NATURAL RESOURCES MANAGEMENT PLAN

for the

HENAHENA CONSERVATION UNIT

Photo by Don Coons

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STATE OF HAWAI'I
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EXECUTIVE SUMMARY

The Henahena Conservation Unit is located within the Puʻuwaʻawaʻa Forest Reserve, directly below the Forest Bird Sanctuary. It is the largest of the 11 conservation units in the forest reserve, encompassing an area of 824 acres (368.3 ha). The unit was formerly part of Puʻuwaʻawaʻa Ranch (Henahena Mauka Paddock) and has been grazed for decades by domestic livestock and wild animals. Stray cattle and a large population of feral sheep, goats, and pigs still occupy the area. Forest cover is degraded, but native vegetation has excellent potential for recovery. A large complex of ancient lava tubes provide habitat for rare cave invertebrates. Many passages contain deposits of subfossils bird bones and archeological features left by ancient Hawaiians. Several species of endangered plants and animals are found within the unit and portions of five (5) federally designated Critical Habitat Units are included within its boundaries.

This plan is one of a series of site-specific plans for the management of conservation units in the Puʻuwaʻawaʻa Forest Reserve. It is intended to supplement the Puʻuwaʻawaʻa Resource Management Plan and serve as an internal document to guide DOFAW in their management and restoration work in the Henahena Conservation Unit. The plan presents a brief history of Henahena land use, description of cultural and natural resources, and proposed actions for the restoration and sustainable management of the area. Specific management actions are recommended for infrastructure maintenance, forest restoration, invasive weed control, ungulate control, wildlife habitat improvement, lava tube protection, managing human activity, wildfire prevention, and resource monitoring.

INTRODUCTION

The Henahena Conservation Unit is one of 11 areas designated for special protection under the Puʻuwaʻawaʻa Resource Management Plan approved by the Hawaii Board of Land and Natural Resources on July 15, 2003. That plan presents 62 unique objectives that are intended to provide a framework for management of the land over a 10-year period. Management Objective #9 in that document calls for fencing native forest conservation units and subsequent removal of all ungulates. Unit-specific management plans are needed to set objectives and outline strategies for rare species protection, forest restoration, cave management, and threat abatement. This is the first of such plans.

The unit contains a number of important geological, biological, paleontological, and cultural features that should be protected. Key attributes of the unit are as follows:

- Lava tube systems with more than 100 entrances.
- Avian subfossil deposits in lava tubes.
- Rare cave-adapted arthropods.
- Endangered birds and mammals.
- Stands of endangered ʻaiea (*Nothocestrum breviflorum*) trees.
- Stands of mature sandalwood trees (*Santalum paniculatum*).
- Rare endemic plants.
- Critical habitat for five taxa of endangered species.
- Cave habitation sites used by ancient Hawaiians.

GENERAL SETTING

Location and Property Description

The Henahena Conservation Unit is located on the northern flank of Hualalai volcano between 3,400 and 4,200 feet elevation (1,036 and 1,280 m). It is managed by the State of Hawaii as a portion of the Puʻuwaʻawaʻa Forest Reserve and is also included within the Hawaiʻi Experimental Tropical Forest unit administered by the U.S. Forest Service. The unit lies downslope and adjacent to the Puʻuwaʻawaʻa Forest Bird Sanctuary, encompassing an area of 824 acres (fig. 1). Unimproved roads delineate portions of the unit and provide adequate access to most areas (fig.2).

Land Use

The Henahena unit was formerly leased by Puʻuwaʻawaʻa Ranch for pasture purposes and was part of the "Henahena Mauka Paddock". No English translation for Henahena could be found, but *Henahena* and *Henehene* can mean the same thing in Hawaiian since both are listed as variants of the other (S. Gon, pers. comm.). *Hene*, for example, can be a hill slope and that interpretation may be the basis of the paddock name. Henahena pastures have been grazed for decades by domestic livestock and feral animals. Most cattle were removed from the area in 2003 and new growth of native trees and shrubs is evident at many locations. Old paddock fencing still exists, but most sections are in poor condition and not adequate to exclude cattle. Feral sheep, goats and pigs still roam the area, a situation that continues to compromise plant regeneration.

THE REGULATORY ENVIRONMENT

Zoning

Hawaii's zoning regulations dictate the kinds of uses and projects that are acceptable in any given area on the island. Chapter 205 of the Hawai‘i Revised Statutes (HRS) grants power to the Land Use Commission to zone all lands into four districts: Agriculture, Conservation, Urban, and Rural. The conservation unit falls within the state's Agriculture District. This designation permits livestock grazing, cultivation of crops, forest clearing for pasture improvement, timber harvesting, and development of wind energy facilities. County zoning reaffirms or further refines state land use classifications.

Critical Habitat Designation

Critical Habitat has been designated by the U.S. Fish and Wildlife Service for a number of plant and animal species at Pu‘uwa‘awa‘a. Critical Habitat is a term in the Endangered Species Act identifying geographic areas that are essential for the conservation of threatened or endangered species and may require special management considerations. Designation of land as critical habitat does not require the landowner to implement recovery actions or to manage the land in a certain way, but it does require the landowner to consult with the USFWS if they undertake projects that entail Federal funding or permitting. Portions of five (5) Critical Habitat units occur within the Henahena Conservation Unit. These units are designated for one animal and four plant species, all of which are endangered:

- *Manduca blackburni*
- *Delissea undulata*
- *Hibiscadelphus hualalaiensis*
- *Nothocestrum breviflorum*
- *Zanthoxylum dipetalum*

Mitigation for Loss of Endangered Plant Species

The game mammal hunting program at Pu‘uwa‘awa‘a is expected to result in the incidental take of all unprotected plant species listed as endangered. DOFAW is currently preparing a Habitat Conservation Plan for Game Mammal Management that will describe strategies and actions needed to mitigate impacts caused by game animals. Plant species most affected will be protected and established in suitable areas (onsite and offsite) at a rate of three to one for each case of incidental take (Draft HCP for Game Mammal Management in North Kona, Hawai‘i). The Henahena Conservation Unit is one of the units selected for protection in the draft Habitat Conservation Plan.

THE PHYSICAL ENVIRONMENT

Climate

The climate at Puʻuwaʻawaʻa can generally be classified as subtropical in nature. Weather is similar to that in other upland Kona forests. Mornings are generally clear and sunny. During the day, the surface of Hualalai volcano absorbs large amounts of solar radiation. This heats air over the mountain and creates updrafts. The rising air mass draws in moist marine air that condenses as it moves upward. Cloud cover and/or rain typically occur in the afternoon. The cycle reverses in the evening. Cold air descends from the mountain summit and drives cloud cover out to sea.

A map of median annual precipitation, consisting of isohyet lines, is available in digital form from the State of Hawaiʻi (Giambelluca et al., 2013, http://rainfall.geography.hawaii.edu/interactivemap.html). This map indicates that average annual rainfall in the unit declines with decreasing elevation. During the climatological base period 1978-2007, annual rainfall averaged 39 inches in the southwestern corner of the unit, but decreased to less than 29 inches in the northeastern corner. However, Kona storms can create large annual fluctuations in rainfall. These weather systems develop west of Hawaiʻi, bringing moist southerly winds and rain which can persist for a week or more (Giambelluca and Schroeder, 1998). Most precipitation falls from January through May, with January being the wettest month (PRISM, 2008).

Geology

Volcanic activity at Puʻuwaʻawaʻa has created many unique geologic features. These include ʻaʻa, pahoehoe, and trachytic lava flows; volcanic glass or obsidian; cinder cones (pumice); spatter or tuff cones (coarse near-vent fallout); lava tubes with associated entrances and skylights; and other features including sink holes, lava trenches, cracks, rift zones, and tree molds. The conservation unit's most important geologic attribute is its exceptional density of lava tubes. These form when the surface of lava, flowing in a channel, cools and hardens. As the eruption ceases, the molten lava drains from the tube leaving an empty passage. Sections of lava tube often collapse creating skylights, sinkholes, cracks, and trenches. These openings can be very deep and often have vertical or undercut walls.

Geologic maps published by Wolfe and Morris (1996) place Henahena lavas in two general age classes. The unit is predominately covered with lavas that erupted 2,350± years B.P., but an older flow (3,000 to 5,000 years old) covers the southwest corner of the unit (fig. 3). All of these lava flows orignated on Hualalai. Pahoehoe (smooth, relatively unbroken material) is the primary

substrate in the unit. This lava type covers over 80 percent of the area and supports the complex maize of lava tubes that characterizes Henahena. Distinct ʻaʻa lava flows (loose, cobbled material) occur in the extreme western and eastern sections of the unit and at a few locations where they intermix with pahoehoe (fig. 4). This lava type does not generally support lava tube systems.

Subterranean Features

Lava tube systems are of special scientific interest, support significant flora and fauna assemblages, and play an important role in maintaining biological diversity. Volcanic caves contain objects of archeological, cultural, paleontological, and geological significance. They are, however, intrinsically fragile, being susceptible to rapid deterioration through vandalism, siltation, flooding, agricultural development, indiscriminate forest clearing, quarrying, and recreational activities. Underground passages may be damaged or collapse by driving vehicles or heavy equipment over them. Hawaii's cave protection law (2002) provides the legal basis for protecting lava tubes in the state.

An extensive lava tube complex, and associated flora, fauna, and paleontological deposits, are the most important features at Henahena. This combination of geological and biological attributes is exceptional within the Hawaiian Islands. Lava tubes are scattered throughout the conservation unit. Most of these begin upslope in the Forest Bird Sanctuary, continue through the unit, and extend below the lower boundary. The Potato Hill and Delissea systems generally define the limits of lava tube distribution in the unit (fig. 7). Lava tubes in this area are extremely complex with braided passages and multiple levels. Many are highly segmented and commonly blocked by lava plugs, breakdown piles, and other lava barriers. Lava tubes vary in size from a few feet in diameter to huge caverns. A number of passages have been mapped underground by volunteer cavers. This work was accomplished using compass, clinometer, and tape. However, many other passages await similar documentation as well as biological surveys (Table 1). GPS coordinates for over 100 cave entrances have also been recorded in the conservation unit to date, but many more undocumented openings exist. The swarm of volcanic openings and scattered tree molds at Henahena make foot travel somewhat hazardous. Hikers are often reminded of this danger by the presence of cattle and pig bones, visible at the bottom of many lava tube skylights.

