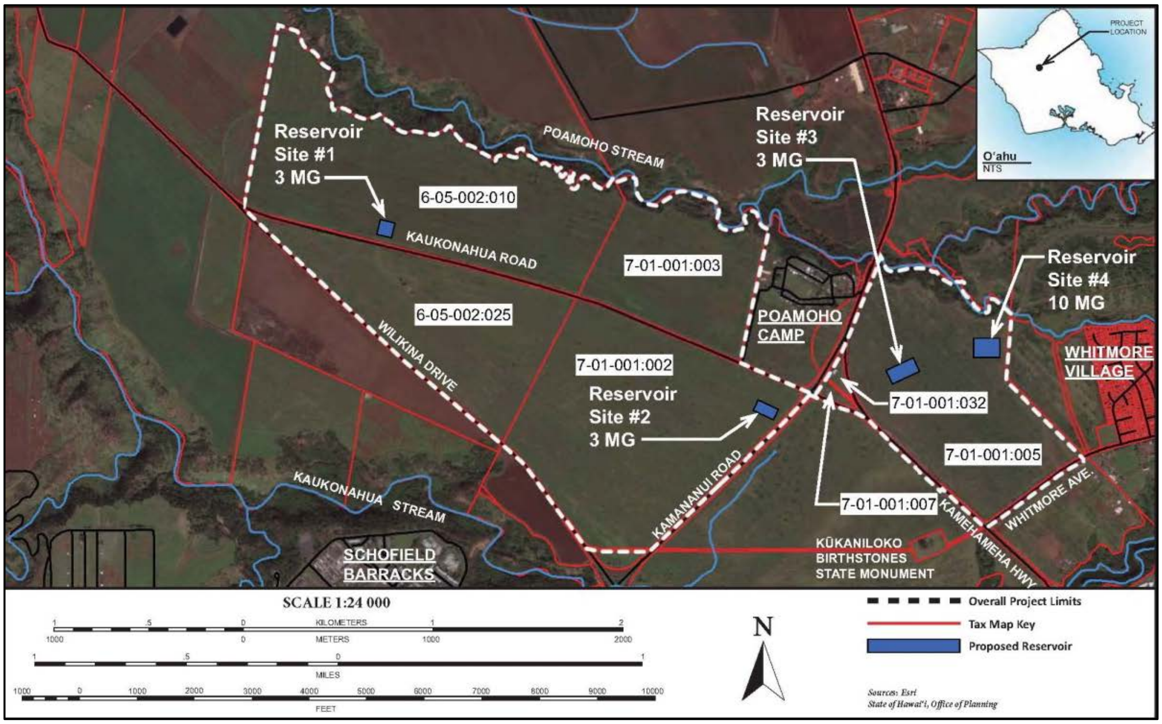
GENERAL BACKGROUND

R-1 recycled water is the highest quality of treated wastewater (tertiary disinfected), allowed by the DOH Reuse Guidelines. R-1 recycled water complying with the 2002 DOH Reuse Guidelines is permitted to irrigate all crops including vegetables. Currently, two wastewater treatment plants in Central O'ahu – the Wahiawā and Schofield Wastewater Treatment Plants (WWTP) - produce tertiary disinfected recycled water which is used for irrigation.

The City and County Department of Environmental Services has completed the upgrade of the Wahiawā WWTP to produce approximately 1.6 mgd of R-1 quality recycled water. However, DOH will not classify the effluent as R-1 until a pipeline is constructed to get the recycled water out of the reservoir because the primary disposal method must be direct reuse outside of the reservoir. The Wahiawā Reservoir then becomes the secondary disposal option. In response to this requirement, the State Agribusiness Development Corp. (ADC) stepped up and is planning the construction of a pipeline and 19.2 million gallons of reservoir storage on their Galbraith lands with the intent to utilize all of Wahiawā's R-1 water. However, until the pipeline is constructed, the Wahiawā WWTP effluent will still be considered R-2 affecting the entire Wahiawā Reservoir and Irrigation System. R-2 recycled water cannot be used on certain edible crops. North Shore farmers have complained that the water quality limitations and associated regulatory requirements associated with the Wahiawā irrigation system restricts their ability to expand their farms and grow other crops. The Wahiawā Irrigation System is the primary source of irrigation water for North Shore agricultural lands and supplies about 20 mgd. Unused irrigation water drains from the reservoir dam into Lower Kaukonahua Stream.

The State Legislature has appropriated funding for ADC to begin designing the R-1 distribution pipeline from Wahiawā WWTP to its Galbraith lands. Once the design is completed, ADC will seek construction funding.

Schofield WWTP tertiary disinfected recycled water is discharged into the Wahiawā Irrigation System below the Wahiawā dam. A pipeline from the Schofield WWTP has been constructed to the Kunia agricultural lands and could meet the DOH direct reuse requirement to be classified as R-1 recycled water. The Army's plans to reuse R-1 water for irrigation at Schofield Barracks and Wheeler Army Airfield have not progressed for years due to funding constraints. The Army continues to pay Dole $500,000 annually to take all of its treated recycled water for disposal, a cost that could be avoided at least in part, if recycled water was reused on base and in Kunia. Current flows are approximately 2.6 mgd.



Galbraith Lands and Proposed Reservoirs
(Source: Galbraith Estate Reservoirs Environmental Assessment)

PRELIMINARY SCOPE

1) To improve the water quality of Wahiawā Reservoir, the plan is to redirect recycled water out of the reservoir. The first step is to design and construct the R-1 pipeline from the Wahiawā WWTP to ADC's Galbraith lands for direct reuse and to construct planned reservoirs to store irrigation water. ADC and ENV are entering into a Memorandum of Understanding (MOU) to make this happen, and BWS is assisting where possible. The State Legislature with the leadership of Senator Dela Cruz is prepared to fund these improvements when funding is available.

2) To ensure diversified agriculture will fully utilize the R-1 recycled water, a holistic agricultural support system will be needed, inclusive of available and viable farm lands, access to inexpensive, high quality irrigation water, a produce processing facility, workforce housing and agricultural education programs to train and inspire a new generation of educated and motivated farmers. To meet these requirements, ADC and its Galbraith Lands are part of the Whitmore Project. The Whitmore Project is a plan to revitalize agriculture through the development of a produce processing and agricultural technology park at Dole's Whitmore warehouses, workforce housing in Wahiawā, and an agriculture curriculum in partnership with Wahiawā schools.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

ADC, DOA, ENV, BWS, Dole Foods Inc. and DOE.

ESTIMATED COST

$19,000,000 to implement the ADC Galbraith recycled water system plan.

REFERENCES

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Pobuck, Jack. Capital Improvement Projects Program Coordinator, City and County of Honolulu Department of Environmental Services. Email Communication, November 18, 2011.

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14. Wahiawā Irrigation System Improvements

PROBLEM STATEMENT

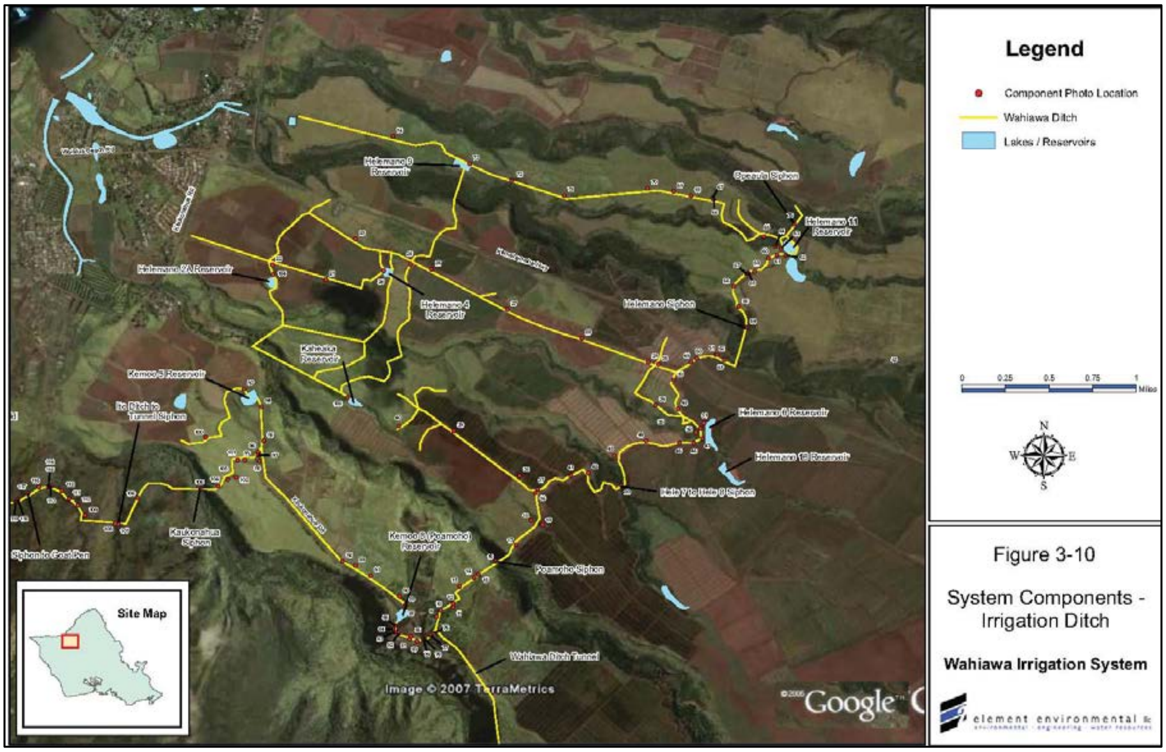
Surface irrigation water is less expensive than pumping ground water, and where available is used for agricultural irrigation. The main supply of surface irrigation water for North Shore is via the Wahiawā Irrigation System (WIS), which was constructed during the plantation era and is in need of repairs to maintain operations and reduce system water losses. With water savings, more water could be available for additional agriculture and for streamflows to support native stream plants and animals.

GENERAL BACKGROUND

The WIS consists predominantly of open, unlined ditches with various forms of lining, pipes, flumes, and tunnels in locations where the terrain requires (i.e., in areas of steep slopes, the ditch is often lined to mitigate slumping or caving-in of the ditch walls). An assessment of the WIS in 2007 found the irrigation system generally in fair condition in the portions that are used most frequently, predominantly the agricultural area that lies between Kaukonahua Road to the southwest and Kamehameha Highway to the northeast. The irrigation system shows more signs of deterioration toward either end of each of the two forks (the Ito Ditch and the Wahiawā Reservoir Ditch northeast of Kamehameha Highway).

Kamehameha Schools has made over $10 million in improvements over the past eight years to the portions of the WIS that serve their lands. The ditch systems on their lands are the ʻŌpaeʻula Ditch and Kamananui/Kawainui Ditch, extending from ʻŌpaeʻula Stream to Waimea Bay. Improvements were largely piping the system from the stream diversions to the reservoirs and fields.

The Dole-owned portion of the WIS includes Helemano Reservoir Ditch, which collects irrigation water in Upper Helemano Reservoir (Tanada Reservoir) from the upper reaches of Poamoho and Helemano streams, and partial ownership of the Wahiawā Reservoir. The Dole system has been maintained to continue functioning but is still in need of repairs, many of which will require a significant outlay of capital for repairs in the future. The *Assessment of the Wahiawā Irrigation System for the State Agribusiness Development Corporation* in 2007 estimated the costs for immediate repairs at approximately $4.2 million, of which Dole has completed approximately $2.1 million in repairs, leaving approximately $2.1 million remaining for immediate repair work. Dole is currently in the process of repairing the Wahiawā Dam, Wahiawā Reservoir Outlet Tunnel, Helemano 6 Reservoir Dam, and Kemoʻo 5 Reservoir Dam.



Wahiawā Irrigation System Components
(Source: Assessment of the Wahiawā System, September 2007)

Even after the above repairs, there are considerable water losses occurring in the system, due to the mostly open nature of the system and additional needed repairs. An estimated $10 million of work needs to be done to improve the condition of the ditches in the Dole-owned portion of the WIS. Most farmers are already economically challenged in maintaining their farm operations; however increasing irrigation water rates to fund the improvements to will be essential for improving water quality and quantity. Agricultural subsidies must be pursued to ensure affordable irrigation water rates.

To assist in identifying ditch section water losses, BWS in cooperation with Dole conducted seepage runs of the Kaukonahua to Kawailoa portion of the Dole WIS in September 2012. Sections of the ditch surveyed that did not have diversions into agricultural fields showed losses ranging from negligible to over 3 mgd. The greater losses were seen with larger flow near the Wahiawā Reservoir in unlined segments of the ditch system and where lined segments need repair.

More gaging and metered data is needed to definitively know which sections of the WIS are experiencing the greatest water losses. This additional data is needed for the sections already surveyed as well as the Mokulēʻia segment and the mauka-makai aqueducts off the Kaukonahua to Kawailoa portion which were not surveyed.

Even without additional data it is known that unlined ditch sections have greater losses than lined or piped portions. As the agricultural demand for irrigation water increases, Dole Foods has the opportunity to repair ditch lining and pipe the ditch to reduce water losses to deliver more irrigation water to the fields that need it.

Addressing the improvements to the WIS will take great efforts in the short and long term. While Kamehameha Schools has already invested in and improved the portion of the WIS on their lands, much remains to be done with the Dole-owned portion. The expected increases in agriculture on the North Shore will require water for irrigation and reducing the WIS losses will assist in making more water available.

PRELIMINARY SCOPE

1) Continue to assess water losses and needed improvements and prioritize where they are needed. The unlined portions of the ditch ultimately need to be piped to reduce system losses. Priority areas will include the portions of the ditch closest to the reservoir which carry the greatest flows and therefore have the potential for the greatest savings. Also, areas with slope or other terrain challenges should also be prioritized due to potential erosion.

2) Create a WIS Water Users entity for assistance and cooperation in improving and maintaining the irrigation system. A user group entity could be a conduit for obtaining grants and other funding that would not be available to Dole as a single business.

3) Solicit government and grant funding for improving the Wahiawā Irrigation System. Obtaining funding from the State is challenging; however, legislators have been supportive of past efforts to support agriculture.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

Dole*, Irrigation System Water User Group*, DOA, ADC.

ESTIMATED COST

More than $12 million.

REFERENCES

Dan Nellis, Operations Director, Dole Food Company Hawai'i. October 26, 2011 meeting.

Kalani Fronda, Senior Land Asset Manager, Kamehameha Schools. October 2013. Materials and conversation.

State of Hawaii Agribusiness Development Corporation. 2007. *Assessment of the Wahiawā Irrigation System.*

15. Agricultural Water Reliability: Water Storage, Back-up Wells, and Stormwater Reclamation

PROBLEM STATEMENT

A significant limitation to agriculture on the North Shore is the lack of surface water reliability, especially during dry periods and drought. By increasing water storage, or by supplementing surface water with ground water wells, irrigation water can be more reliable year-round. Stormwater could be a potential source for irrigation water uses and should be explored.

GENERAL BACKGROUND

Water Storage

Reservoirs play an important role in agricultural operations as part of the water delivery irrigation system. The reservoirs impound water during times of surplus and release water in a controlled manner when needed. Without reservoirs, the number of arable acres for agriculture use would be significantly lower.

The current capacity of reservoirs on the North Shore is approximately 3,500 million gallons. Given the current agricultural demand for the North Shore of 24.4 mgd, and assigning distribution system water losses at 50%, there might be approximately 70 days of water reserve. However, the Wahiawā Reservoir, which has a capacity of 3,000 million gallons, is not usually maintained to its fullest capacity because of flooding concerns. Moreover, the reservoir is managed for aquatic life, so it cannot be assumed it would be completely drained. Based on these variables, there may be less than two months of irrigation water available during a drought, starting from a period of all reservoirs at full capacity. Other constraints to expanding reservoir storage include the liability of dam ownership, and the costs for dam improvements and certification, which can be in the hundreds of thousands of dollars. ADC is planning 19.2 million gallons of reservoir storage in four reservoirs on its Galbraith lands. Rather than constructing dams, ADC will be excavating below grade to reduce the liability of potential dam failure.

Back-up Wells

To support irrigation system failures or a drought situation, ground water wells could be used as a back-up source. This coordinated management of surface and ground water supplies to maximize the yield of overall water resources is known as conjunctive use. However, current CWRM policy precludes the granting of two water use permits from different aquifers (and different water management areas) for the same end use. CWRM has considered using the "water emergency" provisions of the Code (174-62(g) HRS) to address emergency situations, but to date, no process has been established.

Stormwater Reuse

Surface water is the prime source for agricultural irrigation purposes and the most cost effective. Pumping ground water from existing wells, as well as drilling and maintaining new wells, is extremely expensive. Stormwater capture is a possible alternative for increasing water supply that should be examined. Many storm drains in Wahiawā already drain into the Wahiawā Reservoir, so some stormwater reuse is already occurring. However, stormwater reuse opportunities are not available in the North Shore district itself, because the small scale stormwater structures in North Shore are located along the coastline and are not adjacent to agricultural fields.

Farmers may also use stormwater harvesting techniques already. The open space of agricultural areas, layout of fields (which convey stormwater in organized flow paths), and existing infrastructure (such as ponds, tanks, and irrigation channels) offer opportunities for stormwater reclamation and reuse. These can be further developed to improve their reclamation and reuse characteristics. In addition, other opportunities can be examined, such as constructed wetlands, excavated basins, infiltration trenches and injection wells for ground water recharge.

A water bio-remediation system is currently used at the UH CTAHR Livestock Experiment Station in Waiale'e to collect rain, cow manure, and other runoff in a deep well. Solids settle at the bottom, and residual water gets pumped into carbon tanks. From there, it is piped to a nitrogen tank, where nitrate-rich water is distributed back into the farm. Aside from increasing water security, this system has improved the cleanliness of the environment around the farm and reduced the manure runoff in the pasture.

PRELIMINARY SCOPE

One way to increase the quantity of water available for agricultural irrigation is through irrigation distribution system improvements, which is addressed in Project 14. This project focuses on other alternatives to increase water availability and reliability.

Water Storage

- Assess reservoir storage options, capacity, distribution and relationship to surface water sources

Back-up Wells

- Explore conjunctive use to maximize the yield of available water resources

Stormwater Reclamation

- Investigate potential stormwater reclamation projects, including bio-remediation
- Work with farmers to increase small scale stormwater capture and storage

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

Water Storage: DOA/ADC*, DLNR Engineering Branch. Back-up Wells: CWRM*. Stormwater Reclamation: USDA/NRCS*. Additional: Dole, Kamehameha Schools, DOH Stormwater Quality Branch, West O'ahu SWCD, USACE, Landowners

ESTIMATED COST

To be determined.

REFERENCES

CWRM, 2008. *A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawai'i.*

Nellis, Dan. Operations Director, Dole Food Company Hawai'i. November 16, 2012. Email communication.

State of Hawai'i, Department of Agriculture. 2010. *Economic Impacts of Agricultural Reservoir Closures in Hawai'i.*

16. BWS Conservation Programs

PROBLEM STATEMENT

Potable water usage, treatment, and delivery are essential for residents and visitors to the North Shore. To ensure adequate access to clean, fresh water for drinking and domestic use, it will be necessary to maintain an efficient delivery system while encouraging consumer conservation of the limited potable water resource.

GENERAL BACKGROUND

BWS has been actively promoting water conservation since its inception in 1929 and created a Conservation Section in 1990 to implement specific conservation programs to reduce potable water use. The effort has been successful. From 1990 to 2010, O'ahu's BWS-served population grew by over 92,000 people (an 11% increase). However, while growth and development on the island did occur, island-wide BWS water use has actually decreased by 7% during the same time period. Thus, despite the growth and development that has occurred on O'ahu in recent years, BWS water use has not dramatically increased, due in large part to the BWS Water Conservation Program, the expansion of recycled water use and the economic incentives of rising water and sewer rates from 2005.

Water conservation can be defined as practices, techniques, and technologies that eliminate waste and improve the efficiency of water use. Water conservation, as a fundamental component of effective water resource management, is applicable to those who deliver water as well as those who consume water. Water conservation is often equated with temporary restrictions on water use and is a useful tool during times of service disruptions or drought. Water conservation programs can also emphasize lasting improvements in water use efficiency.

Growth in water demand has traditionally been met by developing new water sources. However, water conservation programs can reduce current and future water demands, to the benefit of BWS, the community, and the environment. The economic value of these conservation measures is direct savings to consumers' water and sewer bills through reduction in consumptive water use, and savings to BWS referred to as "cost avoidance." If enough water is saved, it may defer, prevent, or downsize new water source development. At a general development cost of $6 per gallon, for example, a savings of 0.5 to 1.0 mgd would translate to a cost avoidance of about $3 million to $6 million. Water conservation provides savings through decreased operational and capital costs for the following: 1) Treatment (chemicals and testing); 2) Pumping (electricity); 3) Wastewater treatment (due to reduction in potable water use); and 4) Development of new water sources (i.e. wells, tunnels, pumps, treatment plants, distribution mains, reservoirs).

The environmental value of water conservation in the North Shore will directly benefit the health of the district's watersheds. About two-thirds of North Shore's BWS water use is for residential uses. Each day, every household has the opportunity to improve the health of the district's watersheds by making conscious efforts to reduce its daily water consumption. **In the North Shore, every gallon of water conserved by a household is one more gallon of water that will remain in North Shore aquifers.** A proactive water conservation program is a fundamental element of long-term sustainable watershed management.

The BWS "Water Conservation Program" is currently organized as:

1) Public Education and Outreach

2) Leak Detection, Repair, and Maintenance

3) Large Water Users Program

4) Regulation

5) Alternative Source Development, Recycling, and Conservation Alternatives.

The principal elements of these five program clusters are described in detail in Chapter 3 under the description of the BWS system. BWS encourages water conservation across the entire district of the North Shore to reduce pumping costs and to conserve North Shore aquifers.

PRELIMINARY SCOPE

Additional conservation practices could produce the following desired outcomes:

- Reduce BWS system water loss to 10% or less.
- Reduce the amount of water BWS must produce from its North Shore sources.

Conservation projects and programs that BWS would like to further pursue in North Shore include but are not limited to: rain barrel workshops, water conservation education and awareness in urban and agricultural sectors, water loss best management practices, and promoting additional use of recycled water (Wahiawā and Schofield). Near-term plans (one to five years) include:

Expand partnerships with community organizations and agencies promoting water conservation. Many community organizations and agencies' missions also support the goal of water conservation. By partnering with these organizations, greater gains can be made in promoting conservation messages and implementing water saving practices.

Continue and expand water conservation education and incentive programs. Existing programs have been effective particularly for the residential sector, and should continue. Programs have included Fix-a-Leak week, school education programs, the Hālawa Xeriscape Garden and the Unthirsty Plant Sale. In the North Shore, BWS could host joint water conservation demonstration events and programs. In particular, BWS could partner with Waimea Valley to conduct a native plant landscape workshop that relies only on rainfall for water.

Ongoing conservation education efforts and planned expansion include:

1. Development of a wider range of new conservation programs for the North Shore. Due to changes in FDA food processing standards, BWS expects an increase in potable water meters for agriculture, especially for food processing and vegetable crops. Conservation efficiencies in processing produce and irrigation will be essential to conserve the resource and system capacities. BWS expects to maintain its agricultural water rate subsidy in support of agriculture and the availability of locally grown produce.

2. The Public Awareness Program includes school educational programs, water conservation poster and poetry calendar contest, printed literature, tours of BWS facilities, Hālawa Xeriscape Garden events, Fix a Leak week, restaurant table tents, toilet flappers and dye tablets, Neighborhood Board messages, Public Service Announcements, commercials and articles in the newspaper on water conservation.

3. Indoor and outdoor water use surveys of commercial businesses, government facilities, hotels and multi-family residential developments to determine current hardware, irrigation and water uses, including water budgets with recommendations for savings. BWS will monitor baseline and post-retrofit uses.

4. Residential and commercial native plant and drought tolerant landscape workshops where customers will learn about native plants that rely only on rainfall and limited irrigation water.

5. Weather-based irrigation system controllers where large irrigation systems are retrofitted with cost effective weather stations to fine-tune water application rates to weather and landscaping needs.

6. Food service incentives consisting of a restaurant survey of water fixtures, equipment and practices based on the State’s Green Program guidelines.

Reduce water losses in the system. System losses can be reduced through leak detection and repair, and through main failure analysis that includes collecting and investigating main failures, and identifying the potential causes of and solutions to premature pipeline failure.

POSSIBLE PARTICIPATING AGENCIES/ORGANIZATIONS

BWS*.

ESTIMATED COST

The island-wide projected breakdown of estimated dollars spent on water conservation programs is as follows:

- $100,000 per year for Public Education and Outreach and Large Water Users Programs.
- $500,000 per year for Leak Detection, Repair & Maintenance.
- $15 million over the next six years for Alternative Source Development, Recycling & Conservation Alternatives.
- $300 million over the next six years for Pipeline Replacement (This proactive infrastructure renewal program reduces water losses and increases system reliability).

REFERENCES

Board of Water Supply staff

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4.4 WATERSHED MANAGEMENT STRATEGIES

The following section outlines and describes **watershed management strategies.** Generally, a "strategy" is a series of actions that help to achieve a common objective. These strategies are similar to the "Projects with Champions," in that the strategies help to achieve NSWMP objectives and sub-objectives. However, watershed management strategies do not currently have a project champion or are much smaller in scope than a project. These strategies were developed from community and agency consultations (See Chapter 2.9 "Stakeholder Consultation") as well as from the planning team's coordination meetings with BWS, DPP, and CWRM.

Surface Water Management Strategies

A. Assess Stream Ecosystem Health. Hawai'i's State Water Code mandates that *"adequate provision shall be made for the…protection and procreation of fish and wildlife."* Limited data makes it difficult to assess the health of streams, native biota, and stream habitats in order to compare it with historical information and to assess and plan for future needs. Data collection is especially important for streams with diversions, in order to determine the impact of diversions on the stream's aquatic life. Studies are needed for North Shore streams to more accurately assess stream health and to be the basis of IFS and stream management plans. Data from biological assessments can be used to develop management actions such as stream clearing, identifying appropriate riparian buffer widths, removing invasive species, redesigning flood channels, restoring streams and protecting streams by establishing measurable IFS. **Possible Champions and/or Partners:** DLNR ENG, DFM.

B. Implement Kaiaka Bay Watershed Flood Mitigation Projects and Planning. Flooding is a major community issue in Waialua and Hale'iwa. Many residents feel that there have been too many studies and not enough action to alleviate flooding issues. The Kaiaka Bay Watershed Participatory Assessment and Action Project identified possible flood mitigation projects, including: 1) a feasibility study regarding long term flood mitigation strategies, 2) construction of wetlands, storage ponds, and other flood mitigation works, and 3) a study on potential locations for additional dams at key locations for flood mitigation. **Possible Champions and/or Partners:** USACE, DLNR.

C. Conduct a Dredging Study & Systematic Maintenance of Key Areas. The USACE conducted flood plain analyses of DLNR-proposed stream dredging at Paukauila and Kaukonahua streams in 1999 and 2002, respectively. The studies found that periodic maintenance dredging of key areas would be required to maintain the carrying capacity and flood elevations. DLNR dredged Paukauila Stream in 2001, and the City of Honolulu completed dredging of their portion of Paukauila Stream in 2006. However, the DLNR Engineering Department is not aware of any dredging maintenance plans that DLNR prepared, nor any future DLNR dredging projects proposed for Paukauila, Kaukonahua, and Ki'iki'i streams. The Honolulu City Capital Improvement Projects budget listed Ki'iki'i stream dredging for fiscal year (FY) 2014 – previously slated for implementation in FY 2006.

Due to continual sediment deposition from both coastal and riverine processes, a routine maintenance program for clearing channel debris should be established. The program should include field inspections after any major flood event. Because the streambanks are owned by various landowners, DLNR and City and County of Honolulu Department of Facilities Maintenance should work with the residents and owners of Paukauila, Kaukonahua, and Ki'iki'i Streams to develop a maintenance program. **Possible Champions and/or Partners:** DLNR ENG, DFM.

Ground Water Management Strategies

D. Implement Drought Mitigation Strategies. There are uncertainties of water demand and supply projections given the changing nature of the global climate. As more droughts and flooding are forecast, questions arise as to how to mitigate the effects on agriculture and wildfire on the North Shore. Agriculture on the North Shore, which is highly dependent on surface water, is susceptible to drought. Back up ground water supplies are needed. For wildfire, the City and County of Honolulu Drought Mitigation Strategies (2004) recommend drought mitigation projects such as development of an O'ahu Wildfire Coordinating Group, fuel hazard reduction within the wildland urban interface, and inventory and maintenance of firefighting water sources. $1,500,000 was appropriated by the City Council for FY 2014 to acquire land, plan, and design a new location for the Waialua Fire Station. The existing Waialua Fire Station is over 70 years old, located in a flood zone, and is too small to accommodate a water tanker needed for drought-increased fire risk. **Possible Champions and/or Partners:** CWRM, HFD, BWS, DOA, DOFAW, NRCS.

E. Improve Wastewater Treatment. There are no municipal connections for wastewater on the North Shore, and the majority of residents and businesses use cesspools that may be more than 50 years old. Cesspools have the potential for contaminating ground and surface waters. They do not provide much, if any, treatment of wastewater prior to it flowing into the surrounding ground. These contaminants can find their way to streams and shorelines, posing potential health risks to terrestrial and aquatic environments. These risks can be reduced by implementing the North Shore Regional Wastewater Alternatives Plan (2012) strategies, such as: cesspool systems upgraded to septic tanks; the use of injection wells above the underground injection control (UIC) line or water reuse for neighborhood clusters; existing wastewater systems upgrades; and a small wastewater treatment facility for larger commercial and residential areas. In July 2015 Governor David Ige signed into law a bill that authorizes a tax credit of up to $10,000 for conversion of cesspools located within 200 feet from a shore, perennial stream or wetland, or within a source water assessment area. Eligible properties in the North Shore with cesspools should be encouraged to convert or upgrade. **Possible Champions and/or Partners:** Homeowners, Homeowner Associations, DOH, ENV.

F. Encourage Gray Water Reuse. Gray water is wastewater that is discharged from showers, washing machines, and sinks that are not used to dispose of food preparation matter or toxic waste. The primary benefit of gray water reuse would be to reduce the amount of water collected in individual wastewater systems, thereby reducing the rate at which individual wastewater systems reach storage capacity. This would help to mitigate leaching of wastewater from individual wastewater systems into fresh water sources. And, reuse of gray water would reduce the demand for potable water used for outdoor irrigation. In 2009, DOH prepared *Guidelines for the Reuse of Gray Water* for homeowners, land users, contractors, and engineers on the use of gray water in the State. DOH has supported water reuse provided public health is not compromised. Gray water reuse systems should be encouraged on the North Shore. **Possible Champions and/or Partners:** DOH, BWS, ENV, DPR.

Nearshore Water Strategies

G. Support Mālama Pūpūkea-Waimea Makai Watch. The goal of the Makai Watch Program at the Pūpūkea Marine Life Conservation District (MLCD) is to enhance the management of near-shore marine resources by providing community members opportunities for direct involvement in management activities. The Makai Watch Program consists of three main components: building community awareness with outreach, biological and human use monitoring, and incident observation and encouraging compliance. The overriding goal for the Makai Watch volunteers is to be the "eyes and ears" for DLNR Division of Conservation and Resource Enforcement (DOCARE). DOCARE's goal is to enforce the State regulations that protect our natural resources. However, DOCARE has limited resources. Often when a violation is called in there is no response even when a live operator does answer the phone. The project would benefit from a DLNR docent available on site more frequently. The Mālama Pūpūkea-Waimea Makai Watch has been successful in preventing violations and in improving the ecosystem health, however Mālama Pūpūkea-Waimea needs continued volunteer and fundraising support. **Possible Champions and/or Partners:** Hui Mālama o Pūpūkea-Waimea, DOCARE.

H. Designate Waialua Reef as a Marine Life Conservation District. Designation of a MLCD off of Waialua Beach Road might enable this reef system to rejuvenate itself for future recreation and as a source of income for the local fisherman. MLCDs are established by DLNR Division of Aquatic Resource (DAR). Suggestions for areas to be included in the MLCD system may come from the State Legislature or the general public. Once an area is recommended for designation as an MLCD, it is evaluated by the DAR with regard to a number of criteria. These include public accessibility, marine life and future potential values, safety from a public usage standpoint, compatibility with adjoining area usage, and minimal environmental or ecological changes from the undisturbed natural state. In addition, the area should have clearly defined boundaries so that it is easily recognizable for compliance and enforcement. The area must also be of suitable size - large enough so that fish populations can be restored even with ongoing fishing activity outside the MLCD, but small enough so that fishermen are not denied the use of unreasonably vast fishing areas. If the recommended area meets the above criteria, the DAR conducts a thorough investigation consisting of bottom topography and fish surveys. Input from the general public, citizen groups, and governmental and private agencies is also considered. Public meetings are held, after which regulations for the area are drawn up. A public hearing is then held on the proposed regulations, with final approval obtained from the Board of Land and Natural Resources and the governor. **Possible Champions and/or Partners:** North Shore residents, State representatives, DLNR DAR.

Land Management Strategies

I. Restrict Off-Road Vehicles in Conservation Areas. Off-road vehicles should be restricted in ecologically sensitive areas. In the coastal areas off-road vehicles cause beach erosion and harm coastal resources. In the mauka areas, off-road vehicles contribute to soil erosion and increase sediments in run-off. Frequent use of off-road recreational vehicles also damages the root systems of plants and destroys existing areas of vegetation. Recreational areas specifically designated for off-road vehicle use should be identified and maintained with vegetative buffers and other mechanisms to reduce soil erosion and stream sedimentation during storm events. **Possible Champions and/or Partners:** DOCARE, HPD, private landowners, neighborhood watch organizations.

J. Promote Pollution Prevention Awareness and Education. Public awareness and education outreach can help to reduce polluting behaviors. Education is one of the most powerful tools to enhance environmental conditions and reduce pollutant loads by increasing awareness of watershed conditions and providing opportunities that allow community members to participate in the solution. Education programs in schools can help in reaching the adult population as well as children who bring home new values that can inspire a change in their parents. Short lessons as part of a larger science or social studies curriculum could include service projects such as water quality monitoring and native tree planting.

In addition, adult education and outreach programs, if correctly designed, can be effective tools for community members who care about their resources but may not know how to help or participate. The most effective education programs connect people with the resource through hands-on activities that lead to structured outcomes, turning education into action. Involving individuals in the solution returns ownership of (and responsibility for) the resources to the community. Solutions and educational opportunities can be offered via local television programs, eco-tours, or community-participation projects such as beach cleanup days and storm drain stenciling. If water quality degradation is prevented in the first place, then restoring water quality will no longer be an issue. **Possible Champions and/or Partners:** DOE, BWS, ENV, DOH, DLNR DAR, neighborhood organizations.

Cultural Resources/Traditional Practices Strategies

K. Record North Shore Oral History. Watershed or ahupuaʻa management by Native Hawaiians involved information acquired during a relationship with the ʻāina (land) that developed over hundreds of years. In more recent history, families that worked the plantations also had an intimate understanding of the landscape. Much of the knowledge and information may be lost with the passing of older generations and elders. Recording the oral histories of the North Shore will provide an opportunity to utilize local knowledge for sound decision making in resource management while preserving the legacy and traditions of its people and places. Kamehameha Schools and Waimea Valley could be repositories for these studies. **Possible Champions and/or Partners:** North Shore Chamber of Commerce, NSCLT, OHA, Waialua Hawaiian Civic Club, SHPD, UH Center for Hawaiian Studies, UH Center for Oral History.

L. Create North Shore Ahupuaʻa Boundary/Stream Markers. A key strategy to helping residents and visitors understand Native Hawaiian culture would be to identify Hawaiian practices of land and resource management by ahupuaʻa units. A stream signage program would help to educate the general public about the particular characteristics of the major streams in the district, threats that may impact a particular stream, and simple strategies or best management practices that community members can implement to mitigate those threats. Stream signage could also include contact information for groups or agencies that are involved in stream stewardship for those interested in joining stream stewardship efforts. A subsequent project would involve establishing teams of kūpuna and college students from each of the ahupuaʻa to conduct community awareness programs to educate their ahupuaʻa on the cultural and natural resources of their area and share Hawaiian sustainability practices to mālama these resources. **Possible Champions and/or Partners:** DAR, ENV, DPR, DPP, DTS, DOT, USGS.

Water Supply Strategies

M. Repair and Replace BWS Pipelines. This strategy **s**upports the BWS Capital Program projects on the North Shore. BWS water systems are a complex configuration of many different components interacting to meet the needs of its customers. Since its beginning in 1929, BWS has managed Oʻahu's municipal water resources and distribution system in order to provide customers with a safe and dependable water supply. BWS is the largest municipal water utility in the State, serving almost one million customers on Oʻahu with approximately 150 mgd of potable water, approximately 10 mgd of recycled water and 1 mgd of brackish water. The BWS water systems are comprised of 94 active potable water sources, four nonpotable water sources, 91 booster pump stations, 170 reservoirs, and more than 2,000 miles of pipeline serving over 160,000 customer accounts.

To keep the water flowing to nearly every community on Oʻahu, BWS must carefully and proactively manage and invest in its complex system. The BWS Capital Program consists of repairing and replacing aging infrastructure, expanding the system to accommodate planned growth and maintaining and updating the various tools and resources support systems that are critical to delivering water. The components of BWS water systems can be organized under four main categories: 1) Source, 2) Pipeline, 3) Storage, and 4) Treatment. Transmission and distribution pipelines constitute the bulk of the BWS water system's assets. BWS funds the capital program through a combination of water rates, revenue bonds and impact fees. BWS periodically conducts a water rate study to evaluate the necessity of increasing rates and fees to support growing infrastructure, power and miscellaneous costs.

BWS plans 11 miles of additional 8-inch pipeline replacements in Haleiwa along Kamehameha Highway totaling $11.9 million in 2018. **Possible Champions and/or Partners:** BWS.

N. Incorporate Climate Change Plans and Initiatives into North Shore Water and Watershed Planning. Impacts from global climate change create new challenges in Hawaiʻi including ocean and atmospheric warming, acidification, sea level rise, coastal zone erosion, increased frequency and severity of storm surges, floods and drought.

In 2007, Hawai'i enacted *A Global Warming Solutions Act 234* to cap greenhouse gas emissions to the 1990 level by 2020. In 2012, *Climate Change Adaptation Priority Guidelines Act 286* was passed by the legislature and signed into law by Governor Neil Abercrombie. Hawai'i is one of few states in the nation to adopt a statewide climate adaptation policy for addressing the impacts of climate change. Because the policy is an amendment to the Hawai'i State Planning Act, all county and state actions must consider the policy in its land use, capital improvement, and program decisions. The Office of Planning is currently working with various stakeholders, primarily through the Ocean Resources Management Plan (ORMP) program, to implement the policy. The ORMP includes county, state, and federal stakeholders who implement public projects and programs. The ORMP is a coordinated effort that includes input from the community, businesses, and non-profits that contribute to and support these efforts.

The Pacific Islands Climate Change Cooperative (PICCC) provides a range of services and tools to help managers in Hawai'i and other Pacific Island groups make informed decisions for conservation of natural and cultural resources. These services include climate models at the archipelagic and island scales, ecological response models, and implementation and monitoring strategies for island species, resources, and communities. The goal of PICCC is to help managers reach explicit biocultural conservation objectives in the face of climate change and ongoing threats such as fire, land conservation, and invasive species.

These coordinated actions, publications, and future publications should be utilized to incorporate best available information into water and watershed projects and initiatives on North Shore. **Possible Champions and/or Partners:** UH Center for Island Climate Adaptation and Policy (ICAP), Pacific RISA, Ocean Resources Management Plan Policy and Working Groups (CZM, BWS; the Planning Departments of O'ahu, Hawai'i, Maui and Kaua'i Counties; DOA; DOH; DLNR; DOT; OHA; Marine and Coastal Zone Advocacy Council, NOAA; USACE; US Coast Guard; UH School of Ocean and Earth Science and Technology, UH Sea Grant College Program), PIRCA, PICCC.

O. Implement the Energy Savings Performance Contracting Strategy for Selected BWS Facilities. BWS initiated a system-wide energy audit contract to evaluate all water system facilities, buildings, and the automotive fleet. Using the Energy Saving Performance Contracting method, BWS will solicit recommended energy efficiency improvements over the next 20 years. Currently, a Power Cost Adjustment provides BWS the ability to recover any electrical cost overages from the previous year above and beyond what was used to calculate the rate increases. BWS annually reviews and modifies the Power Cost Adjustment so that the adjustment only recovers unanticipated energy cost overages from the prior fiscal year. With the Energy Saving Performance Contract, BWS will gain a better understanding of their energy cost, implement energy efficiency improvements, and pass the savings on to their customers. **Possible Champions and/or Partners:** BWS.

