Since Wittfogel's controversial theory linking irrigation with "oriental despotism," western archaeologists have focused a great deal of attention on early forms of irrigation and water management. During the late prehistoric period in ancient Hawaii, irrigation and other water management practices supported the sociopolitical evolution of a proto-state formation, and archaeological interpretations of these developments have dominated the literature. This report uses the archaeological data as a point of departure in an analysis of the meaning and management of water. Woven into the archaeological data is an analysis of Hawaiian chants, legends, and proverbs in an attempt to better understand the meaning of water to the indigenous people of the Hawaiian islands. This report is based on the premise that intraisland (windward-leeward) and interisland (geological-hydrological) variation produced localized meanings of water, particularly as they were related to the characters of Kane, Kanaloa, Lono, and Ku. Further, these meanings changed over time, largely in relation to population growth, production intensification, and increasing sociopolitical complexity.
WATER: ITS MEANING AND MANAGEMENT IN PRE-CONTACT HAWAI‘I

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PREFACE

I have attempted to describe the early management of water for agricultural use within a Hawaiian cultural context, using an approach called processual cultural ecology. I must acknowledge the work of three particular archaeologists—Patrick Kirch, Timothy Earle, and Marion Kelly—whose published accounts on water management, production intensification, and evolution of sociopolitical complexity in pre-contact Hawai‘i provide the central data for this report. In many cases, their precise and detailed descriptions and analyses are quoted at length because I feared that by paraphrasing, I might do damage to the spirit and meaning of their work. The quality of archaeological and ethnohistorical data on water management on each island varies considerably, so I have also attempted to identify where more in-depth archaeological research would further elucidate traditional water management practices. This research, it should be noted, may lead to the revision of some of the theoretical models presented in this report, an example of which I give in my conclusions.

As an anthropologist, I make no claim to special expertise in this topical area. This research endeavor focuses on the human experience in Hawai‘i previous to European contact, and I believe the research has informed and improved my teaching about Hawai‘i and Polynesia. This is an initial account of an extremely rich topic deserving much more scholarly attention. I hope that some new avenues of research are opened, particularly for Native Hawaiian scholars far more knowledgeable than I with respect to Hawaiian language, culture, and history.
GLOSSARY OF HAWAIIAN WORDS

'a`a  a type of lava
ahupua'a  land division usually extending from the land to the sea, so called because the boundary was marked by a heap (ahu) of stones surmounted by an image of a pig (pua'a)
'ai  to rule, reign, or enjoy the privileges and exercise the responsibilities of rule, and one who does so
'ai  land, earth
ali`i  chief, chiefess, king, queen, noble
'amama  finished, of a pre-Christian prayer (said almost at the end of a prayer); to finish a prayer; to pray and sacrifice
'ape  large taro-like plants
'auwai  ditch
'awa  kava
heiau  place of worship
honua  land, earth
ho'oka'awale  to separate, distinguish; to cause a division
huli  taro top, as used for planting; shoot
i'a  fish or any marine animal, such as eel, oyster, crab, whale
'ilii  land section, next in importance to ahupua'a and usually a subdivision of an ahupua'a
'iliahi  a poetic description of the waters of Waimea Stream, Kaua'i, the waters of which after a storm are said to be red along one bank
imu  underground oven
ka  the one who; the person in question
kainga  Polynesian term for extended family
kalo  taro
kanoa  bowl, as for kava; hollow of land, pit; circular
kapu  taboo, prohibited, forbidden
kapu noho  taboo requiring everyone to sit in the presence of the chief or when his food container, bath water, and other articles were carried by
kele  watery, muddy, wet swampy
kia'aina  governor; governorship
kō'ele  small unit farmed by a tenant for the chief
kona  leeward side of island; name of leeward wind
kōnane  to play kōnane, an ancient game resembling checkers, played with pebbles placed in even lines on a stone or wood board called pōpā kōnane
konohiki  headman of an ahupua'a land division under the chief
kū  land section
kua'wi  long, straight stone walls
kula  plain field; open country; pasture
kulū  a drop
kupua  demigod, especially a supernatural being possessing several forms
kupuna  grandparent, ancestor, relative of the grandparent's generation
lawai’a
fisherman; fishing technique; to fish

lo‘i
irrigated terrace, especially for taro

loko
pond

loko i’a kalo
combination fishpond and taro patch

loko wai
freshwater pond

luakini
temple; large heiau where ruling chiefs prayed and human sacrifices were offered

luna
boss, overseer, or supervisor

mahi’ai
farmer; to farm, cultivate

maka‘āinana
commoner; populace; people in general

makahiki
ancient festival beginning about the middle of October and lasting about four months, with sports, religious festivities, and a taboo on war

makai
on the seaside, toward the sea, in the direction of the sea

Menehune
legendary race of small people who worked at night, building fishponds, roads, temples; if the work was not finished in one night, it remained unfinished

mō‘ī
a rank of chiefs who could succeed to the government but who were of lower rank than chiefs descended from the god Kane

mo’o
narrow strip of land, smaller than an ‘īli

mo’o ‘āina
land parcel

nāulu
sudden shower

‘ōhia ‘ai
the mountain apple, a forest tree growing to fifty feet tall and found on many islands of the Pacific

‘okana
district or subdistrict, usually comprising several ahupua‘a

‘o‘opu
general name for fishes included in the families Eleotridae, Gobiidae, and Blennidae

pāhoehoe
smooth, unbroken type of lava

pāo‘o
name for several varieties of ‘o‘opu, especially Istiblennis zebra, Entomacrodus marmoratus (marbled blenny)

Pō‘alima
fifth day; work on the chiefs plantations, so called because this work was done on Fridays

po‘e
people, persons, group

poi
the Hawaiian staff of life, made from cooked taro corms, or rarely breadfruit, pounded and thinned with water

pu‘uone
pond near the shore, as connected to the sea by a stream or ditch

‘ulili
wandering tattler

‘uwā‘u
dark-rumped petrel (Pterodroma phaeopygia sandwichensis)

wai
water, liquid, or liquor of any kind other than seawater, juice, sap, honey

wai‘ula
red water with surface of fire

NOTE: Hawaiian words are spelled here as they are in Mary K. Pukui and Samuel H. Elbert’s Hawaiian Dictionary (1979, University of Hawaii Press). Because the use of diacritical marks is a fairly recent practice, some words appear in quoted material in the text without these marks.
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INTRODUCTION

In this report, I focus on the water management practices and strategies of native Hawaiians prior to the arrival of Captain James Cook in 1778 and sustained European contact. The report begins with a description of geological and ecological variations on the main Hawaiian islands and a survey of the environmental settings that greeted the first human settlers. The report next delineates an evolutionary sequence for pre-contact Hawaiian culture and analyzes Hawaiian oral traditions—chants, legends, and proverbs—in an attempt to show the meaning of water in the life of the early Hawaiians. For the early Hawaiians, management of water did not entail sustained and wasteful exploitation of their natural resources, but respect for, and communication with, supernatural sources. The report then provides a detailed analysis of the major archaeological and ethnohistorical research on the development of increasingly complex water management systems on the major islands. For each island, conclusions are also drawn concerning cultural changes accompanying water management intensification. The report concludes with a summary of the meaning and management of water in pre-contact Hawai‘i and identifies some important gaps in the archaeology of Hawaiian water management.

EARLY GEOLOGY AND ECOLOGY

The Hawaiian archipelago extends for 2574 km from northwest to southeast in the Pacific Ocean and consists of a group of 132 islands, islets, sand cays, and reefs. The first migrants arrived from Eastern Polynesia around A.D. 200 to 300, settling on the islands that lie at the southeast end of the archipelago (the major islands that are inhabited today) and on Nihoa and Necker. These early Hawaiians had to modify their settlement patterns and agricultural practices as they adapted to the environments of islands of different geologic ages and landforms (Kirch 1985, p. 25).

The Hawaiian islands have a subtropical climate. Although they are at the northern margin of the tropics, they are cooled by the currents from the Bering Sea. The temperature ranges from below freezing on the high peaks of the higher volcanoes to about 36°C at sea level on the leeward coasts.

Trade winds from the northeast persist throughout most of the year. Occasionally the trades are interrupted during the winter months by the kona (southerly) winds that blow for a few days or weeks at a time. The trade winds and the kona winds bring rain to the islands, and when the moisture-laden trade winds reach the steep volcanic mountains, rainfall occurs. Thus,
the greatest rainfall occurs on the windward side of the ranges, with maximum precipitation occurring at an elevation of between 610 and 1829 m, "depending on the form and height of each island" (Stearns 1985, p. 31). The winds become warmer and drier on the leeward side, producing a semiarid climate.

The distribution of rainfall over the islands is not only uneven but subject to considerable seasonal variation. The highest rainfall occurs during the months from October to April, with the summers being drier, except in Kona on the island of Hawai‘i, where the maximum rainfall takes place during June and August (Kirch 1985, p. 25). The windward–leeward rainfall pattern is a major factor in the development of landforms and vegetation.

The Hawaiian islands are volcanic in origin and very young geologically. They emerged from the ocean floor about 25 million years ago during the Miocene Age. Kaua‘i, Ni‘ihau, and O‘ahu, the oldest islands, were built above sea level during the Pliocene Age. The other major islands, the youngest being the island of Hawai‘i, were built during the Pleistocene Age. It appears that the volcanoes that formed these islands became extinct in the following manner (Macdonald 1983, p. 38):

The volcanoes were built along a line, probably a series of cracks, extending in a northwest-southeast direction across the ocean floor. Starting at the northwest end, at Kure Island, about 30 million years ago, the centers of eruption gradually shifted, until today only the volcanoes at the southeastern end of the chain are still active.

As volcanoes became extinct, cliffs were cut and drainage systems developed. The cliffs, formed by marine erosion, dropped hundreds of meters into the ocean. There was a long erosion period of about one to two million years, and soils were formed. This erosion period was followed by the submergence of about 2743 m of the islands (measured from the ocean floor). Later, on all islands except Lāna‘i, a new period of volcanism started, which continued into the Holocene Age (Stearns 1985, p. 114). By the time the Polynesian migrants arrived, volcanism had stopped on all islands except the newer ones of Maui and Hawai‘i (Kirch 1985, p. 33).

Some of the islands had wooded mountains, and some were favored with rivers and waterfalls. The soil, formed of decomposed basalt, was red and sandy and probably rich in iron but lacking in other minerals necessary for high fertility. Much of the rain fell on steep cliffs, forming high waterfalls that were difficult to reach, and water was scarce on the southeast plains, where red soil was found.

The distribution of water resources influenced the Polynesians’ settlement patterns. The oldest islands, Kaua‘i and O‘ahu, are the most eroded and dissected and thus have more rivers and streams than the newer, less eroded islands. The source of all fresh water in Hawai‘i is rainfall—part of which runs to the sea in streams, another part of which evaporates, and the remainder of which moves through the soil to form groundwater and springs.
Because the Hawaiian islands are mountainous and small, streams usually originate on steep terrain, in the heavy rainfall on the mountains, and run towards the coast. Most streams have only minor branches, generally in the upper reaches, and are very flashy. On the older, more eroded islands, such as Kaua'i and O'ahu, perennial streams can be found. However, on the younger islands, runoff seldom occurs due to the great permeability of the younger volcanoes there, so few perennial streams can be found. For example, on Hawai'i, only a few perennial streams are found from Waipi'o to Pololū and in the Hilo area. According to Stearns (1985, p. 291):

No perennial stream enters the sea between the Wailuku River near Hilo, along the entire coast line of Kilauea, Mauna Loa, and Hualalai volcanoes, and the entire western and north side of Kohala Mountain, a distance of more than 220 miles. Except for a short stretch of the windward slope of East Maui, no streams reach the sea. No streams reach the coast on Kaho'olawe Island, Lanai Island, West Molokai, the Waianae Range on Oahu, or on Ni'ihau Island. Only on Kauai do perennial streams flow to the sea along most of the coast. There, the low flow of the streams is maintained by persistent rainfall in the mountains and by perched springs.

Thus, the best areas for settlement were the windward valleys, which had more stable and reliable sources of water, higher rainfall, and more permanent streams.

The first settlers brought with them crops, pigs, dogs, insects, and the full range of their Polynesian culture, both its agricultural and fishing traditions and its religious practices. There was not, apparently, a continuous migration of people, but just a few canoe loads initially, with probably fewer than one hundred founding settlers (Kirch 1985, p. 286). These young islands offered them a variety of environments, but little food was available. Many different species of birds and insects had evolved, and the coastal zone “supported large nesting populations of various seabirds, which would have provided a ready food source for the colonizers” (Kirch 1985, p. 29).

The early Polynesians settled along the coasts near the freshwater resources and practiced subsistence fishing, as well as some subsistence agriculture, relying mainly on shifting cultivation (the practice of rotating gardens through an area of primary or secondary growth). Unfortunately, we do not know much about these first colonists. The earliest archaeological sites are at Bellows Beach on O'ahu and Pu'u Ali'i on the island of Hawai'i, neither of which appears to be the first settlement. At the Bellows site, archaeological evidence of pigs and dogs, as well as some “indirect evidence of an agricultural subsistence base,” was found (Kirch 1982a, p. 2). Both sites are in favorable localities, Bellows in a fertile windward valley and Pu'u Ali'i “adjacent to one of the richest fishing grounds” in Hawai'i (Kirch 1985, p. 298). Existing archaeological evidence suggests that settlements were dispersed along the coasts and in permanently watered windward valleys, where the Hawaiians practiced a combination of shifting agriculture and subsistence fishing. However, we must keep in mind
that the kona coast of O'ahu—that is, the Honolulu area—has been largely destroyed for archaeological research, and evidence of early settlement in this area may be permanently lost.

During this period, there was little rank differentiation between chiefs and commoners, as these small populations were closely linked by bonds of kinship (Kirch 1985, p. 302). The environmental impact of these early settlers was small due to their low numbers and dispersion, but changes slowly started to occur.

SEQUENCE OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT

The sequence of settlement and agricultural development used in this report will follow Kirch's Hawaiian cultural sequence and integrate Cordy's and Hommon's evolutionary sequences for Hawaiian society (Kirch 1985, p. 296; Cordy 1981; Hommon 1976).

Colonization and Initial Settlement (A.D. 200–600)

As mentioned above, the Hawaiian archipelago was probably colonized sometime during the three centuries before A.D. 600 (Kirch 1985, p. 298). The initial settlements apparently took place in the coastal areas, where there was good fishing, and in the well-watered windward valleys. Subsistence depended mainly on the marine resources available and shifting cultivation.

The dispersion of these settlements facilitated the formation of independent chiefdoms with small populations. Cordy (1981, p. 42) called this stage “simple society,” where there were only two “rank echelons,” chiefs and commoners. Hommon (1976, p. 230) referred to the social organization of this early period as “archaic maka‘āinana,” where all members were “related by bonds of kinship and the chiefs were considered senior relatives whose authority was based to a great extent on institutionalized generosity.”

About A.D. 600, the rapidly increasing population began to have an effect on its environment, and concurrent with environmental changes came changes in the social, cultural, and religious beliefs of the settlers. The survival of the early settlers depended on the successful establishment of the domesticated plants and animals they had brought with them to Hawai‘i. This required the application of land-management techniques, such as shifting cultivation and water control, which had been developed prior to the settlement of Polynesia (Yen 1973; Barrau 1965; Kirch 1982a, p. 1).
Adaptation and Development Period (A.D. 600–1100)

During the adaptation and development period, a distinct Hawaiian culture began to emerge. Settlements continued to be located in the fertile, well-watered windward valleys; and rich fishing grounds, such as those off South Point on the island of Hawai‘i, provided abundant marine resources. Early Hawaiians thoroughly explored their new environments, establishing settlements on all major islands. There is evidence of sporadic use after A.D. 900 of some leeward areas, such as on Kaho‘olawe and at ‘Anaeho‘omalu on the island of Hawai‘i (Kirch 1985, p. 302).

The population continued to increase at high rates as there were no restrictions on the availability of agricultural land, and resources were plentiful. Kirch (1985, p. 302) estimated that by the end of this period, the overall population had reached 20,000. However, Kelly (1989, p. 103) estimated a smaller population that reached only 8,000 by the end of the eleventh century. An increasing population meant an intensification of the shifting cultivation practiced along lower valley slopes, which probably led to localized erosion. There is no direct evidence of irrigation works from this period. It is likely, though, that wetland taro was growing throughout the windward regions in favorable spots and that extensive exploitation of marine resources continued.

Prehistoric Hawaiians modified their environment in their efforts to subsist and to build, when the population continued to grow, a new and more productive economy. The lowlands and valley slopes were cleared for agricultural purposes, forest resources were utilized, birds were hunted for feathers and food, and reefs were exploited, with some being converted to fishponds. These processes of change only accelerated in the decades that followed.

The pattern of social organization continued to be characterized by simple, independent chiefdoms with rank differentiation between chiefs and commoners. However, there is little evidence that class stratification existed at this point.

Two of the sites discussed in detail later in this report—Hālawa Valley on Moloka‘i and Kahana Valley on O‘ahu—are relegated to this period.

Expansion Period (A.D. 1100–1650)

The five and a half centuries of the expansion period are characterized by an almost explosive increase in population to hundreds of thousands of people. Kirch’s (1985, p. 303) analysis of the archaeological data led him to theorize that the lowlands of all islands became densely populated and people started moving inland and to leeward areas, with some settling in even the most arid and marginal regions of the Hawaiian archipelago.
Other changes in settlement pattern took place. Dispersed small household clusters were found throughout the interiors of windward valleys and along leeward coastlines. Population growth led to extensive development and intensification of all aspects of economic production. At this time, there emerged a Hawaiian agricultural system with two distinct components:

1. Water control systems that created artificial hydrological media (water, soil, and nutrients) suitable for the intensive cultivation of taro
2. Extensive systems of shifting cultivation in which fire was used for clearing vegetation and a range of crops, including banana and yam, was produced

According to Kirch (1982b, p. 5):

Over the ensuing one and a half millennia these systems were adapted, expanded, and intensified until they had come to dominate the lowland landscape of the archipelago. There is scarcely [sic] an area in the lowlands (if it receives greater than 500 mm rainfall and is not steep cliff) that upon archaeological reconnaissance does not yield evidence of indigenous Polynesian agricultural use.

From this period, we find the first direct evidence of taro irrigation: stone-faced pondfields and irrigation channels in interior valleys, such as those in Mākaha on O‘ahu and Hālawa on Moloka‘i, and the large valley-bottom systems of Hanalei on Kaua‘i. These sites are discussed in detail later in this report.

There was also rapid agricultural expansion in the leeward areas, where various field systems were developed after clearing dry forests and shrubs. The Kona, Waimea, and North Kohala uplands of the island of Hawai‘i supported large systems by the end of this period, and on Kaho‘olawe, there was extensive clearance and exploitation of the upper plateau. According to Kirch (1982a, p. 4):

Expansion and intensification of the leeward field systems are closely linked with a phase of rapid population growth, beginning about the 13th century AD and peaking about AD 1650. Mākaha on O‘ahu and Lapakahi on the island of Hawai‘i had dryland field systems that were constructed after A.D. 1200 (Green 1969, 1970; Rosendahl 1972; Kirch 1982a).