In dry environments like Henahena, native tree growth and survival is greatly increased by their proximity to lava tube systems. This phenomenon is very apparent at Henahena where long narrow stands of mature ʻohiʻa trees grow in otherwise open pastures. Surveys indicate that these stands are associated with and generally follow large lava tube systems. Increased moisture

availability in subterranean passages apparently provides improved growing conditions for plants that are able to extend their roots into this environment.

Soils

Nine soil orders have been documented on Hawaii Island (Gavenda, et al., 1998). Two of these, Andisols and Histosols are the primary soil orders found in the conservation unit. Andisols are soils that developed from volcanic ejecta such as ash, pumice, and cinder. They contain very large amounts of organic matter in the soil surface layer (horizon). Andisols are generally highly productive soils. However, their aluminum and iron clay contents have a very strong capacity to absorb phosphorus, making this element unavailable for plants. With proper fertilization, this soil type can be made productive for a wide range of food crops (Deenik and McCellan, 2007).

Histosols are generally called bogs, moors, peats or mucks. These are soils that develop from organic materials and consist of more than 50 percent organic material in the surface horizons. They typically occur in cool, moist environments that are so wet that they have anaerobic conditions in the soil profile. In Kona, Histosols formed on recent lava flows where organic matter from decaying vegetation has accumulated. If these soils formed on ʻaʻa lava, the organic matter is mixed with the ʻaʻa fragments, making them very stony (up to 80 percent rock fragments). If they formed on pahoehoe lava flows, the organic matter accumulated above pahoehoe bedrock (table 2). Natural vegetation, growing on Histosols, is usually dominated by ʻohiʻa trees and various native fern species (Deenik and McCellan, 2007).

Soil series are the most specific soil classification within each soil order. These assemblages are typically delineated by parent material, rainfall, soil depth, slope conditions, drainage, and permeability. Seventeen soil series are represented in the Puʻuwaʻawaʻa Forest Reserve and Forest Bird Sanctuary. Additionally, non-soil strata such as lava flows, ash, cinder land, badland, and sand and gravel alluvium cover many areas. Hawaiian soil series are named (without diacritical marks) after geographic place names. Soil series represented in the Henahena Conservation Unit are Halekula (Andisol), Kamawai (Andisol), and Puuiki (Histosol), but the Kamawai/Puuiki combinations cover the greatest area (NRCS Soil Survey Staff. 2008) (Table 2; fig. 5). Soils in the conservation unit have some level of compaction and erosion associated with past logging and cattle ranching activities.

THE BIOTIC ENVIRONMENT

Vegetation

The Henahena unit supports a seasonally dry woodland plant community, characterized by low

rainfall and frequent droughts. It is a transitional vegetation zone that connects the moist montane mesic above and lowland dry forests below. This woodland is an important conservation link between the two forest types and supports both mesic and dry forest plants. Tree canopy crown cover varies greatly within the conservation unit, increasing from scattered (5-25%) in the eastern portion to open (25-60%) in the central and western portions (Jacobi, 1989). Understory vegetation currently consists primarily of non-native pasture grasses, especially Kikuyu (*Pennisetum clandestinum*) and fountain grass (*Pennisetum setaceum*). Forest cover has declined substantially in the past 50 years. Blackmore and Vitousek (2000) used aerial photos to measure the long-term loss of forest cover in the adjacent Waihou Conservation Unit. They found that the aerial extent of dense forest decreased 62 percent between 1954 and 1994 and that the area covered by grassland increased by 237 percent. A similar situation is apparent at Henahena.

Plant Communities: The Henahena forest is dominated by ʻohiʻa (*Metrosideros polymorpha*), mamane (*Sophora chrysophylla*), kolea (*Myrsine lanaiensis*), and koa (*Acacia koa*), respectively (fig. 6). Naio (*Myoporum sandwicense*) and iliahi or sandalwood (*Santalum paniculatum*) are widely scattered throughout the area. Common subcanopy shrubs include ʻaʻaliʻi (*Dodonaea viscosa*), mamake (*Pipturus albidus*), pilo (*Coprosma sp.*), and ʻulei (*Osteomeles anthyllidifolia*). The indigenous huehue (*Cocculus trilobus*) vine is widespread on the forest floor, while native ferns in the genera *Asplenium, Cibotium, Dryopteris, Pteris,* and *Tectaria* are generally restricted to shady locations. Kopiko ʻula (*Psychotria hawaiiensis*), papala (*Charpentiera obovata*), papala kepau (*Pisonia brunoniana*), aʻiaʻi (*Streblus pendulinus*), olopua (*Nestegis sandwicensis*), and kuluʻi (*Nototrichium sandwicense*) are present on ʻaʻa lava flows and outcrops, but in very low numbers. Detailed lists of native plants found at Puʻuwaʻawaʻa were reported by Takeuchi (1991) and Giffin (2009).

Unique Species: Sandalwood or ʻiliahi is an important component of the Henahena forest. It grows on pahoehoe and ʻaʻa lava flows in association with ʻohiʻa, mamane, and koa. *Santalum paniculatum* is endemic to the Island of Hawaiʻi and the only species found at Puʻuwaʻawaʻa. This species was a common forest component in the early 1900's. Koebelle (1900) reported finding sandalwood trees at Puʻuwaʻawaʻa with a trunk diameter over 18 inches in size. Today, sandalwood occurs at low frequencies, primarily in the Henahena area.

Plants in this family (Santalaceae) are terrestrial, hemi-parasitic shrubs or trees and are represented by two genera in Hawaiʻi, *Exocarpos* and *Santalum*. Four separate endemic species of sandalwood grow in the Hawaiian Islands and are valued for their aromatic heartwood oils. Within these species are several unique varieties, but only one, *Santalum freycinetianum* var.

lanaiense, has been officially recognized as endangered (Wagner, et al., 1999). Hawai‘i remains the only region in the world where sandalwood is being commercially harvested without regulations according to United Plant Savers, a group dedicated to protecting native medicinal plants and their habitat in the United States and Canada.

Sandalwood has important economic, cultural, and biological attributes. The value and fragrance of sandalwood increases with age, but only the heartwood and roots bear the fragrance for which the species is famous. Traditional Hawaiian uses of the fragrant heartwood include medicinal applications, and production of perfume, firewood, and musical instruments. Sandalwood trees provide habitat for a number of native birds and insects. Long-horned beetles (*Plagithmysus* sp.) and endemic death-watch beetles (*Holcobius* sp.) feed on the wood of the plant and larva of native moths (*Scotorythra corticea*) feed on the foliage. Rats, mice, and cardinals love the seeds and may take entire seed crops preventing germination in the wild. Foliage is palatable for cattle, sheep, and goats. Grazing will substantially reduce growth and preclude regeneration of the plant. Sandalwood is highly susceptible to fire and direct or indirect contact kills even large trees. (Merlin and VanRavenswaay, 1990; Stemmermann, 1990).

Rare Species: Several plant species at Henahena are considered rare or have been officially listed by the USFWS as threatened or endangered. Rare species are those that have no formal designation, but are considered by experts to be imperiled (Table 3). These species require protection to ensure their continued survival.

The endangered ‘aiea is scattered throughout the Pu‘uwa‘awa‘a Forest Reserve, but their greatest density occurs in the Henahena unit. These trees are generally restricted to lava tube openings and rough ‘a‘a lava flows where they are somewhat protected from ungulate damage. In 1909, Rock (1913) noted that ‘aiea were “exceedingly common” at Pu‘uwa‘awa‘a. He goes on to say that “The trunks, owing to their softness are easily damaged and often eaten out by thirsty cattle, and are often covered with peculiar looking scars, and covered with knobs, increasing the ungainly appearance of the tree. It may be said here that none of the species of Nothocestrum (*aiea* trees) deserves any claim to beauty; in fact they are the most ugly trees which the Hawaiian Islands possess”.

‘Aiea is a member of the nightshade family (Solanaceae) and includes herbs, shrubs, climbers and occasionally trees, many of which contain alkaloids. This group is represented in Hawai‘i by three native and nine introduced genera. The endemic genus, *Nothocestrum*, contains four species, two of which (*N. breviflorum* and *N. pelatum*) are classified as endangered (Wagner, et al., 1999). Two species of ‘aiea (*N. breviflorum* and *N. longifolium*) occur at Pu‘uwa‘awa‘a.

These tomato relatives are stout trees, typically with contorted trunks. *N. breviflorum* is semi-deciduous, often dropping its leaves during dry periods. *N. longifolium* grows in wetter locations and retains its leaves all year. The tubular yellow flowers of both species give off a pleasant fragrance and produce small orange fruit.

Delissea undulata (no common name) is an extremely rare lobelia. It was thought to be extinct until 1992 when a single individual was found growing in a collapsed lava tube at Henahena. This plant produced a few seeds before dying a few years later. Seedlings were propagated at Lyon Arboretum in Honolulu and then out-planted in exclosures at Puʻuwaʻawaʻa, effectively preventing the species extinction.

Fencing the world's last remaining *Delissea undulata* plant at Henahena (3,520 feet elevation. Copywrite © 1995 National Geographic Society. Reprinted courtesy of National Geographic Magazine, September 1995.

Wildlife

Many groups of terrestrial animals are conspicuously absents from the native Hawaiian fauna. Reptiles, amphibians, and mammals, except for bats, were unable to reach the island without the aid of man. As a result, Hawaii's native terrestrial fauna is dominated by only three groups of animals: birds, mollusks, and arthropods (especially insects).

Mammals: The Hawaiian hoary bat or ʻopeʻapeʻa (*Lasiurus cinereus semotus*) is Hawaii's only native land mammal. This secretive creature is often observed at Puʻuwaʻawaʻa and is known to commute and forage in the conservation unit. However, no information is available about its distribution, population size, roosting sites, or breeding activity. Ongoing koa forest regeneration is expected to create additional suitable habitat for this endangered mammal.

