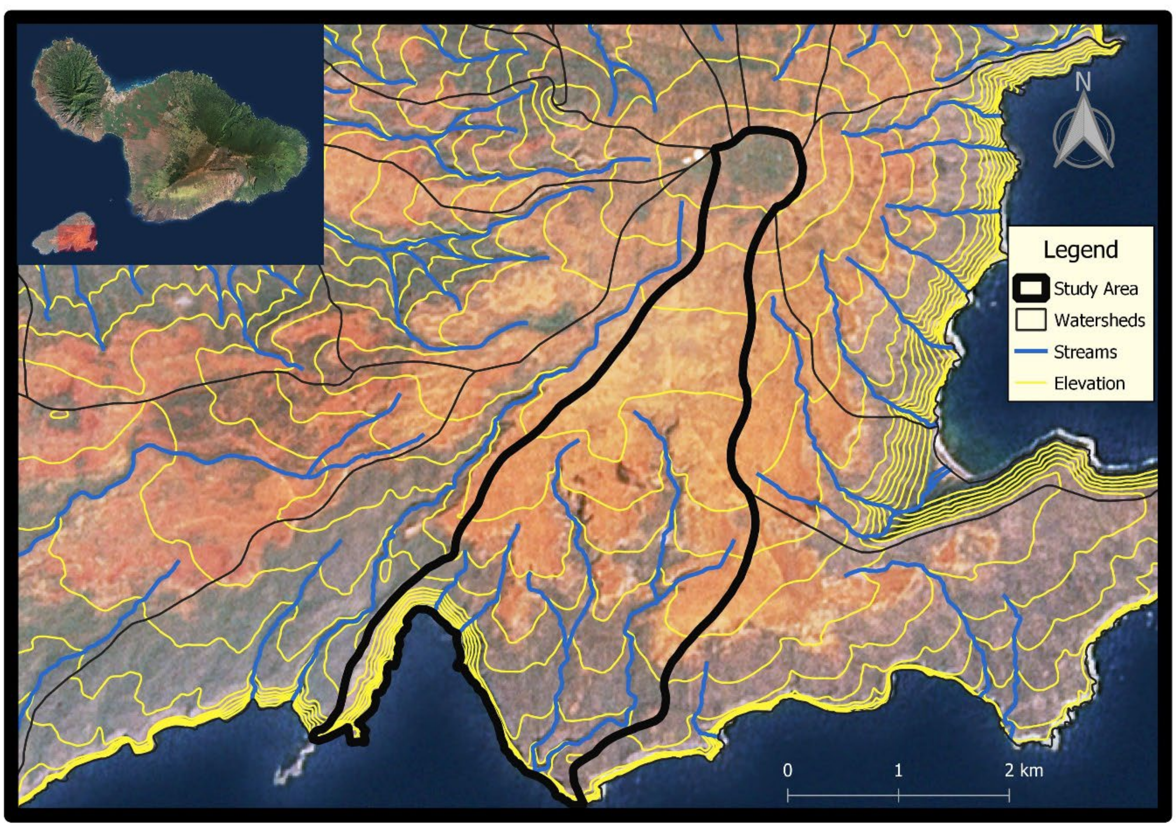
Restoration of Impaired Waters from Non-Point Source Pollution in the Kamōhio Watershed on Kahoʻolawe 2023 to 2040

Watershed Plan - 9E

Kahoʻolawe Island Reserve Commission

August 1, 2022



Cover photo: Kamōhio Watershed on Kahoʻolawe

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KŪKULU KE EA A KANALOA

The life and spirit of Kanaloa builds and takes form.

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EXECUTIVE SUMMARY

This Watershed Plan - 9E is written for the 886ha (2189A) Kamōhio Watershed on Kaho`olawe. Soil loss is estimated at 9,477 T/Y, and could be reduced an estimated 8.5T/A/Y over a 17 year time frame. Surface runoff on Kahoʻolawe is estimated at 7 x 10^7 m^3 or 19 billion gallons each year, sometimes with sediment content at 90% (Cox, 1995), and much of this enters into the pristine ocean waters and unique reef environment off of Kaho'olawe. Water quality information for Kamōhio Watershed is scarce, but restoration work combined with monitoring has begun to supplement the paucity of baseline data.

Partnerships, and education and outreach programs will continue to be refined with the cultural integration of volunteers that will assist with the restoration work on island. A community-based approach will assure success in executing the field work required to reverse the current soil erosion trends on Kaho'olawe and continue to fulfill the vision of restoration on the island established by the Kahoʻolawe Island Reserve Commission (KIRC).

Six Management Measures are proposed for implementation during 3 Phases of restoration in Kamōhio Watershed, including irrigation, native plants, soil amendments, non-native plant control, check dams (gabions and wattles), and monitoring. Nine monitoring components are also proposed, including rainfall, stream stage, vegetation plots (relevés), plant survival rates, soil erosion pin transects, soil infiltration rates, ocean turbidity, baseline photo points and drone images. Rainfall will be recorded and compared to stage in Kaneloa stream. Vegetation plots will be used to measure species presence, increases in native plant cover, and decreases in bare soil before and after restoration. Plant survival rates will capture success along irrigated planting corridors (Tier I) and augered planting holes (Tier II). Using soil erosion pin transects previously established in 2011 and read again in 2015, estimated sediment load reduction in tons/acre/year (T/A/Y) has been calculated (10.7 T/A/Y) and will be updated to compare with new projected soil loss (sediment load) rates. New soil erosion pin transects may be installed in a proposed Project site primarily in Tier II. Soil infiltration rates will be measured in restored and non-restored soils using a 1 liter, four sample technique developed by the USGS in Honolulu. An archaeological monitoring component will assure the compliance with State and Federal Laws when installing Restoration modifications. Finally baseline photo points and Drone Imagery along with Airborne Lidar will be established to capture effectiveness of Management Measures in Kamōhio Watershed over a 17-year time span.

Strategies for improving water quality in the Watershed are aimed at reducing current soil erosion rates measured at -2.4mm/year, and thereby reducing sediment load by 0.5 T/A/Y (~5%/Y) from 10.7 T/A/Y to 10.2 T/A/Y. This Watershed Plan addresses the 9 EPA (9E) elements for assessing the results from restoration and managing storm water runoff

in Kamōhio Watershed. An initial $364,872.18 budget for a three-year project is presented addressing the NPS Pollutant, “Excessive Sedimentation”. It would provide funds for personnel including a full time Natural Resources Specialist II, the operation of the KIRC vessel ´Ōhua, running of Base Camp and installation of Management Measures that will decrease sediment load and begin to mitigate the severe soil erosion that continues to occur in Kamōhio Watershed.

INTRODUCTION

This Watershed Plan compiles water quality information regarding Kamōhio Watershed on the island of Kahoʻolawe (Appendix A). The goal and purpose are to reduce sediment load of the Non-Point Source (NPS) pollutant "Excessive Sedimentation" in Kamōhio Watershed. This project aligns with the mission of the State of Hawai’i, Department of Health (DOH), Clean Water Branch, which is to protect and improve the quality of water resources for the enjoyment and use by the people of the state through the prevention and reduction of NPS pollution. This Watershed Plan was prepared for the DOH Clean Water Branch by the KIRC providing information and assistance regarding issues and concerns in the Watershed, to conform to requirements of the State of Hawaiʻi, DOH, Section 319 (h) of the Clean Water Act.

Watershed Goals and Management Objectives

A preliminary goal in this Watershed Plan is to outplant 30,000 plants in a first 3 year (2023-2026) predetermined Project Site Tier I and Tier II). 40,000 plants in a 4-year (2026 – 2030) project for Phase II and 50,000 plants in a 10-year (2030-2040) Project for Phase III in the lower reaches in Tier I. Phase II in the head waters of Kamōhio Watershed and proven Management Measures would include soil erosion control devices (wattles) in conjunction with irrigation lines to form corridors that serve as both a substrate for the plants to get established in (with added soil amendments). Also, they capture soil during overland sheet flow. For soil erosion, check dams will be constructed where appropriate in shallow stream gulches to capture sediment runoff. For Phase III, it may prove too difficult (and far) to bring water down from the summit unless separate smaller 10,000-gallon tanks, linked together to break up water pressure are utilized.

While a few older technical reports (https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/adec184d-a87e-40fd-864a-206c73a305b7/content) have been written modeling Kahoʻolawe’s watersheds, stream systems and drainage basins, and the effects of runoff from Kaho`olawe watersheds, newer technologies are available to use (Airborne Lidar and ARCGIS Earth) to define the geographic delineations of Kamōhio Watershed to accurately capture future changes with restoration activities.

The primary goal of the Watershed Plan is to reduce sediment load and to restore the eroded landscape with native plants in the Kamōhio Watershed on the island of Kahoʻolawe. Implementing Management Measures will address the NPS Pollutant "Excessive Sedimentation" and reduce soil erosion rates, high levels of suspended sediment in Kaneloa stream and subsequent turbidity in the near shore ocean environment in Kamōhio Bay. Altering the terrestrial ecosystem will aid in the regeneration of dryland forest native plants such as ʻAʻaliʻi (*Dodonaea viscosa*) which is a host for the native Hawaiian Blue Butterfly (*Udara blackburni*). Also, introducing the endangered plant ʻOhai (*Sesbania tomentosa*) and false sandalwood or Naio (*Myoporum sandwicense*) will provide habitat for the native yellow faced bee (*Hylaeus spp.*) and other native insects (Appendix B). Reducing runoff and excessive sedimentation into the marine environment will assist in maintaining the pristine nature of the near shore reefs and ocean waters. Monitoring these improvements to the land will assure the Management Measures in place are contributing to the reversal of the accelerated soil erosion that has been occurring for decades.

Management objectives of the Watershed Plan are to minimize storm water runoff and subsequent entry into the near shore ocean environment in Kamōhio Bay by; (1) improving the native ecosystem in Kamōhio Watershed with native dryland plant species, (2) reduce soil erosion and therefore sediment load by 0.5 T/A/Y (~5%/Y) in the Kaneloa stream system, which will reduce subsequent turbidity in the near shore ocean environment, and (3) increase percent cover of native vegetation and reduce percent cover of bare soil in hard pan areas in Kamōhio Watershed. Through monitoring and statistical analysis of the stream stage, vegetation data and soil erosion pin transects, and visual analysis of baseline photo points and drone images and Airborne LIDAR, it should be apparent that restoration efforts on land are providing a difference in the reducing sediment load into Kaneloa Stream. Also, this datum should serve as a baseline for future research in Kamōhio Watershed.

Partnerships and Stakeholders

Other Partnerships the KIRC has established partnerships with, and who have knowledge of existing programs and resources that address concerns in the Watershed are, the USGS Pacific Islands Research Center (PIRC) in Hawaiʻi, the USGS Pacific Coastal and Marine Center (PCMC) in Santa Cruz, CA (both since 2005), and the USGS Pacific Islands Water Science Center (PIWSC) in Honolulu (since 2017). These departments assisted with obtaining valuable baseline data to analyze stream stage, suspended sediment, discharge, soil infiltration rates, ocean turbidity and sediment fractions (clay, silt, sand) in the near shore ocean off Kahoʻolawe. The University of Hawaiʻi, Maui Campus has partnered with the KIRC (since 2009), educating local Maui

High School students with Hawaiian ancestry in preparation for college in a national program called “Summer Bridge”. The University of Hawai‘i, Department of Civil and Environmental Engineering at Manoa has assisted the KIRC (since 2017) with analysis of stream stage, ocean wave and current measurements, and archaeological feature vulnerability and preservation. The Center for Global Discovery and Conservation Science at Arizona State University in Tempe Arizona and the Institute for Pacific Islands Forestry, Pacific Southwest Research Station, USDA Forest Service in Hilo, HI have partnered with the KIRC in 2020 for the LiDAR, multispectral and high-resolution photography component.

Public Outreach

Current partnerships include an exhibit with the Maui Ocean Center (since 2018), entitled Kaho‘olawe; History and Healing. With content from the Bishop Museum in Honolulu and the Smithsonian Institution in Washington D.C., the display (Figure 1) details the history of the island from pre-contact to today. Throughout 2019, KIRC Restoration staff frequent the exhibit once a week to interpret the information given regarding the island’s importance in Hawaiian culture and the involvement in American Naval History. The Non-Point Source (NPS) Brochures which were prepared for the last four DOH Projects are handed out to visitors on a weekly basis.

Figure 1 Exhibit about Kaho`olawe at Maui Ocean Center (Photo Maui Ocean Center)

The Maui Nui Botanical Gardens are also assisting the KIRC in propagating the endangered Palupalu o Kanaloa (*Kanaloa kahoolawensis*) plant at their facility in Kahului, Maui. Also, Ho’olawa Farms in Haiku, Maui is propagating 3 individual plants of the *K.*

kahoolawensis. As part of a Working Group, the rare plant and propagation facility in Olinda, Maui has been caring for and propagation seedlings of the Kanaloa plant for eventual out planting on Kaho`olawe once plant numbers are sufficient. Both Ho'olawa Farms in Haiku, Maui, Native Nursery, LLC in Kula, Maui have been propagating native plants for the DOH projects since 1998 and 2015, respectively.

KAMŌHIO WATERSHED CHARACTERIZATION

The Watershed of Kamōhio is 886ha (2189A) in size located on the South side of Kaho'olawe (Figure 1). It extends from the summit of Kaho'olawe at 450m (1477ft) to sea level. The Hydrologic Unit Code for Kamōhio Watershed is HUC 7020 (CWRM, 2005). A Google Earth map (Figure 2 and 3) shows the Kaneloa stream system in the Kamōhio Watershed.

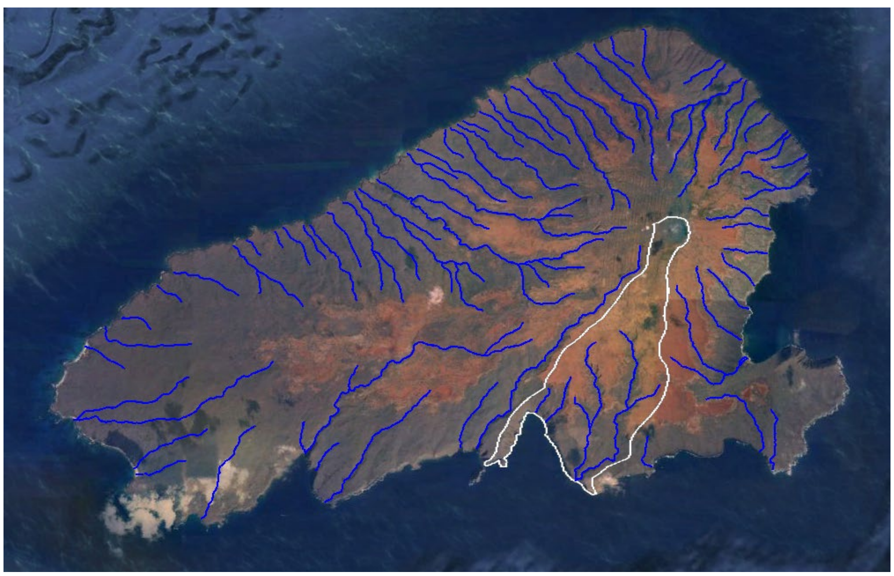


Figure 2 Kamōhio Watershed (white) and streams (blue) on Kaho'olawe

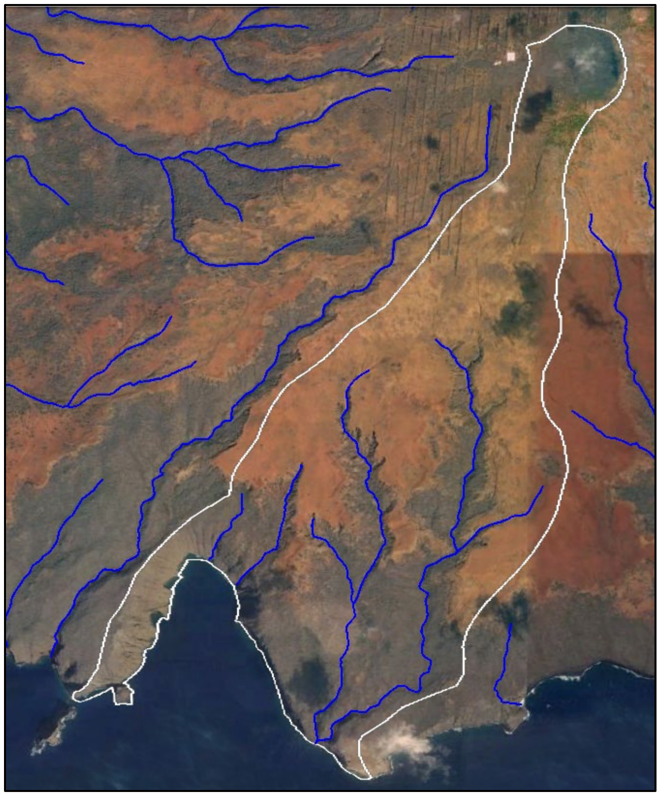


Figure 3 Kaneloa stream system (blue) in Kamōhio Watershed (white)

Source: Waters Data features from EPA MyWaters and WATERS Geospatial Tool (https://www.epa.gov/waterdata/viewing-waters-data-using-google-earth)

UXO Clearance Levels

Based on U.S. NAVY data, during the Parsons-UXB Clearance Project (1998-2004) an approximate total of 24.7% of the island was not cleared of unexploded ordnance (UXO). Approximately 75.3% of the island was surface cleared (Tier I) out of which 9.7% of the subsurface was cleared to a depth of 4 feet (Tier II) (PUXB, 2004). The boundaries of these two clearance types (Tier I and Tier II) in Kamōhio Watershed are presented in Figure 4.

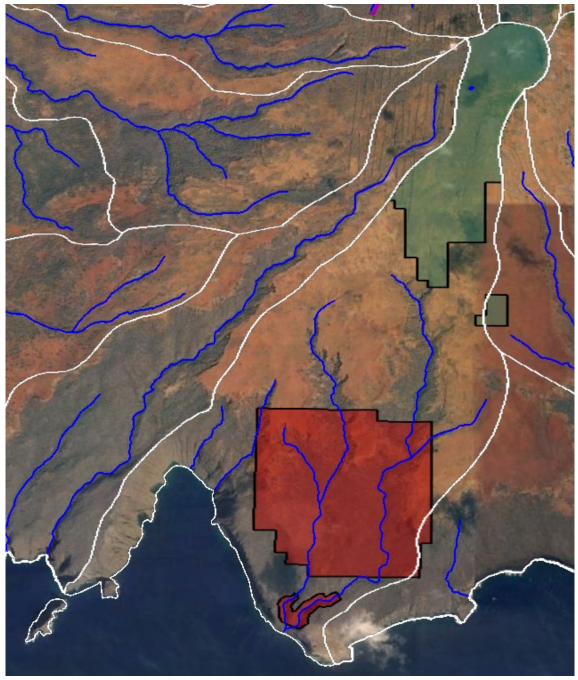


Figure 4 UXO Clearance levels in the Kamōhio Watershed

Note: Clear = Tier I (Surface only), Green = Tier II (sub surface to 4 feet depth), Red = No Clearance.

Table 1 lists the estimates of percentages and area of UXO clearance levels in Kamōhio Watershed

Clearance Level	Map Color	Percentage of Kamōhio Watershed	Area (Ha)	Area (A)
No Clearance	Red	35%	310	766
Tier I	Clear	40%	354	876
Tier II	Green	25%	221	547
Total		100%	886	2189

Table 1 Percentages and area of UXO clearance levels in Kamōhio Watershed

U.S EPA Section 303(d) list of impaired waters and 305(b)

Under Section 303(d) of the U.S. EPA Clean Water Act, states are required to submit a list of impaired and threatened waters to the U.S. EPA still needing a Total Maximum Daily Load (TMDL). Section 303(d) requires states to submit a list of waters that do not attain (or maintain) applicable water quality numeric criteria, plus a ranking of impaired waters for TMDL based upon the severity of pollution. However, as of 2018 (U.S. EPA, 2018), Kamōhio Watershed (or any Watershed) on Kaho’olawe is not on the 303(d) list of impaired waters. The State of Hawai'i, DOH prepares the Monitoring, Assessment and TMDL documents under Section 305(b) and requires states to describe the overall status of water quality statewide.

SOIL TYPES IN KAMŌHIO WATERSHED

Soil types in Kamōhio Watershed are listed in Table 2 (USDA, 2011, NCSS, SSURGO, Soil Web network) and shown in Figure 5.

Soil Type Number	Soil Type Name	Slope (%)
1	Typic Torriothents (40%, badlands – Typic Haplotorrox (35%) – Rock outcrop complex (25%)	10 to 30
5	Typic Haplotorrox, 5 to 15 percent slopes	5 to 15
6	Typic Haplotorrox, wind polished	3 to 12
7	Typic Haplotorrox, wind polished	12 to 20
9	Typic Torriothents, aeolian	3 to 15
20	Rock outcrop (80%) – Lithic Torriothents complex (20%)	50 to 150
23	Lithic Torriothents (70%) – Rock outcrop complex (30%)	5 to 15
24	Lithic Torriothents (55%) – Rock outcrop complex (45%)	15 to 30
25	Rock outcrop (60%) - Lithic Torriothents complex (40%)	30 to 50
27	Typic Torriothents (80%), Saprolite – Rock outcrop (20%)	5 to 20
32	Typic Haplotorrox (85%), dark surface, severely eroded. Black Subsoil (15%)	3 to 8

Table 2 Eleven soil types in Kamōhio Watershed

Figure 5 Soil types in Kamōhio Watershed

The properties of soils (physical, chemical, biological) are crucial to re-establishing plant communities of degraded sites and are integral to success of restoration projects (Jordan et al., 1987).

Entisols (Torriothents)

Entisols (orthent is a suborder) are of recent origin.

> *"The central concept is soils developed in unconsolidated parent material with usually no genetic horizons except an A horizon. All soils that do not fit into one of the other 11 orders are Entisols. Thus, they are characterized by great diversity, both in environmental setting and land use. Many Entisols are found in steep, rocky settings."* (https://www.uidaho.edu/cals/soil-orders/entisols).

Oxisols (Haplotorrox)

Oxisols (torrox is a suborder) are very highly weathered soils that are found primarily in the intertropical regions of the world.

> *"These soils contain few weatherable minerals and are often rich in Fe and Al oxide minerals. Most of these soils are characterized by extremely low native fertility, resulting from very low nutrient reserves, and high phosphorus retention by oxide minerals and low cation exchange capacity (CEC). Most nutrients in Oxisol ecosystems are contained in the standing vegetation and decomposing plant material. Despite low fertility, Oxisols can be quite productive with inputs of lime and fertilizers."* (https://www.uidaho.edu/cals/soil-orders/oxisols).

Population Information

Population on island can range from 0 to 100 people depending upon the access from the KIRC and the Protect Kaho'olawe 'Ohana (PKO). There is usually zero population in Kamōhio Watershed, unless KIRC staff and a volunteer group (usually comprised of 15 to 20 people) are actively restoring a project site, or visiting a former planting site or a cultural site (Pōkāneloa Stone and petroglyphs).

HAWAIIAN NATURAL PLANT COMMUNITIES

Hawaiian dry forests are highly endangered with 90% endemism and forty-five percent of Hawaiian dry forest taxa are on the USFWS Federal Endangered Species List (Pau et al., 2009). One of the conservation targets for the Hawaiian High Islands Ecoregion is the Lowland Dry System (TNC, 1998) consisting of Natural Plant Communities below 1,000m (ca 3,000ft) elevation and receiving less than 127cm (50 inches) annual precipitation. While this system is represented on Kahoʻolawe, it is designated with an alien/anthropogenic land cover. The Hawaiʻi Heritage Program (now the Hawaiʻi Biodiversity and Mapping Program) developed a classification system (HHP, 1998) to categorize Natural Plant Communities in Hawaiʻi by elevation, precipitation, and major native plant associations. Table 3 lists the four Natural Communities presently in Kamōhio Watershed, of the 21 identified on Kahoʻolawe.

	Natural Community	In Kamōhio Watershed
1	ʻAkiʻaki Coastal Dry Grassland	X
2	ʻAkulikuli Coastal Dry Herbland	
3	ʻIlima Coastal Dry Shrubland	X
4	ʻUlei Lowland Dry Shrubland	
5	ʻAʻaliʻi Lowland Dry Shrubland	
6	Akoko Lowland Dry Shrubland	
7	*Cressa truxillensis* Coastal Dry Herbland	
8	Dwarf Naupaka Coastal Dry Shrubland	
9	Halapepe Lowland Dry Forest	
10	Hawaiian Mixed Shrub Coastal Dry Cliff	X
11	Hinahina Coastal Dry Shrubland	
12	Kawelu Lowland Dry Grassland	
13	Koʻokoʻolau Lowland Dry Shrubland	
14	Koaiʻa Lowland Dry Forest	
15	Lama Lowland Dry Forest	
16	Lama-Olopua Lowland Dry Forest	
17	Maʻo Coastal Dry Shrubland	
18	Naio Coastal Dry Shrubland	
19	Pili Lowland Dry Shrubland	X
20	Pohuehue Coastal Dry Shrubland	
21	Wiliwili Lowland Dry Forest	

Table 3 Four of the twenty-one Natural Communities on Kahoʻolawe that occur in Kamōhio Watershed

Native Coastal Dry Grasslands and Shrublands

The classification of Hawaiian plant communities is based on elevation, moisture regimes, and physiognomy. The name of each plant community in Kamōhio Watershed consists of the dominant or co-dominant species and the following Native Dry Plant Community descriptions are from Wagner et al., (1999).

ʻAkiʻaki (*Sporobolus virginicus*) Coastal Dry Grasslands are present on Kahoʻolawe mostly along the coastlines. These grasslands are salt tolerant and typically cover ocean-facing dunes.

ʻIlima (*Sida fallax*) Coastal Dry Shrublands occur mostly on flat, rocky sites. The environment is harsh with highly seasonal precipitation, large temperature fluctuations and intense solar radiation. Nehe (*Melanthera integrifolia*) forms a co-dominant with ʻIlima on southwestern Kahoʻolawe.

Hawaiian Mixed Shrub Coastal Dry Cliff occurs on the dry coastal cliffs of Kahoʻolawe and may include ʻilima (*Sida fallax*), ʻakoko (*Chamaesyce celastroides var. amplectans*) and kawelu grass (*Eragrostis variabilis*).

Pili (*Heteropogon contortus*) Lowland Dry Shrublands form an extensive natural community along the northwest coast of Kahoʻolawe. These areas were possibly maintained by early Hawaiʻian's by regular firing to foster Pili grass production. Pili grass does not form a stable community and might be subject to eventual displacement by woody invaders. Pili grass growing on Kahoʻolawe with seed heads is pictured in Figure 6.

Figure 6 Pili (*H. contortus*) grass on Kahoʻolawe

Non-Native Vegetation

Non-native species refers to a species transported or established outside its native range by the activities of humans. It has been estimated that the rate of new species establishment in the Hawaiʻian Islands was approximately one new species every 35,000 years prior to human arrival and it is now on the order of 20-30 species/year. Those that are problematic are termed invasive which significantly disrupt the community structure or proper function of an ecosystem. Of the approximately 13,000 alien species of plants that have been introduced to Hawaiʻi, only about 1% (130 species) of those have become invasive so far. Biological evidence suggests another 200-300 species already present in the state may become problems in the future. Some of the invasive alien species (IAS) found on Kahoʻolawe (and in Kamōhio Watershed) are listed here.

Buffel grass (*Cenchrus ciliaris*) is one of the most abundant grasses and dominant ground cover on Kaho´olawe. It is a mat forming rhizomatous perennial grass native to Africa and Asia and has been naturalized in Hawai'i since the 1930's. It is an undesirable species because of its adaptation to fire, aggressive and competitive growth habit and allelopathic roots and leaves.

Glycine (*Neonotonia wightii*) was first collected in Hawai'i in 1975, this aggressive vine colonizes disturbed areas and is widely naturalized. *Neonotonia* is distinguished from *Glycine* by its psuedoracemose inflorescences and calyx with the completely connate upper two lobes.

Guinea Grass (*Megathyrsus maximum*) (Syn *Panicum*) is a large perennial bunch grass with wide leaves and a large spreading panicle of tiny flowers and was probably naturalized prior to 1871 (Hillebrand, 1888). Native to Africa it was introduced in Hawai‘i as a forage grass and can form dense ground cover beneath Kiawe trees and shade out native plants beneath it as it dries out. It can carry fire and forms thickets in parts of the Kamōhio Watershed, and, has the potential to invade archeological sites and displace the structural integrity of the historic property.

Indian Fleabane (*Pluchea indica*) Native to southern Asia and first collected by Rock on O'ahu in 1915, this fleabane will hybridize with Sour Bush (*Pluchea carolinensis*) to form *Pluchea X fosbergii.*

Ironwood (*Casuarina equisetifolia*) native to Australia and introduced to Hawai‘i around 1882, it is scattered throughout the Tamarisk windbreaks and is beginning to spread. The regeneration of this species is a potential problem, as it can form dense stands with thick needle litter, which preclude other species from growing beneath it.

Koa Haole (*Leucaena leucocephala*) was introduced to Hawai‘i in 1837 and grows at all elevations on Kaho‘olawe.

Lantana (*Lantana camara*) is found in Kamōhio Watershed and many bio-control agents have been introduced to Hawai‘i to control it (Davis et al., 1992). In conjunction with the bio-controls, low rainfall on Kaho´olawe might be the reason for its lack as a dominant ground cover.