The extensive dryland field systems, found mainly in the leeward areas, represent an intensification of shifting cultivation. As the population increased and agricultural land became more limited, the period during which the ground was allowed to lie fallow was shortened and the landscape started to look as if it were in permanent field cultivation. Originally, the fields were few and large, but over time they were divided into smaller and smaller parcels. For example, in A.D. 1450, shifting cultivation was practiced at the Lapakahi fields; by A.D. 1800, an intensified form of the field system—characterized by permanent plot boundaries, crop rotation, and intensive labor practices—was in place. The Waimea–Lāʻamilo field complex, dependent on rainfall and intermittent irrigation, was probably in use by the mid-seventeenth century (Kirch 1985, p. 231).

The Kona system was used intensively during the seventeenth and eighteenth centuries. This system covered about 139 km² on Hualalai and Mauna Loa. The kuaʻiwi (stone walls)
followed the slopes, defined rectangular plot boundaries, and, in some areas, were used to control erosion and retain water.

It was here in the leeward area of the island of Hawai‘i that a powerful line of paramount chiefs and a political center evolved. These developments, as Kirch (1982a, p. 4) suggested, were linked to the competition for limited agricultural land:

[T]he most elaborate and highly stratified Polynesian chiefdoms arose in regions dependent upon shifting cultivation (rather than irrigation).

During this period, fishing and shellfish gathering were also intensified, as is evident by the many rock-shelter fishing camps found at coastal sites.

**Protohistoric Period (A.D. 1650–1795)**

During the three centuries before European contact, population pressure and sociopolitical change resulted in the expansion and intensification of the agricultural system. According to Kirch (1985, p. 223):

[T]here was a major increase in the construction of irrigated pondfield systems beginning about the fifteenth to sixteenth century. Further, such construction was still continuing when European explorers arrived on the scene.

Depending mainly on the availability of water and windward–leeward rainfall patterns, which varied from island to island, irrigation systems could be found in the following regions (Earle 1980, pp. 10–14; Kirch 1985, p. 220):

- **Major zones of irrigated agriculture**, such as the windward valleys of Kaua‘i, O‘ahu, Moloka‘i, and Maui and some important pockets in leeward O‘ahu (such as Mānoa and Waikīkī) and leeward Maui (Lahaina)
- **Secondary zones of irrigated agriculture**, such as the geologically mature sections of Kaua‘i, O‘ahu, Moloka‘i, and Maui; the geologically less mature regions (such as the districts of Puna and Ko‘olau on Kaua‘i); and the leeward southern and western coasts of Kaua‘i, O‘ahu, Moloka‘i, and Maui
- **Scattered zones of irrigated agriculture**, such as the leeward sections of Kaua‘i, the extreme western, eastern, and northern points of O‘ahu; the southeastern coast of Moloka‘i; the island of Lāna‘i; the windward sections of Moloka‘i; and the Kohala–Hamakua coast of Hawai‘i

The irrigation systems varied widely in size and complexity, ranging from small groups of about ten fields on stream-side terraces in deep valley interiors to large complexes along wide valley bottoms. One of the largest systems, known as System 22 and found at Wai‘oli Stream in Hanalei on Kaua‘i, irrigated almost 54 ha (Kirch 1985, p. 220).

Kirch (1985, pp. 221–222) distinguished four types of irrigation systems, ranging from simple to complex:
• Type I consists of simple "barrage" terraces made of stone built across a narrow stream channel. There is no separate ditch. Permanent streams are diverted using boulder and cobbled dams, and the water is carried through stone-lined canals. An example is found in Hālawa Valley on Moloka'i.

• Type II consists of a single ditch that feeds directly into the uppermost field of a small group of fields, with the water flowing from one field to another through small gateways. In Anahulu Valley on O'ahu and Hālawa Valley are examples of a single ditch that splits into two branches near the uppermost fields, with water flowing to small groups of fields cultivated by three households.

• Type III consists of an irrigation canal built along the periphery of the field, allowing for more control of the distribution and allocation of water. Anahulu and Hālawa valleys have examples of this type of system.

• Type IV consists of two ditches, with the lower one being used simultaneously for drainage and irrigation. An example is found in Hālawa Valley.

There were also irrigation systems built over natural springs, such as that found in Waialua on O'ahu, and trenches cut on hill slopes above terraces to supplement the stream flow from shallow water tables. Water from these trenches was diverted through short ditches to the upper fields. An example of this is found in Mākaha Valley on O'ahu (see Figure 1; from Kirch 1977, figure 5).

The 'auwai (irrigation ditches) varied also in size and length. The longest ditch is in the district of Halele'a on Kaua'i and is about 3.7 km long, whereas the shortest is only about 10 m long. In the leeward areas of southeastern Maui, western Hawai'i, Lāna'i, and Kaho'olawe, where there are no perennial streams and very few springs, there was virtually no pondfield irrigation (Kirch 1985, p. 220). Pondfield irrigation requires an abundant supply of water, which cannot be found in the leeward areas.

Overpopulation and the intensification and expansion of agriculture it caused resulted in some instances of environmental deterioration. This can be seen clearly in the case of Kaho'olawe. This small island (116 km²) is too flat to generate much rainfall and is sheltered from the trade winds by the bigger islands, so it has a dry, arid climate. However, there is evidence that its central plateau once was covered with parkland vegetation and a deep layer of soil. The island was settled sometime during the expansion period. Shifting cultivation reached a peak intensity about A.D. 1475 to 1600, but the environment could not sustain this continuous slash-and-burn cultivation. By the mid-1600s, there was massive erosion and little vegetation left, so the population declined. By A.D. 1700, the interior of Kaho'olawe was abandoned completely (Kirch 1982a, p. 4).

FIGURE 1. Four types of pondfield irrigation systems: Type I, narrow channel barrage system; Type II, single-ditch, direct-feed system; Type III, peripheral-ditch, multiple-feed system; and Type IV, multiple-feed, irrigation plus drainage system
Kirch argued that the continuous environmental degradation resulting from human actions probably led to a lowering of the carrying capacity, which may have resulted in a decline in human population. Kirch (1982b, p. 6) suggested:

As a result of population increase and concomitant agricultural development, the greater part of the lowland landscape of the archipelago had been converted to a thoroughly artificial ecosystem prior to European advent.

The land seen by the Europeans had been transformed by centuries of modification and intensive use. In a few cases, this intensification of production may have led to some environmental degradation. However, in most cases, production intensification involved a highly organized cadre of workers using a technology geared toward the careful conservation of resources. This is clear when analyzing the decentralized upland ‘auwai system in terms of its effect on nature, labor, and the economy.

Kelly (1985) argued that upland ‘auwai systems had numerous positive effects on the environment. According to Kelly, these systems

- Decentralized water flow at upland sources
- Minimized lowland flood forces by reducing water mass & velocity
- Prolonged usefulness of surface-water supply for irrigation
- Recharged ground water supply via infiltration
- Minimized land runoff & coastal siltation
- Preserved soil nutrients in cultivation areas
- Provided controlled water supply in lowland habitation areas
- Maintained upland fish habitats & enhanced water control for coastal fishponds

Kelly also argued that upland ‘auwai systems had beneficial effects on labor in that they provided perennial employment and resulted in the development of environmental awareness and a conservation ethic. Furthermore, Kelly said that the upland ‘auwai systems had a positive economic outcome in that they resulted in diversified resource-exploitation options, increases in the food supply, and a decentralized population.

Early European observers wrote at great length about Hawaiian cultivation. To these outside observers, Hawaiian plantations were gardens stretching for as far as they could see (see quotations from Stewart [1830], Vancouver [1798], Menzies [1920], and Kotzebue [1821] on pages 41 and 42 of this report).

SOCIAL ANDpolitical ORGANIZATION

The following overview of Hawaiian social and political organization is largely based on the archaeological research of Kirch (1985), Cordy (1981), and Hommon (1976), as well as on the more recent historical analysis of Kame‘elehiwa (1992). The archaic concept of maka‘āinana disintegrated, and the gap between chiefs and commoners widened, as “the concept of kinship centered increasingly within the local community” (Hommon 1976, p. 231).
Cordy (1981 p. 42) termed this community a "complex society" in which a third echelon was added and the independent chiefdoms had populations of about 2,000 to 8,000 individuals. Before European contact, this complex society continued to evolve with the addition of a fourth echelon and the growth of islandwide, multidistrict polities of up to 100,000 individuals (Cordy 1981, table 5). By the A.D. 1600s, control by chiefs was no longer based on kinship but on power (Hommon 1976, p. 231):

By 1600, the cleavage between commoners and chiefs had advanced to such an extent that the control exercised by the chiefs was no longer based on kinship, but rather on the demonstration of the monopoly of power. Thus, the formation of the ali'i and maka'ainana classes, and ultimately the development of the ahupua'a as a largely self-contained socioeconomic unit were necessary pre-conditions to the formation of the Hawaiian primitive state. During the first half of the 17th century there was a significant reduction of population growth. Competition among powerful chiefs over control of the resulting stabilized productivity led to the formation of socio-political boundaries through force — i.e., conquest warfare.

The chiefs tried to maintain and consolidate their power through small-scale warfare, usually involving competition between large extended family groups. Kame'eleihiwa (1993, p. 41) asserted that power was also enhanced through the careful consideration of genealogies.

During the last one hundred years of the protohistoric period, as the amount of available land decreased, the need for defining territorial boundaries increased. This, together with more pronounced rank differences, led to the establishment of the ahupua'a and a more stratified social system characterized by strong territorial control directed by chiefs. With this increased control came additional responsibilities for the chiefs in meeting the needs of their families and the land.

In the beginning, the rights to land were validated by membership within a descent group and kainga residence. Later, ownership or stewardship of land passed into the hands of the ali'i. In the later stages of Hawaiian sociopolitical evolution, the ali'i, in the process of distancing themselves from the maka'ainana, continued to make strong genealogical claims of descent from the gods. According to Kirch (1985, p. 294), the development of the more stratified social system initiated a radical change in land tenure. The islands were divided into ahupua'a (large radial sections of land running down from the forested uplands across agricultural lands to the coast, and encompassing both land and ocean resources). Ahupua'a were self-sufficient to some extent. Different production patterns were the result of differences in local resources (e.g., land, water, and tool materials). Each of these units was under the control of a lesser chief, who in turn appointed a steward to supervise production, collect tribute, and control water resources. Smaller sections of the ahupua'a, called 'ili and mo'oi, were held and worked by households or groups of commoners (Kirch 1985, p. 2).

Before discussing early water rights, the changes in those rights during prehistoric and protohistoric times, and the evolution of water control and management, we need to try to understand the meaning of water to the Hawaiians and how this meaning evolved over time.
Kirch’s (1985) evolutionary sequence for Hawaiian culture suggests that water management practices intensified over the period from A.D. 200 to 1795 and that the rate of intensification accelerated in the three hundred years prior to European contact. During the first millennium in which the settlers adapted to the varied environments of the Hawaiian archipelago, they employed simple and relatively unchanging methods of water management while developing complex concepts of the meaning and value of water. Their management of water from springs, running streams, and rain was based on their respect for and communication with their gods. For the Hawaiians of the seventeenth and eighteenth centuries, water took on additional meaning as one of the spoils of war since it was a resource for which they contested. It would be tempting to discuss water management in this later developmental period only, and only in terms of “population growth,” “irrigation intensification,” and “social stratification,” for these are the concepts that dominate the Western social scientific discussion of water management in non-Western societies (Steward 1955; Leach 1961; Millon 1962; Price 1971; Mitchell 1973; Lees 1973; Adams et al. 1974; Earle 1978, 1980). However, a major guiding principle of my analysis is that Hawaiian water management can be best understood only after considering the cultural meaning of water in ancient Hawai‘i. A major assumption of my analysis is that the cultural meaning of water changed over the fifteen hundred years of Hawaiian cultural evolution. In the sections that follow, I will argue that as the environment changed, particularly with the production intensification of the expansion (A.D. 1100–1650) and protohistoric (A.D. 1650–1795) periods, the meaning and importance of four primary Hawaiian gods—Kāne, Kanaloa, Lono, and Kū—also changed, with the extent of these changes varying from island to island.

The task, then, is an ambitious one: to cull the literature and present a convincing argument about the meaning of water to early Hawaiians. This is an initial attempt at a synthesis of past and present sources, and it is hoped that this preliminary analysis will provide the basis for further research and inquiry.

Any comprehensive and cogent analysis of the meaning of water in pre-contact Hawai‘i must rely, in part, on the oral historical materials—legends, myths, chants, and proverbial and poetical sayings—that mention or allude to water. Fortunately, there are many useful sources for these materials: Beckwith (1940, 1951), Emerson (1909), Fornander (1916–1917, 1918–1919, 1919–1920, 1969), Handy (1927), Handy et al. (1972), Kamakau et al. (1964, 1976), Kepelino (1932), Malo (1951), Melville (1969), Pukui (1983), and Wichman (1931).
 Oral History: Prayers, Chants, Legends, Myths

Two gods appear to be most central in Hawaiian perceptions of the source, control, and creative potential of water: Kāne, the god of procreative life, and Lono, the god of rain and patron of agriculture (Handy et al. 1972, p. 81; Wichman 1931, p. 19). Two other gods, Kanaloa and Kū, also played roles in water management: Kanaloa’s desire for water was the complement of Kāne’s power to provide it; and Kū’s role as the god of war became intertwined with Lono’s as chiefs waged war to secure lands and control water.

Water in Relation to Kāne and Kanaloa

Kāne was the god of fresh water and sunlight, two essential elements for growth and life. His procreative powers were manifest in the flowing rivers, streams, springs, rain, and sunlight, “the life-giving elements in nature which nourished taro” (Handy et al. 1972, p. 81). He was also the supreme god: he came first and created all things, including heaven and earth (Kepelino 1932, p. 8). In the creation chants known as Kumu Honua, the earth was made out of honua kele (muddy earth), and after it was formed, Kāne created all plants, animals, and humans (Kepelino 1932, p. 16).

The primacy of Kāne is evident in the following prayers (Handy et al. 1972, p. 81):

Life to the land!
Life from Kane,
Kane the god of life.

Life to the people!
Hail! Kane-of-the-water-of-life. Hail!

and

O Kane-of-the-water-of-life
Preserve us thy offspring.

Kāne’s multiple, integrative characteristics and potential are clearly expressed in He Mele no Kane (Emerson 1909, pp. 258–259):
A query, a question,  
I put to you:  
Where is the water of Kane?  
At the Eastern Gate  
Where the Sun comes in at Haehae;  
There is the water of Kane.

A question I ask of you:  
Where is the water of Kane?  
Out there with the floating Sun,  
Where cloud-forms rest on Ocean’s breast,  
Uplifting their forms at Nihoa,  
This side the base of Lehua;  
There is the water of Kane.

One question I put to you:  
Where is the water of Kane?  
Yonder on mountain peak,  
On the ridges steep,  
In the valleys deep,  
Where the rivers sweep;  
There is the water of Kane.

This question I ask of you:  
Where, pray, is the water of Kane?  
Yonder, at sea, on the ocean,  
In the driving rain,  
In the heavenly bow,  
In the piled-up mist wraith,  
In the blood-red rainfall,  
In the ghost-pale cloud-form;  
There is the water of Kane.

One question I put to you:  
Where, where is the water of Kane?  
Up on high is the water of Kane,  
In the heavenly blue,  
In the black piled cloud,  
In the black-black cloud,  
In the black-mottled sacred cloud of the gods;  
There is the water of Kane.

One question I ask of you:  
Where flows the water of Kane?  
Deep in the ground, in the gushing spring,  
In the ducts of Kane and Loa,  
A well-spring of water, to quaff,  
A water of magic power—  
The water of life!  
Life! O give us this life!

Kāne-i-ka-pahu-wai (Kāne with a calabash of water) pours water upon the earth in the form of rain, a divine gift from the gods, thus giving life to all vegetation. In Kumulipo, the creation chant (Beckwith 1951, p. 60), the stanzas describing Kāne’s creative energy are as follows:

112. The man with the water gourd, he is a god  
Water that causes the withered vine to flourish  
Causes the plant top to develop freely

115. Multiplying in the passing time  
The long night slips along  
Fruitful, very fruitful  
Spreading here, spreading there  
Spreading this way, spreading that way

120. Propping up earth, holding up the sky  
The time passes, this night of Kumulipo  
Still it is night

Melville (1969, p. 13) interpreted these three stanzas as recounting the spread of vegetation and the multiplication of the population. Kāne, in Melville’s interpretation, was the “supporting root” containing the essential energy that drove reproductive growth.

The following prayers recognize the centrality of Kāne, along with Kanaloa, in the production of food (Wichman 1931, p. 11):

O Kane, O Kanaloa,  
Here is the taro, the banana,  
Here is the sugar cane, the awa,  
See, we are eating it now.

and
O Kane, O Kanaloa,
Here is the awa for you,
Here is the sugar cane,
Here is the banana—
We eat and drink by your power.

As the god of sunlight, Kane was particularly important to wetland taro cultivation: it was crucial that not too much sunshine “scorch the crop” or too little “encourage rot and sickly growth” (Wichman 1931, p. 19).

Although Kane possesses multiplicative and integrative characteristics and potential, it is his association with Kanaloa that appears to emphasize his identification as the source of spring water and ‘awa. The legend of how several springs came into existence as a result of Kane’s actions and Kanaloa’s desire is recounted by Handy et al. (1972, pp. 64–65) as follows:

Kane and Kanaloa are said to have come to Hawaii from Kahiki . . . addicted to ‘awa drinking. They traveled about the islands and sometimes stopped to brew their ‘awa at places where there was no water, hence the need to open springs. They first came to Kauai, then to Oahu, then to Kohala on Hawaii, where they lived in the heiau named Mo‘okini. From Kohala they went to Hamakua, and on to Hilo. Near there, at the cliff named Ka‘awali‘i (The small ‘awa) they prepared to brew ‘awa and found there was no water. Kane thrust his spear into the ground, and water came forth. This spring, which continued to flow, was called “The-Water-of-Kane-and-Kanaloa.” Again at Ka Lae (South Point) in Ka‘u they needed water for their ‘awa, and Kane thrust his spear into a rock, where water flowed out. This spring, continuing to flow, likewise was called “The-Water-of-Kane-and-Kanaloa,” although today it is no longer there. They went to Maui, and there at Hamakua needing water for their ‘awa, they again opened a spring. This spring, which also continued to flow, was called “Kanaloa’s Water.”

The following story of two springs opened by Kane and Kanaloa in a valley named ‘Ohi‘a, near Wailua on the windward coast of Maui, was told by Annie Kalau (Ka Nupepa Ku‘oko‘a, October 4, 1923; quoted in Handy et al. 1972, p. 65):

The name of the valley is ‘Ohi‘a and in it is a spring belonging to two supernatural beings, Kane and Kanaloa. Here is a short story that the traveller got: While these two were travelling, they came to this place and spent the night with the natives there. They chewed some ‘awa, put them into an ‘awa bowl (kanoa) but had no water for it. The strangers asked the natives for water. They had some but it wasn’t clean. So these two supernatural ones walked up to the foot of the hill, and thrust their spears into the ground. Kane thrust his spear down and withdrew it and so did Kanaloa. This was the strange thing about it—Kane’s water came with a roar and Kanaloa’s with a soft, rippling sound. It was said that Kane was bad tempered and that was why his water rumbled, Kanaloa was gentle and that was why his water sounded softly. These are very refreshing springs as cool as ice water. Much water comes from those two holes, and they supply the taro patches of that valley with water.