Birds: ʻApapane (*Himatione sanguinea*) and Hawaiʻi ʻamakihi (*Hemignathus virens virens*) are the only two native honeycreepers regularly observed in the conservation unit. The ʻelepaio (*Chasiempis sandwichensis*), a native flycatcher, is occasionally present in the unit along with the endangered Hawaiian hawk (*Buteo solitarius*). Over 90 percent of all hawk nests discovered at Puʻuwaʻawaʻa over a twelve year period (1990-2002) were restricted to a band of forest that included the Henahena and Waihou conservation units. The endangered Hawaiʻi creeper (*Oreomystis mana*) has been observed in the unit, foraging on ʻohia trees. This species was last sighted near the upper boundary (4,000 ft. elev., 1,220 m) on November 4, 1999 by J. Giffin and R. David.

Land Snails: A particularly rich land snail fauna was formerly present at Puʻuwaʻawaʻa, but most of these interesting creatures are now thought to be extinct. The largest mollusk to inhabit the area was an agate or tree snail (*Partulina confusa*). Empty shells of this snail are widespread at Puʻuwaʻawaʻa, but live individuals have not been found for decades. Subfossil records indicate that tree snails were formerly common between 2,300 and 4,400 feet (701.2 and 1,341 m) elevation with highest densities in the Henahena paddocks. Deposits of preserved land snail shells are also present on Puʻu Iki cinder cone and in lava blisters at the base of Poʻohohoʻo cinder cone. The current status of *P. confusa* is unknown, but it is possible that a few individuals may still survive at Puʻuwaʻawaʻa.

Forest Arthropods: Several arthropod species found at Henahena are considered sensitive by experts and require protection to ensure their continued survival. Many are restricted to specialized habitats or hosts that occur only at Puʻuwaʻawaʻa. A few forms are new to science and have not yet been named (table 4).

Blackburn's sphinx moth (*Manduca blackburni*) is Hawaii's largest endemic insect. It was considered to be extinct on Hawaii Island in the late 1970's (Gagne and Howarth, 1985). In December 1998, this species was rediscovered in the dry forest at Pu'uwa'awa'a (1,800 ft., 549 m elevation) by two professional photographers. They filmed a few immature caterpillars feeding on the leaves of Argentinean tree tobacco (*Nicotiana glauca*) and native 'aiea. Both trees are in the nightshade family, but 'aiea is the primary host plant for this rare animal. On February 18, 2001, a DOFAW biologist observed an adult *Manduca* moth at the PWWFBS cabin (4,000 ft., 1,220 m elevation). The moth was attracted to a light trap where it was captured, photographed, and released. On May 22, 2002, a DOFAW botanist found several mature caterpillars feeding on five-year old out-planted 'aiea trees in the forest bird sanctuary. This sighting is significant since it is the first record of *Manduca* reproducing on out-planted 'aiea. In 2011, DOFAW staff members found *Manduca* eggs and larvae on the leaves of 'aiea trees in the Henahena Conservation Unit, indicating the importance of this area as moth habitat. Henahena currently supports the greatest density of 'aiea remaining at Pu'uwa'awa'a and, therefore, comprises the best remaining native habitat for the species.

No detailed information is available on the current distribution or abundance of *Manduca* on the Island of Hawai'i, but free flying adults have now been recorded from Kohala and Hualalai volcanoes. At Pu'uwa'awa'a, moth numbers appear to have increase in the past few years due to the recent invasion of tree tobacco. Larvae are known to readily feed and develop on this weed. There is some concern that *Manduca* is becoming wholly dependent, or even specialized, on tree tobacco, now that the original hosts (*Nothocestrum* spp.) are so rare. Captive rearing efforts in the laboratory have also confirmed that *Manduca* larvae readily accept leaves of the indigenous popolo (*Solanum americanum*), a thin-leafed herbaceous plant, and develop successfully on them (Rubinoff and San Jose, 2010). *Manduca blackburni* was listed as endangered by the USFWS on February 1, 2000 and critical habitat for this species was designated on June 10, 2003. The hawk moth critical habitat unit at Pu'uwa'awa'a encompasses an area of 24,597 acres (9,954 ha).

Long-horned cerambycid beetles in the endemic genus *Plagithmysus* are an important conservation target at Henahena. All members of this complex group have evolved from a single immigrant ancestor. They fill a variety of niches in Hawai'i, but live almost exclusively on native trees and shrubs. Most species are so highly specialized that they can only exist on specific host plants. Many of the species are considered rare, but even common taxa are seldom seen by the casual observer due to their cryptic behavior. At least 136 species and subspecies of *Plagithmysus* are currently recognized by taxonomists. The island of Hawai'i supports 46 of these species, the greatest number known from any island.
Female plagithmysines oviposit their eggs on branches and stems of dead or dying woody

plants. Larvae hatch and bore under the bark to feed, leaving distinctive trails in the wood. At maturity, they excavate a cell (usually in the heartwood) and remain there to pupate. Emerging beetles bore through the bark to escape, leaving numerous exit holes in the dead tree. Adults are not attracted to flowers or artificial light, but they are drawn to damaged or freshly fallen trees of their particular host species. The five most important host plants for long-horned beetles are koa, alani, ʻohiʻa, mamane, and mamake *(Pipturus albidus*), respectively (Gressitt, 1980). Larvae of Cerambycid beetles are a major source of food for forest birds, particularly Hawaiian honeycreepers (Perkins, 1903).

Plagithmysus simplicicollis is one of the rarest long-horned beetles in the genus. This species is restricted to Puʻuwaʻawaʻa with the entire world population centered in the vicinity of the Henahena Conservation Unit (3,400 to 3,750 ft., 1,037 to 1,143 m elevation). Larvae feed exclusively on the wood of the endangered ʻaiea tree. Survival of this rare species depends completely on the continued existence of its endangered host plant.

Long-horned beetle (*P. simplicicollis*) reared from ʻaiea.

Plagithmysus elegans, another long-horned beetle, is on the verge of extinction. This insect feeds only on the rare papala tree. At Puʻuwaʻawaʻa, this insect has been collected in the Henahena unit. Both long-horned beetle species are considered "Species of Concern" by the USFWS. *Plagithmysus montgomeri* is somewhat more common, but depends on the rare ʻakoko tree for its continued survival.

Koa bugs (*Coleotichus blackburniae*) are threatened with extinction even though their host (*Acacia koa*) is generally common. Parasitism by biological agents, released for control of the southern green stink bug, is thought to be the major cause of their decline. Immature and adult koa bugs are frequently found in the Henahena unit, hiding in the foliage of koa trees. They feed by extracting juice from koa seed pods (Perkins, 1913).

Yellow-faced bees (Colletidae: *Hylaeus* sp.) are widespread in the Puʻuwaʻawaʻa Forest Reserve, but the greatest species diversity is found near the eastern boundary of the Henahena unit. A total of 15 species have been identified in the forest reserve to date (Giffin, 2009). This number is more than half of the total species (28) known from the big island. Seven Puʻuwaʻawaʻa species are listed as Species of Concern by the USFWS (May 10, 2006): *H. coniceps*, *H. difficilis*, *H.*

filicum, *H. hula*, *H. kona*, *H. ombrias*, and *H. pubescens*. However, this listing does not reflect the true status of group. *H. hula*, *H. kona*, and *H. paradoxicus*, are considered very rare, and probably endangered while *H. dimidiatus* and *H. ombrias* are restricted to endangered habitats. The remaining nine species are more common (Magnacca, 2007). *H. akoko* is new to science and is known only from Puʻuwaʻawaʻa (Daly and Magnacca, 2003). Females of *H. paradoxicus* are unique in that they are the largest species of the group and can be easily identified by their mahogany red abdomen. *Hylaeus* species nest in preexisting cavities such as hollow stems, wood holes, under bark, in crevices, under rocks, and burrows in soil.

Yellow-faced bees forage on several community-dominant plants at Puʻuwaʻawaʻa including ʻohiʻa, koa, olapa, naio, mamane, pukiawe, aʻaliʻi, and the rare poola. However, ʻakoko (*Chamaesyce olowaluana*) is one of the most favored host plants despite its rarity and peculiar flowers, which are minute and effectively petal-less (Magnacca, 2007). When flowering, these trees can support a great diversity of bees. On August 1, 2002, Magnacca (2007) collected nine species of yellow-faced bees from a single ʻakoko tree located approximately 0.1 mile east of Potato Hill (4,200 ft. elev.). There were almost no bees on other flowering trees nearby. The protection and restoration of ʻakoko is an important conservation action for the continued survival of several rare *Hylaeus* species that have extremely limited distributions (Magnacca, 2007).

Yellow-faced bees are important pollinators for many native plant species. In fact, they are almost the only regular floral visitors to some rare plant species and almost completely avoid the use of exotics. These bees are undoubtedly important for native plant reproduction and, therefore, ecosystem health (Magnacca, 2007). Most of the species are threatened with loss of native host plants, competition with other non-native bees, and introduced ants.

Cave-Adapted Arthropods: Lava tubes provide subterranean habitats for diverse communities of specialized underground animals (insects, spiders, and crustaceans). The ceilings, walls, and floors of lava tube passages are often draped with roots from trees growing above ground. Roots that penetrate passage interiors provide the primary nutrient source for cave-adapted creatures. The removal or loss of surface vegetation will interrupt nutrient sources for the subterranean ecosystem and result in the loss of obligate cave arthropods.

More than 26 species of cave-adapted arthropods are known from the Island of Hawaiʻi (Howarth, 1991). At least 13 of these occur in lava tubes at Henehena (Table 5). Further, two species of obligate cave arthropods discovered in the conservation unit are new to science and are not known to exist elsewhere (Hock and Howarth, 1999). They are a blind cixiid planthopper (*Oliarus makaiki*) and an eyeless terrestrial crustacean or amphipod (family Talitridae).

Cave plant hopper (*Oliarus polyphemus*). Photo by Peter and Ann Bosted.

Cave millipede ((*Nannolene* sp.). Photo by Peter and Ann Bosted.