5 IMPLEMENTATION

5.1 INTRODUCTION
5.2 WATER USE AND DEVELOPMENT PLAN
5.3 PHASING AND FUNDING OF PROJECTS WITH CHAMPIONS
5.4 WATERSHED MANAGEMENT – PRIORITY WATERSHEDS AND CATALYST PROJECTS
5.5 IMPLEMENTATION AND FUNDING: SOURCES AND STRATEGIES

5.1 INTRODUCTION

This final chapter of the *North Shore Watershed Management Plan* (NSWMP) contains the key plan elements of the NSWMP and implementation guidance. The material in this chapter highlights selected implementation tools and techniques.

This chapter presents implementation guidance for the NSWMP in the following sections:

5.2 Water Use and Development Plan
5.3 Phasing and Funding of "Projects with Champions"
5.4 Watershed Management – Priority Watersheds and Catalyst Projects
5.5 Implementation and Funding: Sources and Strategies

The NSWMP will be updated and revised with future North Shore Sustainable Community Plan updates. These periodic updates will allow for revisions and refinements of watershed data, analysis of important trends, issues and policies, water demand projections, implementation strategies, and an opportunity to monitor progress in accomplishing plan objectives and watershed planning benefits listed below:

- Power of holistic watershed approach that provides a suite of resource actions mauka to makai and incorporates social, environmental, and economic considerations.
- The importance of efficiencies in conservation that allow the balancing of meeting multiple demands including resource management, restoration, and cultural rights.
- The benefits of collaboration that bring together diverse interests around a common goal.
- The education and inspiration of youth and future generations to become involved in resource management for future sustainability.

5.2 WATER USE AND DEVELOPMENT PLAN

This section presents the potential timing of source project implementation to meet projected water needs by 2035 and beyond. The North Shore water demand projections are provided in detail in Chapter 3 and Appendix E, and descriptions of supply sources and projects to meet these future demands are provided Chapter 3 and 4, respectively.

5.2.1 Summary of Demand and Supply – Most Probable Demand Scenario

Table 5.1 summarizes the most probable water demand scenario by water system with supply sources that may be used to meet the demands. The total demand is more than 33 mgd by the year 2035. The total supply to meet the demand exceeds 35 mgd. Ground water supply in *Table 5.1* is existing permitted well uses, and surface water supply is existing use via Kamehameha and Dole Food Inc. water distribution systems.

The domestic water supply systems are supplied by ground water to meet current and future water demands. A mix of surface water and ground water are used to meet the current and future agricultural demands.

Based on the demand projections for the North Shore and known supply sources, the analysis shows there are adequate water supplies to meet the most probable demand scenario.

Table 5.1 Summary of North Shore Most Probable Demand Scenario and Supply

	2010	2015	2020	2025	2030	2035
DOMESTIC WATER SYSTEMS						
BWS Potable Water System Demand	2.81	2.80	2.89	2.94	3.00	3.01
BWS System - Permitted Ground Water Use[1]	3.75	3.75	3.75	3.75	3.75	3.75
Dole Potable Water System Demand	0.00	0.13	0.13	0.13	0.13	0.13
Dole - Permitted Ground Water Supply[1]	0.26	0.26	0.26	0.26	0.26	0.26
North Shore Water Company Potable Water System Demand	0.12	0.12	0.13	0.15	0.16	0.18
North Shore Water Company - Ground Water Supply[1]	0.15	0.15	0.15	0.15	0.15	0.15
US Army/State DOT Dillingham Airfield System Demand	0.06	0.06	0.06	0.06	0.06	0.06
Federal Systems - Ground Water Supply[1]	0.06	0.06	0.06	0.06	0.06	0.06
AGRICULTURE						
Agriculture Water Demand	24.15	25.17	26.19	27.21	28.23	29.25
Ag, Surface Water Supply						
KS Surface Water Supply	3.50	3.50	3.50	3.50	3.50	3.50
Dole Surface Water Supply[2]	8.90	8.90	8.90	8.90	8.90	8.90
Ag, Recycled Water Supply						
Wahiawā Waste Water Treatment Plant (R-1)[3]	-	-	-	1.60	1.60	1.60
Ag, Ground Water Supply						
KS Ground Water Supply[1]	3.21	3.21	3.21	3.21	3.21	3.21
Dole System - Ground Water Permitted Use[1]	1.41	1.41	1.41	1.41	1.41	1.41
State Ag Stations - Ground Water Supply[1]	0.03	0.03	0.03	0.03	0.03	0.03
Other Ground Water Supply[1]	12.80	12.80	12.80	12.80	12.80	12.80
Future Ground Water Permit(s)[4]	-	-	-	-	-	-
TOTAL WATER DEMAND	**27.14**	**28.27**	**29.40**	**30.48**	**31.57**	**32.62**
TOTAL WATER SUPPLY	**34.07**	**34.07**	**34.07**	**35.67**	**35.67**	**35.67**
Kalo Water Demand	1.00	1.50	1.50	2.00	2.00	2.50

Note: Water quantities are in million gallons per day (mgd)

1 CWRM Water Use Permit (WUP) Index (2010); permitted uses for fresh and brackish water wells. Existing unused sustainable yield is available for new wells subject to CWRM water use permit approval.

2 Existing surface water use with current level of losses; additional water demands need to be met through water conservation savings that means more efficient transport of water through the system.

3 Effluent from Wahiawā WWTP that will be used for Galbraith lands which are included in the overall agricultural demand beginning in 2025.

4 Future ground water permits for lands within the Dole WIS system should be granted after WIS system efficiency improvements that maximize existing supply sources have been implemented

5.2.2 Summary of Demand and Supply – Ultimate Demand Scenario

The ultimate demand scenario is a scenario that assumes the full build-out of residential units within the North Shore Sustainable Community Plan Community Growth Boundary, and irrigation of all the prime and unique agricultural lands outside of it. The ultimate demand scenario is for an unspecified time in the future as it reflects an end state that might occur based on land use plans, land use constraints and considerations of climate change impacts. The ultimate demand scenario is meant to test the foreseeable limits of supply and demand in the North Shore district to inform long range water resource management plans and policies on natural water resources, source augmentation and conservation efficiencies. The ultimate demand scenario is used for watershed planning purposes and is not tied City and County of Honolulu Department of Planning population projections.

Table 5.2 shows the demands and supply sources for the ultimate scenario. The total estimated demand for municipal uses is 6 mgd, for agriculture about 73 mgd, and for kalo 10 mgd for a total of 88 mgd.

The supply sources for the ultimate scenario differ from those used to meet the most probable scenario. Due to the unbounded timeframe, it is assumed that all supplies may be more fully developed and distribution systems will have improved efficiencies. The ultimate scenario assumes that the distribution systems deliver water efficiently with minimal losses.

The ground water supply sources include the entire North Shore aquifer sustainable yields (62 mgd) and with well development up to those amounts. For the Wahiawā aquifer, the currently permitted well amounts (totaling about 5 mgd) supplying the North Shore district and Galbraith lands are used.

For surface water supply, allowable surface diversions are used and based on declared uses in 1992 which equate to 33 mgd.

Recycled water from the Wahiawā Wastewater Treatment Plant (WWTP) is included as a supply as it may be used for irrigation of the Galbraith lands. The Schofield WWTP production is not included as it is expected that reuse of the increased 3 mgd output will not continue to be placed into the Wahiawā Irrigation System because the cost for that disposal might eventually be recovered by creating more localized uses in Central Oʻahu.

In total, these supply sources add up to 102 mgd which would be enough water to meet the ultimate scenario demand of 89 mgd. Chapter 3 provides more details on these supply sources. A comparison of the most probable demand scenario and the ultimate demand scenario with these total supply sources is provided in *Figure 5.1*.

Table 5.2 Ultimate Demand Scenario and Supply

DEMAND (all units in mgd)	
Domestic	6
Agriculture	73
Kalo	10
TOTAL DEMAND	**89**
SUPPLY (all units in mgd)	
Ground Water Sustainable Yields (Waialua, Kawailoa, Mokuleia aquifer systems)	62
Ground Water Permitted Uses (for North Shore wells in Wahiawa aquifer system)	5
Recycled Water (Wahiawā WWTP)	2
Surface Water (CWRM Diversion Listing)	33
TOTAL SUPPLY	**102**
Balance = Supply - Demand	**13**

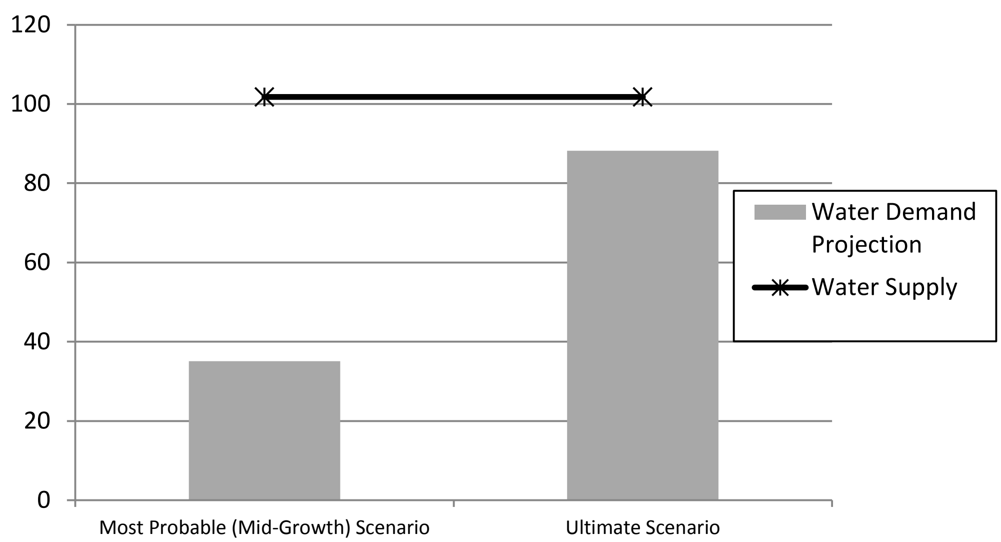

Figure 5.1 North Shore Demand and Supply: Most Probable and Ultimate Scenarios

5.2.3 Seasonal and Climate Change Effects on Supply and Demand

One water supply issue not captured in overall demand and supply comparisons of the most probable and ultimate demand scenarios is the availability water supplies during dry periods and drought conditions. These may results from seasonal fluctuations or long term-climate change impacts. Regardless of cause, they can have a significant impact on agricultural viability. While surface water is far less expensive to use than ground water, it is assumed that during critical periods, surface water may not be available and ground water may be used as a back-up supply. *Table 5.3* below shows a comparison of the surface and ground water sources on the North Shore and seasonal availability.

Table 5.3 Surface and Ground Water Source Comparison

Water Source	Cost	Water Distribution Efficiency	Season Availability
Surface Water	Low	Low (Wahiawā Irrigation System) High (Kamehameha Schools Kawailoa System)	Highly variable based on rainfall and limited reservoir storage
Ground Water	High	Mid-High	Low variability; affected by amount of recharge in long term

5.2.4 Ground water

Ground water is used for domestic water use and for agricultural irrigation where surface water is not available and as a back-up supply for surface water systems during dry periods.

The Board of Water Supply is not planning for future well development on the North Shore as current wells have capacity to supply the projected needs to 2035, although additional permitted use may be requested if potable agricultural demand increases. BWS will **repair and replace pipelines** (Strategy M) as needed to reduce main breaks and water distribution system losses, and continue the **BWS Conservation Programs** (Project 16) to reduce demands. Dillingham Ranch's planned addition of an agricultural subdivision will likely not require an additional well as an existing well or wells could be utilized to supply this demand. The domestic Dole system and US Army/State DOT system for Dillingham Airport do not have planned increases in demand and will likely stay at the 2010 levels.

If additional lands outside of the Wahiawā Irrigation System are brought into agricultural production and need irrigation, there may be additional water use permit requests. Sustainable yield in Kawailoa and Waialua Aquifers is available (Table 3.2). Mokulēʻia aquifer's sustainable yield is close to completely allocated; however, based on reported 2010 pumpage very little of the allocations are actually being used. Revocation of water use permits by CWRM may be needed before additional water use permits can be issued.

The availability of water for current kalo on the North Shore is largely via springs which are ground water that comes to the surface. Springs are administered as surface water. However, nearby ground water withdrawals may have localized effects on springs and should be carefully monitored to avoid loss of water for loʻi kalo.

5.2.5 Surface Water

As discussed surface water supply for agriculture is susceptible to drought as it is susceptible to changes in weather and has limited storage capacity to provide a buffer during periods of drought. While currently there appears to be ample water supply on the North Shore for agriculture, there may be periods without enough water. The two projects below could reduce seasonal fluctuations and generally improve surface water availability.

Wahiawā Irrigation System Improvements (Project 14), especially for the portion owned and operated by Dole foods, are needed to reduce system losses. This would improve stewardship of water resources, increase water availability during droughts, and provide additional supply for future agriculture demand. In the ultimate scenario, surface water supply assumes system losses have been reduced to minimal levels so that more water is available for use. This project is a priority and will likely take many years to accomplish in order to reduce water loss and improve delivery efficiency.

Agricultural Water Reliability (Project 15) includes **water storage** guidance that can assist with making water available during dry periods. The recommendation is to assess potential water supply storage and not further reduce the water supply options for agricultural irrigation water. While water storage should be maintained and improved, it will not always provide enough water for sustained periods of drought. Ground water supplies may be needed as **back-up wells** to allow water supplies for agriculture during drought periods. After such periods, the wells should be rested to allow ample recovery before the next drought periods.

5.2.6 Recycled Water and Other Supply Options

Wahiawā Reservior Water Quality Improvements (Project 13) may occur in the mid to long term once funding is procured for piping of water to Galbraith lands as part of the Whitmore project. Storage and membrane filtration improvements at the WWTP may reduce upset events but the DOH must still evaluate whether Wahiawa reservoir water could be considered unregulated and used on all crop types.

5.3 PHASING AND FUNDING OF "PROJECTS WITH CHAMPIONS"

Table 5.4 on the following pages presents North Shore watershed management projects phasing. Projects, which have project champions, are largely ongoing projects with multiple moving parts. The phases are described in terms of short-term and long-term project phases. Short-term is the 1-5 year timeframe, and long-term is 5 or more years.

The table summarizes the project's current status, short term actions, long-term actions (if applicable), and potential funding sources. The projects are listed in the same order as they were listed in Chapter 4.

Table 5.4 Watershed Management Project Phasing

Project	Current Status	Short-Term Actions 1-5 Years	Long-Term Actions 5+ Years	Potential Funding Sources
1. Kaukonahua Stream TMDL Implementation	• Vegetation management efforts • Feral ungulate control • Erosion and sedimentation management measures • Stream flow and sediment monitoring • Ko'olau Mountains Watershed Partnership coordination	Obtain funding for studies and monitoring	• Develop a comprehensive implementation strategy and detailed implementation plan • Identify uses and conservation practices below the Forest Boundary and address in future watershed planning • Develop a Waste Load Allocations implementation plan and a Waste Load Allocation monitoring plan for the North Fork Kaukonahua Stream • Implement Waste Load Allocations for the North Fork Kaukonahua Stream TMDLs • Form a regionalized water quality monitoring program	• C&C Hon • DOH • US Navy • USDA/NRCS • USFWS
2. Measurable Instream Flow Standards	Interim instream flow standards	• Conduct public fact gathering meetings in North Shore on priority streams • Obtain funding to conduct stream studies	• If funding is acquired, conduct in-stream and non-instream studies to develop measurable IFS • Then establish measurable IFS for priority streams	• CWRM
3. Waialua-Kaiaka Watershed Restoration Study	• Waiting on Congress to give USACE new start authority by funding the Study in the Energy & Water Appropriation Bill	Secure appropriation for funding	• Initial reconnaissance phase study • Feasibility study if Federal participation is warranted • Local communities and local governments pursue structure relocations and flood proofing	• US Congress

Table 5.4 Watershed Management Project Phasing (cont.)

Project	Current Status	Short-Term Actions 1-5 Years	Long-Term Actions 5+ Years	Potential Funding Sources
4. Potable Wellhead Protection	• North Shore potable wells are tested for contaminants • Public health protection measures are implemented when contaminants detected	• Work with landowners to conduct well source area inventories • Begin protection plans/studies	Implement a source water protection program	• DOH • BWS
5. Mokulēʻia Potable Water System Improvements	• North Shore Water Company working to resolve issues regarding fixture counts • Completing additional analysis and reports	Look into possibility of BWS extending water main		• Dillingham Ranch ʻĀina, LLC • BWS
6. Agricultural Best Management Practices	NRCS assists farmers to create conservation plans and implement conservation practices	Secure appropriations for funding additional conservation practices	Implement conservation measures on croplands	• USDA/NRCS • Oʻahu RC&D • Landowners
7. Low Impact Development Techniques	LID practices incorporated into the 2013 amended Rules Relating to Storm Drainage Standards for development > 1 acre	Encourage LID for development < 1 acre and for existing infrastructure replacement	Revisions to LID guidelines to focus infrastructure on that best suited to improving North Shore water quality	• ENV/DFM
8. Pūpūkea Paumalū Risk Management	Plan available	Conduct individual plans for potential hazards	Implement recommended actions	• NSCLT • USACE • DLNR

Table 5.4 Watershed Management Project Phasing (cont.)

Project	Current Status	Short-Term Actions 1-5 Years	Long-Term Actions 5+ Years	Potential Funding Sources
9. Waimea Valley Conservation Action Plan	Implementation in progress	• Develop a Forestry Stewardship Plan • Continue to increase efforts and efficiency in the control of invasive weeds • Prepare management plans for the High Priority Areas • Increase the hunting effort towards target of 50% ungulate removal • Seek funding for fencing project and staff hires • Continue to strengthen community bonds through workdays and events	Implement actions outlined in the Forestry Stewardship Plan	• OHA • Center for Plant Conserva-tion
10. Koʻolau & Waiʻanae Mountains Watershed Partnerships	• Implemen-tation of KMWP Management Plan • Implemen-tation of WMWP Management Plan	• Expand established fencing exclosures in the Upper Helemano and Upper Kawaiʻiki Drainage • Construct additional watershed resource protection fences • Conduct native forest restoration in priority watershed areas • Continue feral ungulate management • Invasive weed control	Expand native plant and habitat restoration	• US ARMY • NRCS • Private grants
11. Kalo Restoration Projects	• KS recently purchased stream corridor property	• Conduct archaeological research • Identify potential water sources • Identify potential kalo farmers	• Encourage kalo farmers to offer educational programs • Monitor water supply	• CWRM • NRCS • UH CTAHR

Table 5.4 Watershed Management Project Phasing (cont.)

Project	Current Status	Short-Term Actions 1-5 Years	Long-Term Actions 5+ Years	Potential Funding Sources
12. KS Loko Ea Fishpond and ʻUkoʻa Marsh Restoration	KS has partnered with Mālama Loko Ea Foundation and Pono Pacific to oversee restoration of the sites	Continue workdays and other restoration activities	Create a path between Loko Ea and ʻUkoʻa	• DOH • DOFAW • EPA • KS
13. Wahiawā Reservoir Water Quality Improvements	Recent improvements to the Wahiawā WWTP are in a testing phase	Secure funding to route Wahiawā WWPT R-1 water for use on nearby Galbraith lands	Develop storage for system upsets-	• ENV Wastewater Branch • State Legislature • Agriculture Development Corporation
14. Wahiawā Irrigation System Improvements	Repairing the outlet system and replacing current flume diversion system	• Land ownership changes • Reservoir up-grades • Investigate bids and available funds to pipe complete system	• Pipe system completely - no longer an open ditch system • Ongoing improvements	• Hawaiʻi Legislature • Dole
15. Agricultural Water Reliability: Water Storage, Back-up Wells, Stormwater Reclamation	• Reservoirs store water for times of need • Farmers are already practicing water reuse	• Assess reservoirs storage capacity • Explore conjunctive use • Investigate potential storm-water reclama-tion projects	Work with farmers to increase storm-water capture and storage	• DOA • DOLE
16. BWS Conservation Programs	BWS is improving its conservation program plan with new programs, tools and staffing resources	Implement high priority conservation measures	Continue to expand high priority conservation pro-grams throughout Oʻahu	• BWS

5.4 WATERSHED MANAGEMENT – PRIORITY WATERSHEDS AND CATALYST PROJECTS

5.4.1 Criteria Used to Select Priority Watersheds and Catalyst Projects

As part of the NSWMP process, the planning team selected four Priority Watershed "Systems" of Kiʻikiʻi, Paukauila, Anahulu, and Loko Ea *(Figure 5.2).* The Watershed Systems are made up of three to four watersheds based on the major stream systems of the area, as follows: the Kiʻikiʻi System (Poamoho, the North and South Forks of Kaukonahua, and Kiʻikiʻi streams draining into Kaiaka Bay), the Paukauila System (ʻŌpaeʻula, Helemano and Paukauila Streams also draining into Kaiaka Bay), the Anahulu System (Kawaiʻiki, Kawailoa, Kawainui and Anahulu Streams draining into Waialua Bay). The Kiʻikiʻi and Paukauila Systems have many of the same watershed issues, so they are discussed together. The Loko Ea watershed is also included (Loko Ea Stream also draining into Waialua Bay), although it is not a watershed system. The Watershed System boundaries follow the CWRM Water Hydrologic Units.

In line with the five major objectives of the Oʻahu Water Management Plan, "priority watershed" was defined as a watershed that:

- provides various opportunities to promote sustainable watersheds,
- protects or enhances water quality and quantity,
- provides many opportunities to protect Native Hawaiian rights and traditional customary practices,
- presents special opportunities for organizing and implementing important watershed management actions, and/or
- provides significant ground water or surface water supplies to meet current and future demand.

The selection of a Priority Watershed is not meant to diminish the importance of other watersheds in the North Shore district. Rather, the selection of these Priority Watersheds provides an opportunity to develop implementation strategies at a more detailed level. Detailed strategies for other watersheds in the district can be developed as part of the NSWMP in future updates.

For each of the Priority Watersheds, the following material is presented:

- Brief Watershed Profile
- Water Resources Management Issues
- Important Projects and Programs
- Action Agenda for a Catalyst Project: What, Who, Where, How, When

Catalyst Projects are a high priority project within the watershed that, when implemented, will provide guidance, connectivity, collaboration, and drive for other projects and programs within the particular priority watershed – that is, the project can be a catalyst for positive action and change.

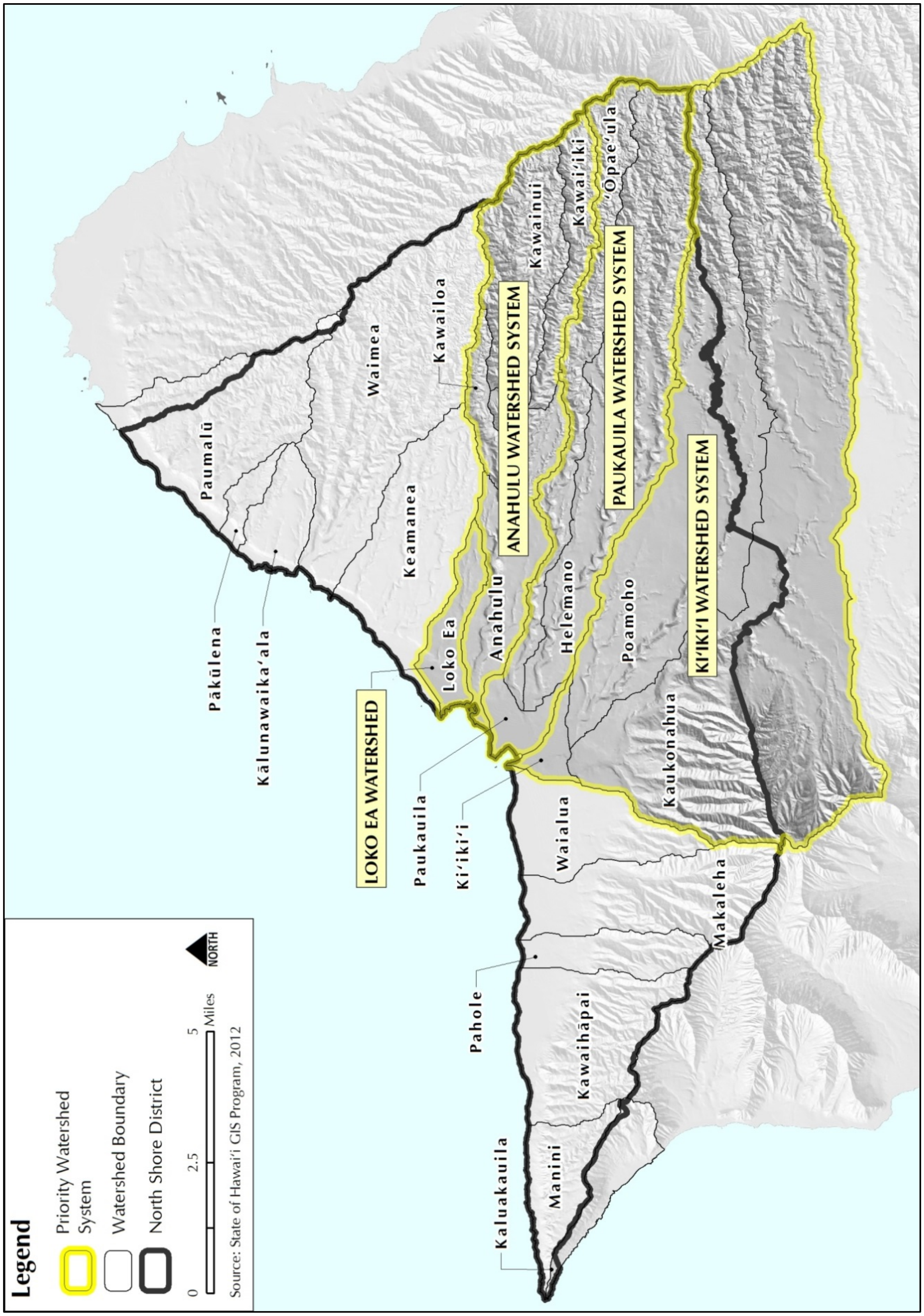

Figure 5.2 North Shore Priority Watershed Systems

5.4.2 Ki'iki'i System - Poamoho, Kaukonahua and Ki'iki'i Watersheds and Paukauila System - 'Ōpae'ula, Helemano and Paukauila Watersheds

The Ki'iki'i and Paukauila Systems *(Figure 5.3)* were selected as priority watersheds because:

- Major portions of the Wahiawā Irrigation Systems' currently irrigated agricultural fields are within the Ki'iki'i and Paukauila Watershed System areas.
- A majority of surface water sources and diversions for agricultural irrigation on the North Shore are within the Paukauila System.
- The Paukauila System overlies the Waialua and Wahiawā aquifers and contains the primary drinking water wells used for supplying the North Shore district. Well permits for the Waialua aquifer have reached their limit and have undergone a permit revocation process to accommodate new permit requests.
- Flooding-prone areas with major populations are located within the Ki'iki'i and Paukauila watersheds.
- Both watershed systems received some of the highest overall North Shore watershed ratings in the *Atlas of Hawaiian Watersheds* (2008) based on watershed area, land cover, annual rainfall, stream reach diversity, total stream length, and extent of estuarine areas.
- In comparison to other watersheds in the North Shore, watersheds within the Ki'iki'i and Paukauila Watershed Systems are ranked among the highest as priorities for restoration due to not meeting, or facing imminent threat of not meeting, water quality standards. These rankings are based on the *Hawai'i Unified Watershed Assessment* (1998) and the *2008/2010 State WQ Monitoring & Assessment* (2012).
- According to *Statewide Assessment of Forest Conditions* (2010), Paukauila watershed is among the most in need of restoration and also has interested and capable stakeholders to develop and implement watershed plans.

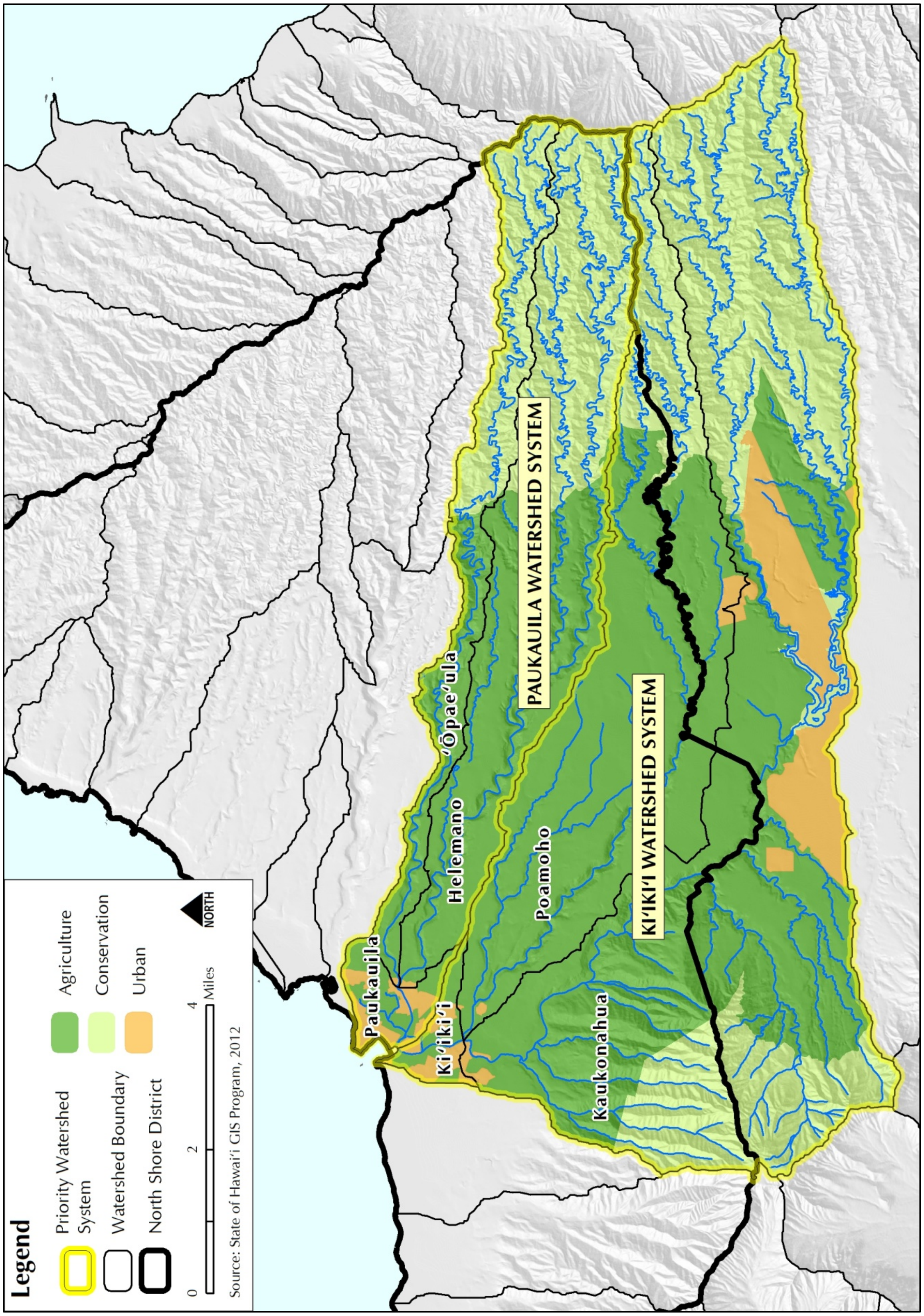

Figure 5.3 Priority Watershed Systems: Ki'iki'ki and Paukauila

5.4.2.1 Brief Watershed Profiles

The 80-square mile Ki'iki'i-Paukauila Stream drainage basin is the largest basin on the Island of O'ahu *(Figure 5.3).* The Ki'iki'i and Paukauila Watershed Systems begin in the Wai'anae Mountains, stretch across the central plain and up into the Ko'olau Mountains. Approximately half of the Ki'iki'i System falls outside of the North Shore Watershed Management Plan district. Ki'iki'i Stream (with tributaries Poamoho and the North and South Forks of Kaukonahua streams) and Paukauila Stream (which includes Helemano and 'Ōpae'ula streams) flow into Kaiaka Bay. Leakage of freshwater through caprock into Ki'iki'i and Paukauila streams and Kaiaka Bay is estimated to be seven mgd.[4]

Kaukonahua, Poamoho, and Helemano streams were once used to irrigate extensive taro fields in the Ki'iki'i and Paukauila Watershed System areas.[1] Today, the waters and tributaries of the Ki'iki'i and Paukauila Watershed Systems are part of the Wahiawā Irrigation System (WIS). Diverted water was used for sugar cane, and now is used for diversified agriculture. The WIS consists of Wahiawā Reservoir, Wahiawā Dam, and an irrigation ditch system extending 30 miles.

Ki'iki'i Stream is a candidate for stream protection and meets Blue Ribbon criteria, according to the HSA (1990). Ki'iki'i Stream was ranked as Moderate in terms of aquatic ecosystem health based on the presence of less than three indicator native species. Kaiaka Bay serves as a critical habitat for endangered marine species and has been shown to contain rich and diverse coralline and microalgae species diversity that are vulnerable to the impacts of streambank erosion.[2]

The land use districts that currently make up the Ki'iki'i and Paukauila Watershed Systems within the North Shore district are comprised of 70% agricultural, 22% conservation, and 2% urban. A majority of this area (60%) is privately owned by Dole Food Inc./Castle & Cook and 21% owned by Kamehameha Schools (KS). 17% of the Ki'iki'i and Paukauila Watershed Systems are designated as the Kawailoa Training Area, leased by the US Army from private landowners.

Areas of the Ki'iki'i and Paukauila Watershed Systems that fall within Kawailoa Training Area are managed by the Army through their *O'ahu Implementation Plan* (2008) and *Integrated Natural Resources Management Plan, 2010-2014, Island of O'ahu* (2010). A partnership of the Army, KS and KMWP is in the process of expanding established fencing exclosures. Large areas of 'Ōhi'a and Koa are found in the Ko'olau Mountains of Ki'iki'i and Paukauila Watershed Systems. This area is also essential habitat for O'ahu Tree Snails, with Threatened or Endangered (T&E) birds, damselflies, and high T&E plant concentrations.

A Total Maximum Daily Load (TMDL) study for the North and South Forks of Kaukonahua was approved by the EPA in 2010. The TMDL priority for Poamoho and Lower Kaukonahua streams is medium, with nutrients and turbidity as the pollutants in excess. The TMDL priority for 'Ōpae'ula, Helemano and Paukauila streams is low, also with nutrients and turbidity as the pollutants in excess. The TMDL priority for Ki'iki'i is also low, with unknown pollutants in excess. Nutrients and turbidity could be caused by erosion, animal wastes, use of fertilizers, and human waste. High levels of stream contaminants will accelerate eutrophication, decrease oxygen in the water, are toxic to fish, and could be of considerable harm to other organisms as well as to humans if ingested.[3]

Flooding is a major issue in Waialua and Haleʻiwa, communities within the Kiʻikiʻi and Paukauila Watershed Systems *(Figure 5.3).* These low-lying areas are vulnerable to flooding due to the watershed's large size and the number of streams and gulches that converge at the shoreline (including Kiʻikiʻi Stream, Paukauila Stream and the Anahulu River). During high-peak discharges, flood waters overtop the streambanks, inundating the low-lying residential and agricultural lands. Modifications to natural drainage patterns (e.g. increased erosion and sedimentation) restrict stream flow and further compound flood hazards in this area. A possible contributor of sedimentation into the streams is land left vacant after sugarcane and pineapple went out of production.[2] In addition, blockage of bridge openings by debris restricts flow, causing flood waters to back up and inundate low-lying areas.

Recently completed or ongoing drainage system studies to address the community's concerns about flooding in the Waialua-Haleʻiwa area include: (1) Haleʻiwa Road Drainage Improvements Engineering Study and (2) Kaukonahua Stream Dredging Study (from Otake Camp to Kaiaka Bay).[2] DLNR has dredged the Paukauila Stream mouth. DLNR is also working with the residents and owners of Kaukonahua Stream to develop a routine maintenance program for clearing channel debris and sediments (including field inspections after a major flood event), and working with landowners to re-vegetate fallow lands. Even with this activity, many residents feel that there have been too many studies and not enough action to alleviate flooding issues.

5.4.2.2 Water Resources Management Issues and Opportunities

Water resource management issues and opportunities for the Kiʻikiʻi and Paukauila Watershed Systems include:

- Irrigation system water losses are unknown but presumed high due to the aging system;
- Drinking water wells have been contaminated with chemicals related to agricultural activities;
- Stream sedimentation is harmful to aquatic life and a contributor to flood conditions.

5.4.2.3 Important Projects and Programs

Chapter 4 of the NSWMP includes descriptions of eight "Projects with Champions" and four "Watershed Management Strategies" that will have an effect on the Kiʻikiʻi and Paukauila Watershed Systems. These projects are:

- Kaukonahua Stream TMDL Implementation (Project #1)
- Measurable Instream Flow Standards (Project #2)
- Potable Wellhead Protection (Project #4)
- Agricultural Best Management Practices (Project #6)
- Low Impact Development Techniques (Project #7)
- Koʻolau and Waiʻanae Mountains Watershed Partnerships (Project #10)
- Wahiawā Reservoir Water Quality Improvements (Project #13)
- Agricultural Water Reliability: Water Storage, Back-up Wells, and Stormwater Reclamation (Project #15)
- Assess Stream Ecosystem Health (Strategy A)

- Implement Kaiaka Bay Watershed Flood Mitigation Projects & Planning (Strategy B)
- Conduct a Dredging Study & Systematic Maintenance of Key Areas (Strategy C)
- Implement Drought Mitigation Strategies (Strategy D)

5.4.2.4 Catalyst Project Action Plan

The two Catalyst Projects are:

- Wahiawā Irrigation System Improvements (Project #14)
- Waialua-Kaiaka Watershed Restoration Study (Project #3)

The first Catalyst Project for the Ki'iki'i and Paukauila Watershed Systems, **Wahiawā Irrigation System (WIS) Improvements**, was selected because:

- 70% of the Ki'iki'i and Paukauila Watershed Systems within the North Shore district are zoned Agriculture.
- Given the needed repairs and mostly open nature of the system, there are considerable water losses in the system even after recent repairs. A minimum of $10 million of work needs to be done to improve the condition of the ditches in the Dole-owned portion of the WIS.
- The expected increases in agriculture on the North Shore will require water for irrigation and reducing the WIS losses will assist in making more water available.

The action plan for **Wahiawā Irrigation System Improvements** can be summarized as follows:

- **WHAT needs to be done:** The *Assessment of the Wahiawā Irrigation System for the State Agribusiness Development Corporation* in 2007 estimated the costs for immediate repairs at approximately $4.2 million, of which Dole has completed approximately $2.1 million, leaving approximately $2.1 million remaining for immediate repair work. Dole is currently in the process of repairing the Wahiawā Dam, Wahiawā Reservoir Outlet Tunnel, Helemano 6 Reservoir Dam, and Kemo'o 5 Reservoir Dam. Given the needed repairs and mostly open nature of the system, there are considerable water losses in the system even after the above repairs. An estimated minimum of $10 million of work needs to be done to improve the condition of the ditches in the Dole-owned portion of the WIS. Additional funds are needed to improve the open ditches to a piped system for lower water losses.

- **WHO needs to take action:** Dole, as the owner of a majority of the system in need of repairs, has and will need to continue maintenance and repairs of the irrigation system. Creation of a WIS Water Users entity could provide a funding conduit for assistance in improving and maintaining the irrigation system.
- **WHERE will planning and implementation take place?** Priority areas include the portions of the ditch closest to the reservoir which carry the greatest flows and therefore have the potential for the greatest losses. Also, areas with slope or other terrain challenges should be prioritized due to potential erosion. The unlined portions of the ditch ultimately need to be piped to reduce system losses.
- **HOW will the planning and implementation work be carried out?** Dole needs to continually assess and prioritize water losses and needed improvements.
- **WHEN will the work take place?** Dole has been completing repairs since 2008, and is currently repairing the outlet system and replacing the current flume diversion system. Reservoir upgrades are expected within the next five years. Available funds will need to be investigated in order to determine the time frame for piping of the complete system.
- **What will be the COST of the planning and implementation?** It is expected that the total cost for needed repairs will be approximately $12.1 million. The cost for piping the system is unknown at this time, although Kamehameha Schools expended more than $10 million in system improvements which included piping the system on their lands.
- **Where will PROJECT FUNDING come from?** A portion of the funding will come from Dole itself. A WIS Water Users entity could be created for obtaining grants and other funding that would not be available to Dole as a single business. Dole will also need to solicit government and other grant funding for improving the Wahiawā Irrigation System. Obtaining funding from the State is challenging; however, legislators have been supportive of past efforts to maintain agriculture operations.

The second Catalyst Project for the Kiʻikiʻi and Paukauila Watershed Systems is the **Waialua-Kaiaka Watershed Restoration Study.** This project was selected because:

- Flooding in the Paukauila and Kiʻikiʻi watersheds occurs frequently, impacts residents and businesses, and is a drain on City, State, and Federal resources.
- There is a lack of holistic hydrologic information for use in planning adequate flood-control measures to reduce and prevent the loss of life and property due to flooding in the Waialua and Haleʻiwa areas.
- A Watershed Restoration Study will identify all water resources problems in the watershed and evaluate possible solutions in a coordinated fashion, including flooding, ecosystem degradation, land use practices, urban development, etc.