Another spring on Maui attributed to the two gods was found in the barren southwest part of the island. On O‘ahu, springs attributed to the two gods were found in the following places: Kalihi Valley, at a place named Puna-Wai-o-Kalihi (Spring Water of Kalihi); Koko Head; Waikāne Valley; and Wai‘alae, where the spring watered a lo‘i complex for taro.

Green and Pukui (1936, p. 113) recounted a legend similar to Annie Kalau’s. When Kāne and Kanaloa were traveling in the vicinity of Koko Head in southeastern O‘ahu, a barren region, they arrived at Hanauma Bay.
"O Kane! [said Kanaloa] we keep on going and we are dying of hunger! let us eat." Kane looked about and saw that there was no water for mixing their refreshment of awa drink. He struck the earth with his staff and water gushed forth. . . . They had not gone far when Kanaloa wanted to eat again . . . so Kane again struck the earth with his staff and water gushed forth. [A]nd many were the waterholes made by Kane between Hanamauma and Laeahi.

The ruins of a shrine dedicated to Kanaloa have been found on Kaua‘i, beyond Kekaha. The site is on an arid slope above the seashore, near which is a spring referred to on modern maps as "Sacred Spring."

**Water in Relation to Lono and Kū**

Dryland cultivators regarded as their patron the rain god Lono, who took on special significance on the island of Hawai‘i. Lono was referred to in many ways. For example, he was named Lonowaimakua (Lono, father of waters), Lononuinohokawai (Great Lono dwelling in the waters), and Lono-of-the-rain-burdened-dark-cloud. The rains of Lono, which typically began in August and September, were "awaited with eagerness in the kula lands" (Wichman 1931, p. 19). The dryland cultivator went out into his fields and prayed (Wichman 1931, p. 20):

> This is our taro, O Lono—yours and mine. . . . Protect our taro—send the rains born in the heavens.

After many months, the taro was ready for harvesting and the farmer offered prayers to Lono to continue protecting his fields. An underground oven was prepared, and Lono was offered choice pieces of taro and pig with a prayer (Wichman 1931, p. 21):

> The food is cooked—our fresh taro; here is the taro; here is the pig. Come, partake of this, our food. O god of Farming!

Lono and Laka were the principal fertility gods. With their help crops were planted; in their service farmers worked, unless dedicated to some other god or goddess. The worship of and service to these gods were, in ancient days, under the guidance and instruction of priests dedicated to and guided by the gods (Wichman 1931, p. 13).

Another rite, the annual *makahiki*, was celebrated in honor of Lono. The *makahiki* was held in the month called *Ikuwa* (what is now late October to early November), the time of "dark rough seas, wind, thunder, lightning and unceasing rain . . . [when] the bad weather of the rainy season has taken full possession" (Kepelino 1932, p. 94). This rainy period would usually last until February, when sweet potato and dryland taro would thrive on "the plains of Ka‘u, the slopes of Kona, and windward Haleakala on Maui" (Handy et al. 1972, p. 330).

The ceremonies associated with the *makahiki* probably originated and were most highly elaborated on the island of Hawai‘i, where Lono was believed to have lived in ancient times. The famous *heiau* at Kealakekua was dedicated to him, and it was there he promised to return. According to Handy et al. (1972, p. 331):
On the island of Hawaii, the mo‘i or paramount chief acted as host to Lono during the festival. On behalf of Lono he received the offerings or tribute from all the people, collected by landlords on altars dedicated to Lono in every district. The produce and land of each district was kapu until the tribute had been accepted as sufficient by the chief tax collector who accompanied the procession headed by the staff symbolizing the god.

Following the release of the land from the kapu there was feasting and general festivity.

According to Malo (1951, p. 141):

The Makahiki was a time when men, women and chiefs rested and abstained from all work, either on the farm or elsewhere. It was a time of entire freedom from labor. . . . During these four months [Ikawa, Weleha, Makalii, Kaele], then, the people observed Makahiki, refraining from work and the ordinary religious observances.

Lono was worshipped in the makahiki season and prayed to during planting and harvesting times. Although he does not appear to be a god of multiple characteristics and potential like Kane, he apparently had a more intimate relationship with his worshipers, the dryland cultivators. For ancient Hawaiians cultivating the kula lands, managing water meant maintaining a close relationship with Lono on a daily basis.

Handy et al. (1972, p. 98) quote two prayers said to Ku after the planting of the huli (taro tops) was completed and before harvesting:

O god, O Ku-the-striver, O Ku-of-joint-action,
Make our taro grow prolifically, O Ku-of-joint-action,
Make our taro have stalks like the banana, O Ku,
Make our taro have stems like the 'ape, O Ku,
Make our taro have leaves like the banana, O Ku,
That a man may be hidden amongst our taro, O Ku;
O Ku-of-joint-action, my god until the taro reaches maturity, O Ku;
Amama, the kapu is over; the prayer has gone on its way.

and

O my god of the maturing of the taro,
O Ku-of-joint-action,
In the morning our taro will be pulled up,
Clustered together, carried on poles;
The imu for the taro will be lighted.
The taro baked in the imu, the imu opened, the taro peeled;
Our taro will be pounded, placed in a calabash;
It will be mixed, this taro of ours and of Ku-of-joint-action.
Firewood will be chopped, the imu lighted,
The pig strangled, the bristles of the pig singed off,
The pig disemboweled, and our pig baked in the imu,
O Ku-of-joint-action.
When the pig is cooked it will be cut up;
Men, women and children will eat of the pig, of the poi, of our taro—
The mighty planter's and yours, O Ku-of-joint-action.
To [the gods of] the lesser ranks and the greater ranks:
Reverent has been the kapu, reverent the freeing,
That life may be given to the earth.
Amama, the kapu is freed; the prayer has gone on its way.

Ku, as the god of action, was ultimately responsible for all the creative activities of the people. In the context of taro cultivation, the “joint action” of Ku probably refers to the cooperative labor required to build, maintain, and protect taro lo'ii systems, as well as to the
planting, caring for, and harvesting of large quantities of taro in the late expansion and protohistoric periods.

Kū’s association with water is directly tied to taro lo‘i production and the expansionary warfare that netted additional taro lands in the last two centuries of Hawaiian prehistory. Kirch (1985) linked the building of luakini heiau dedicated to Kū with irrigation expansion in Mākaha Valley on O‘ahu and Hālawa Valley on Moloka‘i. Summarizing the research of Green (1980) on Mākaha Valley, Kirch (1985, p. 119) made a cogent point:

During this final phase of development, Kāneʻaki Heiau was rebuilt and its size more than doubled, converting it to a luakini-class temple of human sacrifice, dedicated to the war god Kū. Such an event could only have been undertaken by a paramount chief. Also during this period, a main irrigation ditch was constructed down into the dry lower valley, permitting the chiefs to further intensify the valley’s productive capacity.

Drawing on his own research in Hālawa Valley, Kirch (1985, p. 130) strengthened the links among Kū, taro lo‘i expansion, and warfare:

The major development of irrigation, however, appears to have taken place during the final, Mana Phase (A.D. 1650–1800). By the end of this period the entire valley floor was covered in well-constructed pondfield complexes, some with irrigation canals up to 1,386 meters long. It was probably also during the Mana Phase that the valley’s two major temple sites, Mana and Pāpā Heiau, were constructed. Both of these are luakini-type temples, dedicated to Kū, the god of war. Mana Heiau is reputed to have been built during the rule of Alapa’inui, a high chief of Hawai‘i Island, who conquered Moloka‘i about A.D. 1720.

Kū’s association with water appears strongest during the last two centuries of Hawaiian prehistory, when population growth necessitated increased taro productivity. In the kula lands that dominated the island of Hawai‘i, this pressure was intensified; and Kū, the god of warfare, and Lono, the god of rainfall and agriculture, became particularly important (see Kame‘eleihiwa 1992, pp. 44–49, for a fuller discussion of Kū and Lono). When the chiefs from the island of Hawai‘i came to conquer the rich, wet valleys of Maui, Moloka‘i, and O‘ahu, they undoubtedly brought their enhanced Kū and Lono beliefs with them. In the well-watered valleys of Maui, Moloka‘i, Kaua‘i, and O‘ahu, Kāne and Kanaloa had provided abundant water and sunlight for taro production. With the evolution of complex chiefdoms on O‘ahu and Maui in the late protohistoric period, Kū and Lono were elevated in importance. Perhaps on O‘ahu and Maui, Kāne, the embodiment of water and sunlight, came to be perceived as a constant; while Kū and Lono, the embodiment of warfare and agricultural production, respectively, represented variability, a variability in part controlled by temple construction, makahiki rituals, and an expanding priestly class. Kaua‘i, unconquered by the chiefs from the island of Hawai‘i, probably continued to give primacy to Kāne and Kanaloa. However, with the evolution of more complex chiefdoms on Kaua‘i, Kū may have taken on greater importance.
Oral History: Proverbial and Poetical Sayings

Another approach to assessing the meaning of water in old Hawai‘i is to analyze proverbial and poetical sayings in which *wai* (water) plays a meaningful role. These sayings are particularly illuminating, as Pukui (1983, p. vii) has eloquently stated:

Since the sayings carry the immediacy of the spoken word, considered to be the highest form of cultural expression in old Hawai‘i, they bring us closer to the everyday thoughts and lives of the Hawaiians who created them.

My analysis is based on some of the proverbs and poetical sayings from Pukui’s (1983) ‘*Olelo No‘eau*. For each of these sayings, Pukui provided the original Hawaiian text, an English translation, and, where necessary, an interpretation. These are reproduced here to assist the reader. Although Pukui did not attempt to group the sayings into categories of meaning because she felt that “a single saying often speaks to many topics,” I am presenting the ones I have selected in the following categories: life and the body, personal characteristics and relationships, characteristics of specific locales, and peace and war, contest and conflict.

**Water in Relation to Life and the Body**

As the chants and legends quoted above suggest, water was a powerful symbol of life to the old Hawaiians. Pukui has three proverbs that specifically and clearly make this symbolic link.

#2482 Ola i ka wai a ka ‘opua.
*There is life in the water from the clouds.*
Rain gives life.

#2178 Mohala i ka wai ka maka o ka pua.
*Unfolded by the water are the faces of the flowers.*
Flowers thrive where there is water, as thriving people are found where living conditions are good.

#598 He hue wai ola ke kanaka na Kane.
*Man is Kane’s living water gourd.*
Water is life and Kane is the keeper of water. To dream of a well-filled water gourd that breaks and spills its contents is a warning of death for someone in the family.

In this last proverb, Kane is named and the strong and meaningful relationship between water and life is abundantly clear: an empty water gourd is a powerful symbol of death. Not surprisingly, water also plays a role in illness.

#2705 Pū‘ali kalo i ka wai ‘ole.
*Taro, for lack of water, grows misshapen.*
For lack of care one may become ill.

In the following poetical saying, the flowing, continuous movement of water is a metaphor for genealogy and descent.

#2602 Papani ka uka o Kapela; pua‘i hānono wai‘ole o Kukaniloko; pakī hunahuna ‘ole o Holoholokū; ‘a‘ohe mea nana e ‘a‘e paepae kapu o Liloa.
Close the upland of Kapela; no red water gushes from Kukaniloko; not a particle issues from Holoholoku; there is none to step over the sacred platform of Līloa.

The old chiefs and their sacredness are gone; the descendants are no longer laid to rest at Ka-pela-kapu-o-Kaka'e at ʻĪao; the descendants no longer point to Kukaniloko on Oʻahu and Holoholoku on Kauai as the sacred birthplaces; there is no one to tread on the sacred places in Wʻaiʻpō, Hawaiʻi, where Līloa once dwelt.

Finally, a water gourd figures prominently in defining a young individual’s place in his or her life cycle.

#1506 Ka nui e pa’a ai i ka hue wai.
The size that enables one to carry a water bottle.
Said of a child about two years old. In Kaʻū where fresh water was scarce and had to be obtained from upland springs, every person who went helped to carry home water. When a child was about two, he was given a small gourd bottle for carrying water.

Carrying a small water gourd may represent the first economic contribution of a young Kaʻū Hawaiian to the life of the family and the community.

**Water in Relation to Personal Characteristics and Relationships**

Water is generally associated with prosperity and authority, as in the proverb below.

#1188 I kani no ka ‘alae i ka wai.
A mudhen cries because it has water.
A prosperous person has the voice of authority.

Particular types or features of water are associated with specific personal characteristics. In the following proverbs, we see that rushing, overflowing water is associated with impropriety, humility, and strength.

#1134 Hū ka wai i ke pili.
The water overflows to the pili grass.
Said of anything that overflows its boundaries, including a person whose behavior goes beyond the bounds of propriety.

#1122 Huʻea pau ʻia e ka wai.
All scooped up by rushing water.
Everything is told, no secrets are kept.

#2627 Pepe i ka wai o Niuliʻi.
Crushed by the water of Niuliʻi.
Rendered helpless or made humble and obedient.

#2630 Pihaʻā moe wai uka.
Stones that lie in the water in the upland.
Experts in strenuous sports. They are compared to the stones that not even a freshet can wash down to the lowland.

#1929 Kūpinaʻi i ke alo o Haoaloa.
Keeps repeating in the presence of Haoaloa.
The din of shouting is heard again and again. Also, the noise keeps flowing like rushing water.

While rushing, overflowing water was related to clamor and calamity, smoothly flowing water symbolized proper process, prosperity, and snobbish pride.

#755 Hele no ka wai, hele no ka ʻalā, wali ka ʻulu o Halepuaʻa.
The water flows, the smooth stone [pounder] works, and the breadfruit of Halepua’a is well mixed [into poi].

Everything goes smoothly when one is prosperous.

#1102 Ho'omoe wai kahi ke kāhō.
Let all travel together like water flowing in one direction.

#2574 Pa'ihi 'oe la, lilo i ka wai, 'a'ohe 'ike iho i ka hoa mua.
Well adorned are you, borne along by the water, no longer recognizing former friends.
Said of one who grows proud with prosperity and looks down on his friends of less prosperous days.

Rippling and still water is linked to quietness, geniality, and kindness.

#393 Hā'ale i ka wai a ka manu.
The rippling water where birds gather.
A beautiful person. The rippling water denotes a quiet, peaceful nature which attracts others.

#2916 Waipahē wale.
As gentle as still water.
Said of a person who is genial and kind.

Rippling and shallow water is associated with personal vanity.

#1054 Holu ka wai o Ka'uliili i ka makani.
The water of Ka'uliili ripples in the wind.
A humorous saying applied to one whose proud swagger is like the movement of the 'ūlili (wandering tattler).

#1680 Ke 'anapa nei ka waili'ula o Mānā.
The water in the mirage of Mānā sparkles.
Said of one who is overdressed.

Dark and dirty water is linked with evil, trouble, and wrongdoing.

#1765 Ke lepo ke kumu wai, e hua'i ana ka lepo i kai.
When the source of the water is dirty, muddy water will be seen in the lowland.
When the thoughts are dirty, dirty words are heard.

#1238 'Inā e lepo ke kumu wai, e hō'ea ana ka lepo i kai.
If the source of the water is dirty, the muddy water will travel on.
Where there is evil at the source, the evil travels on.

#2859 Uhiuhi lau māmāne ka wai o Kapāpala.
Covered with māmāne leaves is the water of Kapāpala.
The stream in Kapāpala, Ka'ū, often becomes very muddy. The people used to place māmāne branches in the water to help the mud settle so that some drinking water could be obtained. This saying applies to a person who tries to cover up the wrongdoing of another.

#2429 O ka mea ukuhi ka i 'ike i ka lepo o ka wai; o ka mea inu 'a'ole 'oia i 'ike.
He who dips knows how dirty the water is, but he who drinks does not.
He who does the work knows what trouble it takes; he who receives does not.

21
Blocked water represents inertia and stalemate, while water that has dried up is a metaphor for withering joy and solitude.

#1925 Ku palaka ka wai o Welokā.
The water of Welokā is blocked.
Said of a person who has lost interest or becomes inactive, or of a situation that is at a standstill.

#2126 Malō ka wai i ka lā.
The water dries up in the sun.
Joy withers in the presence of wrath.

#24 Aia aku la i kula panoa wai ‘ole.
Gone to the dry, waterless plain.
Gone where one may find himself stranded or deserted.

Hawaiians clearly distinguished types and features of water and associated these with various personal characteristics and relationships. Water had its source in Kane and Lono, but as it rushed, flowed, rippled, slowed, darkened, and dried out, it symbolized life and the significant personal and social relations that enrich life.

**Water in Relation to Characteristics of Specific Locales**

Pukui has many proverbial and poetical sayings about various features of the islands of Hawai‘i, Maui, O‘ahu, and Kaua‘i. These provide a colorful context for the ethnohistoric and archaeological data presented in a later section of this report.

From the island of Hawai‘i, Pukui draws sayings about the water-related features of Hilo, Ka‘ū, Kohala, and Kekaha. Whereas Hilo was a rainy community cross cut by gulches and streams, Ka‘ū, Kohala, and Kekaha were communities where water was in scarce supply and where the ingenuity of the people was necessary for survival.

#1245 Inu wai kōlī‘uli‘u o Hilo.
Drink the waters of the distant sky in Hilo.
The rain of Hilo is a chief source of drinking water.

#242 ‘Au umauma o Hilo i ka wai.
Hilo has breasted the water.
To weather the storm. The district of Hilo had many gulches and streams and was difficult to cross.

#2132 “Māmā Hilo?” “‘Ae, māmā Hilo i ka wai ‘ole.”
“Is Hilo light?” “Yes, Hilo is light for lack of water.”
A question asked of a runner, and his reply. It means that the way is clear, with no robbers or unpleasant experiences, and no rains to swell the streams and make traveling difficult.

#1610 Ka‘ū, i Palahemo.
In Ka‘ū at Palahemo.
Palahemo is a pool near Kalae in Ka‘ū. Salt water is found under the fresh water, and any disturbance, like the dropping of a heavy stone, reverses the water, so that the salt water rises to the top. This place is famed in songs and chants.

#1887 Ku ka hale i Punalu‘u, i Ka-wai-hū-o-Kauila.
The house stands at Punalu‘u, at the gushing waters of Kauila.
Said of one who has found peace and comfort at last. Ka-wai-hū-o-Kauila is a spring, the gift of a turtle goddess to the people of Punalu‘u, Ka‘ū, Hawai‘i. The people of that locality feared the cannibal woman Kaikapū, who lived near their best springs. In order to avoid her and obtain water, they dived to the sea floor where fresh water bubbled up—hence the name Puna-lu‘u (Water-dived-for). Seeing their difficulty, a turtle goddess created this spring.