Avian Paleontology

The most important avian fossil deposits ever discovered on the Island of Hawai‘i occur in volcanic lava tubes at Pu‘uwa‘awa‘a. Passage skylights and sinkholes created natural pitfalls where flightless and volant birds were trapped over the ages. The vast majority of these remains were deposited long before rodents or ungulates were introduced to the islands. They probably remained undisturbed for centuries except for occasional trampling by other victims, erosion from dripping water, and dispersal by flood waters. Perpetual darkness and stable temperature conditions allowed remains to persist in caves over long periods of time, facilitating their preservation. Preserved bird bones found at Pu‘uwa‘awa‘a are not per mineralized like traditional fossils and, therefore, are correctly called “subfossils”. Over time, remains of some animals have been covered by falling rocks or buried in collapsed lava tube passages. Damage to subfossil deposits also occurs when domestic cattle and feral ungulates enter lava tubes or fall into openings and trample bird bones before dying.

Fossil skull of an extinct flightless goose.

Fossil remains of an extinct flightless goose.

Numerous remains of previously unknown or recently extinct bird species have been discovered in Henahena lava tubes (Giffin, 1992, 2009; James and Olson, 2003). Subfossil records document the area's avian diversity prior to the arrival of man and shortly thereafter.
Bird remains discovered at Henahena can be broken into four distinct groups. Prehistorically extinct species include flightless rails (*Porzana* spp.), giant flightless geese (*Branta rhuax*), hammer-billed crows (*Corvus* sp.), and giant nuku-pu‘u (*Hemignathus vorpalis*). Historically extinct species include the moho or Hawaiian rail (*Porzana sandwichensis*) and Hawaii ‘o‘o (*Moho nobilis*). Species that are still extant, but endangered include dark-rumped petrels (*Pterodroma phaeopygia sandwichensis*), nēnē (*Branta sandvicensis*), Laysan ducks (*Anas laysanensis*), and ‘alae-‘ula or gallinules (*Gallinula chloropus*). Species that no longer exist at Pu‘uwa‘awa‘a, but occur elsewhere on the Island include ‘oma‘o or Hawaiian thrush (*Myadestes obscurus*) and band-rumped storm petrels (*Oceanodroma castro*). Subfossil bones that have been removed from lava tubes at Henahena and are now in collections at Lyman Museum in Hilo, Bishop Museum in Honolulu, and the Smithsonian Institution in Washington D.C. Many caves still contain remains awaiting removal or possible on-site protection (Table 6).

THE CULTURAL ENVIRONMENT

Cultural and Historic Resources

Hawaiians likely utilized upland forests, including the Henahena area, for extracting specialized resources such as bird feathers, hardwoods, and forest plants for traditional and medicinal usage. Caves were an integral component of traditional Hawaiian activities and served multiple functions including habitation, water collection, food storage, refuge, and burial/interment (Dougherty, 2008). Several Hawaiian names were associated with volcanic cave formations. These included *ana, lua, pao*, and *‘a‘a‘a*, all of which have similar meanings. Henahena lava tubes contain numerous archeological features left by ancient Hawaiians including, rock platforms,

fire pits, and calabash cradles for catching water. Some caves are littered with charcoal from torches. No burial sites were encountered in any of the Henahena caves.

Several historic-era structures are present within the conservation unit. Stone walls, constructed by ranchers to contain cattle, are a common feature in the landscape. A well preserved stone corral also exists near the lower (northern) boundary of the unit at 3,600 feet (1,097 m) elevation. This enclosure is approximately 272 by 448 feet (85 by 140 meters) in size and covers an area of about three acres (1.2 ha). An old redwood water tank was formerly present in the southeast corner of the unit, but it recently collapsed and is no longer functional.

Lava tube entrances were sometimes modified by early ranchers to prevent the loss of livestock. Rock walls were built around a few skylights to prevent cattle from falling into the openings and stone ramps were constructed in volcanic pits to aid in removing trapped animals.

RESOURCE MANAGEMENT OBJECTIVES AND STRATEGIES

Management objectives and strategies for the Henahena Conservation Area should focus on restoration of native forest cover, protection of subterranean life forms, protection of fossil bird deposits, and preservation of cultural features. The actions needed to achieve these goals are presented below.

Objective 1: Control Ungulates

Fencing plays a critical role in native forest protection. The exclusion of ungulates by fencing allows native vegetation to recover from past damage. Boundaries of the unit are generally delineated by old, deteriorated ranch fences or rock walls. However, the southern boundary shares a common ungulate-proof fence with the Forest Bird Sanctuary. Other boundary segments are either unfenced or lack ungulate-proof fences.

A primary management objective is total removal of domestic cattle and feral pigs, sheep, and goats from the conservation unit. Ungulates cause extensive damage to native forests by feeding directly on plants (foliage, branches, and bark), uprooting vegetation, and by trampling. These animals also transport noxious weed seeds on their fur and in their feces. Ungulate removal should occur as soon as unit fencing is completed.

Recommended Actions:

- Complete the environmental assessment process for new fence construction if needed.
- Update existing archeological inventory to reflect recent unit boundary changes.

- Construct ungulate-proof boundary fences around the unit.
- Remove all domestic cattle and feral ungulates from the conservation unit using organized drives, traps, dogs, snares, and hunting.
- Fence all lava tube entrances that allow ungulate access into the fenced unit.

Objective 2: Maintain Infrastructure and Improvements.
A network of unimproved roads serves most sections of the conservation unit. However some of these are only accessible by 4WD all-terrain vehicles (ATV).

Recommended Actions:

- Improve the access road along the northern boundary.
- Maintain all existing roads serving the unit.
- Maintain conservation unit boundary fencing.
- Maintain existing protective fences around individual rare plant species.

Objective 3: Restore Forest Cover.
Formal designation of conservation unit boundaries and removal of domestic livestock is a critical step in forest recovery. Native vegetation is still threatened, however, by feral animals, invasive weeds, rodents, slugs, ants, and other non-native organisms. Koa restoration is especially important. Research at other locations on the Island of Hawaii has shown that developing stands of koa physically modify pasture lands and create conditions more favorable to growth and survival of native understory species (Baker et al., 2009). Grassland soils at Puʻuwaʻawaʻa may be nitrogen limited. By re-establishing nitrogen fixing trees such as koa and mamane, these limitations may be lessened. An established canopy of mamane and koa will also help shade out non-native pasture grasses and provide an environment more beneficial to shade tolerant understory native species. Forest restoration and associated activities (non-native species control etc.) will be prioritized in the Henahena Conservation Unit based on relevant factors such as 1) likelihood of success; and 2) restoration of critical habitat for threatened and rare species. In highly degraded areas, threat mitigation (such as removal of fine fuels) will be given priority.

Recommended Actions:

- Outplant forest "infrastructure species" like koa, ʻohiʻa, mamane, and aʻaliʻi to speed forest recovery.
- Protect native plants from damage by excluding domestic and feral mammals.
- Scarify soils in open grasslands to stimulate germination of koa and mamane seeds.

Objective 4: Prevent the Introduction and Spread of Habitat Modifying Weeds.
Invasive non-native plants pose a particular threat to native vegetation. The introduction of non-native plants began with the arrival of the first Polynesians and this practice continues today. Non-native species often have few ecological controls and thrive under disturbed conditions created by man and his introduced animals. Introduced species may aggressively out-compete native species, degrade native habitats, and impact sensitive species. Plants posing the greatest threats to forest recovery at Henahena include fountain grass, kikuyu grass, banana poka (*Passiflora mollissima*), silk oak (*Grevillea robusta*), cape ivy (*Delairea odorata*), fireweed (*Senecio madagascariensis*), lantana (*Lantana camara*), tree tobacco (*Nicotina glauca*), daisy fleabane (E*rigeron karvinskianus*), and Maui pomakani (*Ageratina adenophora*). In most cases, it will not be possible or even desirable to eliminate these species altogether. Therefore, the following recommendations focus on targeting those species with the greatest potential for habitat disruption. Control activities will be thoughtfully scheduled to accommodate the most effective post control success (i.e. restoration activities or maintained perpetually as fuel breaks).

Recommended Actions:

- Control fountain grass by mowing, weed-whacking old foliage, or pulling plants and then treating new growth with herbicides.
- Control Kikuyu grass by treating foliage with herbicide. Multiple treatments may be necessary to control grass species.
- Control silk oak by applying herbicide to all trees within the conservation unit and in a buffer zone one-half mile wide around the unit.
- Prevent banana poka from spreading and covering native trees and lava tube skylights.
- Locate, map, and control other high priority weed infestations with herbicide applications or by manual removal.
- Prevent new habitat-modifying weeds from establishing/spreading.
- Utilize domestic livestock to reduce fire fuel biomass around the perimeter of the conservation unit.
- Implement recommendations described in the Three Mountain Alliance Weed Management Plan (Rubenstein and Berkowitz, 2009) for the North Kona Management Area.

Objective 5: Protect Native Invertebrates
Many native invertebrates are obligate specialists on rare host plants. Since some host plants are in turn threatened or endangered, their importance in terms of invertebrate conservation is considerable. Several native arthropod species are currently facing local extirpation or

extinction at Puʻuwaʻawaʻa due to the loss of their host plants. Blackburn's sphinx moth depends on the continued existence of ʻaiea, its primary host plant. Long-horned beetles (*Plagithmysus* spp.) are at risk as they are highly specialized feeders and many of their host trees are rare or endangered. Yellow-faced bees are threatened by various factors at Puʻuwaʻawaʻa. Habitat loss, competition with introduced honeybees (*Apis mellifera*), and predation by ants are especially detrimental. Feral honeybees establish hives inside lava tube openings, tree cracks and other holes. These highly social insects aggressively displace native bees (Staples and Cowie, 2001) and are a major competitor for nectar and pollen resources in some areas (Daly and Magnacca, 2003). Honeybees can travel up to 8 km (4.97 miles) from the nest site to forage for nectar, pollen, and resins (Triplehorn and Johnson, 2005). Introduced ants prey on several species of native insects and compete with them for food and nesting sites.