Molasses grass (*Melinis minutiflora*) is a mat forming perennial grass from Africa introduced to Hawai'i for cattle forage. The grass is common in dry lowlands and can choke out other vegetation. The consequences of molasses grass invasion are typically an increase in the frequency and severity of fire and the replacement of native vegetation (Hughes et al., 1991).

Silver Oak (*Grevillea robusta*) or Silk Oak is an Australian tree introduced to Hawai'i in the late 1800's as a potential timber species. Although rare in occurrence on Kaho´olawe, it should be removed wherever it's found on island.

Sour bush (*Pluchea carolinensis*) is found in Kamōhio Watershed and is native to Mexico, the West Indies, and northern South America. (See also *P. indica*)

HISTORY

Table 4 lists the time periods of history for Kaho´olawe

Time Period	Years	Description
Pre-European Contact	1000AD	Kaho´olawe settled
Early Contact Period	1779-1825	Western Explorers
Missionary Period	1825-1853	Puritan Missionaries from Boston
Early Ranch Period	1853-1910	Great Mahele under Kamehameha III
Forest Reserve Period	1910-1918	Territorial Governor of Hawai'i Walter Frear
Late Ranch Period	1918-1941	Angus MacPhee, and his partner Harry Baldwin
Military Period	1941-1980	December 7, 1941, Pearl Harbor
Joint Use Period	1980-2003	December 1, 1980, Consent Decree
State Use Period	2003 to present	November 11, 2003, control of access to the island was returned to the State of Hawai'i from the U.S. Navy.

Table 4 Summary of historical periods on Kaho´olawe

By 1884, in the Early Ranch period, more than 9,000 goats and 12,000 sheep were present on the island. Over grazing soon became problematic and the severe erosion problems experienced today are a direct result of these large and uncontrolled ungulate populations (Table 5).

Year	Goats	Sheep	Pigs	Cattle	Horses
1859	Present	2,075	Present		
1875		20,000			
1881	2,000	1,000			
1884	9,000	12,000		200	40
1888		1,000		800	100
1890		1,200		900	
1903 to 1904		5,000			

Year	Goats	Sheep	Pigs	Cattle	Horses
1904				60	
1909	5,000	3,200		40	40
1920				500	
1939	25	200		500	17

Table 5 Summary of Goat, Sheep, Pig, Cattle, and Horse Populations on Kahoʻolawe from 1859 to 1939

In January 1976, an initial group of nine people traveled from Maui across to Kahoʻolawe and occupied the island on the first of 9 "illegal" landings. Unfortunately, during the 8th landing George Helm and Kimo Mitchell were tragically lost at sea on March 5, 1977. The protest gained national attention because of this loss, and the Protect Kahoʻolawe ʻOhana (PKO) was created.

In 1977, A Civil law suit, *Aluli* v. *Rumsfeld*, (Civil Action File No. 76-0380) was filed in the U.S. District Court in the District of Hawai'i. The suit sought compliance with environmental, historic preservation and religious freedom laws. On September 15, 1977, the Federal Court ordered a partial summary judgment in favor of Aluli and the Protect Kahoʻolawe ʻOhana, requiring the U.S. Navy to prepare an EIS and to inventory and protect historic sites on the island. As a result of this decision, the entire island was placed on the National Register of Historic Places in 1981.

On December 1, 1980, due to the damaging practices of the military, the court settled with *Aluli* v. *Brown* (formerly *Rumsfeld*), by issuing a Consent Decree and Order mandating the U.S. Navy to survey and protect historic and cultural sites on the island, to clear surface ordnance from 10,000 acres, continue soil conservation and re-vegetation programs, eradicate goats, and limit ordnance impact training to the central one third of the island. It also allowed the PKO monthly access to the island for religious, educational, and scientific activities. Through those monthly accesses, the PKO has regularly visited the island for religious and cultural purposes, as well as for re-vegetation and conservation programs. On March 18, 1981, the entire island was listed on the National Register of Historic Places and designated the Kahoʻolawe Archaeological District. The military cleared Unexploded Ordnance (UXO) from an estimated 14,000 acres and finally after 200 years, the goats were eliminated in 1993.

Future Periods

HRS Chapter 6K states;

"Upon its return to the State, the resources and waters of Kahoʻolawe shall be held in trust as part of the public land trust; provided that the State shall transfer the management and control of the island and its waters to the

sovereign Native Hawaiian entity upon its recognition by the United States and the State of Hawai'i."

U.S. NAVY Prompt Response

While April 9, 2004, marked the last day the U.S. Navy was present on the island, they are still responsible to destroy UXO found in the future. For example, on December 5, 2005, a U.S. Navy Prompt Response Team came to Kahoʻolawe to destroy items such as 5" shells (rounds), 2.75" rockets and propellant cores, 40mm projectiles and point detonating fuses. KIRC personnel will continue to observe and record UTM coordinates on UXO Discovery Reports for any UXO uncovered by soil erosion and give that information to the U.S. Navy.

PAST AND PRESENT REVEGETATION EFFORTS IN KAMŌHIO WATERSHED ON KAHOʻOLAWE

Re-vegetation projects in Kamōhio Watershed on Kahoʻolawe from 1988 to 2020 are summarized in Table 6 (KICC, 1993) and Figure 7.

Year	Organization	Project Name	Comments
1979 to 1993	DLNR, DOFAW and U.S. Navy.	Tamarisk Windbreak Project.	Plant 30,000 Tamarisk and Ironwood trees to abate erosion due to high winds.
1985-1989	Native Hawaiian Plant Society	NHPS I-IV	Native plants in barren hardpan
1988-1991	US Army Corps of Engineers Construction Engineering Research Laboratory (CERL)	CERL Phase I	Near Lua Makika crater, berms and wiliwili trees
1988-1991	"	CERL Phase II	Mid-Watershed
2003	KIRC	Pili grass C shapes	80 C shapes
2004	KIRC	DOH I	Native plants on irrigation
2010	KIRC	Pili grass kipukas	Seeded with *Achyranthes splendens* (Ewa hinahina)
2011-2014	KIRC	Pili grass kipukas /Lithic Mulching	LZ 3 area
2015	KIRC	Paper bags with mulch and native seed	From Hawai´i Conservation Conference
2018-2019	KIRC	CIP I Dryland Forest	14,800 native plants on irrigation
2019-2020	KIRC	CIP II Dryland Forest	14,800 native plants on irrigation

Table 6 Revegetation Projects in Kamōhio Watershed

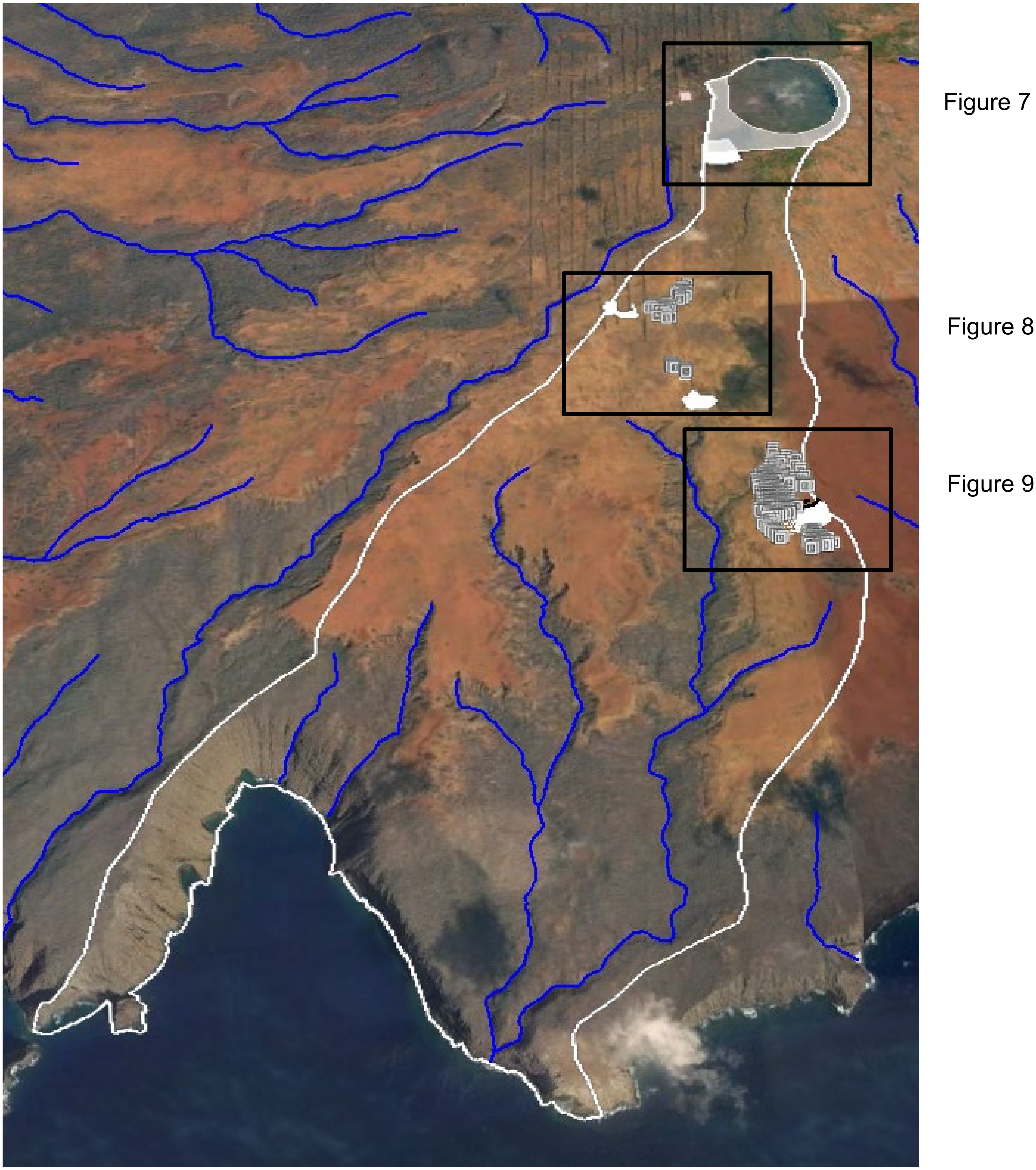


Figure 7 Overview of past revegetation efforts in Kamōhio Watershed

Figures 8, 9 and 10 highlight the inserts from Figure 7.

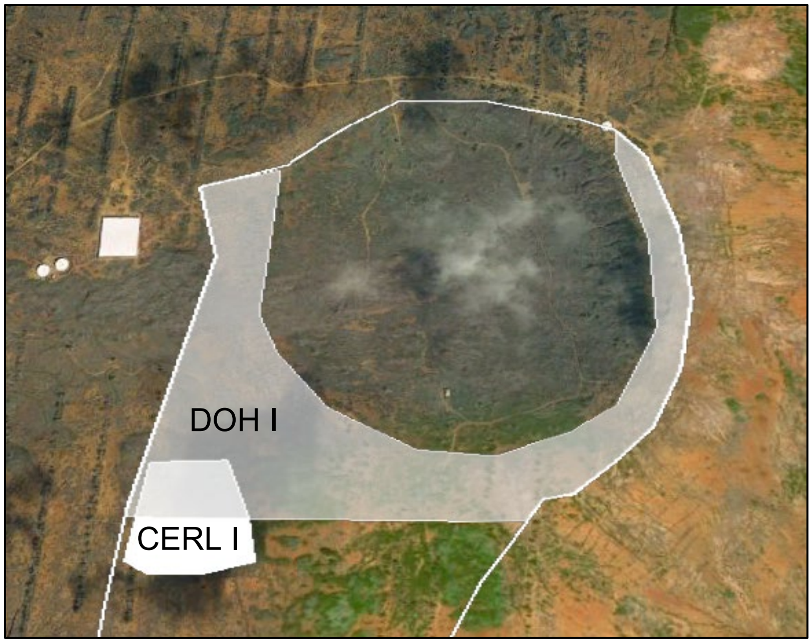


Figure 8 Location of CERL Phase I and DOH I in Kamōhio Watershed

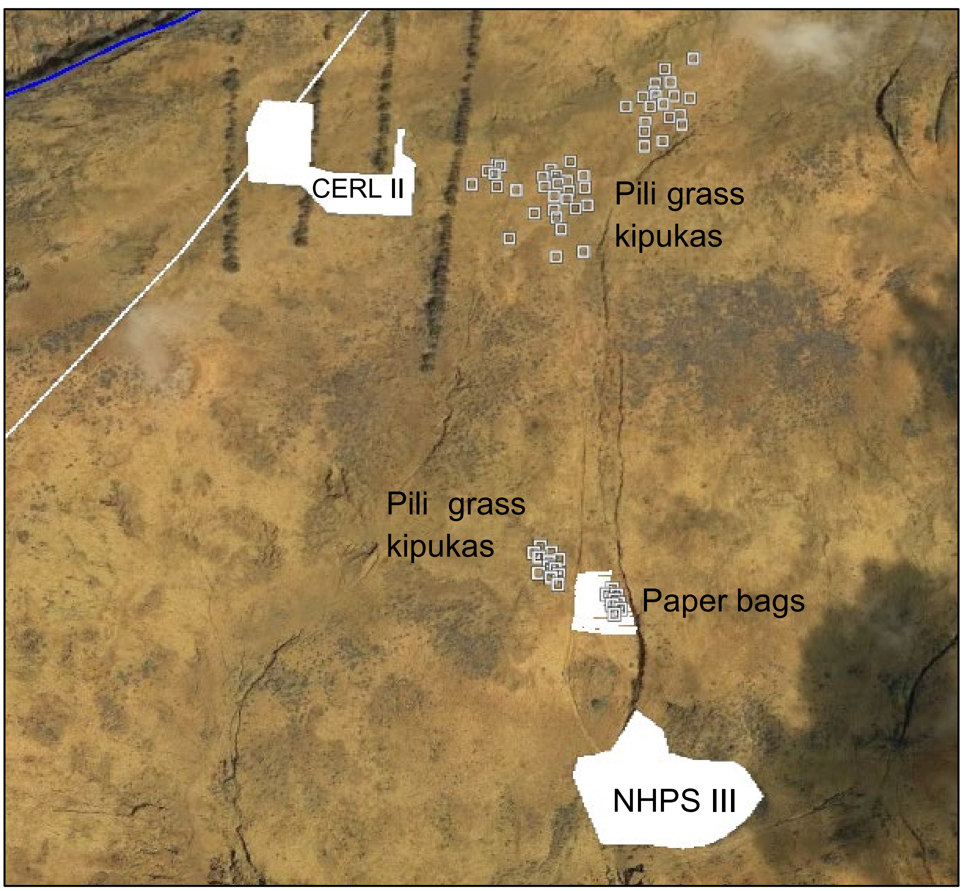


Figure 9 Location of CERL Phase II Pili grass kipukas, paper bags with mulch and NHPS in Kamōhio Watershed

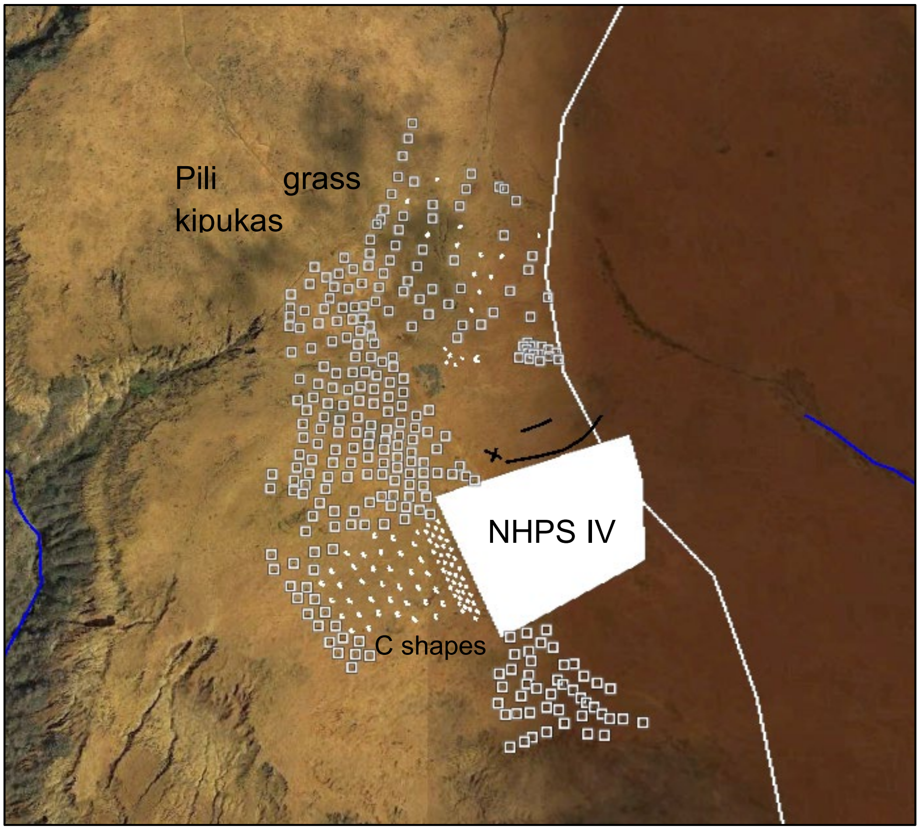


Figure 10 Location of Pili grass kipukas, C shapes and NHPS II in Kamōhio Watershed

Figure 11 illustrates the CIP dryland forest project in Kamōhio Watershed.

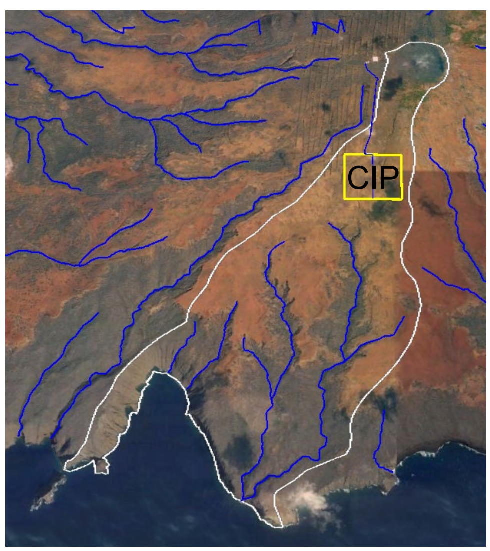


Figure 11 Location of CIP Dryland Forest project outline in Kamōhio Watershed

Tamarisk and Ironwood Wind Breaks (1979-1993)

The State of Hawai´i Division of Forestry and Wildlife (DOFAW) along with the U.S. NAVY began a 14-year project from 1979-1993, planting 30,000 tamarisk (*Tamarix aphylla*) and ironwood (*Casuarina equisetifolia*) trees (with the use of shape charges for planting holes) as wind breaks in 800 acres (KIRC, 1998). Figure 12a, b shows the location of the wind breaks in Kamōhio Watershed.

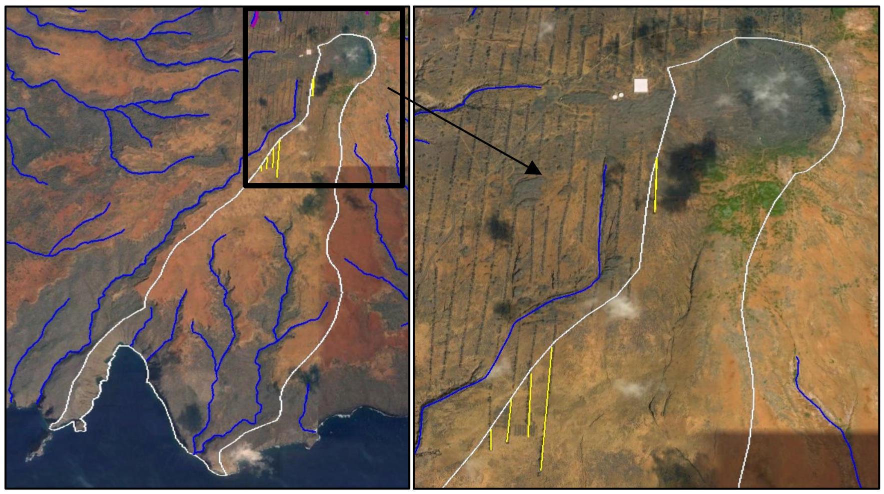


Figure 12a, b Location of tamarisk and ironwood wind breaks (yellow) in Kamōhio Watershed

Native Hawaiian Planting Society (1985-1989)

Between 1985 and 1989 the Maui Native Hawaiian Plant Society (NHPS) along with aid from the U.S Navy, USDA, Hawai´i DLNR, University of Hawai´i and the Sierra Club, initiated a demonstration project with the goal of reestablishing a native dryland forest in the most degraded windswept area of the island without irrigation (hand watered initially) and fertilization. They planted more than 23,000 plants consisting of 34 species (Ziegler et al., 2000). The NHPS along with Rene Silva was trying to "identify an efficient and effective way to revegetate Kaho´olawe without supplemental watering" (KICC, 1993).

Table 7 lists the native Hawaiian plant taxa in NHPS IV that have been observed since 1998 to 2019 growing in this area.

	Hawaiian Name	**Plant taxa**	**Comment**
1	´Akoko	*Chamaesyce celastroides* (E)	
2	´A´ali´i	*Dodonaea viscosa*	
3	Ma´o	*Gossypium tomentosum*	
4	Hinahina	*Heliotropium anomalum*	
5	Nehe	*Melanthera integrifolia*	Formerly *Lipochaeta*

	Hawaiian Name	Plant taxa	Comment
6	´Ulei	*Osteomeles anthyllidifolia*	
7	Hala	*Pandanus sp.*	
8	Naupaka	*Scaevola coriacea* (E)	
9	Akulikuli	*Sesuvium portulacastrum*	
10	´Aki ´aki	*Sporobolus virginicus*	
11	Hau	*Thespesia populnea*	

Table 7 Plant taxa observed in NHPS IV area from 1998-2019
E = USFWS Endangered Plant

Figure 13 illustrates the locations of four NHPS planting areas in Kamōhio Watershed.

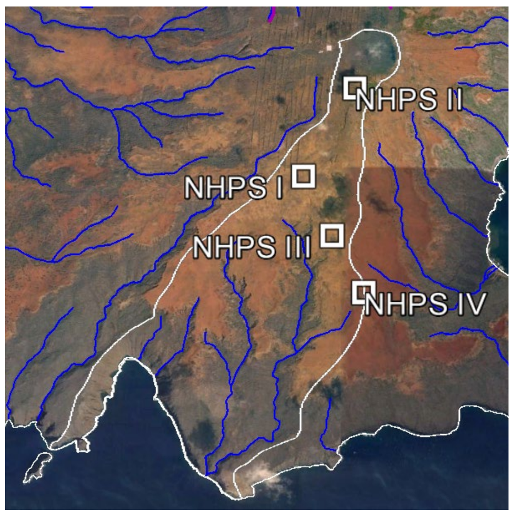


Figure 13 Four NHPS sites in Kamōhio Watershed on Kaho´olawe

CERL Phase I (1988-1991)

Located near Lua Makika Crater, CERL Phase I (Figure 7) occurred in December 1988-1991 with a drill seeder and fertilization. Three rows of 310 native shrubs and trees were out-planted (Table 8).

Hawaiian name	Plant taxa	Number
Wiliwili	*Erythrina sandwicensis*	102
´Ulei	*Osteomeles anthyllidifolia*	29
´A´ali´i	*Dodonaea viscosa*	49
Koa	*Acacia koa*	45
Koʻoloaʻula	*Abutilon menziesii (E)*	35
Ma´o	*Gossypium tomentosum*	40
	Total	310

Table 8 310 native shrubs and trees planted in CERL Phase I
E = USFWS Endangered plant

One non-native legume and six non-native grasses including Buffle (*C. ciliaris*), Bermuda grass (*C. dacytlon*) and weeping lovegrass (*E. curvula*) were out planted and these last three performed the best (Warren and Aschman, 1993). Table 9 lists the non-native species out planted in the site in 1988.

Common Name	Plant Taxa	Comment
Bermuda grass	*Cynodon dactylon*	“NK-37”
Plains bristle grass	*Seteria leucopila*	
Buffalo grass	*Buchloe dactyloides*	
Green panic grass	*Megathyrsus maximum*	Formerly *Panicum maximum*
Buffle grass	*Cenchrus ciliaris*	“T-4464”
Yellow bluestem	*Bothriochloa ischaemum*	“WW Ironmaster”
Glycine	*Neonotonia wightii*	Formerly *Glycine wightii* (Legume)

Table 9 Plant taxa out planted in CERL Phase I

It was surmised that the aggressive climbing habit of the legume glycine (*N. wightii*) in the presence of trees and shrubs, may harm woody plants and would not be recommend for future revegetation efforts on Kaho´olawe. Also, the weeping lovegrass (*E. curvula*) was not included in the seeding mixture and probably arrived as a contaminant (Warren and Aschman, 1993).

Table 10 lists the soil characteristics in CERL I and II (Ziegler et al., 2000).

Soil Characteristics	Value	Comments
pH	6.8	
P	15 ppm	Phosphorus
K	325 ppm	Potassium
Ca	839 ppm	Calcium
Mg	543 ppm	Magnesium
Total N (TN)	0.1%	Total Nitrogen
Organic Carbon (OC)	1.2%	
Zn	0.3 ppm	Zinc
Electrical Conductivity (EC)	0.3 mmhos cm^{-1}	
Saturated Hydraulic Conductivity	117.5 Mm $hour^{-1}$	
Field Bulk Density	1.16g cm^{-3}	
Soil Moisture at saturation	0.47g g^{-1}	

Table 10 Chemical and physical characteristics of surface soils (0-10cm) within the general area of the CERL Phase I and II planting sites on Kaho´olawe.

CERL Phase II (1990)

CERL Phase II (Figure 9) was a larger scale revegetation effort than CERL Phase I. A chisel plow seeder with modifications to scarify the soil, plant and fertilize in a single pass was used in January and November 1990 to reduce costs and plant more efficiently. Table 11 lists the non-native plants utilized in CERL Phase II.

Common name	Plant taxa	Comment
Buffle grass	*Cenchrus ciliaris*	
Bermuda grass	*Cynodon dactylon*	
Weeping lovegrass	*Eragrostis curvula*	Intentionally included in CERL Phase II
Italian rye grass	*Lolium multifolium*	

Table 11 Nonnative plants in CERL Phase II

Although glycine (*N. wightii*) was not planted in CERL Phase II in 1990, it eventually showed up in the project site in 1996. Unfortunately, none of these projects quantified soil loss.

KIRC Plantings in Kamōhio Watershed (2003-2020)

<u>Native Out Plantings in Lua Makika Crater (2003)</u>

Figure 14a, b illustrates the native plantings in Lua Makika crater on irrigation lines in 2003.

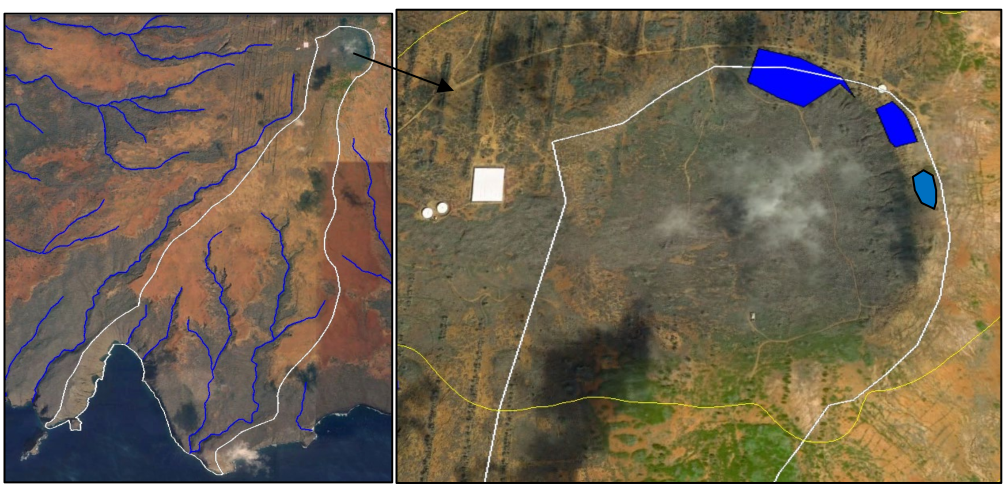


Figure14a, b Native out plantings in Lua Makika Crater

Several of the species planted on irrigation lines included ´aweoweo (*Chenopodium oahuense*), ‘a‘ali‘i (*Dodonaea viscosa*) and wiliwili (*Erythrina sandwicensis*). Other plantings that were tried in Lua Makika crater were Loulu (*Pritichardia sp.*) palm and `Aiea (*Nothocestrum latifolium*).

DOH I (2003-2005)

An initial two-year restoration grant occurred from 2003 to 2005 from the State of Hawai´i, Department of Health, Clean Water Branch DOH I (ASO LOG No. 04-184) entitled "Watershed Restoration at Moa´ulanui, Kaho´olawe, Hawai´i" (KIRC, 2005). The project out planted native grasses, shrubs, and trees on irrigation around the border of Lua Makika crater and included the headwaters of Kamōhio Watershed (Figure 15).