#2380 ‘Ohu’ohu Punalu‘u i Ka-wai-hū-o-Kauila.
Punalu‘u is adorned by the rushing water of Kauila.
Refers to Punalu‘u, Ka‘ū.

#1762 Ke kula wai ‘ole o Kama‘oa.
The waterless plain of Kama‘oa.
The plain of Kama‘oa, in Ka‘ū, was well-populated, but its people had to go upland for their water supply.

#2220 Na ‘ilina wai ‘ole o Kohala.
The waterless plains of Kohala, where water will not remain long.
After a downpour, the people look even in the hollows of rocks for the precious water.

#1716 Kekaha wai ‘ole o na Kona.
Waterless Kekaha of the Kona district.
Kekaha in Kona, Hawai‘i, is known for its scarcity of water but is dearly loved by its inhabitants.
Pukui also has one saying about sacred pools at Kīlauea and Ni‘ihau.

#1653 Ka wai hūnā a ka pāo‘o.
The hidden water of the pāo‘o fish.
A little pool of water on Lehua often mentioned in the chants of Ni‘ihau. It is said to be guarded by a supernatural pāo‘o fish. When this fish rises to the surface, its back resembles the surrounding rocks, which makes the pool difficult to see. When the pāo‘o sinks to the bottom, the water can again be seen. Also, a pool not far from the crater at Kīlauea. The priests of Pele who knew of its location obtained water from it to mix the ‘awa drinks they offered to her. Like the pool on Lehua, a supernatural pāo‘o fish guarded it. This pool was destroyed during the making of a road.

Two poetical sayings make reference to the flowing and swirling streams of Maui.

#2300 Na wai ‘ehā.
The four wai.
A poetic term for these places on Maui: Wailuku, Waiehu, Waihe‘e, Waikapū, each of which has flowing water (wai).

#1649 Ka wai ho‘iho‘i lā‘i o ‘Eleile.
The water of ‘Eleile that carries back the ti-leaf stalk.
The pool of ‘Eleile on Maui is famed in songs and chants. Visitors throw ti stalks into the pool and watch the water carry them all around before washing them downstream.

The waters of O‘ahu are depicted as mysterious and unpredictable in the following proverbs.

#1655 Ka wai kumu ‘ole.
The water without source.
Kawahāpāi, O‘ahu. 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 their 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 renamed Ka-wai-hāpai (The-carried-water) and the water supply was named Ka-wai-kumu-'ole (Water-without-a-source).

#2917 Wai pe'epē'e palai o Waiakekua.
The water of Waiakekua that plays hide-and-seek among the ferns.
Waiakekua is in Mānoa.

#2731 Pukana wai o Kahuku.
The water outlet of Kahuku.
Refers to the outlet of an underground stream that once flowed from Kahuku to Waipahu, Oʻahu.

The lakes and abundant waters of Kauaʻi figure prominently in Hawaiian proverbs.

#2874 'Umeke piha wai o Mānā.
A calabash full of water is Mānā.
Refers to Mānā, Kauaʻi, which is flooded during the rainy season.

#2860 'U'īna ka wai o Nāmolokama.
The water of Nāmolokama falls with a rumble.
Nāmolokama Falls, Kauaʻi, is famous in chants and legends.

#1662 Ka wai 'ula 'iliahi o Waimea.
The red sandalwood water of Waimea.
This expression is sometimes used in old chants of Waimea, Kauaʻi. After a storm Waimea Stream is said to run red. Where it meets Makaweli Stream to form Waimea River, the water is sometimes red on one side and clear on the other. The red side is called wai 'ula 'iliahi.

#404 Haehae ka manu, ke 'ale nei ka wai.
Tear up the birds, the water is surging.
Let us hurry, as there is no time for niceties. Kane'alohi and his son lived near the lake of Halulu at Waiʻaleʻale, Kauaʻi. They were catchers of 'uwaʻu birds. Someone falsely accused them of poaching on land belonging to the chief of Hanalei, who sent a large company of warriors to destroy them. The son noticed the agitation in the water of Halulu and cried out a warning to his father, who tore the birds to hasten cooking.

Water in Relation to Peace and War, Contest and Conflict

In Pukuiʻs collection, it is interesting to note the numerous connections between tranquil, still, or rippling waters and personal and interpersonal peace.

#2050 Mai hōʻaleʻale i ka wai i lana mālie.
Do not stir up water that is still.
Do not stir up contention when all is peaceful.

#2053 Mai hōʻoni i ka wai lana mālie.
Do not disturb the water that is tranquil.
Let the peaceful enjoy their peace.

#1019 Hōʻale i ka wai ua lana mālie.
Stirring up still waters.
Said of one who stirs up controversies.

Although water generally symbolized peace, comfort, and beauty, wai also came to carry symbolic value in relation to contest and conflict.

#1264 I wai noʻu.
Give me water.
Said to challenge another to a game or contest.

#973 He wai 'au'au ia no ke kanaka.  
Bathing water for the man.  
Said of a hero who is expert in dodging spears. Spears are like bathing water to a warrior who loves to fight.

The final six proverbs quoted here link water to warfare.

#825 Hemo ke alelo o Kaumaka i ka wai.  
The tongue of Kaumaka came out in the water.  
Said of one who has had a good trouncing. Kaumaka, a defeated chief, was put to death by drowning.

#1151 I 'auhe'e o Ka'uiki ika wai 'ole.  
Ka'uiki was defeated for the lack of water.  
When 'Umi, ruler of Hawai'i, went to Hāna to battle against Lono-a-Pi'ilani of Ka'uiki, thirst weakened the Maui warriors. Often used later to mean "without water or the needed supplies we cannot win."

#1711 Ke inu aku la paha a'u 'Alapa i ka wai o Wailuku.  
My 'Alapa warriors must now be drinking the water of Wailuku.  
Said when an expected success has turned into a failure. This was a remark made by Kalaniōpu'u to his wife Kalola and son Kiwala'ō, in the belief that his selected warriors, the 'Alapa, were winning in their battle against Kahekili. Instead they were utterly destroyed.

#1237 Imua e na pōki'i ia inu i ka wai 'awa'awa.  
Forward, my younger brothers, until you drink the bitter water [of battle].  
Uttered by Kamehameha as he rallied his forces in the battle of 'Iao Valley.

#1029 Ho'i hou ka wai i uka o Ao.  
The water returns again to the upland of Ao.  
A Maui expression referring to a person who goes upland for water. This saying came from the battle of Ka 'uwa'upali, when Kamehameha defeated the warriors of Maui in 'Iao. The stream was dammed with bodies, and the water ran red with blood. The people had to travel far inland to find uncontaminated water.

#2727 Pūkākā na lehua o Mānā, 'auwana wale iho no i ka 'auwai pakī.  
Scattered are the warriors of Mānā, who go wandering along the ditch that holds little water.  
A boast after winning a battle.

In these final sayings, specific references are made to places and people, so it is possible to estimate when they were first used. The origin of these proverbs can clearly be traced to the late expansion and protohistoric periods, when the frequency and ferocity of warfare were increasing. For example, the origin of proverb #1151 can be traced to the sixteenth century, when 'Umi invaded Maui to take up the cause of his brother-in-law who was being mistreated by Lono-a-Pi'ilani (Fornander 1916–1917, p. 246). The origin of other Pukui proverbs can be traced to battles fought at the end of the protohistoric period, in 1776 (#1711) and 1790 (#1237 and #1029) (Fornander 1919–1920, p. 286; Fornander 1918–1919, p. 470). In these cases, warfare was motivated, at least in part, by the desire to expand chiefly holdings of productive,
well-watered taro lands. It is not surprising, then, that in the last two centuries of Hawaiian prehistory, water acquired more sanguinary connotations.

In sum, the meaning of water may have gone through the following transformations. In the early centuries of Hawaiian settlement and colonization, water was abundant and was associated with peace, productivity, and prosperity. In the final two hundred years of Hawaiian expansion and evolution toward a proto-state, it took on an additional meaning. Water, as the ultimate prize of conquest, became intimately associated with warfare. While Kane and Lono remained the sources of water, Kū became the means of its control.

The importance of water and Lono, the god of agriculture, increased as the population grew and more water and agricultural land were required for production. To secure these resources, paramount chiefs conquered lesser ones. Simple Hawaiian society was therefore transformed into a complex, stratified one; and Kū came to be associated with the control of water and the potential it provided for increased political power.

**EARLY WATER RIGHTS AND MANAGEMENT**

We are now ready to analyze early water rights and how these rights evolved in relation to increasing population pressure and political complexity.

During the expansionary period, land and water were managed by the paramount chiefs, who allocated their use to lower-ranking chiefs and, through them, to the common people, who were the ones occupying and cultivating the land (Perry 1912, p. 92). There was a large supply of water, and irrigation was needed mainly for taro production. The needs of the people were few and easily provided for, so the rules governing the use of land and water were simple.

With population growth and the extension and intensification of agriculture, the regulation and management of land and water became more important and complex. According to Kameʻeleihiwa (1992, p. 29):

> The complexity of the Hawaiian agricultural system is reflected in the naming of each ‘Āina parcel, lo‘i, and fishpond with personal names as well as definitive terms. Furthermore, all of these names and terms were known, understood, and accounted for by all of the Ali‘i, which is no small feat in a preliterate society. In traditional Hawai‘i, memorization and a keen mind were invaluable tools.

The construction of the ‘auwai was done under the supervision of the konohiki (headman of an ahupua‘a under a chief). In the case of a large ‘auwai diverting the water of a natural stream to irrigate two or three ahupua‘a, the konohiki who provided the largest number of men to do the work was the supervisor. The diverted water was then distributed among the konohiki in proportion to which each had contributed to the labor force amassed for the construction of the
'auwai. Thus the chief who provided more men to work had rights to more water (Nakuina 1893, p. 79).

_Auwais_, were generally dug from makai—seaward or below—upwards. The _konohiki_ who had the supervision of the work having previously marked out where it would probably enter the stream, the diggers worked up to that point. The different _ahupuaa_’s, _ili_’s or _ku_’s taking part in the work, furnished men according to the number of cultivators on each land. There was no limit though to the number of laborers any land might furnish, and it often happened that a small _ku_ or _ili_ was sometimes represented in the _auwai_ making by more men than a much larger land or _ahupuaa_, and would thus become entitled to as much or more water, at the distribution of the water privileges, than were assigned larger tracts.

This system of distributing water in proportion to the labor provided for building the _‘auwai_ “was in its results the equivalent of a system of distribution in accordance with the acreage planted” (Perry 1912, p. 92). Each _konohiki_ would try to provide enough labor to obtain the water he needed to cultivate his land. If a _konohiki_ who had some water rights contributed more men for the maintenance of the _‘auwai_, he was rewarded with an additional allotment of water. Thus the system encouraged increased production (Perry 1912, p. 93).

These early water rights clearly reveal that “fairness” was a basic Hawaiian value. A fair share of the water supply was the amount needed by a _konohiki_ to use for feeding those who worked the land under his supervision.

On the other hand, water rights or privileges could be lost if not used. For example, if a _konohiki_ who had obtained rights to enough water to irrigate all his land allowed some of his land to go uncultivated, he would not receive more water than he needed for the cultivated portion.

The responsibility of maintaining the ditches fell upon those whose lands were watered. Failure to carry out this responsibility resulted in the temporary or permanent loss of water rights. In extreme cases, those negligent were dispossessed of their lands (Perry 1912, p. 94).

_Dams_ were constructed to distribute water. The dams were loose walls of stones and clods of earth and grass built tall enough to divert the water into the _‘auwai_. Only half or less of the water flowing in the stream could be diverted, as the rights of the people who lived _makai_ of the stream were to be respected. If a dam was built in violation of this rule, it was leveled by the landholders below it. When it was rebuilt, delegates from the lands below were present to ensure that a “due proportion” of the water remained in the stream (Nakuina 1893, pp. 79–80). Each parcel of land received its share of water through smaller branch ditches.

There were different methods of water distribution at different times and places. The method probably used earlier, when the population was smaller and the demand for water was less, was as follows: beginning at the highest point, the people on each parcel of land would take all the water they needed before the water was permitted to flow to the next parcel; this process was repeated until the people at the lowest level received their share, and then the cycle started all over again. However, as the demand for water increased—or perhaps when there
was a shortage of water, such as during times of drought—this method was gradually replaced
by a more precise one based on intervals of time (the Hawaiians calculated time by the
positions of the sun and the stars). Water was allowed to flow into certain lots on certain days
of the week or at certain hours of the day or night. In cases where the cultivated lands were
large neighboring lots, water was flowed all night to one lot and all day to the other lot for the
period needed to water all the subdivisions (Perry 1912, p. 94).

Another method was the watering of small lo‘i with the overflow or percolation from
adjacent patches (Perry 1912, p. 95), as described by Nakuina (1893, p. 81):

Bordering on the upper portions of most auwais are small loi limited in size and number,
generally on a hillside, or on the borders of a gulch. These loi are generally awarded kulu or drops;
that is, they are entitled to continual driblets of water, and no one having a water share may turn
the water entirely away from them unless, in times of scarcity, it should be seen that these loi or
lo‘i were full to overflowing.

Loi entitled to kulu water have no time set apart in the regular rotation. Holders of kulu loi were
subject to all the auwai duties.

The konohiki of each ahupua‘a divided the water among the holders of the ahupua‘a, ‘ili,
and mo‘o. The konohiki with the most rights over an ‘auwai was invariably its luna. He
controlled and apportioned water to each mo‘o ‘āina (holding of the common people cultivating
the land) (Nakuina 1893, p. 80). The luna wai was the superintendent of the ditch and was
responsible for the maintenance and distribution of water as well as the settlement of disputes
that arose. However, water disputes were very rare. The konohiki tried to secure equal rights
for everyone and prevent quarrels: “A spirit of mutual dependence and helpfulness prevailed,
alike among the high and the low, with respect to the use of the water” (Perry 1912, p. 95).
Only with this basic value could the Hawaiians prosper and cultivate the land for their food.
During the dry season, the luna wai could transfer water from the lands that had more than
necessary to those in need. If someone was caught breaking a dam, he was killed and his body
put on the breach as a warning to others.

Water rights were for taro cultivators. Cultivators of dryland crops had no claims on
water in the rotation. Sugarcane and banana were planted on lo‘i banks, so they got moisture
from the seepage or ooze from the walls separating the pondfields.

Having laid down the settlement patterns and evolutionary cultural sequence and having
acquired a better understanding of the meaning of water to early Hawaiians, we now have the
tools to start an island-by-island study of water management, mainly through the discussion of
archaeological and ethnohistorical evidence from the main irrigation sites.

For each island, a summary is presented of its location, climate, geology, and surface
hydrography. Following each summary, the most important irrigation sites are discussed.
Although the quality and quantity of the data vary from island to island—that is, some sites
have been extensively studied by archaeologists, whereas others have been described only by
early Western observers—it is still possible to make some inferences about Hawaiian water management and its relation to the evolution of Hawaiian society and its major gods.

Lānaʻi

Lānaʻi is 95 km southeast of Honolulu and 15 km west of Maui and has an area of 365 km². Its climate is subtropical, and its mean annual temperature is about 20°C. Partly sheltered from the northeast trade winds by west Maui and east Molokaʻi, the island is dry, barren, and subject to droughts (Stearns 1985, p. 29; Cordy 1970, p. 45). Dust clouds form during the windy season.

Because the island is small and relatively smooth, the geographic distribution of its rainfall is not as spotty as on the other islands. The average annual rainfall is less than 254 mm along the coast and about 965 mm at the summit. Kona storms (frontal storms moving in from the south), which bring heavy downpour, account for a considerable part of the annual rainfall. These storms occur on the southern side, where the island is not sheltered by larger islands. Nāulu occur during hot weather (Stearns 1940, p. 66). December is the wettest month, and summer is the dry season (Stearns 1940, p. 65).

Lānaʻi consists of a single basaltic dome, 1027 m high and about 20 km across, which has collapsed at its summit. It has five geomorphic areas: central basin, canyon country, northwest rift zone, southwest rift zone, and south rift zone (Stearns 1985, p. 234).

Along the coast, there are a few springs, which flow during low tide, but the water is brackish: “The basal water along the coast is brackish and unfit for human consumption except along the shore of the canyon country” (Stearns 1940, p. 84). There is one basal-water spring that flows during low tide from the north side of Lae Hi Point (Stearns 1940, pp. 84). Some springs are also found along the beach to the east of Kūahua Gulch. According to Stearns (1940, pp. 72–74):

Streams seldom flow except when kona storms strike the island, which is only a few days in a year. Maunalei Gulch had apparently the only perennial stream on the island prior to its diversion.

The aboriginal population of about 3,150 prior to 1778 according to Emory depended chiefly on dew collected on oiled tapas or whipped from heavy shrubbery. Water that accumulated in natural depressions was husbanded carefully, and a few wells were dug along the coast and were plastered on the seaward side with mud and straw to stop the infiltration of sea water. Even with this device these wells yielded water at low tide that was so brackish that it was usable only because the Hawaiians had by necessity become accustomed to it. Sometimes the Hawaiians also went to the small springs in the distant hills and carried home the water from them in gourds.
Kaho'olawe

Kaho'olawe is a small island of 117 km², lying 11 km off the south coast of Maui and 27 km southeast of Lāna'i. Because it is a low island and is sheltered from the trade winds by the larger islands, it has a semiarid climate (Stearns 1940, p. 124). However, stiff strong winds blow constantly from the east, making it the windiest island (Stearns 1940, p. 124).

Most of the rain occurs during the months of November to April, and rainfall varies between about 686 mm and 457 mm. Occasional kona storms bring heavy rains, and nāulu also occur (Stearns 1940, p. 124). Being a dry, windy island, Kaho'olawe has no trees. During the windy season dust clouds extend for many kilometers.

Kaho'olawe is a single volcanic dome composed of 'a'a and pāhoehoe basalt. The higher part of the island was once vegetated and covered with deep soil (Stearns 1985, p. 243). Depending on the frequency of the rains, water a few feet deep remains part of the year in the craters of Keāliahalo and Keāliahuna (Stearns 1940, p. 130). In Ahupū and Hakioawa and in some gulches, next to the walls, there are old Hawaiian wells. According to Stearns (1940, p. 131), "about 50 Hawaiians obtained drinking water from wells in gulches during historic time."

Kaua'i

Location, Climate, Geology, and Surface Hydrology

Kaua'i has an area of 1438 km² and is 52 km across at its widest point. It is separated from O'ahu by the Kaua'i Channel, which is about 115 km wide (Stearns 1985, p. 246). It has a mild subtropical climate with temperatures usually ranging from 21°C to 25°C. The extreme temperatures recorded at Lihue range from 11°C to 31°C. The temperature is lower in the mountains. Northeasterly trades blow almost constantly. During the winter, occasional kona storms bring heavy downpour, and rain from cyclonic storms falls at random. The highest mean annual rainfall, 11 836 mm, occurs at Mount Wai'ale'ale (Macdonald et al. 1960, pp. 113, 115).