DOFAW's practice of issuing right-of-entry permits for commercial bee keeping on state forest lands presents a potential conservation problem for native bees. Introducing swarms of honeybees into yellow-faced bee habitat encourages direct completion between the two species for limited resources and may adversely affect native bee survival.

Recommended Actions:

- Restore native arthropod habitat by propagating and out-planting host plant species that support rare insect associations.
    a. Plant ʻaiea and popolo seedlings to provide a native food source for larvae of the endangered Blackburn's sphinx moth.
    b. Plant ʻaiea and papala seedlings to provide a native food source for rare long-horned beetle larvae (*Plagithmysus elegans* and *P. simplicicollis*).
    c. Plant ʻakoko seedlings to provide nectar for native bees and a food source for rare long-horned beetles (*Hylaeus* spp.and *Plagithmysus montgomeryi*)
    - Place seedlings in close proximity or interspersed among existing wild individuals that support target arthropods. This will facilitate natural colonization of the new plants.
    - Protect new plantings within the conservation unit as needed to prevent damage by rodents, game birds, and pest insects.
    - Restrict commercial bee keeping activities to areas more than five miles away from conservation unit boundaries.
    - Remove feral bee colonies from lava tubes and dead trees whenever possible.
    - Control ants by removing established colonies.
    - Avoid application of pesticides on host plants unless absolutely necessary.
    - Control slugs by baiting plants in exclosures with metaldehyde snail bait.

- Monitor for the presence or absence of rare host-dependent insects on new plant communities to determine the effectiveness of management actions.

Objective 6: Control Pest Insects

Big-headed ants (*Pheidole megacephala*) are a serious threat to the survival of endemic forest insects at Puʻuwaʻawaʻa. Cerambycid beetles, emerging from mamane and lama wood, are often attacked by armies of ants. Ants chew off the antennae and fore legs of these beetles and kill many of them before they can exit their pupal cells and take flight. Ants are also known to prey on other native insects and are suspected to significantly affect the survival of nestling birds. Ants commonly "farm" aphids on native vegetation, a practice that can severely weaken host plants and kill seedlings (Messing et al., 2006)

Yellow-jackets (*Vespula pensylvanica*) are ubiquitous at Puʻuwaʻawaʻa and develop extremely high population densities during dry periods. These predatory wasps pose a threat to native insects, birds, and humans.

Recommended Actions:

- Control ant colonies with baits such as Amdro.
- Ensure all nursery grown plants are obtained from ant free facilities.
- Restrict importation of construction materials and supplies from ant infested areas.
- Control yellow-jacket wasps and honeybee nesting colonies whenever found. Dusting hives with Ficam B (1% Bendiocarb) may be effective.

Objective 7: Control Non-native Mammals

Rats, mongooses, feral cats, and feral dogs are serious threats to native plants and animals. Rats damage the flowers, fruit, seeds, and bark of native plants. Their appetite for seeds is probably a major reason for the reproductive failure of certain species. These rodents are a particular threat to sandalwood tree reproduction as they actively collect and eat seeds in large quantities. Rats and mongooses are important predators of native wildlife including arthropods, snails, and birds. They also prey on the eggs and young of native birds and introduced game birds. Feral cats are equally destructive to native wildlife species.

Recommended Actions:

- Deploy rodenticides such as Zinc Phosphide for rats and Diphacinone for mongooses at seedling out-planting sites.
- Trap rats, cats, dogs, and mongooses as needed.

Objective 8: Restore Forest Bird Habitat

Koa is a keystone species for endemic Hawaiian wildlife and should be the focus of habitat restoration activities in the conservation unit. This fast growing tree in the pea family (Fabaceae) is considered one of the most important host plants for endemic Hawaiian invertebrates. These insects and their larvae are in turn fed upon by native forest birds. Hawaiian birds use koa for nesting, feeding, roosting, and other requirements of their life cycle. Some nectivorous avian species even switch to an insectivorous diet when rearing their young. The success of many wildlife species at Puʻuwaʻawaʻa depends on the presence of koa as a forest dominant.

Recommended Actions:

- Scarify sections of open grassland with a bulldozer to stimulate koa seed germination.
- Control vectors of avian diseases by preventing mosquitoes from breeding in water tanks and other bodies of standing water.
- Reduce competition from non-native birds by limiting the abundance of banana poka. Flower nectar produced by this plant is a major food source for Japanese white-eyes.

Objective 9: Protect Lava Tube Ecosystems

Plant communities growing above lava tubes are an integral part of subterranean ecosystems. Roots of native species, especially ʻohiʻa and mamane, are the primary source of energy for Hawaiian cave life. Any damage to surface vegetation by land clearing, soil erosion, invasive plants, or ungulate activity adversely affects the underground environment and survival of endemic cave organisms. Fire is perhaps the most destructive agent for underground life as it destroys their nutrient sources.

Recommended Actions:

- Survey and map all important lava tube systems including their entrances.
- Conduct archeological surveys to locate and identify important cultural features.
- Prevent animals from damaging vegetation above lava tube passages.
- Construct barrier fences to keep domestic and wild herbivores out of lava tubes.
- Establish bait stations to poison rodents in fenced areas and at cave entrances.
- Control fountain grass and other introduced plant species above lava tubes.

Objective 10: Manage Human Activity

Management, research, educational, and public recreational activities have the potential to damage conservation unit resources. Some attractions in the conservation unit, such as caving, are highly sensitive and/or hazardous. Staff and visitors alike need timely information about the

effects of wildlife disturbance, potential for habitat damage, and special hazards.

Recommended Actions:

- Conduct hazard assessments, particularly in areas of high human activity.
- Determine and recommend activity intensity levels for recreational features in the unit.
- Prevent entry to lava tubes set aside for preservation of fossil bird deposits.
- Create and post informational, advisory, boundary, and warning signage as needed.
- Generate other informational material about resource protection, fire hazards, and unit closures.

Objective 11: Minimize the Threat of Wildfire.

Forest fires are a common occurrence at Puʻuwaʻawaʻa. The combination of highly flammable exotic grasses and dry atmospheric conditions creates an extreme fire hazard during most months each year. Large wildfires have been a common occurrence in recent decades. Fires generally originate along the Mamalahoa Highway (Highway 190), but several have started at more isolated sites. A series of firebreaks has been constructed along the highway to help retard the spread of roadside fires. No firebreaks are available at higher elevations or around the conservation unit.

On March 5, 1995 a major wildfire was accidently started at Puʻuwaʻawaʻa when campers staying at Shangri-la cabin, accidentally started a grass fire. This fire quickly burned down the ranch cabin and spread into the adjacent Puʻuwaʻawaʻa Forest Bird Sanctuary. Over 600 acres of valuable forest bird habitat were burned in the lower northeast corner of the 3,800 acre sanctuary. Another 300 acres of native vegetation in the Henahena mauka paddock were also burned. The smoldering fire was finally extinguished 16 days later (March 15th) when heavy rains drenched the area. However, the burn stimulated thousands of koa and mamane seeds to germinate and the resulting seedlings attracted large numbers of feral sheep. These animals browsed extensively on the new growth and many of the seedlings were consumed before sheep could be controlled.

Recommended Actions:

- Update regional fire plan with all cooperators.
- Complete fire training for staff.
- Establish/implement fire prevention and response protocols for staff and visitors.
- Identify/purchase needed fire suppression equipment.
- Plan/construct additional water catchment/storage capability.

- Develop grazed buffer zones around conservation units to protect them from wildfire.
- Reduce fuel loading on conservation unit roads by mowing.
- Establish fuel free parking areas for vehicles and safety zones for people.
- Remove fire fuels around the perimeter of rare plant exclosures by grazing or mowing.

Objective 12: Monitor Resources

Resource monitoring and recording changes over time provide critically important data for managing biological resources. This information will allow the determination of trends, as well as noting the results of management actions. Monitoring provides a consistent, definitive way of knowing what is going on with the resource. For example, transects designed to monitor vegetation recovery in the unit will document changes in the plant community composition, including the distribution and abundance of invasive plant species, and will help gauge the ability of disturbed habitat to recover in the absence of ungulate activity.

Recommended Actions:

- Prioritize and document the efficacy of management actions.
- Establish photo-plots to visually record changes in forest cover over time. Mark each plot with a numbered iron post and record GPS coordinates. Repeat photos every 5 years with views in all four cardinal directions.
- Check fences monthly for damage or signs of ungulate ingress.
- Monitor efficacy of invasive weed control activities.
- Establish/monitor permanent ungulate transects.
- Establish/monitor permanent vegetation transects.
- Determine human use thresholds that would trigger management/remedial actions.

Objective 13: Research Needs

Scientific research activities are needed to support plant and wildlife restoration efforts and management objectives set forth in this plan. Offering guidance on the types of studies needed may help students and researchers develop projects that will enhance our understanding of biological resources in conservation units and the steps necessary for their conservation.

Recommended Actions:

- Determine the specific effects of alien bees and ants on the survival of yellow-faced bees.
- Investigate the nesting biology and food habits of yellow-faced bees.
- Determine the extent of native plant pollen usage by yellow-faced bees and the role of these insects in perpetuating native ecosystems.
- Investigate feeding habits of Blackburn’s sphinx moth and consequences of switching

from native host plants (*Nothocestrum* spp.) to the non-native tree tobacco.

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Table 1. Lava Tube Systems at Henahena (updated 4/20/2011).