The action plan for the **Waialua-Kaiaka Watershed Restoration Study** can be summarized as follows:

- **WHAT needs to be done:** Petition the US Congress to fund the Study in the Energy & Water Appropriation Bill, giving USACE new start authority. Securing legislative funding for flood studies and actions will require community initiative. Once funded, an initial reconnaissance phase study can be developed. If Federal participation is warranted, a feasibility study can then be conducted. The local communities and local governments will then need to seriously pursue structure relocations and flood proofing.
- **WHO needs to take action:** Continued collaboration of responsible agencies is needed to identify and implement measures to alleviate flooding issues. Those agencies that can have a direct influence on flooding issues include the US Congress, USACE, National Flood Insurance Program, ENV, FEMA, NRCS, DLNR Engineering, DPP, DFM, UH Mānoa, North Shore Neighborhood Board #27, and the community.
- **WHERE will planning and implementation take place?** Planning and implementation will occur at those areas within Waialua and Haleʻiwa that are flooded most frequently, as well as areas along the streams that are the cause of downstream flooding. Flooding occurs frequently at locations like Otake Camp, Cane Haul Road, and the Haleʻiwa Shingon Mission.
- **HOW will the planning and implementation work be carried out?** Once funding is approved, the USACE will identify all water resources problems in the watershed and evaluate possible solutions in a coordinated fashion. These include flooding, ecosystem degradation, land use practices, urban development, etc. Implementation projects and programs will be need to be coordinated among USACE, DLNR, and DFM.
- **WHEN will the work take place?** Initial planning work began in 1976. The goal for the short term is to secure appropriation for funding within the next five years. Once this occurs, an initial reconnaissance phase study can take place. If Federal participation is warranted, a feasibility study will determine appropriate flood control measures. It will be up to the local community and local governments to seriously pursue structure relocations and flood proofing.
- **What will be the COST of the planning and implementation?** It is estimated that a USACE initial reconnaissance phase study will cost approximately $300,000, and $3 million for the feasibility study if federal participation is warranted. Implementation project costs will be identified in the feasibility study.
- **Where will PROJECT FUNDING come from?** Initial funding will need to be designated by US Congress with some fiscal sponsorship by a local sponsor, most likely a State of Hawaiʻi agency, in order for USACE to complete the studies.

5.4.3 Anahulu System - Kawaiʻiki, Kawainui, Kawailoa and Anahulu Watersheds

The Anahulu Watershed System *(Figure 5.4)* was selected as a priority watershed because:

- Anahulu River and watershed are part of a known ancient system that provided sustenance to large numbers of Native Hawaiians. The Anahulu waters and tributaries also are part of an existing agricultural irrigation system.
- It received one of the highest overall North Shore watershed ratings in the *Atlas of Hawaiian Watersheds* (2008).
- The Koʻolau Mountains within the Anahulu System are essential habitat for Oʻahu Tree Snails, with high Threatened or Endangered plant concentrations.
- The 1998 *Multi-Attribute Prioritization of Streams Project* listed Anahulu River as fourth in the Potential Diverted Valuable Streams category for Oʻahu. It scored above many of the Potential Heritage Streams for the aquatic resources score; however, because it has stream diversions, it was not considered eligible as a Potential Heritage Stream.
- In comparison to other watersheds in the North Shore, watersheds within the Anahulu Watershed System are ranked among the highest as priorities for restoration due to not meeting, or facing imminent threat of not meeting, water quality standards. These rankings are based on the *Hawaiʻi Unified Watershed Assessment* (1998) and the *2008/2010 State WQ Monitoring & Assessment* (2012).
- According to *Statewide Assessment of Forest Conditions* (2010), Anahulu watershed is among the most in need of restoration on Oʻahu and also has interested and capable stakeholders to develop and implement watershed plans.

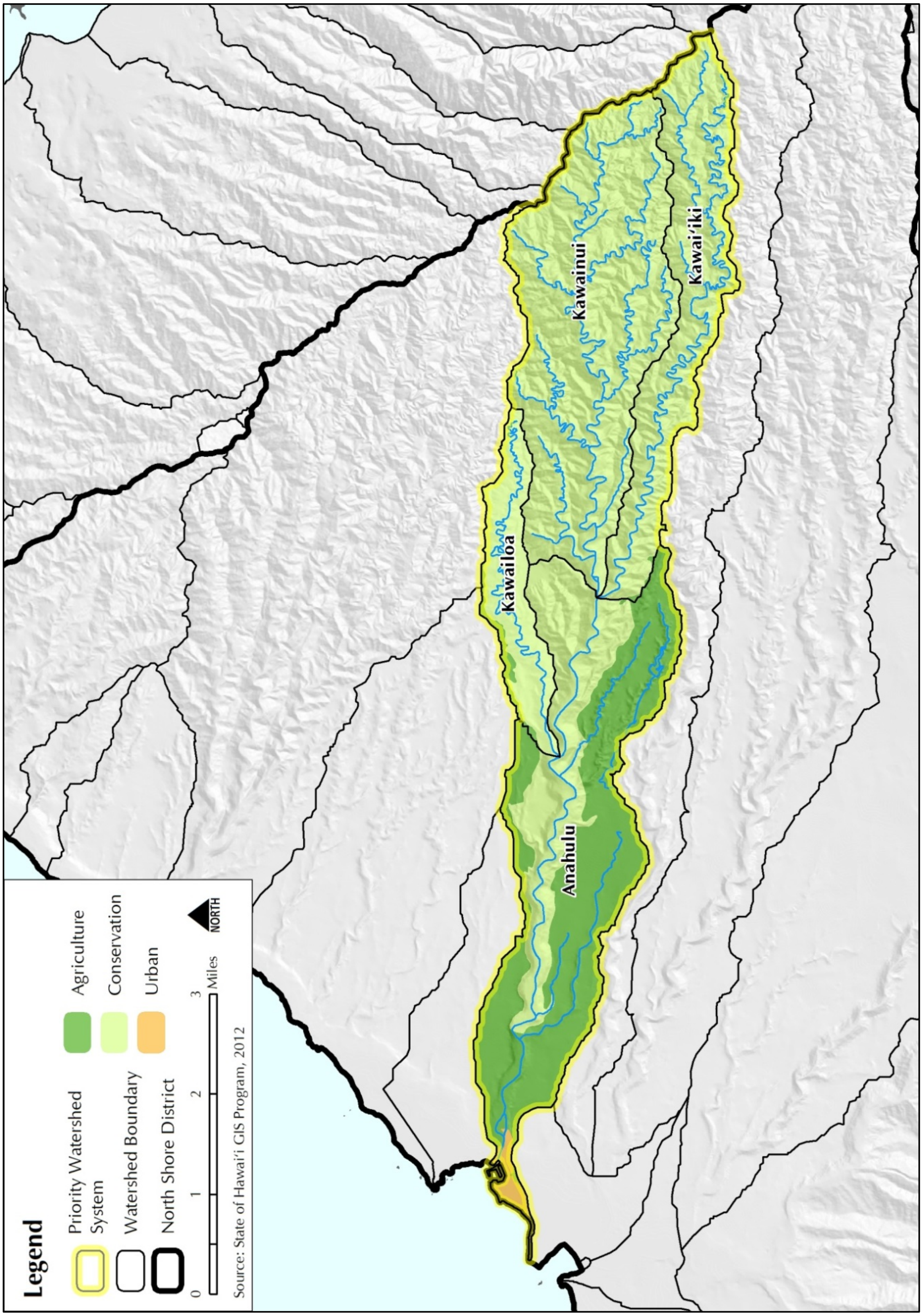

Figure 5.4 Priority Watershed System: Anahulu

5.4.3.1 Brief Watershed Profile

The Anahulu Watershed System is located along the eastern portion of the North Shore district, spanning from Waialua Bay up into the Ko'olau Mountains *(Figure 5.4).* It is bounded to the south by the 'Ōpae'ula and Paukauila watersheds and to the north by the Waimea, Keamanea and Loko Ea watersheds, and has an area of approximately 16 square miles (10,395 acres). The Kawai'iki, Kawainui, Kawailoa and Anahulu Streams (a combined total of approximately 67 miles) drain into Waialua Bay. Freshwater leakage through the caprock into Anahulu River and into the bay is estimated to be 5 mgd.[4] The land use districts that currently make up the Anahulu Watershed System are comprised of 70% conservation, 28% agricultural and 2% urban. A majority of the Anahulu Watershed System is privately owned by Kamehameha Schools (KS), with 63% of the Anahulu Watershed System designated as the Kawailoa Training Area, leased by the US Army.[5]

Anahulu River and watershed are part of a known ancient system that provided sustenance to large numbers of Native Hawaiians. Archaeology has uncovered permanent habitation/ house sites, dry land agricultural sites, and irrigated agricultural systems. The presence of perennial water was a significant factor influencing prehistoric and early historic settlement patterns in the Anahulu Watershed System. Water-borne sediments carried and deposited by alluvial action were deposited at stream meanders, creating alluvial flats and terraces readily amenable to traditional agricultural pursuits, such as taro irrigation.[6]

The Anahulu waters and tributaries are also part of an existing agricultural irrigation system. Diverted water was used for sugar cane, and now is used for diversified agriculture. On agricultural lands of the Anahulu Watershed System, Kamehameha Schools has worked with their agricultural tenants to implement best management practices on their farms. Kamehameha Schools has instituted an irrigation system maintenance and improvement program with substantial upgrades to irrigation infrastructure, stream diversions and wells.

The Anahulu Watershed System is in a fairly natural state. The *Hawai'i Stream Assessment* (HSA, 1990) lists the percent of native forest as 30%. The 1998 *Multi-Attribute Prioritization of Streams Project* (MAPS) listed Anahulu River as fourth in the Potential Diverted Valuable Streams category for O'ahu. Anahulu River contains native species that are considered good indicators of a potentially high quality stream ecosystem, qualifying it as "Substantial" in aquatic resources in the *HSA* (1990). This area of the Ko'olau Mountains is also essential habitat for O'ahu Tree Snails, with Threatened or Endangered (T&E) birds, damselflies, and high T&E plant concentrations.

There are a number of threats to the aquatic environment. The Anahulu River has four introduced stream species that are known to both prey upon native species and compete with them for food and habitat, as well as introduced plants and pigs that are a threat to the Anahulu System riparian resources.

Also, Anahulu River estuary and Kawailoa Stream were listed as a Low TMDL Priority on the 2008/2010 303(d) list for nutrients and turbidity. Anahulu River drains into a wetland estuary and then to Waialua Bay, a Fisheries Management Area. Hawai'i Department of Health (DOH) has designated Waialua Bay as a Water Quality Limited Segment for turbidity. Water Quality Limited Segments do not meet and are considered not likely to meet minimum water quality criteria.[7] The major sources of pollutants discharging into the embayment include sediment from the drainage basins, household cesspools, and injection wells from treatment plants.[8]

5.4.3.2 Water Resources Management Issues and Opportunities

Water resource management issues and opportunities for the Anahulu Watershed System include:

- Ownership is concentrated (Kamehameha Schools);
- Preservation and expansion of kalo farming;
- Development of educational programs and interpretive resources;
- The continued implementation of forest conservation measures among the Kamehameha Schools, US Army and Koʻolau Mountains Watershed Partnership organizations;
- Improving wastewater treatment for those cesspools and wastewater treatment plants near Waialua Bay.

5.4.3.3 Important Projects and Programs

Chapter 4 of the NSWMP includes descriptions of four "Projects with Champions" and three "Watershed Management Strategies" that will have an effect on the Anahulu Watershed System. These projects are:

- Measurable Instream Flow Standards (Project #2)
- Agricultural Best Management Practices (Project #6)
- Koʻolau & Waiʻanae Mountains Watershed Partnerships (Project #10)
- Agricultural Water Reliability: Water Storage, Back-up Wells, Stormwater Reclamation (Project #15)
- Improve Wastewater Treatment (Strategy E)
- Record North Shore Oral History (Strategy K)
- Create North Shore Ahupuaʻa Boundary/Stream Markers (Strategy L)

5.4.3.4 Action Agenda for Catalyst Project

The Catalyst Project for the Anahulu watershed is **Kalo Maintenance and Restoration** (Project #11). This project was selected because:

- North Shore was known for its food abundance, which was attributed in part to the development of extensive acreages of loʻi complexes and development of the numerous fishponds. These resources should be restored and utilized where feasible for future food production and cultural educational programs.
- One likely area for possible kalo expansion is the Kamehameha Schools lands along the Anahulu Stream. The Anahulu Stream corridor or gulch is known for its abundance of post-contact archaeological sites, and part of the lands that produced an abundance of foods for native Hawaiians. Kamehameha Schools recently purchased most of the remaining inholdings so that they have complete ownership of the stream corridor.
- The kalo restoration would support those Native Hawaiian cultural practitioners who can provide the educational aspect of kalo cultivation, coupling labor with education and the art and technology of agriculture.

The action plan for **Kalo Maintenance and Restoration** can be summarized as follows:

- **WHAT needs to be done?** Many of the springs in the makai area are being utilized already for growing kalo or other wetland crops (e.g. lotus root). While there may be some expansion of the spring sources, most expansion will need to be in areas where stream water can be provided. KS will also need to identify and obtain source(s) of funding to develop kalo lands and ensure that water from springs and/or streams is available.
- **WHO needs to take action?** As the landowner, Kamehameha Schools will take the lead in kalo restoration. Support for the project may come from CWRM, existing farmers, US Natural Resources Conservation Service, Farm Bureau, and the University of Hawaiʻi College of Tropical Agriculture and Human Resources.
- **WHERE will planning and implementation take place?** The focus area for Kalo Maintenance and Restoration will be the Anahulu watershed.
- **HOW will the planning and implementation work be carried out?** The following tasks are needed:
  - Conduct archaeological and archival research to understand history of the area and potential cultural sites.
  - Identify potential water sources and request water use as needed. Both springs and stream waters are considered diversions and require coordination with CWRM.
  - Identify potential farmers with skills and interest for available parcels.
  - Encourage the kalo farmers to also offer educational programs along with the farming practices to provide opportunities for learning about and access to native Hawaiian cultural practices.
  - Monitor springs and streams for water supply where they supply loʻi kalo.
- WHEN will the work take place? Within the next five years.
- **What will be the COST of the planning and implementation?** $20,000 annual cost for stream gage installation, maintenance and data collection, and an additional $20,000 annually for data quality check and reporting. Project costs for loʻi restoration projects can start around $100,000.
- **Where will PROJECT FUNDING come from?** Kamehameha Schools will provide a majority of the funding. Clean Water Act 319 funds are potentially available for projects that improve Anahulu Stream water quality. USGS has a program that may potentially fund half of the cost of stream flow gages.

5.4.4 Loko Ea Watershed

The Loko Ea Watershed *(Figure 5.5)* was selected as a priority watershed because:

- ʻUkoʻa Marsh and Loko Ea Fishpond are two important cultural resources within the Loko Ea Watershed that contributed to the abundance and wealth of Waialua being known as ʻāina momoma (fattened land).
- The Hawaiʻi Stream Assessment (1990) considers Loko Ea a "substantial" riparian resource stream due to no detrimental plants or animals, the presence of recovery habitat, a number of threatened and endangered birds, and over 0.5 square miles of wetland.
- The Hawaiʻi Watershed Prioritization Process (2009) ranks the Loko Ea Watershed among the top 50 watersheds in need of restoration.

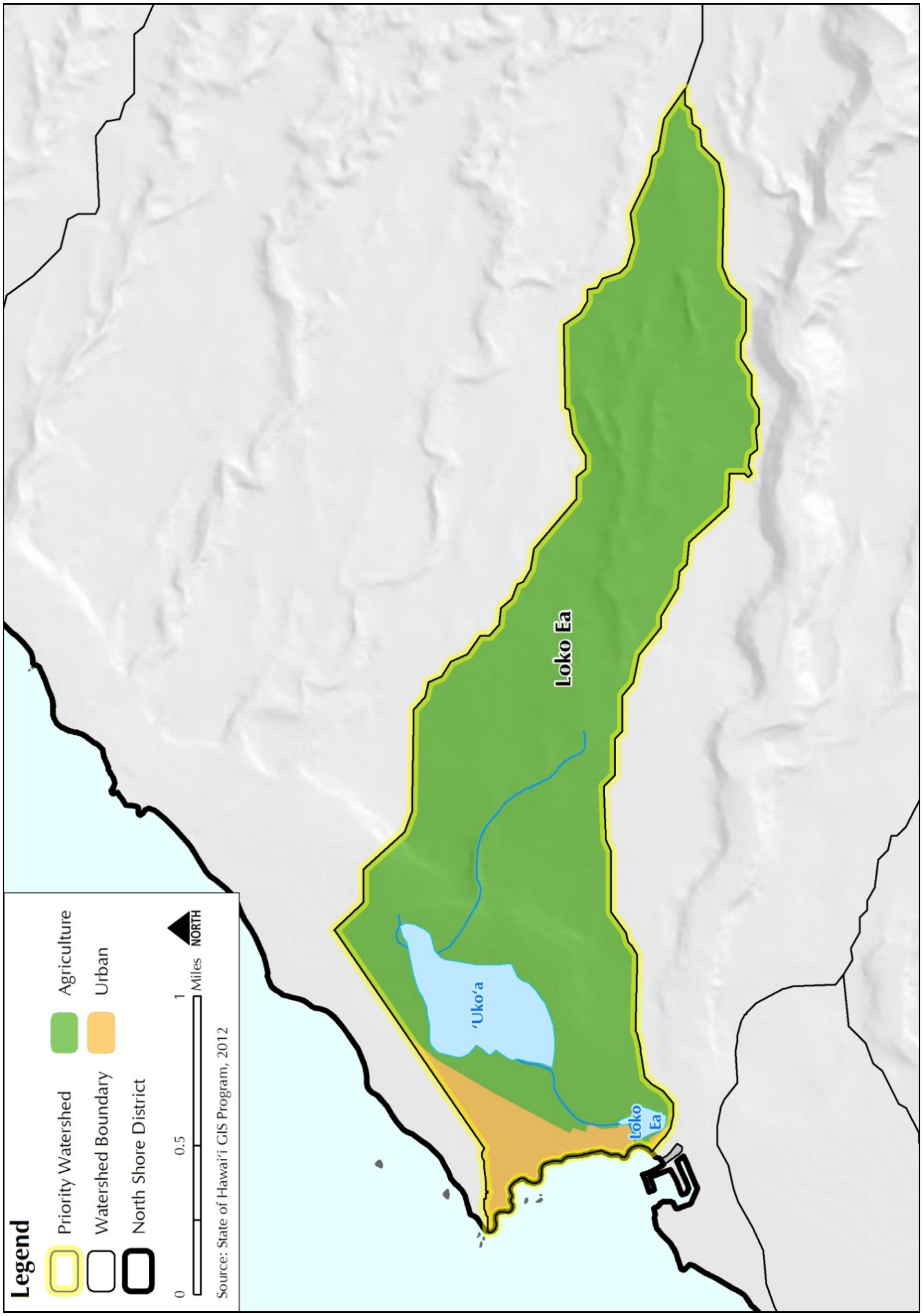

Figure 5.5 Priority Watershed: Loko Ea

5.4.4.1 Brief Watershed Profile

The Loko Ea Watershed is located on the eastern side of Waialua Bay, between the Anahulu and Keamanea watersheds. 88% of the watershed is zoned agriculture with the remaining 12% as urban. The approximately two square mile watershed is drained by Loko Ea stream, which runs through ʻUkoʻa Marsh and Loko Ea fishpond before depositing into Waialua Bay, a Fisheries Management Area. Loko Ea means "rising pond" in Hawaiian.

The Loko Ea Watershed is part of the Kawailoa ahupuaʻa that in pre-contact times was politically important in agricultural and aquacultural production. This was notably due to the extensive taro irrigation complexes and the well-known royal fishponds ʻUkoʻa and Loko Ea.[9]

ʻUkoʻa Marsh and Loko Ea Fishpond are still among the major wetland areas on the North Shore. The approximately 115-acre ʻUkoʻa Marsh is part of a previously much more extensive wetlands area around Kawailoa Road north of Haleʻiwa town and south of the former Kawailoa Landfill.[10] Loko Ea Fishpond is a 10-acre brackish inland pond that used to be connected to ʻUkoʻa via an open water channel extending about one mile south. This channel still exists and some water flow remains during heavy rains, but it is choked with vegetation. Loko Ea is connected to the sea by a short channel and water control gates.

The Loko Ea Watershed is entirely owned by Kamehameha Schools (KS). KS is working with groups such as Pono Pacific, Ducks Unlimited, The Nature Conservancy, and the United States Fish and Wildlife Service (USFWS) to control predators and expand habitat to protect the Hawaiian stilt, Hawaiian duck and the gallinule.[11] Loko Ea fishpond has been under restoration since 2007, and is used for educational purposes. A wetland management plan was completed in 2010 for ʻUkoʻa Marsh. Plans are underway for restoration of both ʻUkoʻa Marsh and Loko Ea Fishpond.

5.4.4.2 Water Resources Management Opportunities and Issues

Water resources management issues and opportunities for Loko Ea include the following:

- The cultural and ecological importance of fishponds and their role in the ahupuaʻa and watershed system have diminished over time;
- KS is sole owner of the watershed and is engaged in both education and restoration initiatives;
- There is potential for restoring increased wetland ecosystem function and habitat for the Hawaiian stilt, Hawaiian duck and the gallinule.

5.4.4.3 Important Projects and Programs

Chapter 4 of the NSWMP includes descriptions of three "Projects with Champions" and six "Watershed Management Strategies" that will have an effect on the Loko Ea Watershed. These projects are:

- Measurable Instream Flow Standards (Project #2)
- Agricultural Best Management Practices (Project #6)
- Kalo Maintenance and Restoration (Project #11)

- Surface Water Management Strategies (Strategy A)
- Implement Drought Mitigation Strategies (Strategy D)
- Improve Wastewater Treatment (Strategy E)
- Promote Pollution Prevention Awareness and Education (Strategy J)
- Record North Shore Oral History (Strategy K)
- Create North Shore Ahupuaʻa Boundary/Stream Markers (Strategy L)

5.4.4.4 Action Agenda for Catalyst Project

The Catalyst Project for Loko Ea is **Kamehameha Schools Loko Ea Fishpond and ʻUkoʻa Marsh Restoration** (Project #12). This project was selected because:

- Historically fishponds provided not only food, but also had important ecological functions such as buffering the effects of flooding.

The action plan restoring the ʻUkoʻa Marsh and Loko Ea Fishpond could involve the following elements:

- **WHAT needs to be done?** Continued conservation/wetland management of ʻUkoʻa Marsh to restore ecosystem functionality, including: invasive species control, predator control, litter prevention, and possible silt dredging. Continued restoration and educational components for Loko Ea Fishpond include: fishpond work days, educational programs, development of a preservation plan to guide future efforts at the fishpond to restore the fishpond and increase its productivity, and assessment of water quality issues and needed mitigation measures. An opportunity for a path between Loko Ea and ʻUkoʻa Marsh is also being researched by Kamehameha Schools.
- **WHO needs to take action?** Kamehameha Schools and their lessees Pono Pacific and Mālama Loko Ea Foundation.
- **WHERE will the project be located?** Within and surrounding ʻUkoʻa Marsh and Loko Ea Fishpond.
- **HOW will the planning and implementation work be carried out?** The projects are managed by Pono Pacific and Mālama Loko Ea Foundation.
- WHEN will the work take place? Ongoing.
- What will be the COST of the planning and implementation? More than $500,000 for the efforts at both locations.
- **Where will PROJECT FUNDING come from?** Kamehameha Schools and grants obtained by and through KS lessees, Mālama Loko Ea and Pono Pacific.

5.5 IMPLEMENTATION AND FUNDING: SOURCES AND STRATEGIES

This section includes a discussion of **implementing entities** and **dedicated funding source for watershed projects and programs**. This material is preliminary in nature, and is intended to stimulate discussion and debate on how best to provide significant resources for implementing management projects and strategies for priority watersheds throughout the State of Hawai'i.

5.5.1 Implementing Entities – Public and Private Sectors

The implementation of the many elements of the NSWMP will depend on the future availability of resources – expertise, manpower, organization, and funding – from both the public and private sectors. A number of public agencies and private non-profit organizations have been named in this plan as possible implementers of specific projects and programs. These agencies and organizations include the following:

Public Agencies

Federal

- Department of Housing and Urban Development (HUD)
- Environmental Protection Agency (EPA)
  - Wetland Program Development Grants
- Federal Emergency Management Agency (FEMA)
  - National Flood Insurance Program
- Federal Highway Administration (FHWA)
- Federal Recovery Lands Acquisition Program
- Marine Corps Base Hawai'i (MCBH)
- National Oceanic and Atmospheric Agency (NOAA)
- National Science Foundation (NSF)
- National Trust for Historic Preservation (NTHP)
  - National Trust Preservation Fund
- US Army
  - Army Compatible Use Buffers Program
- US Army Corps of Engineers (USACE)
- US Army Garrison Hawai'i (USAG-HI)
- US Army National Guard (USANG)
- US Coast Guard
- US Congress
- US Department of Agriculture (USDA)
  - Farm Service Agency
    - Conservation Reserve Enhancement Program
  - Natural Resource Conservation Service (NRCS)
    - Conservation Innovation Grants Program
    - Environmental Quality Incentives Program
  - Wildlife Habitat Incentives Program

- US Fish and Wildlife Service (USFWS)
    - Partners for Fish and Wildlife
    - Pacific Islands Coastal Program
- US Geological Survey
- US Navy
    - Construction Battalion

State

- Board of Land and Natural Resources (BLNR)
- Commission on Water Resource Management (CWRM)
- Department of Agriculture (DOA)
    - Agribusiness Development Corporation (ADC)
- Department of Education
- Department of Health (DOH)
    - Clean Water Branch (CWB)
        - Clean Water Act Section 319 Grants
    - Environmental Planning Office (EPO)
    - Stormwater Quality Branch
- Department of Land and Natural Resources (DLNR)
    - Bureau of Conveyances (BOC)
    - Department of Aquatic Resources (DAR)
    - Division of Conservation and Resource Enforcement (DOCARE)
    - Division of Forestry and Wildlife (DOFAW)
        - Hawai‘i Forest Stewardship Program
        - Hawai‘i Forest Legacy
        - Hawai‘i Legacy Land Conservation Program
        - Natural Areas Partnership
        - Safe Harbor Agreements and Habitat Conservation Plans
        - Urban and Community Forestry – Kaulunani
    - Division of State Parks
    - Engineering Division
    - State Historic Preservation Division (SHPD)
    - West O‘ahu Soil and Water Conservation District (WOSWCD)
- Department of Transportation (DOT)
- Hawai‘i Legacy Lands Fund
- Hawai‘i State Legislature
    - Hawai‘i Tourism Authority (HTA)
    - Land Use Commission (LUC)
    - Natural Area Reserves (NARS) Commission
    - Office of Conservation and Coastal Lands (OCCL)
- Office of Hawaiian Affairs (OHA)
- Office of Planning (OP)
    - Coastal Zone Management (CZM)
    - Marine and Coastal Zone Advocacy Council (MACZAC)
- University of Hawai‘i at Mānoa
    - Center for Hawaiian Studies
    - Center for Island Climate Adaptation and Policy (ICAP)
    - Center for Oral History

  - o College of Tropical Agriculture and Human Resources (CTAHR)
  - o Cooperative Extension Service
  - o Cooperative Fishery Unit
  - o School of Ocean and Earth Science and Technology (SOEST)
  - o Sea Grant Program
  - o Water Resources Research Center (WRRC)

<u>City</u>

- Department of Design and Construction (DDC)
- Department of Environmental Management (ENV)
  - o Storm Water Quality Branch
  - o Wastewater Branch
- Department of Facilities Maintenance (DFM)
- Department of Parks and Recreation (DPR)
- Department of Planning and Permitting (DPP)
- Department of Transportation Services (DTS)
- Honolulu Board of Water Supply (BWS)
- Honolulu Fire Department (HFD)
- Honolulu Police Department (HPD)
- North Shore Neighborhood Board #27

Private/Non-Profit Organizations

- Center for Plant Conservation
- Dillingham Ranch ʻĀina, LLC (DRA)
  - o North Shore Water Company (NSWC)
- Dole Foods, Inc.
- Hawaiʻi Farm Bureau Federation
- Hui Mālama o Pūpūkea-Waimea
- Kamehameha Schools
- Koʻolau Mountains Watershed Partnership
- Mālama Loko Ea Foundation
- North Shore Chamber of Commerce
- North Shore Community Land Trust (NSCLT)
- Oʻahu Invasive Species Committee (OISC)
- Oʻahu Resource Conservation and Development Council (ORC&D)
- Pacific Islands Climate Change Cooperative (PICCC)
- Pacific Islands Regional Climate Assessment (PIRCA)
- Pacific Regional Integrated Sciences and Assessments (Pacific RISA)
- Pono Pacific
- Waialua Hawaiian Civic Club
- Waiʻanae Mountains Watershed Partnership
- Waimea Valley

Many of the above-listed public agencies have one or more funding programs that could provide funds for water supply and/or watershed management projects. Private non-profit entities like the Hawaiʻi Community Foundation are also possible significant sources of funds for environmental improvement projects.

5.5.2 Dedicated Funding Source(s) for Watershed Management Projects

The NSWMP provides policies, objectives, project descriptions and general strategies that collectively serve to guide future water resources management in the district.

City and State agencies are not solely responsible for implementing the NSWMP. CIP appropriations, Federal and private foundation grants, and the work of volunteers and non-profit organizations will all be needed to implement important elements of the Plan.

There has been some discussion over the years among advocates of good watershed management on the need for a "dedicated funding source" for important watershed projects – i.e., a funding source that would provide a fairly regular and significant revenue stream year after year.

$2.5 million was released in 2012 for capital improvement projects for forest protection in Hawaiʻi Island, Maui and Kauaʻi under Governor Neil Abercrombie's "New Day Plan". The 2013 state budget bill also significantly increased funding for forest protection throughout Hawaiʻi. The state budget includes $3.5 million in general funds and $5 million in general obligation bond funding in fiscal year 2014 for watershed protection, as well as an additional $2.5 million in bonds in fiscal year 2015. The budget also includes funds for additional positions for natural resource managers and planners for on-the-ground forest protection projects; $750,000 in both FY14 and FY15 for the Hawaiʻi Invasive Species Council (HISC); and $3.5 million in the fiscal biennium to protect Hawaiʻi's largest remaining tract of dryland forest, located in the Kaʻu district.

In 2014, the Hawaiʻi State Senate passed SB2511, which establishes a watershed initiatives program in DLNR. This program is meant to plan, monitor, and execute watershed protection initiatives to stabilize Hawaiʻi's water sources by doubling the acreage of protected watershed forests by 2021. SB2062 was also passed, which appropriates $1 million in fiscal year 2014-2015 for the identification, establishment, and management of natural area reserves.

In July 2015 Governor David Ige signed into law a bill that authorizes a tax credit of up to $10,000 for conversion of cesspools located within 200 feet from a shore, perennial stream or wetland, or within a source water assessment area. Eligible properties in the North Shore with cesspools should be encouraged to convert or upgrade.

There has also been some public discussion on tapping other sources for watershed management action projects, including:

- a percentage of the annual proceeds from the state's real estate conveyance tax
- a percentage of the Transient Accommodations Tax
- the establishment of "Drainage Districts" funded through special real property tax assessments
- "Watershed Fees" paid by large federal, state, county or private water systems.

The fundamental issue for these funding concepts is: "who benefits and who pays?"

Some of these concepts for continued funding were explored during the 2013-2014 Legislative Session, but many have since been eliminated. One proposed bill with promise redirected one cent of every beverage container deposit in excess of running the program to the natural area reserve fund for expenditure on watershed programs.

The proposed strategies and projects within this plan are the result of a comprehensive watershed analysis and stakeholder consultation process. The projects may involve various governmental agencies and non-governmental organizations. The implementation and funding of these projects are not the sole responsibility of the Board of Water Supply, City and County of Honolulu, or State of Hawai'i. This Plan is intended to guide agencies and organizations in implementing the most important initiatives for North Shore watersheds and water resources; however, implementation will depend on budgetary priorities, the availability of grants, and partnering efforts over the long term.

5.5.3 Implementation Challenges and Barriers

Implementation of complex plans like the NSWMP faces many barriers and challenges, including:

- Limited legal and jurisdictional authority of the many public agencies that need to be involved in implementing elements of the plan;
- Institutional barriers and a resulting need for increased inter-agency and inter-governmental coordination for more meaningful watershed management actions;
- Lack of land control for most of the non-profit organizations that are champions for specific resource management and ecosystem restoration projects;
- Limitations of funding from both public and private funding sources;
- Need for more information and awareness within the community about the complex interaction of land and water resources and land and water uses.

These challenges will not be overcome within the next 5 or 10 or even 20 years. However, there is a growing awareness among public agencies, elected officials, educators, and the general public of the critical importance of learning how to be good stewards of our precious land and water resources. Fresh water resources are limited by the rains that fall on island and careful stewardship of land and water resources is essential for a sustainable Hawai'i.

ENDNOTES

1 Bruner, Ph.D., Phil, 2008. *Archaeological Inventory Survey of an Approximately 75-Acre Portion of the Proposed 861-Acre Dillingham Ranch Development Project, Waialua District, Island of O'ahu, Subdivision, Mokulē'ia, O'ahu.* Cultural Surveys Hawai'i.

2 Department of Land and Natural Resources. 2003. *North Shore Paukauila Streambank Erosion and Riparian Area Community Project: Annual Report to the Twenty-Second Legislature Regular Session of 2004.* Prepared in response to Senate Concurrent Resolution 223, Senate Draft 1, Regular Session of 1995.

3 Yost, Russell. 2008. *Demonstrating Watershed Participatory Assessment and Action, Appendix B9. Results of Soil and Water Sampling by Yost, Russell, et. al.* Demonstrating Watershed Participatory Assessment and Action.

4 Office of State Planning, Hawai'i Coastal Zone Management Program. 1996. *Hawai'i's Coastal Nonpoint Pollution Control Program.*

5 Hawai'i Division of Aquatic Resources and Bishop Museum. 2008. *Hawai'i Watershed Atlas.* Available URL: http://hawaiiwatershedatlas.com/index.html {Accessed March 20, 2014]

6 Dega, M. F. and Kirch, P.V. 2002. *A Modified Culture History of Anahulu Valley, O'ahu, Hawai'i and its Significance for Hawaiian Prehistory.* The Journal of the Polynesian Society, Volume 111, No. 2.

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8 Hawai'i Department of Business, Economic Development and Tourism's Office of Planning – Coastal Zone Management and Hawai'i Department of Health's Clean Water Branch Polluted Runoff Control Program. 2000. *Hawai'i's Implementation Plan for Polluted Runoff Control.*

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10 The Pacific Coast Joint Venture, 2006. *Strategic Plan for Wetland Conservation in Hawai'i.* Prepared by Adonia R. Henry.

11 City and County of Honolulu Department of Design and Construction. 2002. *Final Environmental Assessment Haleiwa Regional Park Skateboard Facility.* Prepared by Bryce E. Uyehara A.I.A., Inc. and Gerald Park Urban Planner.

Oahu Water Management Plan Framework And Scope of Work for Wai`anae, Ko`olauloa and Ko`olaupoko Watershed Management Plans

Submitted to the State Commission on Water Resource Management in Compliance with the Statewide Framework for Updating the Hawaii Water Plan, Oahu County Water Use and Development Plan.

Attachment to BWS Transmittal Letter to CWRM, Dated February 20, 2004.

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OWMP Framework Summary

The OWMP consists of policies and strategies, which guide the activities of the City and County of Honolulu and advises the State Commission on Water Resource Management (CWRM) in the areas of planning, management, water development and use and allocation of Oahu's natural water resources. The OWMP framework proposes regional plans entitled "watershed management plans" and shall be consistent with the following:

1. State Water Resource Protection Plan, State Water Quality Plan, State Water Projects Plan, State Agricultural Water Use and Development Plan and Department of Hawaiian Home Lands water plans as listed in Chapter 174C-31, Hawaii Water Plan, State Water Code.
2. The Statewide Framework for Updating the Hawaii Water Plan (Statewide Framework)
3. The General Plan for the City and County of Honolulu. The General Plan is a comprehensive statement of objectives and policies, which sets forth the long range aspirations of Oahu's residents and the strategies of actions to achieve them. It is the focal point of a comprehensive planning process that addresses physical, social, economic and environmental concerns affecting Oahu. This planning process serves as the coordinative means by which the City provides for the future growth of the metropolitan area of Honolulu. http://dev.honoluludpp.org/Planning/GeneralPlan.aspx
4. 8 Development Plan (DP) and Sustainable Community Plan (SCP) land use planning regions of Oahu. Each community oriented land use plan is intended to help guide public policy, investment, and decision making over the next 20 years. Each plan responds to specific conditions and community values of each region. Ewa and Primary Urban Center are "development plan" areas where growth and supporting facilities will be directed and be the policy guide for development decisions and actions needed to support that growth. The remaining 6 land use areas are "sustainable communities" plans, which are envisioned as relatively stable regions in which public programs will focus on supporting existing populations. The following table lists the 8 land use planning reports with links.

Oahu's Land Use Planning Regions	**Web Page Links to the Plans**
Waianae	http://dev.honoluludpp.org/Planning/DevelopmentSustainableCommunitiesPlans/WaianaePlan.aspx
Ko`olauloa	http://dev.honoluludpp.org/Planning/DevelopmentSustainableCommunitiesPlans/KoolauloaPlan.aspx
Ko`olaupoko	http://dev.honoluludpp.org/Planning/DevelopmentSustainableCommunitiesPlans/KoolaupokoPlan.aspx
North Shore	http://dev.honoluludpp.org/Planning/DevelopmentSustainableCommunitiesPlans/NorthShorePlan.aspx
Ewa	http://dev.honoluludpp.org/Planning/DevelopmentSustainableCommunitiesPlans/EwaPlan.aspx

Oahu's Land Use Planning Regions	Web Page Links to the Plans (Continued)
Central Oahu	http://dev.honoluludpp.org/Planning/DevelopmentSustainableCommunitiesPlans/CentralOahuPlan.aspx
East Honolulu	http://dev.honoluludpp.org/Planning/DevelopmentSustainableCommunitiesPlans/EastHonoluluPlan.aspx
Primary Urban Center	http://dev.honoluludpp.org/Planning/DevelopmentSustainableCommunitiesPlans/PrimaryUrbanCenter.aspx

5. City and County of Honolulu Ordinance 90-62, Water Management establishing the Oahu Water Management Plan establishing water management policies and strategies "for water use and development within each development plan area."
6. Annual Report to the Twenty-First Legislature 2001 Regular Session on Act 152, SLH 2000, Relating to Watershed Protection. The annual report set forth the development of a watershed master plan, including identifying protected watersheds areas, enhancement projects and an implementation plan.
7. Supreme Court Decision on Waiahole Ditch Contested Case applying the Public Trust Doctrine and the Precautionary Principle to water resource management.
8. BWS Sustainability Vision and Mission of "Water for Life" to enhance the quality of life of our community by providing world-class water services. Protecting the environment and supporting Oahu's economy while involving the community achieve BWS goals of sustainable water supplies for future generations. BWS accomplishes these goals with our watershed protection and water conservation partnership programs and diversifying our water supplies, both natural and alternative technologies, such as recycled water, seawater desalination and ocean resource development.

<u>Background:</u>

The Commission in 1990 formally adopted the initial Hawaii Water Plan, prepared by various state and county agencies. Further updates in 1992 were deferred pending additional refinement of plan components. In 1994, the City and County of Honolulu began their initial revision to the Oahu Water Management Plan. The draft OWMP update was completed in January 1998 and is the most current reference document. However, it was not submitted for adoption because Oahu's water situation was in a state of flux, with major changes in the agriculture industry, including the closing of the Oahu Sugar Company and the Waialua Sugar Company.

In 1999, the Honolulu Board of Water Supply (BWS) initiated the integrated resource planning process to update the Oahu Water Management Plan, Oahu's County Water Use and Development Plan. The integrated islandwide water planning effort was met with significant opposition, which surfaced in our public participation process. After almost two years of effort, we did not move beyond the public participation process and so before we started the water planning stage, we decided to stop and re-evaluate our approach. We summarize the main lessons learned as follows:

1. It is important to have equal focus on resource protection, conservation and restoration as on water use and development. There needs to be a reassurance that our natural resources are protected and our water supplies are sustainable before planning on water use and development can successfully occur.
2. It is important to elevate the community's knowledge about water related issues so the interested community can actively participate in a community-based planning process. It is equally important that the planning document is written so that it is easily understood.
3. The islandwide integrated approach elevated community concerns on growth limits and regional water transport. The integrated approach is more complex on Oahu because approximately ¾'s of Oahu's water systems are interconnected. The communities needed assurance that there were sufficient water resources within their watersheds before islandwide regional water needs were discussed.