Kaua'i is a dissected basaltic dome. Four formations can be distinguished in the Waimea Canyon volcanic series (Stearns 1985, pp. 255–257):

1. Nāpali formation, consisting of thin flows of basalt that accumulated on the sides of the volcano
2. Olokele formation, consisting of massive flows of basalt that accumulated in the Olokele or summit caldera
3. Haupu formation, consisting of massive flows of basalt that accumulated in the Haupu caldera
4. Makaweli formation, consisting of basaltic accumulation in the Makaweli graben

After a long period of erosion, the Koloa volcanic series started, followed by a long period of repose about 3.8 million years ago. Soils were formed, and streams cut deep canyons through the weak Nāpali lava. The sea eroded the coast, forming broad shelves backed by steep cliffs of bare rock (Stearns 1985, p. 260). As Kaua‘i is the oldest island, it is the most eroded.

Rainfall is the source of all fresh water in Kaua‘i. Part of it runs to the ocean in streams, another part of it evaporates, and the remainder moves down through the soil to become groundwater (Macdonald et al. 1960, p. 120). The island has perennial streams that flow all the way to the ocean, except in the area to the west of Waimea Canyon. Large, uniform streams from the rainy uplands flow in deep, steep-walled valleys. There are also many high-level springs and seeps, and Kaua‘i has the only currently navigated river in Hawai‘i.

**Pre-Contact Water Management**

Of all the islands, the most detailed archaeological research on pre-contact Hawaiian water management was conducted for Kaua‘i. I will synthesize the research results to demonstrate the kind of archaeological data it is possible to amass on water management in pre-contact Hawai‘i.

In his survey of Kaua‘i, Bennett (1931, p. 19) noted that the “[r]emains of agricultural terraces are very extensive and quite well preserved.” He also recorded numerous religious shrines and house sites found in proximity to agricultural terraces. Some of these terraces were very extensive, reaching almost to the sea, whereas others were located deep (approximately 14 km from the sea) in the interior of Waimea Valley (Earle 1978, p. 77). Many lo‘i remains can be found on O‘ahu in the interiors of similarly deep valleys.

Building on the survey data recorded by Bennett, Earle conducted detailed archaeological research in the valleys of Halele‘a, which include Hā‘ena, Hanalei, and Wainiha, on the north central coast. Earle (1978, p. 77) characterized the irrigation systems he found as follows:

The archaeological remains indicate a considerable range in the size and complexity of irrigation systems. The largest and most complex systems were located near the sea, on the extensive alluvial plains which are still farmed today. These sites have many relatively large pondfields and intricate ditch complexes. In contrast, along the narrow interior valleys and along minor streams near the coast, terraced sites are found wherever pockets of alluvial soils have developed and could be irrigated. Characteristically, these small sites have only a few dozen fields and a short irrigation ditch.

The problem of determining the age of complex taro irrigation in Halele‘a was addressed by Schilt (1980) and Athens (1983) in Hanalei. Based on radiocarbon dating of soils found beneath pondfield surface remains, Schilt argued that pondfield agriculture might have begun as early as the seventh century. However, Athens conducted a similar analysis at Hanalei and derived “considerably later dates” (Kirch 1985, p. 101).
Hā'ena, located on the border of Halele'a and the district of Nā Pali, has also been studied intensively by archaeologists. Hammatt et al. (1978b, p. 168) developed a tentative cultural sequence for the Kē'ē Beach site in Hā'ena, which Kirch (1985, p. 103) summarizes as follows:

[T]he first phase consisted of a “transient marine-oriented ‘fishing settlement.’” By about A.D. 1200 there was a “population increase with a broader resource base,” and settlement expanded inland. The 1400s witnessed “the development of intensified irrigation agriculture in inland areas with a continued use of the littoral environment,” a pattern that evidently continued up until the historic period.

**Description of Sites**

Earle (1978) was able to map many of the terrace systems, so his research provides valuable data on the irrigation technology of pre-contact Halele'a. His findings are presented in abridged form here.

**Site Ka-D5-4.** This site covers approximately 8.0 ha in the western part of the alluvial fan at the mouth of Limahuli Stream in Hā'ena (see Figures 2 and 3; from Earle 1978, figures 6.2 and 6.3). Approximately 0.5 km from the sea, Limahuli Stream emerges from a narrow mountain valley onto the alluvial coastal plain. The plain, sloping gently northward toward the sea and westward away from Limahuli Stream, was extensively terraced for taro pondfields, which were still in use in 1850. Earle divided these pondfields as follows: System 1, comprised of sections “a” through “f”; and System 2, comprised of sections “g” through “j” (see Figure 3).

Site Ka-D5-4 was irrigated by two ditches originating in narrow Limahuli Valley. Earle (1978, pp. 82–84) detailed the path of both ditches as follows:

The higher ditch (System 1) ran along the base of the mountain ridge until it split into two segments just above the present road. The western segment (1A), which irrigated section “f,” has been mostly destroyed by bulldozing, but the lowest part is still traceable. This ditch turned sharply northeast along the bottom of section “f” where it would have drained exhaust water. The eastern segment (1B) has been badly eroded but its path is discernible. It bordered section “a” and then split around a stone enclosure with the left fork disappearing into section “c” and the right into section “b.” Below an eroded area, a segment of the right fork is shown above section “e.”

The second ditch complex (System 2) comes off the Limahuli stream about 80 m below the first intake. The primary ditch ran directly down the slope and into sections “g” and “h” where it apparently terminated. Below these sections, an isolated segment of ditch is located so that it would have drained exhaust water from the upper sections and, in turn, fed this water to sections “i” and “j.”

Ditches were usually stone-lined and measured 1 m wide and 0.8 m deep. Their slope was minimal from the stream to the top of the sections, at which point they were made perpendicular to the contours of the alluvial plain and the pondfields (see Figure 4; from Earle 1978, figure 6.4). Through most of the ditches, water flow was controlled by a combination of ditch size, ditch slope, and stone diversions. In one ditch, an oval, stone-lined pool received water from sections “g” and “h.” This water was then fed alternatively to sections “i” and “j.”
FIGURE 2. Extensive irrigation complex on coastal alluvial plain with variable topography, Site Ka-D5-4, Hā'ena, Kaua'i
Reprinted from Earle (1978) by permission of the publisher.

FIGURE 3. Representation of Site Ka-D5-4, Hā'ena, Kaua‘i, showing the divisions into sections “a” to “j.” Heavy dashed lines indicate location of irrigation ditches. Darkened area in section “g” is shown in detail in Figure 4 (which is figure 6.4 in Earle 1978).
FIGURE 4. Detailed layout of irrigated terraces on steep and broken topography at section "g" of Site Ka-D5-4, Hā'ena, Kaua'i. See Figure 3 for location of section "g" in relation to rest of Site Ka-D5-4.
The pool probably stopped the forward movement of rushing water, making accurate distribution possible.

The variability in pondfields is clearly indicated in Table 1 (from Earle 1978, table 6.1). In upper site areas with a steep and broken topography, pondfields were small, ranging in mean patch size from 56.5 m² (section “a”) to 87.0 m² (section “h”). In this upper area, each pondfield consisted of a terrace surrounded by stone retaining walls over 1 m high. In order to accommodate the difficult topography, terraces were built in highly irregular patterns.

In the lower portions of the site, which had more even topography, pondfields were larger, ranging in mean patch size from 96.9 m² (section “c”) to 505.3 m² (section “e”). The front of each of these terraces was reinforced by a straight retaining wall, which usually was 0.4 to 1 m high. Earle (1978, p. 86) described how water would have been distributed in these larger pondfields as follows:

Distribution of water among pondfields would have been handled either directly by the ditch network or indirectly by patch to patch flow. In sections (“f,” “g,” and “h”), where a ditch ran through the patches, there was direct access to water. In other sections, a ditch terminated at the top of the section and water would have been fed from one patch to the next down the slope. These sections can be identified in Table 6.1 (Table 1 in this report), by a relatively high mean number of distributary patches (2.9–8.5). This latter situation would have required careful control to insure that all patches received the correct flow of water.

Immediately adjacent to the larger pondfield terraces of Site Ka-D5-4, at the lowest elevation, was Kēʻē Fishpond. This fishpond received fresh water, not from irrigation runoff but from subsurface groundwater. The pond was apparently dug down to groundwater, which was raised by irrigation seepage.

**Site Ka-D5-5.** This site covers approximately 1.4 ha of the alluvial fan east of Limahuli Stream and across the stream from Site Ka-D5-4 (see Figures 4 and 5; from Earle 1978, figures 6.4 and 6.5). Site Ka-D5-5 has a fairly constant slope northward toward the sea and runs parallel to the stream, which bounds it on the west. From a natural bend in the stream, a ditch 1 m wide and 0.5 m deep ran at an angle across the top of the pondfield system. A continuous series of terraces between the ditch and a small stream at the bottom of the site made up the pondfield system. The pondfields were regular rectangular terraces with a mean patch size of 278.1 m²; the front portion of the terraces was reinforced with stone walls about 0.5 m high. Water was fed directly to the highest patches and then distributed from patch to patch down the slope.

**Site Ka-D5-6.** This site is located on the alluvial fan east of Limahuli Stream and just south of Site Ka-D5-5 (Figure 5). The site is slightly rocky and slopes fairly steeply northward away from the mountain ridges looming overhead (Earle 1978, p. 90). One section of the site is steep, but generally the surface is even. On the north, Site Ka-D5-6 is bordered by a natural marsh fed by groundwater from below the cliffs. A single ditch connected to Limahuli Stream
TABLE 1. Characteristics of Taro Pondfields for Archaeological Sites in Ha‘ena and Wainiha, Kaua‘i
From Earle 1978

<table>
<thead>
<tr>
<th></th>
<th>Minimum Number</th>
<th>Mean Patch Size in Meters</th>
<th>S.D.</th>
<th>N</th>
<th>Site Slope</th>
<th>Mean Number Intermediary Patches</th>
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<td>of Patches</td>
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<td>a</td>
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<td>71.5</td>
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<td>e</td>
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<td>57</td>
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<td>194.9</td>
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<td>251.6</td>
<td>89</td>
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carried water around the ridge front, but no lateral ditches were discovered because they had been destroyed.

One section of the site is a long (180 m) and narrow (13 to 54 m) area with about forty pondfields (Earle 1978, p. 91). These narrow pondfields form one to seven tiers of terraces, with each terrace averaging 96.2 m², wrapping around the contour of the fan. The front walls of the terraces were constructed in a fashion identical to that of the terrace walls at Site Ka-D5-4. Because of absence of secondary ditches, Earle (1978, p. 91) concluded that “water was fed into the top patches and then flowed down the terrace tiers.”

Another section of this site was comprised of forty-seven pondfields, consisting of small, irregularly shaped terraces (mean size 37.4 m²) constructed on small patches of alluvial soil between massive boulders. Natural drainage channels transected the site. The terraces were constructed across these channels to form a long series one or two terraces wide. Again, because of the absence of secondary ditches, Earle concluded that water was fed to the top terrace and then channeled down to the lower ones.

**Site Ka-D5-7.** This site is located in Hā'ena, just east of Site Ka-D5-6, on the lowest slopes of the mountain ridges facing the sea. The site slopes fairly steeply northward away from the mountain ridges. The topography is moderately rocky, and the alluvial soil is kept moist by a series of small permanent springs along the ridge base. Water from these springs was channeled to the highest patches of the site.

The terraces of Site Ka-D5-7 were, for archaeological analysis, poorly preserved, but they appear to have been rectangular in shape. One section of the site was a long (157 m) and narrow (13 to 38 m) area of forty-two pondfields, forming one to five tiers of terraces. These terraces had an average size of only 50.0 m² and were reinforced with stone retaining walls. Another section of the site—covered with dense, thorny vegetation—was not mapped in detail. Earle (1978, p. 93) estimated that “perhaps a dozen” terraces were located in this section, covering an area about 22 m wide and 71 m long. For both sections, the absence of preserved ditches made it impossible to estimate the number of distributary patches, but Earle (1978, p. 93) concluded: “It seems probable that water was fed into the first pondfield tier and then to lower tiers in order.”

**Site Ka-D5-8.** This small, well-preserved site is located in Mānoa Valley in Hā'ena, on an alluvial terrace standing more than 5 m above Mānoa Stream (see Figure 6; from Earle 1978, figure 6.6). The west side of the site rises sharply to the ridge bordering the valley, whereas the east side drops off to the streambed. The site is of special interest because, in addition to irrigation systems, it has dry farming, habitation, and ceremonial structures (Earle 1978, p. 94).
The head dam was located just above the naturally steep section of Mānoa Stream, where a stone percolation dam might have diverted water into the primary ditch. The ditch is poorly preserved, but Earle was able to trace 120.6 m of it from the intake to the main terraces. Earle (1978, p. 94) described in detail the ditch complex as follows:

Near the intake, the ditch followed along the contour of the slope for about 36 m and was retained here by an earthen embankment. The ditch then ran down the steep and rocky alluvial terrace until it reached the top of the pondfields. The average slope of the ditch was .105. Due to poor preservation, it was impossible to reconstruct the ditch’s cross section, but apparently it was a simple earthen channel, stone lined at points.

In the major section of this site, there were thirty-three well-defined terraces, with a total area of 2409 m²; another 5583 m² might have been irrigated. The terraces form a series of narrow tiers, with each tier having one or two terraces. The walls are up to 1.2 m high, nearly straight, parallel to the site’s contours, and battered 10° to 30° off the perpendicular. The mean patch size, 85.2 m², is relatively large, considering the steep slope. Water appears to have been fed directly to the top patches and then channeled down the tiers. The mean number of distributary patches, 8.3, is very high.

Approximately 36 m from the ditch’s intake, on relatively flat land just below the ditch, are two small sets of nine terraces each. These were probably not irrigated but instead received seepage from the adjacent ditch.

**Site Ka-D6-11.** This site of approximately 3.7 ha is about 2 km from the ocean and rests on an island in Wainiha Stream (see Figure 7; from Earle 1978, figure 6.7). Wainiha is a braided stream and has narrow islands, which were used as taro pondfields. The island containing the site is humpbacked, slightly rocky, and covered with deep, moderately rocky alluvial soil. It is long (540 m) and narrow (145 m) and has a natural channel cutting across it. The channel is now dry due to hydrological changes in the valley, but, according to Earle (1978, p. 96), it once merged with a secondary channel that connected with the main stream.

The well-preserved head dam is about 6 m long, 2 m wide, and 0.4 m high. It was placed on a secondary, natural channel of the stream just upstream of a natural fall. River cobbles were piled up to create a long mound-percolation dam.

Earle (1978, pp. 96, 98) described the ditch system at the site as follows:

Below the intake, the ditch was a simple earth channel which ran 100 m from the head dam to the first patches. Then it ran along the middle of the island with patches to either side. Above the patches, the ditch slope is gentle (.006), but it became steeper (.016–.021) as the ditch ran among the patches. There was also a change in construction of the ditch in these two segments. In the upper segment, the ditch was a simple unlined channel dug perhaps 1 m below the natural land surface. Near the top, it was over 2 m wide but it narrowed to about 0.4 m in the bottom. The cross section of the ditch in the lower segment was quite distinct. It was rectangular, 90 cm wide and 40 cm deep, and stone lined. The ditch was separated at several points from the bordering patches by a double-faced and earth/rubble-filled wall, 80–150 cm wide and 35–45 cm high.

Secondary ditches were difficult to trace due to poor preservation.
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FIGURE 7. Sections "a" to "c" of Site Ka-D6-11, Wainiha, Kaua'i
The pondfields were marked by surrounding embankments of earth and stones. Generally, stones were not used as embankment facing, but in this case, they were incorporated into the facing as a way of clearing them from agricultural fields.

The mean patch size for the site's three sections ranged from 194.9 to 409.0 m². The mean number of distributary patches ranged from 1.0 to 5.6. As Earle (1978, p. 98) noted, "there is an obvious trend toward a more complex distributary pattern in the lower section of the site."

Site Ka-D10-9. Site Ka-D10-9 was a fishpond with a small area of taro cultivation located at the mouth of Waileia Stream in Hanalei. Along one edge of the fishpond, coconut and breadfruit trees were grown.

Site Ka-D10-10. This site, located just east of 'Anini Stream in Hanalei, has a unique topographical feature: a ridge separating the valley from the seashore. A contour irrigation ditch forming a U-shape around the ridge is the only feature preserved at the site. Water was diverted from 'Anini Stream around the base of the ridge and into the ditch, which was kept in place by a stone-faced earth embankment. The pondfields, no longer visible, were built below the ditch, facing the sea, and went down almost to the water.

Types of Irrigation Systems

From the detailed archaeological descriptions provided above, Earle (1978) identified four types of irrigation systems in the Halele'a area (see Figure 8; from Earle 1978, figure 6.10).

Type A: Alluvial Terrace. Type A irrigation systems are found on alluvial terraces flanking permanent central or tributary streams. Site Ka-D5-8 has an example of such a system. Earle (1978, p. 103) distinguished two variants within Type A as follows:

If the primary ditch taps a central stream, the minimum distance required to gain the necessary height advantage is quite long. If, however, the source is a tributary stream or if the main stream has a steep slope, the distance from intake to agricultural fields may be much shorter. The primary ditch continues to run along the ridge slope above the fields until it terminates at a natural barrier like a cliff or lower tributary. In the lower sections of valleys, such ditches may be over a kilometer long but they are shorter on interior or small valleys.

The agricultural zones vary from a moderately steep (.08 to .20) strip of taluivial soils near the lower ridge to a gently sloped (.04 to .10) area of alluvial soil bordering the stream. Whether found at a central or tributary stream, the top patches are fed directly from the primary ditch, and the lower patches are fed in sequence. In Type A systems, "[s]econdary ditches are unnecessary except where the distance from ditch to stream is more than about eight terrace tiers" (Earle 1978, p. 103). Drainage is handled by simply rechanneling the overflow back to the stream.

Type B: Alluvial Coastal Plain. Type B irrigation systems are found on coastal plains near the mouths of streams. Examples include the systems at Sites Ka-D5-4, Ka-D5-6,
FIGURE 8. Typology of irrigation systems at Halele'a, Kaua'i: Type A, alluvial terrace; Type B, alluvial coastal plain; Type C, alluvial island; and Type D, alluvial bottomlands.
and Ka-D10-10. The upper sections of these systems, where the primary ditch taps the stream, are Type A systems. However, the ditch extends around the ridge face so that it runs above the alluvial coastal plain parallel to the sea. The ditch eventually loses its height advantage, relative to the plain, and travels as far as possible through the irregular marshy terrain.

Springs can be an alternative water source for Type B systems. Earle (1978, p. 104) detailed the layout of these systems in Halele‘a as follows:

Since these springs form point sources in a line along the lower slopes of the coastal ridge, the need for a primary contour ditch is eliminated. The patches are located below the primary ditch or springs. The agricultural zone starts as moderately steep (.06–.20) taluviol soils and then levels out into the alluvial plain (slope .001–.070) which extends down to the coastal sand dunes. The terraced patches near the ditch are fed directly from the ditch but the patches in the plain require secondary and often tertiary ditches to distribute water.

