APPENDICES

for

FINAL ENVIRONMENTAL ASSESSMENT
FOR THE
HALEAKALĀ HIGH ALTITUDE OBSERVATORY SITE
MAUI, HAWAI‘I MANAGEMENT PLAN

University of Hawai‘i
Institute for Astronomy

October 25, 2010

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LIST OF APPENDICES

While some of the surveys and assessments were conducted for specific projects within HO, they are discussed and provided in this Environmental Assessment for their environmental resources information content.

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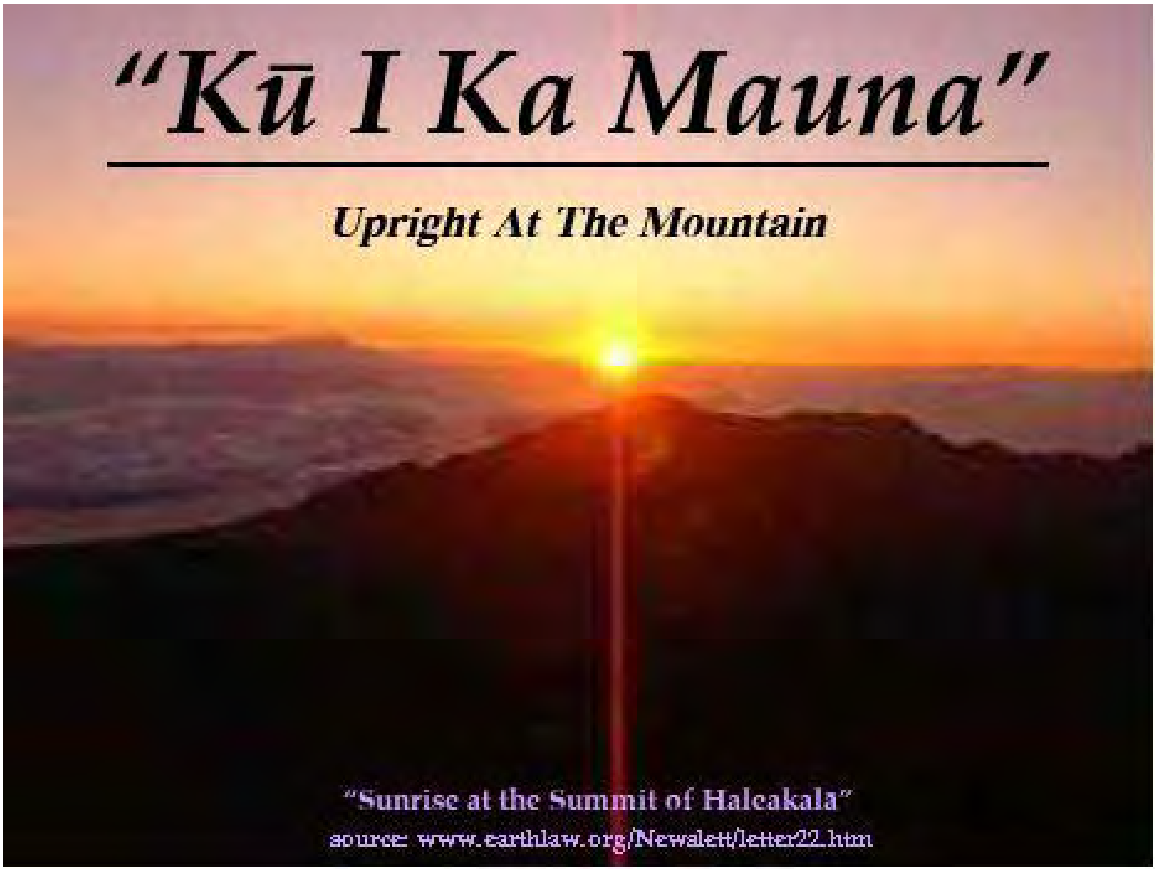
APPENDIX A