In February 2000, CWRM adopted a framework for updating the Hawaii Water Plan to provide focus and additional guidance to each agency responsible for updating specific plan components. CWRM recognized the complexities in addressing water resource planning and views the plans as "living documents which over several plan iterations will result in a truly comprehensive water plan" (Statewide Framework page 1-2)

In August 2000,the Hawaii Supreme Court's decision on the Waiahole Ditch Contested Case, and the remand hearings, provided additional guidance for water resources planning, like the precautionary principle. In addition, three public trust uses of water were identified; domestic use, instream use and water for traditional and cultural practices. Commercial and agricultural water uses are in a lower category.

In 2001, BWS broadened its mission to "Water for Life", which strives for sustainability of all water supplies and to enhance the quality of life of our community by providing world-class water services.

The 2000 Act 152 Watershed Protection required the development of a watershed protection master plan that identified priority watersheds and protection projects for implementation. Act 152 renewed BWS investment in watershed protection recognizing the importance of watersheds for the sustainability of our groundwater supplies and streams. To date, about $1 million has been invested by BWS into Oahu's watersheds and aquifers. Noteworthy watershed protection projects are as follows:

- Ka`ala Bog Fencing to prevent feral animals from destroying the Mt. Ka`ala native habitat.
- Grant to the Oahu Invasive Species Committee to control invasive plant species within the Ko`olau watersheds
- Ala Wai Mauka Restoration Project for the Ko`olau Mountain Watershed Partnership
- BWS and Kamehameha Schools funded a USGS study to assess the hydrological and biological features and also funded the Punalu`u Agricultural Lands and Irrigation System Assessment to help set the in-stream flow standard for Punalu`u Stream.
- Waihe`e Valley Make a Difference Day invasive species removal
- Malama O Manoa "Kuleana Project" to change the residential practices of the Manoa Ahupua`a to increase awareness of water conservation and polluted runoff control.
- Watershed protection studies in Ala Wai, West Honolulu and Central Oahu.
- Ka`ala Farms and Mohala I Ka Wai educational awareness program
- Makaha Valley Restoration project
- Wai`anae and Ko`olauloa Watershed Management Plans

From 2001 to the present, several mountain and urban watershed partnerships have been established among BWS, agencies, organizations and community groups. Together, these partnerships have identified watershed protection projects and plans have been developed and funded. The following partnerships have been developed:

- Ko`olau Mountain Watershed Partnership
- Mohala I Ka Wai in Wai`anae
- Punalu`u Watershed Partnership
- Waihe`e Ahupua`a Initiative
- Ahupua`a Restoration Council of He`eia
- Malama O Manoa
- Wai`anae Kai Watershed Partnership
- University of Hawaii Manoa / BWS Water Conservation Partnership
- Hawaiian Electric Co. / BWS Energy and Water Conservation Partnership

Watershed Planning Approach:

The OWMP Framework proposes individual planning documents referred to as regional watershed management plans, which collectively will be the Oahu Water Management Plan. The regional watershed management plans will address the water needs, both present and future, for the 8 land use districts on Oahu. Rather than an islandwide approach brought down to each watershed, the watershed planning approach will start from the basic planning unit, each watershed or "ahupua`a" and expand it to the region or "moku". It is important that this watershed management plan allow equal focus on resource protection, conservation and restoration as well as on water use and development. The watershed approach is supported by the following references:

- The planning regions will be consistent with and support each of the 8 DP/SCP land use planning regions established in the General Plan. The State Water Code, Chapter 174C-31(b)(2), requires that "Each water use and development plan shall be consistent with the respective county land use plans and policies, including general plan and zoning".
- The Statewide Framework for Updating the Hawaii Water Plan, Page 3-26, Need for Flexibility, recognizes the need for appropriate flexibility in the county plans due to institutional and /or funding constraints, to encourage innovation as well as to accommodate unique and county-specific concerns.
- The Statewide Framework Page 3-19 also requires the preparation of "**regional plans** for water development including recommended and alternative plans, costs, adequacy of plans and relationship to water resource protection and quality plan." (Emphasis added).

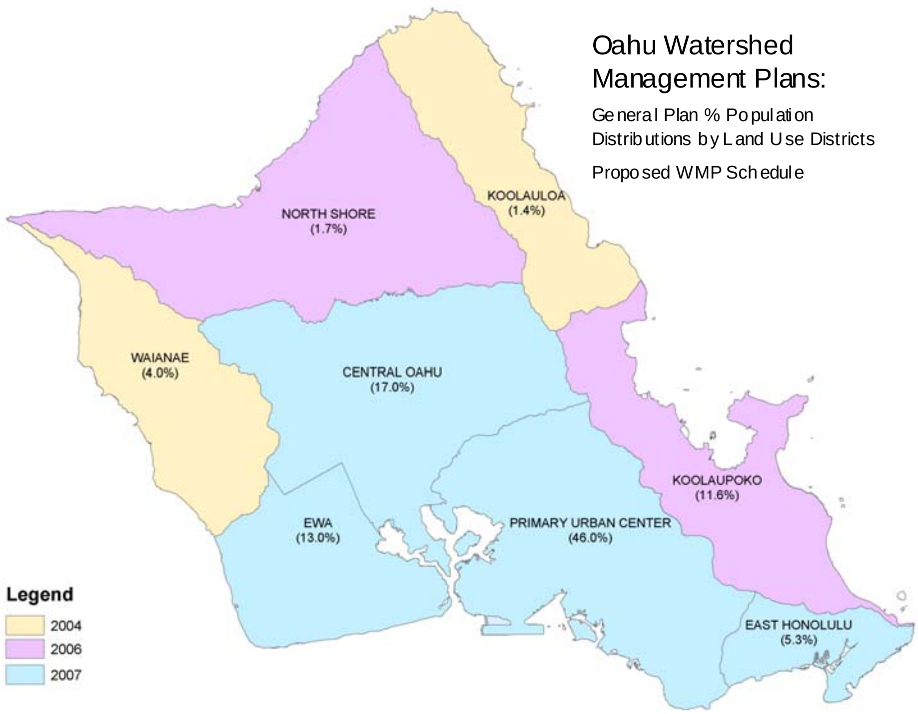
The watershed management plans will have the following key themes:

- Community-Based: In addition to public meetings, there will be many small group meetings with the community to educate, understand and apply the community's thinking and values about water resources. A wide-range of community meetings will be conducted including regional organizations such as Mohala I Ka Wai, Malama Ohana and the Neighborhood Boards, to local councils and associations, down to key individual meetings. The BWS watershed partnerships will be asked to provide representation for the community and key stakeholder groups.
- Environmentally Holistic: The watershed approach from mountains to the coral reefs recognizes the inter-dependence of water and land. The watershed management planning approach will not only address water use and development in the urban and agricultural zoned lands, but also describe protection strategies and enhancement projects for the forest reserves, conservation districts, streams and near-shore waters.
- Action-Oriented: The plan will describe specific watershed protection projects as well as natural and alternative water supply facilities that can be implemented by federal, state and city agencies and programs. The projects will be presented in a budgetary level format with information specific enough to support grant funding requests or an agency's capital improvement program.
- Alignment with State and County Water and Land Use Policies as stated above.
- Reflects Ahupua`a Management Principles: The watershed management plans will incorporate Ahupua`a principles in the plans. The community's help will be needed to identify their thinking and values about water. Living with Ahupua`a values and protocols is

very important to culturally intact communities, like Wai`anae and Ko`olauloa. Ahupua`a principles are not major factors in all districts, such as the urban metropolitan districts, however, these principles can still be used to guide water resource planning.

Proposed Schedule of Funding and Plan Approval:

The Oahu graphic below, shows the 8 land use areas on Oahu and the proposed funding schedule for the watershed management plans.



The following table lists the proposed funding schedules and anticipated target dates for submittal to CWRM for plan approval. The approval dates are based on an 18-month planning time frame and are only estimates and therefore subject to change.

Watershed Planning Areas	**BWS Funding Schedule Fiscal Year**	**Target Dates for Submittal to CWRM for Plan Approval**
Wai`anae, Ko`olauloa	FY 2004	1st Qtr FY 2006
North Shore, Ko`olaupoko	FY 2006	2nd Qtr FY 2007
South Oahu: (Ewa, Central Oahu, Primary Urban Center, East Honolulu)	FY 2007	2nd Qtr FY 2008

* BWS Fiscal Year is July 1 to June 30.

The four-year funding schedule is proposed due to the following reasons:

1. The Statewide Framework recognizes that implementation of the requirements and recommendations will need to be phased over the next several years and possibly over successive iterations of the updating process for the Hawaii Water Plan. (Statewide Framework Implementation Plan, Page 4-1)
2. BWS budgetary and staffing constraints.
3. As this watershed approach is new and unique, we are proposing an 18-month planning process to develop a baseline format and obtain the necessary approvals.
4. Wai`anae, Ko`olauloa, North Shore and Ko`olaupoko are designated as low growth, sustainable communities in the General Plan. The water demand projections for these areas show only marginal water demand increases through the planning horizon, currently 2025.
5. BWS is participating in active watershed partnerships in the Wai`anae and Ko`olauloa areas among others and these partnerships could assist in the public participation process.
6. South Oahu will be funded after the 4 rural districts for the following reasons:
    - To allow time for progress on the Section IV Framework Implementation Plan; Phase I Framework Adoption and Initial Updates to Hawaii Water Plan components, Phase II Development and Funding of New Framework Initiatives and Phase III Component Integration Phase of the Statewide Framework.
    - To allow time to complete the on-going products of the CWRM led Pearl Harbor Monitoring Group as part of the Milestone Framework for the Revised Pearl Harbor Sustainable Yields. Since 1998, BWS has funded over $4 million for the construction of deep monitor wells throughout Oahu and have committed staffing resources for the monitoring of these wells on a quarterly basis. These wells will be essential in the groundwater monitoring and modeling efforts currently underway to increase our understanding of the groundwater supply in the Pearl Harbor and Honolulu aquifers.
    - To allow time to complete the Board of Water Supply's 3-dimensional groundwater model of the Honolulu aquifers.
    - To allow time to incorporate state projects water demands and agricultural water needs. We understand that the State Water Projects Plan was recently completed and the State Agricultural Water Use and Development plan is now underway.
    - The watershed management plans for South Oahu will be funded in the same fiscal year and may be combined into a single plan to more easily address the integration of water resources.

    In calendar year 2000, South Oahu consumed about 78% of the islandwide municipal source pumpage of 154.6 mgd. We anticipate that the South Oahu watershed management plan(s) will fully utilize the IRP decision tools as described in the Statewide Framework for Updating the Hawaii Water Plan. The scope of work contemplated for the South Oahu regional watershed plan(s) will provide for compiling and developing water demand projections for domestic, commercial, industrial, agricultural, and nonpotable uses of municipal, state, federal and private water systems. It will also include assessment of environmental factors as part of the project objectives and evaluation criteria to be developed for the purpose of evaluating resource options and water management strategies.

Commitment for Agency Coordination:

As each watershed management plan moves forward and in addition to the public participation process, we anticipate several staff meetings with CWRM, City Department of Planning & Permitting and BWS to update our planning progress and obtain feedback and guidance. At key milestones, as coordinated with CWRM staff, we will present updates to the CWRM, tentatively mid-way through the planning process, after the public review draft is available, during plan approval and as otherwise requested by the CWRM. A schedule will be developed.

Each watershed management plan will be submitted for approval as separate documents, closely supporting each respective DP/SCP land use plan. At the completion of the first iteration of all planning regions, there will be a consolidating process to provide an islandwide perspective and to resolve any remaining inter-regional issues.

Proposed Scope of Work, Major Project Elements:

As each planning region is funded, their scopes of work will be submitted to the CWRM for review and approval. The proposed scopes of work for the Wai`anae and Ko`olauloa sustainable community plan areas are being submitted for CWRM review and approval (see attached). The draft scopes and planning approach were discussed with some of the community leaders and organizations in Wai`anae and Ko`olaupoko, and their feedback incorporated. The major project elements for the FY 2004 watershed management plans for Wai`anae and Ko`olauloa are:

1. Project Organization
2. Preliminary Watershed Analysis
3. Preliminary Stakeholders Consultations
4. Preliminary Watershed Management Strategies
5. 5-year Watershed Action Plan
6. Water Use and Development Plan
7. Draft Report
8. Final Report
9. Watershed Management Plan Approval

Summary of Current Water Distribution:

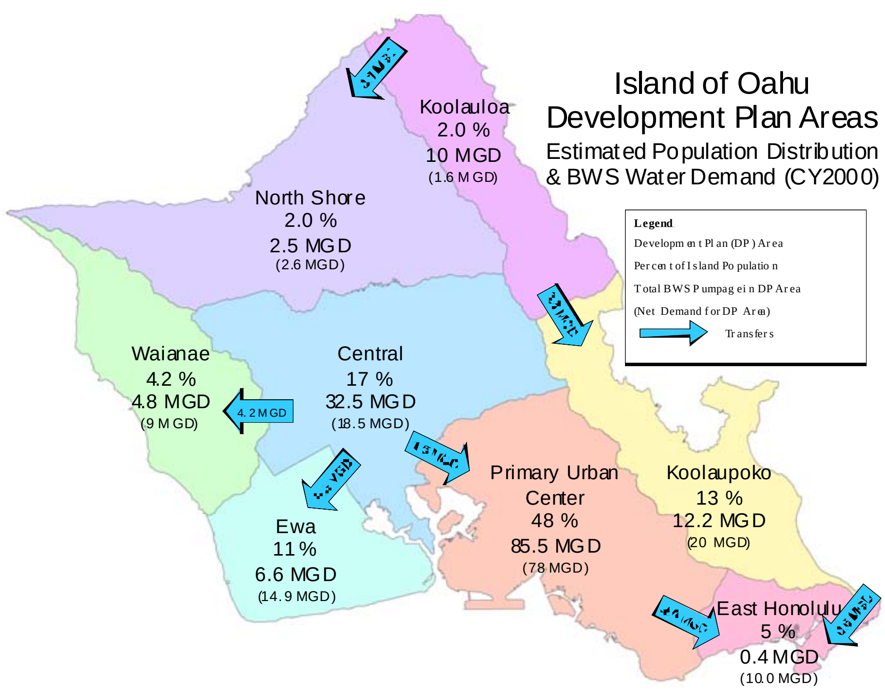
As part of the process of initiating the update of the OWMP and consistent with the guidelines set forth in the Statewide Framework for Updating the Hawaii Water Plan, we have compiled information on existing and projected water demands and sources of supply for the municipal system. BWS has evaluated the adequacy of the supply to meet the potable and nonpotable needs through ground water and recycled water sources. Water demand will be met with existing and funded source projects beyond the estimated 5-year planning period during the completion of all of the regional watershed management plans for Oahu.

The sustainable communities of Wai`anae, North Shore, Ko`olauloa and Ko`olaupoko have essentially the same water demand throughout the planning period. The existing sources and infrastructure in these areas are adequate to provide potable water service through the planning horizon and therefore, additional integration of water supplies between these regions will be limited.

In South Oahu, the water supplies, both natural and alternative, will be fully integrated and described in a future scope of work that once funded in FY 2007, will be submitted to CWRM for their review and approval. The following summarizes the main land use and water planning highlights in South Oahu.

- The City's General Plan directs the majority of the growth to South Oahu.
- Based on the City's growth forecast evaluating population, visitors, housing and employment factors, we forecast an increase in potable water demand for Oahu averaging about 1.1 million gallons per day per year, most of which will occur in South Oahu. In 5 years the BWS system demand is expected to increase by about 5.5 mgd, from 156 mgd in 2003 to 161.5 in 2008. New sources in the Waipahu-Waiawa Water Management Area, as identified in the City DP and SCP land use plans, will be able to provide adequate water supply.
- In addition, in that time period, recycled water facilities in Ewa and Central Oahu will be expanded to continue to off-set additional groundwater development.
    - In 2000, BWS acquired and now operates the 12 mgd Honouliuli Water Recycling Facility supplying irrigation and industrial process water for Ewa.
    - BWS has also funded the design of a delivery system to utilize approximately 3.0 mgd of Wahiawa recycled water in Central Oahu.
- The Kalaeloa seawater desalination plant is currently under design and will bring an additional 5.0 mgd of potable water supply to the second city of Kapolei.

For your information, a summary of Oahu's estimated population distribution based on the 2000 census, BWS potable water demand in calendar year 2000 and water distribution is provided among the 8 land use regions. The is essentially the base case of existing water demand and distribution in the BWS system, which will referenced in the watershed management plans.



B PLANS, POLICIES, GUIDELINES, AND CONTROLS

B.1 OVERVIEW
B.2 FEDERAL PLANS AND CONTROLS
B.3 STATE OF HAWAIʻI PLANS AND CONTROLS
B.4 WATER RIGHTS IN HAWAIʻI
B.5 THE PUBLIC TRUST DOCTRINE AND THE PRECAUTIONARY PRINCIPLE
B.6 CITY AND COUNTY OF HONOLULU PLANS AND CONTROLS
B.7 PUBLIC/PRIVATE PARTNERSHIPS
B.8 REFERENCES

B.1 OVERVIEW

The development of the Honolulu Board of Water Supply's Watershed Management Plans (WMPs) is guided by various Federal, State, and County statutes, ordinances, plans, and controls with specific policies regarding the use and management of water. The critical water policies have been outlined in this section to ensure compliance with and adherence to the broader context under which this plan falls. The framework for developing the WMPs is provided by:

- State Water Code
- Statewide Framework for Updating the Hawaiʻi Water Plan
- Oʻahu Water Management Plan Framework
- Act 44: An Act to Provide for the Encouragement and Protection of Agriculture, Horticulture, and Forestry
- Act 152: Relating to Watershed Protection, 2000 and the Annual Report to the Twenty-First Legislature 2001 Regular Session on Act 152.

Additionally, the O'ahu Watershed Management Plan strives for consistency with:

- Federal Clean Water Act and Safe Drinking Water Act
- All of the Hawai'i Water Plan components
- Department of Hawaiian Home Lands (DHHL) water plans as listed in the Hawai'i Revised Statutes (HRS) Chapter 174C-31
- Hawai'i State Plan
- General Plan for City and County of Honolulu
- County Development Plan/Sustainable Communities Plans
- City and County of Honolulu Ordinance Chapter 30: Water Management
- Supreme Court Decision on Waiāhole Ditch Contested Case applying the Public Trust Doctrine and Precautionary Principle
- BWS Sustainability Vision and Mission of "Water for Life."

This section is not meant to be a summary of these guidance documents, but a characterization of the Major policy objectives that form the framework for the development of the WWMP. For more detailed information, the reader is directed to the original documents.

B.2 FEDERAL PLANS AND CONTROLS

Federal policy documents generally refer to the quality of recreational and drinking waters in order to protect the health and safety of users.

B.2.1 Clean Water Act (CWA) of 1977, Amended 1987

The Clean Water Act (CWA) is the common name for the 1977 legislative amendment to the Federal Water Pollution Control Act Amendments of 1972. The objective of the CWA is *"to restore and maintain the chemical, physical, and biological integrity of the Nation's waters"* so they can support *"the protection and propagation of fish, shellfish, and wildlife and… recreation in and on the water."*[1] It provides the basic structure for regulating pollutant discharges to waters of the United States and sets water quality standards for all contaminants in surface waters. The CWA employs a variety of regulatory and non-regulatory tools to significantly reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff.

The CWA requires states to prepare and submit a 303(d) List of Impaired Waters every two years. This list includes waterbodies not expected to meet state water quality standards, even after application of technology-based effluent limitations to the U.S. Environmental Protection Agency (EPA). States are required to determine the level of impairment for that waterbody based on all existing and readily available surface water quality data and related information.[2]

B.2.2 Safe Drinking Water Act (SDWA) of 1974, Amended 1996

Enacted in 1974, the purpose of the Safe Drinking Water Act (SDWA) is to protect public health by regulating the nation's public drinking water supply. Amended in 1996, the SDWA recognized the provisions of source water protection, operator training, funding for water system improvements, and public information as critical components to safe drinking water. The following are important programs as authorized by the SDWA:

- National standards for drinking water. Determined by EPA, these standards ensure consistent national water quality by setting enforceable maximum contaminant levels, which are the maximum permissible levels of a particular drinking water contaminant in a public water system.
- State source water assessment program. The Hawai'i Source Water Assessment Program (SWAP) is the first step in the development of a comprehensive drinking water source protection program. The SWAP requires delineation of the area around a drinking water source within which contaminants might filter through to that supply source. The SWAP requires an inventory of activities that might lead to the release of microbiological or chemical contaminants in the area. The Hawai'i SWAP report is currently under agency review.

B.3 STATE OF HAWAIʻI PLANS AND CONTROLS

State water policy goals generally seek to protect, conserve, and manage the resource in such a way as to maintain its quality and availability for future generations.

B.3.1 Constitution of the State of Hawaiʻi

Article XI, Section 1 (Conservation, Control and Development of Resources) of the State Constitution mandates the State and its political subdivisions to conserve and protect its natural resources, including water. The State is to promote development and utilization of water in a manner that conserves and sustains the resource. As with all public resources, water is held in trust by the State for the benefit of the people.[3]

Article XI, Section 7 (Water Resources) expresses the State's obligation to *"protect, control and regulate the use of Hawaiʻi's water resources for the benefit of its people."* It also mandates the establishment of a water resources agency that *"shall set overall water conservation, quality and use policies; define beneficial and reasonable uses; protect ground and surface water resources, watersheds and natural stream environments; establish criteria for water use priorities while assuring appurtenant rights and existing correlative and riparian uses and establish procedures for regulating all uses of Hawaiʻi's water resources."*[4]

B.3.2 Hawaiʻi State Plan

It is the goal of the State, under the Hawaiʻi State Planning Act (HRS, Chapter 226), to achieve: a) a strong and viable economy; b) a desired physical environment; and c) physical, social, and economic well-being for its people. The objectives and policies of the State Plan that are pertinent to the development of the Watershed Management Plans are discussed below:

B.3.2.1 Physical Environment: Land-Based, Shoreline, and Marine Resources

It is the objective of the State to make prudent use of Hawaiʻi's land-based, shoreline, and marine resources and to protect unique and fragile environmental resources. It is the policy of the State to consider multiple uses in watersheds, provided such uses do not detrimentally affect water quality and recharge functions.[5]

B.3.2.2 Physical Environment: Land, Air, and Water Quality

It is the objective of the State to maintain and pursue an improved quality of land, air, and water resources and to promote greater public awareness of Hawaiʻi's environmental resources. In support of this, it is the policy of the State to:

- Promote the proper management of Hawaiʻi's land and water resources
- Promote effective measures to achieve desired quality in Hawaiʻi's surface, ground, and coastal waters
- Foster recognition of the importance and value of land, air, and water resources to Hawaiʻi's people, their culture, and visitors.[6]

B.3.2.3 Facility Systems: Water

It is the objective of the State to adequately accommodate domestic, agricultural, commercial, industrial, recreational, and other needs within resource capacities. It is the policy of the State to:

- Coordinate the development of land use activities with existing and potential water supply.
- Support research and development of alternative methods to meet future water requirements well in advance of anticipated needs.
- Reclaim and encourage the productive use of runoff water and water discharges.
- Assist in improving the quality, efficiency, service, and storage capabilities of water systems for domestic and agricultural use.
- Support water supply services to areas experiencing critical water problems.
- Promote water conservation programs or practices in government, private industry, and the general public to help ensure adequate water to meet long-term needs.[7]

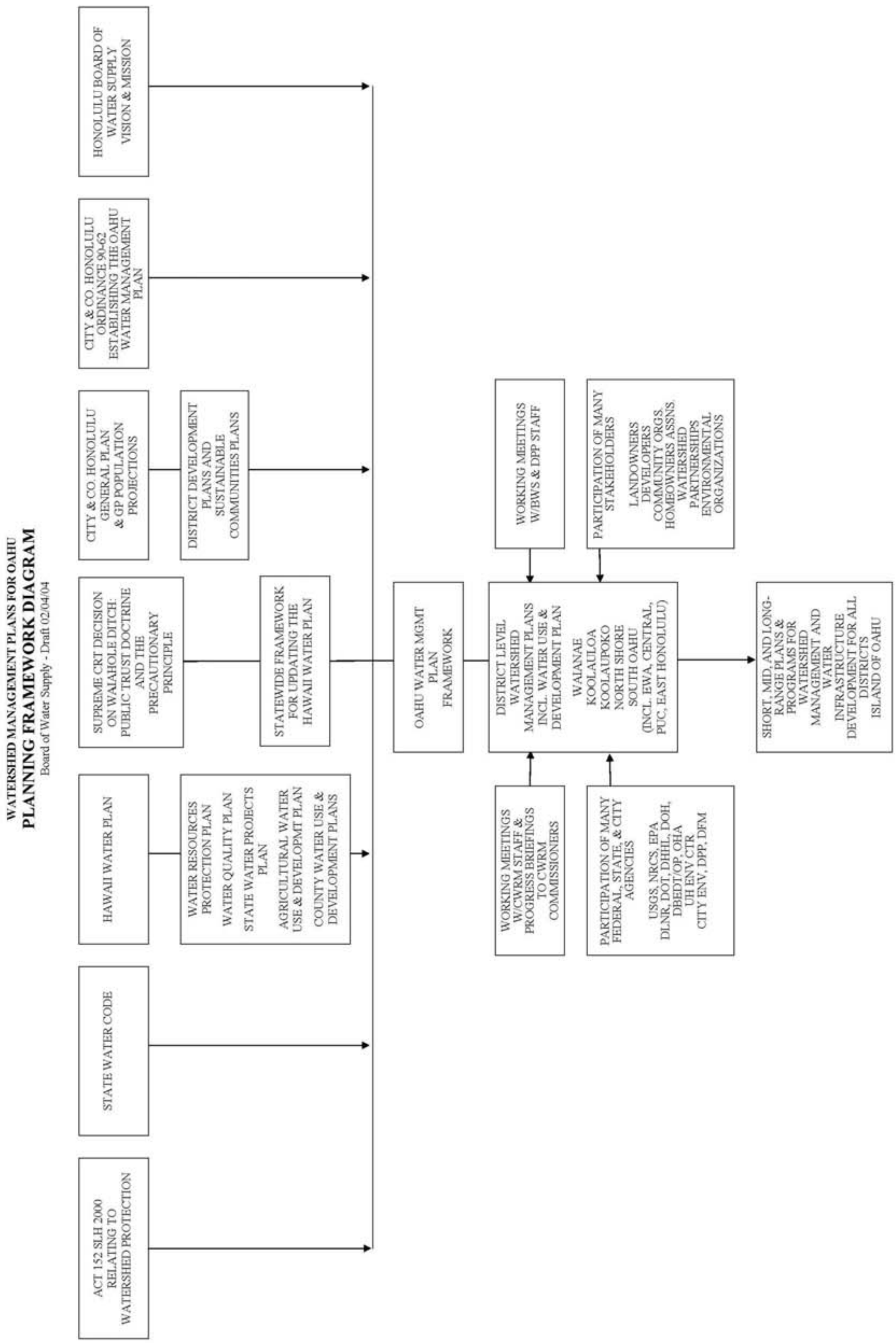


Figure B.1 O'ahu Watershed Management Plan Framework Diagram

B.3.3 State Water Code

The State Water Code (Code) was enacted in 1987 as HRS Chapter 174C by the State Legislature to protect and manage Hawai'i's surface and ground water resources. The Code recognizes five general policies regarding water:

- Waters of the State are held for the benefit of the citizens of the State, who have a right to have the waters protected for their use.
- The Hawai'i Water Plan is the guide for developing and implementing a program of comprehensive water resources planning to address the problems of supply and conservation of water.
- The Code shall be liberally interpreted to obtain maximum beneficial use of the waters of the State for purposes such as domestic, aquaculture, irrigation and other agricultural, power development, and commercial and industrial uses. However, adequate provision shall be made for the protection of traditional and customary Hawaiian rights, the protection and procreation of fish and wildlife, the maintenance of proper ecological balance and scenic beauty, and the preservation and enhancement of water of the State for municipal uses, public recreation, public water supply, agriculture, and navigation.
- The Code *"shall be liberally interpreted to protect and improve the quality of waters of the State… The people of Hawai'i have an absolute interest in the prevention, abatement, and control of both new and existing water pollution and in the maintenance of high standards of water quality."*
- The State Water Code shall be liberally interpreted and applied to conform to the intentions and plans of the counties in terms of land use planning.[8]

The Commission on Water Resource Management (Commission) was created within the State Department of Land and Natural Resources to administer the State Water Code. The Commission is responsible for the protection and management of water resources through appropriate measures such as setting policies, defining uses, establishing priorities while assuring rights and uses, and establishing regulatory procedures. The Commission has jurisdiction over land-based surface water and ground water resources, but not coastal waters. The protection and management of these water resources is carried out through resource assessments, planning, and regulation. Generally, the Commission is responsible for addressing water quantity issues, while water quality issues are under the purview of the State Department of Health.[9]

B.3.4 Hawaiʻi Water Plan

The State Water Code also mandates the development of the Hawaiʻi Water Plan (HWP), whose process is to be guided by the Commission. The HWP objectives include: (1) obtaining maximum reasonable beneficial use of water; (2) proper conservation and development of the waters of the State; (3) control of the waters of the State for such public purposes as navigation, drainage, sanitation, and flood control; (4) attainment of adequate water quality as expressed in the water resource protection and water quality plans; and (5) implementation of the Code's water resource policies.

The Hawaiʻi Water Plan originally consisted of four parts: the Water Resource Protection Plan (WRPP), the Water Use and Development Plans (WUDP) for each county, the State Water Projects Plan (SWPP), and the Water Quality Plan (WQP). An Agricultural Water Use and Development Plan (AWUDP) was added through Act 101 by the 1998 State Legislature.

As of June 2015, the status of the HWP components was as reflected in the following table:

Hawaiʻi Water Plan Components	Official Document	Status
Water Quality Plan (WQP)	June 1990	Update in progress
State Water Projects Plan (SWPP)	February 2003	Oʻahu update in progress
Water Resource Protection Plan (WRPP)	June 2008	Update in progress
Agricultural Water Use and Development Plan (AWUDP)	December 2004	Update in progress
Hawaiʻi WUDP	August 2010	Update completed
Kauaʻi WUDP	1990	Update in progress
Maui/Lānaʻi/Molokaʻi WUDP	1990	Update in progress
Oʻahu WUDP	1990	
• Koʻolau Loa	August 2009	Update completed
• Waiʻanae	August 2009	Update completed
• Koʻolau Poko	September 2012	Update completed
• North Shore		Update in progress
• ʻEwa		Update in progress
• Central Oʻahu		Update in progress
• East Honolulu		Awaiting funding
• Primary Urban Center		Awaiting funding

Specific requirements that the Code established for the county WUDPs include discussion of the status of water and related land development, future land uses and related water needs, and regional plans for water developments.[10] The WUDPs must also be consistent with the WRPP, WQP, county land use plans and policies (including General Plans and Zoning), and State land use classification and policies.[10]

B.3.5 Statewide Framework for Updating the Hawai'i Water Plan

The Code calls for coordination between the Commission and other State and County agencies to formulate an integrated and coordinated program to develop and update the Hawai'i Water Plan (HWP). To effectively implement these requirements, the Commission established a Statewide Framework in February 2000 to incorporate the techniques of Integrated Resources Planning.

The Statewide Framework established that the intent of the County WUDP was to ensure that future water needs of the County are met and to provide guidance to the Commission for decision- making on water uses and water reservation requests. Evaluation of the current HWP components, including the County WUDPs, noted several areas of improvement and planning complexities that need to be addressed. Implications of the Statewide Framework to the WUDPs are as follows:[11]

- Establish a focus that promotes the welfare of the resource, unrestricted by jurisdictional responsibility.
- Avoid unrealistic simplification of complex water availability and allocation scenarios.
- Address competing uses within the overall planning context.
- Address a range of future water demand projection scenarios, taking into account impact to the physical, environmental or other socioeconomic costs of the strategies, and plan for uncertainties.
- Integrated planning is needed to address competition for available resources.
- Greater sophistication is necessary in planning for future water resource development, especially for the uncertain agriculture, military, urban land development, and tourism industries.
- Public involvement and education is a necessary component of the plan process.
- Closer monitoring and implementation of management strategies to protect the aquifer from over-withdrawal are necessary.
- Management strategies should consider the full range of development options, including balancing various source developments with non-structural options and articulate decision- making criteria.
- Recognize and plan for water requirements for all legally protected water rights.

The Statewide Framework recommended plan elements that should be included in the WUDP updates. These elements are:[12]

- Submission of a County-Specific WUDP Project Description
- Coordination with the Commission
- Stakeholder and Public Involvement
- County Public Participation Process
- Objectives and Criteria
- Consistency with the WRPP
- Current and Future Demand Forecast
- Water System Profiles
- Resource and Facility Options
- Strategies Development and Evaluation

- Flexible Sequence of Supply, Infrastructure, Storage, and Conservation Program Additions Needed
- Uncertainties
- Final Strategy Selection
- Modeling Tools
- Implementation Plan
- Underlying Assumptions
- Flexibility
- County-Specific Project Descriptions
- Priorities and Objectives
- County IRP Scope
- WUDP Schedule

B.3.6 State Watershed Protection and Management Program, Act 44 (1903) and Act 152 (2000)

During the expansion of the sugar and cattle industries in the late 1800s in Hawai'i, it was recognized that in order to ensure a steady supply of abundant water, legislation was needed to promote stronger conservation measures for Hawai'i's forests. On April 25, 1903, Act 44, An Act to Provide for the Encouragement and Protection of Agriculture, Horticulture and Forestry, was passed by the Territorial Legislature, thereby creating Hawai'i's forest reserve system and the basis for public-private partnerships to protect these resources.

Since the enactment of Act 44, *"public and private investment in watershed protection and management has increasingly diminished and, once again, our forested watersheds are steadily degrading."*[13] Act 152, Relating to Watershed Protection, passed in 2000, recognized that *"Hawai'i's forests function as critical watersheds and are the primary source of fresh water for the islands… have evolved into efficient ecosystems that capture and store appreciably more water than any other natural milieu… [and] are vital recharge areas for Hawai'i's underground aquifers and a dependable source of clean water for its streams."*[13] It therefore called for the development of a Watershed Protection Master Plan to provide for the protection, preservation, and enhancement of important watershed areas.

The Annual Report to the Twenty-First Legislature 2001 Regular Session on Act 152 was prepared by the watershed protection board created by Act 152. This annual report contains some policies that are specific to particular areas. Therefore, each Watershed Management Plan should refer back to this report to identify any policy or reference that specifically applies to the appropriate Development Plan or Sustainable Communities Plan area. Key points of the 2001 Annual Report that pertain specifically to North Shore include:

- A recommendation that forested watersheds that are important for recharge should be a priority as they affect the water sources for agricultural, industrial, and domestic use.[14]
- The Ko'olau forests are a primary water resource for the island of O'ahu with an estimated sustained yield of over 133 billion gallons of water each year and are a habitat for several thousand native species and natural communities.[15]
- The Ko'olau Mountains Watershed Partnership, consisting of major landowners within the watershed and associated non-landowner interests, is a valuable asset in the holistic, sustainable management of the watershed.[16]

B.4 WATER RIGHTS IN HAWAI'I

Water rights and uses in Hawai'i are governed by the State Water Code[17] and the common law. The Water Code preserved appurtenant rights but not correlative and riparian rights in designated water management areas. Thus, when a ground water management area is designated, existing correlative uses within that area can be issued water use permits under the existing use provisions of the Water Code, but unexercised correlative rights are extinguished. Similarly, when a surface water management area is designated, existing riparian uses within that area are eligible for water use permits as existing uses, but unexercised riparian rights are extinguished. Furthermore, the Hawai'i Supreme Court has ruled that when there is an undisputed direct interrelationship between the surface and ground waters, designation of a ground water management area subjects both ground and surface water diversions from the designated area to the statutory permit requirement.[18] Presumably, permits would also be required for ground and surface water diversions when the interrelationship occurs in a surface water management area.

While water use permits are required only in designated water management areas and the common law on water rights and uses continue to apply in non-designated areas, other provisions of the Water Code apply throughout the state. Thus, for example, well construction and pump installation permits are required for any new or modified ground water use and stream diversion and stream alteration permits are required for any new or modified surface water diversions. If the proposed stream diversion will affect the existing instream flow standard, a successful petition to amend the interim instream flow standard is also required.

B.4.1 Correlative Rights

Under the common law, owners of land overlying a ground water source have the right to use that water on the overlying land as long as the use is reasonable and does not injure the rights of other overlying landholders.[19] When the amount of water is insufficient for all, each is limited to a reasonable share of the ground water. Overlying landowners who have not exercised their correlative rights cannot prevent other landowners from using the water on the theory that they are using more than their reasonable share. They must suffer actual, not potential, harm. Only when landowners try to exercise their correlative rights and the remaining water is insufficient to meet their needs, can they take action to require existing users to reduce their uses.

B.4.2 Riparian Rights

Riparian rights are rights of land adjoining natural watercourses and are the surface water equivalent of correlative rights to ground waters; i.e., the use has to be on the riparian lands, the use has to be reasonable, and the exercise of those rights cannot actually harm the reasonable use of those waters by other riparian landowners. The Court had originally stated that the right was to the natural flow of the stream without substantial diminution and in the shape and size given it by nature,[20] but later concluded that the right should evolve in accordance with changing needs and circumstances. Thus, in order to maintain an action against a diversion which diminishes the quantity or flow of a natural watercourse, riparian owners must demonstrate actual harm to their own reasonable use of those waters.[21]

B.4.3 Appurtenant Rights

Appurtenant water rights are rights to the use of surface water utilized by (non-riparian) parcels of land at the time of their original conversion into fee simple lands; i.e., when land allotted by the Mahele was confirmed to awardees 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.[22] 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.[23] Once established, future uses are not limited to the cultivation of traditional products approximating those utilized at the time of the Mahele,[24] as long as those uses are reasonable, and if in a water management area, meets the 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 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.

B.4.4 Extinguishing Riparian or Appurtenant Rights

Unlike appurtenant rights, which are based in the common law, the Court has interpreted riparian rights as originating in an 1850 statute.[25] This has led to a curious inconsistency in that, while unexercised appurtenant rights are preserved and unexercised riparian rights are extinguished in designated water management areas, actions by private individuals can extinguish appurtenant but not riparian rights. Both appurtenant and riparian rights cannot be severed from the lands they are attached to, and such rights pass with the title to the land whether or not the rights are expressly mentioned in the deed. If the transferor of the land attempts to reserve the riparian right in the deed, the reservation is not valid and the right nevertheless belongs to the transferee as the new owner of the land. The law with regards to appurtenant rights is not clear. The Court in Reppun held that where a landowner attempted to reserve an appurtenant right while selling the underlying land, the reservation is not valid and the attempt to reserve extinguishes the appurtenant right. In doing so, the Court reasoned that there is nothing to prevent a transferor from effectively providing that the benefit of the appurtenant right not be passed to the transferee.[26] This difference is due to the Court's interpretation that riparian rights had been created by the 1850 statute, so any attempt by the grantor to reserve riparian water rights in the deed when riparian lands are sold is invalid. Presumably, the inconsistency could be cured by legislation providing a statutory basis for appurtenant rights. In fact, the Court in the Waiāhole Ditch Contested Case cited to the Water Code's recognition of appurtenant rights and legislative comment to the effect that *"Appurtenant rights may not be lost."*[27] However, the Court did not explicitly discuss its prior Reppun decision, so it is unclear whether its Waiāhole decision overruled Reppun.

B.4.5 Appropriated Uses

Appropriated uses are uses of surface or ground waters on non-riparian or non-overlying lands. In the case of ground water, *"(p)arties transporting water to distant lands are deemed mere 'appropriators,' subordinate in right to overlying landowners …(T)he correlative rights rule grants overlying landowners a right only to such water as necessary for reasonable use. Until overlying landowners develop an actual need to use ground water, non-overlying parties may use any available 'surplus' (citations omitted)."*[28] For surface waters, *"the effect of permitting riparian owners to enjoin diversions beneficial to others in the absence of a demonstration of actual harm may occasionally lead to wasteful or even absurd results… The continuing use of the waters of the stream by the wrongful diversion should be contingent upon a demonstration that such use will not harm the established rights of others."*[29] Thus, appropriated uses are not based on water rights but are allowed as long as they are reasonable and do not actually impinge on correlative and riparian rights. Note that appurtenant uses would be a type of appropriated uses if they were not based on appurtenant rights, and that in fact, the history of appurtenant uses in the Kingdom of Hawai'i has led to their establishment as water rights superior to riparian rights. Also note that when a water management area is designated, appropriated uses become superior to unexercised water rights, because appropriated uses become existing uses and are eligible for water use permits, while unexercised correlative and riparian rights are extinguished.