The drainage problem on the flat alluvial plain was traditionally turned into an advantage through the construction of fishponds.

**Type C: Alluvial Island.** Type C systems are found on islands in permanent streams. An example is the system at Site Ka-D6-11. Near the top of the island, a primary ditch taps a secondary channel of a permanent braided stream. The ditch runs down the central ridge of the island, and patches begin within 100 to 150 m of the intake. Pondfields on either side of the ditch are fed directly or indirectly by short secondary ditches. Drainage is not a problem, as water is easily led back to the braided stream.

**Type D: Alluvial Bottomland.** Type D systems are found in the alluvial bottomland of a small stream. The whole valley is converted into a single agricultural system through the damming of the stream. Site Ka-D10-9, primarily a fishpond, was the only example Earle gave of a Type D system that has been studied.

**Managerial Requirements of Irrigation Systems**

Earle (1978), in analyzing his research in Halele‘a, considered Wittfogel’s “hydraulic theory,” which focused on the managerial requirements of large-scale irrigation and the evolution of centralized bureaucratic “proto-states.” According to Wittfogel, two aspects of irrigation technology could have encouraged organized, centralized management: (1) sophistication of system design and (2) schedule of labor investment (Earle 1978, p. 105). The Halele‘a irrigation complex, however, was of a very simple design that would not have required specialized knowledge to create (Earle 1978, p. 105):

For Halelean irrigation... [t]he technology was based on only the most basic hydrologic principles—water flows downhill along the line of least resistance.... There are no sophisticated aboriginal hydraulic devices like measuring weirs or siphons and there are no unusual feats of engineering like massive head dams or high terrace walls.

The Hawaiians at Halele‘a employed a simple technology in every feature of their irrigation system—head dam, irrigation ditch, diversion devices, and pondfields. The head dam was an unreinforced mound of river cobbles placed at natural bends, rapids, or falls. The
head provided resistance to water flow, and a portion of the water was diverted to the primary ditch. The ditches were typically narrow and shallow and occasionally lined with stone. Water diversion was controlled by the size of the cut in the ditch bank, the relative slope between the primary and secondary ditches, and the number of rocks used to dam the primary ditch. Pondfields were generally level basins surrounded by an earthen bund, and the terraces supporting the pondfields were not large. The retaining wall supporting the terraces was usually less than 1 m high. Earle (1978, p. 106) concluded:

There is no evidence that the construction of such irrigation systems would demand specialized, technical knowledge beyond the practical proficiency of the subsistence farmer.

In a subsistence economy, the basis for sustaining life is the conservation of energy. Thus, for the Hawaiians at Halele‘a, if with simple technology they achieved the production needed, there would be no reason to spend great amounts of energy on a more complex method of irrigation. We must keep in mind that the early settlers brought with them the knowledge of irrigation technology. They had to adapt this knowledge to their new environment and to the resources available. In some cases, only simple technology was needed; in other instances, a more complex form of irrigation was required.

In Earle’s assessment, Halele‘a irrigation practices were not based on careful scheduling of labor investment. Labor investment was relatively small, as alteration of the natural topography was minimal. Pondfields were constructed using cut-and-fill methods “whereby the level terrace was built up with earth excavated from the rear of the terrace to fill in the terrace front” (Earle 1978, p. 106). Retaining walls were built of locally excavated rock, requiring little labor for transport. Large pondfields were probably built in successive stages; and irrigation systems were built slowly, by accretion. Thus Earle (1978, p. 107) concluded that centralized labor management and scheduling were not necessary for ditch construction and maintenance at Halele‘a: “Because the irrigation ditches were not designed to maximize productive area, no overall design was necessary.”

It also appears, based on the data and arguments presented by Earle, that water management practices used to intensify taro production did not lead to the evolution of centralized political control on Kaua‘i.

**Historical Data**

In 1778, when Captain Cook (Beaglehole 1967, p. 269) arrived at Waimea on Kaua‘i in search of agricultural provisions, his observation of Hawaiian taro cultivation was as follows:

Plantations . . . were chiefly of Tara, and sunk a little below the common level so as to contain the water necessary to nourish the roots.

Eight years later, British explorers Portlock and Dixon arrived at Waimea. A more detailed description emerged from this visit (Portlock 1789, p. 191):
The greatest part of these plantations are made upon the banks of the river, with exceedingly good causeways made with stones and earth, leading up the valleys and to each plantation; the taro-beds are in general a quarter of a mile over, dammed in, and they have a place in one part of the bank, that serves as a gateway [for water].

Portlock accurately described the pondfield complex but incorrectly identified the ditch network and stated that the patches were irrigated by periodic stream flooding (Earle 1978, p. 110). Captain George Vancouver arrived on Kaua‘i in 1782 and penetrated farther inland, where the primary irrigation ditches came out of Waimea Canyon. Menzies (1920, pp. 28–29), the expedition’s botanist, described what he and Vancouver observed:

We walked to the conflux of these two streams [which form the Waimea River], and found that the aqueduct which waters the whole plantation is brought up with much art and labor along the bottom of the rocks [cliff] from this north-west branch, for here we saw it supported in its course through a narrow pass by a piece of masonry raised from the side of the river, upwards of 20 feet and facing its bank in so neat and artful a manner as would do no discredit to more scientific builders. Indeed the whole plantation is laid out with great neatness and is intersected by small elevated banks conveying little streams from the above aqueduct to flood distant fields on each side at pleasure, by which their esculent roots are brought to such perfection, that they are the best of every kind I ever saw.

The Land Records of 1850 were analyzed by Earle (1978, pp. 120–128), who attempted to draw conclusions from them about water management in Halele‘a. In these records, irrigated lands at Halele‘a were divided into three overlapping categories: loko, loko kalo, and lo‘i. These categories were not mutually exclusive because fish were grown in pondfields and taro in fishponds. In the loko, fish production was the focus and taro cultivation was secondary; in the loko i‘a kalo, there was an equal emphasis on both fish and taro; and in the lo‘i, taro cultivation was emphasized and fish production was secondary. For Kaua‘i, Kikuchi (1973, 1976) reported a total of 65 loko, both shoreline and inland ponds, which were built prior to 1830. In relation to freshwater management, the inland ponds are of greater interest. Based on the work of Kikuchi (1976), Kirch (1985, p. 213) identified two additional types of inland ponds: pu‘uone, which are “situated near the sea but separated from it by a ridge of sand, connected to the ocean by a channel or ditch”; and loko wai, freshwater ponds for milkfish or mullet.

From an impressive and comprehensive analysis of the Land Records, Earle (1978) drew the following conclusions about water management in Halele‘a:

In terms of percentage of gross irrigated agricultural area, the dominance of the main streams becomes clear: main streams, 70%; side streams, 6%; independent streams, 12%; and ground water, 12%. (p. 123)

Length of the primary and major secondary ditches was estimated for thirty-six historic irrigation systems. . . . The average length is 447 m with a range from 0 to 3745 m. Nine of these systems . . . functioned without ditches by tapping groundwater sources directly or by terracing across a valley as described for Type D systems. . . . Only five systems . . . used ditches longer than 1 km; these systems contained 34% of the total gross irrigated area[a] . . . . In thirty-seven of the forty-two historic irrigation systems, potential conflict was minimized by a simple ditch network lacking major branches. The primary ditch conveyed water the full length of the
agricultural system and gave farmers direct access to this water. Direct access to the primary ditch was guaranteed by the layout of individual land holdings within a system. (p. 126)

[T]he irrigation systems in Halele'a were for the most part small in size. . . . [T]he mean net area of these systems was calculated to be 1.93 ha. (p. 127)

A typical Halelean irrigation system was used cooperatively by only a limited number of farmers. The mean number of farmers receiving grants within an irrigation system was 4.7. . . . Four systems . . . were used by ten or more farmers receiving grants. (p. 127)

The historic irrigation systems of Halele'a were virtually all community level projects. Because the territorial communities (ahupua'a) were usually physically isolated from each other by ridges, a given ditch network serviced the agricultural lands of a single community. . . . Evidence, therefore, clearly indicates that irrigation systems were historically contained within the jurisdiction of a single community. This restriction would have minimized the potential managerial difficulties involved in the irrigation systems. (pp. 127–128)

Earle combined both detailed archaeological and historic data to describe clearly the large and productive water management system of Halele'a. These were the lands of Kāne and Kanaloa, with heavy rainfall and many perennial streams and springs. The labor and management expenditures were therefore low, compared to those on the other islands in the Hawaiian archipelago. For the people of pre-contact Halele'a, irrigation made agricultural production a year-long process, so there was no need for cyclical *makahiki* rituals to Lono or *luakini heiau* in honor of Kū. Each valley had its own abundant agricultural resources, and disputes over resources and water allocation were, at the time of Cook's arrival in Waimea, probably less severe than on O'ahu and Hawai‘i. Earle does argue, however, that intensification of irrigation in the district of Halele'a was primarily a function of competition between chiefs.

In the district of Kona on the drier, leeward side of Kaua‘i, important archaeological research was conducted by Kikuchi (1963) on coastal sites and by Sinoto (1975) and Hammatt et al. (1978a) at Kōloa. At Kōloa, a dense concentration of sites over an area of 186 ha indicates a unique settlement pattern. A survey by Hammatt et al. (1978a) revealed some 583 sites, including 175 stone enclosures and 108 stone-house platforms. According to Kirch 1985, p. 104):

These were integrated with an extensive agricultural field complex that appears to incorporate both irrigated and dryfield cultivation patterns. . . . Drawing water from the Waikomo Stream, "an extensive system of highly developed *'auwai* fed the upslope ends of the wet field systems at Kōloa" [Hammatt et al. 1978a:40]. These ditches "branch off throughout the project area in a generally dendritic pattern subdividing downslope to feed separate field complexes" [Hammatt et al. 1978a:44].

The Menehune ditch is another major irrigation system on Kaua‘i. Bennett (1931, pp. 105, 107) emphasized the fine shaping and dressing and careful fitting of stone for this system. The distinctive stone work and other unique features of Kaua‘i archaeology—for example, ring and stirrup poi pounders, vesicular basalt block grinders, double inner-barbed one-piece fishhooks, and hematite octopus sinkers—have been used to argue that the island’s population originated and developed independently. Kirch (1985, p. 106) concluded that these distinctive
archaeological discoveries “more likely are a reflection of the island’s distance from the rest of the chain, and represent local developments that simply did not spread to the other islands.”

This “distance from the rest of the chain” also factored into Kamehameha’s inability to conquer Kaua’i: the Hawai‘i-island thrust, driven by Lono and Kū, never reached the island. In the drier leeward areas, complex water management systems could be supported by permanent stream flow; and although competition among Kaua‘i chiefs apparently resulted in irrigation intensification in the windward valleys, it is probable that Kāne and Kanaloa remained central in the people’s perceptions of the source and management of water. Relative to O‘ahu in the late protohistoric period and the island of Hawai‘i in earlier times, Kū and Lono probably played much less of a role in water management. In short, the people of Kaua‘i were the “Planters of Kāne,” not the “Planters of Lono” (a designation and chapter title from Kirch 1985).

O’ahu

Location, Climate, and Geology

O‘ahu is located between Kaua‘i and Moloka‘i, separated from the former by the Kaua‘i Channel, which is about 116 km wide, and from the latter by the Kaiwi Channel, which is about 40 km wide. It has a subtropical climate and lies in the belt of northeasterly trade winds, which persist throughout the year. During the winter, the trades are occasionally interrupted by kona winds, which blow for a few days. Both kona and trade winds bring rain to the island.

O‘ahu has an area of 1564 km² and four geomorphic areas: Ko‘olau Range, Wai‘anae Range, Schofield Plateau, and Coastal plain. The eastern part of the island is formed by the Ko‘olau Range, which is 60 km long and deeply eroded by streams. The western part of the island is formed by the Wai‘anae Range, which is 35 km long and older than the Ko‘olau Range. The lava flows from the Ko‘olau Range toward the older Wai‘anae Range form the Schofield Plateau. Parts of the Coastal plain are found to the north and south of the Schofield Plateau; other parts include the ‘Ewa coral plain west of Pearl Harbor, Honolulu plain, Waialua–Haleiwa plain, and Kahuku plain (Stearns 1985, pp. 115–117).

Pre-Contact Water Management

There are abundant ethnohistorical data on the numerous water management systems on O‘ahu. However, none of these systems has received the comprehensive and detailed attention from archaeologists that the one in Halele‘a on Kaua‘i has. Archaeology of O‘ahu (McAllister 1933) is a comprehensive survey of archaeological sites and incorporates a great deal of ethnohistorical data. “Dynamics of Production Intensification in Precontact Hawaii” (Kelly 1989) focuses on O‘ahu to a great extent and is a comprehensive and cogent analysis
integrating traditional, archaeological, and ethnohistorical data on fishponds, taro ponds, and dryland cultivation in the protohistoric period. "Pre-European Hawaiian Agricultural Systems: Their Endpoint" (Cordy 1970) is a useful discussion and survey of major O'ahu archaeological sites. Two reports, "Archaeological Survey of Kahana Valley, Ko'olauloa District, Island of Oahu" (Hommon and Barrera 1971) and "Mākaha Before 1880 A.D." (Green 1980), contain useful analyses of these important sites.

The well-watered alluvial valleys on O'ahu, with their extensive 'auwai and lo'i systems, attracted the attention of, and clearly impressed, many early Western observers, among them Stewart (1830, p. 143), who wrote the following in his journal:

It [taro] here occupies most of the cultivated ground, especially such as is capable of being overflown by water; and the planting, irrigation, and necessary care of it, forms the most laborious part of the native farming. The islanders have arrived at great skill in the cultivation of this plant; and perhaps their mode of growing it, considering the general face of the country, scarce admits of improvement, unless it be in the implements with which they work. The beds in which the taro stands are usually square or oblong, of various sizes, from that of a few yards to half an acre. These are formed with great care; first by excavating the earth to a depth of two or three feet, and converting the dirt thrown out into strong embankments on every side. The sides and bottom are then beaten with the woody ends of the cocoa-nut leaf, which are broad, and, when dry, exceedingly hard, till they are impervious to water; after which, the tops of the ripe root, by which the plant is propagated, cut off just below the formation of the leaves, are set out eighteen inches or two feet apart, in a thin layer of soil and dried grass, and the water let upon them till the leaves float on its surface. The roots are kept thus covered with water, till they become fit to eat: a period of from nine to fifteen months, though they continue to grow for two years or more, and improve in quality to the end of that time.

Waikīkī-Kapahulu-Mō‘ili‘ili-Mānoa. Many early Western observers commented on what Kelly (1989, p. 89) termed the "Waikīkī-Kapahulu-Mō‘ili‘ili-Mānoa complex." Captain Vancouver (1798, pp. 163-164), who visited O'ahu in 1792, described it in detail:

Our guides led us to the northward through the village, to an exceedingly well-made causeway, about twelve feet broad, with a ditch on each side.

This opened to our view a spacious plain . . . the major part appeared divided into fields of irregular shape and figure, which were separated from each other by low stone walls, and were in a very high state of cultivation. These several portions of land were planted with the eddo, or taro root, in different stages of inundation, none being perfectly dry, and some from three to six or seven inches under water. The causeway led us near a mile from the beach, at the end of which was the water we were in quest of. . . . In this excursion we found the land in a high state of cultivation, mostly under immediate crops of taro; and abounding with a variety of water fowl, chiefly of the duck kind. . . . The plains . . . from the labour bestowed in their cultivation, seem to afford the principal portion of the different vegetable productions on which inhabitants depend for their subsistence. . . . At Woahoo [O'ahu], nature seems only to have acted a common part in her dispensations of vegetable food for the service of man; and to have almost confined them to the taro plant, the raising of which is attended with much care, ingenuity, and manual labour.

Vancouver's botanist, Menzies (1920, pp. 23–24), praised the large pondfield system:

We pursued a pleasing path back into the plantation, which was nearly level and very extensive, and laid out with great neatness into little fields planted with taro, yams, sweet potatoes and the cloth plant. These, in many cases, were divided by little banks on which grew the sugar cane and a species of Draecena without the aid of much cultivation, and the whole watered in a most ingenious manner by dividing the general stream into little aqueducts leading in various directions.
so as to be able to supply the most distant fields at pleasure, and the soil seemed to repay the labor and industry of these people by the luxuriancy of its productions.

Another detailed observation of the same system came from the explorer Kotzebue (1821, p. 102), who visited O‘ahu in 1815:

The luxuriant taro-fields, which might be properly called taro-lakes, attracted my attention. Each of these consisted of about one hundred and sixty square feet, forms a regular square, and walled round with stones, like our basins. This field or tank contained two feet of water, in whose slimy bottom the taro was planted, as it only grows in moist places. Each had two sluices, one to receive, and the other to let out, the water into the next field, whence it was carried farther. The fields became gradually lower, and the same water, which was taken from a high spring or brook, was capable of watering a whole plantation. When the taro is planted, the water is lowered to half a foot, and the slip of a gathered plant stuck into the slime, where it immediately takes root, and is reaped after three months. The taro requires much room, having strong roots; it strikes forth long stalks and great leaves, which appear to swim on the water. In the spaces between the fields, which are between three and six feet broad, are pleasant shady walks, planted on both sides with sugar-cane or bananas. They also use the taro-fields as fish-ponds. In the same manner as they keep the river-fish here, they keep the fish in the sea, where they sometimes use the outer coral-reefs, and form from them to the shore a wall of coral-stones, thus making fish-preserves in the sea. Such a preserve requires much labour, but by no means so much art as the taro-fields, which serve for both purposes.

I have seen whole mountains covered with these fields, through which the water flowed gradually down, each sluice forming a cascade, and falling between sugar-canes and banana-trees into the next tank. Sugar plantations, taro-fields, and far-scattered plantations succeeded each other on our road.

Campbell ([1822] 1967, pp. 115–116) emphasized the labor required to create such an extensive pondfield system:

The mode of culture is extremely laborious, as it is necessary to have the whole field laid under water; it [taro] is raised in small patches, which are seldom above a hundred yards square; these are surrounded by embankments, generally about six feet high, the sides of which are planted with sugar-canes, with a walk at top; the fields are intersected by drains or acqueducts, constructed with great labour and ingenuity, for the purpose of supplying the water necessary to cover them.

These Western observers were viewing a complex taro pondfield and water management system near the end of the protohistoric period (A.D. 1650–1795). The Waikiki–Kapahulu–Mō‘ili‘ili–Mānoa complex appears to be the product of “extremely laborious” effort, whereas the Halele‘a one, in Earle’s assessment, is the product of labor invested gradually over a considerable period.

Because this area of O‘ahu was urbanized rapidly, it may not be possible to recover sufficient archaeological information to estimate the date construction of this complex began. Kelly (1989, pp. 94–96), through a careful analysis of Hawaiian traditions, provided a time frame for the development of these pondfields: the reign of a dynasty of O‘ahu chiefs founded by Ma‘ilikukahi, whose move to have the island thoroughly surveyed resulted in the establishment of definite and permanent boundaries between landholdings. To support this more structured land-tenure system, Ma‘ilikukahi enacted a legal code whereby theft by chiefs from the people was forbidden. Using Fornander’s (1969) thirty-year generation count (hereafter referred to as “Fornander count”) and Stokes’ (1933) twenty-year generation count
(hereafter referred to as “Stokes count”). Kelly arrived at estimates of A.D. 1360 and 1514, respectively, for Ma‘ilikukahi’s year of birth.

