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**Water for Life**  
The History and Future of Water on O'ahu



## Welcome to Water for Life.

We at the Honolulu Board of Water Supply (BWS) are working hard to preserve and protect our most essential resource—our water. We are blessed with many gifts here in Hawai‘i, and a plentiful supply of the best water in the world is at the top of that list. We have also been blessed with a community that has worked with us when we have asked for conservation.

This is a new era, with new challenges, and the BWS is meeting those challenges with a renewed commitment to our vision and mission. We invite you to participate in our vision through efforts that will be undertaken in your community. The BWS has developed goals to support water resource planning, based on the ahupua‘a model of sustainable resource management. In a world of limited resources, meeting these goals will require balance, understanding, and shared responsibility. These goals enable the BWS to fulfill its roles and responsibilities in a larger system of agencies contributing to the management of water resources.

To understand where we are going, it is necessary to understand where we have come from. To that end, we have prepared this booklet – **Water for Life: The History and Future of Water on O‘ahu**. Thank you for your participation in making the BWS’s conservation efforts a success.

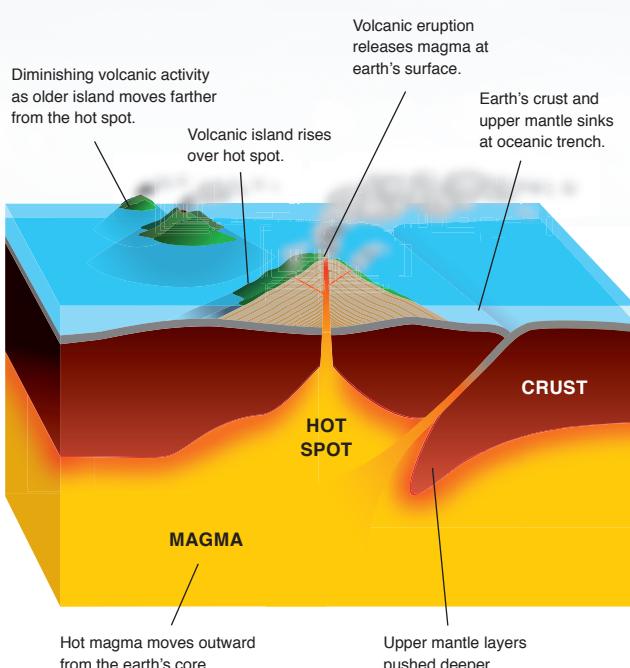
# Ka Wai Ola

All life needs water. Hawai'i's volcanic landmass and high rain-catching ridges gave each island the tools to create an efficient and dependable water source.

## HOW WATER IS MADE

### Born of Fire and Water

The Hawaiian Islands are part of a long chain of volcanoes rising up from the sea floor. Eruptions over hundreds of thousands of years built an island that finally emerged above sea level. As the Pacific Plate moved to the Northwest, new islands emerged above the stationary hot spot.

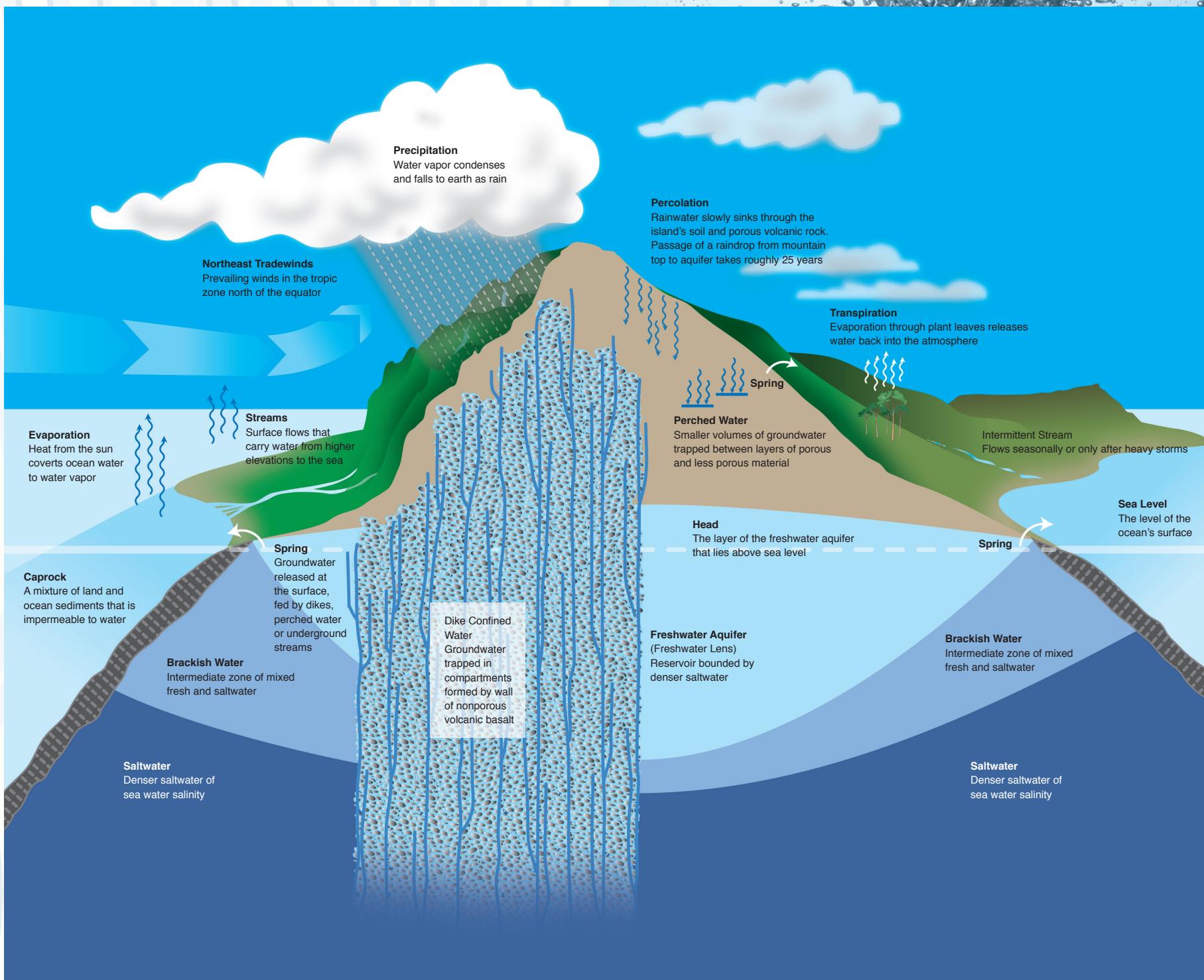


O'ahu was built by two volcanoes, the remnants of which are the Wai'anae and Ko'olau mountains. Over time, the two volcanoes joined to form a single island that was further shaped by erosion and volcanic eruptions. Erosion covered the coastal reefs and built the high, fertile plateau of central O'ahu.

## The Origins of Water

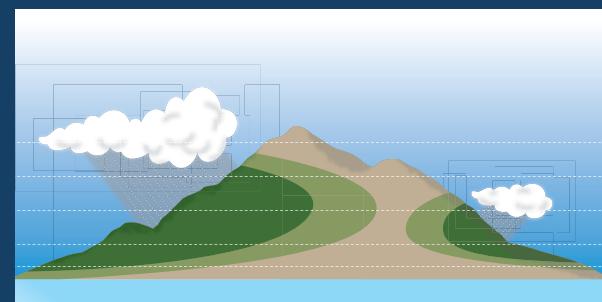
The hydrologic cycle is one of constant motion and transformation. As water changes form through evaporation and condensation, energy is released and absorbed, linking water to the environment's larger energy cycle.

Rainfall is one part of the water cycle equation. A reliable water supply also depends on a healthy, balanced natural ecosystem to catch and store water.

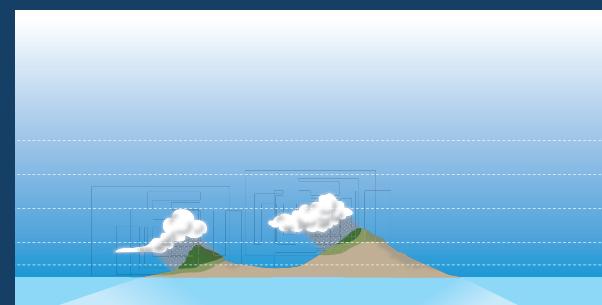


## HOW THE AGE AND SHAPE OF OUR MOUNTAINS AFFECT RAINFALL

O'ahu's steep mountains are key to the island's ability to attract clouds and abundant rainfall.



On young high mountains such as Hawai'i Island, clouds drop their precipitation before they are pushed to the highest elevations, leaving the upper reaches dry and desert-like.



On older eroded islands such as O'ahu and Kaua'i, rainfall is heaviest on the windward slopes and mountain peaks, allowing lush vegetation to cover even the highest ridges.



A relatively flat island such as Ni'ihau has very little rainfall because it lacks the high elevation slopes. Without the slopes, winds cannot push moist air upwards to produce clouds and precipitation.

# RAIN FORESTS AND THE WATER CYCLE

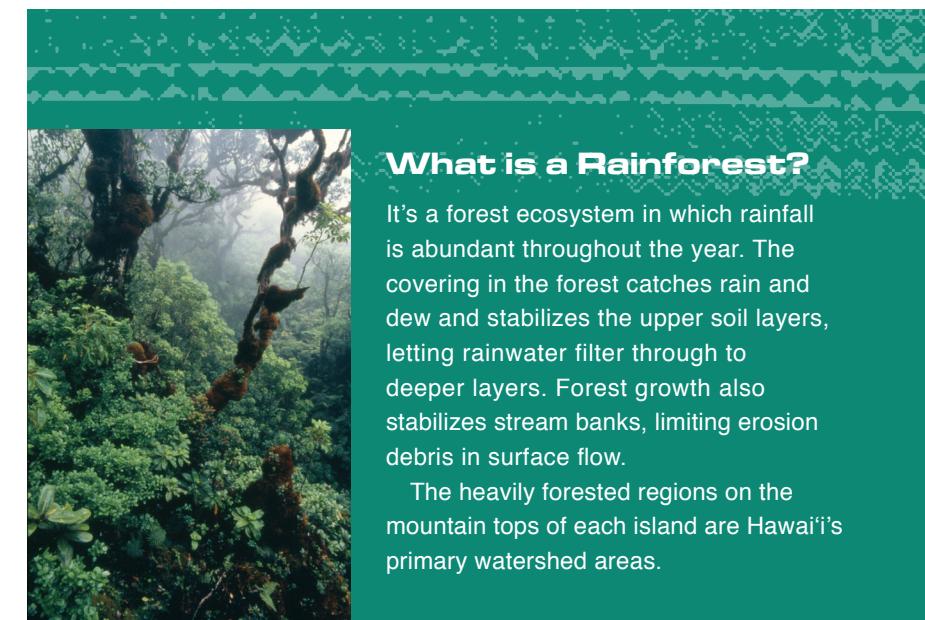
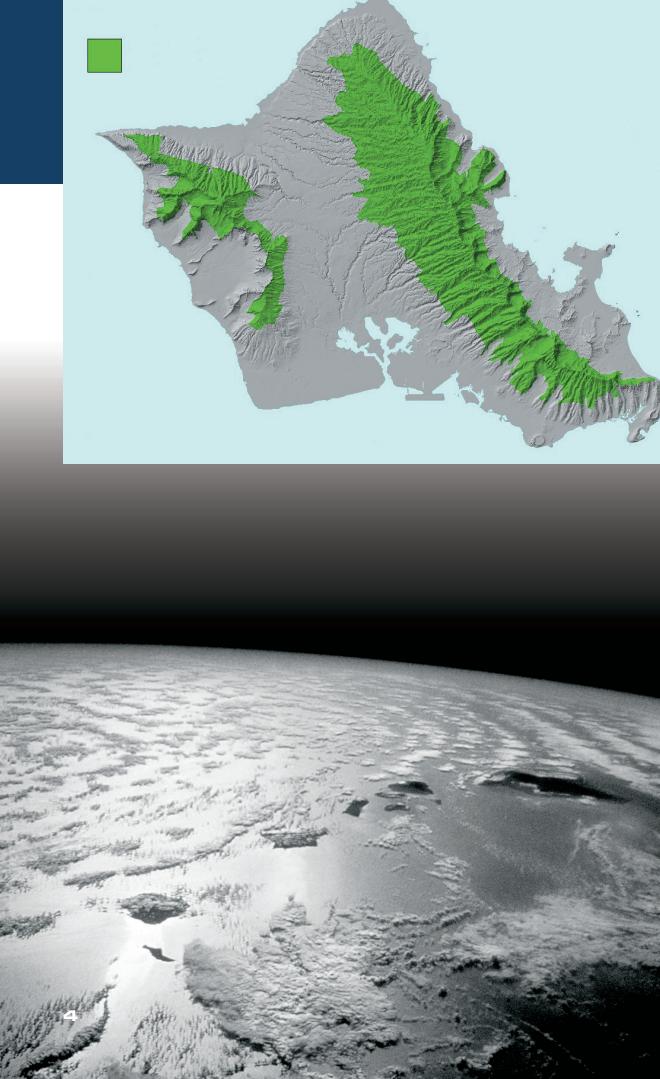
## The Watershed is Our Collection Basin

Rainfall is only one part of the water cycle equation. O'ahu also interacts with the skies to funnel water from the atmosphere back to land. The island's topography, augmented by a healthy, balanced natural ecosystem, catches, collects, and stores water.