B.4.6 Obsolete Rights: Prescriptive and Konohiki Rights

Until 1973, surface waters were treated as private property and could be owned. Prescriptive water rights were the water equivalent of "adverse possession" in land ownership, where open and hostile occupation of another's private property for a specified number of years entitled the occupier to take legal ownership, because it raised the legal presumption of a grant. Prescriptive rights to water were exercisable only against the ownership of other private parties and not against the government. Thus, under prescriptive rights, appropriated uses could ripen into a prescriptive right superior to riparian rights. (Some early Court cases viewed appurtenant rights as a type of prescriptive right.) In 1973, the Court voided private ownership of water resources and prescriptive rights because of public ownership of all surface waters.[30] As for ground water, two early cases (1884[31] and 1896[32]) reflected the then prevailing law on surface waters that water could be private property, but those cases also concluded that prescriptive rights cannot be exercised against subterranean waters that have no known or defined course; i.e., you could not adversely possess what you could not see. In 1929, the Court adopted the correlative rights rule,[33] in which the overlying landowners could not use the water as they pleased, because it was a shared resource.

Until 1973, "konohiki lands," or lands whose title had passed from persons documented as konohiki, owned the "normal daily surplus water" in excess of waters reserved by appurtenant and prescriptive rights. Despite a number of earlier cases, in 1930 the Court had concluded that riparian rights had never been the law in Hawai'i.[34] The 1973 Court, instead of overturning that decision, found a statutory basis for riparian rights in the 1850 statute. In 1973, in addition to voiding any private property interest in water, the Court ruled that there can be no "normal daily surplus water," because the recognition of riparian rights entitled owners of riparian lands to have the flow of the watercourse in the shape and state given it by nature.[35]

B.4.7 Native Hawaiian Water Rights

The Water Code contains the following provisions on Native Hawaiian water rights (section 174C-101):

- Provisions of this chapter shall not be construed to amend or modify rights or entitlements to water as provided for by the Hawaiian Homes Commission Act, 1920, as amended, and by chapters 167 and 168, relating to the Molokai irrigation system. Decisions of the commission on water resource management relating to the planning for regulation, management, and conservation of water resources in the State shall, to the extent applicable and consistent with other legal requirements and authority, incorporate and protect adequate reserves of water for current and foreseeable development and use of Hawaiian home lands as set forth in section 221 of the Hawaiian Homes Commission Act.
- No provision of this chapter shall diminish or extinguish trust revenues derived from existing water licenses unless compensation is made.
- Traditional and customary rights of ahupuaʻa 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 hīhīwai, ʻōpae, ʻoʻopu, limu, thatch, ti leaf, aho cord, and medicinal plants for subsistence, cultural, and religious purposes.
- The appurtenant water rights of kuleana and taro lands, along with those traditional and customary rights assured by this section, shall not be diminished or extinguished by a failure to apply for or to receive a permit under this chapter. (The exercise of an appurtenant water right is still subject to the water use permit requirements of the Water Code, but there is no deadline to exercise that right without losing it, as is the case for correlative and riparian rights, which must have been exercised before designation of a water management area.

B.5 THE PUBLIC TRUST DOCTRINE AND THE PRECAUTIONARY PRINCIPLE

The Waiāhole Ditch Contested Case drew upon principles from the Public Trust Doctrine and Precautionary Principle in one of the landmark decisions in Hawai'i water law.

B.5.1 The Public Trust Doctrine

In its review of the Waiāhole Ditch Contested Case, the Hawai'i Supreme Court held that: 1) title to the water resources is held in trust by the state for the benefit of its people; 2) article XI, sections 1 and 7 of the Hawai'i Constitution adopted the public trust doctrine as a fundamental principle of constitutional law in Hawai'i; 3) the legislature incorporated public trust principles into the Water Code; and 4) nevertheless the Water Code did not supplant the protections of the public trust doctrine, which the Court would continue to use to inform the Court's interpretation of the Water Code, define its outer limits, and justify its existence.[36]

The Court has identified four trust purposes, three in the Waiāhole Ditch Contested Case, and a fourth in its 2004 decision, In the Matter of the Contested Case Hearing on Water Use, Well Construction, and Pump Installation Permit Applications, Filed by Wai'ola o Moloka'i, Inc. and Moloka'i Ranch, Limited:

- Maintenance of waters in their natural state;
- Domestic water use of the general public, particularly drinking water;
- The exercise of Native Hawaiian and traditional and customary rights, including appurtenant rights;[*] and
- Reservations of water for Hawaiian home lands.

The Court also identified the following principles for the water resources trust:[†]

- The state has both the authority and duty to preserve the rights of present and future generations in the waters of the state;
- This authority empowers the state to revisit prior diversions and allocations, even those made with due consideration of their effect on the public trust;
- The state also bears the affirmative duty to take the public trust into account in the planning and allocation of water resources and to protect public trust uses whenever feasible;
- Competing public and private water uses must be weighed on a case-by-case basis, and any balancing between public and private purposes begin with a presumption in favor of public use, access, and enjoyment;

ENDNOTES

[*] Although the Court has not ruled specifically on the issue, the exercise of an appurtenant right presumably would have to be done in a traditional and customary manner if it is to be considered a public trust purpose. Otherwise, commercial uses of appurtenant rights would be a protected public trust use. Note, however, that unexercised appurtenant rights cannot be extinguished, and this also applies to commercial uses of appurtenant rights as long as that use is reasonable and beneficial.

[†] While these principles are directed at surface water resources, they apply equally to ground water resources.

- There is a higher level of scrutiny for private commercial uses, with the burden ultimately lying with those seeking or approving such uses to justify them in light of the purposes protected by the trust; and
- Reason and necessity dictate that the public trust may have to accommodate uses inconsistent with the mandate of protection, to the unavoidable impairment of public instream uses and values; offstream use is not precluded but requires that all uses, offstream or instream, public or private, promote the best economic and social interests of the people of the state.

B.5.2 The Precautionary Principle

When scientific evidence is preliminary and not conclusive regarding the management of the water resources trust, it is prudent to adopt "precautionary principles." The Court's interpretation as explained in the Waiāhole Ditch Contested Case is as follows:

- As with any general principle, its meaning must vary according to the situation and can only develop over time. At a minimum, the absence of firm scientific proof should not tie the commission's hands in adopting reasonable measures designed to further the public interest.
- The precautionary principle simply restates the commission's duties under the Constitution and the Code. The lack of full scientific certainty does not extinguish the presumption in favor of public trust purposes or vitiates the commission's affirmative duty to protect such purposes wherever feasible. Nor does its present inability to fulfill the instream use protection framework render the statute's directives any less mandatory. In requiring the commission to establish instream flow standards at an early planning stage, the Water Code contemplates the designation of the standards based not only on scientifically proven facts, but also on future predictions, generalized assumptions, and policy judgments. Neither the Constitution nor the Water Code constrains the commission to wait for full scientific certainty in fulfilling its duty toward the public interest in minimum instream flows.

The Court's linking of the Public Trust Doctrine to the Precautionary Principle offers significant guidance to the Watershed Management Plans. The tenets of the Precautionary Principle state that::

- There is a duty to take anticipatory action to prevent harm to public resources;
- There is an obligation to examine the full range of alternatives before starting a new activity and in using new technologies, processes, and chemicals; and
- Decisions should be open, informed and democratic and include affected parties.

In this regard, "precautionary actions" may include:

- Anticipatory and preventive actions;
- Actions that increase rather than decrease options;
- Actions that can be monitored and reversed;
- Actions that increase resilience, health, and the integrity of the whole system; and
- Actions that enhance diversity.

The Public Trust Doctrine establishes a general duty to take precautionary actions and thus shifts the burden of proof to non-trust purposes and requires preventive action in the face of uncertainty.

B.6 CITY AND COUNTY OF HONOLULU PLANS AND CONTROLS

City and County of Honolulu water policies generally relate to water in regard to development goals, sustainability, and as a system that cannot be separated between its natural and human uses.

B.6.1 General Plan (GP)

The General Plan is required by City Charter as a statement of (1) the long-range social, economic, environmental, and design objectives for the general welfare and prosperity of the people of O'ahu and (2) the broad policies which facilitate the attainment of the objectives of the plan.[37] The 1992 GP, as amended, discusses eleven public policy areas that provide the framework from which the City and County of Honolulu derives public policies that address all aspects of health, safety, and welfare within its jurisdiction including: population, economic activity, the natural environment, housing, transportation and utilities, energy, physical development and urban design, public safety, health and education, culture and recreation, and government operations and fiscal management. The GP contains policies that are specific to particular areas. Therefore, each Watershed Management Plan should refer back to the original document to identify any policy or reference that specifically applies to the appropriate Development Plan or Sustainable Communities Plan area. The County WUDP, and specifically the North Shore Watershed Management Plan, needs to consider:

Population
Control population growth to the extent possible to avoid social, economic, and environmental disruptions, plan for future population growth, and establish a pattern of population distribution that will allow the people of O'ahu to live and work in harmony. The specific policy toward these objectives is to direct growth according to population policies set forth in the GP by providing land development capacity and needed infrastructure to distribute 1.7 percent of the island-wide population to the North Shore region by 2025.[38]

Economic Activity
Provide, encourage, and promote economic opportunities and maintain the viability of agriculture. Maintain agricultural land along the Windward, North Shore, and Wai'anae coasts for truck farming, flower growing, aquaculture, livestock production, and other types of diversified agriculture.[39]

Natural Environment
Provide, preserve, and enhance our natural environment by restoration, mitigation, and increasing public awareness and appreciation of our island resources. Policies to achieve these objectives include:

- Seek the restoration of environmentally damaged areas and natural resources.
- Retain the Island's streams as scenic, aquatic, and recreation resources.
- Design surface drainage and flood-control systems in a manner which will help preserve their natural settings.

- Protect the natural environment from damaging levels of air, water, and noise pollution.
- Protect plants, birds, and other animals that are unique to the State of Hawai'i and the Island of O'ahu.
- Increase public awareness and appreciation of O'ahu's land, air, and water resources.
- Protect the island's well-known resources: its mountains and craters; forests and watersheds areas; marshes, rivers, and streams; shoreline, fishponds, and bays; and reefs and offshore islands.
- Provide opportunities for recreational and educational use and physical contact with O'ahu's natural environment.[40]

Housing
Provide a choice of living environments which are adequately served by public utilities. Encourage residential development in areas where existing roads, utilities, and other community facilities are not being used to capacity and discourage development where the aforementioned cannot be provided at a reasonable cost.[41]

Transportation and Utilities
Develop and maintain an adequate water supply for the needs of residents, visitors, agriculture, and industry. Encourage the development of new technology that will reduce the cost of providing water and support the recycling of wastewater. Encourage a lowering of per-capita consumption of water. Maintain existing utility systems to avoid major breakdowns, provide improvements to reduce substandard conditions, plan for the timely and orderly expansion of utility systems, and increase efficiency by encouraging a mixture of uses with peak demand periods at different times of the day.[42]

Physical Development and Urban Design
Coordinate the construction of public facilities with location and timing of development. Policies that support this objective include:

- Plan for the construction of new public facilities and utilities in the various parts of the Island according to the following order of priority: first, in the primary urban center; second, in the secondary urban center at Kapolei; and third, in the urban-fringe and rural areas.
- Coordinate the location and timing of new development with the availability of adequate water supply, sewage treatment, and drainage.[43]

Health and Education
Coordinate county health codes and other regulations with State and Federal health codes to facilitate the enforcement of water pollution controls.[44]

Government Operations and Fiscal Management
Ensure that government attitudes, actions, and services are sensitive to community needs and concerns.[45]

B.6.2 Development Plans and Sustainable Communities Plans

The County Development Plans (DP) and Sustainable Communities Plans (SCP) for the eight land use districts established in the General Plan were developed to guide public policy, investment, and decision-making for a planning horizon of 20 years. Each DP or SCP contains guidance that is specific to the district it addresses. Therefore, each Watershed Management Plan should refer back to the appropriate DP or SCP to identify any policy or reference that specifically applies to the area being studied.

The North Shore SCP recognizes this district as relatively stable, with a vision to protect the community's natural, scenic, cultural, historic, and agricultural resources. The following are land use policies and guidelines from the North Shore SCP that have implications for the North Shore Watershed Management Plan:

- Historic and Cultural Resources
  - Emphasize physical references to Ko'olau Poko's history and cultural roots.
  - Preserve significant historic features.
- Agricultural Uses
  - Encourage small-lot agricultural uses and prevent conversion of agricultural lands to non- agricultural uses.
  - Provide supporting infrastructure, services, and facilities to foster and sustain agricultural operations.
  - Implement policies and incentives to promote active, long-term agricultural uses.
- Residential Uses
  - Maintain the predominantly low-rise, low-density, single family character of the region.
  - Reduce average density guidelines to 2-8 units per acre in urban fringe areas and 0.2-4 units per acre in rural areas.
- Water Systems Development:
  - Integrate management of all potable and nonpotable water sources, including ground water, stream water, storm water and effluent, following State and City legislative mandates.
  - Adopt and implement water conservation practices in the design of new developments and the modification of existing uses, including landscaped areas and as a major element in integrated water resource planning.
- Wastewater Treatment
  - Connect all wastewater produced within the Urban Community and Rural Community boundary areas to municipal or military sewer service systems.
  - Where feasible, use water recycling as a water conservation measure.
- Drainage System
  - Promote drainage system design, which emphasizes control and minimization of polluted run-off and the retention of storm water on-site and in wetlands.
  - View storm water as a potential source of water for recharge of the aquifer that should be retained for absorption rather than quickly moved to coastal waters.
  - Select natural and man-made vegetated drainageways and retention basins as the preferred solution to drainage problems wherever they can promote water recharge, help control non-point source pollution, and provide passive recreation benefits.

  - Keep drainageways clear of debris to avoid flooding problems.
- Natural Resources
  - Adapt the concept of "ahupua'a" in land uses and natural resource management.
  - Protect watersheds, natural resources, and water supplies
  - Preserve park lands, wilderness and beach reserves and conserve natural ecosystems of endemic plants, fish, and wildlife forestry.
  - Protect coastal lands, marine waters, fishponds, and tide pools.
- Mountain Forested Lands
  - Protect watersheds by retaining existing acreage in the State Conservation District or within the area defined by the Preservation boundary or designated Preservation.

B.6.3 Revised Ordinances of Honolulu, Chapter 30: Water Management

The O'ahu Water Management Plan (OWMP) was enacted by Ordinance No. 90-62 in 1990, and codified as Chapter 30, articles 1, 2, and 3, Revised Ordinances of Honolulu, The OWMP provides a long-range 20-year plan for the preservation, restoration, and balanced management of ground water, surface water, and related watershed resources for O'ahu.

The State Water Code (HRS Chapter 174C) mandates the preparation and adoption of a water use and development plan by each county as part of the Hawai'i Water Plan. In adopting the plan, the City and County of Honolulu recognizes that water is a limited resource, the development and use of which must be carefully planned. The Water Use and Development Plan for the City and County of Honolulu, which is called the OWMP, is intended to fulfill the requirements set forth by the State Water Code.

The OWMP consists of overall policies and strategies and regional watershed management plans, which guide the activities of the City and County of Honolulu and advises the State Commission on Water Resource Management in the areas of planning, management, water development and use, and allocation of O'ahu's limited water resources. In areas where a regional watershed plan has not been adopted, Articles 1, 2, and 3 of Chapter 30 and the Technical Reference Document for the OWMP, dated March 1990, shall serve as the water use and development plan.

The intent of the Ordinance is to ensure (1) optimum utilization of the existing water supply in order to minimize the need for the development of additional potable ground water resources, (2) preservation of the aquifers for the benefit of future generations, in perpetuity, by proper management of O'ahu's ground water sources, (3) timely development of additional potable ground water sources and alternative sources to provide for additional consumer demand, and (4) that growth in consumer demand will be compatible with available water supply.[46] The following policies recognize the vital role water plays in supporting land use activities and apply to all County agencies in their powers, duties, and functions and include the following:

- Facilities for the provision of water shall be based on the General Plan population projections and the land use policies contained in the DPs/SCPs and depicted on the DP and SCP Land Use Maps.

- System flexibility shall be maintained to facilitate the provision of an adequate supply of water consistent with planned land uses. The municipal water system shall be developed and operated substantially as an integrated island-wide water system.
- Close coordination shall be maintained between Federal, State, and County agencies involved in the provision or management of water to ensure optimal distribution of the available water supply.
- The quality and integrity of the water supply shall be maintained by providing for the monitoring and protection of the water supply in accordance with the requirements of the State Water Code.
- The development and use of nonpotable water sources shall be maximized in a manner consistent with the protection of the ground water quality.
- Water conservation shall be strongly encouraged.
- Alternative water sources shall be developed wherever feasible to ensure an adequate supply of water for planned uses on O'ahu.[47]

B.6.4 O'ahu Water Management Plan (OWMP) Framework

The Honolulu Board of Water Supply (BWS) prepared and submitted to the Commission the OWMP Framework and Scope of Work for the eight regional watershed management plans for each of O'ahu's land use districts to comply with the Statewide Framework for Updating the Hawai'i Water Plan. The Commission approved the OWMP Framework in 2003. The OWMP Framework of eight regional watershed management plans provides equal focus on resource protection, conservation, and restoration, as well as water use and development.

The watershed management plans are community-based, environmentally holistic, action-oriented, in alignment with State and County water and land use principles, and based on ahupua'a management principles.

B.6.5 Honolulu Board of Water Supply (BWS) Mission

The BWS' mission is *"Water for Life, providing safe, dependable water supply now and into the future,"* which expanded the BWS' focus from water systems and services to meeting the needs of the community, economy, and environment. In fulfilling its mission, BWS provides safe and dependable water supply in the context of sustainability of all water resources and the environment.

B.7 PUBLIC/PRIVATE PARTNERSHIPS

The value of public/private partnerships has been increasingly recognized as an important tool in natural resource protection, restoration, and conservation. Various partnerships have been formed in each of the County's Development Plan/Sustainable Communities Plan areas. The following is a discussion of the goals of existing and potential partnerships in North Shore.

B.7.1 Ko'olau Mountains Watershed Partnership

The Ko'olau Mountains Watershed Partnership was created in 1999 to cooperatively protect and manage the Ko'olau watershed, which consists of the most intact native forests on O'ahu and provides the majority of the island's water supply. Voluntary membership is comprised primarily of agencies and major landowners or lessees, defined as those who own or lease 100 acres or more. The partners include the Honolulu Board of Water Supply, Bishop Museum, Kamehameha Schools, Queen Emma Foundation, U.S. Army, the State of Hawai'i Agribusiness Development Corporation, Department of Hawaiian Home Lands, Department of Land and Natural Resources, and the Pacific Cooperative Studies Unit of the University of Hawai'i. Of the 111,047 acres within the partnership boundary, 100,484 acres are under the jurisdiction of partner entities. The KMWP is actively implementing their management plan, developed in 2002.

The goals of the partnership are:

- To develop funding capacity to support mauka watershed initiatives,
- To increase public and political support and form new island-based mauka watershed partnerships, and
- To develop and implement individual projects having mutual interests, such as invasive species control, fencing, forestry management, and mapping.

B.7.2 Wai'anae Mountains Watershed Partnership

The WMWP area covers 144,000 acres in the Wai'anae Mountains. WMWP include Board of Water Supply, Department of Land and Natural Resources, Gill-Olson Joint Venture, Ka'ala Farms, Inc., MA'O Organic Farms (Wai'anae Community Re-Development Corporation), US Army Garrison Hawai'i, and Navy Region Hawai'i. These groups work together to cooperatively develop and implement management strategies for the Wai'anae Mountains, mauka to makai. The WMWP has participated in the following activities for the North Shore: aerial imagery weed mapping and control;[48] meetings and community outreach on feral goat control; coordination of the Ka'ena Point Advisory Group; native plant seed collection and propagation; and assistance with Pahole weed control trials. Future projects include watershed resource protection fences, native forest restoration in priority watershed areas, feral ungulate management and invasive weed control.

The Watershed Management Plans will use the framework set forth in these documents and policies to develop plans that are consistent with Federal, State, and County plans and policies, cognizant of community values and visions, and useful to agencies, organizations, and individuals seeking to protect, conserve, and enhance water resources on O'ahu.

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C O'AHU WATER USE PERMIT INDEX

The State Commission on Water Resource Management maintains a database of permitted uses of water. Both fresh water and brackish water wells are listed in the following table that documents the well owner, well name, well number, volume permitted for withdrawal by the water use permit, and use of the water. The wells are further categorized by aquifer system area.

The permitted ground water uses are documented in the following table.

O'ahu Water Use Permit Index (Fresh water and Brackish water)

Dated: May 21, 2012

Well Owner	Well Name	Well No.	WUP	Use Description
Aina Nui Corporation	EP 10 A to K	2006-01 to 11	0.957	Urban Nonpotable Use
Del Monte Fresh Produce	Kunia 1 & Basal Monitor	2703-01 & 02	1.075	Agriculture, irrigation for 2,595 acres pineapple; contaminant removal
Grace Pacific Corp.	Upper Quarry	2103-06	0.044	Industrial washing and dust control
Grace Pacific Corp.	Makakilo Lower Quarry	2104-01	0.124	Industrial washing and dust control
Honolulu BWS	BP Nonpotable 1 & 2	2006-14, 15	1.000	Municipal Nonpotable Irrigation Ko Olina Resort
Honolulu BWS	Honouliuli I - 1 & 2	2303-01, 02	2.240	Municipal Use
Honolulu BWS	Honouliuli II - 1 to 4	2303-03 to 06	4.480	Municipal Use
Honolulu BWS	Makakilo	2004-04	1.500	Municipal Use
Ko Olina Golf Course	Ko Olina	2006-13	0.700	Golf course irrigation
State DLNR Engineering	Ewa Desalt Basal	1905-04	0.500	Supply brackish desalination plant
Navy Public Works Center	Barbers Point Shaft	2103-03	2.337	Military and State use at Kalaeloa
		Total WUP	**14.957**	
		Ewa-Kunia Sustainable Yield	**16**	
		Available	**1.043**	
		2010 Annual Pumpage	**12.143**	

Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Kahana Wells	3353-01, 02	0.600	Municipal Use
Division of State Parks	Kahana Valley	3352-01	0.008	Kahana Valley Park system serving 16 residences
Kualoa Ranch, Inc.	Saito	3251-03	0.200	Irrigation of 50 acres of pasture
Kualoa Ranch, Inc.	Tomasu	3251-01	0.288	Irrigation for 46 acres of pasture & 4 acres of aquaculture
Kualoa Ranch, Inc.	Kaaawa - Yamamoto	3351-04	0.005	Irrigate one acre of papaya
		Kahana Sustainable Yield	**15**	
		Total WUP	**1.101**	Remaining WUP's for salt water use
		Available	**13.899**	
		2010 Annual Pumpage	**0.360**	

Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Kalihi Pump Station	1952-06 to 08, 16 to 19, 22	6.948	Municipal Use
Honolulu BWS	Kapalama #1 & #2	2052-13, 14	1.500	Municipal Use
KS / Bishop Estate	Kamehameha Sch A & B	2051-01, 02	0.229	Domestic use for Kamehameha Schools
Oahu Country Club	OCC Irrigation	2050-01	0.060	Irrigation for 187-acre golf course
Palama Settlement	Palama Settlement	1952-15	0.024	Irrigation
		Kalihi Sustainable Yield	**9**	
		Total WUP	**8.761**	Remaining WUP's for salt water use
		Available	**0.239**	
		2010 Annual Pumpage	**5.424**	

Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Kapolei Irr 1 & Irr 2	1905-08, 10	0.302	City of Kapolei back-up irrigation for R-1 recycled water system
Kalaeloa Solar One	KS1	1905-11	0.300	
KPI	Kapolei Golf Course A,B&E	2003-01, 02, 05	1.000	Kapolei Golf Course irrigation supply
State HHFDC	Kapolei Irr C-1, D	2003-07, 04	0.494	Kapolei Village landscape irrigation and dust control
State HCDC	East Kapolei	2003-08	0.237	Kapolei Village landscape irrigation and dust control
		Kapolei Sustainable Yield		*Managed by chloride limit of 1,000 mg/l*
		Total WUP	***2.333***	
		2010 Annual Pumpage	**0.747**	

Well Owner	Well Name	Well No.	WUP	Use Description
Attractions Hawaii	Waimea Falls 1	3803-01	0.100	Currently Unused
Attractions Hawaii	Waimea Falls 2	3803-03	0.200	Currently Unused
Henry FA	Sunset - Henry F	4002-06	0.005	Use for 4 acres of pasture land
Honolulu BWS	Waialee I	4101-07	0.339	Municipal use
Honolulu BWS	Waialee II	4101-08	0.411	Municipal Use
Nakamura T	Sunset - Nakamura	4002-09	0.001	Irrigation of 2 acres of banana and citrus
Paniolo Ranch	Paniolo Ranch	3704-01	0.430	Livestock and irrigation of pasture land
Sean Ginella	Kawela Mauka	4100-06	0.102	Irrigation
Sean Ginella	Paumalu	3901-01	0.300	Livestock
University of Hawaii	Waialee	4101-10	0.026	Dairy & piggery wash water
		Kawailoa Sustainable Yield	**29**	
		Total WUP	**1.914**	
		Available	**27.086**	
		2010 Annual Pumpage	**0.425**	

O'ahu Water Use Permit Index (Fresh water and Brackish water)

Dated: May 21, 2012

Well Owner	Well Name	Well No.	WUP	Use Description
Campbell Estate	Kahuku Mill Batt	4057-11	0.028	Domestic & Irrigation of 40 acres of various crops
Campbell Estate	Kahuku P12 Batt	4057-07	0.300	Irrigation of ag parcel
Campbell Estate	Kahuku P3-1 & P3A-3	3957-01 & 03	1.244	Agriculture irrigation & domestic; truck farm (40 ac.) & taro (20 ac.)
Campbell Estate	Kahuku Pump 8	4057-06	0.670	Agriculture irrigation & domestic; truck farm (40 ac.) & taro (20 ac.)
Campbell Estate	Kawananakoa	4056-01	0.576	Domestic & Irrigation for 135 acres of ranchland & cattle
Campbell Estate	Kii Wildlife 1 to 4	4157-05, 06, 07, 13	1.000	Habitat maintenance
Campbell Estate	Pump 12A Batt	4057-10	1.200	Aquaculture for 25 acres prawns
Director of Public Works	Kahuku TVWF 2011	4059-01	0.017	Military car wash
Diversified Ag Promotions LLC	Kahuku Air Base	4158-12, 13	0.300	Aquaculture, Agriculture, Pasture, Residential
ELC Foundation	Hauula ELC	3755-03	0.019	Nursery (2 acres) and landscape
Hanohano Enterprises, Inc.	Punaluu-Hanohano	3553-01	0.432	Aquaculture over 70 acres & domestic for 250 units
Hawaii Reserves Inc.	Egg Farm	3956-05	0.001	Supply chicken and egg farm needs
Hawaii Reserves Inc.	Kapaka Farm 1	3554-01	0.038	30 acres diversified fruits & vegetables
Hawaii Reserves Inc.	Kapaka Farm 3	3654-03	0.190	Irrigation
Hawaii Reserves Inc.	Laie Maloo	3755-04	0.039	Agriculture
Hawaii Reserves Inc.	Prawn Farm	3856-07	0.171	Agricultural irrigation over 60 acres
Hawaii Reserves Inc.	Quarry D	3856-04	0.036	Irrigation for 51 acres bananas, papayas, grass
Hawaii Reserves Inc.	Truck Farm	3755-06	0.142	Irrigate 51 acres of grass
Hawaii Reserves Inc.	Welfare Farm	3855-04	0.091	Irrigate 39 acres bananas, papayas, grass
Holt LW	Hauula	3654-02	0.002	Irrigation of 1 acre of coconut trees
Honolulu BWS	Hauula	3655-01	0.180	Municipal use
Honolulu BWS	Kahuku 1 & 2	4057-15, 16	0.600	Municipal use
Honolulu BWS	Kaluanui Wells 1 to 3	3554-04 to 06	1.093	Municipal use
Honolulu BWS	Maakua	3655-02	1.120	Municipal use
Honolulu BWS	Punaluu I	3553-02	0.190	Municipal Use
Honolulu BWS	Punaluu II - 1 to 6	3553-03, 04, 06 to 08; 3554-03	4.405	Municipal Use
Honolulu BWS	Punaluu III - 1 & 2	3453-06, 07	1.327	Municipal Use
Islands Found	PCC Lagoon	3855-09	0.568	Supply lagoon's aquatic life, provide circulation
James Campbell Company LLC	Kahuku Pump 6	3957-07	0.026	Agriculture
James Campbell Company LLC	Malaekahana	3956-01	0.062	Domestic service to 33 homes, Malaekahana Park and ranch
Kaio P	Kaio	3956-07	0.017	Irrigate 3 acres of taro, on choi, other
Kuilima	Opana 1 & 3	4100-04 & 05	0.346	Municipal, Individual Domestic, Industrial
Laie Water Co.	BYU Campus, Quarry	3855-06 to 08; 3856-05 & 06	1.375	Municipal for 607 residential, BYUH, Commercial, Laie School
Ming Dynasty Fish Co.	Amor RCA Brackish	4258-04	0.010	Aquaculture
Nihipali G N	Pahumoa	3855-12	0.009	Supply 1 home, irrigate 3.5 acre banana
Ota G	Punaluu	3453-03	0.006	Irrigation of 2 acres of bananas and vegetables
State DOA	Pump 1	4057-01	0.307	Domestic & Irrigation of 215 acres of various crops
Turtle Bay Resort LLC	Kuilima 1	4158-14	0.302	Golf course irrigation
Turtle Bay Resort LLC	Pump 2 Bat, Kahuku Land	4159-01 & 02	1.075	Agriculture
Turtle Bay Resort LLC	Turtle Bay GC	4100-01	0.017	Golf course irrigation
White RE	Laie	3855-05	0.013	Irrigation of 9 acres of bananas and domestic use at 3 residences
		Koolauloa Sustainable Yield	**36**	
		Total WUP	**19.544**	Remaining WUP's for salt water use
		Available	**16.456**	
		2010 Annual Pumpage	**17.853**	

Well Owner	Well Name	Well No.	WUP	Use Description
Chang DWA	Kahaluu-Chang	2750-09	0.002	Irrigation of 6 acres for heliconias & ginger
Honolulu BWS	Haiku Tunnel	2450-01	1.340	Municipal Use
Honolulu BWS	Haiku Well	2450-02	0.457	Municipal Use
Honolulu BWS	Iolekaa Well	2549-01	0.153	Municipal Use
Honolulu BWS	Kahaluu Tunnel	2651-01	2.128	Municipal Use
Honolulu BWS	Kahaluu Well	2651-03	0.927	Municipal Use
Honolulu BWS	Kuou I - 1 & 2	2348-02, 03	2.375	Municipal Use
Honolulu BWS	Kuou II	2348-05	0.100	Municipal Use
Honolulu BWS	Kuou III	2348-06	0.700	Municipal Use
Honolulu BWS	Luluku Tunnel	2349-01	0.713	Municipal Use
Honolulu BWS	Luluku Well	2349-02	1.050	Municipal Use
Koolau Management	Koolau GC 1 & 2	2347-02, 03	0.150	100 Acres golf course, landscape, fire protection
Montgomery RL	Laakea Hawaiian Resort	2751-08	0.036	Supply 2 homes, livestock, 12 acres fruits, vegetables
State DOH	HI State Hospital	2448-01	0.088	Domestic consumption; nursery irrigation 2,280 sq. ft.
State HCDC	Waiahole A and B	2853-04, 05	0.075	Serve 110 homes, 305 acres of bananas, papayas, etc.
Valley of the Temples, LLC	Heeia	2550-01	0.018	Irrigate 65 acres grass, Temple fish ponds, domestic
		Koolaupoko Sustainable Yield	**30**	
		Total WUP	**10.312**	
		Available	**19.688**	
		2010 Annual Pumpage	**10.227**	

Oʻahu Water Use Permit Index (Fresh water and Brackish water)

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Well Owner	Well Name	Well No.	WUP	Use Description
C&C Facility Maint	Facility Maint 1 & 2	1806-09 & 10	3.340	Industrial: Power Plant
Kalaeloa Partners, L.P.	Kalaeloa PW 1 to 9	1805-04 to 12	3.168	Industrial cooling of cogeneration plant
State DLNR DOWALD	Ewa Caprock	1905-05	0.500	Supply brackish desalination plant
VIP Sanitation, Inc.	VIP Sanitation	1805-16	0.003	Irrigation, flush & clean portable toilets & trucks
		Malakole Sustainable Yield		*Managed by chloride limit of 1,000 mg/l.*
		Total WUP	***7.011***	Remaining WUP's for salt water use
		2010 Annual Pumpage	**4.513**	

Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Kalihi Shaft	2052-08	9.500	Municipal Use
Honolulu BWS	Moanalua 1 to 3	2153-10 to 12	3.790	Municipal Use
Honolulu Country Club	Honolulu Int CC	2154-01	0.346	Irrigate golf course
Kaimana Ventures Limited	Moanalua	2153-02	0.021	Irrigate taro and fish pond, misc. uses
Navy Public Works Center	Red Hill Shaft	2254-01	4.659	Navy usage
U.S. Army	Fort Shafter	2053-11 & 13	1.035	Military use
U.S. Army	TAMC 1 & 2	2153-07, 08	0.609	Military use
		Moanalua Sustainable Yield	**16**	
		Total WUP	**19.960**	
		Available	**-3.960**	
		2010 Annual Pumpage	**17.143**	

Well Owner	Well Name	Well No.	WUP	Use Description
Dole Company	Pump 5	3411-04, 06 to 11, 13	2.550	Irrigate 315 acres of sugar cane
Dole Company	Pump 11	3409-13	0.530	Irrigate 133 acres of sugar, 75 gpm domestic
Hawaii Fish Co.	Hawaii Fish Co. 1	3412-04	0.576	Fish hatchery & farm
Mark Hamamoto	Hamamoto - 2006	3306-16	0.013	Domestic, 6-acre agriculture and domestic
Metropolitan Mortgage & Securities Co. Inc.	Crowbar Ranch	3410-01	0.500	Domestic, irrigation of polo field, pasture
Metropolitan Mortgage & Securities Co. Inc.	Mokuleia 1	3310-01	1.250	Agriculture and domestic
Metropolitan Mortgage & Securities Co. Inc.	Mokuleia 2	3310-02	0.850	Irrigation and domestic use
Mokuleia Aquafarm	MAF 1	3409-24	0.250	Aquaculture (2 acres fish and taro)
Mokuleia Assoc.	Mokuleia Assoc.	3409-16	0.000	Well sealment planned
Mokuleia Hmstd	Mokuleia Hmstds	3410-05	0.000	Stock watering
Mokuleia Land	Shop Well	3410-03	1.500	Domestic & irrigation for Mokuleia Homesteads
Singlehurst	Stanhope Farms	3308-02	0.056	Agriculture, Irrigation, domestic
State DLNR-Engineering	Mokuleia	3309-02	0.127	Cattle water, pasture & nursery irrigation
State DOT-Airports	Dillingham Airfield	3412-02	0.055	Supply airfield, Camp Erdman, and some residents
U.S. Air Force	USAF Kaena Pt.	3314-03	0.018	Currently Unused
Waialua High School	Waialua HS	3407-25	0.039	Irrigation of football, baseball and play fields
		Mokuleia Sustainable Yield	**8**	
		Total WUP	**8.314**	
		Available	**-0.314**	
		2010 Annual Pumpage	**0.175**	

Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Beretania P Station	1851-12,13,31,33 to 35,67,74,75	7.000	Municipal Use
Honolulu BWS	Manoa II	1948-01	0.700	Municipal Use
Honolulu BWS	Wilder Avenue Wells 1 to 4	1849-13 to 16	7.000	Municipal Use
Kawaiahao Church	Kawaiahao Church	1851-73	0.030	Domestic consumption & irrigation
McKinley HS	McKinley Aqua 1 & 2	1850-28, 29	0.085	10 Aquaculture tanks
Pacific Club	Pacific Club	1851-07	0.040	Domestic and irrigation for private club
Pagoda Hotel	Ala Moana	1750-09	0.020	Industrial irrigation
Punahou High School	Punahou	1849-10	0.158	Drinking, pool, irrigation
Queens Hospital	Queens Hospital	1851-54	0.237	Municipal use, air conditioning cooling, lawn
		Nuuanu Sustainable Yield	**14**	
		Total WUP	**15.270**	Remaining WUP's for salt water use
		Available	**-1.270**	
		2010 Annual Pumpage	**15.232**	

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Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Kaimuki Pump Station	1748-03 to 10	4.000	Municipal Use
Honolulu BWS	Palolo Wells	1847-01, 02	1.310	Municipal Use
Kokusai Kogyo	Kapahulu	1749-19	0.336	Supplies water to hotel, incl. drinking water
		Palolo Sustainable Yield	**5**	
		Total WUP	**5.646**	Remaining WUP's for salt water use
		Available	**-0.646**	
		2010 Annual Pumpage	**6.289**	

Well Owner	Well Name	Well No.	WUP	Use Description
Aoao Suncrest/Shores/Lombard/Avalon	Gentry Area 24	2001-10	0.022	Irrigation of 7.37 acres landscaped area and roadway
Arbors Association	Arbors GV 1	2001-07	0.063	Irrigation for Arbors & Golf Villa 1, Area 3
C&C Envir Serv	Honouliuli STP 1 and 2	1902-03, 04	0.500	WWTP in plant process water, emergency backup
C&C Parks & Rec	Geiger Park	2001-03	0.030	Irrigation of 10-acre Geiger Park
Coral Creek	Coral Creek 1, 10 & Lake A	2001-14, 2002-15,19	0.892	Backup golf course irrigation
Coral Creek	Coral Creek 2	2002-17	0.498	Water feature, backup golf course irrigation
Coral Creek	Coral Creek 4	2001-13	0.800	Water feature
Ewa by Gentry Comm. Assoc.	Gentry Entry Irr	2001-02	0.080	Irrigation for 20 acres of Gentry Entry Park
Ewa by Gentry Comm. Assoc.	Soda Creek III	2001-05	0.195	13.23 acres of park lawn & Roadway landscaping
Gentry Companies	Gentry Area 13	1901-05	0.037	Irrigation (common area & roadway)
Gentry Companies	Keaunui Area 30	2001-12	0.225	Irrigation (golf course, common area, park, roads)
Gentry Development Co.	Fort Weaver Apt.	2001-09	0.023	Irrigation of 7.8 acres of landscape and roadways
Gentry Development Co.	Sunrise Apt.	2001-04	0.040	Irrigation for 13 acres of lawn and road landscape
Gentry Homes, Ltd.	Gentry Area 35 #1 & #2	1900-24, 2000-06	0.255	Irrigation (common area & roadway)
Gentry Homes, Ltd.	Gentry Area 45	1901-08	0.066	Irrigation (common area & roadway)
Haseko (Ewa), Inc.	Ocean Pointe 4	1901-06	1.337	Dust control; golf course, roadway irrigation. Supplements R-1
Hawaii Prince Golf Club	EP 22, Wells 1 to 5	1900-02, 17-20	1.201	Golf Course Irrigation including lake evaporation
New Ewa Beach Golf Course	Dug C and D	1900-22, 1959-08	0.600	Irrigate golf course
New Ewa Beach Golf Course	New Ewa Intl G C	1900-21	0.100	Irrigate golf course
Palm Court Association	Palm Court 3	2002-12	0.040	Irrigation for 22 acres of Palm Court 2&3, Area 1C
Palm Villa I Association	Palm Villa 1	2001-06	0.080	Irrigation for 15 acres fo Palm Villas 1, Area 1A
Palm Villa II Association	Palm Villa 2	2001-08	0.048	Irrigate 16 acres of Palm Villa 2, Area 4
U.S. DOC/NOAA/NWS	Pacific Tsunami	1900-23	0.023	Irrigation (30 acres turf)
U.S. Fish & Wildlife	Honouliuli Unit	2101-14	0.216	Maintenance of 37 acre habitat for endangered water birds
U.S. Navy	EP 23	2001-01	5.890	Agriculture irrigation of Navy Blast Zone
		Puuloa Sustainable Yield		
		Total WUP	***13.261***	*Managed by chloride limit of 1,000 mg/l*
		Available		
		2010 Annual Pumpage	**1.374**	

Well Owner	Well Name	Well No.	WUP	Use Description
Kunia Water Association, Inc.	Del Monte Pump 3 & 4	2803-05, 07	3.960	Irrigate for 2480 acres pineapple; 150 residential @ Kunia Village
Alii Turf Co., LLC	Alii Turf	3001-01	0.115	Irrigation
Brent Cullinan	Brent's	3104-03	0.029	Domestic, livestock, agriculture, and reservoir evaporation
Agribusiness Development Corporation	Del Monte Pump 5	3103-01	2.000	Pineapple agriculture
Hawaiian Earth Products	HEP-1	3104-02	0.355	Industrial irrigation
Honolulu BWS	Wahiawa I - 1 to 3	2901-08, 09, 11	3.270	Municipal Use
Honolulu BWS	Wahiawa II - 1 & 2	2902-01, 02	1.000	Municipal Use
Kelena Farms, Inc.	Helemano Pump 25	3203-01	1.442	Agriculture
Sandwich Isles Communications	SIC-01	2801-03	0.100	154.25 net acres for various irrigation, landscape irrigation
U.S. Army	Schofield Batt	2901-02, to 04, 10	5.648	Supply Schofield Base
U S Navy NAVFAC	NAVFAC Wahiawa Deep	3100-02	0.444	Potable supply for NCTAMS
Waialua Sugar	Pump 24	3102-02	2.580	Irrigate 526 acres of sugar cane
Waialua Sugar	Pump 26	3203-02	1.720	Irrigate 506 acres sugar, 1803 acres pineapple
		Wahiawa Sustainable Yield	**23**	
		Total WUP	**22.663**	
		Available	**0.337**	
		2010 Annual Pumpage	**7.694**	