SYSTEM NAME	MAPPED	LENGTH (ft.)	ELEVATION (ft.)	SPECIAL FEATURES
Alani	no			Cave-adapted invertebrates
Ambigua (upper)	yes[1]	6,437	4,400-5300	Extinct geese (subfossils), *Phyllostegia ambigua*
Ambigua (lower)	yes[2]	621		
Delissea (upper)	partial[2]		3,200-5,400	
Delissea (lower)	partial[2]			Extinct crow (subfossil), *Delissea undulata*
Delissea side passage	no			
Display/Upper Owl	partial[2]	8,857		Educational features
Case	no		3,800-3,900	
David Smith	443			
Giant Cow Skull	yes[2]	478		
Hapuu	no		3,400-4,200	Cave-adapted invertebrates
Owl (upper)	partial[2]	5,270	3,000-4,400	
Owl (lower)	partial[2]	2,786		Archeological features
Owl 6-7	partial[2]	2,447		
Petrel	yes[2]	1,345	4,000-4,200	Giant nukupuu (subfossil)
Pig fence	yes[2]	1,332		
Potato hill	no		3,800-3,900	*Thaumatogryllus cavicola*
Shangri-la (upper)	partial[2]		3,200-4,400	
Shangri-la (lower)	partial[2]			
FB Cave	partial[2]	760		
Yellow-jacket	no		4,000-4020	*Oliarus makaiki & Oliarus polyphemus*

[1] Bern Szukalski et al.
[2] Doug Medville et al.

Table 2. Summary of Soil Types at Henahena.

Soil Order	Soil Series	Soil Description (Source: Soil Survey Staff, 2008)
ANDISOLS (Mineral soils)	Halekula	Very cobbly silt loam consisting of moderately deep, well drained soils that formed in basic volcanic ash over ʻaʻa lava flows (3,000 to 10,000 years old). Soil depth to bedrock is 20-40 inches (50-102 cm).
	Kamawai	Extremely cobbly muck consisting of shallow, well drained soils that formed in basic volcanic ash in ʻaʻa lava flows (1,500 to 3,000 year old). Soil depth to bedrock is 10-20 inches (25-50 cm).
HISTOSOLS (Organic soils)	Puuiki	Very cobbly highly decomposed plant material consisting of very shallow, moderately well-drained soil that formed in organic material mixed with basic volcanic ash over pahoehoe lava flows (<5,000 year old). They have greater than 25 percent organic carbon (by weight) in the less than 2.0 mm soil material. Soil depth to bedrock is 2-10 inches (5-25 cm).

Table 3. List of Sensitive Plant Species Identified at Henahena.

Taxon	**Status**	**References**
Legally protected species currently present		
ʻAiea (*Nothocestrum breviflorum*)	END	
Kawaʻu (*Zanthoxylum dipetalum tomentosum*)*	END	
ʻAkoko (*Chamaesyce olowaluana*)	SOC	
Alani (*Pelea hawaiensis*)** (3,300 ft. elev.)	SOC	
Mint (*Stenogyne micrantha*)	SOC	
Legally protected species historically present		
Lobelia (*Delissea undulata*)* (3,520 ft. elev.)	END	Royte, 1995
Hau Kuahiwi (*Hibiscadelphus hualalaiensis*)	END	
Rare species currently with no legal protection		
Papala (*Charpentiera obovata*)	Rare	
Poʻola (*Claoxylon sandwicense*)	Rare	
Nehe (*Lipochaeta subcordata*)	Rare	
Alani (*Melicope volcanica*)	Rare	
Hoʻawa (*Pittosporum hosmeri*)	Rare	
Fern (*Polystichum hillebrandii*)	Rare	
ʻIliahi, sandalwood (Santalum paniculatum)	Rare	
Maʻohiʻohi (*Stenogyne rugosa*)	Rare	

Federal Status: END = Endangered, SOC = Species of Concern

* Recorded from lands adjacent to the unit; may occur within the unit

Table 4. List of Sensitive Animal Species Identified at Hehahena.

Scientific Name	Status	Information Source
Legally protected species currently present		
Surface (epigean) Arthropods		
Manduca blackburni	END	Field surveys
Coleotichus blackburniae	SOC	Field surveys
Ectemnius rubrocaudatus	SOC	Field surveys
*Plagithmysus elegans*** (3,200 ft. elev.)	SOC	Field surveys
Plagithmysus simplicicollis	SOC	Field surveys
Mollusks		
Partulina confusa (possibly extinct)	SOC	Field surveys
Vertebrates		
Buteo solitarius	END	Field surveys
Lasiurus cinereus semotus	END	Field surveys
Oreomystis mana	END	Field surveys
Asio flammeus sandwichensis	SOC	Field surveys
Legally protected species historically present		
Vertebrates		
Branta sandvicensis	END	Field surveys
Corvus hawaiiensis	END	Field surveys
Rare species currently with no legal protection		
Surface (epigean) arthropods		
Plagithmysus montgomeryi	Rare	Field surveys
Tetragnatha kukuhaa	New sp.	Gillespie, 2002

Federal Status: END = Endangered, SOC = Species of Concern

** Recorded from lands adjacent to the unit; may occur within the unit

Table 5. List of Obligate Cave Arthropod Species from Lava Tubes at Henahena.

Taxon	Common Name	Status
Cambalidae		
Nannolene sp. (*Dimerogonus*)	Cave millipede	undescribed
Carabidae		
Mecyclothorax aa (Leibherr, 2008)	Ground beetle	new species
Cixiidae		
Oliarus makaiki (Hoch & Howarth, 1999)	Planthopper	new species
Oliarus polyphemus	Planthopper	
Gryllidae		
Thaumatogryllus cavicola	Cave cricket	SOC
Caconemobius varius	Cave cricket	SOC
Linyphiidae		
Meioneta sp.	Sheet web spider	undescribed
Lithobiidae		
Lithobius sp.	Rock centipede	undescribed
Noctuidae		
Schrankia howarthi (Medeiros et al., 2009)	Cave moth	new species
Phoridae		
Megaselia sp.	Humpbacked fly	undescribed
Reduviidae		
Nesidiolestes cf. ana	Thread-legged bug	SOC
Staphylinidae		
Nesomedon sp.	Rove beetle	undescribed
Talitridae		
Spelaeorchestia sp.??	Cave amphipod	undescribed

Federal Status: END = Endangered, SOC = Species of Concern.

Table 6. List of Subfossil Bird Species Identified from Lava Tubes at Henahena.
X=Extinct; Z=Extirpated; P=Present

Taxon	Common Name	Status
Anatidae (ducks, geese & swans)		
Branta rhuax	Giant flightless goose	X
Branta sandwichensis	Nene, Hawaiian goose	P
Anas laysanensis	Laysan duck	Z
Corvidae (crows, jays & magpies)		
Corvus sp.	Hammer-billed crow	X
Procellariidae (shearwaters and peterels)		
Pterodroma phaeopygia sandwichensis	Dark-rumped petrel	Z
Oceanodroma castro	Band-rumped storm petrel	Z
Meliphagidae (honeyeaters)		
Moho nobilis	Hawai‘i ‘o‘o	X
Muscicapidae (old world insect-eaters)		
Myadestes obscurus	Omao, Hawaiian thrush	Z
Raillidae (rails, gallinules and coots)		
Porzana sp.	Large Hawaiian rail	X
Porzana sandwichensis	Moho, Hawaiian rail	X
Porzana sp.	Tiny Hawaiian rail	X
Gallinula chloropus	‘Alae ‘ula, gallinule	Z
Fringillidae (Hawaiian honeycreepers)		
Hemignathus vorpalis	Giant nuku-pu‘u	X

Figure 1. Location of the Henahena Conservation Unit in the Ahupua‘a of Pu‘uwa‘awa‘a.

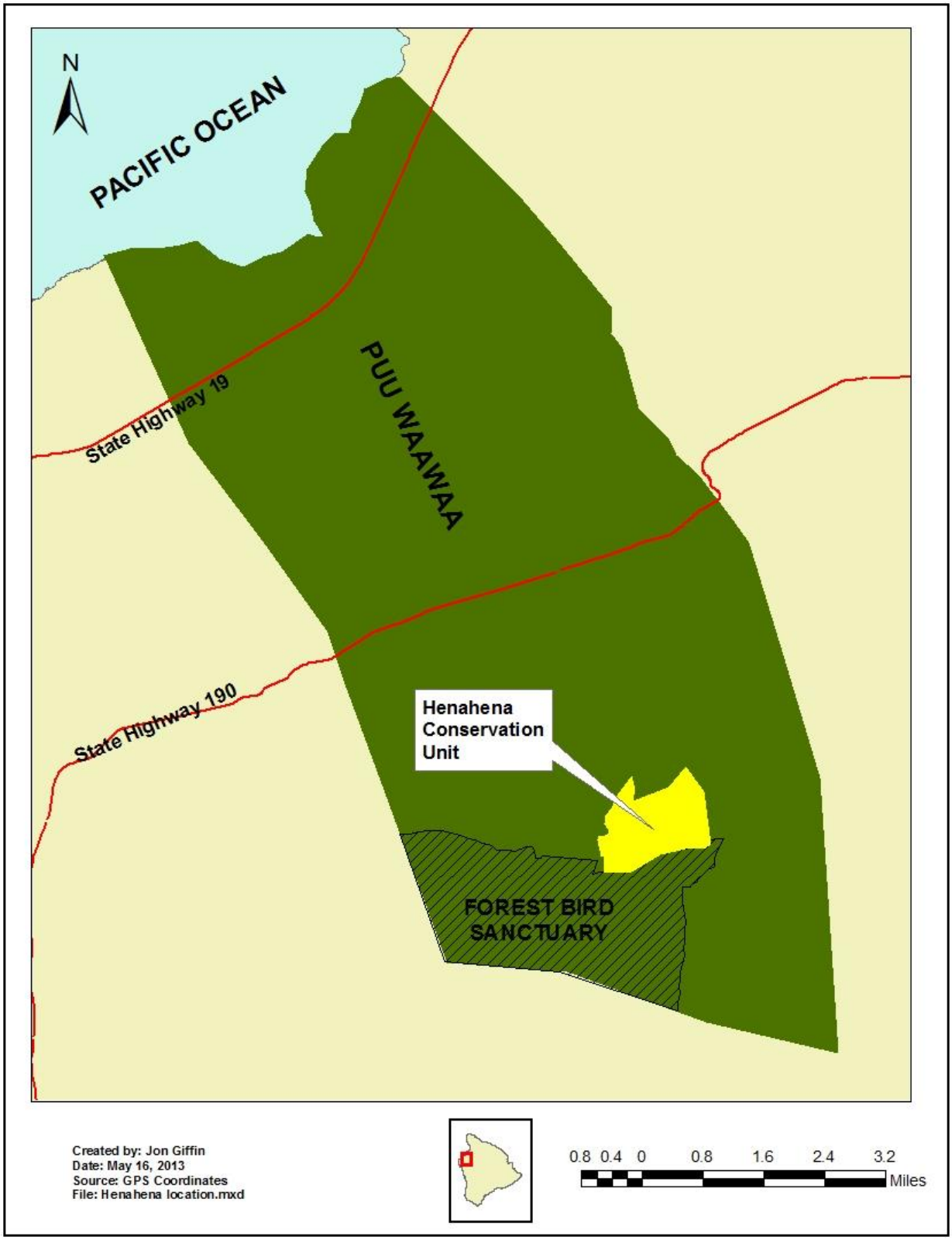

Figure 2. Satellite Image of the Henahena Conservation Unit.