## What is a Watershed?

A watershed is an area of land, such as a mountain or a valley, that catches and collects rainwater. Topography influences whether rainwater moves toward the sea via rivers and streams or via movement underground.

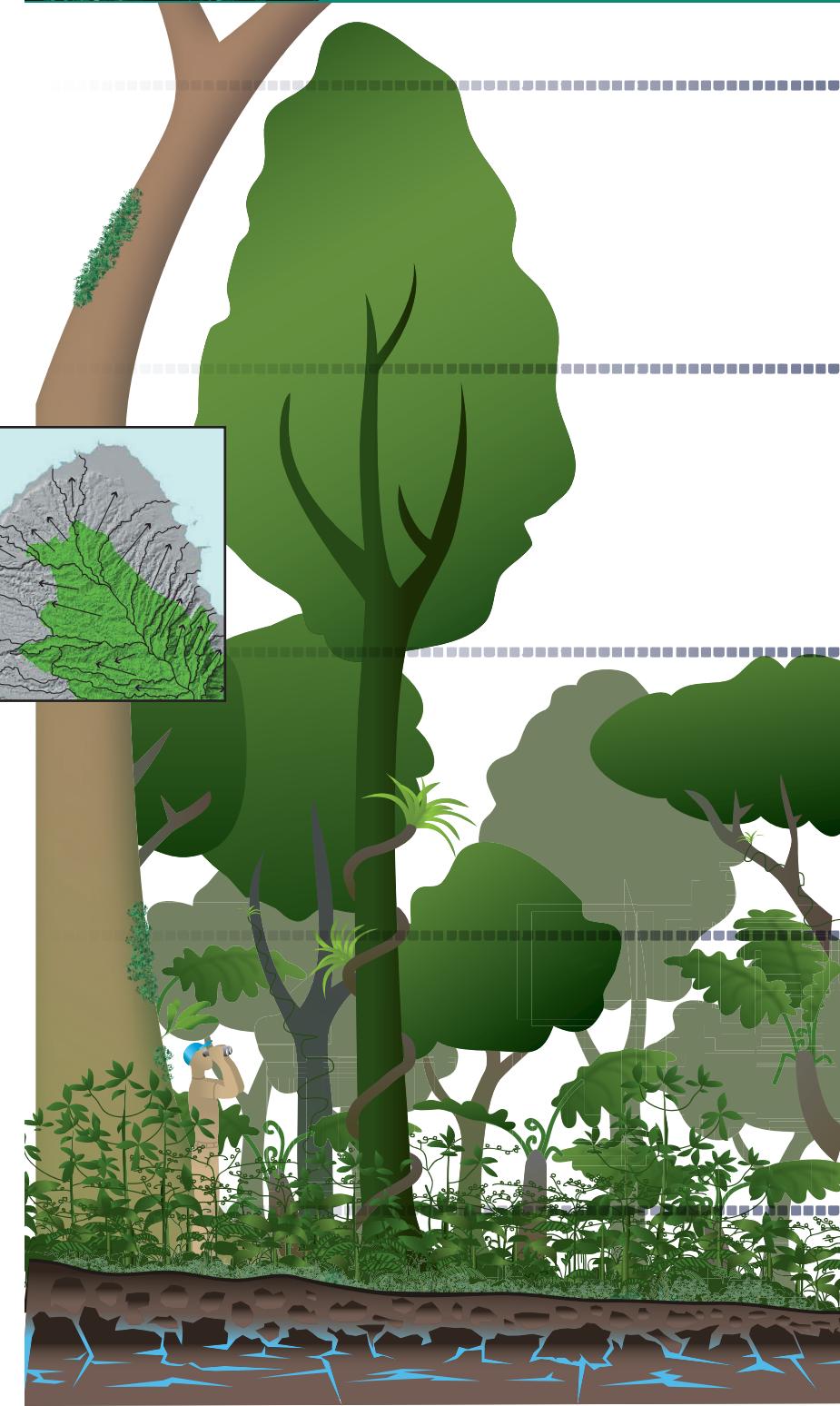
The forests of the Ko'olau and Wai'anae mountains watersheds are critical to collecting rainfall that supplies O'ahu's streams and aquifers.



## What is a Rainforest?

It's a forest ecosystem in which rainfall is abundant throughout the year. The covering in the forest catches rain and dew and stabilizes the upper soil layers, letting rainwater filter through to deeper layers. Forest growth also stabilizes stream banks, limiting erosion debris in surface flow.

The heavily forested regions on the mountain tops of each island are Hawai'i's primary watershed areas.



## The Hawaiian Rainforest is the Ultimate Watershed Cover

Hawaiian native forests have evolved over millions of years to become the best quality watershed covers. Vegetation in the forest fills every level. It soaks up rainfall like a giant sponge, allowing water to drip slowly underground and into streams.



### Emergent Trees

#### *Koa, ʻōhi'a*

These trees are the first to intercept heavy raindrops, absorbing the energy of their fall. Tree leaves pull moisture from passing clouds via condensation (fog drip). Water runs from leaves, down branches, to plants at lower levels.



### Canopy Trees

#### *ʻŌhi'a*

Canopy trees catch the majority of raindrops as well as additional fog drip. Water flows along branches to the trunk; bark texture slows the rate of flow.



### Subcanopy Trees & Shrubs

*'Olapa, kāwa'u, hāpu'u tree ferns, alani*  
This level absorbs tree drip from the layers above, holding much of the water in its vegetative structure and passing some flow along stems to the ground. Subcanopy plants keep the air near the ground water-saturated, slowing evaporation from the ground layer.



### Understory

#### *'ōheo, pū'ahanui, alani, uluhe fern, 'ama'u, hō'i'o, 'ākōlea*

These ferns and shrubs absorb additional water from higher plants as well as the energy of dripping water.



### Ground Cover

#### *Mosses, small ferns such as hoe and Māui, 'ēkaha*

These plants form a spongy absorptive layer just above the soil. They inhibit evaporation from the ground and prevent soil erosion.

## What Happens When the Rainforest is Degraded?

When a forest is degraded, rain falling on bare earth causes erosion. The water-retaining upper soil layers are washed away, leaving behind less permeable clays. Water runs off this impermeable surface rather than filtering down to replenish the aquifer.

Streams that emanate from deforested mountains flood during rains. When the rains stop, these streams run dry.

The loss of stabilizing tree and plant roots results in landslides. Debris carried by streams ends up in the ocean coastal areas, causing siltation of reefs.

When a native forest is eroded and damaged, opportunistic foreign species invade. While these new plants can stabilize bare ground, the watershed cover they create is not as effective as that of the native forest.



This eroded, barren tract used to be a healthy native rainforest. Runoff is greater and more water is now lost to evaporation due to the lack of shade and wind protection.

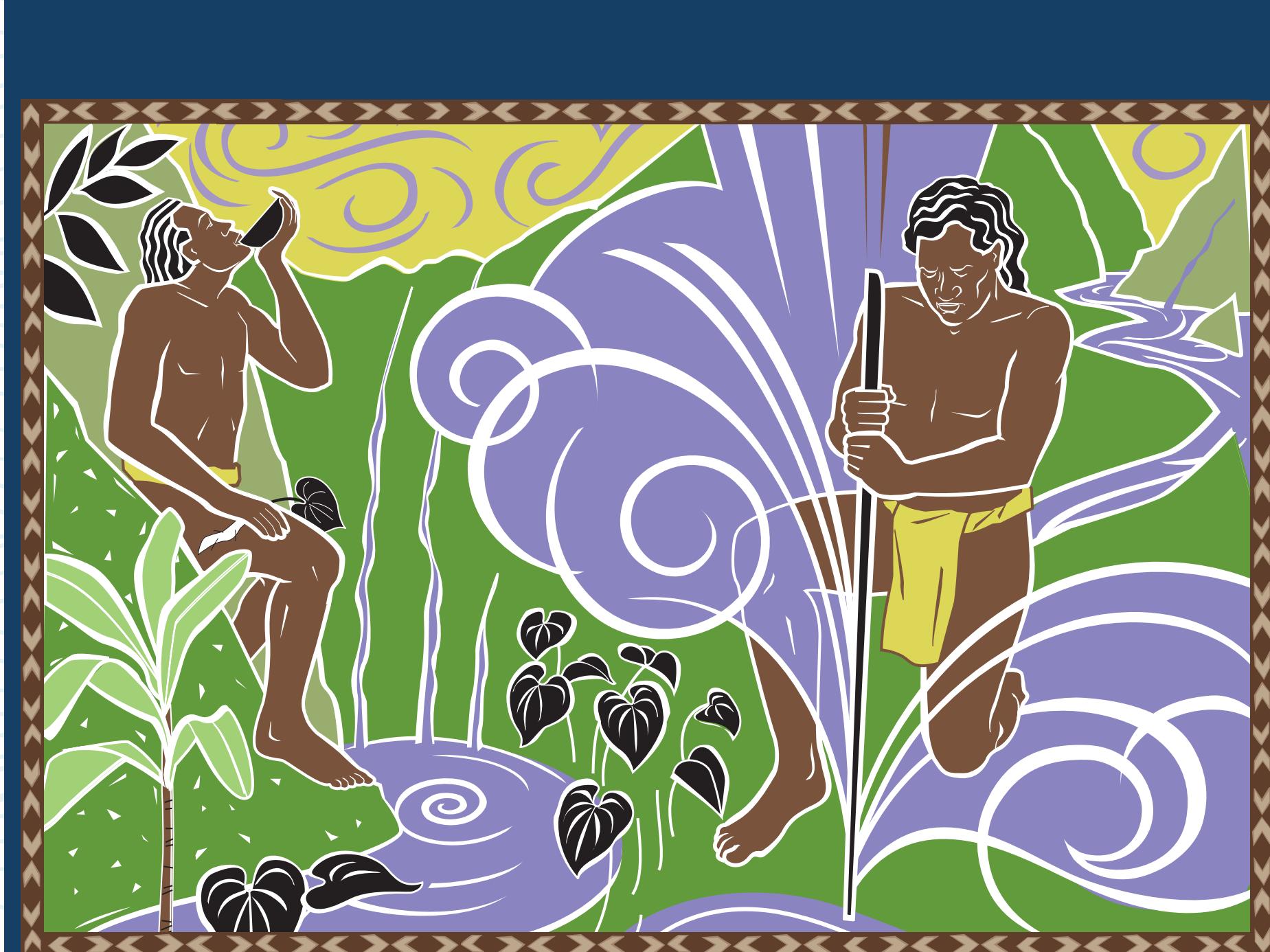
# WATER, THE GREAT GIFT OF THE GODS

## Ka Wai Ola a Kāne

"The Life Giving Water of Kāne" is a term that reflects the special link between the divine and all life forms in nature. The Hawaiians saw gods everywhere in their world: in clouds, trees, stones, and all other parts of the sky, land, and sea that surrounded them.



Man and nature were believed to be part of a larger story of divine creation. Water, the basis of all life, was seen as one of the gods' greatest gifts. The gods would bless the earth with water as long as water was used with respect and water sources were cared for well.



## KĀNE AND KANALOA, The Gods of Hawai'i's Water

Kāne and Kanaloa, the gods of water, traveled throughout the island chain, creating water sources to benefit and sustain all living things.

Both gods were fond of drinking 'awa. When thirst overcame them, each would plunge his digging staff into the ground to bring forth water to be seasoned with 'awa root. Kāne was said to be somewhat gruff and impatient in nature, so the water that he drew from the earth rumbled and roared in the form of large rivers and streams. Kanaloa was said to be very passive and easy-going; he is responsible for calmer water sources, such as springs and pools.

Kāne and Kanaloa were known to roam the drier and more desolate countryside to test the generosity of its people. In areas where fresh water was meager or absent, they would appear and ask for water. If they were turned away without being offered a drink, they would punish the inhospitable by drying up a water source. If they were offered even brackish water, the host would be rewarded with a spring of sparkling fresh water.