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Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Kuliouou Well	1843-01	0.300	Municipal Use
Honolulu BWS	Waialae Iki Well	1746-02	0.190	Municipal Use
Honolulu BWS	Wailupe Well	1745-01	0.300	Municipal Use
		Waialae-East Sustainable Yield	**2**	
		Total WUP	**0.790**	
		Available	**1.210**	
		2010 Annual Pumpage	**0.124**	

Well Owner	Well Name	Well No.	WUP	Use Description
Bishop Estate	Waialae C C	1646-01	0.460	Irrigation of the Waialae Golf Course
Honolulu BWS	Aina Koa	1746-01	0.480	Municipal Use
Honolulu BWS	Waialae Nui Ridge	1746-04	0.997	Municipal Use
Honolulu BWS	Waialae Nui	1747-03	0.700	Municipal Use
Honolulu BWS	Waialae West	1747-05	0.160	Municipal Use
		Waialae-West Sustainable Yield	**4**	
		Total WUP	**2.797**	Remaining WUP's for salt water use
		Available	**1.203**	
		2010 Annual Pumpage	**1.004**	

Well Owner	Well Name	Well No.	WUP	Use Description
Lopez Sons Inc	Haleiwa - Lopez 1	3406-16	0.072	Irrigation of 13 acres truck farm crops
BG Farm	BG Farm	3506-10	0.003	Irrigation supply for 1 acre banana, papaya
Gora, D	Gora	3406-08	0.144	Irrigation, aquaculture, on 7 acres
Honolulu BWS	Haleiwa 1 & 2	3405-03, 04	1.000	Municipal Use
Honolulu BWS	Waialua	3405-01, 02	1.730	Municipal Use
Kawamata, S.	Kawamata, S.	3406-03	0.100	Irrigate banana and watercress crops
Jewett, MJ & WF	Waialua Pump 9	3406-02	0.160	Diversified agriculture
Lopez Family Estate	Lopez 2	3407-02	0.200	Domestic; irrigate 4.5 acres various crops; aquaculture
Poamoho Venture	Poamoho A	3205-02	0.600	Irrigation for 150 acres of diversified agriculture
Kamehameha Schools	Pump 3	3505-01 to 20	1.552	Irrigation for 2370 acres of diversified agriculture
Paradise Shrimp Farm	Paradise Shrimp	3407-38	0.576	Shrimp production
Waialua Sugar	Pump 7B & 7C	3407-11, 12	2.930	Irrigate 440 acres of sugar cane, 125 gpm domestic
Waialua Sugar [02]	Pump 1	3407-04 to 06, 14, 15	2.330	Irrigate 367 acres of sugarcane
Waialua Sugar [02]	Pump 17	3404-01	8.630	Irrigate 990 acres of sugar cane, 300 gpm domestic
Waialua Sugar [02]	Waialua Pump 2 Batt	3307-01 to 06, 08 to 10	4.370	Irrigate 409 acres of sugar cane, some domestic
Waialua Sugar [02]	Pump 2A	3307-07	3.586	Irrigate 429 acres of sugar cane, 600 gpm domestic
Waialua Sugar [02]	Pump 2A	3307-11 to 14	0.864	
Waialua Sugar [02]	Pump 7D & 7E	3407-18, 19	0.180	
BP Bishop Estate Trust	Pump 8	3506-03, 04	1.660	Irrigate 136 acres of sugar cane, domestic
		Waialua Sustainable Yield	**25**	
		Total WUP	**30.687**	
		Available	**-5.687**	
		2010 Annual Pumpage	**3.276**	

Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Aiea Gulch A & C	2355-03, 05	0.980	Municipal Use
Honolulu BWS	Aiea Wells A & B	2355-06, 07	1.300	Municipal Use
Honolulu BWS	Halawa Shaft	2354-01	11.320	Municipal Use
Honolulu BWS	Halawa Wells	2255-37 to 39	1.080	Municipal Use
Honolulu BWS	Kaahumanu I #1 and #2	2357-23, 24	1.110	Municipal Use
Honolulu BWS	Kaamilo	2356-58, 59	1.200	Municipal Use
Honolulu BWS	Kalauao Wells	2355-09 to 14	11.750	Municipal Use
Honolulu BWS	Kaonohi I	2356-55, 56	1.350	Municipal Use
Honolulu BWS	Newtown	2456-01 to 03	1.500	Municipal Use
Honolulu BWS	Punanani	2457-05, 06, 09 to 12	11.970	Municipal Use
Honolulu BWS	Waiau	2457-13 to 15	1.890	Municipal Use
Honolulu BWS	Waimalu Wells	2356-49, 50	0.080	Municipal Use
Lau Taro Farm	Kalauao	2356-70	0.100	Supply farm and a fish pond
Minami Farm	Minami Farm	2455-02	0.158	Agriculture (piggery)
Pearl Country Club	Pearl Country Club	2356-54	0.330	Golf course irrigation (189 net acres)
State of Hawaii	Waimano Trng Sch	2557-01, 02	0.136	Supply for swimming pool, laundry plant
U.S. Navy	Aiea Halawa Shft	2255-32	0.697	Navy usage
		Waimalu Sustainable Yield	**45**	
		Total WUP	**46.951**	
		Available	**-1.951**	
		2010 Annual Pumpage	**35.524**	

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Well Owner	Well Name	Well No.	WUP	Use Description
Honolulu BWS	Waimanalo Tunnel 1 to 4	2044-03, 04, 2045-03,05	0.700	Municipal Use
C&C Honolulu DES	Kailua WWTP	2545-01	0.025	Industrial use
State of Hawaii DLNR-DOFAW	Kawainui 1 to 11	2245-02 to 11, 2345-04, 05	0.202	To serve 24 acres of ponds
Honolulu BWS	Waimanalo I & II	2043-02, 1943-01	0.452	Municipal Use
Honolulu BWS	Waimanalo III	1942-01	0.200	Municipal Use
Roman Catholic Church in the State	SSDC-1	2146-04	0.010	Drinking water
Luana Hills CC	Wells 1, 2, 4, 6	2045-06, 2145-01, 02, 04	0.155	Irrigation for 176.4 acres fo RHCC Golf Course
State DHHL	Reservation		0.124	Reservation via 11/17/93 rule 13-171-63 via CWRM
		Waimanalo Sustainable Yield	**10**	
		Total WUP	**1.868**	Remaining WUP's for salt water use
		Available	**8.132**	
		2010 Annual Pumpage	**0.699**	

Well Owner	Well Name	Well No.	WUP	Use Description
Abe, Tadahiro	Honouliuli	2202-02	0.009	Irrigation supply for 1.5 acre roses
Campbell Estate	EP 18 Battery	2102-02, 04 to 22; 2202-03 to 20	7.969	Diversified Ag
Gary Takiguchi	Honouliuli	2201-02	0.019	Domestic and irrigation (4.8 acres) for six (6) houses
Gentry Hawaii, Ltd. [06]	Waiawa 575-ft 1, 765-ft 2	2658-05, 03	0.000	Municipal use for Waiawa by Gentry, Phase I
Waiawa Ridge Development LLC	Waiawa 575-ft 2	2659-04	0.300	Municipal use for Waiawa by Gentry, Phase I
Harris Rug CL	Harris Rug	2201-14	0.003	Industrial use for laundering or cleaning rugs
Hawaii Country Club	Haw Country Club	2603-01	0.400	Irrigation for Hawaii Country Club
Honolulu BWS	Ewa Shaft (EP 15,16)	2202-21	7.661	Municipal Use
Honolulu BWS	Hoaeae Wells 1-6	2301-34 to 39	6.610	Municipal Use
Honolulu BWS	Kunia I - P1 to P4	2302-01 to 04	5.000	Municipal Use
Honolulu BWS	Kunia II - P1 to P4	2402-01 to 03, 05	2.710	Municipal Use
Honolulu BWS	Kunia III - 1 to 3	2401-04 to 06	3.050	Municipal Use
Honolulu BWS	Manana 1	2458-05	0.700	Municipal Use
Honolulu BWS	Mililani I - P1 to P4	2800-01 to 04	2.670	Municipal Use
Honolulu BWS	Mililani II - P5 & P6	2859-01 to 02	1.590	Municipal Use
Honolulu BWS	Mililani III - 7 & 8	2600-03, 04	1.250	Municipal Use
Honolulu BWS	Mililani IV - 9 to 11	2858-01 to 04	2.022	Municipal Use
Honolulu BWS	Pearl City I - 1 & 2	2458-03, 04	1.150	Municipal Use
Honolulu BWS	Pearl City II - 1 to 3	2457-01 to 03	1.500	Municipal Use
Honolulu BWS	Pearl City III	2557-03	0.500	Municipal Use
Honolulu BWS	Pearl City Shaft	2458-01	1.000	Municipal Use
Honolulu BWS	Waipahu I	2400-01 to 04	6.000	Municipal Use
Honolulu BWS	Waipahu II	2400-05, 06, 08, 14	2.100	Municipal Use
Honolulu BWS	Waipahu III	2400-09 to 13	3.029	Municipal Use
Honolulu BWS	Waipahu IV	2301-44 to 47	3.000	Municipal Use
Honolulu BWS	Waipio Hts P-1 & P-2	2459-19, 20	0.500	Municipal Use
Honolulu BWS	Waipio Hts. I - 1 & 2	2459-23, 24	0.500	Municipal Use
Honolulu BWS	Waipio Hts. II - 1 & 2	2500-01, 02	1.000	Municipal Use
Honolulu BWS	Waipio Hts. III - 1 & 2	2659-02, 03	1.250	Municipal Use
Roman Catholic Church - Hawaii	Honouliuli	2101-01	0.110	Supply for slaughter house
Kenneth Simon	Pearl City	2358-35, 44	0.040	Diversified agriculture
Kenneth Simon	Pearl City	2358-36	0.004	Domestic use for eight (8) residences
Kipapa Acres Assoc.of Owners	Kipapa Acres	2600-02	0.100	Supply residences, agricultural businesses, farm
Mark H. Ortiz	Ortiz	2202-01	0.003	Domestic supply for six (6) residences
Michael Watanabe	Watanabe, A.	2300-11	0.680	Irrigate watercress, onchoy, and taro farm
Michael Watanabe	Watanabe, A.	2300-20	0.400	Irrigate watercress, onchoy, and taro farm
Nazarene Church	Pearl City	2358-49	0.003	Supply Pastor's residence, church
Pearl City Community Church	Pearl City Comm Ch.	2359-10	0.005	Domestic for 10 residential units
Robinson Kunia Land, LLC	Robinson No. 1	2602-03	0.100	Agricultural food processing
Royal Kunia CC	Royal Kunia CC	2401-07	0.600	Irrigate 151 acre Royal Kunia CC Golf Course
State DHHL	Reservation		1.358	Reservation via 11/17/93 rule 13-171-63 via CWRM
TABA FARM, INC	Taba Farm	2358-21, 22, 26, 29	0.864	Agriculture
Tadao Abe	Honouliuli	2201-02	0.002	Domestic
U.S. Fish & Wildlife	PHNWR No. 1	2359-19	0.180	Habitat maintenance
U.S. Navy	Waiawa Shaft	2558-10	14.977	Navy usage
Waiawa Development, LLC	Gentry Waiawa 1	2658-07	0.524	Irrigation of 181-acre golf course
Waiawa Development, LLC	Gentry Waiawa 2	2658-08	0.458	Irrigation of 149-acre golf course
Waikele Golf, LLC	Waipahu WP 1	2301-01 to 10	0.950	Waikele Golf Course irrigation
Yoshimura, D.	Waipahu	2459-21	0.006	Irrigate farm
		Waipahu-Waiawa Sustainable Yield	**104**	
		Total WUP	**84.856**	
		Available	**19.144**	
		2010 Annual Pumpage	**51.819**	

D OVERVIEW OF O'AHU HYDROGEOLOGY

D.1 SETTING
D.2 CLIMATE
D.3 WATER CYCLE
D.4 GEOLOGY
D.5 HYDROGEOLOGY
D.6 SUSTAINABLE YIELD
D.7 INSTREAM FLOW STANDARDS

D.1 SETTING

The island of O'ahu is approximately 600 square miles in size.[1] With less than ten percent of the land area of the State of Hawai'i, O'ahu's importance is not based upon its size, but upon its relationship to the economic and political activity of the state. As the center of business and government, O'ahu is the State's economic mainstay, supporting tourism, military, agriculture, manufacturing, and research and development. Although the City and County of Honolulu and Kaua'i are the smallest counties of the four counties in geographical size, the City and County of Honolulu alone has nearly three-fourths of the State's population with an estimated resident population of 876,000 in 2000.[2]

D.2 CLIMATE

O'ahu's climate is mild throughout the year due to the island's location on the northern fringe of the tropics within the belt of cooling northeasterly trade winds. The two seasons in Hawai'i are the warmer and drier period from May to October and the cooler, cloudier, wet weather from October to April. The coldest month, January, averages 72 degrees Fahrenheit and the warmest, August, 78.5 degrees Fahrenheit. Maximum temperatures rarely exceed 90 degrees Fahrenheit, and minimum temperatures hover around 50 degrees Fahrenheit. The average temperature in the lowlands is 75 degrees Fahrenheit, decreasing 4 degrees Fahrenheit with each 1,000 feet increase in elevation. Humidity of the area is generally within the 60 to 80 percent range.[3]

The contrast between O'ahu's lush green mountains and the arid lowland plains reflects extremely wide rainfall variations. Annual average rainfall on O'ahu ranges from less than 20 inches on the leeward coast to almost 300 inches near the central crest of the Ko'olau Range *(Figure D.1).* Such a marked difference over a distance of less than 15 miles has a significant effect upon water resources.

The sea surrounding O'ahu receives no more than 30 inches of rain each year, far too little to sustain vigorous plant growth in the tropics. However, because the rugged, steep Ko'olau Mountains intercept prevailing trade winds, the moisture carried by these winds is lifted, cooled, and thereby condensed into rain. Rainfall is heaviest high in the mountains and decreases in the leeward direction. The Wai'anae Range is a less effective rainmaker since it lies to the lee of the Ko'olau Range.

Another significant contributor to precipitation is fogdrip. Fogdrip is cloud vapor that clings to vegetation and then drips to the ground. This generally occurs between 2,000 and 6,000 feet above sea level.[4]

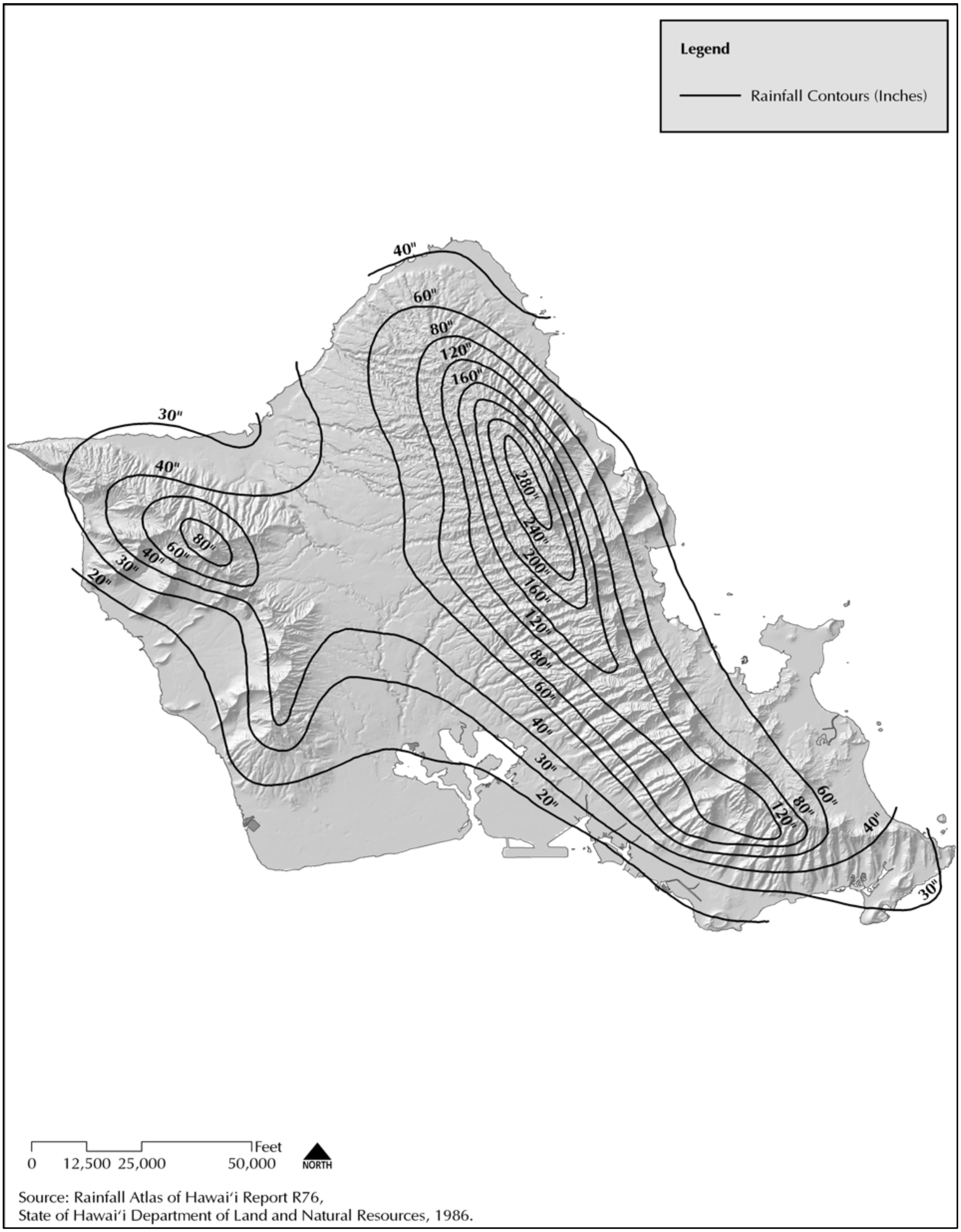


Figure D.1 O'ahu Annual Average Rainfall

Trade winds prevail throughout the year, but are least continuous from October through April, Hawai'i's winter season. During these months, tropical storms occasionally bring heavy rains, which account for practically all the rainfall on the leeward plains. Flooding is more likely during the wet winter weather, and during the dry period, stream flow decreases and the supply of irrigation waters dependent on this source can be an issue.[5]

Climate Change and Rising Sea Levels

Climate variability affects the availability and quality of ground water and surface waters. The following summarizes the key points on climate change identified in the 2006 American Water Works Association (AWWA) Publication *Climate Change and Water Resources: A Primer for Municipal Water Providers.*[6]

- Global average temperatures have increased approximately 0.6 degrees Celsius over the past century and warming is expected to accelerate over the next century. The arctic areas have warmed more rapidly than other areas increasing glacial melt.
- Air pollution has changed the composition of the atmosphere.
- Global warming will change atmospheric and oceanic circulation and the hydrologic cycle leading to altered patterns of precipitation and runoff.
- Global average precipitation and evaporation will increase with warming because a warmer atmosphere can hold more moisture. However, this does not mean that it will get wetter everywhere and in all seasons. Some say average precipitation will tend to be less frequent but more intense. This implies unanticipated extremes, such as unprecedented droughts and floods.
- Climate variability affects the availability and quality of water resources. Long-term climatic trends could trigger vegetation changes that would alter a watershed's water balance. Changes in the quantity of water percolating to ground water will result in changes to aquifer levels, in base flows entering streams and in seepage losses from streams to ground water.
- While artic areas are warming and glaciers are melting more rapidly, current climate models suggest that arctic and equatorial regions may have a tendency to become wetter and that subtropical regions may experience drying. Hawai'i is within the tropical region defined as those areas between the Tropics of Cancer and Capricorn.
- Rising sea levels will introduce new stresses on physical and ecological systems, including aquifers, streams, forests and riparian zones as well as coastal and freshwater aquatic systems. Rising sea levels impact coastal environments in the following ways:
  - Lowland inundation and wetland displacement
  - Altered tidal range in rivers and bays
  - Changes in stream sedimentation patterns
  - Severe storm surge flooding
  - Saltwater intrusion into estuaries and freshwater aquifers
  - Increased wind and rainfall damage in regions prone to hurricanes

Sea level on O'ahu has risen 10 inches over the last century and is expected to rise another 3 feet during this century.[7] The rise is due in large part to the effects of climate change and in small part to O'ahu's slow but steady sinking into the ocean. Greenhouse gases, such as carbon dioxide and methane in the atmosphere hold global heat, melt ice at the polar caps, and coupled with thermal expansion of the oceans, causes sea levels to rise. Carbon dioxide also contributes to ocean acidification.

Aquifers are susceptible where caprock above msl is thin, such as in Pearl Harbor. Brackish caprock sources will be impacted first. Due to density differences, the basal freshwater levels will rise accordingly above rising seawater and the aquifers will tend to migrate inland. Deep wells may be impacted as the brackish transition zone rises to a new equilibrium head, and wells may have to be partially backfilled. Climate change indicators will have to be monitored closely and mitigative measures initiated incrementally to minimize costs and detrimental impacts.

D.3 WATER CYCLE

A continuous cycle of water can be easily traced on small oceanic islands like Hawai'i. As noted most **precipitation or rainfall** begins as moist trade wind air that rises up the mountain side, cools and condenses and falls as rain or fog drip. However, in the winter months (November to April) extra-tropical storms approach from the north, covering the entire island during times when low pressure occurs in the northern Pacific. Sub-tropical "Kona" storms are important for recharging the drier leeward area of O'ahu.

The water cycle is illustrated in *Figure D.2*. The three main elements of the water cycle are precipitation, runoff and evapotranspiration and can be summarized by the equation

$$R=P-RO-ET$$

Where R = recharge, P=precipitation, RO = runoff and ET = evapotranspiration.

Rainfall varies greatly around the island and is measured by a limited network of rain gages. The rainfall data is then extrapolated to represent actual rainfall distribution. Trade wind rainfall in particular can be very localized. Rainfall distribution is based on averages and there are significant variations from wet and dry years. Maintaining existing rain gages are essential and more are needed, especially in critical aquifer systems.

When precipitation occurs faster than it can infiltrate the ground, it becomes **runoff**. Runoff flows over land surfaces into streams and drainage systems and eventually into the ocean. Ground water may supply stream base flows. *Runoff* is measured by stream gages but additional water flows in streams as underflow beneath and around the streams perched upon alluvium and is not measured in stream gages. Storm water flowing overland, through intermittent stream channels and storm drains are difficult to accurately estimate and account for in water budgets.

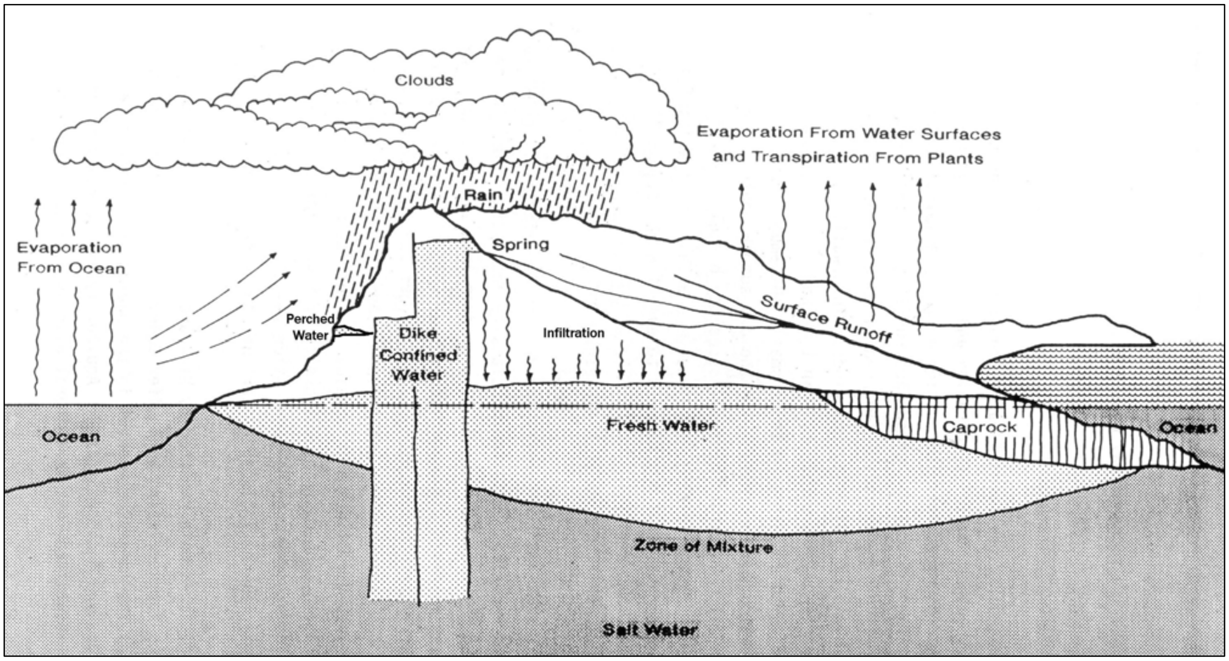


Figure D.2 Hydrologic Cycle ***(Source: O'ahu Water Management Plan, 1990)***

Evapotranspiration is the loss of water from the soil by evaporation and by plant uptake of water as it lives and grows. Evaporation is the change of liquid water to a vapor. As the water heats, vaporization occurs. Warm moist air rises up into the atmosphere and becomes the vapor involved in condensation. There are also evaporation losses from water bodies above the ground and from water that lands on plants and other exposed surfaces. Evapotranspiration is based on pan evaporation data and an assumed vegetative transpiration quantity. Global warming will increase evaporation. Transpiration data is limited to few plant species, yet the vegetative cover is varied and changing over time with different land uses and changing ecosystems, which requires more study.

Percolation or infiltration occurs when precipitation sinks into the ground and becomes ground water. Some factors that affect the rate of infiltration are ground slope, vegetative thickness and soil permeability. Permeability is the measure of how easily a fluid flows through soil and rock. The more permeable, the more quickly precipitation seeps into the ground.

Recharge is water infiltrating into the aquifer. Recharge is not directly measured and is the calculated remainder of rainfall minus runoff and evapotranspiration, in a water budget.

Leakage is the seaward flow of ground water to nearshore waters in the form of springs, seeps and underflow. Leakage is not easily quantifiable and varies in aquifers due to the amount of caprock or lack of sedimentary caprock. There are also freshwater losses to the aquifer transition zone or zone of mixture between freshwater and seawater.

Human activities can alter the components of the water cycle. For example, global warming and forest degradation can change evapotranspiration rates; agricultural and urban development can affect runoff patterns.

D.4 GEOLOGY

The islands of the Hawaiian Archipelago are emerged volcanoes on a great submarine ridge that extends northwesterly and southeasterly for 1,600 miles in the central Pacific Ocean. The creation of the Hawaiian Islands chain is thought to result from a fixed "hot spot" and moving plate tectonics.[8] The ridge and resulting islands are created with the movement of the Pacific plate northwest across the hot spot. The ridge, rising from ocean depths of 20,000 feet, was formed from immense quantities of lava, flow upon flow, spewing forth.

The sequential formation of the archipelago is indicated by the occurrence of submerged older islands in the northwest portion of the chain and by the youngest island at its southeast end, where volcanic activity continues. Eight of the islands are of sufficient elevation to intercept trade wind moisture and large enough to permit settlement.

Comparatively rapid weathering and erosion of their volcanic rock structure has reduced the size and altered the form of the islands. O'ahu is comprised of the remnants of two elongate shield volcanoes, the Ko'olau and Wai'anae volcanic ranges, joined by a broad convex plateau.

The giant Nu'uanu debris avalanche took out much of the seaward flank of the Ko'olau volcano. The eroded Ko'olau volcanic shield, stretching nearly straight northwest southeast for 37 miles from Kahuku to Makapu'u, is O'ahu's principal mountain range. The older Wai'anae volcano, an arcing mountain range 20 miles long from Ka'ena Point to the 'Ewa Plains, makes up the western bulwark of the island.

The peaks of the Ko'olau Range average about 2,500 feet in elevation. The highest point, Kōnāhuanui, overlooking Nu'uanu and Mānoa Valleys in Honolulu, rises to 3,150 feet. The Wai'anae Range peaks are somewhat higher, averaging nearly 3,000 feet. The highest point on the island is Mount Ka'ala in the Wai'anae Range, at 4,025 feet elevation.

The Wai'anae shield volcano emerged first and was partially eroded before the Ko'olau volcano emerged to the east, sending lava flows westward to overlap against the Wai'anae flank. The shield building lavas of the Wai'anae and Ko'olau volcanoes are known as the Wai'anae Volcanics and Ko'olau Volcanics, respectively.

During later periods, erosional and depositional platforms of marine and terrestrial sediments interbedded with lava flows were created around O'ahu. This was very important in determining O'ahu's water resources. These formations formed what is called the caprock and impounds the freshwater lens of ground water from flowing into the ocean. Under the caprock the freshwater lens thickens and is under pressure, a characteristic referred to as artesian, if the piezometric surface of the aquifer is higher than the land surface elevation.

D.5 HYDROGEOLOGY

O'ahu's geology, climate and the water cycle all influence the storage and movement of ground water. The most important feature of the volcanic formations making up the aquifers is that they were emitted on land and not as submarine flows. Under their subaerial environment, degassing and physical emplacement of the lava allowed the physical feature important to permeability to develop. The volcanic rock and their residual soils have a very great capacity to absorb and percolate water, and consequently, the amount of rainfall that recharges the ground water is greater than the amount of rainfall that runs over the surface to the sea. This infiltration and confinement in areas confined by the caprock creates the large ground water bodies on which O'ahu depends for its water supply. It should be noted that while infiltration into the ground water is great, much water is released into the atmosphere through evapotranspiration.

D.5.1 Ground Water

There are several types of general ground water bodies on O'ahu. The most important and most extensive is the "basal freshwater lens" that floats on seawater under much of the southern and northern portions of the island. Less widespread, but of singular importance in some areas, is ground water restrained between impermeable nearly vertical rock structures called "dikes" in the rugged core of the mountains. Dikes form from chilled magma in the fissures that feed lava flows. The third type, of minor significance on O'ahu, is ground water held up, or "perched," on horizontal impermeable beds such as volcanic ash *(Figure D.2).* And, finally there is caprock water, water within the caprock, which is typically brackish water and is perched over the basal water.

D.5.1.1 Basal Water

The immense basal water bodies, which are artesian where they underlie the coastal plain, exist because of the difference in density between freshwater and seawater. Freshwater floats on the heavier seawater, both of which permeate the subsurface rock. This relationship is known as the Ghyben-Herzberg principle. The density ratio between freshwater and salt water is such that, theoretically, for each foot that the freshwater lens stands above sea level (i.e. for each foot of "head"), the lens extends 40 feet below sea level to a midpoint where salinity is half seawater. A zone of mixture ("transition zone") grades upward to freshwater and downward to seawater. For example, if the freshwater head was found to be 20 feet above sea level, it can be reasonably estimated that the depth to the midpoint of the transition zone would be approximately 800 feet below sea level *(Figure D.2).*

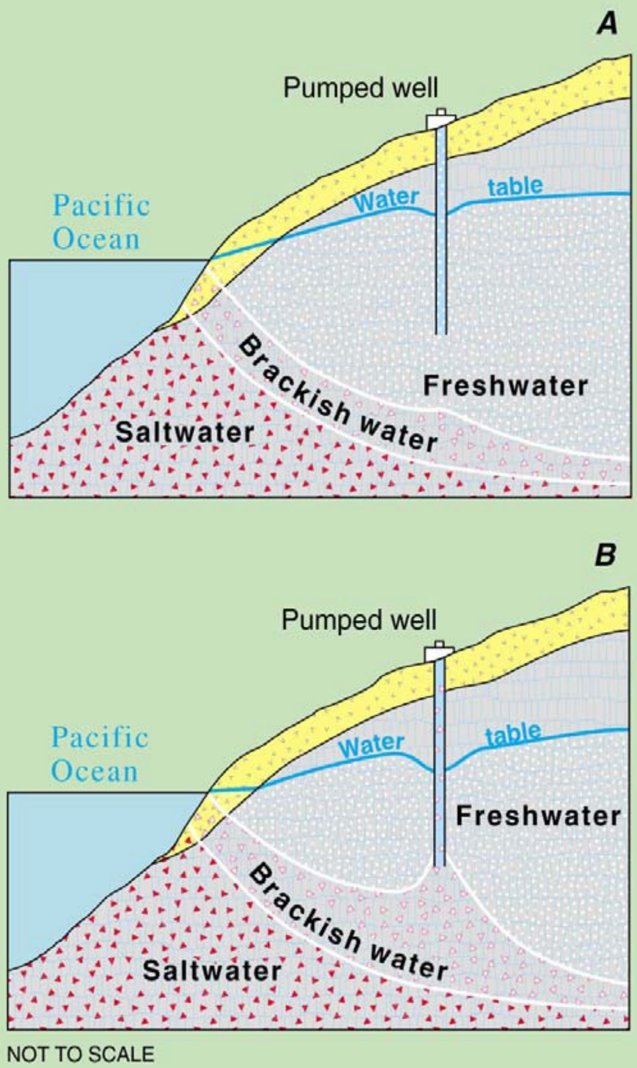
On O'ahu, the Leeward basal aquifers are much larger than the Windward basal aquifers. On the Windward side of the island, the dike complex makes this a much smaller or truncated lens *(Figure D.2).*

Basal waters can be either confined or unconfined. Since confined aquifers underlie the coastal plains, O‘ahu’s aquifers are mostly unconfined. Unconfined aquifers are where the upper surface of the saturated aquifer is not bounded. Confined aquifers are bounded by impermeable or poorly permeable formations.

In some coastal areas there is a relatively impermeable sediment sequence commonly called “caprock.” This caprock barrier tends to restrict the seaward flow of freshwater and causes the thickness of the freshwater lens to be greater than if the caprock were absent. Depending upon the effectiveness of the caprock, the resulting lens could range from local thickening of a relatively thin lens of a hundred feet to over 1800 feet. The amount of water stored in basal lens is significant. Water can be and is withdrawn from the basal aquifer for various uses but mainly for the island’s municipal water supply.

Where fresh and salt water merge, a brackish zone of the mixture forms. The movement of this transition zone, both horizontally inland from the seacoast and vertically upward, presents a constant potential danger of saline contamination to the freshwater portion of the system.

Utilization of brackish water sources for municipal supplies requires reduction of chlorides by blending and/or demineralization. Water containing more than 250 ppm of chloride ion is considered undesirable for drinking.[9] Although BWS prefers to distribute water containing less than 160 ppm, it will consider a higher level of salinity where appropriate to enhance opportunities for blending fresh and brackish water *(Figure D.3)*.



*Saltwater intrusion is a potential problem near the coast. (**A**) Diagram of a well completed in a volcanic-rock aquifer in which withdrawal is small. Only limited saltwater intrusion has taken place. (**B**) Diagram of the same well under conditions of large ground-water withdrawal. Pumping has lowered the water table and caused the freshwater lens to thin. Brackish water has reached the well.*

Figure D.3 Salt Water Intrusion (*Source: USGS Ground water in Hawai‘i*)

D.5.1.2 Dike Water

Water impounded behind impermeable dikes in the mountains is called "dike water," or "high- level water." Dikes are formed when molten magma intrudes and solidifies in conduits within the volcano's rift zone. These conduits may feed eruptions on the surface or may stay beneath the surface. Typically, they consist of nearly vertical slabs of dense, massive rock, generally a few feet thick, that can extend for considerable distances and cut across existing older lava flows. High level water impounded in permeable lavas occurring between dikes in the interior portions of O'ahu is of excellent quality and is generally hydrologically distinct from the basal water found in dike-free areas.

The dike water is not subject to saline contamination because of the high head of the water trapped between the dikes, distance from the sea, and the low permeability of the dikes which inhibits the lateral flow of seawater. However, water leaking through the dikes or overflowing, supplies the basal lens. The Waiāhole Tunnel complex relies on dike water.

Dike-impounded water may discharge at the ground surface where stream erosion has breached dike compartments. Once breached to the water table, the percentage of overall contribution to total stream flow depends on the head of the stored water, how deep the stream has cut into the high level reservoir, the permeability of the lavas between dikes, the size of the compartments as well as connections to other compartments, and the amount of recharge into the compartment that is breached.

In the northern portion of the Wai'anae region and on the windward side of the Ko'olau Range, dikes are exposed at or near sea level. Due to proximity to the ocean and lower head, freshwater within the dikes is in balance with underlying salt water and is classified as dike basal water. Dike basal water is found in windward O'ahu.

D.5.1.3 Perched Water

O'ahu has only minor perched water, but in a few small areas it has met minor supply demands. This type of water is "perched" on top of layers of impermeable material such as dense volcanic rock, weathered and solidified ash, or clay-bearing sediments. Discharge of perched water sometimes occurs as springs where the water table has been breached by erosion. Perched water supplies can be developed by tunnels or by constructing masonry chambers around spring orifices to collect flow and to prevent surface contamination. This type of water is of excellent mineral quality, and like most dike water, is free from seawater encroachment.

Another type of perched water is alluvial water, which is in limited quantities. Alluvial water is found in the more recent alluvial layers and remains perched because of older compacted alluvial layers below. Sometimes small wells can be productive in this area but generally the alluvium provides small amounts of water for O'ahu.

D.5.1.4 Caprock Water

The limestone in the caprock generally contains ground water. Caprock water is mostly brackish to saline. It is recharged from sparse local rainfall, return irrigation water and leakage of basal water bodies. Caprock water occurs around the island with the sizeable 'Ewa Caprock having the most appreciable amount of brackish water that is pumped and utilized. Caprock withdrawals are not counted against basal sustainable yields.

D.5.1.5 Brackish Water

Water occurring in the caprock, the basal water transition zone, and some basal springs comprises a large resource that is presently unused for municipal supplies due to excessive chlorides (salt) content. Chlorides range from just above recommended drinking water limits to that nearly of seawater.

D.5.1.6 Salt Water

Salt water exists in basal and caprock formations underlying the fresh and brackish aquifers. Salt water can be extracted with wells and used for aquaculture and to assist in building cooling systems. Salt water replaces the use of potable water for cooling towers in chilled water air conditioning systems.

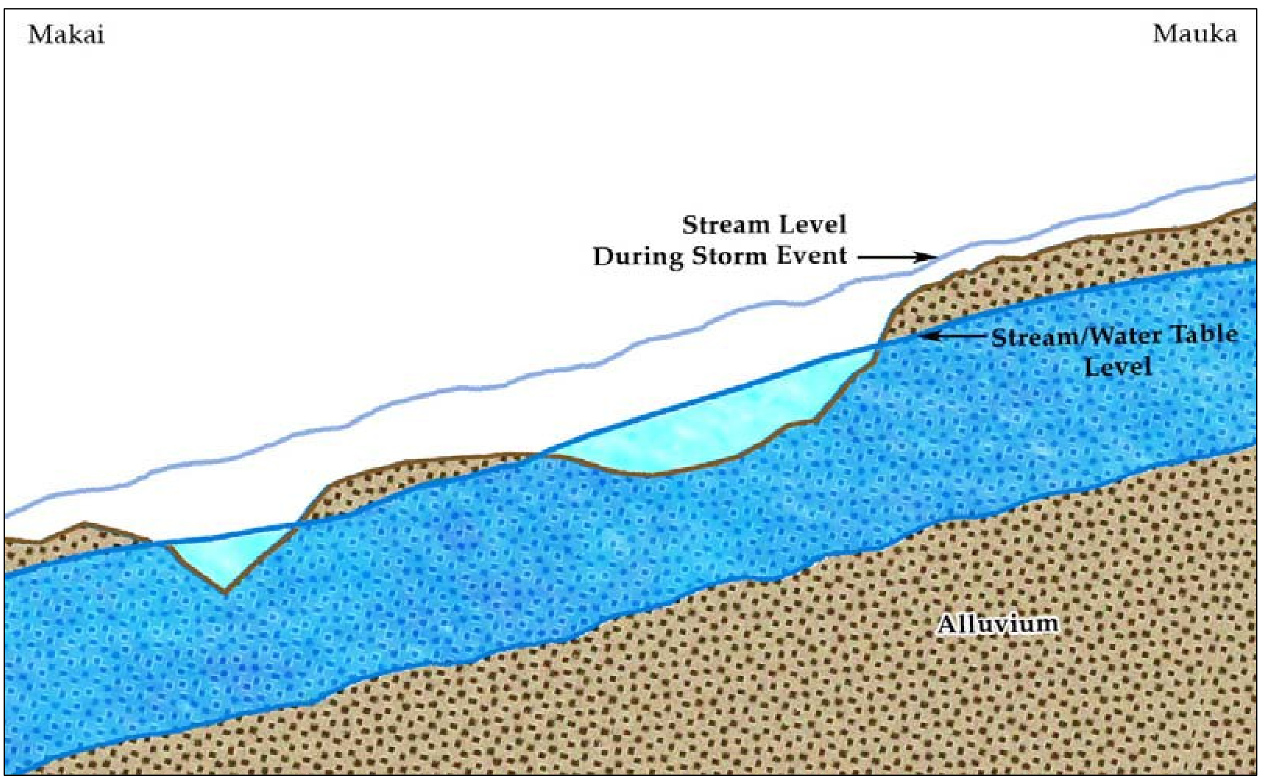


Figure D.4 Intermittent Streams During Wet and Dry Periods

D.5.2 Surface Water

Streamflow from O'ahu's perennial and intermittent streams is significant to agricultural pursuits and environmental and cultural values, especially on the windward side. Although the island is deeply incised by many stream valleys, the amount of perennial streamflow reaching the sea is comparatively low. Storm flows may be very heavy, but because of their short duration stream recharge may be slight.