Cultural Resources Evaluation for the Summit of Haleakalā, March 2003



March, 2003

Cultural Resources Evaluation for the Summit of Haleakalā

Prepared for
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CKMculturalresources

Summit of Haleakalā
Report #2

Final

Tax Map Key 2-2-7-08 18.1 Acre Site

Cultural Resources Evaluation for the Summit of Haleakalā[1]

[1] Haleakalä: Kaupö District. 8,201 feet in height. North (+) Latitude: 20o 4217. West(-) Longitude: 156o 1036. This data was extracted from the United States Geological Survey GNIS Database(November 2000).

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ABSTRACT

CKM Cultural Resources conducted a Hawaiian Cultural Resources Evaluation for the Summit of Haleakalā, 18.1 acres at Kolekole[1], Mākena/Kilohana, Maui, Hawai'i.

The study is in accordance with the Office of Environmental Quality Control guidelines, which describes resources having Hawaiian cultural value. It will describe potential impacts from further development, along with measures that could be employed to possibly mitigate those impacts. The study will evaluate the cultural significance of historic and prehistoric resources identified during an archaeological inventory survey and assist in the development of a general preservation plan for those resources. It will also address the requirement of the Office of Hawaiian Affairs for cultural impacts. Specifically, the document will address potential effects on Hawaiian culture, and traditional and customary rights, as described in the legislation known as <u>Act 50, Sessions Laws of Hawai'i, 2000</u>.

The summit of Haleakalā is considered throughout the Polynesian culture as a *Pu'u Honua*[2] (a sacred place). For the entire island of Maui, it is <u>the</u> most sacred site in terms of its past history and association to the ancient primordial gods and goddess of the past who dwell there. Prior to the arrival of the Hawaiians, which is estimated have been in the 3rd Century, the entire Hawaiian island chain was immersed in mythology, and Haleakalā was the focal point of spiritual activity.

The lives of the ancient Hawaiian people depended on the appeasement of the gods. Much work and devotion was bestowed on the *aumakua*[3] (personal gods) and other gods that they dealt with on a daily basis. Every natural element (the wind, rain, thunder, lightning, sun, moon, and ocean) had a definite impact on their lives.

Just by looking at the foundation of the clouds on Haleakalā, the ancient fishermen in Waikapū (and elsewhere) would know what type of fishing they were going to do that day, and would appropriately take their pole, throw net, spear, or canoe to go deep sea fishing. They would also pay tribute to their fishing shrine (Ku'ula) after catching what fish they needed for the day. Thus, the elements were an integral part of the *kāpo'e Kahiko*[4] (the people of old).

Hopefully this report will enhance the knowledge of the readers, and help them to grasp the life and times of the ancient Hawaiian people that roamed these islands and who paid tribute to the complexities in their culture. The same understanding should be afforded to the modern day Hawaiians, who are trying to survive in

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[1] Kolekole – Kilohana Mākena District: 10,012 feet tall. North (+) Latitude: 20o 4238, West (-) Longitude 156o 1533. This data was extracted from the United States Geological Survey GNIS Database (November 2000)

[2] Glossary: Term

[3] Glossary: Term

[4] Glossary: Term

today's culture. They have been left a legacy that is thousands of years old, but it must be understood using today's logic. That is a challenge indeed.

Note: As much as possible, throughout this report, the spelling of Hawaiian vocabulary and place names have been standardized to present orthography.