Ma‘ilikukahi’s grandson, Kalamakua, born about A.D. 1420 (Fornander count) or 1554 (Stokes count), “is said to have been responsible for developing large taro gardens in what was once a vast area of wet-taro cultivation on O‘ahu: the Waikiki–Kapahulu–Mo‘ili‘ili–Manoa area” (Kelly 1989, p. 95). These extensive gardens were irrigated with water from streams in Manoa and Pālolo valleys and from large nearby springs.

Ma‘ilikukahi’s great-granddaughter, Kukaniloko, born about A.D. 1450 (Fornander count) or 1574 (Stokes count), is a legendary figure who, as a great and powerful chiefess, “kept the country peaceful and orderly” (Kelly 1989, p. 95).

In sum then, according to the legendary materials analyzed by Kelly, there developed on O‘ahu, sometime between the late fourteenth and early sixteenth centuries, a need for careful surveying and boundary marking, resulting in a more structured land-tenure system. It appears that, two generations later (sometime in the mid-fifteenth to mid-sixteenth century), Kalamakua was responsible for further intensification of the Waikiki-area complex. Finally, one generation later, Kukaniloko played a legendary role in maintaining peace and order on O‘ahu.

By contrast, the Halele‘a system on Kaua‘i probably evolved over a greater time span and without the need for intervention by chiefs and centralized sociopolitical control.

Kelly refers to two other O‘ahu chiefs in her analysis. Kākuhihewa, born in A.D. 1540 (Fornander count) or 1634 (Stokes count), was said by Kamakau (McAllister 1933, p. 186) to have built a government house for himself forty fathoms long, and fifteen fathoms wide, which was named Pamoa. The main purpose of this house was for debating land divisions, claiming ancestors, genealogy registration, practice with war club, spear thrusting, astrology, designing, astronomy, konane, instruction in royal ancestral songs, royal songs, running, cliff leaping, bowling, sliding, boxing.

Kūali‘i was born about three generations after Kākuhihewa (A.D. 1660 [Fornander count] or 1714 [Stokes count]) and became a mō‘ī.

Between the mid-fifteenth century and the end of the eighteenth century, this and other taro pondfield systems discussed below played a prominent role in the evolution of a centralized, islandwide polity on O‘ahu by providing resources for that polity. By contrast, the Halele‘a system on Kaua‘i seems to have provided resources only for the population of an ahupua‘a.

Nu‘uanu. Although there was a very extensive agricultural system in Nu‘uanu Valley, detailed and comprehensive archaeological research has not been conducted there. Cordy (1970, pp. 57–58) does, however, provide a good general description of the valley system,
based on extensive ethnohistorical accounts (Kotzebue 1821; Macrae 1922; Bingham 1847; Wilkes 1845; Simpson 1843).

The agricultural system extended from the mouth of the valley, about 1.6 km inland from Honolulu, and the fields extended "about three-quarters of a mile wide" (Bloxam 1925, p. 38) up the valley to the base of the Koʻolau Range. The most important crop was taro, which was grown in small square or rectangular plots. The walls separating the plots were 1 to 2 m wide, were constructed of earth and stone, and had growing on top of them banana and sugarcane. The planting of taro was staggered to provide corms in different stages of development. The taro ponds were also used as fishponds and were fed with water from an irrigation system connected to the main stream.

Archaeological research in the valley has focused on two other features: petroglyphs and fortifications. Kirch (1985, p. 116) pointed to three artificial cuts that served as fortifications and speculated: "This fort may have been the actual scene of the famous battle of Nuʻuanu in 1795, when Kamehameha defeated the Oʻahu forces." Nuʻuanu Valley was bestowed with all the riches of Kāne. During the battle of Nuʻuanu, however, it was Kū who played the most active role. Kamehameha’s dramatic victory occurred nearly two decades after Captain Cook’s arrival and may have resulted in the decline of Kāne and the elevation of Lono.

**Honolulu to Waipiʻo–Waikele.** Little or no archaeological research on water management has been conducted in the area from Honolulu to Waipiʻo–Waikele. However, early Western observers did take note of the agricultural activity in the area. Of this area Campbell ([1822] 1967, pp. 103, 115) said:

> Every stream was carefully embanked, to supply water for the taro beds. Where there was no water, the land was under crops of yams and sweet potatoes. ... The flat land along shore is highly cultivated; taro root, yams, and sweet potatoes, are the most common crops; but taro forms the chief object of their husbandry.

Other early Western observers noted that the land adjacent to Pearl Harbor was highly cultivated (Bloxam 1925, p. 33), but only at the "lower ends of the small valleys ... with the taro in ponds" (Macrae 1922, p. 31). Although there was no mention of water management in the Pearl Harbor area, taro patches were observed along streams in the Moanalua area (Macrae 1922, p. 32; Ii 1959, p. 95). In Waiawa, taro was cultivated in patches at the mouth of the river (Cordy 1970, p. 61); and eastward of the river, a fishpond was built with "large stones across a small inlet" (Bloxam 1925, p. 46). Nearby, to the west of the river, a ravine was filled "with bananas, taro and healthy breadfruit trees" (Macrae 1922, p. 30).

Much of the information on wet-taro agriculture in Waipiʻo–Waikele comes from Ii (1959, p. 20), who was born there in 1800:

> When Ii [John Papa Ii is speaking about himself] was a small boy he went from Kumelewai to Honolulu with the attendants who cared for him. Before they left, the attendants prepared some
mullet from the ponds containing taro mounds so that the boy would have food when he became hungry on the road. The fish were salted, wrapped in taro leaves, and taken on a carrying pole.

Kūmelewai was apparently near a stream (Waikèle Stream?) where taro was grown and near two inland fishponds, Hanaloa and Lualualei (Cordy 1970, p. 62). Ii reportedly learned the kapu noho on his way to upper Waipi‘o “to make ditches for the farms” on Kīpapa Stream (Ii 1959, p. 28). In the following passage, Ii (1959, p. 77) spoke of his love for Waipi‘o:

Here is a wonderful thing about the land of Waipio. After a famine had raged in that land, the removal of new crops from the taro patches and gardens was prohibited until all of the people had gathered and the farmers had joined in thanks to the gods. This prohibition was called kapu ʻohiʻa because, while the famine was upon the land, the people had lived on mountain apples (ʻohiʻa ʻai), tīs, yams, and other upland foods. On the morning of Kane, an offering of taro greens and other things was made to remove the ʻohiʻa prohibition, after which each farmer took of his own crops for the needs of his family.

In the drier leeward valleys of Oʻahu, and Kauaʻi as well, perceptions of Kane were probably different from those in the well-watered windward and alluvial valleys. For the people of Waipiʻo—Waikèle, Kane was, well into the nineteenth century, associated closely with the end of famine and the renewal of agricultural production. In the period after Kamehameha’s conquest of O‘ahu, it is possible that Kane was transformed into a god more like Lono, the god of rainfall and agriculture from the kula lands of the island of Hawai‘i.

**Mākaha Valley.** When the archaeology of Mākaha Valley was conducted, the area was divided into two sections (Green 1980). Earle (1980, p. 12) provided a detailed description of the topography of these sections as follows:

[T]he lower valley . . . extends about 3.9 km inland from the sea and is a broad, gently sloping plain about a kilometer wide along the Makaha stream; and the narrow upper valley . . . extends an additional 4.1 km to the Waianae-Waiula mountain ridge. Alluvial soils are found along the lower stream and in pockets in the upper valley, although there is apparently no coastal alluvial floodplain . . . Rainfall in the valley catchment is somewhat limited—about 500 mm at the coast to a maximum 2000 mm at the mountain ridge.

The valley was intensively studied by a team under the direction of Green of the Bishop Museum from 1968 to 1970. The lower slopes had been extensively modified for the development of an intensive dryland gardening complex that included “low terraces, water diversion walls, and extensive mounds” (Kirch 1985, p. 117).

Yen et al. (1972) also studied Mākaha Valley; they excavated an irrigated pondfield complex for taro cultivation. Hommon (1970, table 2) reported the identification in the upper valley of thirty-six terrace sites, which received water from permanent sources, and twenty-nine irrigation systems, which had a combined area of 6.38 ha. Most of the systems used short ditches to tap the main stream and were quite small, averaging 0.22 ha (Earle 1980, pp. 12–13).

Green (1980) developed the following cultural sequence for the valley. Settlement probably occurred about A.D. 1100 “as a part of the general pattern of settlement in leeward areas after the populations of the windward coasts had begun to swell” (Kirch 1985, p. 118).
In the fifteenth and sixteenth centuries, cultural change began to accelerate. Inland areas in the valley were permanently settled, and irrigation systems, where stream flow was adequate for taro cultivation, were constructed in the upper valley. At this time, the building of the agricultural temple Kāneʻākī Heiau commenced (see Figure 9; from Kirch 1985, figure 227). This was an important event for it indicated, according to Green (1980, p. 75), “the presence in the valley of a ranking chief able to build his own sizable Lono-type heiau, and the means for achieving a surplus of goods for his own use by intensifying the valley’s productive capacity.”

The link between taro pondfield irrigation and increasing political complexity is clearly evident in the Mākaha Valley archaeological record. However, it is possible that this temple was not dedicated to Lono but, as indicated by its name, to Kāne.

In the final period of the valley’s evolution, this agricultural heiau was transformed into a luakini heiau dedicated to the war god Kū, an act only attributable to a mōʻī. At this time, according to Kirch (1985, p. 119), “the Mākaha Valley was integrated into the fabric of the large-scale political systems that characterized Hawai‘i at European contact.”

During this time, a main irrigation ditch also was constructed in the lower valley to increase production from these kula lands. Perhaps only in this final phase could it be said that Kāneʻākī Heiau, now dedicated to the war god Kū, had become intimately associated with Lono.

**Kahana Valley.** Kahana Valley, the first windward valley to be comprehensively surveyed on O‘ahu, is located on the northeast coast in the district of Ko‘olauloa. Most of the sites at Kahana appear to date to the protohistoric period in the Hawaiian cultural sequence; however, one site, disturbed by activities at an adjacent fishpond, dates to the eighth century (Kirch 1985, p. 75). Hommon and Barrera (1971, pp. 38, 43) summarized their findings regarding agricultural and water management practices in this important windward valley as follows:

The agricultural pattern of Kahana valley is represented by two types of archaeological features—those in plots of land that were probably irrigated from permanent streams and originally constructed for the growing of wet taro, and those in plots of land that received crop water from rainfall and intermittent streams, and were used for crops such as dry taro and sweet potatoes.

The two major types of archaeological feature that formed parts of the wet or irrigated agricultural system of the valley were wet terraces and ‘auwai (irrigation canals). A total of 120 wet terraces were recorded in Kahana valley....

Most of the 120 wet terraces in Kahana valley were built on gently sloping alluvial areas along permanent streams... to form a series of earthen steps for retention of irrigation water. Most terraces consisted of a stone retaining wall and the relatively flat land behind it; many terraces included stone walls on one or both sides of the flat terrace surface.... Most of the wet terraces were quite small in area [see Table 2; from Hommon and Barrera 1971, table 3]. The total growing surface of all wet terraces recorded in this survey was only about 10,080 square meters, or 1.08 hectares (about 2.7 acres). This area includes most of the alluvial flats along Kahawainui (upper Kahana) stream and its tributaries as well as the three terraces recorded in Kawa valley and a few terraces in the lower valley. This figure seems unusually small for a valley as large as Kahana.
FIGURE 9. Stages in the construction of Kâne'äkî Heiau, Mâkaha Valley, O'ahu. The conversion from stage 5 to stage 6 probably correlated with a change in the temple's function from an agricultural to a war temple (luakini).
### TABLE 2. Dimensions of Irrigated Terraces, Kahana Valley, O‘ahu

From Hommon and Barrera 1971

<table>
<thead>
<tr>
<th>Survey Area</th>
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<th>Feature Designation</th>
<th>Terrace Dimensions (m, to nearest 0.1m)</th>
<th>Terrace Area (m, to nearest sq m)</th>
<th>Height of Retaining Wall (m)</th>
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Mean Terrace Dimensions: 12.9 | 7.1 | 83.6 | 0.5

* Average
** Lacks stone wall
For example, in the upper section of Makaha, a valley of similar size in leeward Oahu, more than 300 wet terraces were recorded (Hommon 1970:112-14), averaging 149 sq meters in area. The total area of irrigated terraces was 4.9 hectares (12.1 acres).

Along the alluvial benches of the main tributaries, there is a scarcity of agricultural land, which may reflect "either a preservation problem or an avoidance of the flood zone" (Earle 1980, p. 12). More recent research at Kahana Valley suggests that Kahana Bay extended much farther inland at the time of Hawaiian settlement (see Kirch 1985, p. 109). Earlier sites might be found, therefore, more inland, under centuries of alluvial deposit from mountains in the Koʻolau Range.

Hommon and Barrera (1971, pp. 85–87) incorporated into their report McAllister’s earlier site identifications, which included Kapaʻeleʻele fishing shrine, Kauninio fishing shrine, Hilo Lāʻau cave, Huilua fishpond, and Puʻu Makane heiau. These sites all figure in Hawaiian legend and lore about Menehune, kupua, and old fishing gods. Kahana Valley probably represents an early Hawaiian settlement with a classic subsistence pattern: efficient, low-intensive water management and agricultural production, plus exploitation of abundant fish resources.

Luluku. Recent research was done by Allen-Wheeler (1985) on the Luluku upland agricultural system in Kāneʻohe in the district of Koʻolaupoko. Kelly (1989, p. 89) synthesized the relevant findings of this research as follows:

An archaeological survey team has recently found and recorded a large complex of stone-faced, terraced, agricultural pondfields, built and used by Hawaiians in past centuries for cultivating wetland taro. . . . The complex, which was found to extend over an area of approximately 4 ha, was irrigated by ditches (‘auwai) that formerly brought water from spring-fed streams originating at the foot of the nearly vertical mountains of the Koʻolaupoko District on Oʻahu. The retaining walls of the terraces measure between 30 cm and 2 m in height, with a mean width of the terraces approximately 5 m, and variations up to about 15 m, depending on the slope of the land. Remains of an irrigation ditch and probable water-flow controls were also found in the area.

Maui

Location, Climate, Geology, and Surface Hydrology

Maui is the second largest island in the Hawaiian chain, covering 1886 km². It is separated from Molokaʻi by Pailolo Channel and from Hawaiʻi by ʻAlenuihāhā Channel.

The climate is semitropical in the lowlands and temperate on the upper slopes of east Maui. Temperature varies with elevation and windward or leeward location. The absolute maximum temperature is 34°C; the absolute minimum, 11°C. The warmest months are August and September; the coolest, January and February. Snow and sleet sometimes fall on the top of Haleakalā volcano in east Maui, while thunderstorms sometimes bring hail.

Rainfall varies widely with elevation, topography, and season, and from year to year. The wettest months are November, December, January, February, March, and April. The
average annual rainfall in east Maui is 305 mm on the southwest coast and 9804 mm at an elevation of 853 m. In west Maui, it ranges from 330 mm in Lahaina, which is on the coast, to 9881 mm at an elevation of 1764 m. The summit of west Maui is the third rainiest place in Hawai‘i, exceeded only by Kūhiwa Gulch in east Maui and Wai‘ale‘ale summit on Kaua‘i. There are occasional kona storms, which bring rains to the leeward side, and nāulu. Persistent kona weather and easterly winds may result in drought on the northeast slope, where great irrigation ditches collect water. Droughts may occur in winter or summer.

Maui, like O‘ahu, is made up of two volcanic mountains: East Maui, or Haleakalā Volcano, and West Maui (Stearns 1985, p. 208).

Most streams in west Maui are perennial. In east Maui, there are only a few perennial streams, despite heavy rainfall on the northeast slopes. These streams originate in springs at relatively low elevations between Ha‘ikū and Nāhiku. There are also a few streams on the southeast slope between Mū‘olea and Kaupō. The streams in the weak basaltic areas of Honomanū (in east Maui) and Wailuku (in west Maui) have relatively flat grades and gravel deposits, so they lose their water very quickly. The streams in the lava fields of Kula, Hana, and Honolua consist of a series of cascades and have short stretches of gravel. Because of intense rainfall and the permeability of the terrain, all streams are flashy (Stearns and Macdonald 1942, p. 43). During droughts, the streams are fed by springs (Stearns and Macdonald 1942, p. 49).

**Pre-Contact Water Management**

Earle (1980, pp. 7–14) identified three types of water management systems on Maui: major zones of irrigated agriculture, found in west Maui at Wailuku and Lahaina; secondary zones of irrigated agriculture, found in west Maui at Kā‘anapali and on the drier south and western coasts; and “scattered zones of irrigated agriculture,” found in the many gulches on the northeastern and southeastern coasts. Only scattered references to these water systems can be found, and little detailed archaeological or ethnohistorical data are available. Handy et al. (1972, p. 93) referred briefly to the construction of one taro pond at Koali‘i in the district of Hana as follows:

[A] stone retaining wall had to be constructed. This required digging away top soil at the base line of the wall until the bottom stones could be laid in firm subsoil. This top soil was thrown up on the slope above the excavation to serve as fill for the terrace. For the foundation, the largest stones that could be handled, available on the hillside, in a stream bed, or on the beach, were pried, rolled, and slid into place. Some stones so used weighed tons. The wall sloped slightly inward toward the top so as to increase stability.

The Waihe‘e–Waiehu region on the northeast coast of west Maui and the Hana and Kahikinui regions of east Maui appear to contain early sites with long occupation sequences. The last two areas were densely settled by prehistoric Hawaiians (Kirch 1985, pp. 135, 142–144). As with windward O‘ahu and Kaua‘i, windward areas on Maui need additional
archaeological investigation if any cultural change due to population increase is to be substantiated.

Maui, second only to the island of Hawai‘i in size, was the seat of many powerful chiefs, including Kamehameha’s archrival, Kahekili. Maui and O‘ahu chiefs frequently fought for control of Moloka‘i. Unfortunately, little is known about the natural and supernatural base on which these powerful chiefdoms were built. This is a glaring void in the archaeology of water management, power, and the Hawaiian cultural sequence.

Moloka‘i

Location, Climate, Geology, and Surface Hydrology

Moloka‘i is a slender island, 60 km long and 16 km wide, with a total area of 673 km². It is 40 km from O‘ahu, from which it is separated by Kaiwi Channel, and 14 km from Maui, from which it is separated by Pailolo Channel. Kalohi Channel, 15 km wide, separates it from Lāna‘i (Stearns 1985, p. 222).

Moloka‘i has a semitropical climate. Its southern, or leeward, slopes are sheltered from the trade winds and are drier than the windward slopes. Kona winds blow during fall and winter. August and September are the warmest months; January and February, the coolest (Stearns and Macdonald 1947, p. 37). The average annual temperature ranges from 22° to 23°C.