On the leeward side of the island, streams are perennial in their headwaters because of high rainfall but intermittent in their lower reaches due to diversions, riparian vegetation, and porous ground conditions. Outflow of basal ground water as springs, especially in the Pearl Harbor area, maintains perennial streamflow near the shoreline. *Figure D.4* shows how areas with porous ground can make streams appear and disappear from the surface, but may be still be flowing beneath the surface.

Perennial streams by definition flow all year round. On O'ahu, they occur within the Ko'olau Mountain watersheds. These streams are sustained by high rainfall and leakage from high-level dike compartments. In addition, low permeability of the dike complex and small easily saturated compartments mean insignificant infiltration losses.

D.5.3 The Relationship between Ground and Surface Water

The aquifer systems in Windward O'ahu consist of basal aquifers, high level dike aquifers and dike basal aquifers, which are a combination of the first two. Three of the windward aquifer system areas – Waimānalo, Ko'olau Poko and Kahana – are generally considered to have a direct relationship between surface and ground water conditions. In Ko'olau Loa, the upper elevations of these dike areas intersect with streams. At lower elevations, surface water may be hydraulically separated from the basal and dike basal aquifers by layers of thick sediments.[10] Case by case test pumping is needed to verify localized site conditions.

The interactions between ground and surface water depend upon the location within a valley. *Figure D.5* shows two locations in a windward valley. Location A is high in the back of the valley and Location B is in the lower reaches of the valley.

At Location A, there is a relationship between ground and surface water as illustrated in *Figure D.6*, (Location A). This is a gaining stream reach, where the dike water supplies water to the stream, and therefore ground water withdrawals affect streamflow. Also, where tunnels tap dikes for water supply, streams can be affected because dike water levels have been lowered.

At Location B *(Figure D.6),* the stream water and ground water are not hydraulically connected. This is a losing stream reach where streamflow is not directly supplied by the basal ground water which occurs far below it. While shallow alluvial wells at this location may affect streamflow, basal well withdrawals of ground water will not. This is the case for the mouth of the valley in Windward O'ahu and for most locations in Leeward O'ahu *(Figure D.7).* The ground water and surface water relationship in the Ko'olau Poko Aquifer System Area will vary between different streams based on long-term well production experience and therefore, significant effects of ground water withdrawal on surface water should be evaluated on a case-by-case basis.

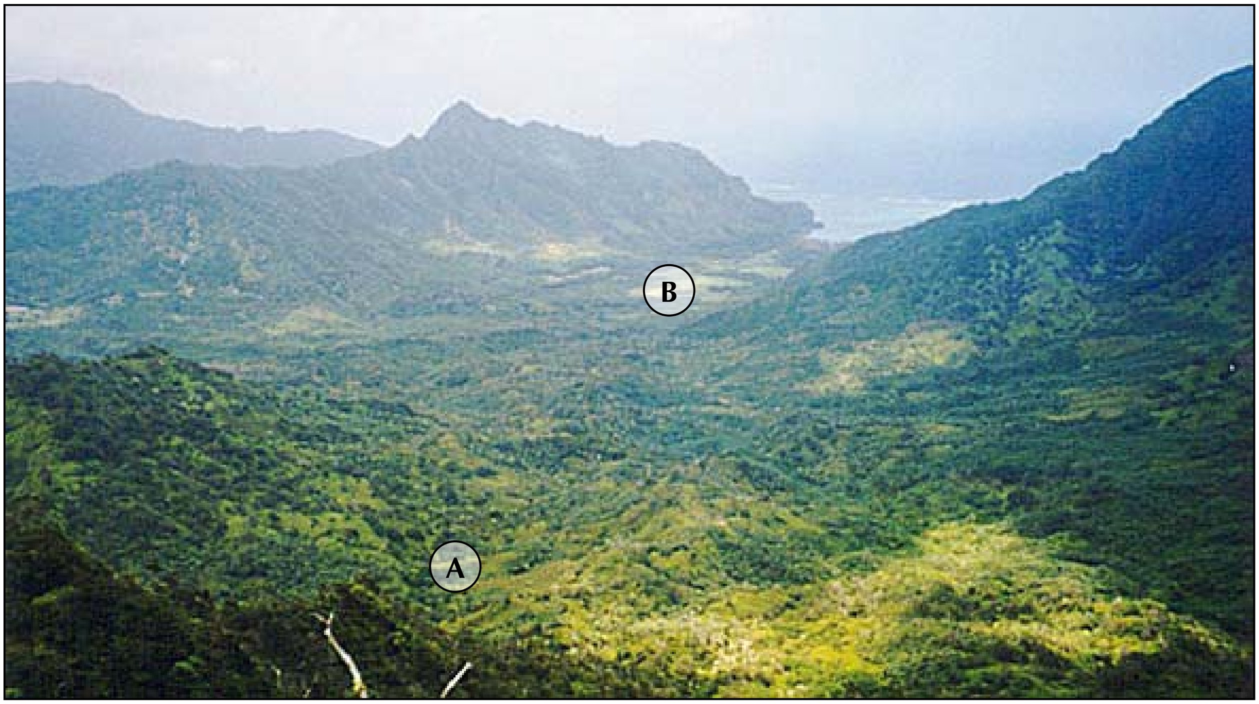
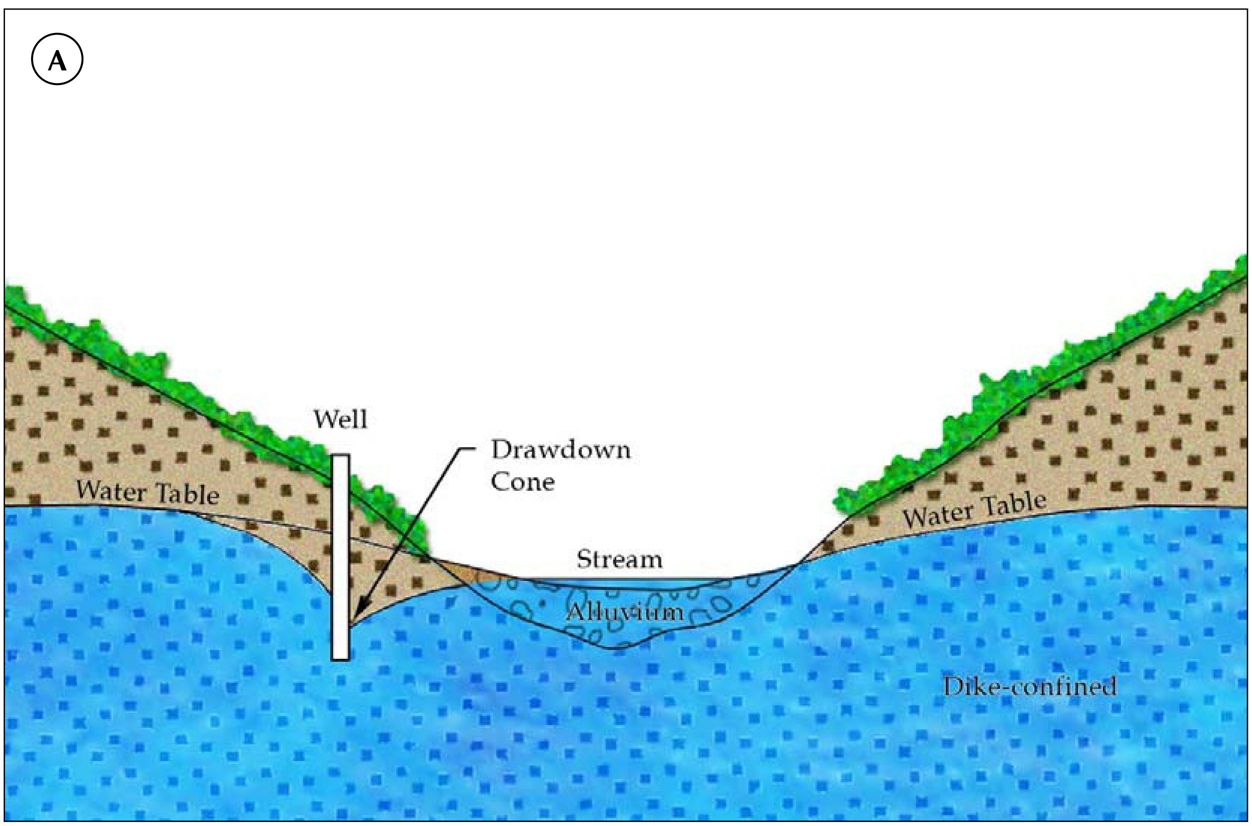
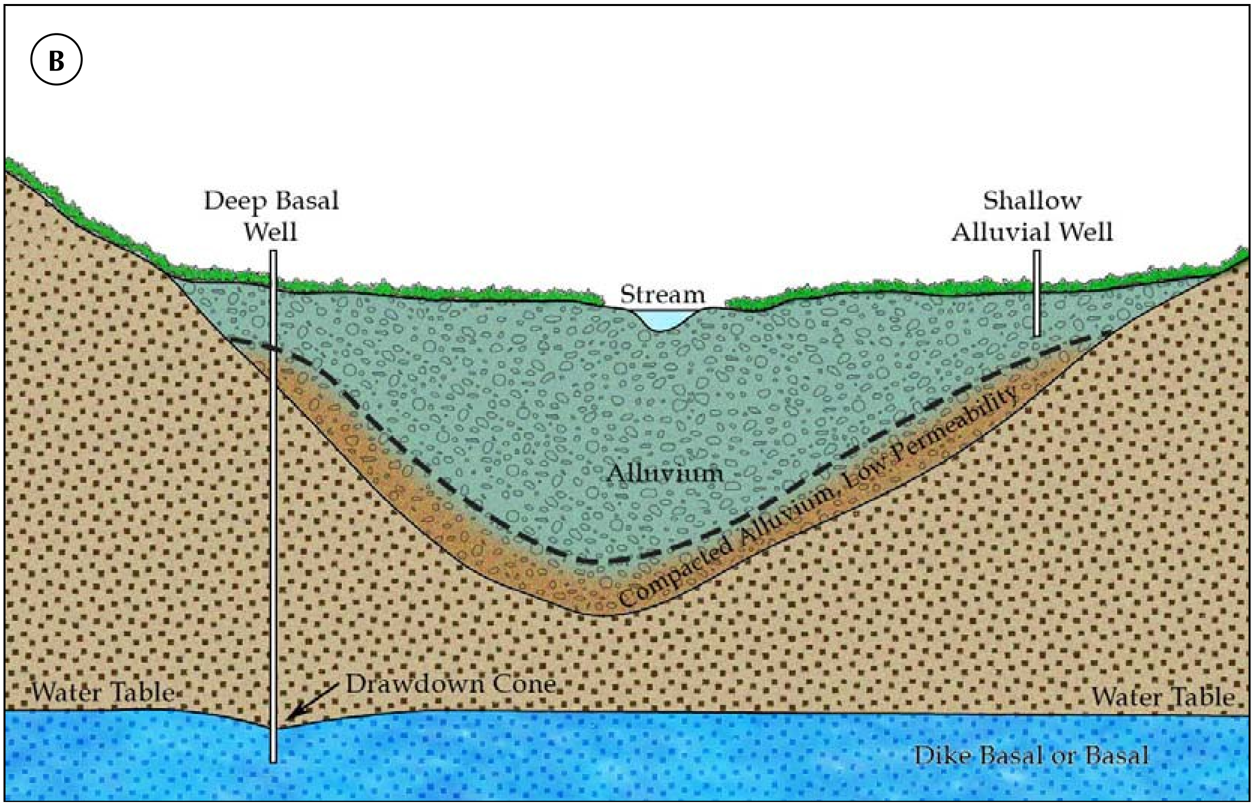


Figure D.5 Typical Windward Valley with Upper (A) and Lower (B) Elevation Stream Locations



Well Affecting Stream Flow



Basal Well **Not** Affecting Stream Flow
Alluvial Well Potentially Affecting Stream Flow

Figure D.6 Well/Ground Water Relationship

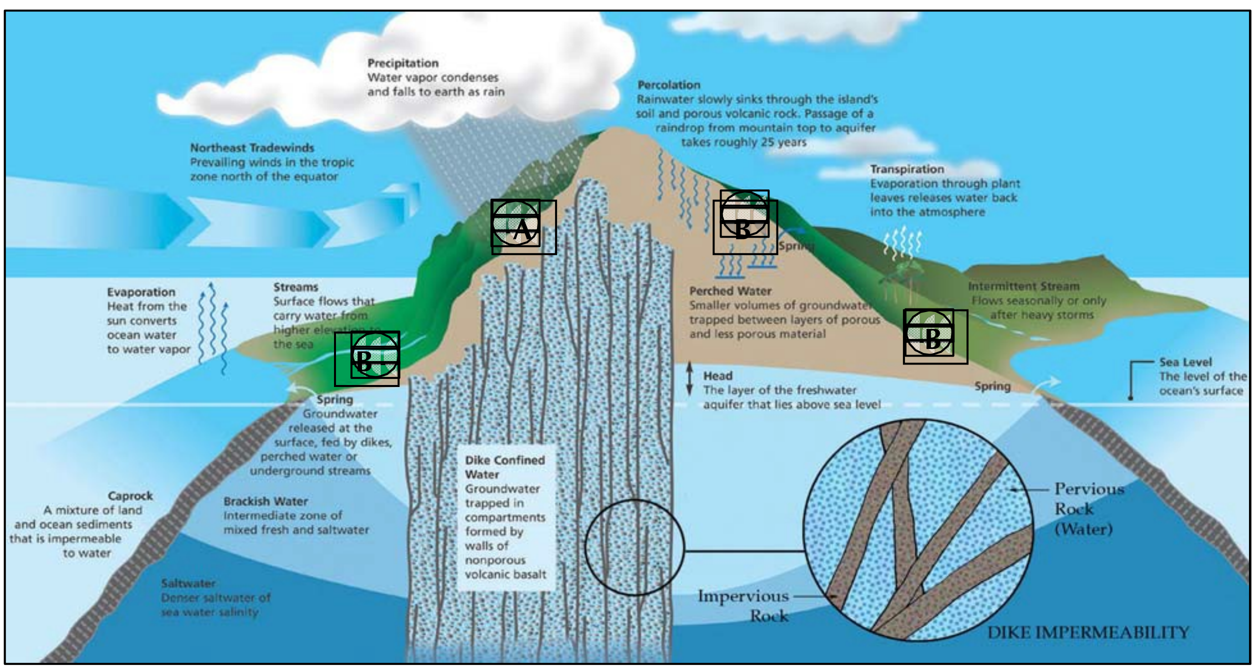


Figure D.7 Island Cross Section with Stream Type and Elevation Locations

D.6 SUSTAINABLE YIELD

Sustainable yields for all aquifer system areas have been adopted as part of the State Water Code's Water Resources Protection Plan (WRPP) and are used for resource management and protection. Sustainable yield is defined by the Hawai'i Administrative Rules as *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.*[11] The island is divided up into Aquifer Sector and System Areas which are management tools that do not imply non-communication or separate independent aquifer bodies. Aquifer Sector Areas generally define large geological boundaries such as rift zones, unconformities or differences in water levels. Aquifer Sector Areas reflect broad hydrogeological similarities and are generally bounded geologic structures, which incorporate topographic divides, such as Honolulu and Pearl Harbor aquifer sectors. Aquifer System Areas such as Waipahu-Waiawa and Waimalu are more specifically defined by ground water hydraulic continuity.

Figure D.8 shows the sustainable yields for the island of O'ahu for each Aquifer System Area. The sustainable yield numbers determined by CWRM are the maximum levels of withdrawal permissable for each Aquifer System Area. *Note: withdrawals affecting streams require amendments to the interim instream flow standards.*

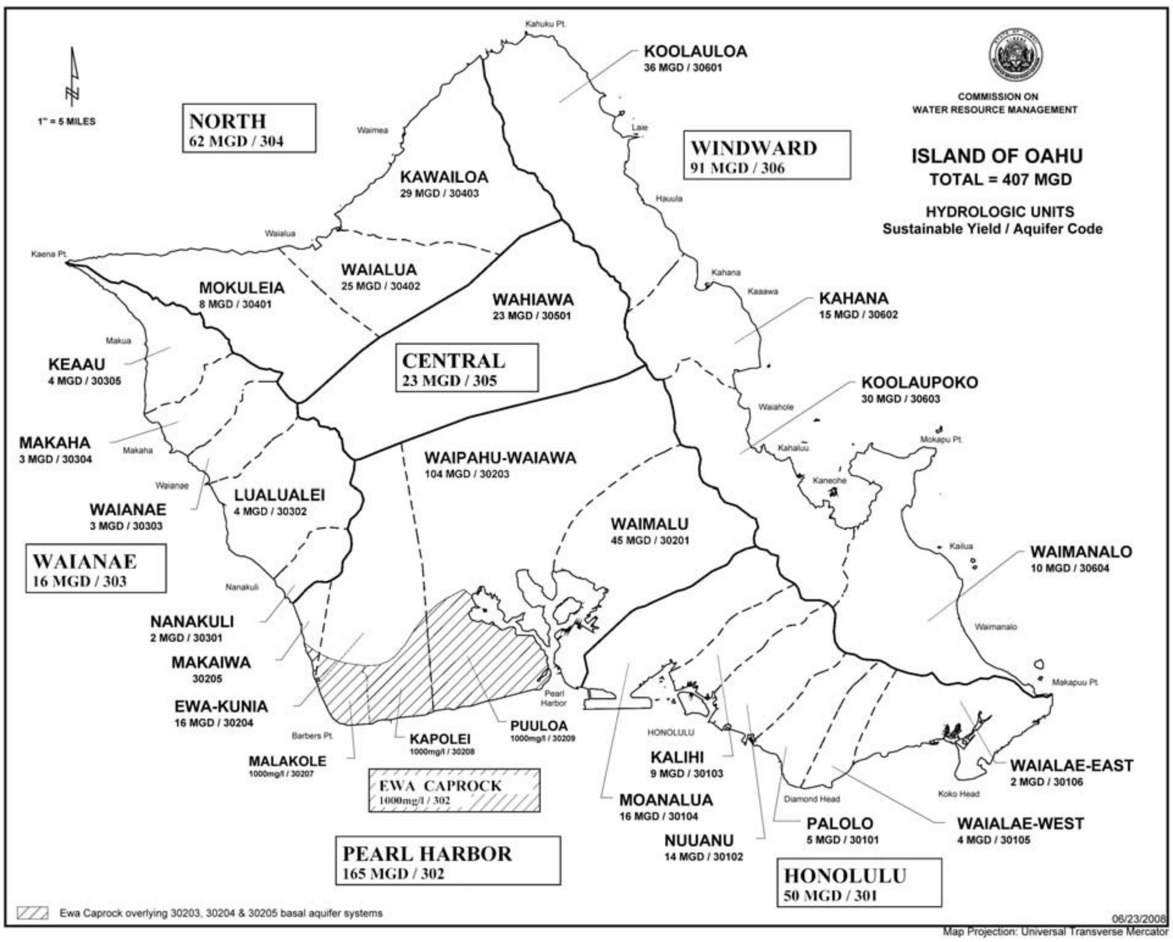


Figure D.8 Aquifer Sector and Aquifer System Area

The WRPP recommends that a periodic review of sustainable yields and pertinent hydrologic data and water quality parameters be done at least every five years (p. I-4). CWRM has periodically reviewed and modified sustainable yields for certain aquifer system areas based upon new information (1991 'Ewa-Kunia, 1993 Wahiawā and Pearl Harbor, 1997 'Ewa Caprock, and 2000 Waipahu-Waiawa and 'Ewa-Kunia).

The sustainable yields have been calculated with the water budget method using the widely accepted Robust Analytical Model (RAM). In August 2003 the CWRM updated the sustainable yields throughout the State using a modified RAM model calibrated to deep monitor well data where applicable. New 3-dimensional numerical ground water models calibrated with deep monitor well data may refine future estimates, but are costly and are only recommended as pumpage and permitted uses approach the adopted sustainable yield.

D.6.1 Recoverability of Sustainable Yield

Recoverability is the ability to feasibly extract ground water through wells or tunnels, up to the adopted sustainable yield. The recoverable amount of water is usually less than (or equal to) the CWRM sustainable yield estimate and is used to plan for uncertainty. Various factors affect the full recoverability of the adopted sustainable yield:

1. **Well spacing and pump size optimization:** In general, a higher level of recoverability can be achieved with many smaller wells spaced evenly throughout the aquifer system area, than fewer larger wells concentrated in a few locations. When pumping ground water, wells have an upconing effect where the saline water is drawn up toward the well *(Figure D.3)*. Even in areas where well pumpage is within the sustainable yield, this may occur because of factors such as total station pumpage and the vertical permeability of the rock. The upconing may progress to a point where salt water begins to come up into wells instead of freshwater. This localized upconing effect can be more pronounced when wells are clustered as show in *Figure D.9*. To avoid the upconing of saline water, wells can be more evenly distributed over the aquifer area as shown in *Figure D.9*.

2. **Surface and ground water interactions:** Full recoverability is affected if a portion of the sustainable yield impacts surface water. Kahana and Ko'olau Loa have dike formations (dike complex and marginal dike zones) near the crest and basal aquifers near the coast. Surface and ground water interactions are more likely in dike formations. Ground water development in the basal formations usually does not have an effect on stream flows. Stream impacts from ground water development are evaluated on a case-by-case basis. Interim instream flow standards as well as appurtenant rights, riparian rights, and existing instream uses directly affect the availability of the portion of ground water interacting with surface water and require the approval of the CWRM.

3. **Separate hydro-geological formations:** The adopted sustainable yields provide a gross estimate for the entire aquifer system area assuming a single homogeneous geologic formation, and do not specifically account for the yields of each of the separate hydro- geological formations within the aquifer system, such as dike, basal, alluvial or caprock formations. CWRM does not count caprock withdrawals against sustainable yields, but does count alluvial withdrawals. In the sustainable yield calculations, residual rainfall is assumed to recharge the basal aquifer formed by alluvium and other geologic formations. Perched aquifers divert recharge from the underlying basal aquifer with the result that sustainable yields are lower from some areas. The hydraulic interaction between these geologic formations is not fully understood, estimated or readily measurable and affect recoverability.

4. **Extended Drought:** Extended drought impacts all water resources and affects recoverability. Oʻahu experienced an extended, multi-year drought from 1998-2003 where rainfall averaged between 60% and 80% of normal levels and several source yields eventually dropped below permitted use. Dike sources declined first due to smaller storage volume compared to basal sources. These six straight years of drought were unprecedented in over 100 years of rainfall record. Sustainable yield and permitted use are based on averages, and BWS basal ground water sources can usually sustain permitted use levels through 3-4 years of drought depending on severity and max day demand.

5. **Municipal Infrastructure Cost:** The cost of infrastructure continues to rise and can affect recoverability in the following ways:
   a. ***Cost*** considerations limit the number of wells and length of connecting pipelines. Exploratory wells in dike and alluvial formations are risky due to potentially low yields and potential affects to IIFS.
   b. ***Land constraints*** such as steep terrain or urbanization can make potential well development infeasible due to high costs.
   c. In general, the higher the uncertainty from the factors noted above, the higher the **financial risk** and the less likely full recoverability will be achieved. However, water may be feasibly extracted through small on-site wells for private water systems.

D.6.2 Waiāhole Management Area

The approximately 25-mile long ditch stretching from Kahana Valley to Kunia was constructed to transport water from windward streams and springs to irrigate sugar cane fields on the drier leeward side *(Figure D.10).* Initial construction on the Waiāhole Ditch and Tunnel System (Waiāhole Ditch) took place between February 1913 and December 1915. During construction, large amounts of dike-impounded ground water were encountered at the high elevations (between approximately 700 to 800 feet elevation) at which the transmission tunnels were being bored, and subsequent extensions of the tunnel system during 1925 to 1933 and again in 1964, have resulted in a system that currently collects mostly dike-impounded ground water. Development of these dike-impounded waters that previously fed Waiāhole (and its tributary Waianu), Waikāne and Kahana Streams through springs and seeps resulted in diminished flows in these streams.

The State CWRM has determined that the Waiāhole Ditch develops an average of 27 mgd, consisting of 23.3 mgd measured at the North Portal, which is directly underneath the crest of the Ko'olau Mountains, and an additional 3.7 mgd is developed on the leeward side measured at Adit 8, where the Waiāhole Ditch surfaces in Waiawa.

The development tunnels of the Waiāhole Ditch system include the Kahana Tunnel (1.1 mgd after bulkheading), Waikāne #1 Tunnel (4.2 mgd), Waikāne #2 Tunnel (1.1 mgd), Uwau Tunnel (13.5 mgd) and the Main Bore from the North Portal to Adit 8 (3.7 mgd). The remaining flows are captured in the ditch between Kahana and the North Portal averaging 3.4 mgd for a total of approximately 27 mgd.

As of 2006, CWRM has authorized a total of 15 mgd available for non-instream uses through water use permits, of which a total of 12.57 mgd has been allocated for leeward uses. 12 mgd of water was added to the Kahana, Waikāne, Waianu and Waiāhole Streams.[12]

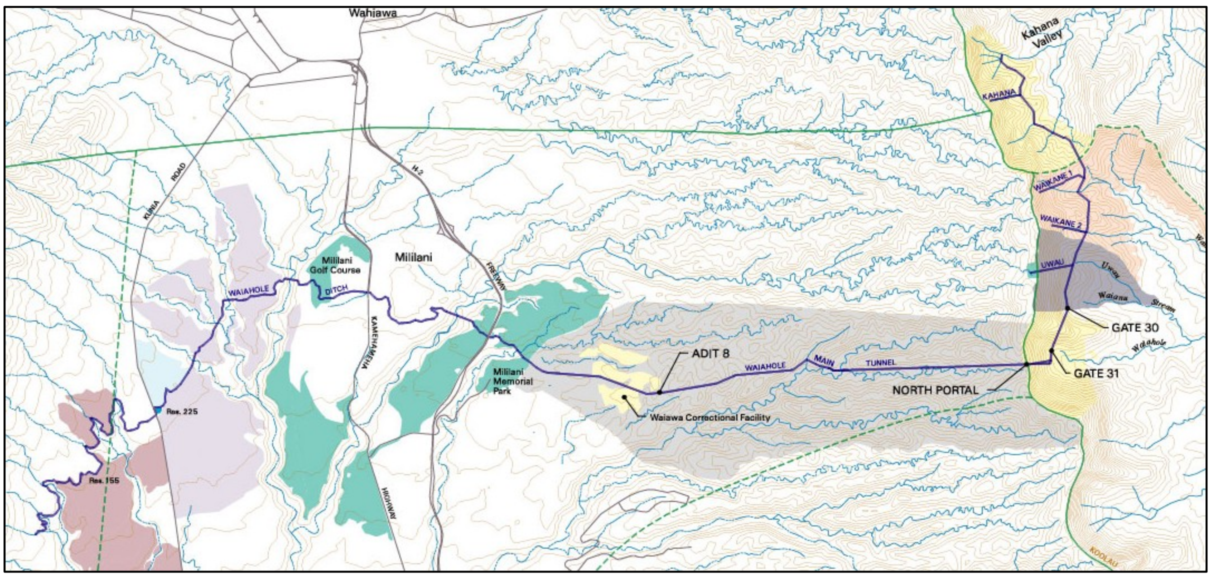


Figure D.10 Waiāhole Ditch System (*Source: CWRM)*

D.7 INSTREAM FLOW STANDARDS

Instream flow standards (IFS) are similar to sustainable yields for ground water, in that their establishment provides a management system that protects the resource and cultural uses while allowing for possible non-instream water use. The State Water Code defines instream flow standards as *"the quantity or 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."*[13] The instream flow standards need to consider the best available information in assessing the range of present or potential instream and non-instream uses. The Hawai'i Administrative Rules lists instream and non-instream uses to be considered *(Figure D.11).* The figure shows the complexity involved in assessing instream and non-instream water uses and there are 87 surface water hydrologic units on O'ahu. The CWRM is working to develop a methodology for amending instream flow standards.

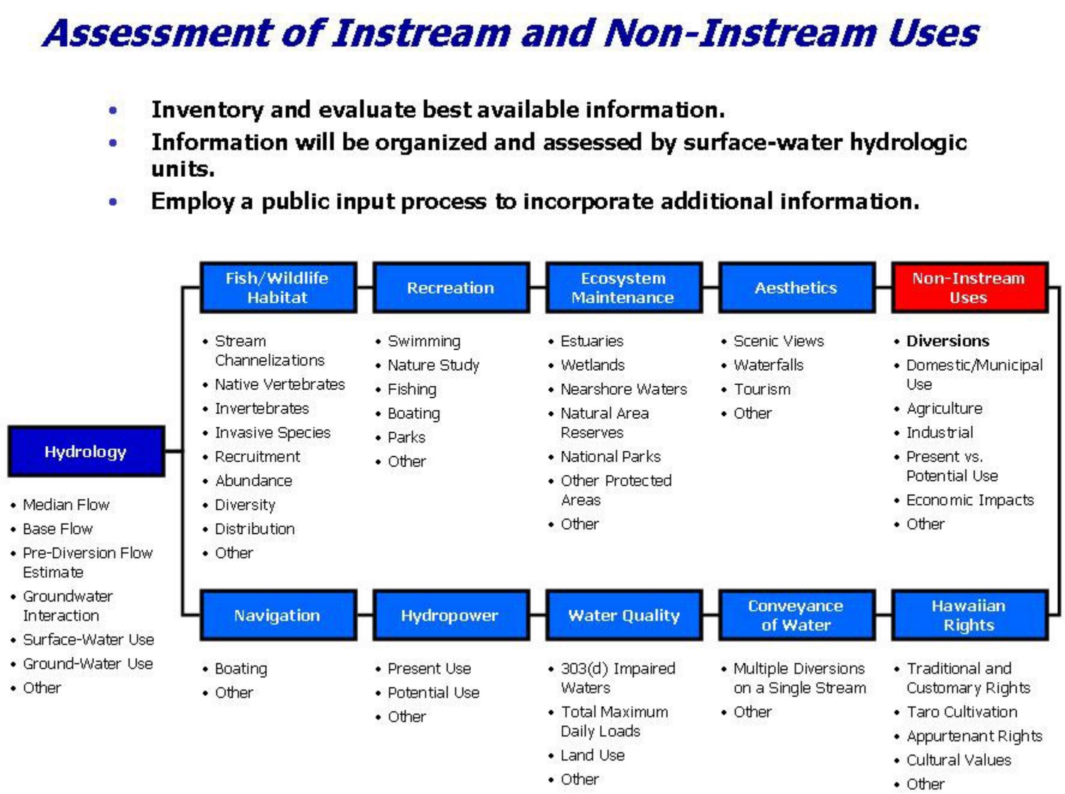


Figure D.11 Information to Consider in Setting Measurable Interim Instream Flow Standards (*Source: CWRM Presentation to Water Commission, June 2006)*

The current instream flow standards for O'ahu streams are called interim IFS and are based on the *"amount of water flowing in each stream on the effective date of the standard without further amounts of water being diverted off-stream through new or expanded diversions."* The effective dates are December 10, 1988 for Leeward O'ahu and May 4, 1992 for Windward O'ahu.[14] In the Waiāhole Contested Case Hearing, the CWRM recognized that *"retaining the status quo (through the adoption of the previous interim standards) helped to prevent any future harm to streams while the scientific basis for determining appropriate measurable instream flow standards is developed and an overall stream protection program put into place."*[15] The stream flows and diversions were not quantified in the standard, however users of surface water and ground water were required to register their uses with CWRM.

In an effort to approximate current water usage, and in accordance with the State Water Code and Chapter 13-168-31, HAR, the CWRM initiated the Registration of Stream Diversion Works and Declarations of Water Use (Registration) process in 1989. This process required the owner or operator of any stream diversion works to register with the CWRM. In September 1992, the Commission released a final report summarizing the findings of the Registration process for both ground and surface water. These reports are referred to as the Declaration of Water Use, Volume I (Declarations Summarized by File Reference) and Volume II (Location Data Sorted by Tax Map Key). The Declarations of Water Use provide a qualitative description of water use, but also includes a number of declarations comprised of claims for water rights, proposed future uses of water, and instream uses.[16]

Table D.1 Amended O'ahu Interim Instream Flow Standards

Stream	1960s Streamflow	Amended Interim Instream Flow Standard	Percent Increase
Waiāhole	3.9 mgd	8.7 mgd	124%
Waianu	0.5 mgd	3.5 mgd	600%
Waikāne	1.4 mgd	3.5 mgd	150%
Kahana	11.2 mgd	13.3 mgd	19%

The CWRM amended the interim instream flow standards for four windward streams - Waiāhole, Waianu, Waikāne and Kahana have been established via the *Findings of Fact, Conclusions of Law, and Decision and Order on Second Remand in the matter of water use permit applications, petitions for interim instream flow standard amendments, and petitions for water reservations for the Waiāhole Ditch Combined Contested Case Hearing (CCH-OA95-1) on July 13, 2006 (Table D.1).*

The 1989 Registration process provided a baseline of current surface water diversions at that time. However, any new diversions constructed or existing diversions altered after the effective dates of the standards are subject to the Commission's regulatory permitting requirements. In essence, surface water diversions that were registered as part of the CWRM's Registration process and currently remain in use can continue to be utilized. Any person wishing to construct a new stream diversion or alter an existing diversion structure is required to obtain a Stream Diversion Works Permit from CWRM. As a result, construction or alteration of structures constitutes an alteration to the stream channel. Therefore, a Stream Channel Alteration Permit is also required (Chapter 13-169-50, HAR). In addition, any change to the instream flow that may result from the constructed or altered diversion requires a Petition to Amend the Interim Instream Flow Standard (Chapter 13-169-40, HAR). Owners of stream diversion works wishing to abandon or remove their diversion structures are also required to obtain a permit from CWRM (Chapter 13-168-35, HAR).

ENDNOTES

1 Atlas of Hawai'i, 1983

2 US Census, 2000

3 O'ahu Water Management Plan Technical Reference Document, March 1990

4 Groundwater in Hawai'i. USGS, FS 126-00

5 State of Hawai'i Agricultural Water Use and Development Plan, December 2003

6 Climate Change and Water Resources: A Primer for Municipal Water Providers by Kathleen Miller and David Yates National Center for Atmospheric Research, American Waterworks Assoc. Research Foundation Publication

7 Rising Sea Levels, Sunny Lewis, Hawai'i Public Radio, July 19, 2006

8 Atlas of Hawai'i, Third Edition, 1998

9 Groundwater in Hawai'i. USGS, FS 126-00

10 Report on the Hydrologic Investigation of Groundwater and Surface Water Conditions in the Windward O'ahu Water Management Area, 1990

11 Water Resources Protection Plan, CWRM, June 1990.

12 Waiāhole Ditch Contested Case

13 State Water Code Section 174-C 3

14 HAR Section 13-169-49 and 49.1

15 Waiāhole Ditch Contested Case

16 Declarations of Water Use, September 1992, State Commission on Water Resource Management

E WATER FORECASTING

E.1 INTRODUCTION
E.2 LOW-GROWTH SCENARIO
E.3 MID-GROWTH SCENARIO
E.4 HIGH-GROWTH SCENARIO
E.5 ULTIMATE SCENARIO
E.6 BWS ISLAND-WIDE DEMAND METHODOLOGY

E.1 INTRODUCTION

Assumptions and methods used in estimating North Shore water demand through the year 2035 and beyond are described in this appendix. The projections, estimated future water needs, assist in planning for future water needs and in determining when infrastructure improvements may be required.

Existing use is based on data from 2010, when available. The base year of 2010 was chosen as it corresponds to 2010 US Census population statistics. BWS existing use is from 2010 metered consumption records and U.S. Census figures were used to determine the population served. The year 2010 was a below normal rainfall year and as a baseline year provides more conservative numbers for planning purposes than a year with normal rainfall. When 2010 data was not available, other available water use information was used.

The Statewide Framework recommends including *"a range of forecasts of the amount of water required over the planning horizon… Among the scenarios are the base case scenario, a high-growth scenario and a low-growth scenario."* The low, mid and high future water use scenarios for the North Shore project limited population growth based on the City and County of Honolulu's (City's) Population Projections, published in September 2009. These are in accordance with the *North Shore Sustainable Communities Plan* (NSSCP) that describes the City's land use and growth policies for the district. Projections reflect the policies set forth in the NSSCP and were made in five year increments through the year 2035. In addition, an "ultimate" water demand scenario for the North Shore is calculated to aid in long-term planning.

For the North Shore, urban development is a small portion of the total land and water use and population growth is expected to be limited. A substantial amount of North Shore land is available for agricultural production. Therefore, agricultural activity is assumed to be the main variable for future water use. Recent displacement of farmers from the 'Ewa Plains and food security and sustainability movements may affect the rate at which agricultural production increases in the future.

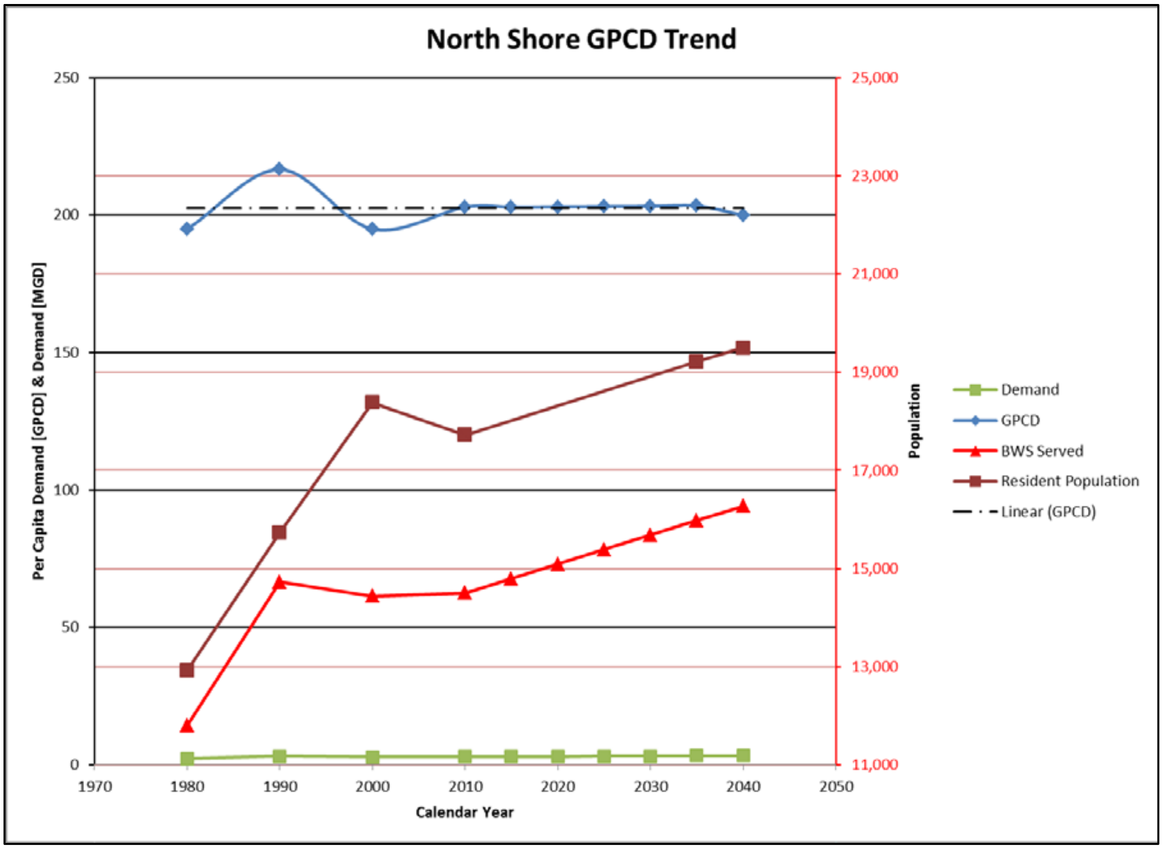


Figure E.1 North Shore Gallons Per Capita Demand Trend

Figure E.1 shows the BWS North Shore water system trend of per capita demand, resident population, BWS served population and water demand historical from 1980 to 2010 and forecasted to 2040. While population is expected to increase, water demand will remain relatively flat due to continuing conservation efforts. With new FDA food safety rules, BWS expects new potable agricultural meters in increase in the future and additional conservation strategies for agriculture will need to be implemented.