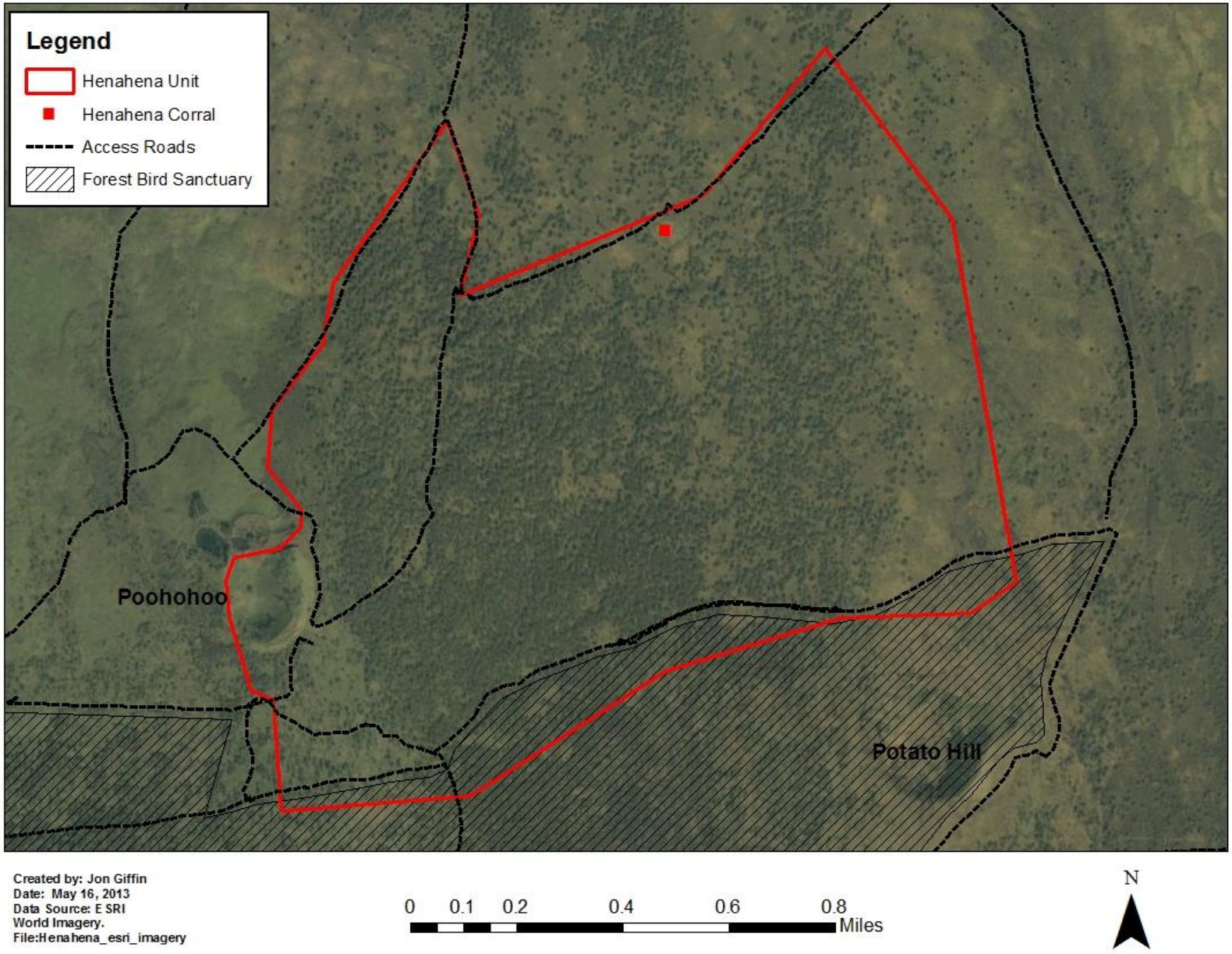

Figure 3. Lava Flow Age Classes in the Henahena Conservation Unit.

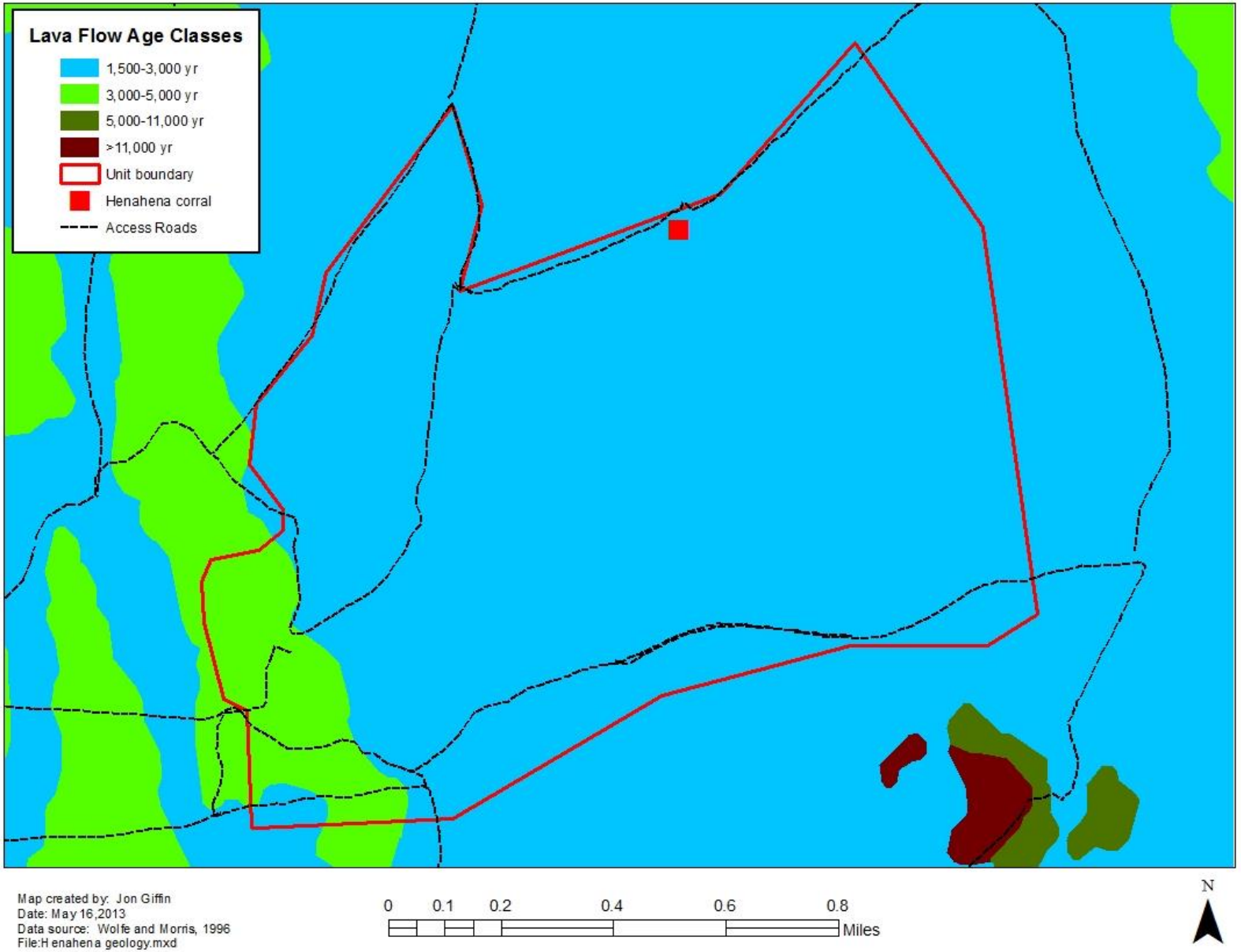

Figure 4. Lava Substrates in the Henahena Conservation Unit.