**Uwē ka lani, ola ka honua  
“when the heavens weep,  
the earth lives”**

- HE 'OLELO NO'EAU, A WISDOM STATEMENT

## LONO, God of the Winter Rains

Lono was the god of rain clouds, the sea, agriculture, and productivity. Ho'olio (winter) was the season of Lono, the time when the rains fell. Ho'olio was the time when the harvest occurred, taxes were paid and spectator sports and sham battles took place between chiefs and royal champions.

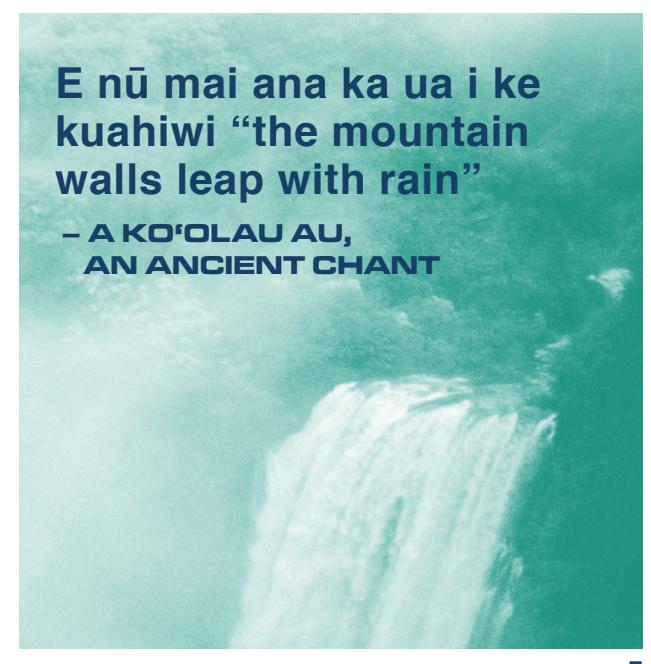
During Makahiki, the time of rituals and celebrations in honor of Lono, his carved image was always present, a constant reminder of his role in continuing the productiveness and fertility of land and sea.

Priests of Lono appealed to him for rain at heiau ho'oulu ua (temples to increase the rains). When severe flooding threatened the Islands, Lono's priests invoked at heiau kālau ua (temples to roast rain). Pleading for relief, priests used underground ovens to bake offerings of rainwater wrapped in folded and cupped ti leaves.



**E nū mai ana ka ua i ke  
kuahiwi “the mountain  
walls leap with rain”**

- A KO'OLAU AU,  
AN ANCIENT CHANT



## ANCIENT HAWAIIANS LIVED IN HARMONY WITH WATER

In ancient times as now, fresh water was the key to life and prosperity. The early Hawaiians settled by perennial streams and springs where water was plentiful and reliable. The abundance allowed the Hawaiians to develop an extensive agricultural system and a sophisticated aquaculture structure.



An area that had many fishponds was called 'aina momona or a "fat" land. This 1908 photograph of a Kāne'ohe fishpond illustrates the splendor of these structures.

## Rivers and Fishponds

Rivers brought life to the landscape. A moderate rainfall sent waterfalls spilling into rivers that carried water to lower elevations. As water flowed to the ocean, it passed through countless wetland taro pondfields before it returned to the river to continue seaward. As it neared the shore, it rejuvenated marshes and wetlands and spilled into lokoia (fishponds).

Hawaiians of old were masters of aquaculture. They built lokoia at river mouths to take advantage of the blend of fresh water and salt water – a blend that provided a favorite environment for the choicest of fish. Building the kuapā (walls) of a lokoia was hard work and took as many as 10,000 men. Every fishpond was unique and built to the contours of the land; kuapā were typically made up of coral or basalt blocks.



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## The Ahupua'a Encompassed All

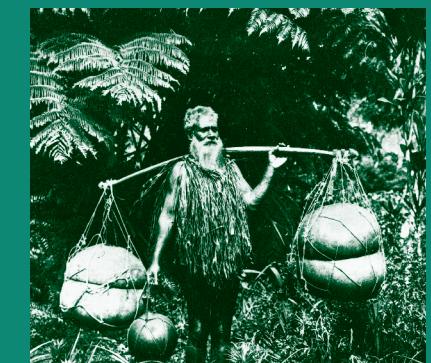
In pre-contact Hawai'i, the land was divided into districts and then into smaller sections called ahupua'a.

Every tenant of an ahupua'a was given access to natural resources. Everyone was allowed to take what they needed to live a full life: spiritually, economically, educationally, and physically.

No one could remove or take more than what they could immediately use. The ahupua'a system ensured that natural systems were kept in balance.

Island topography produced very different communities in leeward and windward areas. Hawaiians gravitated to wetter windward valleys and used abundant stream water to cultivate their staple food, taro. Fishponds built at stream mouths provided a ready source of protein.

Drier leeward areas supported smaller communities which often hugged the coast, giving easy access to ocean fishing areas. Sporadic rainfall and intermittent streams could not support wetland taro. Their main crop was sweet potato. Farmers sometimes carried water to their crops in gourd containers.

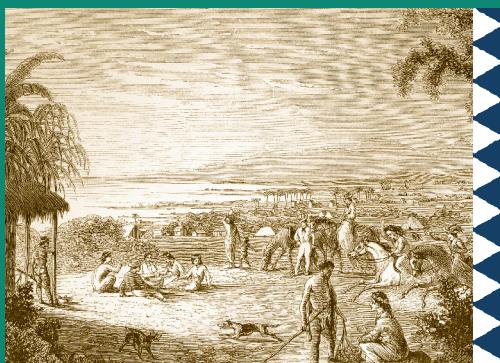
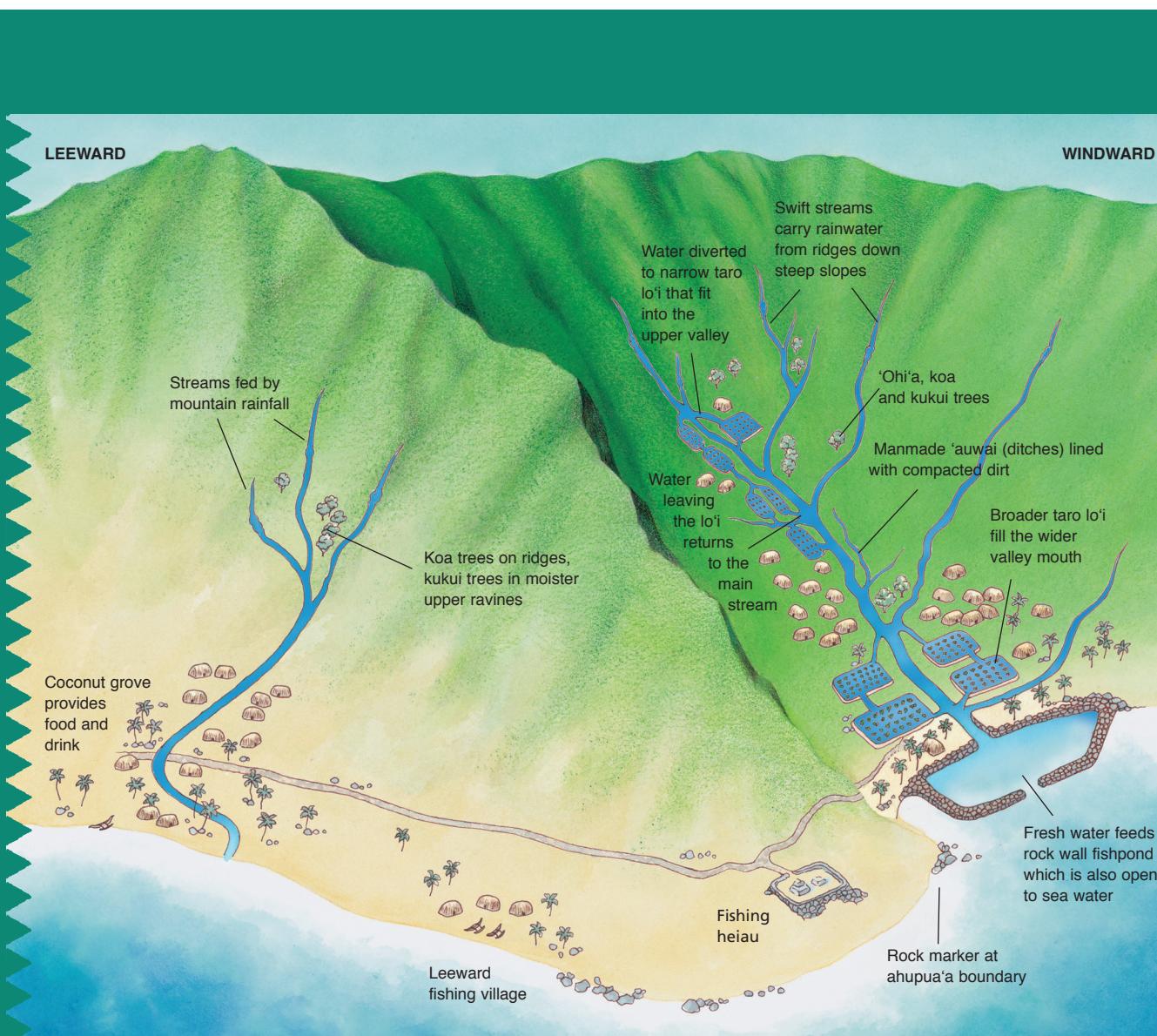


Hawaiians used gourds to transport many things, including water.

## Haloa - Brother Taro

Taro was central to Hawaiian society; it was known as man's older brother, the first-born child of Papa and Wakea, the earth mother and sky father. Hawaiians grew wet and dry taro. Wet taro was grown largely in lo'i (pondfields), which were irrigated with diverted water that flowed through a complex network of 'auwai (ditches).

'Auwai were continually repaired to prevent seepage and waste. Daily water distribution was overseen by luna wai (water manager); farmers were allowed to use water as long as they kept their lo'i productive and helped to maintain streams and 'auwai.

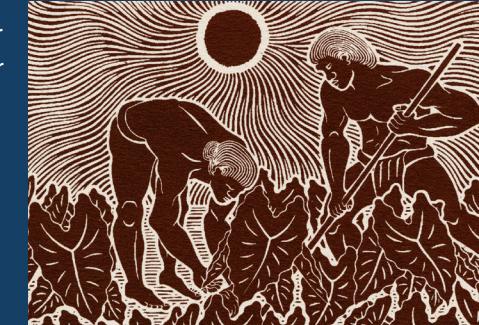


## Formal Rules Governed Distribution and Discouraged Waste

Strict rules governed the use of water in ancient Hawai'i, and it was a grievous offense to waste or misuse the precious liquid. The ali'i ai moku (district chiefs) were the trustees of water and exercised control over it as an instrument of the gods. They established and enforced regulations over water use in upland areas of an ahupua'a so that a pure flow was always available to those who lived at lower elevations.

In addition, they set rigid schedules for cleaning and diverting rivers and streams. Rights and privileges to water were earned, not guaranteed. Farmers were expected to keep their taro fields free of weeds and clutter and to help clean communal streams and rivers.

Those who failed in either regard were disposed of their land and banished. If a farmer dared to water his taro fields without the approval of the luna wai, he was put to death. Disobeying water regulations jeopardized all; the gods were seen to be merciless in this regard.