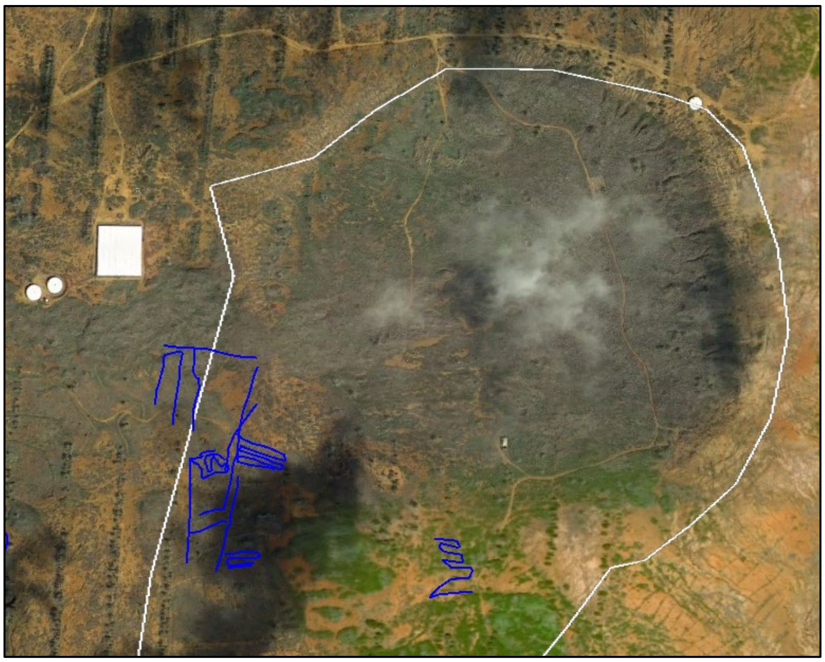


Figure 15 Irrigation lines (blue) in DOH I project site and Kamōhio Watershed boundary (white)

The headwaters of Kamōhio Watershed (including 9 others) were affected in this two year DOH grant.

Pili grass C-shapes (2003)

Many of the native plants from the NHPS IV Project persist today and provide native seed to pili grass (*H. contortus*) bale C-shapes installed by the KIRC in 2003. The pili grass (from Kaho´olawe source material) was grown by USDA Natural Resources Conservation Service (NRCS) in Ho´olehua, Moloka´i. The bales of hay were flown to Kaho´olawe in 2003 and placed in "C shapes" downwind of the NHPS IV area to capture native seed. Figure 16 shows the 80 C-shapes shortly after they were constructed in 2003.

Figure 16 Eighty C-shapes of pili grass (*H. contortus*) bales in Kamōhio Watershed

Figures 17 and 18 list the native and non-native plants, respectively, found within the C-shapes in July 2009 six years later.

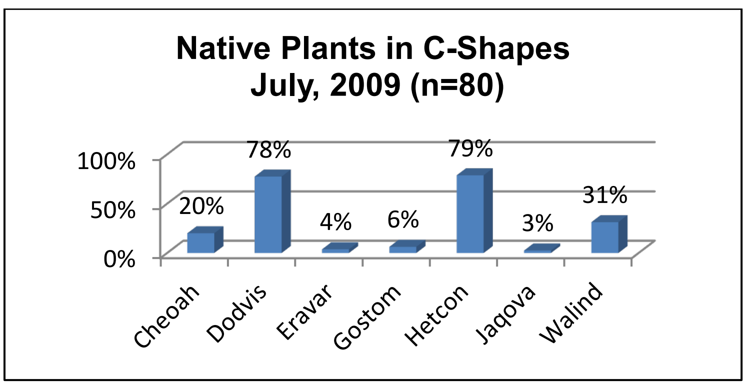


Figure 17 Native plants in C-shapes July 2009

Cheoah = *Chenopodium oahuense*
Dodvis = *Dodonaea viscosa*
Eravar = *Eragrostis variabilis*
Gostom = *Gossypium tomentosum*
Hetcon = *Heteropogon contortus*
Jaqova = *Jaquemontia ovalifolia*
Walind = *Waltheria indica*

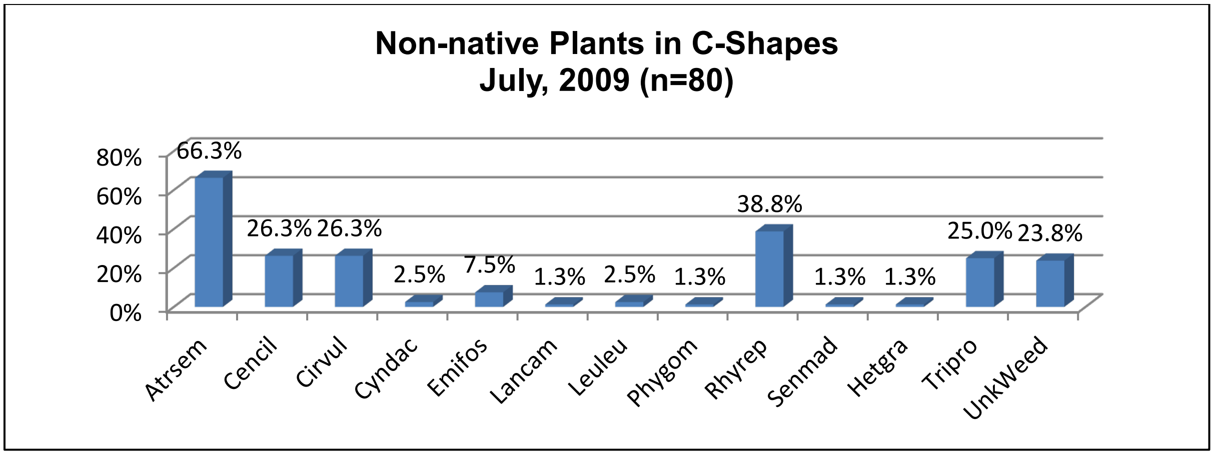


Figure 18 Non-native plants in C-shapes July 2009

Atrsem = *Atriplex semibaccata*
Cencil = *Cenchrus ciliaris*
Cirvul = *Cirsium vulgare*
Cyndac = *Cynodon dactylon*
Emifos = *Emilia fosbergii*
Lancam = *Lantana camara*
Leuleu = *Leucaena leucocephala*
Phygom = *Physocarpus gomphocarpus*
Rhyrep = *Rhyncheltrum repens (Melinis)*
Senmad = *Senecio madagascariensis*
Hetgra = *Heterotheca grandifiolia*
Tripro = *Tridax procumbens*
Unkweed = Unkown weed

The percentage of native plant species observed in the eighty C-shapes in 2009 are listed in Table 12.

Hawaiian Name	Plant Taxa	Percent of C-Shapes
´A´ali´i	*Dodonaea viscosa*	78%
´Aweoweo	*Chenopodium viscosa*	20%
Kawelu (grass)	*Eragrostis variabilis*	4%
Ma´o	*Gossypium tomentosum*	6%
Pili (grass)	Heteropogon contortus	79%

Table 12 Percent of native plants in eighty C-Shapes in 2009

All eighty C-shapes (100%) had native vegetation present in the structure.

<u>Pili grass kipukas with Ewa hinahina (*Achyranthes splendens)* seed (2010)</u>

Constructed in 2010 and seeded with ewa hinahina (*A. splendens*), a native shrub, approximately 40 kipukas were made of pili grass (*H. contortus*) and distributed on the hard pan. Figure 19 illustrates an example of a pili grass kipuka in 2019.

Figure 19 A pili grass kipuka with ewa hinahina (*A. splendens*) in 2019

Capital Improvement Project I (2018 - 2019)

This project was funded by the General Appropriations Act of 2017 and the DLNR Capital Improvement Program (CIP) under Natural and Physical Environment (LNR 906) from the State of Hawai´i. It was entitled "Kaho´olawe Island Reserve Native Dryland Forest Planting and Support". CIP I occurred from 2018 to 2019 and began to establish a dryland native forest with 14,800 native plants on irrigation. Water came through a 1.5" main irrigation line from Tanks 1 and 2, 1.38km (0.86 miles) away. It feeds into 1" sub mains and ¾" laterals with 1 gallon per hour (gph) pressure compensating emitters. Average water use was 6000 gallons per day (@25 gpm) from December, 2018 to October, 2019 from Tanks 1 and 2 and is illustrated in Figure 20.

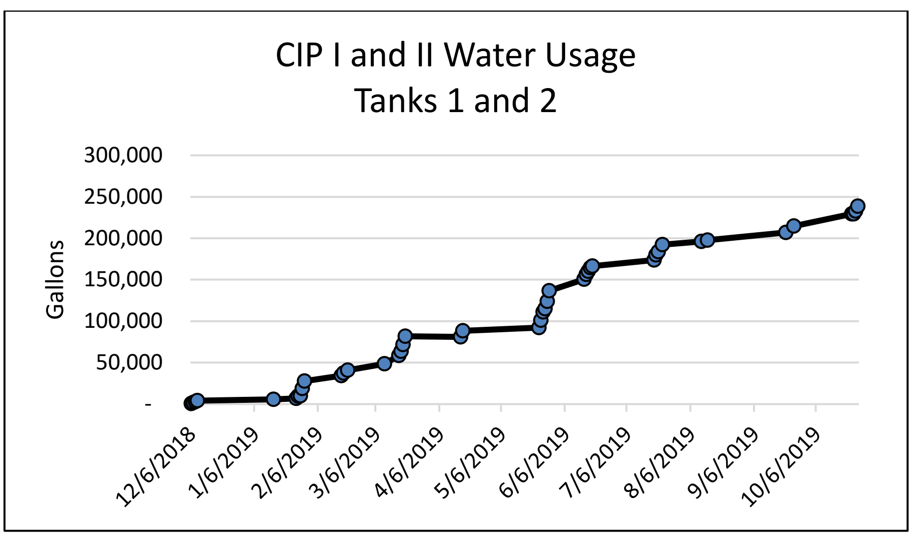


Figure 20 Water use in the CIP I and II project

Planting areas were also prepared by removing non-native species such as koa haole (*L. leucocephala*) and crown flower (*Calotropis gigantea*). During the first year of CIP I 14,800 native plants of 26 species (Table 13) were out planted along 18 irrigation lines with an 80% survival rate (P. Higashino, Personal communication, 2019).

Number	Hawaiian Name	Plant taxa	Sum	Percent
1	Koai'a	*Acacia koa/koai'a hybrid*	610	4.1%
2	Koai'a (non hybrid)	*Acacia koaia*	200	1.4%
3	Ewa hinahina	*Achyranthes splendens*	346	2.3%
4	Kamanomano	*Cenchrus agrimonioides*	608	4.1%
5	´Aweoweo	*Chenopodium oahuense*	400	2.7%
6	Halapepe	*Chrysodracon auwahiensis*	875	5.9%
7	´A´ali´i	*Dodonaea viscosa*	2955	20.0%
8	Kawelu	*Eragrostis variabilis*[1]	635	4.3%
9	Wiliwili	*Erythrina sandwicenses*[1]	438	3.0%
10	Ma´o	*Gossypium tomentosum*[1]	1072	7.2%
11	Pili	*Heteropogon contortus*[1]	400	2.7%
12	Hao	*Hibiscus tiliaceus*	0	0.0%
13	Naio	*Myoporum sandwicense*	0	0.0%
14	´Aiea	*Nothocestrum latifolium*	10	0.1%
15	Kulu´i	*Nototrichium sandwicense*	0	0.0%
16	´Ulei	*Osteomeles anthyllidifolia*	220	1.5%
17	´Ilie´e	*Plumbago zeylanica*	0	0.0%
18	Alahe´e	*Psydrax odorata*	975	6.6%
19	Ohe makai	*Reynoldsia sandwicensis*	15	0.1%
20	Iliahi aloe	*Santalum ellipticum*	33	0.2%
21	´Ohai	*Sesbania tomentosa*[1]	1489	10.1%
22	´Ilima	*Sida fallax*	150	1.0%
23	Mamane	*Sophora chrysophylla*	35	0.2%
24	´Aki´aki	*Sporobolus virginicus*	2442	16.5%
25	Milo	*Thespesia populnea*	66	0.4%
26	Akia	*Wikstroemia uva ursi*	826	5.6%
		Sum	14,800	100.0%

Table 13 Native plant taxa out planted in CIP I
[1]Plant material from Kaho´olawe

Figure 21 is an example of the native plants in CIP I after 10 months on irrigation.

Figure 21 Native plants on irrigation in CIP I

CIP II (2019 - 2020)

CIP II is a continuation of CIP I, allowing the KIRC to further establish a dryland native forest with 14,800 more native plants on irrigation. Out planting began in December 2019 and continued to February 2020. Fires on Kahoʻolawe in late February 2020 delayed the final two planting trips. Figure 22a, b shows the irrigation lines in CIP I and CIP II.

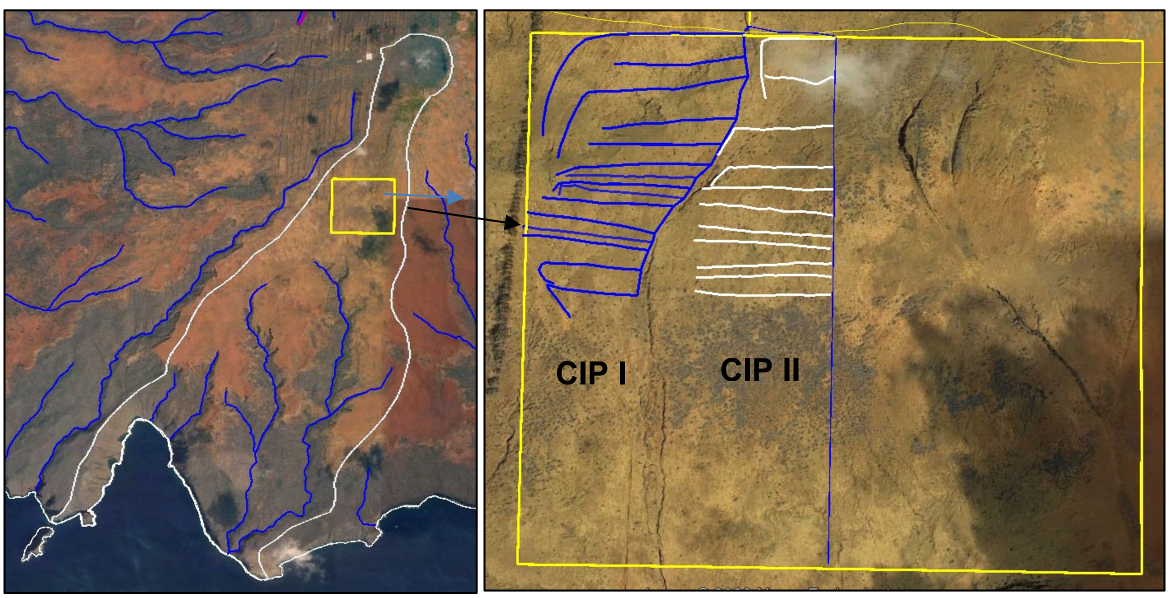


Figure 22a, b Irrigation lines in CIP I and CIP II

None of these KIRC Restoration Projects quantified soil loss.

Soil Erosion Control in Kamōhio Watershed

Sixty-one (61) ProWattles™ and DitchGuard™ check dams were installed above the CIP Project Site (Figure 23a, b) in Kamōhio Watershed.

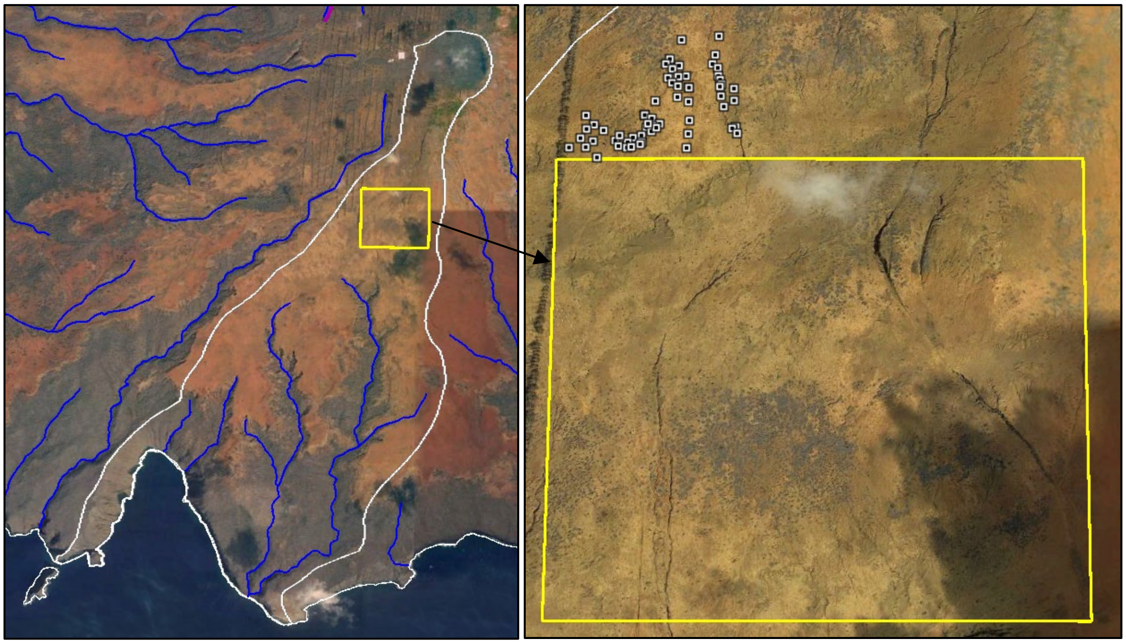


Figure 23a, b Location of 61 check dams installed above the CIP Project Site in Kamōhio Watershed

ERTEC Pro Wattles™ and Ditch Guard™ Check Dams

ERTEC Environmental Systems ProWattle™ (Figure 24) is a slope interruption device which spreads and slows water flow rather than concentrate it.

Figure 24 ProWattle™ installed above the CIP Project site in 2019

By allowing water to flow-through (Figure 25) the mesh, it reduces water velocity and provides particle filtering.

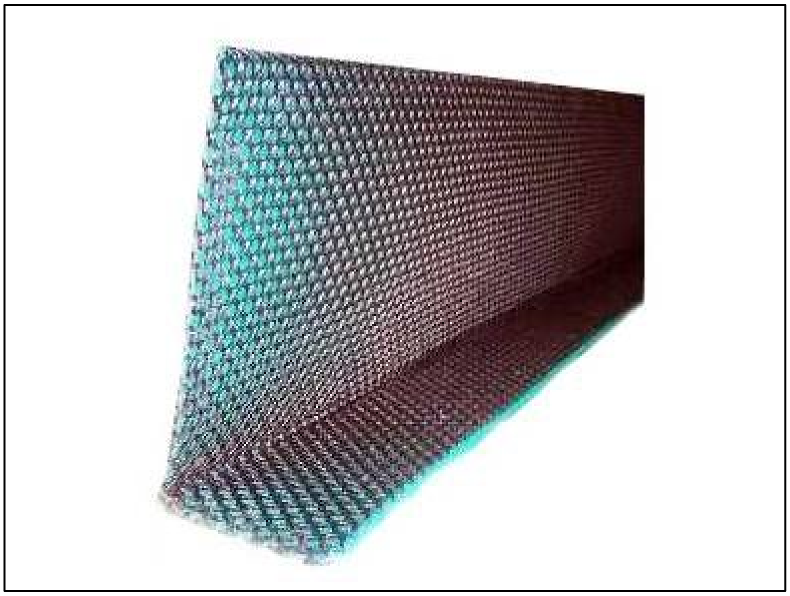


Figure 25 ERTEC Pro Wattle™ material

Ditch Guard™ is a water velocity interruption device and acts like a check-dam to slow concentrated flow and downstream erosive energy. Figure 26a, b illustrates the Ditch Guard™ check dams installed above the CIP Project Site in 2019.

Figure 26a, b Ditch Guard™ installation in Kamōhio Watershed

The effectiveness of these pre-existing NPS Management efforts is self-sustaining (except for the wattles damaged in 2015, and then repaired). They continue to contribute to the reduction of soil erosion, capture of soil and require minimal maintenance.

Proposed Management Activities

Listed in Table 14 are 6 Management Measures to be used in 3 phases in Kamōhio Watershed.

Number	Management measure	Comment
1	Irrigation	1.5” main, 1” sub-main, ¾” laterals with valves and emitters
2	Native Plants	drought tolerant plants
3	Soil Amendments	“Clay Buster”, Black Gold, fertilizer, Kiawe chips
4	Non-Native Plant Control	Mechanical removal
5	Check dams	Gabions/wattles
6	Monitoring	Rain gauge, stream stage, vegetation plots, plant survival rates, soil erosion pin transects, soil infiltration rates, baseline photo points, drone images, Airborne LIDAR

Table 14 Six Management Measures to be used in Kamōhio Watershed

Expected dates of achievement are presented in Table 15.

Year	Phase	Achievements	Comment
2023	Phase 1 - A 3-year project in both Tier I and Tier II areas	Acquire materials for restoration and ship to Kaho`olawe	Archeological Monitoring, Native plants, soil erosion control materials, irrigation lines
2024		Begin installing irrigation lines and native plants. Remove nonnative vegetation	Set up monitoring components, soil erosion control pins photos, rain gauge and Kaneloa stream stage
2025		Finish up first phase of Restoration	Finish native plantings, monitoring
2026-2030	Phase I ends/Phase II (4 years) begins in Tier II headwaters	Choose another work site in the headwaters of the watershed	Continue repairing headwaters of Kamōhio Watershed (Tier II)
2030-2040	Phase III (10 years) begins in lower reaches of watershed Tier I	10 years of Restoration in Kamōhio Watershed	Enter lower reaches of Kamōhio Watershed in Tier I areas

Table 15 Three Phases and Expected dates of achievements

PHASE I (2023 – 2026)

Archeological monitoring will initially take place before any restoration activities begin. They will be demarcated with blue painted 1" x 1" pieces of wood Planting strategies in Tier I levels of UXO clearance will have continuous planting corridors made of wattles with native soil and soil amendments. In Tier II, the planting strategy would consist of augered holes no more than 0.3 meters (1ft.) deep spread 1m (3.3ft) apart. When present, the ¾" irrigation laterals will utilize the pre-existing Tamarisk (*Tamarix aphylla*) wind breaks.

Native plantings will be drought tolerant and non-native species control will be implemented throughout the proposed Project site targeting Invasive Alien Species (IAS). Soil amendments will consist of a G&B Organics® "Clay Buster" product, Black Gold potting mix and fertilizer. Gabions and wattles will be constructed in shallow stream beds and gullies. Monitoring will include comparing rainfall and stream stage, recording species presence and percent cover in 10m x 10m vegetation plots (relevés) using Braun-Blanquet cover classes, plant survival rates, soil erosion pin transects and soil infiltration rates in restored and non-restored areas. Archaeological monitoring will be contracted to ensure compliance with state and Federal laws protecting historical sites in the watershed during Restoration activities. Baseline photo points will be taken in 2023 and retaken in 2026 for comparison of vegetation growth. More photos will be taken as Management Measures are installed. A Suunto sighting compass will accurately determine the cardinal directions (N, E, S, W) of the baseline photo points. Drone images will be captured in 2023 at 15m (50') altitude from these centers and retaken in 2026 to compare restoration Management Measures installed during the three-year Project in Phase 1. The software, DroneDeploy® (http://www.dronedeploy.com) will be used to create an orthomosaic image of restoration areas. Airborne LIDAR will be achieved with the assistance of the Airborne LIDAR group.

Phase II (2026-2030)

This four-year phase could consist of restoration in the headwaters (TIER II) of Kamōhio Watershed and the remainder of the CIP I and II Projects.

Phase III (2030-2040)

A ten-year effort, extending down into the lower reaches of Kamōhio Watershed will take some effort as the water source at the summit will be farther away than the other two phases. However, most of the Excessive Sediment problem in the watershed could be in addressed in Phase III. Both Tier I and uncleared areas would need mitigation, but the uncleared areas will require an EOD and may prove to be challenging install restoration measures.

Archaeological Monitoring

The entire island of Kahoʻolawe was placed on the National Register of Historic Places in 1981. An archaeological site map (Figure 27a, b) illustrates the historic properties (features) in the area in Kamōhio Watershed (Hammet et al., 2001a, 2001b).

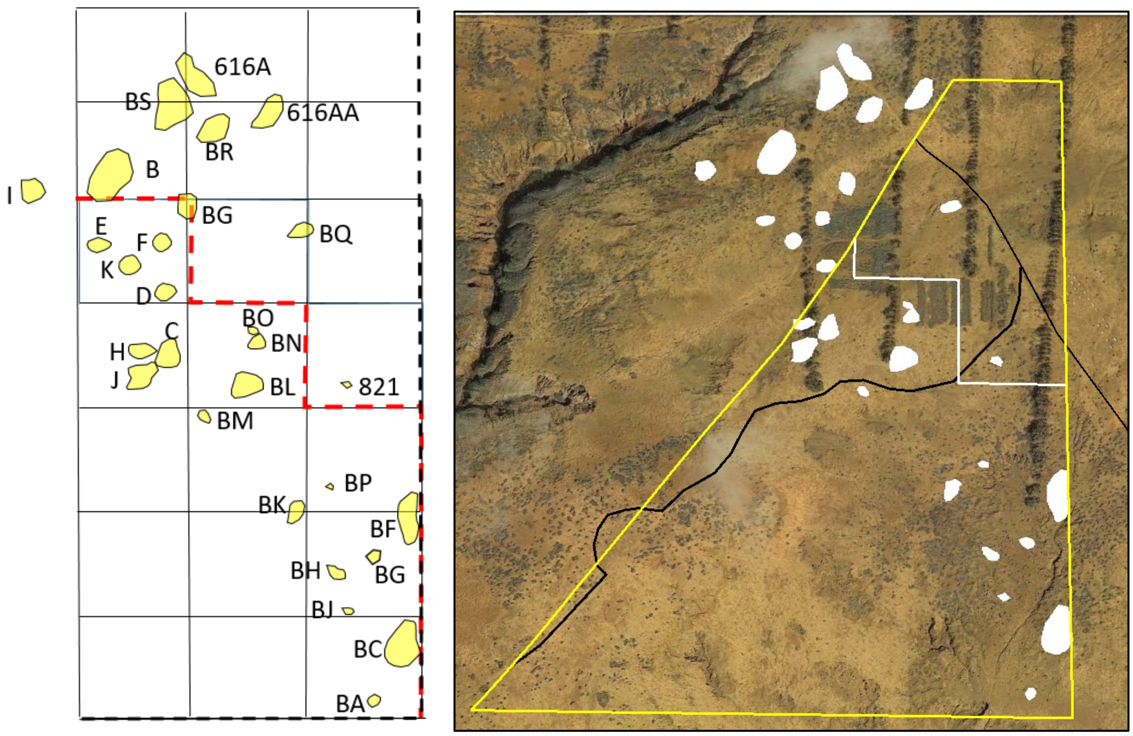


Figure 27a, b Archaeological site (white polygons) map in an area of Kamōhio Watershed

Note: All features belong to Site 110 unless otherwise noted.

Professional archaeological monitoring will also be conducted during the restoration efforts to be sure it has a beneficial effect to any historic sites located within the Kamōhio Watershed. Monitoring procedures will follow the recommendations of Donham (2005). Archaeological monitoring will ensure proper care of artifacts (Table 16) is taken while laying out 1” submains and ¾” laterals and installing soil erosion control devices around the features.

Adze Preform/Reject	Basalt Awl	Basalt Hammerstone	Basalt Core	Volcanic Glass Core	Coral Abrader	Misc	Total
5	5	3	10	8	4	10	45

Table 16 List of 45 artifacts in 27 features in a proposed Project area

The miscellaneous category includes a portion of a polished adze, fragment of a grindstone, worked basalt flake, grinding stone fragment basalt flakes, cowrie shell lure, abrader polishing stone, portion of a basalt grindstone, distal end of a basalt pestle and a scoria abrader (Hammet et al., 2001a, 2001b).

SUMMARY OF NINE EPA ELEMENTS

Partnerships

Through the cooperative management of the critically endangered Hawaiian plant Palu palu o Kanaloa (*Kanaloa kahoolawensis*) a relatively new Working Group for the KIRC has established several new local, State and Federal partnerships with organizations on Maui and Oahu. The plant (new monotypic genus) was initially discovered on `Ale`ale, a sea stack in the Kamōhio Watershed in 1992 and serves as a potential refugia once the plant reaches a population status of 100 plants (KIRC, 2022TBD). Listed below are the new partnership organizational names, points of Contact and Location of facility in the Working Group (Table 17).

	Name	Affiliation
1	Paul Higashino	Kaho‘olawe Island Reserve Commission (KIRC)
2	Lyman L. Abbott	KIRC
3	James Bruch	KIRC
4	Margaret Pulver	KIRC
4	Hank Oppenheimer	Plant Extinction Prevention Program (PEPP)
5	Keahi Bustamente	Department of Forestry and Wildlife (DOFAW)
6	Tamara Sherrill	Maui Nui Botanical Gardens (MNBG)
7	Anna Palomino	Ho‘olawa Farms
8	Nellie Sugii	Lyon Arboretum
9	Cindy Yamamoto	Lyon Arboretum
10	Matthew Keir	Department of Land and Natural Resources (DLNR)
11	Mike Opgenorth	National Tropical Botanical Garden - Hana
12	CJ Elizares	Protect Kaho‘olawe Ohana (PKO)/Makena Golf and Beach Club (MGBC)

Table 17 New Partnerships created with the KIRC for the Management of K. kahoolawensis

While these new partnerships are concentrated on the management of the critically endangered plant, it is relevant to this Watershed Plan as it is based upon the eventual re-introduction of the plant on Kaho`olawe and possibly in Kamōhio Watershed.

Scope of Watershed Planning Effort

Kamōhio Watershed is in desperate need of repair. While the headwaters are partially vegetated with nonnative vegetation like koa haole (L. leucocephala) Kiawe (P. pallida) trees and Tamarisk (*T. aphylla*) trees and grasses, the mid and lower reaches are still barren hardpan and are continuously contributing an estimated 9263 T/Y (877ha) in tons of silt and sediment runoff into the near shore ocean environment of Kaho`olawe.