In *Table E.1* are the population projections for the low, mid and high scenarios for the North Shore. These projections provide the basis for calculating the water demands for domestic uses on the North Shore.

Table E.1 North Shore Population Projections

Scenario	2010	2015	2020	2025	2030	2035
Low-Growth[1]	17,720	17,901	18,082	18,262	18,443	18,624
% of O'ahu population	1.9%	1.8%	1.8%	1.8%	1.8%	1.7%
Mid-Growth[2]	17,720	18,325	18,770	19,126	19,375	19,517
% of O'ahu population	1.9%	1.9%	1.9%	1.9%	1.8%	1.8%
High-Growth[3]	17,720	18,317	18,915	19,512	20,110	20,707
% of O'ahu population[4]	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%

1 Low-Growth Scenario: Approximately half of the *City and County of* Honolulu Department of Planning and Permitting *Socioeconomic Projections* (September 2009)
2 Mid-Growth Scenario: *City and County of Honolulu Department of Planning and Permitting Socioeconomic Projections* (September 2009)
3 High-Growth Scenario: Population projection based on historical population trends (1990-2010)
4 O'ahu projected population (used to calculate the % of O'ahu population) is from the DBEDT's Population and Economic Projects for the State of Hawai'i to 2040 (http://dbedt.hawaii.gov/economic/economic-forecast/2040-long-range-forecast/)

E.2 LOW-GROWTH SCENARIO

The low-growth scenario assumes a population growth at slower rate than the City's projected population increases and a modest rate of growth for increases in agricultural irrigation.

E.2.1 Low-Growth Scenario: Domestic Water Systems

The domestic water demands were calculated using a per capita approach which applies a water use factor to the population served. The per capita (per person) demand is assumed to remain constant throughout the planning period.

Table E.2 shows the population projections for the populations served by various domestic water systems on the North Shore.

The per capita demand for the North Shore BWS system in 2010 was 203 gallons per capita per day (gpcd). The population served by domestic water systems was calculated by adding the visitors present in North Shore and subtracting the residents absent and the population served by private water systems. The North Shore BWS per capita demand was used for the various domestic water systems as it is the largest system.

Table E.2 North Shore Low-Growth Scenario Population Projections

	2010	2015	2020	2025	2030	2035
Resident Population[1]						
North Shore	17,720	17,901	18,082	18,262	18,443	18,624
O'ahu	955,775	976,190	1,003,710	1,029,410	1,052,130	1,071,220
North Shore % of O'ahu	1.9%	1.8%	1.8%	1.8%	1.8%	1.7%
Residents Absent[2]						
O'ahu	53,747	54,780	58,050	60,950	63,730	66,360
North Shore	996	1,005	1,046	1,081	1,117	1,154
Visitor Units[3]						
North Shore	53	48	44	48	48	49
O'ahu	34,040	34,040	34,760	35,950	37,070	38,270
North Shore % of O'ahu	0.16%	0.14%	0.13%	0.13%	0.13%	0.13%
Visitors Present[4]						
O'ahu	86,288	95,390	98,280	101,640	104,810	108,190
North Shore % of O'ahu	0.16%	0.14%	0.13%	0.13%	0.13%	0.13%
North Shore	134	133	124	134	134	139
De Facto Population[5]						
North Shore	16,858	17,029	17,160	17,315	17,460	17,610
O'ahu	988,316	1,016,800	1,043,940	1,070,100	1,093,210	1,113,050
North Shore % of O'ahu	1.7%	1.7%	1.6%	1.6%	1.6%	1.6%
Population Served by Private Water Systems[6,7]						
Dole	0	633	633	633	633	633
North Shore Water Company	5805	580	580	580	580	580
Population Served by BWS[7,8]						
North Shore	13,864	13,403	13,534	13,689	13,834	13,984

1 Population numbers are from City's population projections (September 2009) and are based on policies articulated in the North Shore SCP. Here the growth is 50% of that expected by the projections.

2 Total residents absent for Honolulu County is from State DBEDT, which provides a "residents absent" figure for Honolulu County as a whole. The number of residents absent from North Shore is based on North Shore's proportion of Honolulu County's population.

3 Visitor units are from the 2010 Visitor Plant Inventory (http://files.hawaii.gov/dbedt/visitor/visitor-plant/2010VPI.pdf) and percent increases and decreases are based on the City DPP projections for visitor accommodation units (September 2009).

4 Total visitors present for Honolulu County are from State DBEDT, which provides a "total visitors" figure for Honolulu County as a whole. The number of visitors present in North Shore is proportional to North Shore's percentage of Honolulu County visitor units.

5 De Facto Population = Resident Population – Residents Absent + Visitors Present.

6 There is also US Army/State DOT water system at Dillingham Airfield which is not included in the population numbers. No change is expected and existing pumpage is carried forward in the projections.

7 Helemano Military Reservation is included in the Central O'ahu Watershed Management Plan.

8 BWS-Served Population = De Facto Population – Population Served by Other Domestic Water Systems

The *per capita* water use coefficient was then applied to the projected population for the low-, mid-, and high-growth scenarios to estimate future domestic water system demands in five-year increments through the year 2035. Private water demands for the North Shore Water Company and Dole Foods domestic water systems are expected to remain the same, as is the demand for the US Army/DOT Dillingham Airport. The BWS water system demand is projected to increase with the projected population increases *(Table E.3).*

Table E.3 North Shore Low-Growth Scenario Domestic Water System Projections

Domestic Water Systems	2010	2015	2020	2025	2030	2035
BWS	2.815	2.721	2.747	2.779	2.808	2.839
Dole	0.000	0.128	0.128	0.128	0.128	0.128
North Shore Water Company	0.118	0.118	0.118	0.118	0.118	0.118
US Army/State DOT Dillingham Airport	0.055	0.055	0.055	0.055	0.055	0.055
TOTAL	**2.987**	**3.022**	**3.049**	**3.080**	**3.110**	**3.140**

1 The Federal (US Army/DOT) domestic water system for Dillingham airport will continue with status quo.

E.2.2 Low-Growth Scenario: Agricultural Water Systems

Current diversified agriculture water demands were calculated based on current acreage in agricultural production. Water use was then estimated based on acres served and type of use (diversified agriculture, pineapple, and kalo).

The baseline for agricultural acreage is 6,000 acres of diversified agriculture and 2,500 acres of pineapple as reported in the O'ahu Agriculture: Situation, Outlook and Issues (2011). The 8,500 acres equals approximately 39% of the total Agricultural Lands of Importance to the State of Hawai'i (ALISH) Prime and Unique rated lands in the North Shore *(Figure E.5).* For the low-growth scenario, the increase in diversified agricultural acreage was based on the DPP projections for agriculture employment *(Table E.4).* This increase in diversified agriculture acreage for the North Shore was equal to an annual 0.4% increase with some 5-year intervals experiencing no growth and others periods experiencing upwards of 4% growth *(Table E.4).* The growth factor from *Table E.4* was applied to the existing diversified acreage to project increase under this low-growth scenario.

Table E.4 Percent Increases in Agriculture: Low-Growth Scenario

	2010	2015	2020	2025	2030	2035
Agriculture Employment[1]	210	219	219	225	225	230
Percent Increase		4.3%	0%	2.7%	0%	2.2%

1 DPP Employment Projections (September 2009)

Water demand for diversified agriculture was calculated by multiplying the projected agricultural acreage for each five-year increment by the appropriate water demand factor *(Table E.5)*. For diversified agriculture, a water demand factor of 3,400 gallons per acre per day (gpad) from the 2004 Agricultural Water Use and Development Plan is used.

The water demand factor for pineapple of 1,500 gpad is slightly higher than the University of Hawai'i College of Tropical and Human Resources estimated irrigation levels as around 1,500 gpad has been historically been applied. The pineapple land area and water demands are assumed to remain at present levels into the future.

The diversified agriculture and pineapple water demand factors are field application rates and do not include systems loss factors that occur before reaching the field.

Irrigated pasture lands are included in the diversified agriculture water demands acreage. When pasture lands are irrigated, they are intensely managed and the rate of irrigation is very similar to diversified agriculture water rates. North Shore pasture lands that are irrigated are predominately for horses and total a little over 200 acres

Table E.5 Water Demand for Agriculture-Low Scenario

	2010	2015	2020	2025	2030	2035
Diversified Agriculture						
Area (acres)	6,000	6,257	6,257	6,429	6,429	6,571
Water demand (mgd)[1]	20.4	21.3	21.3	21.9	21.9	22.3
Pineapple						
Area (acres)	2,500	2,500	2,500	2,500	2,500	2,500
Water demand (mgd)[2]	3.8	3.8	3.8	3.8	3.8	3.8
Total						
Water demand (mgd)	24.2	25.0	25.0	25.6	25.6	26.1

1 Water use factor of 3,400 gpad was used for diversified agriculture.
2 Water use factor of 1,500 gpad was used for pineapple.

Water demand for wetland kalo farming was calculated separately because it requires substantially more water than diversified agriculture. Lo'i kalo on the North Shore are served primarily by springs.

Previous studies on the amount of water needed to support healthy kalo fields document a wide range of inflow volumes.[1] These studies, as well as discussions with several kalo farmers, indicate that a general range of 100,000 to 300,000 gad of inflow is needed *(Table E.6)*. Some of the factors that affect lo'i kalo water demand include:

- Temperature of the water in the stream at the point of diversion
- Time of year (season)
- Acres of kalo in each particular stage of growth: fallow, recently planted, growing, and ready to harvest
- Location and size of other diversions upstream of a particular user

Of these factors, water temperature is one of the most critical. Water temperature is itself affected by several factors, including the volume of water in the stream, the length of the stream, the location along the stream, and riparian vegetation cover.

Table E.6 Water Demand Factors Used in Calculating Loʻi Kalo Water Demand

Water Demand Factor in gallons per acre per day (gpad)	Source
100,000 – 300,000	Available kalo water use studies[1].

[1] Available kalo water use studies include USGS 2007 "Report on Water Use in Wetland Kalo Cultivation in Hawaiʻi"; Office of Planning 1995 "Preliminary Assessment of Potential Water Demand for Economic and Instream Uses in the Waiāhole-Kualoa Region," and the "Agricultural Water Use and Development Plan" produced by the State DOA, Penn, D.C. 1997 dissertation on "Water and Energy Flows in Hawaiʻi Taro Pondfields," Watson, L. J. 1964 "Observations made with respect to irrigation and growth of taro at certain patches at Waiāhole and Kahaluu, and Miles, K. 1931 "Report on study of water requirements of taro in Hanapēpē Valley, cooperative study by the Territory of Hawaiʻi and McBryde Sugar Company: ʻEleʻele, Hawaiʻi.

100,000 gpad is used for planning purposes in estimating future water demands for North Shore. While a greater flow is ideal for ensuring healthy kalo, several factors, including appropriate water management, could reduce the needed water flow to 100,000 gpad. Kalo water demand factor was multiplied by the projected loʻi acreage to calculate water demand for the given year.

wetland kalo water demand = acres of loʻi kalo X 100,000 gpad

Expansion of loʻi kalo was based on various assumptions for a low-, mid-, and high-growth scenarios. Currently there are about 10 acres of loʻi kalo on the North Shore. The low-growth scenario assumes only maintenance of the current number of loʻi kalo acres at current water availability.

Table E.7 provides the water demand for loʻi kalo for the North Shore in the low-growth scenario.

Table E.7 Water Demand for Loʻi Kalo Served (Low-Growth Scenario)

	2010	2015	2020	2025	2030	2035
Acres of loʻi kalo	10	10	10	10	10	10
Water demand factor (gpad)	100,000	100,000	100,000	100,000	100,000	100,000
Water demand (mgd)[1]	1.0	1.0	1.0	1.0	1.0	1.0

[1] Loʻi kalo water demand was calculated by multiplying the projected acres of loʻi kalo by the water demand factor of 100,000 gpad.

Table E.8 summarizes the water demand for the North Shore in the low-growth scenario (excluding loʻi kalo demand shown above).

Table E.8 North Shore Water Demand, Low-Growth Scenario

Low-Growth Scenario Water Systems	Base Year	Projected				
	2010	2015	2020	2025	2030	2035
Domestic Water Systems Demand						
BWS	2.81	2.72	2.75	2.78	2.81	2.84
Dole	0.00	0.13	0.13	0.13	0.13	0.13
North Shore Water Company	0.12	0.12	0.12	0.12	0.12	0.12
US Army/State DOT Dillingham Airport	0.06	0.06	0.06	0.06	0.06	0.06
Total Domestic Water Systems Demand	**2.99**	**3.02**	**3.05**	**3.08**	**3.11**	**3.14**
Agriculture Water Demand						
Diversified Agriculture	20.40	21.27	21.27	21.86	21.86	22.34
Pineapple	3.75	3.75	3.75	3.75	3.75	3.75
Total Water Agriculture Water Demand	**24.15**	**25.02**	**25.02**	**25.61**	**25.61**	**26.09**
Total Water Demand	**27.14**	**28.05**	**28.07**	**28.69**	**28.72**	**29.23**

E.3 MID-GROWTH SCENARIO

The mid-growth population scenario is an estimate of water demand based on the policies set forth in the North Shore Sustainable Communities Plan (SCP) and the DPP population projections (September 2009) that reflect the SCP policies *(Table E.1).* The Sustainable Communities Plan emphasizes limited growth for the North Shore and preservation of open space and agricultural lands.

Acreage for diversified agriculture was estimated by assuming that an additional 1,500 acres of diversified agriculture would be on the North Shore by 2035. This additional acreage may be due to farmers' relocation from the 'Ewa Plain and food security and sustainability initiatives.

E.3.1. Mid-Growth Scenario: Domestic Water Systems

Domestic water demand is calculated based on population projections for the BWS water system *(Table E.9).*

Table E.9 Population Projections: Mid-Growth Scenario

	2010	2015	2020	2025	2030	2035
Resident Population[1]						
North Shore	17,720	18,325	18,770	19,126	19,375	19,517
O'ahu	955,775	976,190	1,003,710	1,029,410	1,052,130	1,071,220
North Shore % of O'ahu	1.9%	1.9%	1.9%	1.9%	1.8%	1.8%
Residents Absent[2]						
O'ahu	53,747	54,780	58,050	60,950	63,730	66,360
North Shore	996	1,028	1,086	1,132	1,174	1,209
Visitor Units[3]						
North Shore	53	48	94	98	148	149
O'ahu	34,040	34,040	34,760	35,950	37,070	38,270
North Shore % of O'ahu	0.16%	0.14%	0.27%	0.27%	0.40%	0.39%
Visitors Present[4]						
O'ahu	86,288	95,390	98,280	101,640	104,810	108,190
North Shore % of O'ahu	0.16%	0.14%	0.27%	0.27%	0.40%	0.39%
North Shore	134	135	266	277	418	421
De Facto Population[5]						
North Shore	16,858	17,431	17,950	18,271	18,620	18,729
O'ahu	988,316	1,016,800	1,043,940	1,070,100	1,093,210	1,113,050
North Shore % of O'ahu	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
Population Served by Private Water Systems[6,7]						
Dole	0	633	633	633	633	633
North Shore Water Company[8]	580	580	650	720	790	864
Population Served by BWS[7,9]						
North Shore	13,865	13,805	14,254	14,504	14,783	14,820

1 Population numbers are based on City and County of Honolulu Population Projections (September 2009).
2 Total residents absent for Honolulu County from State DBEDT, which provides a "residents absent" figure for Honolulu County as a whole. The number of residents absent from North Shore is based on North Shore's proportion of Honolulu County's population.
3 Visitor units are from the 2010 Visitor Plant Inventory (http://files.hawaii.gov/dbedt/visitor/visitor-plant/2010VPI.pdf) and percent increases or decreases are based on the City DPP projections for visitor accommodation units (September 2009) and an additional small scale lodging of 50 units in 2020 and 50 units in 2030.
4 Total visitors present for Honolulu County are from State DBEDT, which provides a "total visitors" figure for Honolulu County as a whole. The number of visitors present in North Shore is proportional to North Shore's percentage of Honolulu County visitor units.
5 De Facto Population = Resident Population – Residents Absent + Visitors Present.
6 There is also US Army/State DOT domestic water system at Dillingham Airfield which is not included in the population numbers. Helemano Military Reservation is included in the Central O'ahu Watershed Management Plan.
7 Helemano Military Reservation is included in the Central O'ahu Watershed Management Plan.
8 This includes an additional 91 homes on agricultural lots by 2035 on Dillingham Ranch lands
9 BWS-Served Population = De Facto Population – Population Served by Other Domestic Water Systems

Demand for the domestic water systems under the mid-growth scenario was calculated using the per capita method. Domestic water demands of the Dole system and US Army/State DOT system are expected to remain the constant. The North Shore Water Company demand is expected to increase with an agricultural subdivision of 91 units. The BWS water system demand is projected to increase with the projected population increases *(Table E.10).*

Table E.10 North Shore Mid-Growth Scenario Domestic Water System Projections (mgd)

Domestic Water Systems	2010	2015	2020	2025	2030	2035
BWS[1]	2.815	2.802	2.944	2.944	3.001	3.008
Dole[1]	0.000	0.128	0.128	0.128	0.128	0.128
North Shore Water Company[1]	0.118	0.118	0.132	0.127	0.160	0.175
US Army/State DOT Dillingham Airport[2]	0.055	0.055	0.055	0.055	0.055	0.055
TOTAL	2.987	3.104	3.209	3.274	3.345	3.367

[1] Water use factor of 203 gpcd was used.
[2] The US Army/State DOT domestic water system for Dillingham airport will continue with status quo.

E.3.2 Mid-Growth Scenario: Agriculture Water Demand

Acreage for diversified agriculture was estimated by assuming that an additional 1,500 acres of diversified would be on the North Shore by 2035. This additional acreage may be due to farmer's relocation from the ʻEwa Plain and food security and sustainability initiatives. Diversified agriculture would increase from 6,000 to 7,500 acres by 2035. These lands along with 2,500 acres of pineapple would equate to 46% of the ALISH Prime and Unique rated lands in cultivation on the North Shore *(Table E.11).*

Table E.11 Water Demand for Agriculture: Mid-Growth Scenario

	2010	2015	2020	2025	2030	2035
Diversified Agriculture						
Area (acres)	6,000	6,300	6,600	6,900	7,200	7,500
Water demand (mgd)[1]	20.4	21.4	22.4	23.5	24.5	25.5
Pineapple						
Area (acres)	2,500	2,500	2,500	2,500	2,500	2,500
Water demand (mgd)[2]	3.8	3.8	3.8	3.8	3.8	3.8
North Shore Total						
Water demand (mgd)	24.2	25.2	26.2	27.2	28.2	29.3

[1] Water use factor of 3,400 gpad was used for diversified agriculture.
[2] Water use factor of 1,500 gpad was used for pineapple.

Expansion of loʻi kalo was based on different assumptions for the low-, mid-, and high-growth scenarios. The projected expansion of an additional 15 acres is predominately through Kamehameha Schools plans to expand loʻi kalo at two locations (ʻUkoʻa and Anahulu areas), and the Dole lands for sale that were previously used by Honolulu Poi Company (HPC Foods) that might be brought back into loʻi kalo production. For the expansion lands, ʻUkoʻa Marsh would be spring fed and the other areas, Anahulu and Dole lands would utilize stream water *(Table E.12).*

Table E.12 Water Demand for Loʻi Kalo Served (Mid-Growth Scenario)

	2010	2015	2020	2025	2030	2035
Acres of loʻi kalo	10	15	15	20	20	25
Water demand factor (gpad)	100,000	100,000	100,000	100,000	100,000	100,000
Water demand (mgd)[1]	1.0	1.5	1.5	2.0	2.0	2.5

[1] *Loʻi kalo* water demand was calculated by multiplying the projected acres of *loʻi kalo* by the water demand factor of 100,000 gpad.

Table E.13 summarizes the water demand for the North Shore in the low-growth scenario (excluding loʻi kalo demand which is shown above).

Table E.13 Water Demand, Mid-Growth Scenario

Mid-Growth Scenario	**Base Year**	**Projected**				
Water System	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Domestic Water Systems						
BWS	2.81	2.80	2.89	2.94	3.00	3.01
Dole	0.00	0.13	0.13	0.13	0.13	0.13
North Shore Water Company	0.12	0.12	0.13	0.15	0.16	0.18
US Army/DOT Dillingham Airport	0.06	0.06	0.06	0.06	0.06	0.06
Total Domestic Water Systems Demand	**2.99**	**3.10**	**3.21**	**3.27**	**3.34**	**3.37**
Agriculture Water Demand						
Diversified Ag	20.40	21.42	22.44	23.46	24.48	25.50
Pineapple	3.75	3.75	3.75	3.75	3.75	3.75
Total Water Agriculture Water Demand	**24.15**	**25.17**	**26.19**	**27.21**	**28.23**	**29.25**
Total Water Demand	**27.14**	**28.27**	**29.40**	**30.48**	**31.57**	**32.62**

E.4 HIGH-GROWTH SCENARIO

The high-growth scenario is based on the historical population trends of the North Shore between 1990 and 2010. This period encompasses periods of high and low-growth, and projecting the historic growth rate forward provides a higher rate of growth than City projections (September 2009). For agricultural demand, this high-growth scenario assumes that 60% of the ALISH Prime and Unique lands would be irrigated for diversified agriculture including 2,500 acres of pineapple.

E.4.1 High-Growth Scenario: Domestic Water Systems

Domestic water demands of the Dole system and US Army/State DOT system are expected to remain the constant. The North Shore Water Company demand is expected to increase with an agricultural subdivision of 91 units. The BWS water system demand is projected to increase with the projected population increases show in *Table E.14* and domestic water demands are summarized in *Table E.15* which applies the *per capita* method to most water systems.

Table E.14 BWS-Served Population Projection: High-Growth Scenario

	2010	2015	2020	2025	2030	2035
Resident Population[1]						
North Shore	17,720	18,317	18,915	19,512	20,110	20,707
O'ahu	955,775	976,190	1,003,710	1,029,410	1,052,130	1,071,220
North Shore % of O'ahu	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%
Residents Absent[2]						
O'ahu	53,747	54,780	58,050	60,950	63,730	66,360
North Shore	996	1,028	1,094	1,155	1,218	1,283
Visitor Units[3]						
North Shore	53	48	94	98	148	149
O'ahu	34,040	34,040	34,760	35,950	37,070	38,270
North Shore % of O'ahu	0.16%	0.14%	0.27%	0.27%	0.40%	0.39%
Visitors Present[4]						
O'ahu	86,288	95,390	98,280	101,640	104,810	108,190
North Shore % of O'ahu	0.16%	0.14%	0.27%	0.27%	0.40%	0.39%
North Shore	134	135	266	277	418	421
De Facto Population[5]						
North Shore	16,858	17,424	18,087	18,634	19,310	19,845
O'ahu	988,316	1,016,800	1,043,940	1,070,100	1,093,210	1,113,050
North Shore % of O'ahu	1.7%	1.7%	1.7%	1.7%	1.8%	1.8%
Population Served by Private Water Systems[6,7]						
Dole	0	633	633	633	633	633
North Shore Water Company[8]	580	580	650	720	790	864
Population Served by BWS System[7.9]						
North Shore	13,865	13,798	14,390	14,868	15,474	15,936

1 Population numbers are based on historical population trends of the North Shore between 1990 and 2010.
2 Total residents absent for Honolulu County from State DBEDT, which provides a "residents absent" figure for Honolulu County as a whole. The number of residents absent from North Shore is based on North Shore's proportion of Honolulu County's population.
3 Visitor units are from the 2010 Visitor Plant Inventory (http://files.hawaii.gov/dbedt/visitor/visitor-plant/2010VPI.pdf) and percent increases or decreases are based on the City DPP projections for visitor accommodation units (September 2009) and an additional small scale lodging of 50 units in 2020 and 50 units in 2030.
4 Total visitors present for Honolulu County if from State DBEDT, which provides a "total visitors" figure for Honolulu County as a whole. The number of visitors present in North Shore is proportional to North Shore's percentage of Honolulu County visitor units.
5 De Facto Population = Resident Population – Residents Absent + Visitors Present.
6 There is also Federal domestic water system at Dillingham Airfield which is not included in the population numbers. Helemano Military Reservation is included in the Central O'ahu Watershed Management Plan.
7 Helemano Military Reservation is included in the Central O'ahu Watershed Management Plan.
8 This includes an additional 91 homes on agricultural lots by 2035 on Dillingham Ranch lands
9 BWS-Served Population = De Facto Population – Population Served by Other Domestic Water Systems

Table E.15 Domestic Water System Demand for High-Growth Scenario

Domestic Water Systems	2010	2015	2020	2025	2030	2035
BWS[1]	2.815	2.801	2.921	3.018	3.141	3.235
Dole[1]	0.000	0.128	0.128	0.128	0.128	0.128
North Shore Water Company[1]	0.118	0.118	0.13255	0.146	0.160	0.175
US Army/DOT Dillingham Airport[2]	0.055	0.055	0.055	0.055	0.055	0.055
TOTAL	2.987	3.102	3.237	3.348	3.485	3.594

1 Water use factor of 203 gpcd was used.
2 The US Army/State DOT domestic water system for Dillingham airport will continue with status quo.

E.4.2 High-Growth Scenario: Agricultural

Water demand for agriculture was expected to increase significantly with 50% of the ALISH Prime and Unique lands in irrigated production and totaling 13,000 acres by 2035. This scenario would require tremendous market demand due to either local or external market. The increase in potential agricultural acreage was distributed evenly amongst each five year increment between 2010 and 2035 *(Table E.16).*

Table E.16 Water Demand for Agriculture: High-Growth Scenario

	2010	2015	2020	2025	2030	2035
Diversified Agriculture						
Area (acres)	6,000	6,500	7,000	7,500	8,000	8,500
Water Demand (mgd)[1]	20.4	22.1	23.8	25.5	27.2	28.9
Pineapple						
Area (acres)	2,500	2,500	2,500	2,500	2,500	2,500
Water Demand (mgd)[2]	3.8	3.8	3.8	3.8	3.8	3.8
North Shore Total						
Water Demand (mgd)	24.2	25.9	27.6	29.3	31.0	32.7

1 Water use factor of 3,400 gpad was used for diversified agriculture.
2 Water use factor of 1,500 gpad was used for pineapple.

Expansion of lo‘i kalo was based on different assumptions for the low-, mid-, and high-growth scenarios. The low-growth scenario is a continuation of existing kalo lands. The mid-demand scenario projects that the number of acres would increase by 15 acres. This additional acreage includes Kamehameha Schools plans for kalo expansion and the former Dole lands used by HPC Food, Inc. that could be put into production again. In addition to the above, there are also low lying areas with some springs that might in the future be further developed for additional lo‘i kalo acreage. It is assumed that could be as much as an additional 35 acres (the additional 15 acres from the low scenarios plus the possible 20 from low lying areas), for total lo‘i kalo of 45 acres by 2035.

Table E.17 provides the water demand for lo‘i kalo for the North Shore in the high-growth scenario.

Table E.17 Water Demand for Lo‘i Kalo Served (High-Growth Scenario)

	2010	2015	2020	2025	2030	2035
Acres of lo‘i kalo	10	20	30	35	40	45
Water demand factor (gpad)	100,000	100,000	100,000	100,000	100,000	100,000
Water demand (mgd)[1]	1.0	2.0	3.0	3.5	4.0	4.5

[1] *Lo‘i kalo* water demand was calculated by multiplying the projected acres of lo‘i kalo by the water demand factor of 100,000 gpad.

Table E.18 Water Demand, High-Growth Scenario

High-Growth Scenario	**Base Year**	**Projected**				
Water Systems (mgd)	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Domestic Water Systems						
BWS	2.81	2.80	2.92	3.02	3.14	3.23
Dole	0.00	0.13	0.13	0.13	0.13	0.13
North Shore Water Company	0.12	0.12	0.13	0.15	0.16	0.18
US Army/DOT Dillingham Airport	0.06	0.06	0.06	0.06	0.06	0.06
Total Domestic Water Systems Demand	**2.99**	**3.10**	**3.24**	**3.35**	**3.49**	**3.59**
Agriculture Water Demand						
Diversified Ag	20.40	22.10	23.80	25.50	27.20	28.90
Pineapple	3.75	3.75	3.75	3.75	3.75	3.75
Total Water Agriculture Water Demand	**24.15**	**25.85**	**27.55**	**29.25**	**30.95**	**32.65**
Total Water Demand	**27.14**	**28.95**	**30.79**	**32.60**	**34.44**	**36.24**

E.5 ULTIMATE SCENARIO

The ultimate scenario analyzes each water use sector for end state water use based on future potential land uses and is not bounded by a particular timeframe. The assumptions include long-term land use plans, land use constraints, and consideration of climate change impacts. The ultimate scenario, full build-out at an undetermined future time, is used for watershed planning purposes and is not tied City and County of Honolulu Department of Planning population projections.

E.5.1 Ultimate Scenario: Domestic Water Systems

Domestic demands under the ultimate scenario would occur with the full build-out of an additional 800 acres of residential development within the Community Growth Boundary. A BWS water systems standard usage factor of 2,500 gallons per acre for residential lands is applied to this acreage *(Table E.19)*. This would require an estimated additional 2 mgd above 2010 demand of 3.46 mgd for a total estimated Ultimate Demand of 5.5 mgd.

Table E.19 Ultimate Demand Scenario – Municipal

2010 Demand (mgd)	Undeveloped Lands within Community Growth Boundary	BWS Water System Standard for Residential Development	Estimated Additional Demand (mgd)	Estimated Total Ultimate Demand (mgd)
3.46	800 acres	2,500 gpad	2	5.5

E.5.2 Ultimate Scenario: Agricultural

For agricultural demand under the ultimate scenario, all ALISH Prime, and Unique lands would be in production and irrigated. ALISH Other lands are assumed to be utilized as rain-fed pasture lands.

In the low-, mid-, and high-growth agricultural scenarios, a single agricultural coefficient of 3,400 gpad was used as most of the diversified agriculture would be on lands below the 50″ isohyet of rainfall annually. The 3,400 gpad is from the 2004 Agricultural Water Use Development Plan and is suitable for lands having a similar rainfall and therefore similar ET rates.

BWS hydrologists have estimated that at more than 50″ of rainfall annual, rainfall will typically re-charge ground water and less than 50″ of rainfall will tend not to provide ground water recharge. With climate change, warmer temperatures could affect the annual average evapotranspiration rate. The observed rainfall decrease from 1990 to 2010 was of 12-15%. Applying a15% factor to the annual rainfall isohyet shifts it 7.7″ mauka to a 57.7“ annual rainfall isohyet. For ALISH Prime and Unique lands below the 57.7″ annual rainfall isohyet, 3,400 gpad agricultural coefficient is used. With all ALISH lands in cultivation, there would be lands above the 57.7″ annual rainfall line. For those lands a lower diversified ag water use coefficient of 2,400 gpad (from a study for Windward O‘ahu's Punalu‘u area with annual rainfall greater than 60″) was used to project future diversified agriculture water demand. In the ultimate scenario, pineapple is not assumed. The higher diversified agriculture rate is applied to the lands to account for possible crop changes *(Figure E.2* and *Table E.20).*

The 3,400 gpad number is understood to be conservative enough to account for future increases in demand due to climate change and warmer temperatures. The agricultural coefficient of 3,400 gpad is based on usable acreage, but it has been applied to areas that may have roads and houses, which provides for over estimation.

Table E.20 Ultimate Demand Scenario – Diversified Agriculture

Land Use	Irrigated Agriculture (Acres)	Water Use Coefficient (gpad)	Projected Water Demand (mgd)
Diversified Ag (<57.5″ rainfall)	19,400	3,400	66.0
Diversified Ag (<57.5″ rainfall)	2,400	2,500	5.7
Total	**21,800**	**-**	**71.7**

While the North Shore was once an abundant food producing area for Native Hawaiians, much has changed since that that era of high productivity. Using methodology from a previous study[1] (Kurashima 2011) that modelled potential cultivation systems such as irrigated pondfields and intensive dryland cultivation, Kurashima estimated that the extent of agricultural systems on the North Shore as over 2,000 acres at one time (Kurshima, personal communications). In the analysis for that included the North Shore, crop types were not delineated. Kalo might have been grown as one of the crops and could have been upland or lowland kalo. Lowland kalo would likely have been a smaller portion of the total agricultural lands and would have been more likely on the lands on the slopes of the Koʻolau's which capture greater rainfall than the Waiʻanae Mountains. For the ultimate scenario, a return of wetland kalo to 5% of the 2,000 acres is assumed and would equate to 100 acres of loʻi kalo on the North Shore. Kamehameha Schools' consolidation of lands in Anahulu Valley and plans to expand traditional crops show the most promise. However, the expansion from the current 10 acres to 100 acres will likely take many, many years. *(Table E.21).*

Table E.21 Ultimate Demand Scenario – Kalo

Land Use	Area (Acres)	Water Use Coefficient (gpad)	Projected Water Demand (mgd)
Kalo	100	100,000	7.5 mgd

The total Ultimate scenario demand is 85 mgd with domestic demand of 5.5 mgd and agricultural demand of 71.7 mgd *(Table E.22).* The ability of the North Shore water supply resources to meet this demand is discussed in Chapter 5. Kalo demand is not entirely consumptive use and is considered separately from the total demand.

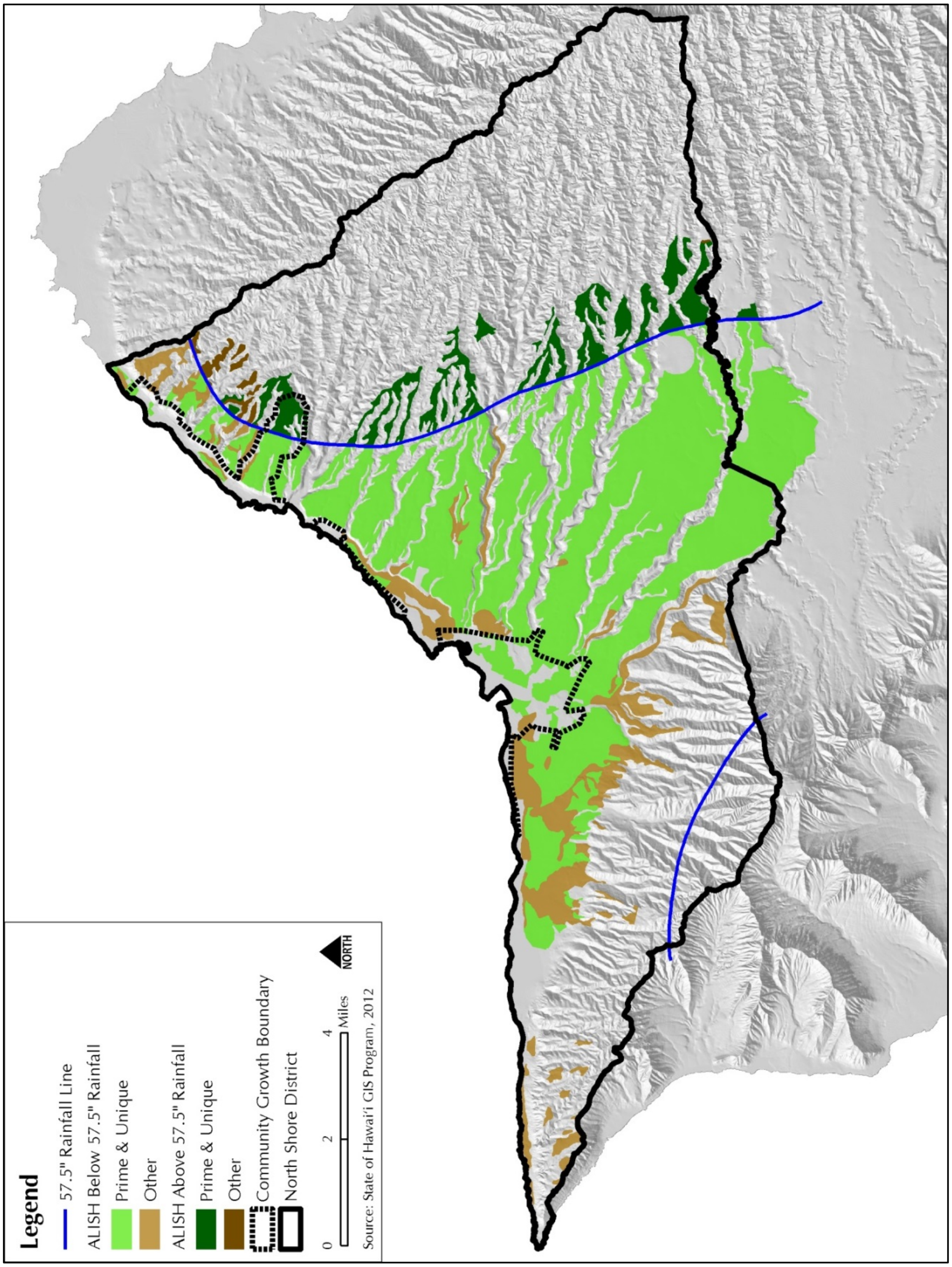


Figure E.2 ALISH Lands and Lands Above and Below 57.5″ of Rainfall

Table E.22 Ultimate Scenario Demand Total

Water Use Sector	Ultimate Demand (mgd)
Domestic	5.5
Agricultural	72.7
Total (without kalo)	**78**
Kalo	7.5
Total (with kalo)	**86**

E.6 BWS ISLAND-WIDE DEMAND METHODOLOGY

BWS forecasts municipal water demand using population forecasts provided by City DPP against BWS trends of per capita demand for 8 of O'ahu's land use districts. BWS island-wide water demand methodology is explained in the Section 1.3.2, Overview Chapter 1, Population Forecasts and Municipal Water Demand. Island-wide, population is increasing but due to a continuing trend of decreasing per capita demand, water demand growth has slowed significantly to about 8 mgd in 2040 *(Figure E.3).*

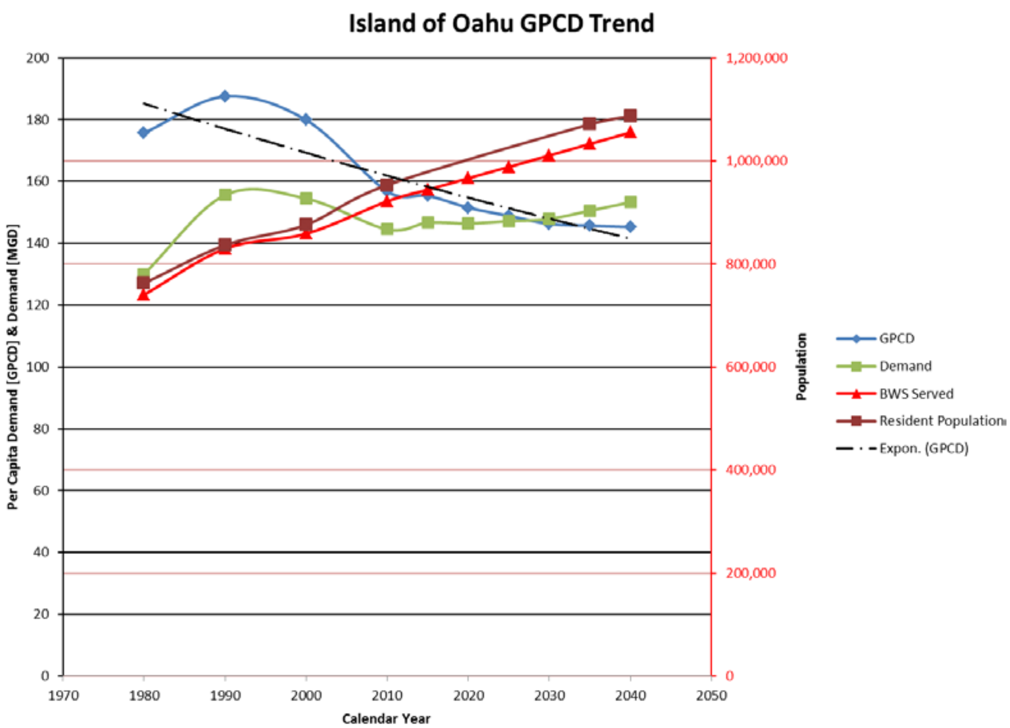


Figure E.3 Island of O'ahu Gallons Per Capita Per Day Trend

[1] Kurshima & Kirsch, 2011. "Geospatial modeling of pre-contact Hawaiian production systems on Moloka'i Island, Hawaiian Islands". *Journal of Archaeological Science.*