## Hawai'i's Water Timeline

LEGEND	GEOLOGY
	AGRICULTURE / OTHER INDUSTRY
	GOVERNMENT
	HISTORY / DEMOGRAPHICS
	WATER AND LAND
4.55 billion BC	Formation of Earth.
4.4 billion	Condensation of water into oceans.
10 million	First plants, insects and birds colonize northern islands in Hawaiian chain.
3.7 million	Waianae volcano emerges as an island.
2.6 million	Ko'olau volcano emerges as an island.
1 - 600 AD	Most archaeologists agree the first Polynesian settlers arrive during this period. They settled on the windward sides of the major islands where reliable water sources are available for farming.
1000s - 1300s	Hawaiian settlements spread to the leeward sides of the islands with houses and farms in the lower valleys. Houses and dryland gardens were on the dry edges of the floodplains.
1300s - 1500s	The Hawaiian population grows exponentially. Large heiau begin to appear. Scattered settlements and dryland fields spread inland on leeward slopes.
1600s - 1700s	Hawaiian population and settlement reaches its maximum extent; land and water resources are administered within the ahupua'a system of land division.
1778	Captain Cook arrives.
1790	Goats, sheep, pigs, and cattle are brought to Hawai'i.
1795 - 1809	Kamehameha I unites the Hawaiian Islands.
1815 - 1830	This is the peak of the sandalwood harvest and trade to China. Many of Hawai'i's lowland forests are burned to detect standing or fallen sandalwood by the fragrant odor of the smoke. Grazing and rooting damage by goats, pigs, and cattle is extensive.
1820	First Protestant missionaries arrive.
1820	William R. Warren makes first unsuccessful attempt to dig a well in Honolulu.
1822	Joseph Navarro of New York digs first water-producing well in Honolulu.
1839	First forestry law in Hawai'i restricts cutting of sandalwood.
1848	The Mahele (Division of Land) opens the way for private land ownership in Hawai'i.
1848	Water tank and piping network constructed to serve whaling ships at Honolulu Harbor.
1849	Nu'uau Reservoir built. Pipes take water from Keokane Spring into Honolulu.
1854	William Webster submits water plans to deal with expected population growth in Honolulu area.
1856	Government claims power to allocate water; develops municipal water supply.
1860	Kingdom of Hawai'i Water Commission established to settle water use disputes.
1860	Act passed allowing Kingdom of Hawai'i to acquire watersheds in five valleys.
1860	Drought in the islands.
1860	The traditional ahupua'a system is effectively gone. Large ranches begin to emerge on the grassland.
1861	American Civil War begins. Increased demand for Hawaiian sugar.
1867	Peck v. Bailey, the first legal case dealing with water, settles competing demands for water from the Wailuku River on Maui.
1872	Bureau of Water Works established.
1872	First government license granted allowing private businesses to take water from streams.
1879	Government passes "Act for the Protection and Preservation of Woods and Forests" which includes watershed preservation.
1880	James Ashley, hired by James Campbell, finds and drills first artesian well on the 'Ewa plain.
1880	Second artesian well drilled on Wilder near Punahoa School by Dr. Augustus Marques; this is the first well in Honolulu.
1880s - 1890s	Top of Ghyben-Herzberg lens is 42 feet above sea level.
1887	Eucalyptus and ironwoods planted on Tantalus and in Nu'uau Valley.
1887	King David Kalakaua forced to sign the "Bayonet Constitution" proposed by planter interests which reduces the king to a figurehead.
1893	American businessmen aided by U.S. Marines overthrow the Hawaiian monarchy and establish a Provisional Government.
1894	Republic of Hawai'i established; replaces Provisional Government.
1895	City Waterworks drills first public water well at site of current Board of Water Supply headquarters.
1896	The Republic hires Rudolph Hering, Sanitary Engineer for New York City, to plan Honolulu's sewer system.
1897	O'ahu Sugar Company develops its first crop of sugar cane.
1898	City Waterworks drills second public water well in Kaimuki.
1898	Territory of Hawai'i annexed by the United States.

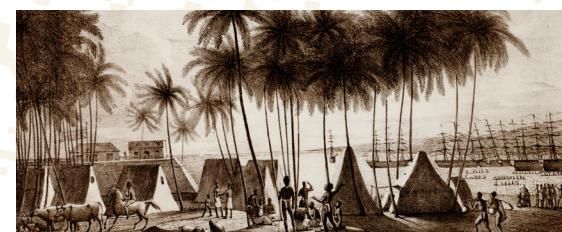
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# TRADE AND INDUSTRY TRANSFORMED OUR NATURAL SYSTEMS

## A Century of Change

In the 1800s, everything changed in the Islands. The kapu system was abandoned. Traditional land and water rights were abolished. A cash economy grew up, fostered first by whalers and traders, then by sugar planters. Thousands of immigrants arrived to work on the plantations. As the century drew to a close, the monarchy was overthrown and Hawai'i was annexed by the United States. O'ahu reeled, trying to cope with it all.

The arrival of Western explorers sparked huge changes in every area of Hawaiian life. Western firepower helped Kamehameha I unite the Islands for the first time and established the monarchy. Western disease decimated the native Hawaiian population. Western traders, missionaries and settlers brought new belief systems: ideas of capitalism, Christianity, and private property.



Honolulu Harbor circa 1822. Change is literally on the horizon for O'ahu.



Above left: In 1852, the first major group of indentured laborers arrived in the Islands. Mass immigration to O'ahu continued through the end of the nineteenth century.

Above right: As the century progressed, Hawaiians were pushed to the margins in their homeland and adopted an array of new conventions, including Western-style clothing.



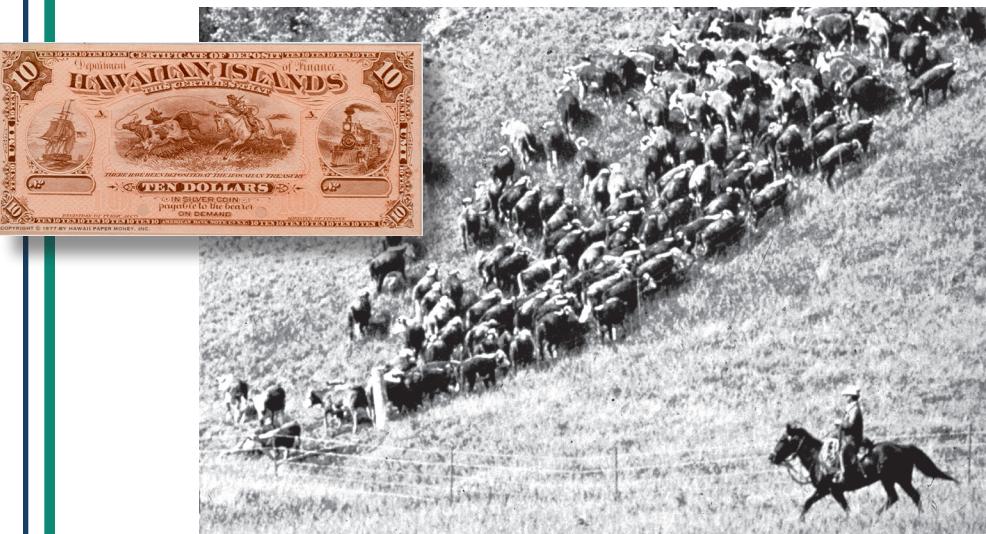
In 1848, the first pipe was built to transport water and from that point on, water engineering became the order of the day on O'ahu. The sugar industry created a huge demand for water. It took 10,000 gallons of water a day to irrigate one acre of sugarcane by furrow irrigation.

## NEW WAYS, NEW WATER SYSTEMS

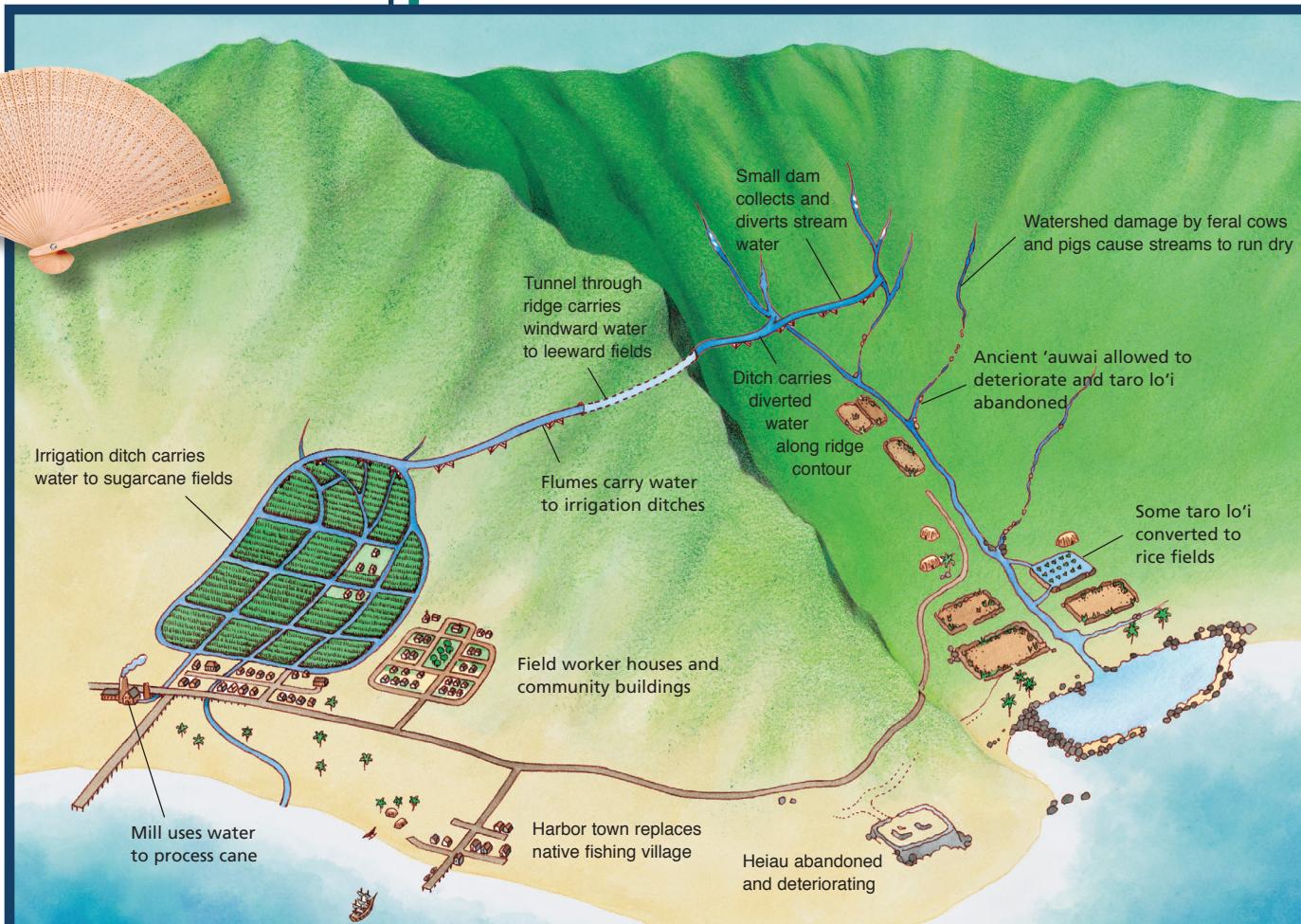
As new industries grew up on O'ahu, the composition of the ahupua'a began to change. The largest changes involved diverting streams to large plantations.

Captain Vancouver brought the first cattle to Hawai'i in 1793; by 1852, there were an estimated 40,000 cattle in the islands. Cattle polluted water sources and destroyed watershed habitat.

Sandalwood was another crop that brought money to the Islands. This fragrant wood was prized in China where it was crafted into fans. The beautiful curios came at a high price: *deforestation*.



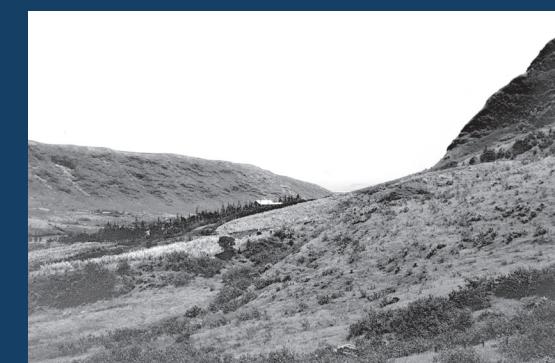
To get water, planters built a massive web of ditches to divert streams. By 1920 more than 800 million gallons a day were being diverted from over a hundred of Hawai'i's streams.



## Watersheds Under Attack

In the 1820s, vast tracts of dry forest on O'ahu's central plains were burned in hopes of detecting sandalwood's sweet aroma. The heart of sandalwood could survive brush fires but the rest of the forest could not.

Feral animals did even more damage. Goats and cattle brought by Western ships destroyed the delicate undergrowth of many of O'ahu's forests. As a result whole forests disintegrated. Without the forests in place, erosion and loss of recharge became another serious problem.



Cows were murder on Hawai'i's forests: they trampled extensively, tracked alien seeds, grazed mercilessly and eventually caused the death of thousands of acres of native fauna.