The main issues of concern are lack of vegetation on the ground to hold the soil when strong wind events and or large stormwater runoff events take place. Because Kaho`olawe is such a windy island, it is very difficult to get vegetation established. It was fortuitous former land managers decided to install windbreaks around the summit of Kaho`olawe in the 1970's and they are beneficial and provide protection for established plants. However, the windbreaks were fairly limited in scope and didn't reach down into the lower portions of Kamōhio or many of the other watersheds on island. Therefore, the main issue of concern is to reverse this annual process of excessive sedimentation leaving the watershed and entering the ocean.

A. IDENTIFICATION OF CAUSES AND SOURCES OF IMPAIRMENT

There are basically two nonpoint sources of pollution that will need to be controlled to achieve load reductions from 10.7 T/A/Y (from 33ha area) above the Kaneloa stream system; 1.) Sediment coming from a large area of bare hard pan in Kamōhio Watershed, and 2.) Instream sedimentation processes such as bank erosion in the Kaneloa stream system (Figure 28).

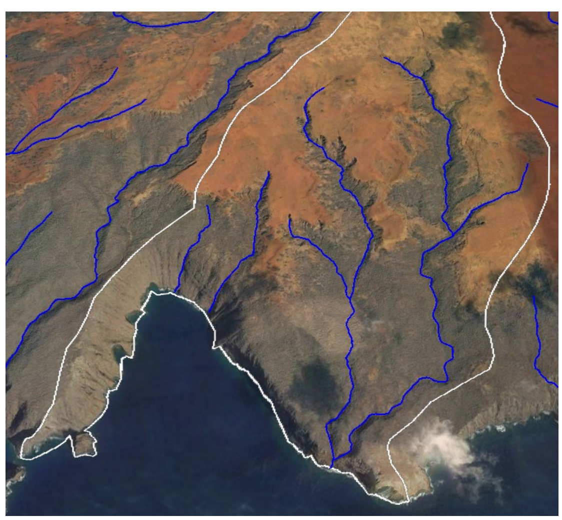


Figure 28 Four tributaries of the Kaneloa Stream system dissecting the hardpan in the Kamōhio Watershed

Geographic Delineations of Kamōhio Watershed

Extending from the entire summit crater of Lua Makika, the upper area of the watershed begins to spread outward as it heads downhill. In the middle section, it broadens to include several stream systems which end up branching out into tributaries in the lower reaches until they enter the ocean.

To capture changes in the status of the soil erosion on island we use stream gages to acquire rates of precipitation and correlate that to stream stage. and conceivably discharge (Q_s). Also, two techniques shared with us by USGS personnel include soil erosion control pin transects which allows us to compute sediment load (T/A/Y), and infiltration rates. Finally, baseline photo points with drone images (orthomosaic imagery) finish the compliment of monitoring components we currently employ.

To increase the vegetative cover on the hardpan, the wattles with irrigation have proven to be very effective. Our goal is also to reduce sediment load in the watershed by 0.5 T/A/Y (~5%/Y) where we are restoring the ecological damage in 3 movable Project Sites (over 17 years) and can be determined to continue to monitor rainfall and stream stage and using soil erosion control pin transects.

<u>Kaneloa Stream System</u>

Consisting of two major tributaries that enter the ocean at ʻIliʻililoa point (Figure 29), and two minor tributaries, the Kaneloa stream system is intermittent and collects water from the 886ha (2189A) Watershed only during seasonal rain events.

Figure 29 Two main tributaries of Kaneloa stream system meeting at ʻIliʻililoa point on Kaho´olawe

At times of stream flow, these two minor and two main tributaries distribute tons of sediment into the near shore ocean environment causing turbidity plumes (Appendix C). Figure 30 illustrates the two minor stream tributaries (A and B) in Kamōhio Watershed entering Kamōhio Bay.

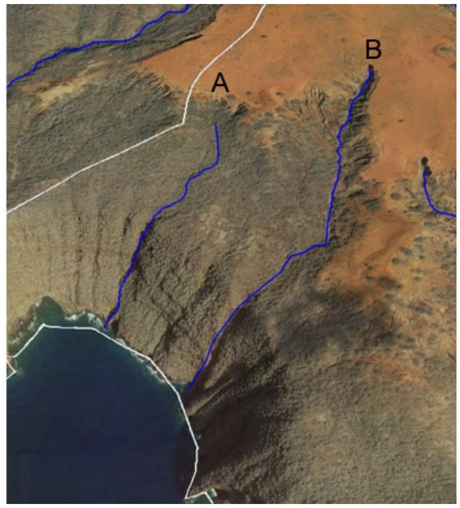


Figure 30 Two minor stream tributaries in Kamōhio Watershed entering Kamōhio bay

Figure 31 illustrates the two main Kamōhio stream tributaries (C and D) and segments in Kamōhio Watershed.

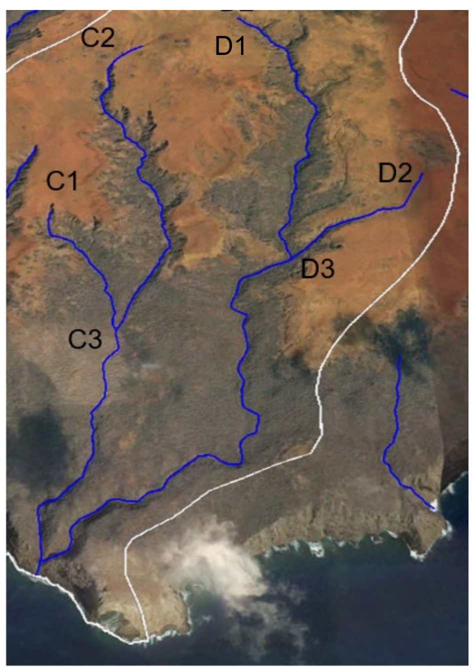


Figure 31 Two mainstream tributaries and segments in Kamōhio Watershed

Table 18 summarizes distance of stream segments, starting elevation, max slope, and average slope of all 4 streams in Kamōhio Watershed

Kaneloa stream system description					Total Elev				
Segment	Distance (mi.)	Total (mi.)	Starting Elevation/Gain (ft)		Gain (ft)	Max Slope (+/-%)		Avg Slope (+/-%)	
A	0.47	0.47	900	900	900	N/A	-77.7	N/A	-31.4
B	0.79	0.79	958	958	958	30.4	-80.6	5.8	-18.7
C1	0.52		878	195		59.6	-24.3	9.1	-7.9
C2	1.38		1081	398		21.2	-62.6	5.6	-7.6
C3	0.83	2.73	683	683	1276	12.5	-91.7	3.4	-13.6
D1	1.23		1079	325		13.6	-22.4	2.2	-6.1
D2	0.59		917	163		28.0	-15.3	9.0	-5.4
D3	1.63	3.45	754	754	1242	25.7	-97.0	3.5	-5.6
Total	7.44			4376					

Table 18 Summary of stream segment, distance, starting elevation, maximum and average slope of four streams in Kamōhio Watershed

The total length of all four streams is 11.97km (7.44 miles) and elevational gains range from 0m to 274m (0 to 900 feet) [A] to 389m (1276 feet) [C]. The two main tributary streams drainage pattern is dendritic with meandering channels. The gradients are very steep towards Kamōhio Bay as the streams fall over cliffs into the ocean. The lag time between rainfall events and stream flow appears to be relatively short indicating soil infiltration rates are low.

Figure 32 also shows further demarcations of Watershed catchments within the Kamōhio Watershed.

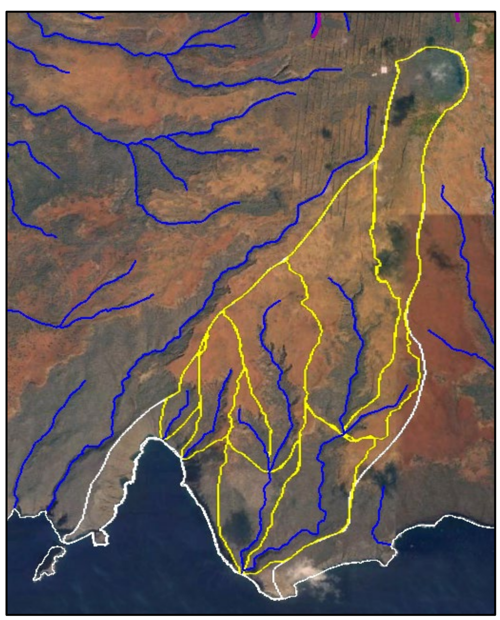


Figure 32 Watershed Catchments (yellow) in the Kamōhio Watershed

The Watershed catchments correlate with the stream segments listed in Table 18 and could become prioritized for implementation of restoration activities in the three Phases over time.

Data Sources, Estimates, Models and Assumptions

<u>Soil Erosion Pin Transects</u>

From 2011 to 2015, rates of soil erosion in Kamōhio Watershed were measured to calculate sediment load using seventeen (17) of an initial 20 soil erosion pin transects. Table 19 lists the sediment load of 10.7 T/A/Y calculated from the soil erosion pin transect measurements.

Year	Watershed	Data Source	Method	Sediment Load
2011-2015	Kamōhio	Soil Erosion Pin Transects (N=17)	KIRC sediment load equation	10.7 T/A/Y

Table 19 Year, Watershed, data source, method and sediment load from 2011 to 2015

Figure 33a, b illustrates the location of the initial 33ha where 20 soil erosion pin transects in and around the CIP project site in Kamōhio Watershed.

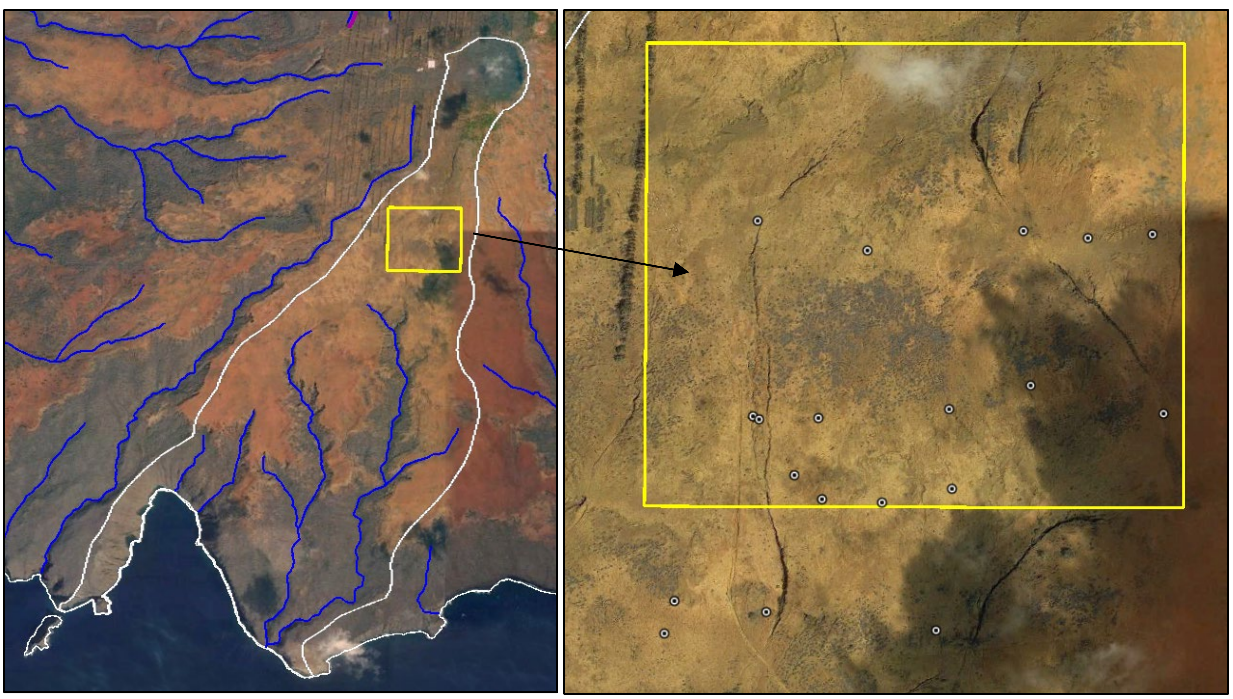


Figure 33a, b Location of 33ha site where 20 soil erosion pin transects in Kamōhio Watershed in relation to the CIP Dryland Forest Project Site

Further representation on a grid map of the 20 pin locations with respect to Tier I (surface cleared only) and Tier II (UXO cleared down to 4 feet depth) clearance boundaries in the CIP project site is presented in Figure 34.

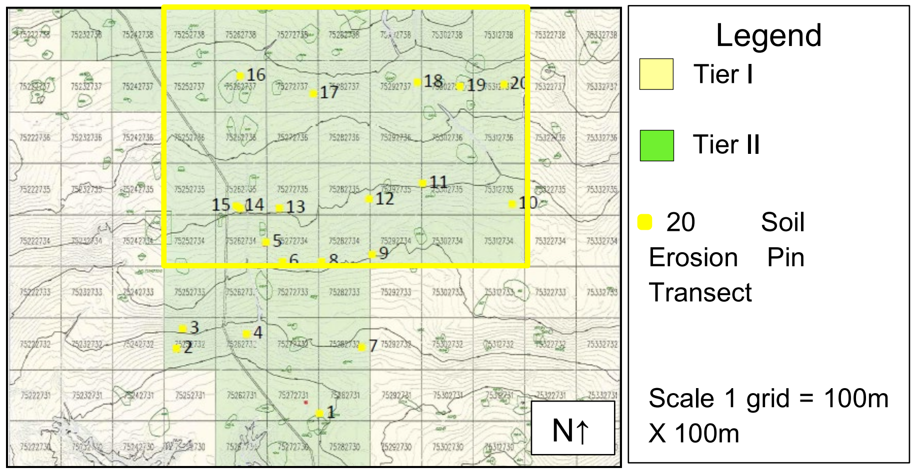


Figure 34 Locations of twenty soil erosion pin transects in the CIP Project Site (yellow) and UXO clearance levels in Kamōhio Watershed

Data for soil erosion pin transects 2 and 3 were not recorded again in 2015. Also, the stainless-steel soil erosion pins (rods) of Transect #7 (Figure 35) were bent in Kaneloa stream bed during a storm event and rendered un-usable.

Figure 35 Bent soil erosion pin transect (#7) rods in Kaneloa stream bed

Therefore, a total of 17 soil erosion pin transects were included to calculate soil loss and sediment load. Using a mean difference of 10.1mm (SE ± 2.6) for 17 transects (Table 20), from 2011 to 2015, a soil erosion value of -2.4mm/year was calculated.

Transect	Mean May 2011 (mm)	Mean July 2015 (mm)	Difference (mm)
1	230.8	228.4	2.4
2			
3			
4	250.1	248.3	1.8
5	225.2	220.8	4.4
6	307.7	302.0	5.7
7			
8	261.4	257.4	4.0
9	250.8	246.9	3.9
10	255.4	225.6	29.8
11	278.4	273.9	4.5
12	308.7	300.1	8.6
13	304.9	304.5	0.4
14	287.6	282.9	4.7
15	273.9	268.6	5.3
16	209.8	190.2	19.6
17	313.3	309.8	3.5
18	328.9	315.5	13.4
19	304.0	282.9	21.1
20	253.3	214.6	38.7
Mean	273.2	263.1	10.1
St Error			2.6

Table 20 Data set for 17 soil erosion pin transects in Kamōhio Watershed

The following equations show how the value of -2.4mm/year of soil loss was calculated;

- 263.1mm – 273.2mm = -10.1mm
- -10.1mm/1520 days = -0.006644 mm/day
- -0.006644 X 365 days = -2.4mm/year

Using the result of -2.4mm/year, a sediment load value of 10.7 T/A/Y was derived using the following equations (Table 21).

Equation			Quantity	Unit	Comment
1	10,000cm^2 x 10,000m^2=		100,000,000	cm^2/ha	Number of cm^2 in 1 ha
2	100,000,000cm^2 ÷ 2.47A/ha =		40,485,830	cm^2/A	Number of cm^2 (=g) in 1 A
3	40,485,830g/Yr ÷ 1000g/Kg =		40,486	Kg/A/Yr	Number of Kg/A/Yr
4	40,486Kg/A/Yr x 2.2lbs/Kg =		89,069	lbs/A/Yr	Number of lbs/A
5	89,069lbs/A/Yr x 0.24g/cm^3		21,377	lbs/A/Yr	0.30g/cm^3 (partial cube)
6	21,377lbs/A/Yr ÷ 2000lbs/T =		10.7	T/A/Yr	Number of T/A/Yr
7	10.7T/A/Yr x 33ha		353	T/33ha/Yr	Number of T/33ha/Yr

Table 21 Equations to calculate 10.7 T/A/Y sediment load from the 2011-2015 soil erosion pin transect data

Equation 1 determines the amount of cm^2 in 1 hectare. Equation 2 calculates the number of cm^2 in 1 acre which equates to number of grams of soil per acre. This assumption is based upon the estimate of 1 cm^3 of soil is equal to 1 gram. Equation 3 determines the number of kilograms per acre. Equation 4 converts number of pounds of soil per acre from kilograms. Finally, equation 5 and 6 use the soil loss figure from restored versus non restored averages of 0.24cm (2.4mm) which is equivalent to 0.24g/cm^3 to determine sediment load at 10.7T/A/Y. The results of seventeen soil erosion pin transects (T-test, N=17, 2 tail, paired) indicate a highly significant difference (p=0.0015) between the means after 1520 days of the initial reading in May 2011 and the second reading in July 2015.

The soil erosion pin transect sediment load estimates of 10.7 T/A/Y (and 353 T/A/Y for the 33ha area perimeter of the soil erosion pin transects) assume 1cm^3 of soil equals 1g. Bulk density of soil in NHPS and control sites in Kamōhio Watershed was between 1.05 - 1.16g/cm3, respectively (Ziegler et al., 2000). For soil type #6 (silty clay loam) in Kamōhio Watershed a bulk density figure of 1.65 g/cm^3 may be used to determine T/A/Y (USDA, 2011).

Critical Areas in Kamōhio Watershed

Horton (1945) describes the maximum or limiting rate at which the soil can absorb rain as it falls is its infiltration capacity (volume per unit of time), and overland sheet flow occurs because of prolonged rainfall at a rate greater than the infiltration capacity of the soil. A large proportion (~50%) of Kamōhio Watershed is bare hard pan soil (Figure 36), which is mostly devoid of plant cover and often exposed to high wind speeds.

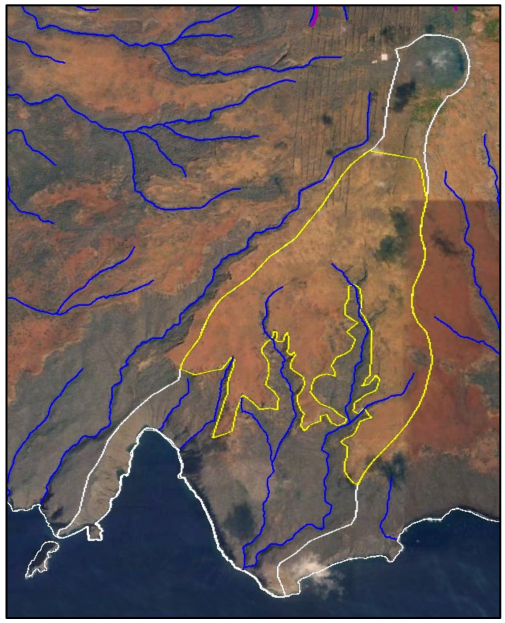


Figure 36 Hard pan (yellow polygon) in Kamōhio Watershed

This hard pan area is susceptible to overland sheet flow as infiltration rates on a silty clay soil are less than soils also consisting of more porous A and B horizons. Table 22 lists the percentages of UXO clearance levels in the hard pan area of Kamōhio Watershed.

UXO Clearance Level	Percentage of hard pan
Tier I	60%
Tier II	30%
No Clearance	10%

Table 22 Percentage of UXO clearance levels in the hard pan area of Kamōhio Watershed

Data Gaps

As of September 2019, the Hakioawa RAWS was no longer recording rainfall. This was problematic, but a new rain gauge installed in Kamōhio Watershed became operational on February 17, 2020. Otherwise, stage data from Kaneloa stream would not have a rain gauge in proximity. The soil erosion pin transects (N=20) previously installed in Kamōhio Watershed and measured from 2011 to 2015, are still present and 19 will be re-measured, but there would be at least a 10-year gap between subsequent measurements. It is unknown what current concentrations of pollutants are in Kaneloa Stream. Soil samples were analyzed in the CERL project sites in 2000. While three USGS water quality samples from two recon pool locations were analyzed in 1978, there has not been any other qualitative summation of the stream waters in Kamōhio Watershed.

Characterizing the Watershed before and after a 3-year period of restoration will allow for the identification of the locations contributing to the pollutant load (sedimentation). Also, developing a Sampling Plan along with additional collection of data to quantify sources of impairment in the Watershed will ensure efficient and effective restoration.

B. EXPECTED LOAD REDUCTIONS

Calculated from a 2011 to 2015 data set with soil loss of -2.4mm/year from 17 soil erosion pin transects, the expected load reduction is 0.5T/A/Y (~5%/Y) for the NPS pollutant "Excessive Sedimentation". Two Management Measures, native planting on irrigation and check dams (gabions/wattles) that will be implemented to achieve the expected load reductions of 0.5 T/A/Y (~5%/Y) are listed in Table 23.

	Management Measure	**Expected Sediment Load Reduction**
1	Native Plantings	0.2 T/A/Y
2	Check dams (Gabions and Wattles) soil erosion control	0.3 T/A/Y
	Total	0.5 T/A/Y (~5%/Y)

Table 23 Management measure and expected load reductions

An estimate of the sediment load, expected load reduction and reduced sediment load (T/A/Y) for Kamōhio Watershed is provided in Table 24.

Watershed	**Area**	**Sediment Load (T/A/Y)**	**Expected Load Reduction (T/A/Y)**	**Reduced Sediment Load (T/A/Y)**
Kamōhio	886ha (2189A)	10.7	0.5 (~5%/y)	10.2

Table 24 Watershed, area, sediment load, expected load reduction, and reduced sediment load

Native out plantings in Tier I will occur with planting corridors made with wattles of burlap rolls and a mixture of native soil and amendments. Wattles will not be installed in Tier II and intrusive activities (auguring planting holes) will only take place in Tier II areas cleared to 1.2m (4ft) depth.

Rainfall from the HOBO® rain gauge installed near the water level logger will be compared to Kaneloa stream stage data. Also, new soil erosion pin data collected in the Watershed will compare current sediment loads (T/A/Y).

Assessment of Erosion Control Needs

Erosion is inherently variable, both temporally and spatially, and sediment delivery to streams does not always coincide with erosion. Therefore, the sediment load allocations are designed to apply to the sources of sediment, not the movement or delivery of the sediment to the streams. Furthermore, Kamōhio Watershed has many hectares of hard pan that need mitigation (some of which are in non-cleared areas of UXO).

To meet future Watershed goals of specific amounts of sediment load reductions, and a determination of the duration and frequency of Management Measures required to meet these objectives, a TMDL for suspended sediment (mg/l) should eventually be established for Kamōhio Watershed. It will describe the pollutant load and establish criteria to set acceptable standards.

C. PROPOSED MANAGEMENT MEASURES

An inventory of existing NPS management efforts in Kamōhio Watershed include the first vegetation efforts shortly after the turn of the century which involved the introduction and planting of non-native species including kiawe (*P. pallida*), koa haole (*L. leucocephala*), ironwood (*C. equisetifolia*) and Australian saltbush (*A. semibaccata*) (Ziegler, et al., 2000, KICC. 1993). In the late 1980's the U.S. Army Construction Engineering Research Laboratory (CERL) revegetation experiments were initiated to determine long term success of several strategies to identify both native and non-native species appropriate for future restoration of the highly eroded hard pan (Warren and Aschman, 1993).

Check dams (gabions/wattles)

Soil erosion control features such as check dams (gabions and wattles), will be installed throughout the Watershed to reduce the sediment load. These are effective devices in that they allow the passage of water to flow, but retain the sediment that drops out of suspension due to a reduction in velocity of the water. The silt that is captured by a gabion provides excellent substrate for native out plantings off irrigation (Figure 37).

Figure 37 Silt captured behind a gabion with a Hawaiian cotton (Ma’o) plant

These plants are then naturally sustained by water from precipitation during subsequent rain events as they are in a natural topographic channel.

In 2015, a series of geotextile check dams (wattles) were constructed in Kamōhio Watershed but were damaged (and subsequently repaired) after a large storm event (Figure 38).

Figure 38 Check dams installed in 2015 and damaged by a large storm event

Due to overland sheet flow on the large area of barren hard pan in Kamōhio Watershed, and an in-stream sediment source in Kaneloa stream system, the NPS pollutant “Excessive Sedimentation” (Figure 39) enters the near shore ocean waters in Kamōhio Bay.

Figure 39 Sediment entering Kamōhio Bay at ´Ili´ililoa point in Kamōhio Watershed

TANKS 1 AND 2 AND RAIN CATCHMENT ROOF

Figure 40a, b illustrates the 1-acre catchment roof and Tanks 1 and 2.

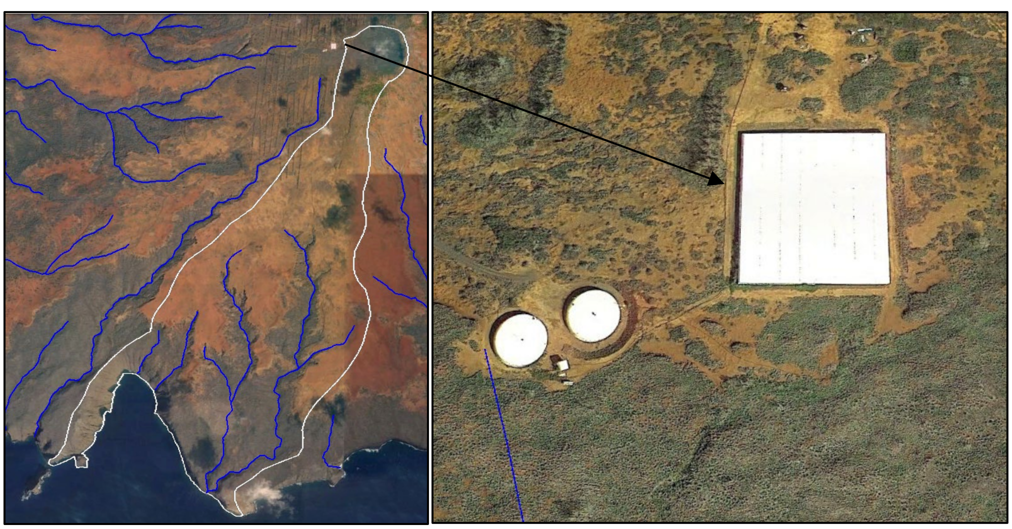


Figure 40a, b One-acre catchment roof and Tanks 1 and 2

The catchment roof has large holes along the six main seams and needs repair. The blue line in the figure above is the beginning of the 1.384km (0.86 mile) 1.5” irrigation main that leads down into Kamōhio Watershed.

Non-Point Source Management Measures

NPS Management Measures are used to control NPS pollution and can be correlated to decreased rates of erosion through monitoring (EPA, 1999). The data quality objective includes updating current soil erosion loss rates in Kamōhio Watershed (including the near shore ocean environment), and comparing them to soil loss rates (sediment load) after restoration efforts from 2011 to 2015.

Geotextiles are used to cover soil, retain moisture, and encourage plants to take root (KERP, 1998). Therefore, geotextiles and burlap bags in conjunction with native grasses such as Pili (*H. contortus)* will be constructed to form check dams (gabions/wattles) in shallow stream channels and gullies to contain the soil and stabilize the exposed sites with native vegetation. Gabions (Triton® polymer filter baskets) will be built in dry streams channels to capture silt. The gabions will be staggered at intervals to reduce high rates of stream flow. The length of the interval will vary depending on the gradient of the deposits expected to accumulate above the dam (Heede, 1976), particularly in gullies that are over 1m in depth. Due to the large amount of bare hard pan soil throughout Kamōhio Watershed, these erosion control measures will also be installed along contours, and overland sheet flow and stream flow rate will be reduced.

Table 25 lists the six Management Measures and estimated amount of pollutant load reduced planned to mitigate the soil erosion problem in Kamōhio Watershed.

	Management Measure	**Pollutant Load reduced**
1	Irrigation System (Main, submain, laterals)	
2	Native Plants	0.2 T/A/Y
3	Soil amendments	
4	Non-Native Plant Control	
5	Check dams (Gabions/Wattles)	0.3 T/A/Y
6	Monitoring	

Table 25 Six Management Measures and expected pollutant load reduction in Kamōhio Watershed

These Management Measures have been used on Kaho´olawe since 2003 and have proven to be effective at reducing and monitoring the reduction of sediment load. Except for hose clamps and valves which rust and decay, the components of the irrigation system have persisted in the field. Native plants from previous projects are providing more plant cover and reducing bare soil. Soil amendments (Clay Buster, Black Gold, Kiawe chips) are critical to provide organic matter to the hard pan soils which lack this key component to plant survival and success. A fertilizer formulated for Hawaiian soils and mycorrhizae is essential for nitrogen fixation in the roots. Non-native plant control is providing more soil substrate for native plants to become established with less competition for water and soil nutrients. Check dams (gabions/wattles) have been capturing tons of soil and providing soil substrate for new plantings. Finally, monitoring allows for the determination of achieving Watershed management goals while creating valuable baseline data for comparisons of Management Measures used for reducing NPS pollutants in the future.