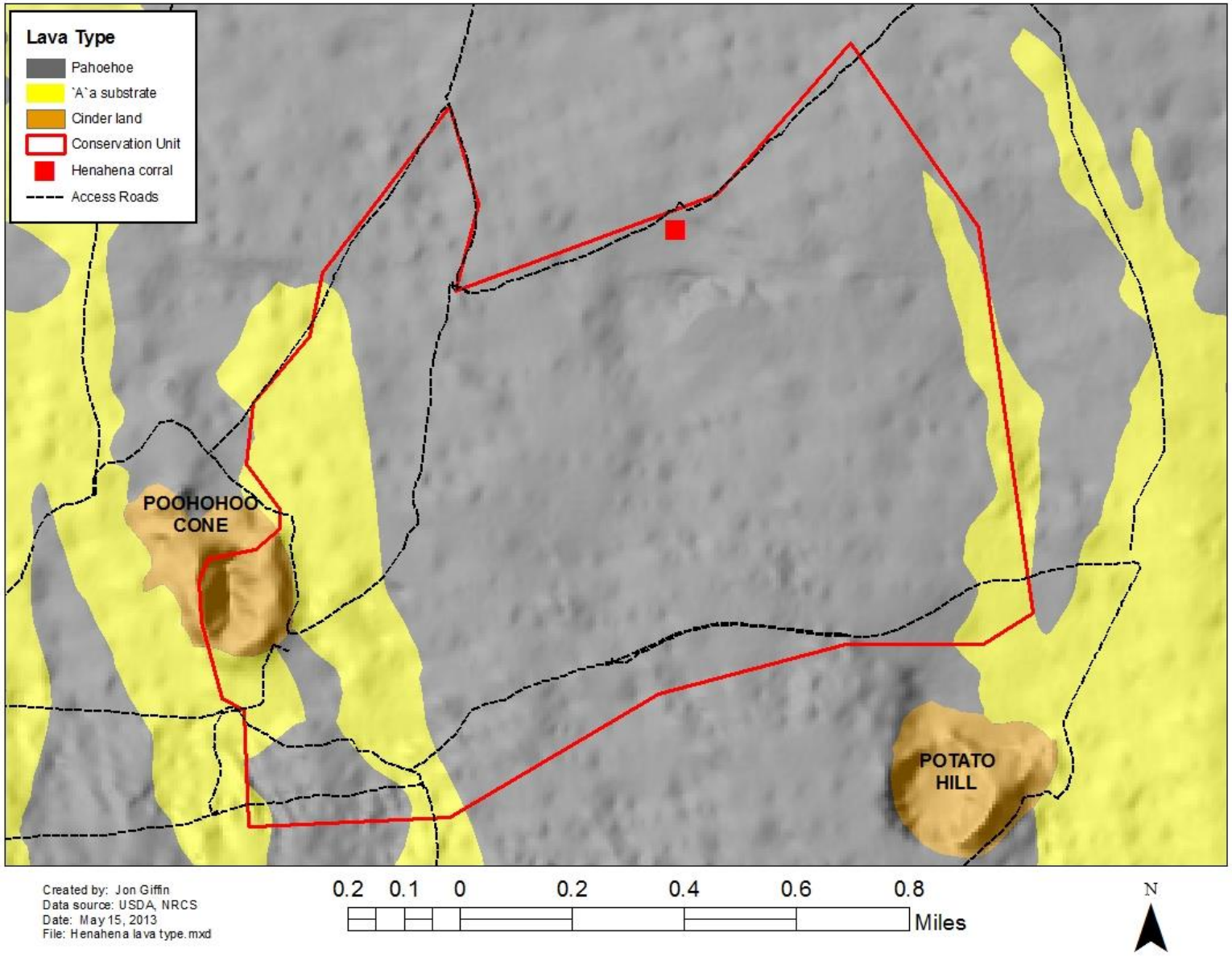

Figure 5. Soil Type Distribution in the Henahena Conservation Unit.

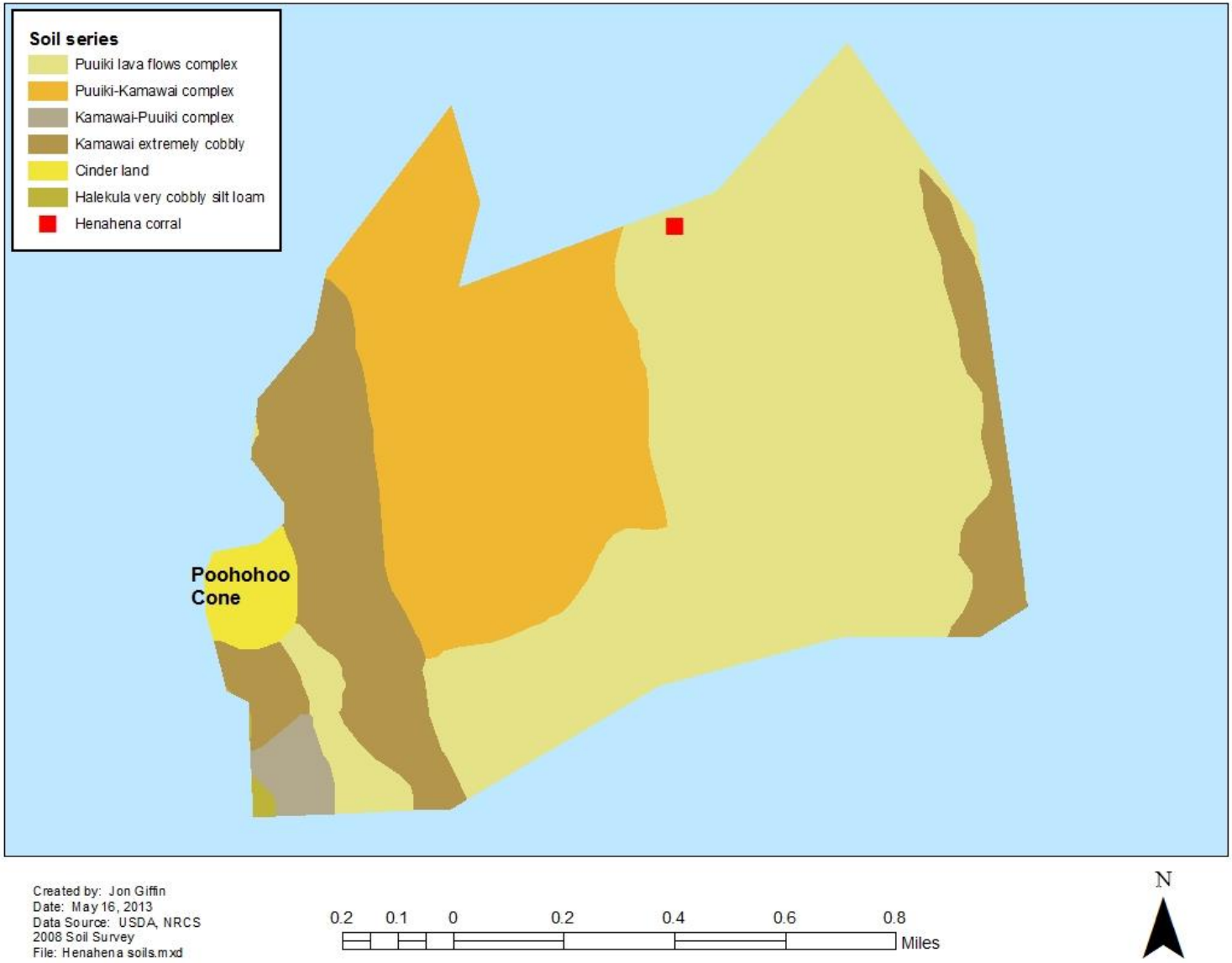

Figure 6. Vegetation Zones in the Henahena Conservation Unit.

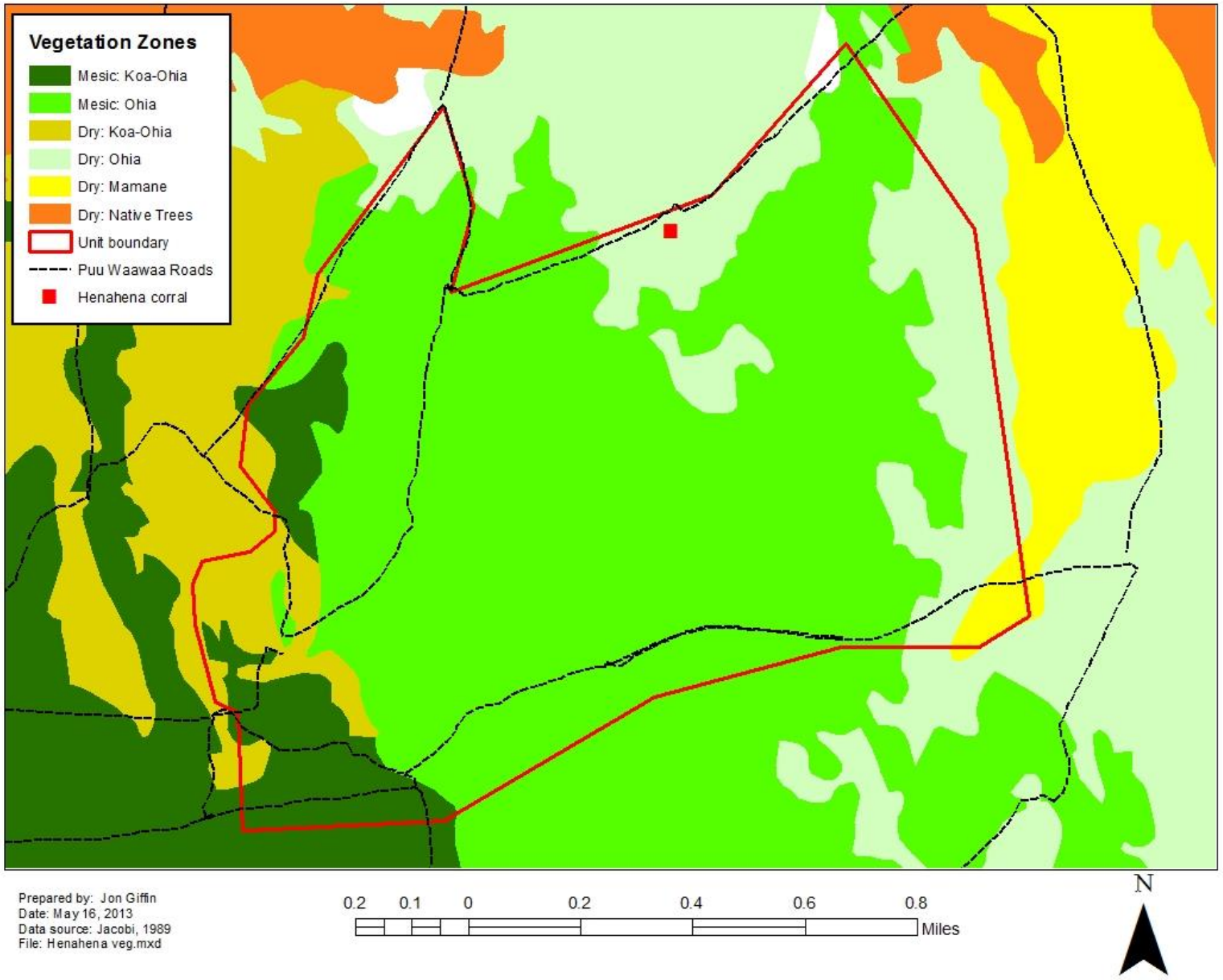

Figure 7. Known Lava Tube Systems in the Henahena Conservation Unit.