## Hawai'i's Water Timeline - continued

1899	Kalihi pumping station built; pumped artesian water from three wells. The pumping station replaced surface water contaminated in Chinatown during an outbreak of bubonic plague.
1899 - 1902	Honolulu's sewer system is built based on Rudolph Hering's design.
1900	City Waterworks drills third public water well in Kalihi.
1903	Territory of Hawai'i assumes control of water supply system. Territory of Hawai'i establishes Board of Agriculture and Forestry with support of HSPA.
1904	James Dole creates Hawaiian Pineapple Company from homestead in Wahiawa. First Territorial Forester hired Ralph Hosmer; first forest reserves protect upper watershed areas.
1906	Wahiawa Reservoir (Lake Wilson) built. O'ahu's deepest reservoir, its spillway includes one of the largest engineered waterfalls in Hawai'i.
1910	Nu'uana Reservoir No. 4 built to supplement earlier lower elevation reservoirs. Prompted by a growing Honolulu, the reservoir provided the added water pressure needed to reach higher stories in buildings. 430 wells operating on O'ahu.
1913	Helemano and 'Opae'ula Reservoirs built, two of four systems engineered for Waialua Sugar Company. Territorial Legislature turns over the operation of the water supply system to the City and County of Honolulu.
1914	City first introduces water meters to cut water consumption.
1915	The Board of Supervisors establishes the Honolulu Water Commission to study the water supply system.
1916	Waiahole ditch system opens.
1918	Pearl Harbor naval station opens.
1920	Water levels in wells are declining and many wells have stopped flowing.
1923	Top of Ghyben-Herzberg lens is 23 feet above sea level; in 1880 it was 42 feet.
1925	Honouliuli Forest Reserve is established after its value as watershed is recognized. It is maintained by the Territorial Board of Agriculture and Forestry, then by the Division of Forestry (until surrender agreement lapses in 1977). Territorial Legislature establishes the Honolulu Sewer and Water Commission.
1926	Driest year on record for O'ahu.
1927 - 1929	Three new pumping plants completed at Beretania, Kalihi and Kaimuki; booster station at Nu'uana also completed.
1927 - 1950s	Division of Forestry and Civilian Conservation Corps fence the boundary of the Honouliuli reserve, build roads and trails, remove cattle, and plant about 1.5 million trees (e.g., silk oak, tropical ash, ironwood, eucalyptus, and Norfolk pine).
1928	Universal metering policy adopted to promote conservation; 13,900 metered water privileges account for 97% of total privileges.
1929	Territorial Legislature establishes the semi-autonomous Honolulu Board of Water Supply, replacing the Honolulu Sewer and Water Commission. Engineer Fred Ohrt is the first Board Manager.
1930	Basic water rate is 12¢ per 1,000 gallons.
1931	Twenty-five percent of land in Hawai'i is in established Forest Reserves (public and private lands).
1932	43 old wells sealed to date; 5 sealed in 1932. 6.9 miles of new pipe laid for water mains.
1934 - 1941	System of monthly billing for water introduced (replaced quarterly billing). CCC reforestation efforts plant an average of two million trees per year in forest reserves.
1940	U.S. fleet of 130 ships arrive in Hawai'i. Navy begins construction on the Red Hill Fuel tanks. Water distribution system of 322 miles of pipe covers 27.2 square miles from Moanalua Valley to Koko Head. 242 new fire hydrants bring the total to 2,140. BWS Engineering Division starts systematic mapping of water distribution networks.
1941	Basic water rate is 18¢ per 1,000 gallons. Construction of Hālawa shaft begins in response to growing population and expanded military presence during World War II.
1941	Pear Harbor bombed on December 7.
1943	Emergency Construction Program, funded by the Federal Works Agency, forms to meet wartime civilian and military water demands.
1944	Hālawa station opens; the inclined shaft and underground pump is the first water facility operating outside Honolulu city limits.
1946	The water main grid system consists of 349 miles of pipe; 11.84 miles of new pipe are laid this year. Basic water rate is 24¢ per 1,000 gallons.
1953	Waimānalo Sugar Company water license reverts to Territorial government. Today the State Department of Agriculture maintains the plantation ditch to serve farmers in Waimānalo.
1959	Suburban Water, which handled areas on O'ahu outside the urban Honolulu area, is integrated into the Board of Water Supply.

## UNCONTROLLED DRILLING LED TO CHAOS AND DROUGHT

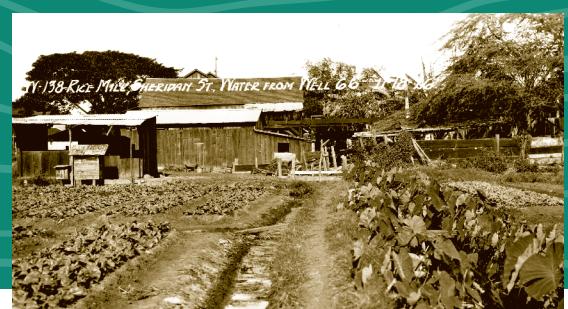
### The Discovery of Groundwater Promised Unlimited Growth

In 1879, James Campbell and James Ashley discovered O'ahu's vast underground water lens. Campbell had purchased 41,000 barren acres on the 'Ewa Plains. Hoping to find water to grow sugar, he hired Ashley, a Californian, to drill a well on the land. Ashley dug 273 feet into the soil and hit liquid gold: a gusher of fresh, clean water. In the years that followed, Campbell drilled over 70 wells on his property. By 1925, he was pumping 105 million gallons a day.

When the underground aquifer was tapped and the water let out of the earth, brown turned to green. The water made everything seem possible. Before too long, wells were being bored all over O'ahu and suddenly, the island's growth seemed limitless.



Entrepreneurs around O'ahu drilled artesian wells using steam-powered rigs that bored through rock and soil to reach the groundwater below. Here the McCandless Brothers are drilling a well on the 'Ewa Plains.



O'ahu's population was growing but its water usage was growing faster. In 1926, Honolulu residents were each using an average of 500 gallons of water a day. By contrast, average daily per capita use in Dallas was 56 gallons. In San Francisco, it was 81 gallons. Chicagoans, who were each using 275 gallons a day, were ordered by the U.S. War Department to cut their water use. Yet this was barely half of Honolulu's daily usage.



### Exploiting the Resource

As O'ahu's rapid growth continued, demands for water escalated. Honolulu's population was swelling: it tripled between 1879 and 1915. By 1889, just ten years after Ashley's discovery, there were over 100 wells on O'ahu; by 1910, there were 430. Everyone, it seemed, needed more water.

Through the end of the 1920's, water development on O'ahu was widespread and largely unchecked. In Honolulu, landowners bored private wells on their properties. Outside the city, more and more land was being put into sugar and other crops and by 1925, sugar companies were pumping some 260 million gallons a day from almost 200 wells.

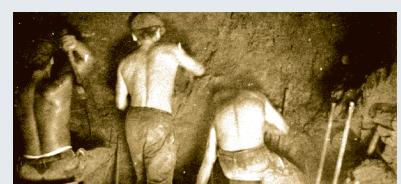
There were some early attempts to oversee water use and development but government oversight was almost all but nonexistent. People took what they needed and left the planning to someone else.



Workmen at the Waiāhole Tunnel Project. Manager Jorge Jorgensen noted: "At the beginning of the tunnel work, three shifts of eight hours each were kept going. This was continued until the large amount of water coming into the tunnel... became troublesome, and on account of the hardship on the men, working eight hours in the cold water, it became necessary to cut the shifts down to six hour each, so that four shifts a day were employed."

### Tunnels Carried Water from Windward Valleys to Arid Central Plains

Planters bored 38 tunnels through the Ko'olau mountain walls. The longest of these was 2.7 miles, tunneled through dense rock. Before the tunnel broke through to the other side, it was described as "a whirling rainstorm, a giant shower bath, a waterspout and a typhoon combined." Thirty-seven windward streams were diverted through the tunnels, for an average flow of 30 million gallons a day.



The grueling work of digging tunnels was often done by hand.



Maintenance crews continued to work on the tunnels long after tunnel construction was complete.

### O'ahu's Water Boom Goes Bust

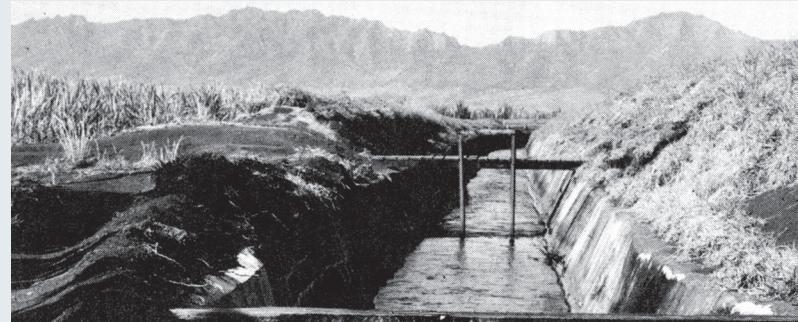
The water free-for-all couldn't last forever. When the first artesian well was sunk on O'ahu, it hit an untouched pristine aquifer that came gushing forth with a geyser of 42 feet above sea level; by 1910 it had dropped by a third. As more and more wells were developed on O'ahu, the aquifer receded resulting in brackish water as wells "salted up." Water was being taken out at a higher rate than rains could replenish the



This flume, built from redwood, was part of the Waimānalo Sugar Company's ditch system. Operating one of O'ahu's smallest plantations, the company took most of its water from the Kailua watershed.

### Ditches Crisscrossed O'ahu, Delivering Stream Water to Plantation Fields

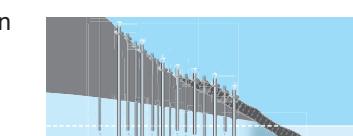
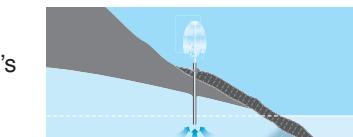
Planters around the island relied on an extensive system of ditches that resembled native 'auwai but for one critical difference: water was allowed to leave the watershed. In the early years of the twentieth century, ditches on O'ahu carried some 70 million gallons a day. They took water from the Ko'olau, Punalu'u, Kailua and Maunawili and delivered it to Waialua, Wahiawā, Kahuku and Waimānalo.



A.H. Hobart is drilling the Gouveia Well circa 1920, which later became the Love's Bakery Well.

aquifer and in 1917, the fledgling Honolulu Water Commission warned that the island's water system was in danger of "complete failure or at least extreme diminution."

To compound it all, the driest weather on record hit O'ahu in 1926. O'ahu's wells numbered over 400, a water crisis was underway. A change had to come.



### Hawai'i's Water Timeline - continued

1959	Hawai'i admitted as a state.
1961	Legislature passes "Groundwater Use Act" to regulate groundwater withdrawals.
1970s	The Hawaiian Renaissance ushers a resurgence of Hawaiian culture in the arts and in thinking about land use.
1970	The reemergence of the ahupua'a land use system gains support.
1971	BWS finishes converting from steam pumps to electrical pumps. Kalīhi Pump is replaced in 1971.
1973	O'ahu Water Plan is updated and planning horizon extended out to 2020. McBryde Sugar Co. v. Robinson decision find the state held water for the benefit of the people and water could not be transferred out of its originating watershed.
1974	"Safe Drinking Water Act" enacted.
1977	A decision is made by the City and County of Honolulu to transform fields of sugar cane in West O'ahu into a new city known as Kapolei.
1978	State Constitutional Convention establishes water as public trust - work begins on the State Water Code.
1979	Kalīhi pumping station established as Fred Ohr Museum.
1980	State of Groundwater Resources of Southern O'ahu published by BWS.
1980s	Honolulu experiences a decade of rapid population growth. Water use also escalates.
1982	Reppun v. Board of Water Supply affirms the McBryde decision.
1985	BWS begins using a granular activated carbon filtration system at the Mililani Wells 1 pumping station due to agrochemicals in the water sources in Central O'ahu.
1987	Enactment of State Water Code sets precedence for allocation of water following shutdown of a plantation irrigation system; regulates both groundwater and surface water.
1987	BWS begins process of GIS mapping for their water system.
1989	Hālawa Xeriscape Garden opens to educate the public about ways to save water in lawns, gardens, and landscaped areas.
1990	BWS establishes the Water Conservation Program as water demand peaks at 157 mgd after a large economic boom that changed the face of Waikiki.
1992	The Commission on Water Resource Management designates Windward O'ahu, from Makapu'u Point to Waimea Bay, as a ground water management area.
1994	Existing users of ground water will now be required to apply for water use permits.
1995	O'ahu Sugar Company closes, prompting reevaluation of stream diversion uses and practices.
1996	Waiāhole Ditch Contested Case begins weighing agricultural water use, stream restoration and drinking water under the State Water Code and the Public Trust Doctrine.
1997	Waialua Sugar Company closes.
1998	BWS modernizes customer accounting system.
2000	Start of 6 consecutive years of drought, unprecedented in over 100 years of rainfall record.
2003	Hawai'i Supreme Court rules on the Waiāhole Ditch Contested Case establishing 3 Public Trust water uses; water in its natural state, water for traditional and customary use, and domestic water use.
2006	BWS acquires the Honolulu water recycling facility, the largest in the State.
2008	John A. Burns School of Medicine uses a district cooling water system for their air conditioning.
2009	State unveils their Hawai'i 2050 Sustainability Plan including water infrastructure.
2010	BWS Wai'anae and Ko'olauoa Watershed Management Plans adopted by City Ordinance, 2 of 8 holistic, long range water resource plans embracing the Hawaiian ahupua'a concept.
2012	Potable water use drops by 16.5% due to successful conservation and recycled water programs.
2015 - 2020	10 billion gallons of water conserved per year.
2016	Ko'olau Poko Watershed Management Plan is adopted by City Ordinance.
2017	BWS does an assessment of their water system and facilities.
2018	Work begins and continues on the 'Ewa, Central O'ahu, Primary Urban Center, and East Honolulu Watershed Management Plans.
2019	Water Master Plan adopted by the Board of Water Supply Board of Directors. Plan is a 30-year road map that will inform and direct BWS policy and implementation strategies.
2020	North Shore Watershed Management Plans adopted by City Ordinance.
2021	Work begins and continues on the final 4 watershed management plans.
2022	Population expected to rise significantly in 'Ewa, Central O'ahu and the Primary Urban Center.
2023	Water Master Plan plans for system upgrades to accommodate growth.