In association with some of these Management Measures are standard operating procedures (SOP’s) which have been written for the benefit of both the KIRC employee and the safety of the volunteer. KIRC SOP’s have been prepared for the implementation of Watershed restoration modifications for safe operation with proper personnel protective equipment (PPE). SOP’s also include instructions for the construction, operation, and maintenance of the 1.5” main, 1” submains, and ¾” laterals for drip irrigation, proper planting techniques, mulching and soil amendments (fertilizer and Mycorrhizae), installation and maintenance of gabions and wattles, and safe and responsible use of Off Highway Vehicles (OHV).

Irrigation System

A previously established 1.5” polyline irrigation main (2019) for irrigation from Tanks 1 and 2 (300,000 gallons) will provide water at planting time and through the dry summer months. A solar DC booster pump that was constructed in 2018 at the large water tanks, provides water to the 1.5” main. The main line will deliver water into 1” submains and then to 3/4” laterals laid out in intervals spaced 25m apart.

Along the 3/4” laterals in Tier I areas, 180° Rain Bird® Xeri shrubblers will be inserted along the planting corridors for distribution of irrigation water. In Tier II, 1 gph pressure compensating emitters will be placed on each augured hole. Other items required to construct the drip irrigation system will include 1” and ¾” PVC valves and inserts, Teflon tape, hose clamps, and two 24” pipe wrenches.

KIRC personnel will be trained for the daily operation and maintenance of the entire irrigation system to prevent deterioration of installations and to be able to repair and provide replacements for parts that may fail. Both the 1.5” main, 1” sub main and 3/4” lateral irrigation lines would be affected by extreme weather. High winds especially have moved the empty and therefore light, irrigation lines. They will be staked down in Tier II with wooden EcoStakes. The 1.5” main line should be cleared of vegetation upon inspection.

Kaneloa Stream Stage (2015 to 2016)

Using a HOBO® water level logger in Kaneloa stream (Figure 41) at 320m elevation (1050 ft) from 12am on 12/11/2015 to 2pm on 2/11/2016, sensor depth data was captured by the University of Hawaiʻi at Manoa, Department of Civil and Environmental Engineering on December 24, 2015. Approximate UTM (NAD83 4N) location is E 752662, N 2273043.

Figure 41 Location of HOBO® water level logger in Kaneloa stream in Kamōhio Watershed

Between 3:00pm to 5:00pm on December 24, 2015, a 0.3" rain event (recorded at Hakioawa RAWS) produced a 0.133 ft. (1.596 in) sensor depth recording at 4:15pm in Kaneloa Stream (Figure 42).

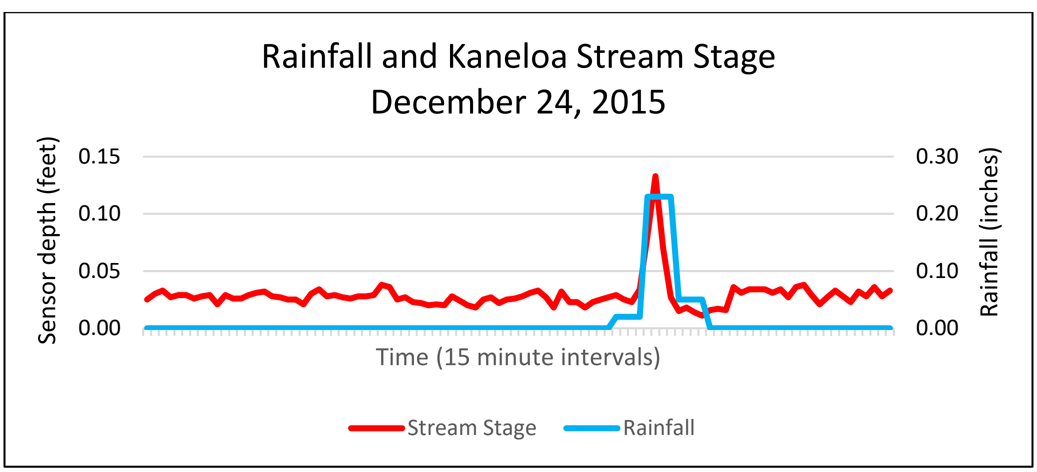


Figure 42 Kaneloa stream stage on December 24, 2015

The data was corrected for barometric pressure and Table 26 lists the rainfall and sensor depth data from 3pm to 5pm on December 24, 2015.

Time	Rainfall (inches)	Sensor depth (ft)
3:00PM	0.02	0.029
3:15pm		0.025
3:30pm		0.023
3:45pm		0.034
4:00pm	0.23	0.081
4:15pm		0.133
4:30pm		0.070
4:45pm		0.027
5:00PM	0.05	0.015
Total	0.30	

Table 26 Rainfall and sensor depth on December 24, 2015 (Hakioawa RAWS)

Therefore, initially on December 24, 2015, at 4:15pm with 0.3" of rain, 0.133ft (1.596") of stream stage occurred in a channel in Kaneloa stream. A HOBO® water level logger has been deployed since January 21, 2020, and is recording stream stage data in the same location as the 2015 to 2016 stream stage data set in Kaneloa Stream. A new Hobo rain gauge is also operational (February 17, 2020) near the water level logger at E 741694, N 2270103.

Manning's Equation

To calculate volumetric flow rate of Discharge (Q), (and suspended sediment, Q_s), Manning's equation (Equation 1) is an empirical formula that applies to uniform flow in open channels and is a function of the channel velocity, flow area and channel slope. It estimates the average velocity of a liquid flowing in a conduit that does not completely enclose the liquid or open channel flow.

Equation 1 (U.S.). $Q = VA = \left(\frac{1.49}{n}\right) AR\frac{2}{3}\sqrt{S}$

[For Metric use, $\left(\frac{1.0}{n}\right)$]

Q= Flow rate (ft^3/s)
V = Velocity (ft/s)
A = Flow Area (ft^2)
N = Manning's Roughness Coefficient
R = Hydraulic radius (ft)
S = Channel slope (ft/ft)

Acquiring stream velocity on Kaho`olawe while it is actively raining may prove difficult and could be set at 1ft/s for computation purposes.

Priority Management Measures

While these Management Measures contribute to reducing sediment load and improving water quality, they are presented in strategic order producing the most favorable outcome for restoration on Kaho‘olawe. Management Measures will be prioritized and ranked using the following criteria. Irrigation in conjunction with native plants, (wattles in Tier I) mulching and soil amendments will be the highest-ranking priority, followed by soil erosion control and non-native plant control with herbicides. Monitoring will occur throughout restoration activities, especially at the beginning and end.

Bottle necks include the delay of staff, volunteers, and restoration materials to Kaho‘olawe due to bad weather and/or high surf. Although access is under the authority of the KIRC, unfavorable weather conditions during the year including large periodic south ocean swells during the summer months can interrupt trips to Kaho‘olawe.

Irrigation and Native Out Planting

Irrigation and establishment of native plants in Kamōhio Watershed is a priority. The plants have been grown and delivered from an approved plant nursery on Maui, and to be used on Kaho’olawe, it has been specified that the plants will be between 20cm to 30cm in height, appear healthy, and be free from arthropods, ants, insects (nematodes) snails and slugs. Some plant materials (seeds) have also been obtained from Lyon Arboretum on O‘ahu and the National Tropical Botanical Garden (NTBG) on Kaua‘i. An example of the seeds of native plant species that have been collected on Kaho‘olawe that are being stored at NTBG on Kaua‘i that may be used in restoration in Kamōhio Watershed are listed in Table 27.

Common Name	Plant Taxa	Form
Ko´oko‘olau	*Bidens mauiensis*	Shrub
Wiliwili	*Erythrina sandwicensis*	Tree
Ma‘o	*Gossypium tomentosum*	Shrub
Koali	*Ipomoea tuboides*	Vine
Nehe	*Melanthera lavarum*	Vine
	Panicum faurei var. *latius*	Grass
	Panicum torridum	Grass
Kolomona	*Senna gaudichaudii*	Tree
‘Ohai	*Sesbania tomentosa*	Shrub

Table 27 Native plant seeds in storage at NTBG that may be used in restoration of Kamōhio Watershed

Invasive Alien Species (IAS) Control

Invasive alien species (IAS) such as Koa Haole (*L. leucocephala*), Lantana (*L. camara*), will be targeted for control using loppers, stump pullers, chainsaws, and herbicide. Crown flower (*C. gigantea*) has become especially numerous in areas of the Watershed as of 2019 and will be cut with a chain saw and treated with herbicide. Non-native plant species control will take place only were deemed necessary to minimize soil erosion. And will take place before planting. Green waste will be utilized on site as erosion control, as it provides retention of soil moisture and adds organic matter to the soil. Herbicide treatment will consist of Triclopyr (Element 4, Garlon 4) with blue Turf Trax® dye. Personnel Protective Equipment (PPE) needed includes hearing protection, leather gloves, nitrile gloves and protective face masks (3M N95) and goggles.

Soil Amendments

Seedlings in the plant nursery will receive EndoMycorrhizae and this is expected to allow the formation of root nodules in the young seedlings and improve the ability of the plants to uptake Nitrogen (N_2) in the form of ammonium (NH_4^+). During planting into the ground on Kahoʻolawe, Clay Buster which also contains mycorrhizae, will be added to the soil. The mycorrhizae association that forms in the roots also reduces stress caused by drought, soil compaction, high soil temperatures, heavy metals, soil salinity, soil toxins and extreme variations in soil pH. Three native plant species which do not form a relationship with the fungi are ʻAweoweo (*C. oahuense*), Kului (*N. sandwicense*) and Ewa hinahina (*A. splendens*). Other soil amendments in the form of fertilizer are needed as the hardpan soils in the Watershed are poor in organic matter and low in micronutrients, especially Zinc (Zn).

Rhizobium sp. (a bacteria) may be used in Koaia (*Acacia koa)* plants to improve nitrogen uptake in the roots.

G&B Organics® Soil Building Conditioner ("Clay Buster")

Ingredients of the Clay Buster product are recycled forest products, bark fines, composted chicken manure, gypsum, oyster shell and dolomite lime (as pH adjustment) guano and kelp meal. It will be used as a top and bottom dressing in the soil corridors. Table 28 lists the mycorrhizae taxa in G & B Organics® Soil Building Conditioner ("Clay Buster").

Taxa	Propagules/cm^3
Pisolithus tinctorius	19.54
Glomus monosporus	0.0024
Gigaspora margarita	0.0024

Taxa	Propagules/cm^3
Glomus clarum	0.0024
Glomus intraradices	0.0024
Glomus deserticola	0.0024
Glomus etunicatum	0.0024
Glomus mossae	0.0024

Table 28 Mycorrhizae taxa in “Clay Buster”

Fertilizer

Fertilizing is expected to improve the survival rate of plants in Kamōhio Watershed and the Nitrogen, Phosphorus, Potassium (NPK) content should have a relatively high P content. Produced for United Agricultural Products Chemicals, the formulation is for Hawaiian soils. An example of a guaranteed analysis of “Kula Blend” fertilizer is listed in Table 29.

Component	Percent
Total Nitrogen (N)	13.00%
Ammoniacal Nitrogen	7.31%
Urea Nitrogen	5.69%
Available Phosphate (P_2O_5)	32.5%
Soluble Potash (K_2O)	10.00%
Sulfur (S)	1.70%
Iron (Fe)	0.06%
Zinc (Zn)	0.07%

Table 29 Guaranteed analysis of Kula Blend fertilizer

Mulching

Mulching around the transplanted native species with aged Kiawe (*P. pallida*) wood chips available on Kahoʻolawe will assist with soil water retention and decrease soil surface temperature as well. The Kiawe wood chips will also provide organic matter to the soil. Although simple in concept, mulching is a critical component of plant survival in the extremely dry and hot weather conditions on Kaho’olawe. Also, the “Clay Buster” may also be applied as a top dressing.

Biochar

A new technique just used in 2021 on Kaho`olawe, Biochar may have promising value to the Restoration techniques in Kamōhio Watershed. Biochar is a carbon-based soil enrichment additive made through a process called pyrolysis where biomass from plant and agricultural waste products, is completely converted into charcoal. This process creates some of the most fertile soils able to retain moisture with higher surface area and porosity. Biochar can retain water and nutrients in the rooting zone making them more available to plants and creating ideal conditions for the growth of macrobiotic communities. (KIRC 2022a).

Location of Management Measures

The 1.5” main extends down 1.384km (0.86 miles) from Tanks 1 and 2 along a Tamarisk wind break (Figure 43) from 438m (1439 ft) to 365m (1200 ft) in elevation.

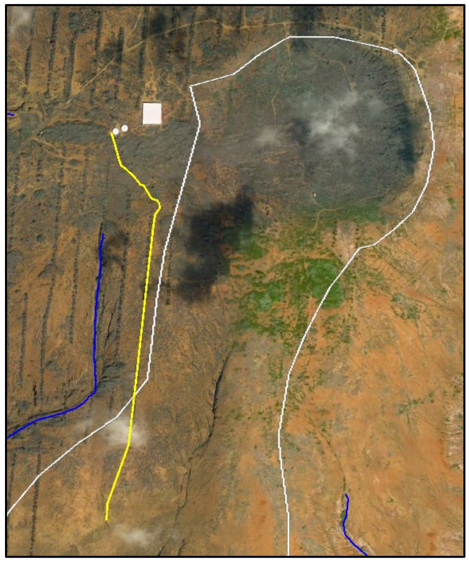


Figure 43 Location of 1.5” Main (yellow line) extending from Tanks 1 and 2 into Kamōhio Watershed

One-inch submains and 3/4” laterals for drip irrigation will be used in restoration areas in the Kamōhio Watershed. Native plants will be placed in planting corridors (Tier I) or augered holes (Tier II). Planting of native grasses and shrubs will occur in the hardpan areas with Kiawe mulch and soil amendments. Non-native plant control will take place in Kamōhio Watershed wherever there are IAS targeted for manual control. Herbicide application will also take place in areas with manually treated non-native vegetation. Where there is significant native plant cover, herbicide application to non-native plant species should not occur as to preserve the integrity of the habitat, as well as the erosion control the vegetation provides. Check dams (gabions/wattles) will be constructed and monitored before and after restoration activities.

Operation and Maintenance of Management Measures

Operation and maintenance of the Management Measures will be the responsibility of the KIRC Project Manager, Project Assistant, Natural Resources Specialist II (NRS II) and on occasion, volunteers. Monthly schedules will be drafted by the Project Manager to guide the work for specific tasks and objectives in Kamōhio Watershed. The operation and maintenance of each management measure and the personnel responsible for the implementation is listed in Table 30.

Management Measure	Operation and Maintenance	Personnel Responsible
Irrigation	Periodic maintenance will include proper upkeep of the Solar booster pump at Tanks 1 and 2. Yearly maintenance will involve walking the 1.5” main looking for leaks at the junctions of the lengths of Polyline Pipe and 1.5” PVC plastic fittings. The 1” submains and 3/4” laterals and valves will be inspected monthly, during watering, to detect leaks and check overall integrity of the system. Emitters and shrubblers will be checked upon installation and lines that have moved will be relocated.	KIRC personnel
Planting, Mulching, and Soil Amendments	Volunteers will be the main work force for carrying out the planting, mulching (including chips), and applying soil amendments. Planting will occur throughout the course of the year depending upon water availability. SOP’s on planting techniques will be reviewed by all participants before these activities are performed.	KIRC personnel and volunteers
Non-Native Plant Control	IAS will be targeted throughout the duration of the Project. Management of IAS will include chainsaws, loppers and herbicides were appropriate.	KIRC Personnel and volunteers (Except herbicide)
Check Dams (Gabions and Wattles)	Check dams (Gabions and Wattles) will require minimal maintenance as they are low lying and will eventually be covered with silt. They will be checked on a minimal basis and repaired if necessary.	KIRC personnel and volunteers

Table 30 Schedule for operation and maintenance of Management Measures

These Management Measures have proven to be effective in reducing sediment load and increasing water quality in past restoration projects in Watersheds on Kahoʻolawe (KIRC, 2005). The amount of sediment deposited behind soil erosion control features (gabions/ wattles) indicates the efficiency of soil dropping out of suspension when the velocity of water is reduced by the device.

D. TECHNICAL AND FINANCIAL ASSISTANCE NEEDS

Formerly using monetary resources from a $44 million Trust Fund from the US Navy UXO Clearance Project, acts from the State of Hawai`i Legislature appropriate funds to the DLNR for the KIRC to allow for the operation and funding of 15 positions. From the Maui Now, Maui News publication (February 2, 2022).

In 1993, the legislature found that the island of Kahoʻolawe was of significant cultural and historic importance to the native people of Hawaiʻi. The legislature also found that, “due to extensive erosion and other ecological problems, the presence of unexploded ordnance, the existence of archaeological and other cultural and historic sites, and the presence of native and endangered flora and fauna, a new management regime was needed to effectively meet the unique challenges of restoring, preserving, and determining the appropriate use for Kahoʻolawe (Maui News, 2022).

Existing sources of technical assistance needed to implement the plan include the KIRC Restoration, Operations and Administrative department personnel. Outside technical assistance may come from the USGS in both Oahu and California, and University of at Manoa personnel in the Engineering department. The three members of the KIRC Restoration department have over 50 years of experience executing the requirements of the past five DOH grants since 2003. An NRS II would be hired full time to perform logistics on Maui and field work on Kaho´olawe. The GIS/LAN Specialist has 20 years of experience as a surveyor and cartographer. An estimated budget for a proposed three-year project in Phase I is listed in Table 31.

Phase I 3 year Budget for Kamohio Watershed, Kaho`olawe					$ 529,872.18		
2023-2026	No.		Total Units	Unit Cost	Grant Funds	Match Funds	Total
Annual Salary	A.	**Personnel Sevices**					
$ 59,364.00	25%	Project Manager Hours	1560	$ 29.30		$ 45,708.00	$ 45,708.00
$ 57,678.00	25%	Project Assistant Hours	1560	$ 28.46		$ 44,397.60	$ 44,397.60
$ 77,938.00	5%	Nat Res Specialist V	312	$ 38.47		$ 12,002.64	$ 12,002.64
$ 67,320.00	5%	GIS/LAN Specialist	312	$ 33.22		$ 10,364.64	$ 10,364.64
$ 50,004.00	5%	Public Information Specialist	312	$ 26.16		$ 8,161.92	$ 8,161.92
$ 35,000.00	100%	Natural Resources Specialist II (3 years)	6,240	$ 19.68	$ 122,803.20		$ 122,803.20
		Fringe	52.61%		$ 64,606.76	$ 47,404.56	$ 112,011.32
		Volunteer Hours (360 volunteers)	14,400	$ 23.56		$ 339,264.00	$ 339,264.00
		Total for Item A			$ 187,409.96	$ 507,303.36	$ 694,713.32
	B.	**Travel**					
		Boat Passenger & Cargo (30 round trips)	30	$ 1,000.00	$ 30,000.00		$ 30,000.00
		Total for Item B			$ 30,000.00	$ -	$ 30,000.00
	C.	**Operating Expenses**					
		Total for Item C			$ -	$ -	$ -
	D.	**Equipment**					
		Native Plants	30,000	$ 2.85	$ 85,500.00		$ 85,500.00
		Irrigation	7,509	$ 1.00	$ 7,508.71		$ 7,508.71
		Soil Amendments	600	$ 14.20	$ 8,520.00		$ 8,520.00
		Drone Software	3	$ 1,200.00	$ 3,600.00		$ 3,600.00
		Burlap rolls	155	$ 150.00	$ 23,250.00		$ 23,250.00
		Shipping Burlap (no tax)	7.75	$ 1,772.29	$ 13,735.25		$ 13,735.25
		Total for Item D			$ 142,113.96	$ -	$ 142,113.96
	E.	**Professional Services**					
		Archaeological Monitoring	3	$ 55,000.00	$ 165,000.00		
		Total for Item E			$ 165,000.00	$ -	$ -
	F.	**Construction Materials**					
		Total for Item F			$ -	$ -	$ -
	G.	**Other Misc Expenses**					
		GE Tax (4.166%)		4.166%	$ 5,348.26		$ 5,348.26
		Total for Item G			$ 5,348.26	$ -	$ 5,348.26
	Total				$ 529,872.18	$ 507,303.36	$ 1,037,175.53

Table 31 Budget for proposed three-year DOH Project

The Grant Funds will cost is $529,872.18 from a Natural Resources Specialist II, Boat Passenger and Cargo at 30 trips) which is necessary for taking staff, volunteers, equipment and supplies to island. Operating Expenses at $1000 per trip (N=30). Equipment will include Native Plants, irrigation, soil amendments and burlap. Professional Archaeological Monitoring will take place during Restoration activities.

For Matching Funds, Volunteers at 14,400 hours (30 trips, 12 volunteers per trip, 360 total people at 40 hours a week). Personnel including the Project Manager, Project Assistant, NRS V (full time plus 52.61% fringe FY23) a GIS/LAN specialist and a Public Information Specialist.

Operation and maintenance by KIRC Staff and volunteers will ensure successful implementation of the Management Measures listed in the budget. Fringe is listed as 52.1% (FY23) and Hawai´i General Excise Tax (GET) is calculated at 4.166%. $529,872.18 for Grant Funds and $507,303.36 for Match Funds equals a total grant amount of $1,037,175.53. The authorities to be relied upon to implement the Kamōhio Watershed Plan are listed in Table 32.

	Authorities
1	Kaho‘olawe Island Reserve Commission (KIRC), State of Hawai‘i – Access to Kaho‘olawe and restoration Management Measures and monitoring
2	University of Hawai‘i Dept. of Civil and Environmental Engineering & Sea Grant College Program [assistance with stream discharge calculations using Manning’s equation]
3	USGS Pacific Islands Water Science Center (PIWSC) – [Soil infiltration rates]

Table 32 Authorities to implement the Kamōhio Watershed Plan

Personnel from the KIRC, DLNR State of Hawai‘i will be instrumental in overseeing the success of the proposed Management Measures. Personnel from the University of Hawai‘i, Department of Civil and Environmental Engineering & Sea Grant College Program and the USGS Pacific Islands Water Science Center (PIWSC) may assist with calculations and acquiring soil infiltration rates.

The technical and financial assistance will include Administrative Services (salaries, supplies, in-kind services, maps) through the NRS V and GIS/Lan Specialist positions. The installation, operation and maintenance of Management Measures, monitoring, data analysis, data management activities and revising the Watershed plan will be handled by the Project Manager and Project Assistant. The Public Information Specialist will be responsible for the Press Releases and NPS Brochure development.

Keys to Successful Implementation

On occasion very large Southern and Western surf swells, tropical storms, hurricanes enter the KIR and effects our main mode of ocean access. This effects the weekly trips that are planned to carry out the restoration work. Also, when the KIC vessel `Ohua goes down and is need of repair, Project success and implementation is at the mercy of the schedule of the Operations department.

Therefore, several contingency plans are put in place for the grants. One is to plant during the wet season October to March, and the perform other functions in the Project Site during the dry portion of the year (watering, extra mulching, weeding, monitoring). Secondarily, if we are delayed installing Management Measures in the Project Site, we have asked for contract modifications in the past to extend the grant.

Lastly, our volunteer base is our main source of field work. We have a waiting list over a yearlong that has groups of 10 volunteers schedule to come to island to implement the Work Plan.

Work Plan

A Work Plan has been written for the last 5 DOH Projects since 2003 for the Hakioawa and Kaulana watersheds. A Work Plan to accompany this Watershed Plan will also include Objectives, Best Management Practices, Monitoring, and a Budget.

Management Strategies

The KIRC hierarchy takes direction from the Commissioners, the Executive Director, the Departmental heads, and the Project Managers. This information is disseminated down to the volunteers who carry out the plan of the day expressed to them on island during an access. In this way, goals are met on a daily basis and work load is split between the days on island evenly to accomplish the tasks at hand.

E. INFORMATION, EDUCATION AND PUBLIC PARTICIPATION COMPONENT

Stake Holders

The stake holders of Kaho`olawe are the seven members of the Kaho`olawe Island Reserve Commission. Codified by law these members represent the public of Maui County and make their decisions based upon information presented to them by the departments of the KIRC including Restoration.

In April 2022 a State of Hawaii legislator and several legislative aides were taken out to Kaho`olawe and inspected the mid-reaches of Kamōhio Watershed (CIP I and II). More legislatores are schedule for the month of August 2022 to also expose them to the realities and difficulties of arriving on island, the logistical and infrastructural setup in Base Camp, and the details of mobilizations up range and just reaching the Watershed to perform restoration activities. Also, they will see the work performed in the restoration project sites to date.

Identify Categories of Stakeholders Stakeholders' Roles and Responsibilities

The Commissioners main roles and responsibilities are to listen to the Executive Director and Departmental Managers in quarterly public forums for suggestions on how to successfully maintain goals and objectives on land, ocean, and cultural protocols.

The skills and resources of the commission changes with different membership but are usually either governor appointed or highly respected personnel in the community. While they are encouraged on occasion to come to Kaho`olawe for access or have worked there in the past, they`re mostly involved with the quarterly Commission meetings.

Initiate Outreach Activities to Build Awareness and Gain Partners

While the KIRC has a Public Information Specialist (PIS), their current role is to write grants, interface with the Commission and perform some field work. Our current PIS leads the KIRC in the responsibility to initiate outreach activities (for example Ho`omau in 2022 on Maui) building awareness with her quarterly Kaho`olawe Newsletter Ko Hema Lamalama and Fiscal Year Summaries. Local Programs include a recent internship with Malama Aina.

Targeting appropriate stakeholders will be achieved by the KIRC Public Information Specialist (and Volunteer Coordinator) that disseminate information in a required orientation, educating the public of the project and encouraging their participation. While on island, restoration volunteers are given cultural and historical education of Kahoʻolawe in an informal outdoor setting by KIRC Staff. Activities on island include addressing management goals stated in this Plan as well as the implementation of the Management Measures outlined.

Evaluation Process

The qualitative process takes place before and after each access to Kaho`olawe. Logistics are discussed and delegated to managers, crew, and field workers. After the access trip is over, data is analyzed quantitatively and determines if results are statistically significant. These before and after approaches effectively tune our Restoration trips into a well-organized and efficient team. Evaluation over time also leads to Quarterly Status reporting, Final Reporting and subsequent new submissions of Project proposals leaning on past success of former restoration work results to the DOH.

Results

In the past 5 DOH projects on Kaho`olawe, all of them have had positive (sometimes statistical) results implying the restoration Management Measures (vegetation plots) were effective in capturing the increase in native plant presence, plant cover (%) and survival rates of the out plantings. Also, soil erosion pin transects, and infiltration rates generally showed a positive trend towards restoration activities significantly reducing erosion and increasing infiltration in the Project Sites. Baseline Photo points and drone imagery have not always been 100% conclusive because of their initial random locations. However, it seems that with this positive precedent, a new watershed receiving priority status on Kaho`olawe would only serve to continue to implement effective and proven BMP's into another severely wasted environment on Kaho`olawe.

Volunteer Workforce

The volunteer work force is fundamental to accomplish the restoration tasks completed in the field. Listed below in Table 33 are seventy-five (75) groups that have come out to Kaho'olawe to participate in restoration work from 2013 to 2020.

	Group
1	Na Pua No'eau
2	Honua Kai
3	St Anthony High School
4	Ka Pā Hula O Ka Lei Lehua
5	Lahainaluna Class of 1962
6	Iolani Key Club
7	Kamehameha Schools Kea'au
8	Montessori School of Maui
9	Island Pacific Academy
10	Queen Liliuokalani Children's' Center - Maui Unit
11	Four Seasons Wailea Staff
12	Saint Anthony High School
13	DLNR Maui
14	Kaiser High School
15	UH Maui College Sustainable Energy Program

	Group
16	Mana Lane Farms
17	Volcano Charter School
18	Kamehameha Schools Kapālama
19	Seabury High School
20	UH Maui College Hawaiian Studies
21	Leeward Community College Kahiai Program
21	Makaha Hawaiian Civic Club
22	Maryknoll High School
22	Maui Nui Botanical Gardens
23	Maui Invasive Species Council
24	Maui land and Pine Puʻu Kukui Watershed
25	Maui Youth and Family Services
26	Mililani High School
27	Kula Kaiapuni O Kekaulike
28	First Hawaiian Bank
29	Lion’s Club
29	Saint Louis High School
30	Hawai’i Youth Conservation Corps
31	Hawai’i Nature Center
32	Ka ʻOlu Makani O Mauna Loa
33	UH Manoa Richardson School of Law ʻAhahui ʻO Hawaiʻi
34	Pacifc Century Fellows
35	Laupahoehoe Public Charter School
36	Native Hawaiian Legal Corporation
37	Queen Liliʻuokalani Children’s Center - Ko’olau Poko and Lanai Units
38	Hawaiian Canoe Club
39	US Fish and Wildlife Service Honolulu Office
40	Kailua High School
41	Maui Youth Leadership Academy
42	UH Hilo Kilohana Program
43	Hawai’i Air National Guard
44	Pacific America Foundation The Calling
45	Kamehameha Schools Kapalama Class of 1990
46	Hawai’i Army National Guard
47	Hui Kapehe (Alu Like)
48	Loko ʻea Haleiwa Fishpond
49	Montessori School Maui
50	Pacific Whale Foundation
51	Sierra Club Oʻahu Chapter
52	Skyline Adventures
53	USGS BRD Hawai’i Volcanoes National Park
54	University of Hawai’i - Ethnic Studies
55	University of Hawaiʻi Lab School
56	UH School Hoala Charter
57	Youth Conservation Corps
58	Four Seasons Hotel - Maui
59	Ka Ipu Kukui
60	Andaz Hotel
61	Hawai’i State DOFAW - Maui
62	Native Nursery, LLC - Maui
63	Hawaii Trail and Mountain Club

	Group
64	Hui Nalu Canoe Club
65	National Park Service - HAVO
66	Trilogy/Blue Aina
67	Skyline Conservation Initiative
68	Maui High School
69	Lahaina Luna High School
70	Leeward Haleakala Watershed Partnership
71	Honolulu Museum of Art
72	Maui Nature Center
73	Malama Maui Nui
74	Change Works
75	Kapa Sun Gear

Table 33 A list of Seventy-five groups that have come to Kaho’olawe to participate in restoration work from 2013 to 2022

The volunteers will provide work for the restoration activities including planting and some of the other BMP’s that are implemented in the Watershed. In 2005 and 2007, posters with the theme Watershed Restoration on Kahoʻolawe, and an oral presentation on the DOH I Project, were presented at the Hawai’i Conservation Conference in Honolulu. The theme for the 2010 Hawai’i Conservation Conference was “*Pacific Ecosystem Management and Restoration: Applying Traditional and Western Knowledge Systems*” and personnel from the KIRC Restoration Department presented a poster on the use of pili grass in restoration efforts in DOH II on Kahoʻolawe. In 2014, the KIRC presented a poster at the Hawai’i Conservation Conference on the progress of DOH III. The 2014 theme of the Conference “Navigating Change in the Pacific Islands” was intended to bridge the challenge of ridge-to-reef conservation while recognizing the broad connection of islands and oceans. This concept is built around the people, places, social, and cultural components that define conservation capacity while realizing that the norm is constantly shifting especially with climate change. Finally, on July 11, 2019, a poster entitled, “Ecological and Native Dryland Forest on the Island of Kahoʻolawe”, was presented to the 26th Annual Hawaiʻi Conservation Conference: He ʻAʻaliʻi Ku Makani Au: Resilience in the Face of Change on O’ahu, discussing the results of the DOH IV Project. The link to the poster is here https://posters212.com/eposterList/details.html?id=48.