Rainfall is greatest on the highest crest of the island and on the windward slopes of east Moloka‘i (Stearns and Macdonald 1947, p. 40), which is steep and uninhabitable (Stearns 1985, p. 225). Constant mist and cloud cover the crest. The highest recorded annual rainfall is about 3810 mm, which fell at the summit of the trail from Wailau Valley to Mapulehu; and the lowest recorded average annual rainfall is 297 mm, which fell at Kaunakakai. The leeward side gets rain during the occasional kona storms (Stearns and Macdonald 1947, pp. 37, 40, 42).

Moloka‘i was built by three volcanoes: West Moloka‘i, East Moloka‘i, and Kalaupapa. East Moloka‘i is an asymmetrical shield dome that formed around an ancient caldera in Wailau and Pelekunu valleys (Stearns 1985, pp. 227–229).

The only perennial streams that reach the ocean are the ones on the windward side of east Moloka‘i, such as Hālawa Stream in the east, Waikolu Stream in the west, and Honouli Wai, Waialua, and Honouli Malo‘o streams on the southeastern slopes (Stearns and Macdonald 1947, p. 47).

The numerous high-level springs on the northern slopes are the source of some of the perennial streams. Hālawa and Pāpalaua streams, as well as others on the southeastern slopes, are largely fed by seepage from swamps. Other streams have enough flow to reach the ocean only after heavy rainfall. There are no perennial streams in west Moloka‘i. All streams are
flashy because the terrain is very steep and highly permeable and because the heavy rainfall is intermittent (Stearns and Macdonald 1947, p. 47).

On the southern slopes of east Moloka'i, several streams are perennial at their upper courses but usually lose their water through seepage and evaporation long before they reach the ocean. Kawela and Kamalō streams are fed by seepage from swamps. The south fork of Kaunakakai Stream is fed at its upper course by seepage from swamps and at its middle course by several springs. Waihānau and Waileia streams on the northern slope also flow most of the time at their upper courses, but during ordinary weather, they sink before reaching the ocean. The intermittent nature of these streams at their lower courses, as opposed to their permanence at their upper courses, is due to their flowing over the very permeable basalts of the lower member of the East Moloka'i volcanic series (Stearns and Macdonald 1947, p. 47).

Meyer Lake is a perched pond, at an elevation of about 610 m, that occupies a shallow depression at the southeastern foot of Pu'u 'Olelo cinder cone. The pond appears to be fed by surface runoff and submerged springs (Stearns and Macdonald 1947, p. 49).

**Pre-Contact Water Management**

Hālawa Valley, broad and approximately 3 km deep, has two large waterfalls “cascading down its amphitheatre rim, feeding a permanent stream” (Kirch 1984, p. 246). The Hālawa site is in a windward location, on large tracts of fertile alluvial and colluvial soils. It dates from A.D. 300 to 500 and shows evidence of a permanent stream-beach settlement and burning resulting from agricultural practice (Kelly and Clark 1980; Schilt 1980; Hoffman 1979; Kirch and Kelly 1975). Kirch (1975, p. 181) identified four phases in the Hālawa cultural sequence: Kaawili Phase (A.D. 650–1350), Kaio Phase (A.D. 1350–1650), Mana Phase (A.D. 1650–1800), and Historic Phase (A.D. 1800–present).

Because of the excellent soil and hydrological features of the valley, some form of wet-taro cultivation probably was practiced since settlement. The development of the water management system for the permanent and intensive cultivation of taro was the focus of Riley’s (1975) research. During the Kaio Phase—when the population expanded inland—the smaller streams were terraced for taro cultivation and lower floodplains modified. The largest pondfields, incorporating about 366 fields (9.5 ha) in a single hydraulic unit and having ditches as long as 1.4 km, were constructed during the Mana Phase (Kirch 1984, p. 249). Riley’s excavations produced clear evidence of intensification of water management and cultivation. He was able to demonstrate that an earlier complex, irrigated with water from a side stream (see Type II description below), was built over with a larger pondfield system, irrigated with water from a main stream (see Type III description below).

Kirch (1985, p. 220) discussed the irrigation complexes at Hālawa Stream in the lower floodplain as follows:
The lower alluvial floodplains ... are ... two relatively large irrigation complexes, one on each side of the permanent stream. Each of these complexes was fed by two ditches and was cultivated by as many as thirty households, with large areas controlled directly by the chief and land manager (konohiki) and cultivated by the commoners on specified days.

Kirch (1984, p. 176) identified the cultivators as the common people:

Labour to cultivate these fields was provided by the common people on a corvée basis. Commoners in Halawa reported that they worked regularly on the po‘alima days (one out of every five days), during which the ko‘ele pondfields of the chief were cultivated.

Riley (1975, table 27) identified, as a result of his research, four types of irrigation systems. Earle (1980, p. 23) developed the following definitions from Riley’s tabular data (see Figure 1; from Kirch 1977, figure 5):

• Type I: spreader terrace systems that use barrage dams across temporary stream channels to distribute water to irregularly terraced fields
• Type II: gravity-fed terrace systems that use a dam on a permanent tributary to divert water through a short ditch to a small set of terraces
• Type III: peripheral-ditch terrace systems that use a dam on a permanent tributary or main stream to divert water through a ditch that runs along the side of a valley and irrigates patches on the alluvial soil between the ditch and the main stream
• Type IV: multiple-ditch terrace systems that use dams on the main stream to divert water through one or more ditches to broad areas of pondfields located on the lower alluvial floodplain

The major developments in irrigation in Hālawa Valley seem to have occurred during the Mana Phase, as noted by Kirch (1985, p. 130):

By the end of this period the entire valley floor was covered in well-constructed pondfield complexes, some with irrigation canals up to 1,386 meters long.

In 1720, it was a high chief from the island of Hawai‘i, not from Maui or O‘ahu, who conquered Moloka‘i. The chief, Alapa‘inui, reputedly built Mana Heiau and dedicated it to Kū, the god of war. Another temple dedicated to Kū, Pāpā Heiau, was also constructed during this phase of Hālawa’s prehistory.

The well-watered and well-managed taro fields of Hālawa were no doubt perceived as a valuable resource. Initially, they were thought of as a gift from Kāne to the people of Moloka‘i. However, in the Mana Phase, they came to be thought of as a reward from Kū to the chiefs of the island of Hawai‘i.
Hawai'i

Location, Climate, Geology, and Surface Hydrology

Hawai'i—150 km long and 122 km wide and covering 10,456 km²—is also known as the "Big Island." It is the largest, newest, and southernmost island and is separated from Maui by 'Alenuihāhā Channel.

Hawai'i has a semitropical climate that varies with elevation and location. The lowest mean temperature is 20°C, and the maximum is 23°C. There are snow and freezing zones on the summits of Mauna Kea and Mauna Loa (Stearns and Macdonald 1946, p. 209).

Most of the Big Island's rainfall occurs on the eastern side of the island; for example, the average maximum rainfall in Hilo is 6096 mm. There is more rainfall from November to April than from May to October, except in Kona, where the reverse is true (Stearns and Macdonald 1946, p. 211). The Big Island is located in the belt of northeast trades (Stearns and Macdonald 1946, p. 209). Some kona storms bring rain to the leeward areas between December and March; however, the eastern slopes are prone to drought (Stearns and Macdonald 1946, pp. 209, 212).

Hawai'i was formed by five volcanoes. From largest to smallest, they are as follows: Mauna Loa, Mauna Kea, Kīlauea, Hualālai, and Kohala. Mauna Loa produced lava flows every seven years for 132 years preceding 1985, and there were outbreaks in the caldera every four years. Kīlauea has contained lava lakes for periods lasting years, and since 1800, it has produced thirty flows outside its caldera. The only eruption that was recorded for Hualālai was in 1800–1801; neither Mauna Kea nor Kohala has erupted in historic time (Stearns 1985, p. 146).

Since Hawai'i is the newest island, it is little eroded, except for the windward slope of Kohala. It has large areas, covered with black rock, where no vegetation grows; and the southwestern side of Kīlauea is a desert (Stearns 1985, pp. 146, 149).

The only perennial streams are found on the northeastern slopes of Mauna Kea and Kohala. The high permeability of the fresh lava on Kīlauea, Mauna Loa, and Hualālai does not allow permanent streams to develop (Stearns 1985, p.146). Furthermore, all streams on the island are flashy due to the high permeability of the terrain and heavy rainfall (Stearns and Macdonald 1946, p. 217).

Pre-Contact Water Management

Although Hawai'i is the largest island in the archipelago, it has, of the major islands, fewer permanent streams and less well-developed alluvial soils. Earle's (1980, p. 14) discussion of irrigation in the archipelago only covered scattered sites in the Kohala–Hāmākua
coast area, while Kirch (1984, 1985) focused on the intricate system of intermittent irrigation at Lālāmilo–Waimea in north Kohala.

Along the windward coast of Kohala, several geologically young valleys cut deeply and dramatically inland. In terms of pre-contact water management, the valleys of Honokāne, Pololū, and Waipi' o appear to be the most significant. In these valleys, irrigation systems were constructed on small and fragmented alluvial benches bordering streams, such as Honokāne Nui and Pololū, or in the beds of small streams, such as ‘Āwini and Honopue. These systems are typically small, restricted in size by the availability of good alluvial soil. Tuggle et al. (1976) recorded twenty-three irrigated terrace sites and noted fifteen possible ones. Near ‘Āpua, on the Kohala coast, Tuggle et al. (1976, p. 121) discovered small coastal shelves irrigated with water from nearby waterfalls and recorded the use of bamboo to tap one such source. Tuggle and Tomonari-Tuggle (1980) concluded, however, that these windward valleys, due to their geomorphological and hydrological conditions, were flood prone. Summarizing Tuggle and Tamonari-Tuggle’s (1980) research, Kirch (1985, p. 178) stated:

It was likely due to these hazards that the valleys were found to have a prehistoric settlement sequence that was short and late, with no evidence of permanent use before the fifteenth century and with most dates falling into the period from A.D. 1500 to 1700.

The Lālāmilo–Waimea agricultural field complex, found on the saddle between the Kohala Mountains and Mauna Kea at an elevation of between 750 and 900 m, was studied by Clark and Kirch (1983) and Clark (1981). Kirch (1984, p. 186) discussed this unique irrigation system as follows:

Throughout the area is a reticulated network of irrigation ditches, feeding off the Waikoloa and Kahakohau Streams. These ditches differ from the typical valley irrigation channels discussed earlier, both in the number of bifurcations, and in the degree of inter-connectivity. Furthermore, the field plots do not appear to have been pondfields, since their surfaces are sloping. Rather, the Lālāmilo system represents a type of intermittent irrigation, not previously reported for Hawai‘i. It represents the extension and modification of valley-bottom techniques of water control to a leeward slope environment. An initial series of radiocarbon age determinations suggests that the system is comparable in age with Lapakahi [A.D. 1450–1800].

While these original efforts at water management proceeded in windward and inland environments, other agricultural field systems were being developed in the kula lands of west Hawai‘i. The Kohala dryland field system, located just south of Māhukona on the north Kohala coast, and the Kona field system, situated above Kealakekua Bay, were observed by Menzies, Vancouver’s botanist, in 1793. With respect to the Kona field system, Menzies (1920, p. 75) noted:

We soon lost sight of the vessels, and entered their bread-fruit plantations.... The space between these trees did not lay idle. It was chiefly planted with sweet potatoes and rows of cloth plant. As we advanced beyond the bread-fruit plantations, the country became more and more fertile, being in a high state of cultivation. For several miles round us there was not a spot that would admit of it but what was with great labor and industry cleared of the loose stones and planted with esculent roots or some useful vegetables or other. In clearing the ground, the stones are
heaped up in ridges between the little fields and planted on each side, either with a row of sugar cane or the sweet root of these islands. Menzies (1920, p. 52) saw the Kohala systems from the sea and remarked:

[I]t bears every appearance of industrious cultivation by the number of small fields into which it is laid out, and if we might judge by the vast number of houses we saw along the shore, it is by far the most populous part we had yet seen of the island.

One segment of the Kohala system, Lapakahi, was studied from 1968 to 1970. On the basis of fifty-four age determinations, Rosendahl (1972) dated the development of this segment to A.D. 1450 to 1800. According to Earle (1980, p. 15), Lapakahi was “an ahupua’a in a geologically immature region where agriculture depended entirely on rainfall and temporary runoff, because water sources for permanent irrigation systems were unavailable.”

The Kona system, as indicated by age determinations, was being used as early as A.D. 1350. It has been suggested that intensive use was made of it during the sixteenth and seventeenth centuries (Kirch 1984, p. 187). Soehren and Newman (1968, p. 6) were able to find no evidence of irrigation in the system and concluded that crops were dependent solely on rainfall.

Kirch (1984, p. 181) argued quite convincingly that the Kohala, Kona, and Lālāmilo–Waimea systems represent an accelerated and large-scale intensification of agricultural production in west Hawai‘i from the fourteenth to the late nineteenth centuries. Kelly (1989, p. 98) suggested that this intensification may have begun during the time of ‘Umi-a-Liloa, who moved to Kailua, Kona, after living in Waipi‘o Valley, “where there was an extensive system of pondfield terraces and irrigation ditches.” Taro produced in Waipi‘o Valley was distributed widely to those areas that could not grow it. Fornander (1916–1917, pp. 228, 230) provided a glimpse of ‘Umi-a-Liloa and his activities in Kona and Waipi‘o as follows:

During his reign Umi-a-Liloa set the laborers in order and separated those who held positions in the government. He separated the chiefs, the priesthood, the astrologers and the skillful in the land. He separated the cultivators, and the fishermen, and the canoe hewers. He set apart the warriors, the spear-warders, and every department with proficiency, and every laborer in their respective lines of work. So with the governors, district superintendents, division overseers and section wardens; they were all set in order.

Umi-a-Liloa had two principal occupations which he undertook to do with his own hands: they were farming and fishing. He built large taro patches in Waipio, and he tilled the soil in all places where he resided, and when in Kona that was his great occupation; he was noted as the husbandman king,... All the chiefs of his government were noted in cultivating the land and in fishing, and other important works which would make them independent.

‘Umi, who is believed to have lived during the latter half of the fifteenth or sixteenth century, depending on the method of generation estimate used, is credited with creating a centralized government and employing a sophisticated division of labor that facilitated production intensification.

West Hawai‘i was the “hearth of the most powerful Hawaiian chieftainship, the line of chiefs descended from ‘Umi and Liloa” (Kirch 1984, pp. 181–182). An excellent account of
land inheritance during the time of Liloa and 'Umi in west Hawai'i and the emergence of Kamehameha from this line of chiefs is provided by Kame'eleihiwa (1992, pp. 53–57).

These final centuries of the Hawaiian cultural sequence were marked by intense rivalry, warfare, and the growing importance of the Kū cult, as indicated by the construction of increasingly large luakini heiau on Hawai'i, Maui, Moloka'i, and O'ahu. The west Hawai'i chiefs were familiar with the destructive power of Kāne in flood-prone windward valleys and his productive power in Waipi'ō Valley. These chiefs directed the extension of valley-bottom water management techniques to the Lālāmilo–Waimea system. They also became increasingly dependent on Lono's rainfall at Kohala and Kona to meet the dietary, ceremonial, and political requirements of a burgeoning population and bureaucracy. Perhaps they subsequently perceived Lono's limitations or acknowledged Kāne's potential, but they expanded their territory for agricultural production through the intercession of Kuka'ilimoku, the "kingdom-snatching" god of war. At 'Īao on Maui, at Hālawa on Moloka'i, and at Nu'uanu on O'ahu, the prized territories were the valleys of Kāne, and into these valleys came the conquering chiefs of Lono.

CONCLUSIONS AND FUTURE RESEARCH

This report has discussed a broad range of pre-contact water management systems in the Hawaiian archipelago. These systems were carefully adapted to islands with older geologic features, deep alluvial valleys, and perennial streams and springs, such as Kaua'i and O'ahu, and to younger islands with limited soil and hydrological potential for irrigation, such as Hawai'i. After analyzing the archaeological and ethnohistorical materials gathered for each island, it is apparent that pre-contact Hawaiian achievements in water management had ecological, economic, and sociopolitical significance.

In trying to understand the cultural context within which these water management systems developed, I analyzed Hawaiian traditions, legends, proverbs, poetical sayings, and ethnohistorical and archaeological data and attempted to explicate local variations in the meaning of water and the character of certain Hawaiian deities.

Leading theories suggest that population growth was a primary factor in the development of pre-contact Hawaiian culture (Kirch 1984; Kelly 1989). Kirch developed the following theoretical model of the relationship between population growth and settlement and agricultural patterns of the Hawaiians:

1. Initial settlement in well-watered windward valleys by a population of perhaps one hundred individuals
2. Movement of individuals in junior descent lines into less favorable leeward valleys as the population in windward valleys increased and inland areas were further exploited
3. Increased agricultural production, resulting from intensification and supporting a larger and more complex political system, as the population increased in both windward and leeward valleys
4. Increased competition for land between competing chiefly lines as population growth accelerated
5. Initiation of interisland warfare and conquest by expansion-minded “usurper” chiefs from junior lines as population pressure on the productive potential of the kula lands of the island of Hawai‘i increased

Over the fifteen-hundred-year period of Hawaiian cultural evolution in both windward and leeward areas, innovations in water management practices clearly played a role in increased agricultural production. Although the size of the Hawaiian population at contact is now being debated (see Stannard 1989), there is no doubt that water management practices were crucial to supporting a rapidly growing population in the protohistoric period.

There are, however, some important gaps in the archaeology of Hawaiian water management. Once these are filled, Kirch’s theoretical model should either be substantiated or revised in significant ways. Additional archaeology in all the windward valleys is necessary to substantiate that they were densely populated prior to the colonizing of less favorable leeward areas. The archaeology of water management on Maui needs much greater attention if we are to understand production intensification in relation to evolving sociopolitical complexity in the protohistoric period. Finally, more detailed and comprehensive accounts of water management in the leeward valleys of Kaua‘i, O‘ahu, and Moloka‘i are necessary to enable comparisons of practices from all over the archipelago.

With respect to the cultural meaning of water, I focused primarily on local variations in the character of the Hawaiian deities most closely associated with water. In addition, I attempted to determine how the character of these deities may have changed over time. I argued that Kāne was of more importance on the older, well-watered islands of Kaua‘i and O‘ahu and in the windward valleys of all islands, and that Lono appeared to be of greatest importance in the kula lands of the youngest island, Hawai‘i, and in the leeward areas of all islands.

Water was a central symbol in Hawaiian culture, so it is indeed possible that the character of each deity was defined, in part, in relation to wai. There is much more work to be done in this area, and perhaps by focusing on central symbols grounded in ancient Hawai‘i’s changing environment, we can come to understand more about traditional deities and their place in the Hawaiians’ perceptions of their universe. Improved archaeology can play a role, but major
discoveries are more likely to be made by Hawaiian *kupuna* and scholars knowledgeable about and respectful of Hawaiian language and culture. I sincerely hope my report plays a knowledgeable and respectful role in the dialogue about the meaning of water, and water management, in traditional Hawaiian culture.

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