# THE EARLY YEARS OF THE BOARD OF WATER SUPPLY

## How Control of Honolulu's Water Supply Changed Hands

In the hundred years before the Board of Water Supply, government control of water passed from the Kingdom to the Republic to the Territory and then to the City. Engineers laid some water pipes during Kingdom years and drilled municipal wells at Beretania and in Kaimuki and Kalihi during the time of the Republic. During the City's era, the Honolulu Water Commission was established. But no group had devised a comprehensive water system, something the city needed desperately as its population boomed.

Droughts and dropping water tables heightened the public's concern, and when an embezzlement scandal rocked the City Water Works, the public demanded a well-run

water system that was above politics. In 1929, after a battle that went all the way to the Hawai'i Supreme Court, the Legislature took unilateral control of water from the City and turned it over to a newly created semi-autonomous City agency, the Honolulu Board of Water Supply.

Act 96 established the structure of the Board of Water Supply. The BWS's policies are set by a seven-member Board of Directors, six of whom are appointed by the Mayor and approved by the Honolulu City Council. The Board of Directors are responsible for appointing the agency's Manager and Chief Engineer.

**WATER BOARD  
TAKES CONTROL  
FEBRUARY 1ST**

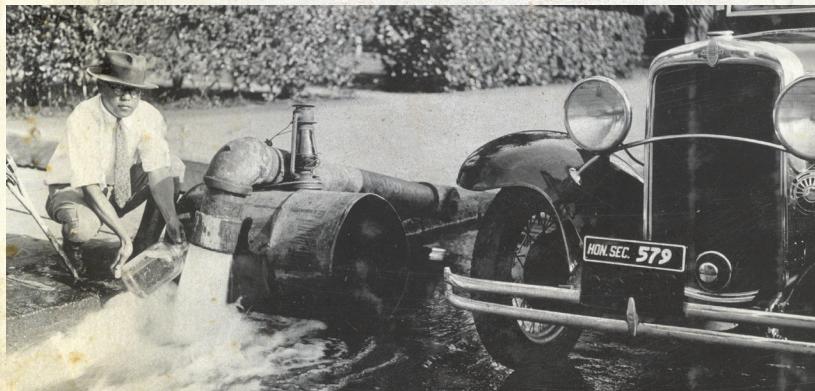
## The Board Gets Down to Business

The newly created BWS was given broad powers over water: to develop it, sell it, and plan for its future on O'ahu. The BWS used the mandate to create the island's first truly effective water management system.

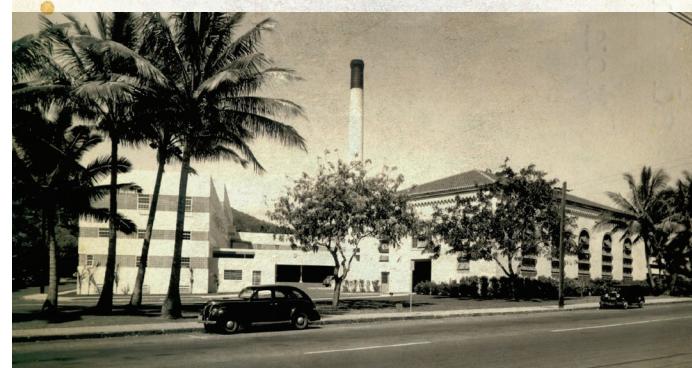
BWS employees located and capped wasteful artesian wells. They put casings inside leaky wells to prevent water loss. They created educational campaigns to teach the public about O'ahu's hydrology. They installed water meters in homes and businesses all across the city and billed water users at fixed rates (in 1930, the going rate for 1,000 gallons of water was 12 cents).

All the efforts paid off. There was a marked reduction in the draw from O'ahu's aquifer and the water table stabilized. To deal with O'ahu's growing population—which doubled in the BWS's first 20 years—BWS staff built water reservoirs, laid larger and better pipes, and made sure the city's pumping stations were in top shape.

They also looked for new sources of water for the city. Just before the outbreak of World War II, they began to develop their first facility outside the city, a new station in Hālawa Valley.



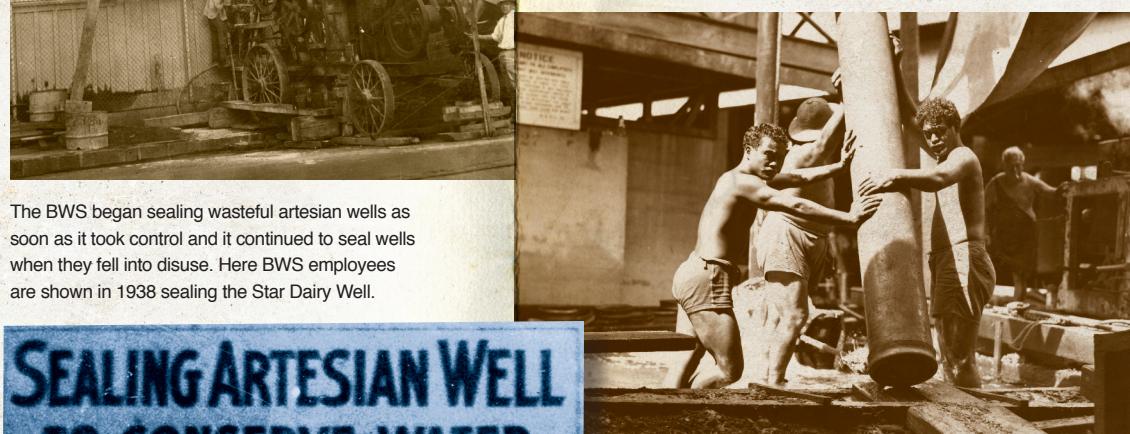
BWS employees also tested well water to make sure that it was safe to drink. Here a technician takes a sample from a Navy well circa 1933.



The Beretania pumping station circa 1940.

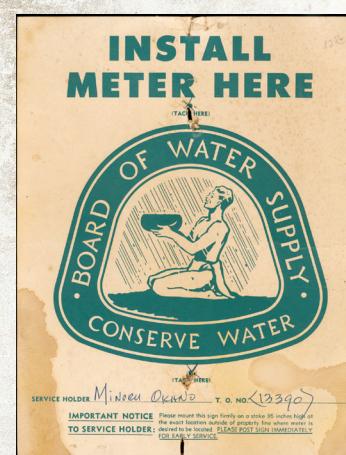


Inside Hālawa Shaft. Concerned about the threat of war, the BWS began developing the new water source. The timing was prescient: the BWS broke ground on the project on December 6, 1941.



BWS employees also continued to put casing inside wells to help catch water that was being lost; this photo was taken in 1940.

## SEALING ARTESIAN WELL TO CONSERVE WATER BOARD OF WATER SUPPLY



WATER SALES 83  
The present rate schedule is as follows:  
For each service there shall be a charge for the service, based on the size of meter, per month, as follows:

For a service with a $\frac{5}{8}$ -inch meter.....	\$ 0.50
" " " " $\frac{3}{4}$ " "	0.75
" " " " 1 " "	1.00
" " " " $1\frac{1}{2}$ " "	1.50
" " " " 2 " "	2.50
" " " " 3 " "	5.00
" " " " 4 " "	7.50
" " " " 6 " "	15.00
" " " " 8 " "	25.00
" " " " 10 " "	45.00
" " " " 12 " "	75.00

Cents per  
1,000 gallons

In addition thereto, for all water drawn there shall be charged:  
For the first 25,000 gallons of water per month, or any part thereof, the Domestic rate of ..... 18  
For water in excess of 25,000 gallons and under 250,000 gallons per month, the Intermediate rate of ..... 14

In 1932, the BWS introduced a monthly billing system for its customers. This report from 1935 shows the established rates of the time.



BWS employees inspected wells around the island to check on outflow rates and sample water. Honolulu's water sanitation program was rigidly governed by standards established by the U.S. Public Health Service.

## FREDERICK OHRT: Engineer and Visionary

Fred Ohrt was the first Manager and Chief Engineer of the BWS from 1929-1952.

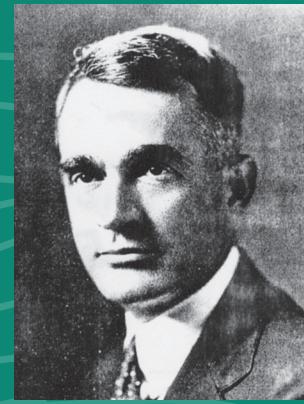
Among Mr. Ohrt's outstanding achievements was his program to locate and seal all leaking wells which resulted in a sharp recovery of diminishing water levels and a marked reduction of over pumping artesian reserves. He was also instrumental in transforming the City and County of Honolulu's water service from a series of separate and inadequate units into a well-engineered and coordinated system that included complete metering of its water customers.

He dedicated himself and the Board to principles that have lasted through time. He believed that water users should be held accountable for their water consumption; that investment in well-designed and attractive water facilities did not sacrifice utility and added value to the community; and that education about water conservation was vital for everyone and the future of water on O'ahu.

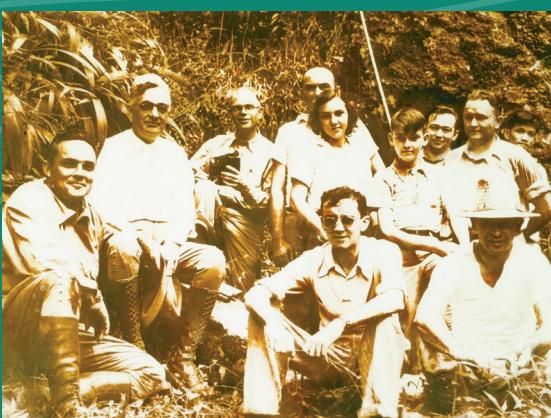
Born in Spreckelsville, Maui, he graduated from Honolulu's St. Louis College (High School) in 1905, attended the University of Oregon, and received his B.S. in Civil Engineering from Cornell University in 1911.

Mr. Ohrt holds the distinction of being Hawai'i's first honorary member of the American Society of Civil Engineers and was also the first honorary member of the Engineering Association of Hawai'i.

The Hawai'i Section of the American Water Works Association named him the first recipient of the George Warren Fuller Award presented posthumously in April 1979.



When Frederick Ohrt retired after leading the BWS for nearly 25 years, the Honolulu Star-Bulletin praised his "technical proficiency, mature judgement, far-seeing vision and fearless integrity."



## AN EFFECTIVE ISLAND-WIDE WATER SYSTEM

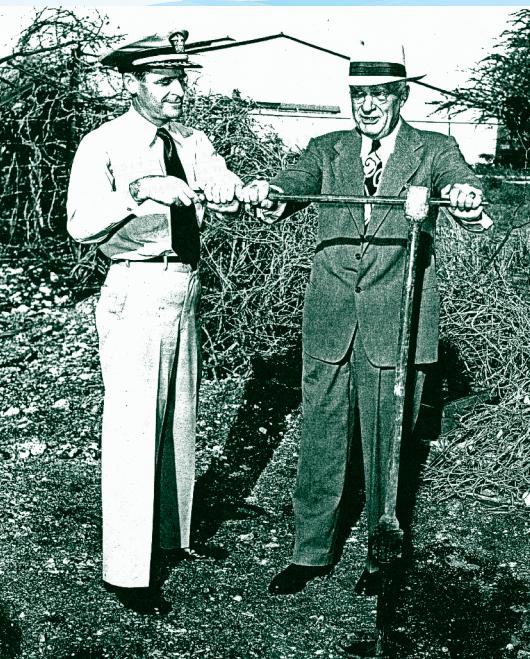
### Keeping Up with O'ahu's Changes

At the end of the 1950s, statehood and the coming of the jet airplane forced another major shift in the Islands. As its population grew, O'ahu's water use rose dramatically: from 64 million gallons a day in 1960 to 138 million gallons a day a decade later.