An award-winning DVD entitled Kaho’olawe: Breath of Our Ancestors “Ka Ha o Ko Makou Mau Kupuna” was produced by the KIRC and Hawai’i Pacific University in 2003 and has been given out to various groups in the State of Hawai’i. Listed in Table 34 are 35 organizations that received the DVD at the Hawai’i Conservation Conferences.

Number	Organization
1	US Army Environmental
2	Big Island Invasive Species Council
3	Bishop Museum
4	Conservation Council of Hawai’i

Number	Organization
5	CSU Pohakuloa Training Area
6	Forest Research Extension Partnership
7	Haleakala National Park Service
8	Hawai'i C's Consultants
9	Hawai'i Department of Forestry and Wildlife
10	Hawai'i Department of Land and Natural Resources
11	Hawai'i Natural Area Reserves
12	Kaelepulu Wetland
13	Kaua'i Endangered Bird Project
14	LARIX
15	Leeward Community College
16	Maui Forest Bird Recovery
17	Maui Invasive Species
18	Na Ala Hele
19	Native Hawaiian Plant Society
20	OSU
21	Stanford University
22	The Nature Conservancy
23	The Nature Conservancy Kaua'i
24	UH CCRT Seed Lab
25	UH College of Tropical Agriculture and Human Resources
26	UH Hilo
27	UH HINHP
28	UH HIP Imi Pono No Ka 'Āina
29	UH NREM Remote Sensing
30	UH REV Coral Ecology
31	USGS Biological Research Division/ Pacific Island Ecosystem Research Center
32	USGS Inventory & Monitoring
33	USGS Maui
34	USGS PBIN
35	Waimea Valley Audubon Center

Table 34 A list of the 35 organizations receiving the KIRC DVD, Breath of our Ancestors

NPS Brochures

Three NPS brochures were developed for the previous DOH Projects (Figure 44).

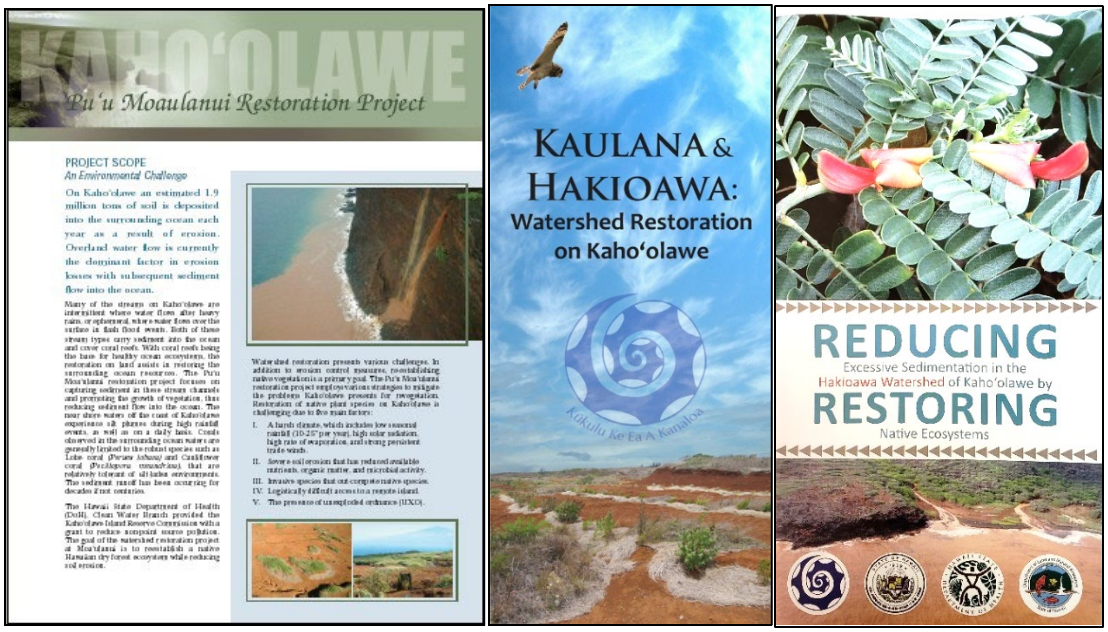


Figure 44 NPS Brochures for previous DOH Projects

A fourth NPS brochure was developed for the 2018-2019 DOH Project in Hakioawa Watershed and includes a description of the Management Measures used in the DOH Project site as well as preliminary results from stream stage, native plantings, and soil erosion control (Figure 45).

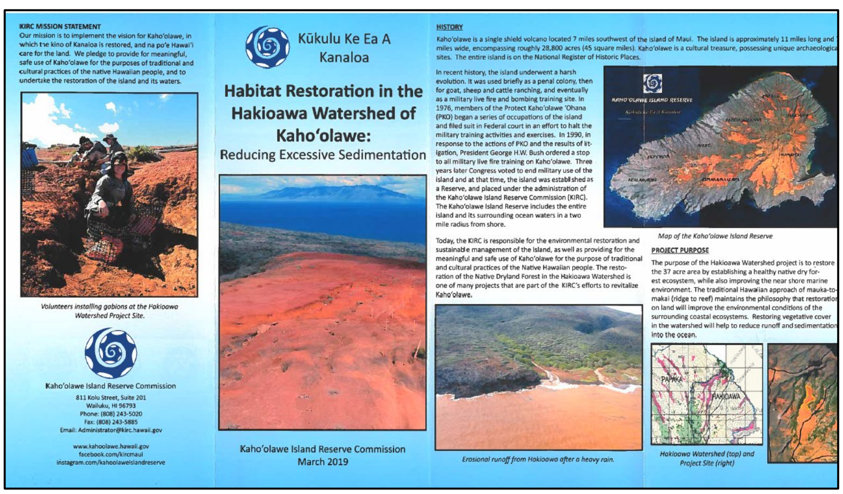


Figure 45 Front page of NPS Brochure for the 2018 to 2019 DOH Project in Hakioawa Watershed

These brochures have been handed out to multiple State and Federal agencies, and an updated NPS brochure will be developed for the DOH Projects and the restoration work in Kamōhio Watershed. Developed by the Restoration Department of the KIRC, they cover the Project Scope, Background, Management Measures, out plantings and Reintroductions, Lessons Learned and Cultural Education of the previous DOH Projects.

The KIRC also publishes a quarterly newsletter that includes project updates, which are intended to serve as a source of information for the public. The newsletter is sent directly to Hawai'i state legislators and members of the Aloha Kaho'olawe campaign. The newsletter is also distributed to the KIRC Constant Contact mailing list which includes over 4,500 contacts. On the internet, the Bishop Museum Web site for Kaho'olawe was developed in conjunction with the Bishop Museum exhibition Kaho‘olawe: Ke Aloha Kupa‘a i ka Aina, and are projects of the Bishop Museum's Native Hawaiian Culture and Arts Program (http://www.bishopmuseum.org/research/cultstud/kaho/index.htm). It contains photographs and cultural information about Kaho'olawe. Finally, the KIRC maintains a web site at http://kahoolawe.hawaii.gov/ with information on open water schedules, upcoming events, bidding and employment opportunities.

Final Reports will be used to disseminate Project information on Non-Point Source pollutants in Kamōhio Watershed to involve the Watershed community in Hawai‘i. It will include the results of the nine monitoring components including the achievement of attaining the goals of reducing sediment load and increased water quality in the Watershed. Results and outcomes of statistical comparisons of soil loss and soil infiltration rates in restored versus non-restored areas will be described in the report to increase public understanding. These measurable indicators of success will support the efficiency and quality of the Watershed Plan and ensure is sustainability.

F. SCHEDULE

A preliminary baseline water quality data set is becoming established for Kamōhio Watershed. The schedule for implementing the six Management Measures and an estimate of when a future target water quality standard (suspended sediment) in Kamōhio Watershed will be achieved is listed in Table 35.

	Management Measure	Phase	Year Begin-Future target year
1	Irrigation System	I-II	2023-2026
2	Native Plantings	I-III	2023-2033
3	Non-Native Species Control	I-III	2023-2033
4	Soil Amendments	I-III	2023-2033
5	Gabions/Wattles	I-III	2023-2033
6	Monitoring	I-II	2023-2026

Table 35 Schedule for the six Management Measures to achieve future target water quality standards

Other implementations to the schedule include the responsibility of the Project Manager to evaluate, review and revise the Watershed Plan. Nine monitoring action items are scheduled with a Final Report for an information/educational component. The criteria for meeting Watershed goals of reducing sediment load and improving water quality will include the installation of native plants on irrigation and soil erosion control devices.

G. A DESCRIPTION OF INTERIM AND MEASURABLE MILESTONES

Measurable Milestones accomplish over time, a fully implemented Watershed Management Plan. A Watershed Plan timeline with Management Measures, monitoring and annual milestones is illustrated in the proposed Project schedule (Table 36).

	Jan/Feb		March/April		May/June		July/August		Sept/Oct		Nov/Dec	
Management Measure												
Irrigation System	X	X	X	X					X	X	X	X
Native Plantings					X	X	X	X				
Weed					X	X	X	X				
Soil amendments	X	X	X	X					X	X	X	X
Gabions/Wattles					X	X	X	X				
Monitor	X	X	X	X	X	X	X	X	X	X	X	X

Table 36 Watershed Plan timeline of the proposed Project schedule with Management Measures, monitoring and milestones

The Watershed Plan timeline (implementation schedule) in Table 36 includes several short- and long-term milestones to determine if Management Measures are being completed on time. These include the irrigation systems on wattles to create the irrigated corridors, native out plantings in Tier I and Tier II, soil amendments, and installation of soil erosion control devices (check dams) to reduce sediment load, and monitoring.

Table 37 includes more detail on the implementation schedule for the 9 items of monitoring.

Monitoring	Rainfall/Stage		Veg Plots		Plant Survival		Erosion/Infiltration		BPP/Drone		Airborne LIDAR	
Task												
Phase I	Jan-June	July - Dec	Jan-June	July - Dec	Jan-June	July - Dec	Jan-June	July - Dec	Jan-June	July - Dec	Jan-June	July - Dec
Year 1	X	X	X		X		X		X			
Year 2	X	X										
Year 3	X	X		X		X		X		X		
Phase II												
Year 1	X		X		X		X		X		X	
Year 2	X											
Year 3	X											
Year 4	X			X		X		X		X		X
Phase III												
Year 1-5	X	X							X	X	X	X
Year 5-10	X	X							X	X	X	X

Table 37 Implementation Schedule for Phase I to III for monitoring in the Watershed Plan.

Milestones

The KIRC has planted over 28,000 native plants on irrigation in Kamōhio Watershed. From 2018 to 2020 two CIP projects (funded by the State of Hawaii legislature) installed plants in the mid reaches of the watershed to produce a native dry forest in the hard pan. A rain gauge and stream stage data logger has been installed in Kaneloa gulch system and has been measuring rainfall since February 2020 and stream stage since January 2020 for baseline data. The December 5 and 6 2021 Kona Loa storm event was recorded and is presented here in this Watershed Plan. Over time this data can be correlated with the effects of restoration efforts in Phase I and II. A set of 19 soil erosion pin transects has been capturing erosion rates since 2011 and was remeasured in 2015. Many soil erosion control devices were installed above the CIP I Project Site and are capturing soil. Pili grass bales with ewa hinahina (*A. splendens*) seedlings were placed on the hard pan in 2010 and have persisted to 2022.

New milestones will be initially out planting the 30,000 native drought tolerant trees shrubs and grasses in the three-year Phase I. Accessible to irrigation water already brought downhill 0.8 miles from the two summit tanks (Tanks 1 and 2), vegetation plots, plant survival, soil erosion pin transects, infiltration rates. Baseline photo points and Drone imagery should show favorable growth over the duration of the Project. In Phase II, the four-year Project Site would move up into the headwaters of the watershed effectively reducing storm runoff from this higher section to the lower reaches. Also accessible to the irrigation water from the summit out planting the 40,000 native plants in Tier II will be accomplished using wattles as irrigated corridors. Finally, for the third 10-year Phase III, probably the most challenging due to the lack of water from the summit, milestones will include getting 1000's of meters of geotextile (Burlap) out on the hard pan to reduce overland sheet flow and capture sediment. Also, it would provide a substrate for a determined and specialized list of only the most drought tolerant native plants, for example Pili (*H. contortus*) grass and `A`a`li`i (*D. viscosa*) shrubs. LIDAR could be included in Phase II and III.

Bench Marks to Measure Progress

A typical benchmark for measuring progress is not only ordering and receiving, but also shipping the materials and supplies out to Kaho`olawe. It is a logistical challenge (large surf, boat repair) to move materials and supplies from Maui to where they are needed in the field on Kaho`olawe. A second bench mark is to get the irrigated wattles installed along with soil amendments to prepare for out planting. These two bench marks occur every access. Other benchmarks which occur more infrequently are the nine monitoring components. It is especially important to obtain the measurements of the soil erosion pin transects to let the erosion process proceed in time for a second comparative reading. Finally, the quarterly status reports and Final Report are excellent Bench Marks that check to see if we are on track and have completed our stated objectives.

<u>Measure Progress and Make Adjustments</u>

In the last few decades, thousands of native plants have been re-introduced into the depauperate ecosystems on island to ameliorate the lack of host plants for native insects and fauna (owls). We have measured it with precision and written the results into reports for the USGS and the DOH.

Over time soil amendments and fertilizers, brands and amounts have been altered, and the KIRC may be moving towards a Biochar system. The KIRC has moved away from plastic geotextile to a burlap material, so raptors (owls) do not get their talons stuck in the fabric. Making subtle changes to the way we accomplish our list of deliverables will always occur in conjunction with local and regional suppliers.

<u>Progress</u>

When Kaho`olawe entered its Ranching period, it was already decimated from feral goat (*Capris hirtus*) populations introduced in 1773 by Chief Kahekili on Maui. The Military Period was able to remove some of the goats, but it wasn't really until 1993 that all the ungulates were off the island. Probably the most significant environmental result was now the ability of the plants that remained both native and non-native to proliferate. The summit area was till barren and devoid of vegetation while the area was labeled a dust bowl on older maps. Today, we have thousands of native plants on and off irrigation surviving in the harsh conditions on island. As we have worked on the DOH Projects since 2003, the KIRC has been able to establish change in the Project Sites. This small piece by piece approach is unfortunately slow but methodically effective. Opening up Kamōhio Watershed and the hundreds of hectares of barren soil it holds, devoid of vegetation will allow for a much larger area than ever before, to be mitigated on Kaho`olawe.

Adjustments

The KIRC has had to adjust after a large fire in 2020 burned down our equipment and storage shed on island located at LZ Squid. Many of our irrigation supplies and tools were destroyed and we have had to relocate to a new storage depot at Base Camp. Fortunately, we are progressing and slowly restocking our equipment. As the KIRC moves forward with this Watershed Plan, a regenerative supply of material will help us maintain our current pace of restoration activities.

Native Out Plantings

Drought tolerant, native dry forest plant species used on Kahoʻolawe since 2003 will be included in restoration of Kamōhio Watershed on Kaho´olawe (Table 38).

No.	*Plant Taxon*	Common Name	No.	*Plant Taxon*	Common Name
1	*Abutilon menziesii*	Koʻoloaʻula	21	*Nesoluma polynesicum*	Keahi
2	*Acacia koa*	Koaiʻa (hybrid)	22	*Nothocestrum latifolia*	ʻAiea
3	*Achyranthes splendens*	Ewa hinahina	23	*Nothocestrum latifolium*	ʻAiea
4	*Artemesia mauiensis*	Hinahina	24	*Nototrichium sandwicense*	Kului
5	*Bidens micrantha*	Kokoʻolau	25	*Osteomeles anthyllidifolia*	ʻUlei
6	*Canavalia pubescens*	ʻAwikiwiki	26	*Panicum fauriei var latius*	Grass
7	*Capparis sandwichiana*	Maia pilo	27	*Pleomele auwahiensis*	Halapepe
8	*Cenchrus agrimonioides* (E)	Kamanomano	28	*Plumbago zeylanica*	Ilieʻe
9	*Chenopodium oahuense*	ʻAweoweo	29	*Psydrax odorata*	Alaheʻe
10	*Cyperus trachysanthos* (E)	Puʻu kaʻa	30	*Rauvolfia sandwicensis*	Hao
11	*Dodonaea viscosa*	ʻAʻaliʻi	31	*Reynoldsia sandwicensis*	Ohe makai
12	*Dubautia linearis*	Kupaoʻa	32	*Santalum ellipticum*	ʻIliahi aloe
13	*Eragrostis variabilis*	Kawelu	33	*Santalum freycinetianum*	ʻIliahi
14	*Erythrina sandwicensis*	Wiliwili	34	*Senna gaudichaudii*	Kolomona
15	*Gossypium tomentosum*[1]	Maʻo	35	*Sesbania tomentosa* (E)[1]	ʻOhai
16	*Heteropogon contortus*[1]	Pili	36	*Sida fallax*	ʻIlima
17	*Ipomoea indica*	Koali awa	37	*Sophora chrysophylla*	Mamane
18	*Ipomoea pes caprae ssp. brasiliensis*	Pohuehue	38	*Sporobolus virginicus*	ʻAkiʻaki
19	*Metrosideros polymorpha*	ʻOhiʻa	39	*Vitex rotundifolia*	Pohinahina
20	*Myoporum sandwicense*	Naio	40	*Wikstroemeia uva ursi*	ʻAkia

Table 38 Forty native plant species out planted on Kaho´olawe from 2003 to 2022.

E = USFWS Endangered Plant
[1]Species that have been propagated from seed collected by field botanists on Kahoʻolawe.

Figures 46 and 47 illustrate the endangered ʻohai (*S. tomentosa*) and endangered kamanomano (*C. agrimonioides*) grass, respectively, used in previous restoration projects on Kahoʻolawe.

Figure 46 ʻOhai (*S. tomentosa*)

Figure 47 Kamanomano grass (*C. agrimonioides*)

These endangered native plant species will be propagated and out planted with irrigation and soil amendments during restoration work in Kamōhio Watershed. Native plant cover will increase, and bare soil will be reduced. Soil infiltration rates will go up with plant roots creating micropores and improving porosity in the hard pan soils.

Soil Erosion Control Devices

Check dams (gabions/wattles) will be constructed with gravel bags in the Watershed in shallow stream channels and gullies reducing stream erosion and capturing soil. Monitoring will document the effectiveness of the Management Measures and provide comparative baseline data for future restoration work.

H. CRITERIA WHETHER LOAD REDUCTIONS ARE BEING ACHIEVED OVER TIME

Load Reduction Evaluation Criteria

The following benchmarks will provide a standard against which future restoration efforts may be compared in meeting Watershed goals of reducing sediment load and improving water quality in the Kamōhio Watershed. An arbitrary amount of 0.5T/A/Y (~5%/Y) is provided here which over 17 years of this Watershed Plan would equal a reduction of 8.5T/A/Y (~85%/Y). The State of Hawai`i DOH grant entitled Operation and Maintenance Plan for Hakioawa Watershed (KIRC, 2022b) was able to reduce in a special situation the amount of erosion between restored and non-restored areas by 28% over a 9-month time frame.

1978 USGS Recon Pools in Kaneloa Stream

A 1978 USGS sampling data set of two recon pools in the lower reaches of Kaneloa stream provide the earliest water quality data set available. The USGS Recon Pool locations are located by the UTM coordinates on the map in Figure 48a, b.

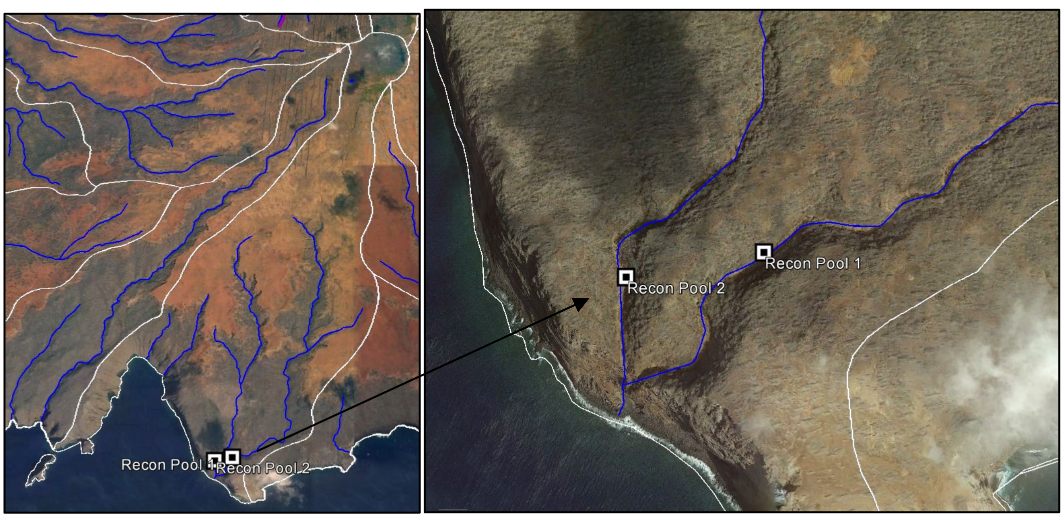


Figure 48a, b Approximate locations of USGS Recon Pools 1 and 2 in Kaneloa Stream

Table 39 lists the locations of the USGS Recon Pools 1 and 2 sampled in Kaneloa Stream in 1978.

Recon Pool	Latitude	Longitude	USGS Sample Number
1	20° 30' 45.62"	156° 35' 14.9"	203053156352500
2	20° 30' 41.62"	156° 35' 19.9"	203053156353000

Table 39 Latitude and longitude of USGS Recon Pools 1 and 2 in Kaneloa Stream

The latitude and longitude of the recon pools are converted to UTM in Table 40.

Recon Pool	Easting	Northing	Comment
1	751592	2270072	Zone 4N, WGS 84
2	751449	2269947	Zone 4N, WGS 84

Table 40 UTM locations of USGS Recon pools 1 and 2.

Over time, with restoration Management Measures in place, stream stage should be reduced with the same amount of rainfall. Continuing to measure stream stage in Kaneloa stream with a HOBO® water level logger and determining Discharge (Q) and suspended sediment (Q_s) with Manning's equation, will help determine if substantial progress is being made towards improving water quality standards. Presently, there has been one temporal correlation on December 24, 2015, between a rainfall event (Hakioawa RAWS) and the amount Kaneloa stream stage rises. Currently, a rain gauge and water level logger (in the same location in Kaneloa stream) are recording data for analysis. A reduction in sediment load will be attributed to native plantings on irrigation, check dams (gabions/wattles) from less storm water runoff and increased soil infiltration rates.

Ocean Turbidity

The waters off Kahoʻolawe were some of the most turbid waters the USGS had observed in the entire state of Hawaiʻi (Presto et al., 2010). Presto (et al., 2010) also mentions that even though Kahoʻolawe has relatively less precipitation and stream discharge compared to other study sites in north Kauaʻi, west Maui, and south Molokaʻi, very high suspended-sediment concentrations and turbidity still occur. Suspended sediment (load) is correlated to discharge and a reduction in the volume of water in the Kaneloa stream system from restoration Management Measures installed should reduce ocean turbidity in Kamōhio Bay. Although the KIRC will not be installing turbidity monitor in Kamōhio Bay due the difficulty of deployment and retrieval in rough and remote ocean conditions, it is assumed any improvement on land will help the outfall into the ocean.

Figure 49a, b and c illustrate the amount of silt that remains on the bottom of the sea floor in the near-shore ocean environment on Kahoʻolawe.

Figure 49a, b, c Residual silt on the near shore ocean bottom

If the interim targets of implementing the Management Measures are not met, the following three criteria will be used to determine whether the plan needs to be revised.

1.) Number of plants in Tier I and Tier II area does not meet specified goals.
2.) The proposed length of irrigation in Tier II (and wattles in Tier I) is not achieved.
3.) The nine monitoring components (see Table 41 below) are not acquired.

If any of these criteria are not met, the plan will need to be revised to account for the discrepancies.

I. MONITORING PROGRAM TO EVALUATE THE EFFECTIVENESS OF IMPLEMENTATION EFFORTS OVER TIME

Monitoring Component

The benchmarks described in Element H will be evaluated though monitoring restoration efforts. There are nine planned components (Table 41) to monitor the effectiveness of restoration Management Measures to reduce sediment load and improve water quality in Kamōhio Watershed.

	Monitoring Component	Subject	Currently Online
1	Rainfall	HOBO® rain gauge near Kamōhio water level logger	X
2	Stream Stage	In Kamōhio stream with HOBO® water level logger	X
3	Vegetation Plots (relevés)	Plants on irrigation	Phase I and II
4	Plant Survival Rates	% Survived	
5	Soil Erosion Pin Transects	Soil erosion in restored versus non-restored areas	X
6	Soil infiltration	Restored versus non restored soils	Tier II only
7	Baseline Photo Points	Native plant establishment and growth	
8	Drone Images	@25m (82') altitude	
9	Airborne Lidar		

Table 41 Nine monitoring components to be used to evaluate the progress of restoration efforts in Kamōhio Watershed

Three monitoring components are currently online, and all will be used to evaluate the progress and effectiveness of the restoration efforts in Kamōhio Watershed. These components will correspond to a Quality Assurance Plan developed once the proposed Project in Kamōhio Watershed commences.

Rainfall

A HOBO® rain gauge (Figure 50) has been installed (as of February 17, 2020) adjacent to the stream stage monitoring location in Kaneloa stream (Figure 51a, b) at an elevation of 323m (1062 ft).

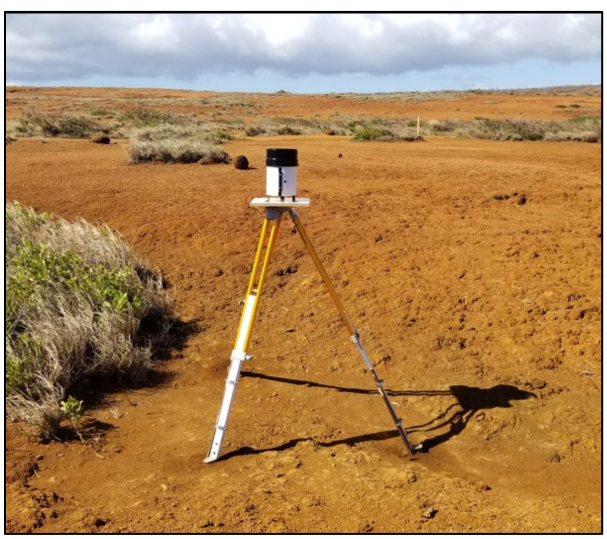
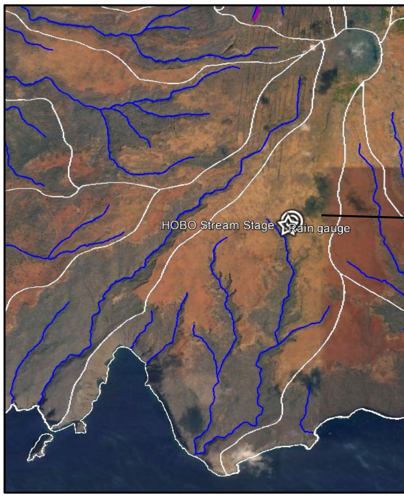


Figure 50 HOBO® rain gauge installed adjacent to the water level logger in Kaneloa stream



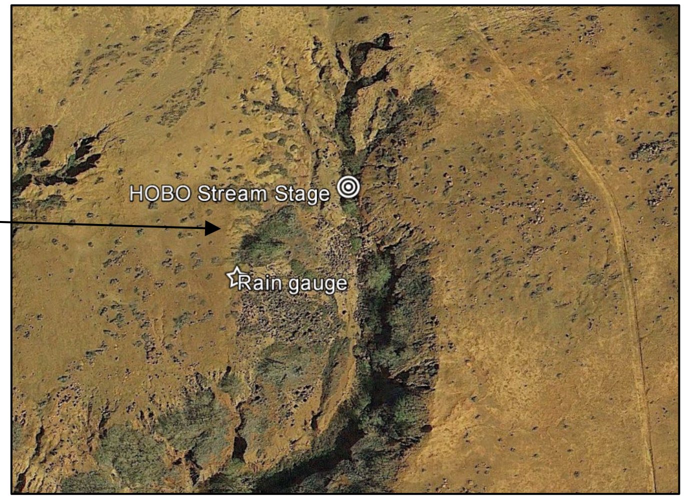


Figure 51a, b Location of rain gauge and stream stage monitoring device in and adjacent to Kaneloa stream

It is recording at 15-minute intervals. Rain gauge model is a UA-003-64 Pendant Temp/Event logger and was calibrated before deployment. Approximate UTM (NAD83 4N) location is E752613, N223009.

Stream Stage

Located on the Southern flank of Pu´u Moa´ualanui, Kamōhio Watershed has expansive acreage of hardpan which has several ephemeral streams that enter Kamōhio Bay. Kaneloa stream stage has been measured (since January 21, 2020) using a HOBO® water level logger recording hydrostatic PSI at 15-minute intervals. This data will be compared to rainfall initially collected from a rain gauge near the rain catchment and a new rain gauge installed (February 17, 2020) near the HOBO® water level logger location in Kaneloa Stream to establish the relationship of rainfall to stream stage. During times of moderate rainfall, Kaneloa Stream will flow as depicted in Figure 52 below.

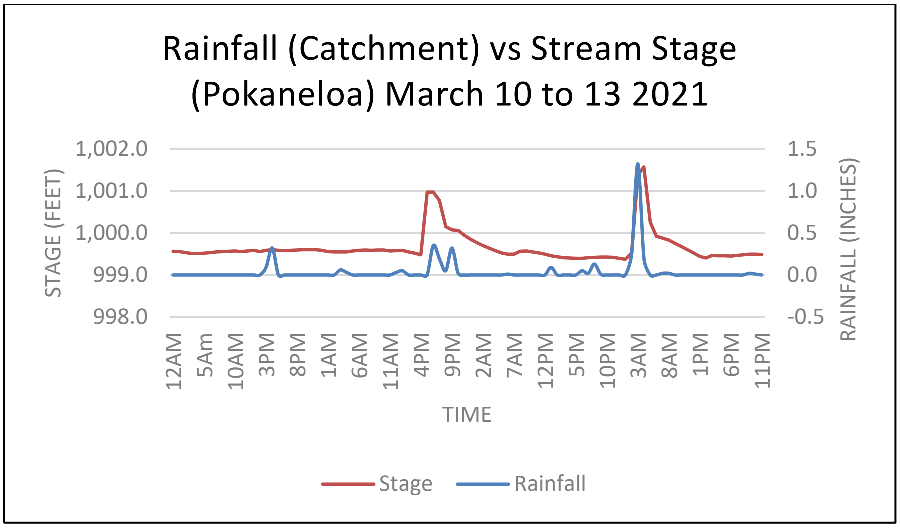


Figure 52 Rainfall and Stream Stage for Kaneloa Stream in Kamōhio Watershed

Corresponding to the peaks in the graph above, the data in Table 42 lists the rainfall (inches) at the rain catchment and Stream Stage (feet) in Kaneloa Stream near the Pōkāneloa Stone.

Date	Rainfall (in)	Stream Stage (feet)
3/10/2021	0.41	0.09
3/11/2021	1.10	1.49
3/12/2021	0.31	0.45
3/13/2021	1.83	2.10

Table 42 Rainfall and Stream Stage at Kaneloa Stream on Kaho´olawe

Graphing this data (rainfall versus stream stage) yields a high correlation of R^2 =0.9386 (Figure 53).

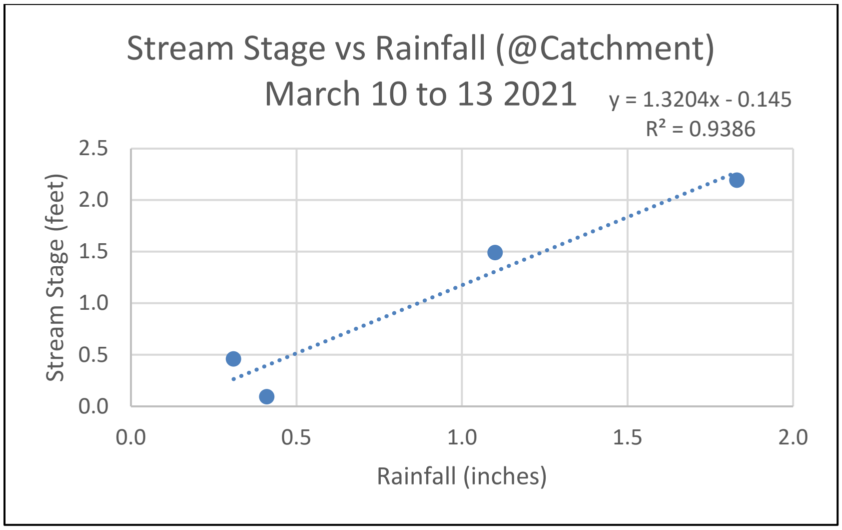


Figure 53 Stream Stage versus Rainfall for May 10 to 13 2021

On December 5 and 6 2021, a Kona Low system entered Maui County and the following information was captured (Figure 54).

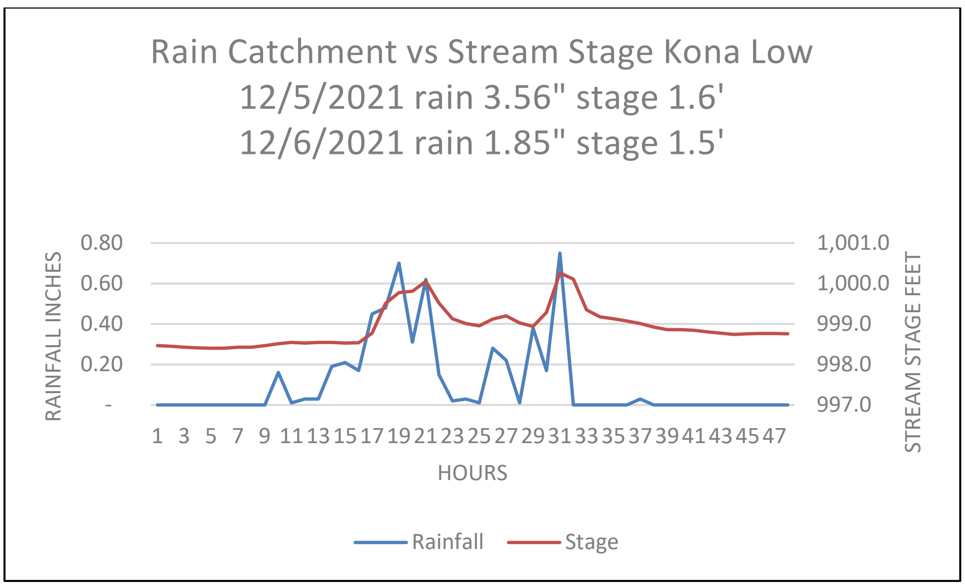


Figure 54 Rainfall and Stream Stage in Kaneloa stream during a 2021 Kona Low

The 3.56" of rain recorded at the rain catchment on December 5, 2022, caused a 1.6' change in stream stage and the 1.85" of rain on December 6, 2022, created a 1.5' change stream stage. These are relatively large values compared to what has been presented before. In time these values should decrease with restoration in the watershed. These data serve as valuable baseline information that can be referred to in time.

Vegetation Plots (Relevés)

In Phase I, randomly placed ten 10m x 10m vegetation plots (relevés) will measure plant species presence and percent cover of native and non-native plants (and bare soil) using the Braun Blanquet (Mueller-Dombois and Ellenberg, 1974) cover classes. The relevés will be initially read in after installation of the irrigated planting corridors. This data will determine if there was a statistically significant (α=0.05) increase in differences in native and non-native plant species presence before and after restoration modifications. Also, changes in percent cover of native and non-native plant species using the Braun-Blanquet cover classes should reflect the mitigating effect of restoration modifications to changes in plant species presence and soil cover. In Phase II, more relevés will be installed to capture the same before and after data of plant species presence and plant cover (%).

Plant Survival Rates

Using random locations along the irrigated planting corridors in Tier I, and augured holes in Tier II, native plant survival rates will be recorded and re-assessed for percent survival rates.

Soil Erosion Pin Transects

The initial installation of stainless-steel rods of the soil erosion pin transects in Tier I (Surface cleared only) will require an EOD Technician and a Schonstedt metal detector (Figure 55).

Figure 55 EOD Technician and Schonstedt metal detector on Kahoʻolawe

In Tier II, transects will be placed in restored and non-restored soils to determine if rates of soil erosion are statistically ($\alpha=0.05$) different. Pairing of transects will allow for the comparison of the rate of soil erosion in a control (non-restored) versus a treated (restored) area and determine soil loss (mm) and sediment load in T/A/Y. While the 2011 to 2015 soil erosion pin data set has been comparatively analyzed, re-reading these 19 transects and establishing new ones near restoration Management Measures for soil erosion will occur once a proposed Project in Phase I and II is underway.

Soil Infiltration Rates

Soil infiltration rates in NHPS sites in Kamōhio Watershed were 94.9 mm h^{-1} and soil moisture at saturation 0.51 g/cm^3 (Ziegler et al., 2000). The mean infiltration rate may be considerably faster in restored soils than the hard pan soil indicating that using native plants with restoration improves porosity and soil infiltration rate. These infiltration values can be compared to current infiltration rates with proven technique using a simple PVC device constructed with the guidance of the USGS.

Determining differences in soil infiltration rates in restored and non-restored areas (Tier II only) in the Watershed will determine the effectiveness of Management Measures in improving soil porosity with the presence of native plants. An 8" diameter PVC infiltrometer constructed with the assistance of the USGS Pacific Islands Water Science Center (PIWSC) in Honolulu will be used (Figure 56).

Figure 56 An 8" diameter infiltrometer

The PVC infiltrometer (8” diameter) will be used to document infiltration rates (liters/hour) primarily in Tier II areas. Tier I areas would require an EOD and metal detection before the measurements are made, therefore, these surface cleared only areas will be avoided.

Baseline Photo Points and Drone Images

Baseline photo points will document vegetation changes over time and drone images with a superimposed 10m x 10m computer grid system will quantify the increase in the amount of plant cover.

Responsible Parties for Monitoring

Responsible parties for monitoring components include the Project Manager, who will calibrate the rain gauge, program the water level logger and download the stream stage data, record information in vegetation plots, record plant survival, establish soil erosion pin transects (with an EOD in Tier I) and read twice, establish and read soil infiltration rates, analyze ocean turbidity with rainfall, take initial and final baseline photo points, quality control check the data entry, and statistically analyze the results. The Project Assistant will assist in downloading the rain gauge and stream stage data and obtain before and after drone images from 25m (82ft) and analyze in the DroneDeploy® software. The NRS II will assist the Project Manager and Project Assistant with all the monitoring components.

LiDAR, Multispectral Imagery and High Resolution RGB Photography

A raw and unprocessed (1-meter resolution) Light Detection and Ranging (LiDAR) data set of topography and vegetation height for Kaho´olawe will be acquired by the Global Airborne Observatory (GAO) (Figure 57).

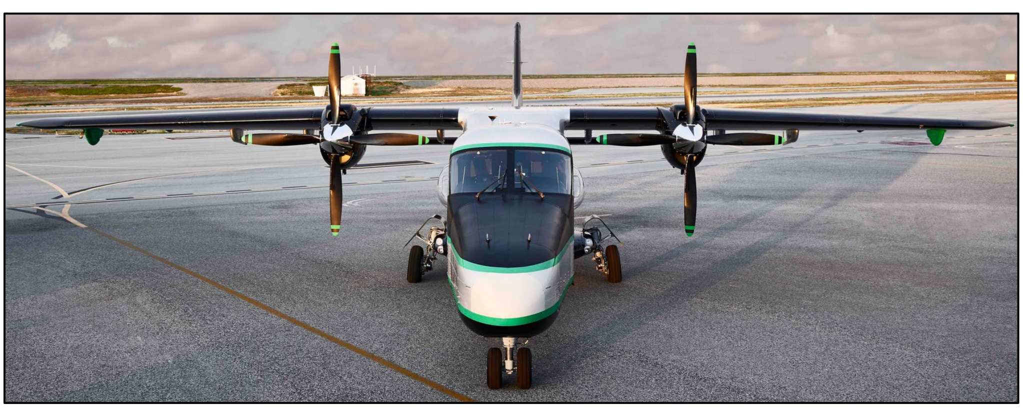


Figure 57 Global Airborne Observatory

Also acquired at this time was multispectral imagery (2-meter resolution) and high resolution (0.5 meter) RGB photography. This data will be processed by Arizona State University and the Global Discovery and Conservation Science personnel to detail the landscape and biomass as well as possibly differentiate between native and non-native plants to produce high resolution species composition maps. Visible-to-Shortwave Infrared (VSWIR) data and Visible-to-Near Infrared (VNIR) imaging spectrometers collected high resolution data. (Figure 58a, b) (http://asnerlab.org/projects/carnegie-airborne-observatory/).

Figure 58a, b Global Airborne Observatory and instruments

The Airborne Taxonomic Mapping System or AToMS has four integrated remote sensing technologies: (i) High fidelity Visible-Shortwave Infrared (VSWIR) Imaging Spectrometer; (ii) Dual-laser, waveform Light Detection and Ranging (wLiDAR) Scanner, (iii) High-resolution Visible-to-Near Infrared (VNIR) Imaging Spectrometer, and (iv) High-resolution Digital Imaging Camera. The VNIR sensor images the chemical content of forests in fine spatial resolution. The VSWIR sensor measures the reflectance of the Earth's surface in 427 channels from the ultraviolet through the visible near-infrared and short-wave infrared, allowing it to measure the chemicals in the environment, such as tree canopies, in fine spectral resolution. Interior of the GAO and sensors are presented in Figures 59a, b (https://gao.asu.edu/building-cao).

Figure 59a, b Interior of GAO and sensors

The VNIR sensor (red box) measures the chemical content of forests (fine spatial resolution) while the VSWIR sensor (gold cylinder) measures the chemical content of forests (fine spectral resolution). The wLiDAR sensor (white box) maps the geometry of the forest by measuring the structure below treetops, branches and to the ground.

SUMMARY

Utilizing proven Management Measures in Kamōhio Watershed will reduce the NPS excessive sedimentation and reduce sediment load by 0.5 T/A/Y (~5%/Y). Establishing drought tolerant, native dry forest plants on irrigation, capturing soil, and increasing infiltration rates will improve water quality and recharge in the aquifer, reducing the amount of runoff into Kamōhio Bay and thereby decreasing ocean turbidity. Modern techniques using LiDAR, multispectral analysis and high-resolution photography will assist with baseline information for future restoration efforts on Kahoʻolawe. In conjunction with many partnerships, the KIRC Restoration Staff will implement the nine monitoring components of the Management Measures installed in Kamōhio Watershed. Finally, this Kamōhio Watershed Plan was mentioned in the updated 2021 Hawai´i's Non-Point Source Management Plan (DOH 2021).

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http://kahoolawe.hawaii.gov
Kaho'olawe Island Reserve Commission Web site

http://coralreefs.wr.usgs.gov/sediment.html
USGS Coral Reef Project

http://water.epa.gov/polwaste/nps/success319/hi_kaho.cfm
http://water.epa.gov/polwaste/nps/success319/upload/hi_kahoolawe.pdf
US EPA Kahoʻolawe Success Story

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NCSS - National Cooperative Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm)
SSURGO - Soil Survey Geographic database (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627)

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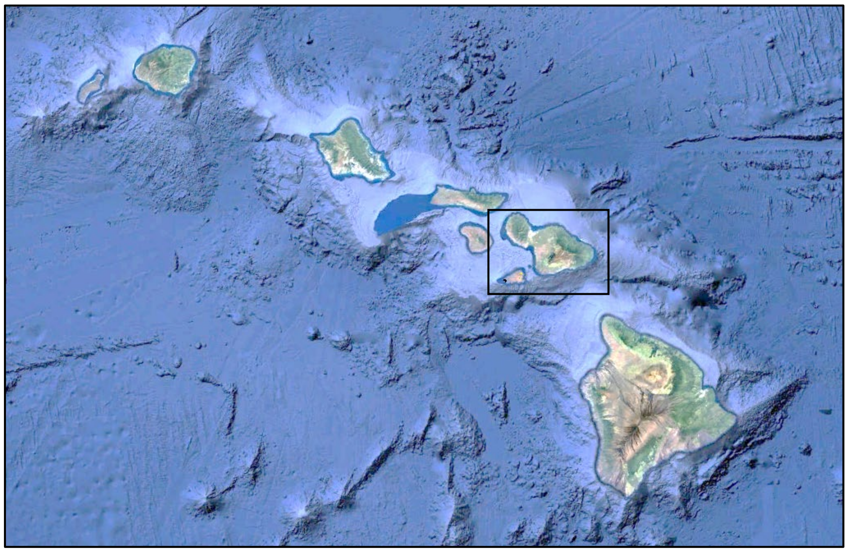
APPENDIX A

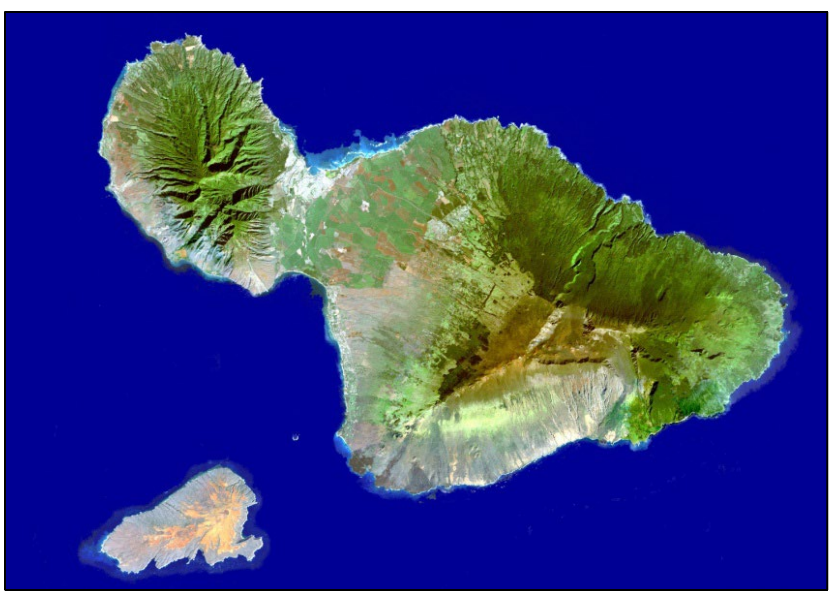
Description of Kaho‘olawe

Kaho‘olawe is the eighth largest of the main Hawaiian Islands and is located 11.2 km southwest of Maui.



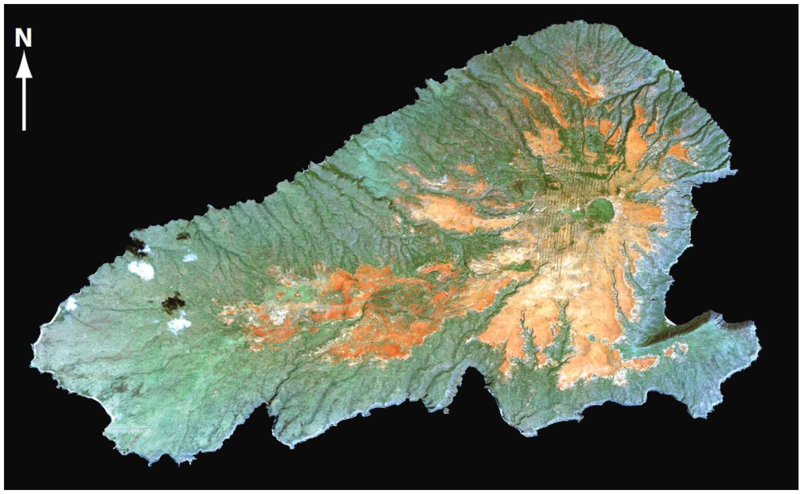
State of Hawai‘i

It is approximately 1.03 million years old (Naughton et al., 1980) and occupies an area of 117km^2 and is 17km long by 11km wide.



Kaho‘olawe and Maui Island

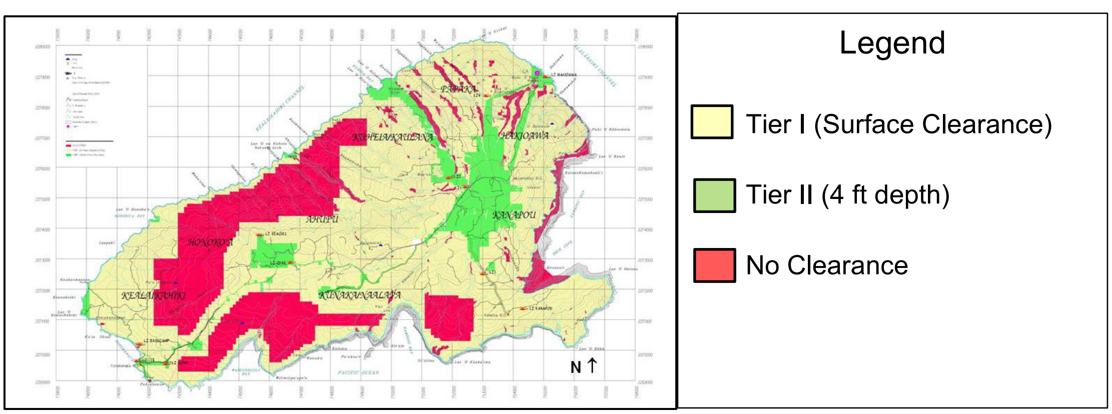
It is a single shield volcano (MacDonald et al., 1983) with a 5km wide caldera and a north rift zone that contains Lua Makika crater and the summit area of Puʻu Moaʻulanui, elevation 452m. A satellite image illustrates the barren hardpan on the island.



Satellite image of Kahoʻolawe

Note: Satellite image is from 2005 QuickBird image from USGS and USDA, NRCS.

The island possesses unique cultural sites (EKF, 1995) and is on the National Register of Historic Places and designated as the Kahoʻolawe Archeological District. From 1941 to 1994, Kahoʻolawe and its surrounding waters were under the control of the U.S. NAVY. Both the island and waters of Kahoʻolawe were used by the U.S. NAVY and allies of the United States as a live fire training area. Despite recent clearance efforts, unexploded ordnance (UXO) is still present (Figure 65) and poses a threat to the safety of anyone accessing the island or its waters (ARMP, 2002).



Final Map from Parsons UXB Clearance Project

Surface runoff on Kahoʻolawe is estimated at 7 x 10^7 m^3 (19 billion gallons) per year (Cox et al., 1995). Dike impounded groundwater system may hold between 21-86 billion gallons of water (County of Maui, 1990). Soil is lost through surface runoff into the ocean causing dense plumes of turbidity. During the period between October and March, there may be three or as many as seven major storm events in any particular year, and these storms may bring heavy rains and are sometimes accompanied by strong 50 mph winds at least on a local scale.

Windblown soils November 11, 2003

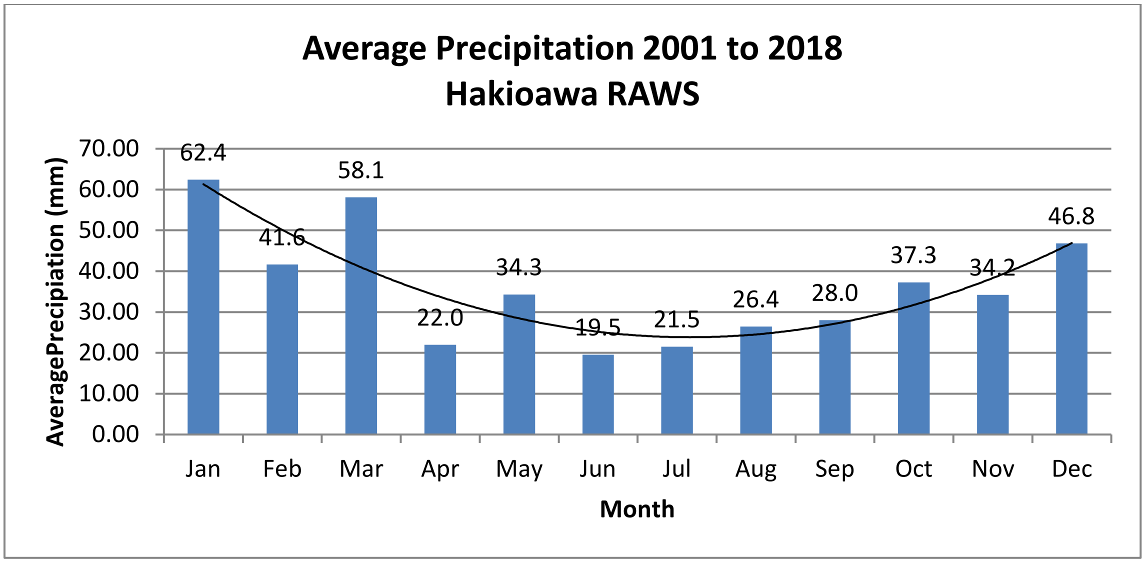
On the open hardpan, wind is the most significant factor preventing revegetation (KERP, 1998).

The storms are usually associated with the passage of a cold front, and may also be associated with a large eddy, or Low, that has been generated in the moving air. Moist, warm air swirling into such eddies produces clouds and torrential rains.

A Watershed is defined as a geographic area in which all sources of water, including lakes, rivers, estuaries, wetlands, and streams, as well as ground water, drain to a common surface water body. Because all Watersheds are defined by natural hydrology and ultimately drain to coastal waters, they are good focal points for managing coastal resources.

Precipitation Trends

Monthly precipitation averages from the Hakioawa Remote Access Weather Station (RAWS) from October 2001 to December 2018 are illustrated below.

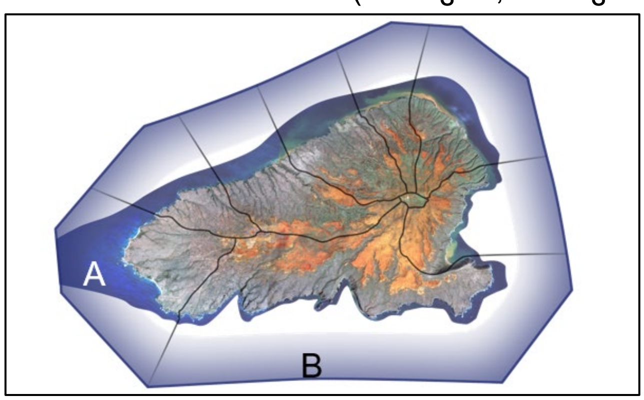


Hakioawa RAWS Average Monthly Precipitation 2001 to 2018

The wettest months are January through March, and the driest are June through August. Appendix D lists the monthly rainfall data from October 2001 to December 2018 from the Hakioawa RAWS.

Kaho'olawe Island Reserve (KIR)

The Kaho'olawe Island Reserve (KIR) is comprised of Zone which includes the island of Kaho'olawe and all the submerged lands and waters between the shoreline and the 30-fathom isobath which surrounds the island (HRS §6K, HAR §13-261).



Zones A and B of the KIR

Zone B is all waters and submerged lands between the 30-fathom isobath surrounding Kaho'olawe and two nautical miles from the shoreline of the island. The black lines are the 9 'ili designations.

The KIRC is responsible for the management of the KIR (78mi^2) which is included in one of the world's most important North Pacific humpback whale (*Megaptera* *novaeangliae*) habitats and the only place in the United States where humpbacks reproduce.

More than 60 percent of coral reefs in U.S. waters are found in the extended Hawaiian Island chain. These complex and diverse marine ecosystems are not only ecologically important but also provide hundreds of millions of dollars annually to Hawai'i's economy. (Field et al., 2005). In the final report of the Kahoʻolawe Island Conveyance Commission (KICC, 1993), Recommendation 2.12 states that;

> "*The State of Hawaiʻi shall recognize the waters surrounding Kahoʻolawe for their pristine nature - and their importance in maintaining numerous marine species populations - and designate these waters with special status under the law*".

The Kahoʻolawe marine protected area in Kamōhio bay encompasses rare intact deep-water habitats of commercially valuable bottom fish. Restoration of marine habitats depends upon the effectiveness of terrestrial revegetation efforts. Aluli and Macgregor (1992) state that Kahoʻolawe is a center for the revitalization of Native Hawaiian Culture particularly with regard to subsistence gathering of marine life.

Effect of Excessive Sedimentation on Benthic Organisms

With its steep cliff faces, rapid descent in depth and strong open ocean currents, the terrestrial run off from Kamōhio Watershed effects deep ocean (benthic) marine resources. Deep water survey cameras were dropped down to 213m (700ft) off the Kamōhio coast and the video imagery showed sedimentation impacting deep water environment and habitat of native bottom fish stocks. While sedimentation has been well documented to affect the shallow fringing reef of the north coast to remain in suspension for weeks, this deep-water video data showed it can also affect benthic organisms off the South Coast of Kahoʻolawe. (D. Tokishi, Personal Communication, 2019).