In 1959, the BWS consolidated its control of O'ahu's water when it took over the agency responsible for water use outside of Honolulu, the Suburban Water System. That year the BWS was also given over \$10 million to develop new water sources, stations, and mains.

In the ensuing decades, the BWS worked to further modernize the water system. In the 1960s, staff switched from lead joint pipes to concrete cylinder pipes, making installation faster and easier. By 1970, electric pumps had entirely replaced steam pumps in stations around O'ahu.

As neighborhoods grew, new water tanks made from reinforced concrete were built. Computers began to monitor island water use and pump water accordingly. As the 20th century drew to a close, the Board was delivering safe, dependable and affordable water to nearly a million people a day.



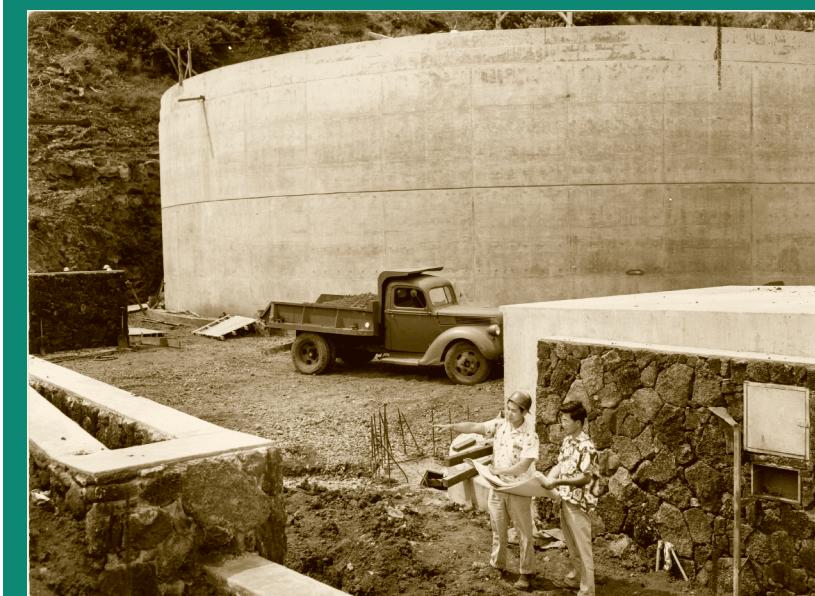
In 1951, the Navy gave the BWS its water supply system at the Naval Air Facility. Here, Frederick Ohrt is shown with Captain W.B. Short turning off the valve that controlled the Navy water.

## Your Water Today

The Board of Water Supply pumps an average of 145 million gallons of water a day serving over 175,000 customer accounts. It maintains over 2,100 miles of pipes and takes care of five shafts, 13 tunnels, 194 wells, 171 potable reservoirs, and 192 booster pumps.

O'ahu's water use increased as the population grew from 64 mgd in 1960 to a high of 157 mgd in 1990, 30 years later. But when BWS's water conservation program began in 1990, water use decreased 10% to 145 mgd in 2017 despite serving close to a million people a day.

The BWS water system today is a modern, integrated island-wide system monitored by computers, SCADA telemetry, and remote Automatic Meter Reading.



## How We Deliver Water

When you turn on your tap, you set in motion a fantastic journey. Water is pumped from the aquifer via wells, shafts, and tunnels. Once up on the surface, it enters an island-wide transmission system. Within the system, water is moved from pumping stations, sometimes via booster stations, to mains and reservoirs where it is stored until needed by homes and businesses.

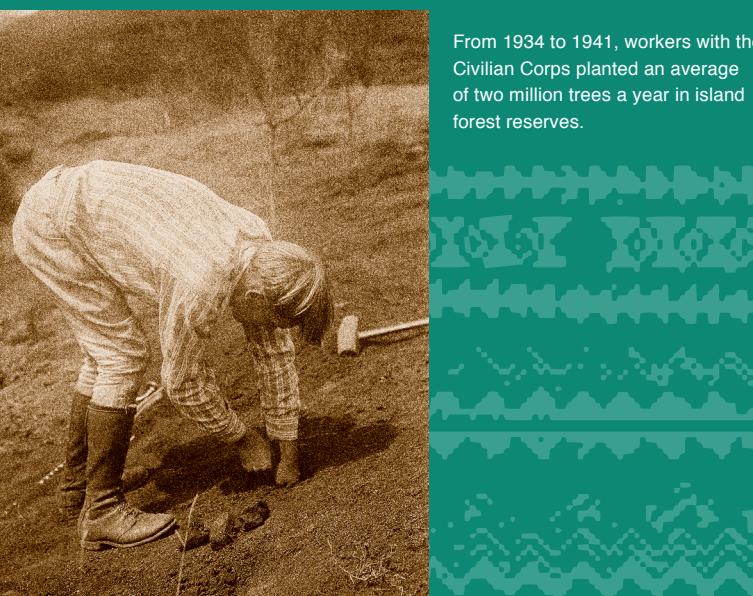
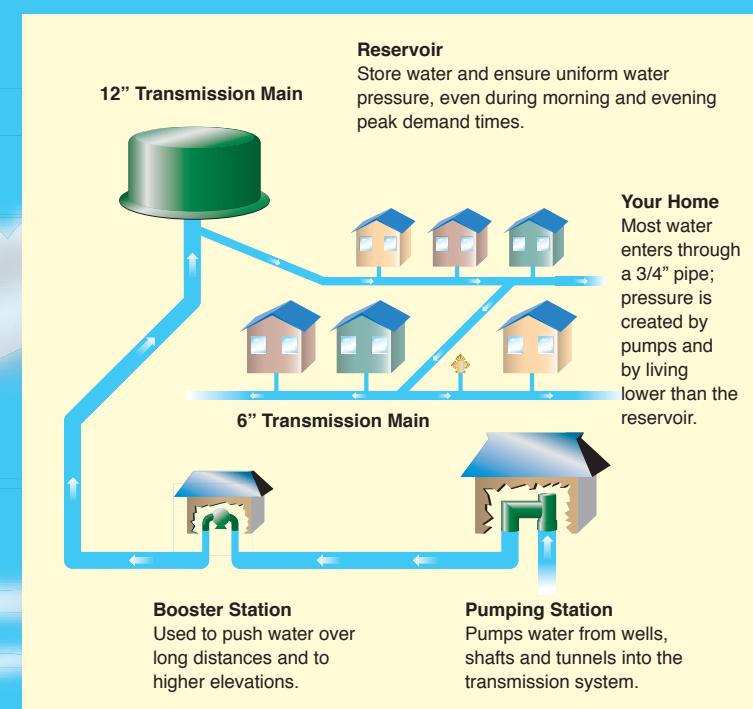
Dike Tunnel  
Draws out groundwater trapped between dikes.

Inclined Shaft  
Reaches down to the top of the aquifer and skims off its upper layers.

Deep Well  
Located over the basalt aquifer. These wells supply the majority of O'ahu's water.

Artesian Well  
Located in the coastal plains. It will flow naturally if the ground is lower than the water table.

Caprock Well  
Pulls non-potable water for irrigation. Located in coastal sediments.



From 1934 to 1941, workers with the Civilian Corps planted an average of two million trees a year in island forest reserves.

## Reforesting the Watershed

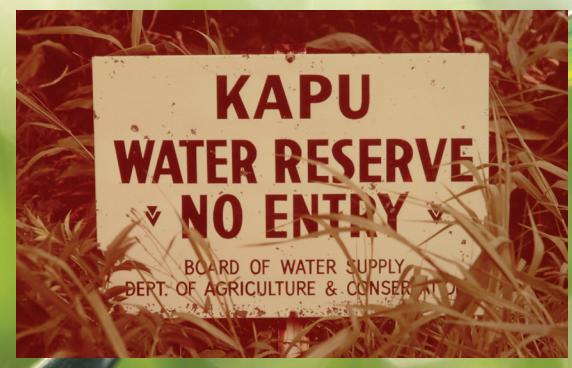
By the beginning of the 1900s, thousands of acres of O'ahu's watershed forest had been destroyed. Sugar planters, who used most of the island's water, were the first to act to protect the watershed. In 1903, the Hawai'i Sugar Planter's Association (HSPA) backed the creation of a Territorial Board of Agriculture and Forestry.

With a mandate to save the watershed, Forestry staff fenced forest reserves, eliminated feral animals, and reforested large tracts of land. Initially, the planters used native trees like koa and 'ohia, but these trees grew too slowly to reverse the erosion and water loss that was plaguing O'ahu. Foresters soon moved to faster growing foreign species like eucalyptus, ironwood, silk oak, and Norfolk pine.

Emergency conservation workers planted trees for the Forestry Board through the 1920s. In the 1930s, federal funds paid for Civilian Conservation Corps workers to do the job. In 1945, a government act directed the BWS to safeguard Honolulu's watersheds. By 1946, the BWS had acquired over 240 acres of reserves in Kalihi, Pauoa, and Mānoa.



A view of Mānoa Valley in 1990. Beginning in 1918, Dr. Harold Lyon of HSPA experimented with 2,000 tree species on 124 cattle-denuded acres above Mānoa, looking for trees that would grow fast enough to stabilize the watershed. His base of operations is now Lyon Arboretum.



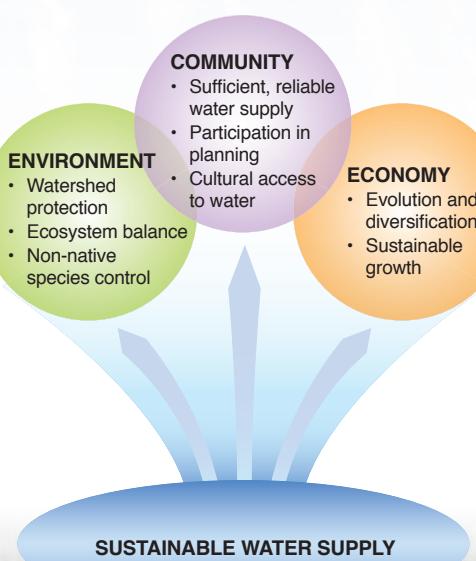
## CREATING A SUSTAINABLE FUTURE

A sustainable future exists when the needs of the community, the economy, and the environment are balanced and in harmony. The BWS is committed to creating a sustainable future on O'ahu, one in which there is enough water for many generations to come.

To understand the future, we at the BWS believe we must understand our past. In old Hawai'i, water was revered as the source of life. It was protected vigilantly and every member of the community was an active steward of the resource. Ancient Hawaiians understood that without careful planning and communal commitment, they might lose their water and with it, their lives.

Working together for the health of our water, we can ensure a sustainable future for all.

All societies are complex; ours is no exception. Every day we have to reconcile the goals of a flourishing community with the needs of a complex, delicate ecosystem. As we move toward the future, we must evolve in ways that protect our people, our land and our water. To do that, we must bring together community members, business leaders and government agencies.



## NEW TECHNOLOGIES, NEW WATER



### Planning for the Future

The threat of water shortages around the globe increases as the planet's population continues to grow, and as the climate changes. To meet these challenges, the BWS is committed to finding state-of-the-art and environmentally-sound methods to guarantee the future of our water.



In 2000, the BWS acquired the state's largest water recycling plant, the Honouliuli Water Recycling Facility located in 'Ewa.