KIRC MASTER PLAN

Since 1995, there have been 6 major planning documents developed for the KIR.

1.) ʻAha Pawalu, a Cultural Protocol for Kanaloa Kahoʻolawe

2.) Palapala Hoʻonohonoho Moku Aina o Kahoʻolawe, Kahoʻolawe Use Plan

3.) Ola I Ke Kai O Kanaloa, Kahoʻolawe Ocean Management Plan

4.) Ho‘ola Hou I Ke Kino O Kanaloa, Kaho‘olawe Environmental Restoration Plan

5.) Access and Risk Management (ARMP) Plan for the Kaho‘olawe Island Reserve

6.) Cleanup Plan, UXO Clearance Project, Kaho‘olawe Island Reserve (by Parsons-UXB Joint Venture for the Naval Facilities Engineering Command Pacific Division)

Vision Statement

"*The kino of Kanaloa is restored. Forests and shrub lands of native plants and other biota clothe its slopes and valleys. Pristine ocean waters and healthy reef ecosystems are the foundation that supports and surrounds the island. Na Poe Hawai‘i care for the land in a manner which recognizes the island and ocean of Kanaloa as a living spiritual entity. Kanaloa is a Pu‘uhonua and Wahi Pana where native Hawaiian cultural practices flourish. The piko of Kanaloa is the crossroads of past and future generations from which the native Hawaiian lifestyle spreads throughout the islands.*"

Mission Statement

"Our mission is to implement the vision for Kaho‘olawe, in which the kino of Kanaloa is restored, and na po‘e Hawai‘i care for the land. We pledge to provide meaningful, safe use of Kaho‘olawe for the purposes of the traditional and cultural practices of the native Hawaiian people, and to undertake the restoration of the island and its waters."

KIRC Strategic Plan (2009 to 2013)

A 5-year Strategic Plan (2009 to 2013) was developed by the KIRC, creating specific Priorities and Core Values. In developing its strategic priorities, the Commission acknowledges the following.

- The primary planning documents previously adopted serve collectively as the foundation for the KIRC, especially Palapala Ho‘onohonoho Moku‘aina O Kaho‘olawe (The Kaho‘olawe Use Plan).
- There is an inherently Native Hawaiian purpose to the Kaho‘olawe Island Reserve, as recognized by history, the public, and in State and Federal laws, including but not limited to the statutory framework for the KIRC and the constitutional protection of customary and traditional access.

- The Protect Kahoʻolawe ʻOhana has a historical and cultural relationship with Kahoʻolawe.
- There are kupuna and families that have traditional and historical relationships with Kahoʻolawe.
- By State law, the Kahoʻolawe Island Reserve is to be managed in trust until such time and circumstances as a sovereign native Hawaiian entity is recognized by the federal and state governments.
- The remote geography of Kahoʻolawe presents its own challenges.
- The environment is fragile.
- There are extensive cultural and historical places.
- There are unexploded ordnance and other hazards.
- Monitoring and management of the risk is a state responsibility. By Federal law, there is a perpetual federal responsibility for the unexploded ordnance.
- The restoration and long-term management of the Kahoʻolawe requires a reliable and permanent funding source to secure the islands future. Currently, the KIRC does not receive regular funding from the State of Hawaiʻi but relies upon the remaining limited resources of the Kahoʻolawe Restoration Trust Fund established from the federal clean-up of the island.
- By state law, commercial uses of the Reserve are banned.

Strategic Priorities

Leadership – To increase the size, diversity, and sustainability of the trust fund and to manage the organization's budget in a manner that protects the trust fund.
To be prepared for the transition of the Reserve to the future Native Hawaiian Sovereign nation.

Restoration and Perpetuation – To access and stabilize cultural sites and provide for appropriate access and cultural practices. To systematically restore the environment.

Stewardship- To develop a significant volunteer base, especially in concert with stewardship organizations such as the PKO, for the purposes of cultural, natural resource, and marine resource restoration. To develop and maintain appropriate and sustainable infrastructure (including on-island and inter-island transportation, energy, communication, water, sanitation, and Kihei information center). To develop an enforcement network spanning the community and government, to protect Kahoʻolawe and its waters from illegal, inappropriate, and unsafe uses. To maintain a significant on-island presence for the purposes of managing and protecting the Reserve.

Education- To develop and distribute educational programs and materials towards the public's understanding of the cultural, historical, and spiritual significance of Kahoʻolawe.

Core Values

KIRC holds these values to be true to its mission and organization;

In our programs and in the way we operate, we embrace Kahoʻolawe's significant role in perpetuating the Native Hawaiian culture. We recognize Kahoʻolawe as a *Puʻuhonua* and *Wahi pana* – a scared place. In our actions, programs, training, and plans, we live and incorporate the values, practices, and protocols of the host culture. Our job is to restore the island and its waters and to increase the culturally appropriate, safe use of the Reserve towards the fulfillment of the vision for Kahoʻolawe.

Kahoʻolawe: 2026

A Strategic Plan entitled "Kahoʻolawe: 2026" has been developed in partnership with the Protect Kahoʻolawe ʻOhana, Office of Hawaiian Affairs, and the Aha Moku Advisory Committee. It establishes guidelines and set the pathway for the future use and development of the Reserve. Community input with statewide focus groups helped to develop program planning and performance measures in 2014. A website (kahoolawe.hawaii.gov/plan-strategic-2026.shtml) allows the public to obtain information regarding the focus group sessions and add input to the Kahoʻolawe: 2026 Strategic Plan.

KIRC Departments

From the spring, 2019 Ko Hema Lama lama newsletter of the Kahoʻolawe Island Reserve, the functions of the KIRC programs are described;

> *"The **Operations** Program provides transport, maintenance, manpower and overall safety within the Kahoʻolawe Island Reserve (KIR). The **Restoration** Program restores native land-based habitats and Watersheds through innovative strategies and addressing erosion control, habitat restoration and enhancement of the island's natural waters systems. The **Ocean** Program manages marine resources within the KIR fostering ancestral knowledge while integrating both ancient and modern resource management techniques. The **Cultural** Program provides for the care and protection of Kahoʻolawe's cultural resources as well as the expansion of meaningful cultural use of the island. The **Administration** Program supports all KIRC Programs while also managing volunteers, GIS mapping, community outreach, library, archive and collections management, fund development finance and human resources."*

Aloha Kahoʻolawe

A campaign to support Kahoʻolawe restoration and access, this initiative invites participation via membership donations, partnerships, and legislative support. Giving levels include Patron, Benefactor and Sustainer and individual donations protect, restore, and preserve the ocean and land in the KIR. The KIRC is a 170(c) 1 government nonprofit authorized per Tax Exempt Status IRS Publication 557 (https://www.irs.gov/pub/irs-pdf/p557.pdf).

Kahoʻolawe Island Reserve Biosecurity Plan

A Kahoʻolawe Island Reserve (KIR) Biosecurity Plan (KIRC, 2018) has been developed for the KIR and aligns with the State of Hawai'i Interagency Biosecurity Plan for 2017-2027 (https://dlnr.hawaii.gov/hisc/plans/hibp/). The KIR Biosecurity Plan outlines expectations for KIRC staff and visitors to be vigilant, and lists protocols for Pre-Border, Border and Post-Border biosecurity detection. It highlights IAS pathways and vectors to and from Maui (and other islands) to the KIR. This KIR Biosecurity Plan has one objective of keeping new IAS from entering the KIR and three (3) actions using an Early Detection/Rapid Response (ED/RR) approach to obtain the objective. The three ED/RR actions are **Prevention**, **Detection** and **Response** and are crucial to a successful Biosecurity Plan preventing new IAS from entering the KIR.

An Integrated Pest Management Plan (IPM) has been included in the Biosecurity Plan to review control methods for insect pests, rodents, and non-native plants in the Kamōhio Watershed. Prioritizing the most important species to target for control is a beneficial outcome of this plan, as well as developing an overall non-native plant management strategy. Project Managers will continue to keep a log of herbicide use and maintain good records of management activities.

A section on Ocean Biosecurity is included and covers proper sterilization of scuba and snorkeling equipment from invasive algae, before bringing them into the KIR. Furthermore, from section 7 of the KIRC form for Permitted Trolling in Zone B, it states under Prevention of Invasive Alien Species,

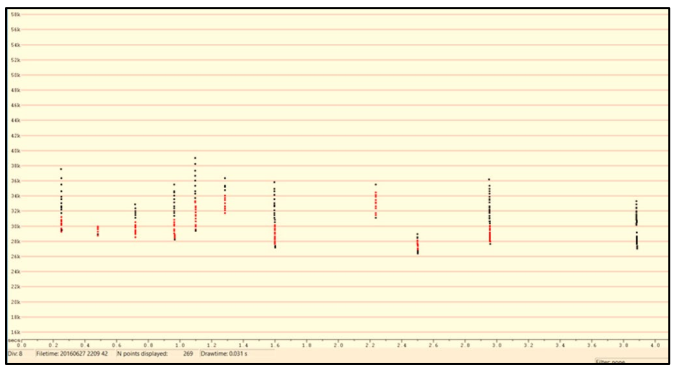
> "*The permittee will be held accountable to prevent any invasive alien species, plant or animal (i.e., invasive algae, barnacles, etc.) into the Reserve regarding the marine environment. It is the responsibility of the vessel operator to ensure vessel hulls are free of any IAS*."

APPENDIX B

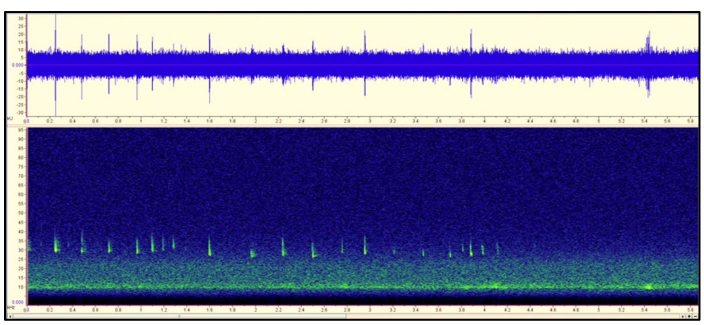
Endangered Animal Species in Kamōhio Watershed

Hawaiian Hoary Bat

Designated as a USFWS endangered species in 1969 under the ESA of 1970 (ESA, 1973) ʻŌpeʻapeʻa or Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) is Hawai'i's only endemic terrestrial mammal. The female is larger than the male, with a wingspan of approximately 27 to 34 cm (10.5 to 13.5 in) and it is a nocturnal insectivore. Calls are emitted from 20 kHz to 200 kHz. The ultrasonic echolocation pulse is very short at 1 to 14 milliseconds. The figures below illustrate the first bat sonar signal detected on Kahoʻolawe in the headwaters of Hakioawa Watershed on June 27, 2016.

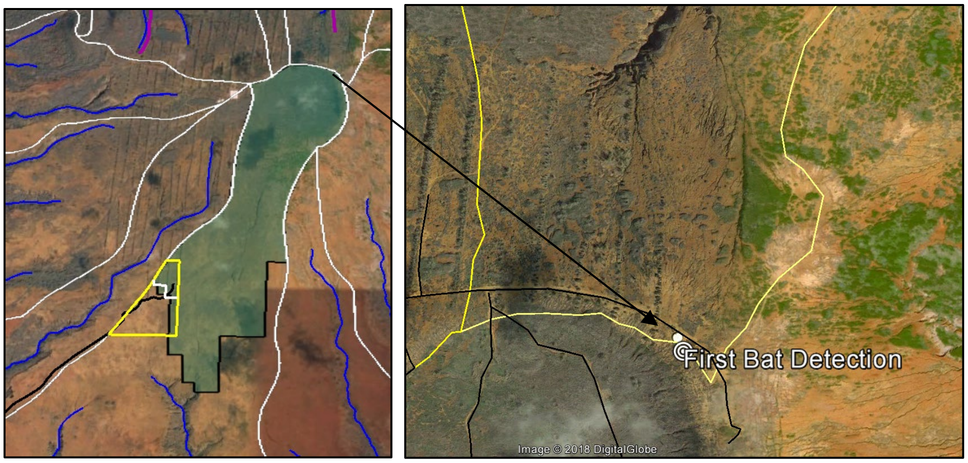


First Hawaiian hoary bat sonar detection on Kahoʻolawe, June 27, 2016



Full Spectrum recording of same Hawaiian Hoary Bat on Kahoʻolawe

A probability of detection (p=0.04) function, from data ranging from April 2016 to May 2017 showed a presence on Kahoʻolawe from July through December with a maximum of 23.9% in September. Peak hours of activity are 3-6 hours after sunset (Bruch, 2018). The figure below illustrates the location of the bat detector on the borders of Hakioawa and Kamōhio Watersheds.



Location of first bat sonar detection on border of Hakioawa and Kamōhio Watersheds

All eight of the bat detectors on Kahoʻolawe recorded presence of Hawaiian Hoary bats from 2016 to 2018 (Bruch, 2018).

Yellow Faced Bee

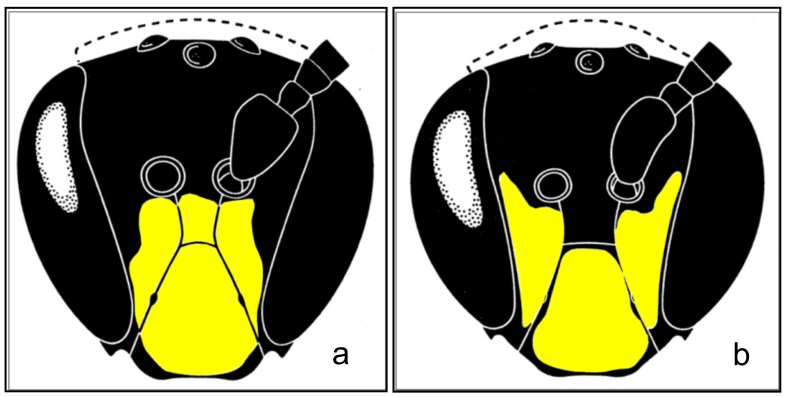
Two species of yellow faced bee (*Hylaeus anthracinus and H. assimulans*) were listed as endangered in a USFWS Final Rule (Federal Register Vol, 81, No, 190, 50 CFR, Part 17) on September 30, 2016, which became effective on October 31, 2016 (USFWS, 2016).

Yellow Faced Bee (*Hylaeus sp.*)
(Photo K. Magnacca)

"Belonging in the Hylaeus genus, and sub-genus Nesoprosopis, there are 60 native species in the Hawaiian Islands. The U.S. Fish and Wildlife Service (USFWS, 2016 has proposed in a Rule, that seven species of Hawaiian yellow-faced bees be listed as endangered under the Endangered Species Act. These were the first bees to gain federal protection in the United States. They are critical pollinators of many endangered native Hawaiian plants, and the decline of these bees could lead to the extinction of the plants that rely upon them. Protection of these imperiled pollinators

will benefit both the bees and the rare plants that they pollinate." Source; (http://www.xerces.org/blog/hawaiian-yellow-faced-bees-the-first-u-s-bees-proposed-for-esa-protection/).

Predation by non-native wasps and ants is a threat which compete with the yellow-faced bees for food and nesting resources. The bees depend on an intact community of native plants and are mostly absent from habitats dominated by non-native plant species" (http://blogs.scientificamerican.com/extinction-countdown/seven-hawaiian-bees-risk-extinction/) (March 31, 2009). The two endangered species which occur on Kahoʻolawe are described below.



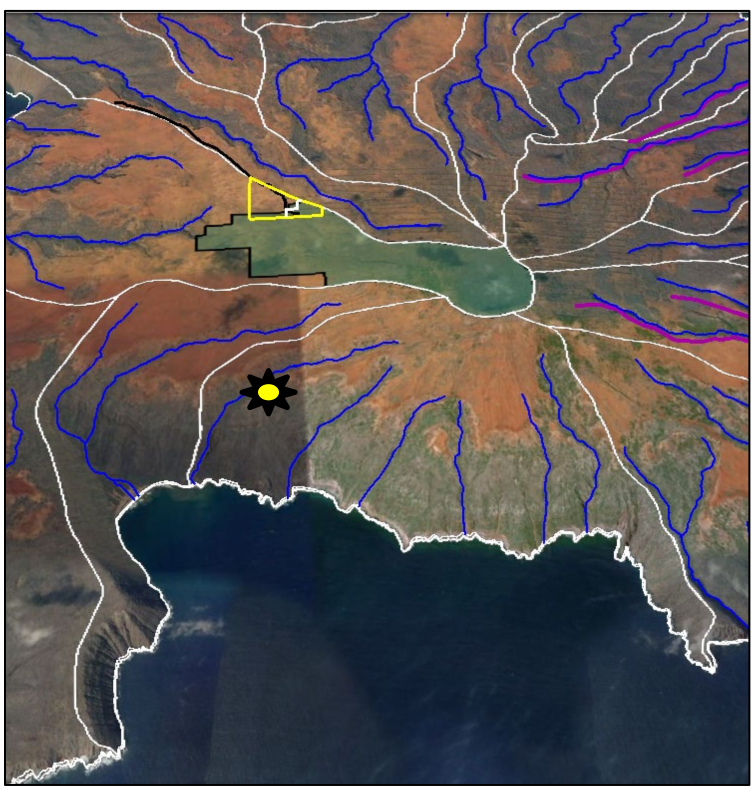
Schematic of two endangered, Yellow-Faced bees on Kahoʻolawe
Note: *H. anthracinus* (a) and *H. assimulans* (b).
Diagrams modified from Daly and Magnacca, 2003, Magnacca 2005a and 2005b.

Hylaeus anthracinus

H. anthracinus is a coastal, Yellow-faced bee endemic to the islands of Oʻahu, Molokaʻi, Kahoʻolawe, Maui, Hawaiʻi, and formerly Lanaʻi. It was observed on Pali o Kalapakea on January 14, 2002, at 305 m (1000 feet) on Akoko (*Chamaesyce celastroides*). It is in imminent danger of going extinct and will require active control and management of the area where populations are known to exist. In 1996, the U.S. Fish and Wildlife Service changed *H. anthracinus* status from a Category 2 Candidate Species (a 1984 designation), to a Species of Concern. As of October 31, 2016, it is listed as endangered (USFWS, 2016). It is distinguished by the single large facial mark, sometimes filling the entire area below the antennae. It is a medium sized bee with smoky wings and black legs. Although it can sometimes be found in moderate numbers, habitat destruction has caused its range to contract significantly. This species was found widely in the early period of Hawaiian insect collecting (1892-1930) but is now restricted to small, potentially vulnerable populations. Male face marks are yellow, consisting of a single large spot. The most recent taxonomic treatment was Daly and Magnacca (2003). *H. anthracinus* is generally found in the coastal habitat and like other coastal species, it can also occasionally be found at higher elevations in dry forest. Flower records include Naupaka (*Scaevola sericea)*, ‘Ilima (*Sida fallax*), Akoko *(Chamaesyce* spp.), Pua Kala (*Argemone glauca)*, Naio (*Myoporum sandwicense)* and Pa‘u o Hi‘iaka *(Jacquemontia ovalifolia* subsp*. sandwicensis)*.

Hylaeus anthracinus on naupaka (*Scaevola sp*.) *flower*
(Photo by Jason Graham)

Its known distribution on Kaho‘olawe is in Lowland Dry habitat along Pali o Kalapakea which is adjacent to Kamōhio Watershed.

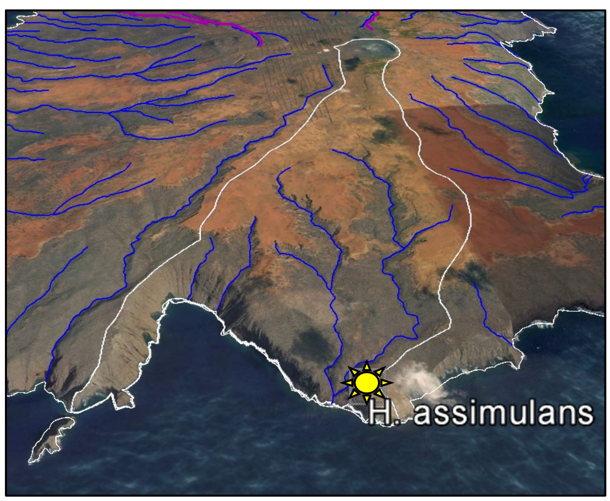


Known distribution of *H. anthracinus* in Lowland Dry habitat along Pali o Kalapakea on Kaho‘olawe

The biggest threat to *H. anthracinus* is habitat loss. Although the species can be found in relative abundance in some areas, native coastal strand vegetation is now extremely rare. Known populations of *H. anthracinus* on Kahoʻolawe are protected under the auspices of the State of Hawaiʻi and the Kahoʻolawe Island Reserve Commission. While susceptible to fire, maintenance of remaining habitat is the highest priority. Research is needed to determine life history requirements, including nest sites and pollen requirements, and to find additional populations. Source (http://www.xerces.org/hylaeus-anthracinus/).

Hylaeus assimulans

H. assimulans is a rare, Yellow-faced bee that is endemic to the Hawaiian Islands and is in danger of going extinct. In 1996, the U.S. Fish and Wildlife Service changed *H. assimulans* status from a Category 2 Candidate Species (a 1984 designation), to a Species of Concern. As of October 31, 2016, it is listed as endangered (USFWS, 2016). Historic collections of *H. assimulans* are from Oʻahu, Maui, and Lanaʻi, and more recently (February 17, 1997) it has also been taken on Kahoʻolawe near ʻIliʻililoa in Kamōhio Watershed.



Known distribution of *H. assimulans* near ʻIliʻililoa in Kamōhio Watershed

Males are black, face marks yellow, while females are entirely black, lacking coloration. The species is considerably larger (especially in the females) than any other Hawaiian species except those in the *H. pubescens* group. However, small specimens (the size of *H. longiceps*) have been taken on Kahoʻolawe. The most recent taxonomic treatment was by Daly and Magnacca (2003). *H. assimulans* inhabits coastal strand and dry forest and it is frequently collected on ʻilima (*S. fallax).* Its greater size may be an adaptation to handling the large pollen of that plant.

In recent collections, it appears to be less restricted to the coast and more often found in higher elevation forest than other species of similar habit. Such a tendency may be related to the dense areas of ʻilima (*S. fallax*) that can sometimes be found in the understory of dry forest. Nesting habits are unknown, but it probably nests in the ground like related species.

The biggest threat to *H. assimulans* is habitat loss, and the only protected populations of *H. assimulans* in the State are on Kahoʻolawe. Also, highly susceptible to fire, maintenance of remaining habitat is the highest priority. Research is also needed to determine life history requirements, including nest sites and pollen requirements, and to search for additional populations. Source (http://www.xerces.org/hylaeus-assimulans/).

Table 43 lists the threats associated with the decline of both *H. anthracinus and H. assimulans* (Daly and Magnacca, 2003).

Number	**Threat**	**Comment**
1	Habitat loss	
2	Decline of native plant hosts	Fire, Invasive Alien Species (IAS)
3	Predation by invasive ants	*Anoplolepis gracilipes* and *Pheidole megacephala*
4	Competition from honey bees	
5	Predation by Western Yellow Jacket Wasp	*Vespula pensylvanica*

Table 43 Threats associated with the decline of *H. anthracinus* and *H. assimulans*

Blackburn Sphinx Moth

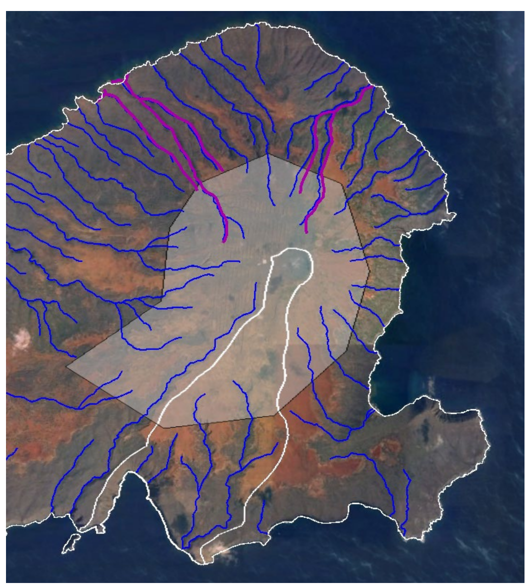
Thought to be extinct, the endangered Blackburn's Sphinx Moth (*Manduca blackburni*) was federally listed on February 1, 2000.

Blackburn's sphinx moth (*M. blackburni*)

It is Hawai'i's largest endemic insect (Rubinoff and San Jose, 2010) and its native host plant is the ‘Aiea (*Nothocestrum sp.*). However, it utilizes the Tree Tobacco (*Nicotiana glauca*) and so that plant will not be cut down in the Kamōhio Watershed but left as habitat for the moth. They will lay their eggs on the leaves and aestivate underground (Rubinoff and San Jose, 2010). Unfortunately, ants were observed on the tree tobacco and pose a threat to the insect instars and eggs. ‘Aiea (*N. latifolium*) has been planted in Hakioawa Watershed in 2018 but was eaten by the three lined potato beetle (*Lema daturaphila*).

Three lined potato beetle (*L. daturaphila*)

Kaho‘olawe has critical habitat designated for the moth which includes the upper and middle sections of Kamōhio Watershed (USFWS, 2003).



USFWS Upper Management Unit 5 (light grey polygon) for Blackburn's Sphinx Moth in relation to Kamōhio Watershed (white line) on Kaho´olawe

This figure illustrates the probable range of Blackburn sphinx moth including Kamōhio Watershed. During March and April of 2018, a survey for Blackburn sphinx moths was conducted by a University of Hawai´i at Manoa graduate student and visiting entomologist which included Kamōhio Watershed. Several larvae were found on tree tobacco (*Nicotiana glauca*) plants in the Watershed, and they concluded "despite the low numbers of non-native host plants (n=73), Kahoʻolawe seems to provide an important habitat and refugia for the reproduction and survival of Blackburn's sphinx moth." (Christine Elliot, Personal Communication, 2018).

Threatened and Endangered Seabird Surveys

From 2016-2017, the Kahoʻolawe Island Seabird Restoration Project deployed 12 Automated Acoustic Monitors (AAM's) on the island including 5 in the Kamōhio Watershed alone which is considered the most productive on Kahoʻolawe for Seabirds (Gondek et al., 2017). Both the endangered Hawaiian Petrel or *ʻuaʻu* (*Pterodroma sandwichensis*) and the Band-Rumped Storm-petrel (*Oceanodroma castro*) have been recorded in Kamōhio (Gon et al., 2017, KIRC, 2018). Partnering with the Maui Nui Seabird Recovery Project, Island Conservation and Conservation Metrics the survey was designed to search for the presence of six species: Hawaiian Petrel, Newell's Shearwater, Band-Rumped Storm-petrel, Bulwer's Petrel, Wedge-Tailed Shearwater, and Barn Owl prior to management actions proposed for the island.


Wedge-Tailed Shearwater pair in Kamōhio Watershed and an acoustic monitor being deployed on ʻAle ʻAle.

Photos: James Bruch

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APPENDIX C

Photos from February 2005 ‘Ili‘ililoa Pt in Kamōhio Watershed

APPENDIX D

Rainfall data 2001 to 2018 (mm) Hakioawa RAWS

Rainfall data (mm)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018		Average
Jan		104.39	62.23	222.00	120.90	10.16	32.79	5.33	159.26	12.19		4.06	40.89	103.63	46.48		8.64	3.05		62.40
Feb		22.61	17.27	121.67	76.45	28.70	8.13	70.36	4.06	11.94	3.05	16.26	19.56	88.14	49.02	5.10	35.81	129.79		41.64
Mar		1.27	56.64	69.09	42.67	203.96	78.49	0.00	49.28	14.99	30.23	60.96	28.19	107.19	42.67	60.71	95.50	45.47		58.08
Apr		28.70	14.48	10.16	20.32	13.21	4.83	11.94	12.70	10.67	3.30	6.86	3.30	5.08	44.20	19.30	104.90	59.44		21.96
May		88.90	1.02	131.83	19.56	9.91	14.22	14.73	14.22		21.08	2.54	54.10	20.83	15.75	56.39	10.41	73.41		34.31
Jun		3.81	21.08	3.56	32.26	0.76	8.64	15.24	4.32		34.80	17.02	12.95	9.65	60.71	52.32	21.08	14.48		19.54
Jul		19.05	20.83	9.14	38.10	7.87	12.19	12.95	1.78		34.04	8.64	43.43	39.62	13.97	25.15	40.64	17.27		21.54
Aug		9.40	5.59	37.08	15.24	1.52	49.02	26.42	0.00	12.45	9.14	9.65	12.70	37.85	120.65	39.12	4.57	58.93		26.43
Sep		3.05	28.45	99.82	39.37	5.59	16.51	42.42	6.10	22.86	17.78	5.83	9.91	8.38	83.06	26.92	14.48	45.72		28.01
Oct	9.14	143.00	24.38	35.81	17.02	158.75	11.94	23.37	11.18	16.76	4.06	2.54	12.19	11.57	37.08	7.62	74.42	70.10		37.27
Nov	132.08	16.51	5.08	30.99	62.48	76.45	81.79	11.68	18.03	25.15	4.06	1.52	31.50	8.89	82.30	2.79	17.78	6.86		34.22
Dec	23.88	1.52	64.77	25.40	6.35	8.38	286.00	23.88	29.72	89.92	4.83	4.83	10.67	38.86	10.92	121.16	67.31	24.13		46.81

End of Kamōhio Watershed Plan