### Honouliuli Water Recycling Facility

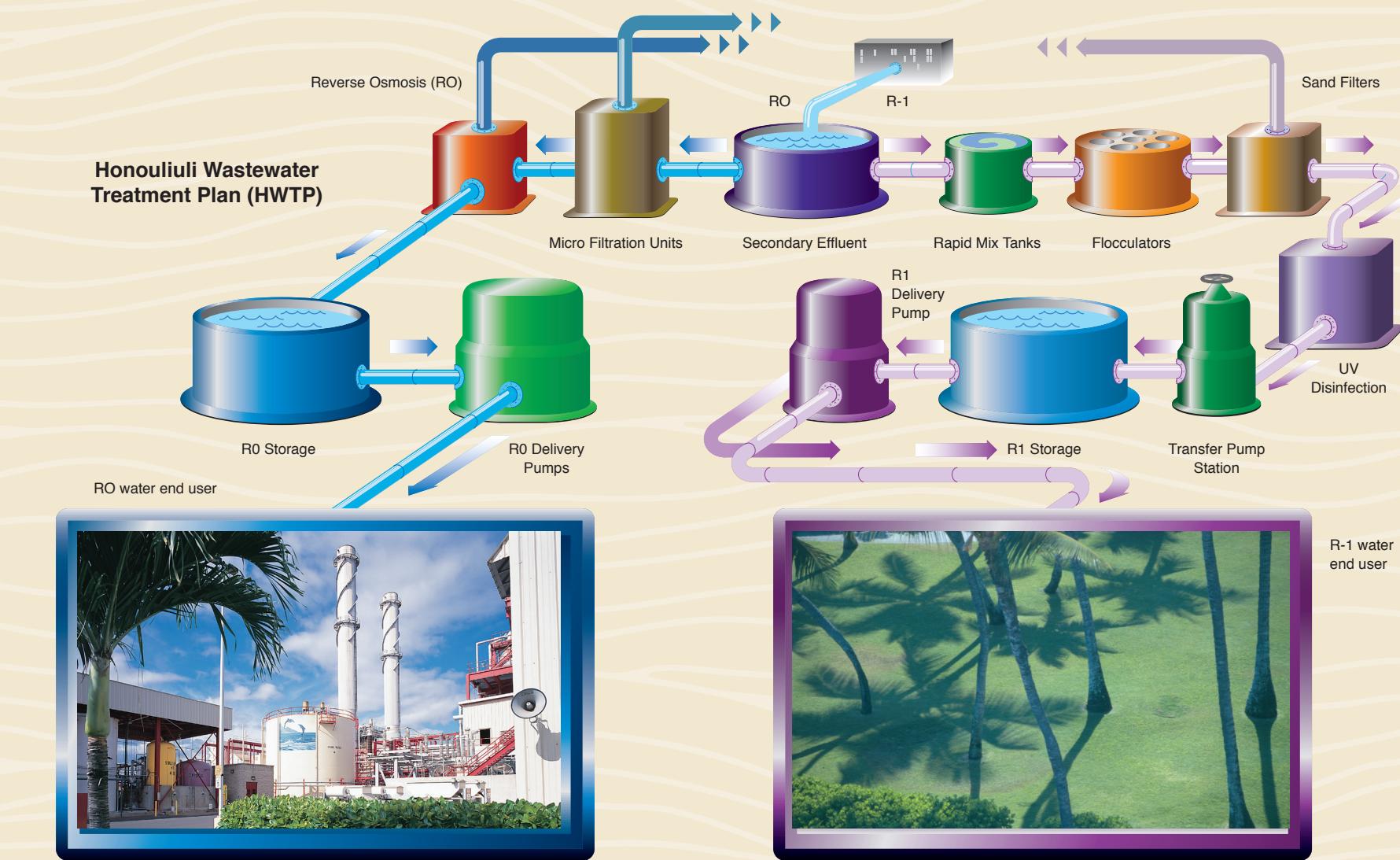
In 2000, the Board of Water Supply acquired the state's largest water recycling plant, the Honouliuli Water Recycling Facility (HWRF).

Treated wastewater is sent to the HWRF for further treatment and eventual reuse. Using two separate processes, the Honouliuli plant produces two grades of recycled water: RO (reverse osmosis demineralized water) for industrial uses and R-1 water for irrigation.

HWRF can produce up to 12 million gallons of recycled water a day. By 2040, the goal is to double the facility's production capacity.

To create RO water for industry, microfiltration units are used to extract solid particles. Reverse osmosis (RO) units then filter out dissolved minerals such as calcium, iron and sodium. (The process also removes bacteria and viruses, which are about 1,000 times larger than a calcium molecule.)

On the R-1 side, rapid mix tanks blend chemicals that help remove solid particles. Flocculators, which gently agitate the mixture, cause these particles to stick together so that they can be filtered out and sent back to the wastewater treatment plant. Ultraviolet (UV) light is used to kill disease-causing organisms.

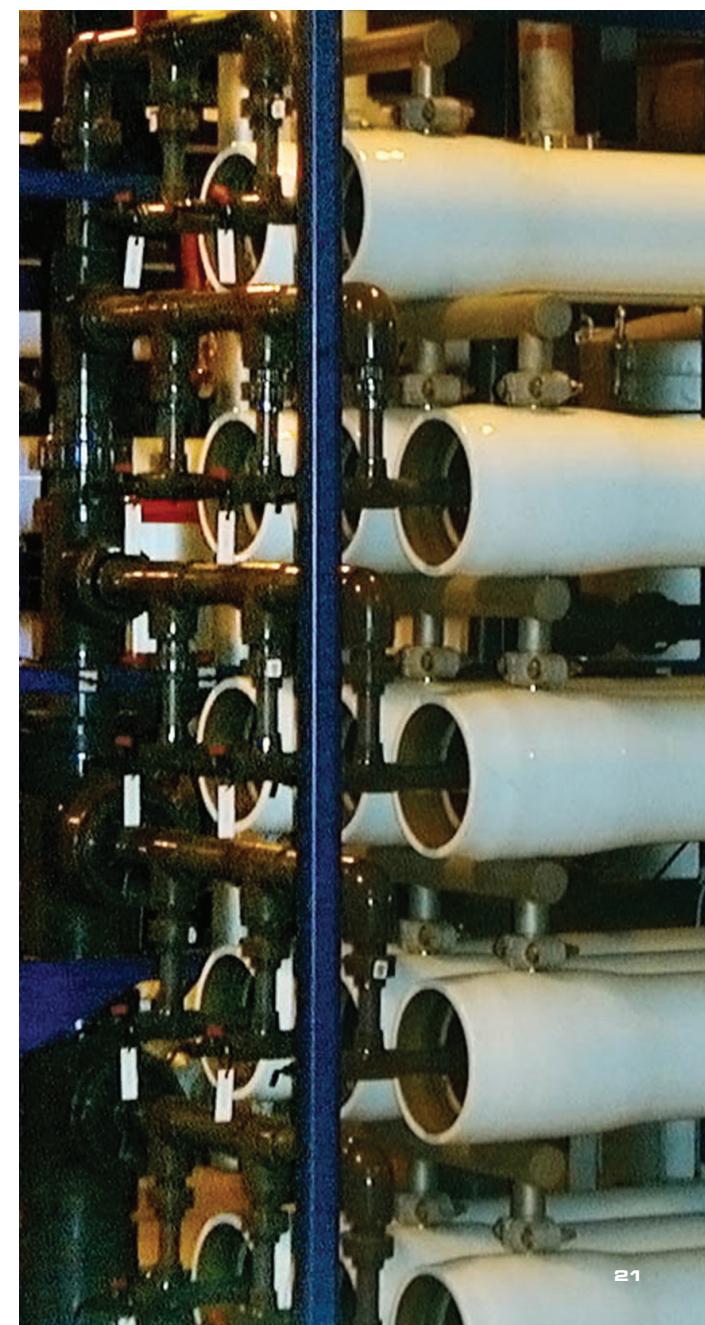


**Exploring technologies to help ensure we have enough water for today and for future generations.**



### Desalination

The BWS is developing its first seawater desalination facility in Kalaeloa and also has plans for a brackish water desalination plant in Kapolei. Climate change models predict rainfall in Leeward O'ahu will drop 60% to 90% by the end of this century. Desalination can supplement reductions in sustainable yield and allow ground water sources to be conserved and recover after severe droughts.





## WATER MASTER PLAN

To secure O'ahu's water future, the BWS has prepared a long-range Water Master Plan. This plan is a comprehensive, broad-based technical program that includes the data, investigations, assessments, and projections necessary to make decisions about O'ahu's water system for the next few decades. It is the BWS's roadmap to meet future needs, establish priorities, and adopt sustainable financing strategies.



Six primary steps provide water from source to tap. These primary steps are managed and enabled on a daily basis through the water system infrastructure and workforce of the BWS.

### BWS SUSTAINABILITY GOALS

For many years, BWS has communicated its efforts through strategic goals: Resource Sustainability, Operational Sustainability, and Financial Sustainability. These over-arching agency goals create alignment with the vision and mission, program priorities and action plans.



#### Resource Sustainability (Safe)

Protect, conserve and manage Oahu's water supplies and watersheds now and into the future through adaptive and integrated strategies.

#### Operational Sustainability (Dependable)

Build an effective organization that continuously works to improve dependable service.

#### Financial Sustainability (Affordable)

Implement sound fiscal strategies to provide safe, dependable and affordable water service.

### BWS Strategic Objectives and Key Action Plans

With the validation of the three strategic goals, the Board Members and senior management team participated in a workshop to review the strategic objectives and identify potential strategic actions to support the three overarching sustainability goals.

Periodic progress reports to the Board and an annual review by the senior management team will ensure that BWS meets these strategic objectives and actions to reaffirm their alignment with the agency's strategic sustainability goals.



## Watershed Management Plans

In addition to the island Water Master Plan, the BWS is developing watershed management plans for each of O'ahu's eight land use districts. The BWS recognizes that healthy watersheds sustain the quality and quantity of O'ahu's streams and groundwater supplies and each region is unique in terms of its water use and resources. These plans are being developed through a process that emphasizes:

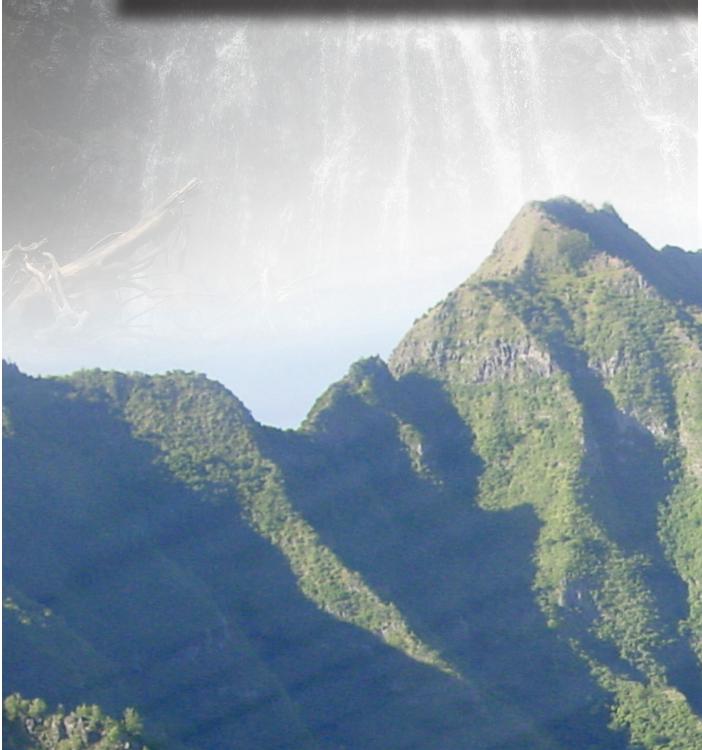
- Community participation and consultation
- Holistic management of watershed resources
- Alignment with important State and City policies and programs
- An action orientation: Implementation of important watershed management programs
- Ahupua'a principles

The development of the eight watershed management plans are proceeding as follows:

- Wai'anae – completed 2009
- Ko'olau Loa – completed 2009
- Ko'olau Poko – completed 2012
- North Shore – completed 2016

Future plans (as of 2018):

- 'Ewa – *in progress*
- Central O'ahu – *in progress*
- Primary Urban Center – *in progress*
- East Honolulu – *to be started shortly*



## Our Work with Other Agencies

In our quest to safeguard Hawai'i's environment and the health of our customers, we work with government agencies such as the U.S. Geological Survey, the State Commission on Water Resource Management, the State Department of Health, the State Division of Forestry and Wildlife, and State Historic Preservation Office.

We work with community groups like the Mohala I Ka Wai in Makaha and Waihe'e Ahupua'a Initiative to do watershed management projects.

The BWS looks to the wisdom of the ancient Hawaiians to manage our island water supply today...and for generations to come.

Before the arrival of Westerners and the changes that occurred on O'ahu in the 19th and 20th centuries, the Hawaiians lived in respectful harmony with the island's freshwater cycle. With the guidance of an 'aha council of respected practitioners and experts, each ahupua'a successfully managed all the natural resources needed to support the community that lived there.

To meet the challenges of modern water management, the BWS wants to make the ahupua'a concept of water planning and resource management a greater part of its community-based water planning process.



## Stay Involved

Thank you for taking the time to learn about O'ahu's water. We hope you have enjoyed this booklet and that you will stay involved in the ongoing story of our island's water.

There are many things you can do to get connected to conservation:

- Join a neighborhood stream cleanup
- Learn xeriscaping
- Look for water leaks in your house
- Turn off the tap!

To learn more, please visit our website at [www.boardofwatersupply.com](http://www.boardofwatersupply.com). If you would like more information, to schedule a speaker in your community, or take a field trip into a watershed area, please give us a call at 748-5041 or email us at [contactus@hbws.org](mailto:contactus@hbws.org).

Remember: each one of us on O'ahu can help to preserve our water supplies. Please do your part to conserve water and protect our watersheds.