OUTLINE

Introduction

I. Specific Area Of Research
- a. Kolekole ("Science City")
- b. Cultural Resources of Kolekole
- c. Ancient and modern use of Kolekole
- d. Kolekole's relationship to surrounding area

II. Impact of facilities on Kolekole
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- a. "Sense of place" classes given to everyone involved in planning and construction on site
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VI. Important names of Haleakalā

INTRODUCTION

"Kū I Ka Mauna"
Upright at the Mountain)
(Report #2)
Cultural Resources Evaluation for the Summit of Haleakalā

March 1, 2003

Introduction – *Eia ka lā hiki:*
The Scope;

The scope of this report is to compile Cultural Resources information that is on the 18.1 acre site at Kolekole, on the summit of Haleakalā. This evaluation will follow the guidelines of the Office of Environmental Quality Control, as it relates to Act. 50, Sessions Laws of Hawaii, 2000. The study will describe resources having cultural value, and will describe potential impacts from further development, along with measures that could be employed to mitigate those impacts. Using information provided by the archeologist, chants, *mo'olelo*[1] (stories), and knowledgeable informants of this area, a general preservation plan for these cultural resources can be developed.

This report is the second of a two phase study. The first report was submitted on December 31st, 2002. It consisted of the Traditional Cultural Practices Assessment on Kolekole, located at the summit of Haleakala. This report shall include the association Haleakalā has to the surrounding *Pae'āina O Hawai'i*[2] (Islands of Hawai'i).

I. Specific and Tangent Areas Of Research

a. Kolekole

Kolekole is sometimes referred to as "Science City" because of the telescopes and observatories that have been built on the summit over the years. From a single telescope it has blossomed into a "complex" consisting of:

Mees Observatory[3].
LURE Observatory.

[1] Glossary: Term
[2] Glossary: Term
[3] Hawai'i Institute for Astronomy, University of Hawai'i Access: October 1, 2002, http://www.ifa.hawaii.edu/halekala

University of Tokyo MAGNUM Project, LURE Observatory.
University of Chicago Neutron Monitor.
Maui Space Surveillance Complex.
The Faulkes Telescope Project[4] (Still under construction)

All of these projects are located in an area of 18.1 acres, which in 1961, an Executive Order by Governor Quinn set aside land on the summit of Haleakalā, in a place known as Kolekole. The land was placed under the control and management of the University of Hawai'i, who established the "Haleakalā High Altitude Observatory Site", sometimes referred to as "Science City". This land is part of the Ceded Land Trust, which includes the *Kanaka Maoli*[5] *(*Aboriginal Hawaiian) as beneficiaries.

The Tangent Areas of Research: Refer to Report #1 on "Traditional Practices Assessment", submitted December 2002.

b. Cultural Resources of Kolekole

The Cultural Resources of Kolekole date back several thousand years, and is an integral part of the Hawaiian culture, both past and present. One can only imagine the sacredness that was afforded to this place because of its association to the primordial gods and goddesses of Polynesian history. Commoners could not even walk on the summit, because, it belonged to the gods. The sacred class of *Na Po'o Kāhuna*[6] (Priest, Sorcerer, Magician, Wizard, and Minister*)* used this place as an ancient learning center. It was a place where the *Kahuna*[7] could absorb the tones of ancient prayer, and balance within the vortex of energy, for spiritual manifestation.

Kahu David Ka'alakea[8], a very venerated Hawaiian Priest, stated that Haleakalā was used by our ancient ancestors to "*kāhea*[9]" (or call) the Sun, and the ancient name for Haleakalā was *Ala Hea Kālā*[10] (The Calling of the Sun). Only *Ali'i* (Royalty) and *Kāhuna* could visit the summit. He said that Kolekole was used to train Kahuna in the arts of healing, and navigating through the use of the stars and constellations. The ancient people felt that they were close to the *Ao holo'oko'a* [11](Universe) when they were at the summit. The only times that the commoners were allowed on the summit was for specific purposes, such as for gathering certain

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4 http://www.ifa.hawaii.edu/faulkes/construction.html
5 Glossary: Term
6 Glossary: Term
7 Glossary: Term
8 **Majority of the information shared in this report, was obtained by word of mouth, from people like the late Kahu David Ka'alakea, as it was the method or our ancestors to preserve the culture orally because we had no written language. One method of preservation was to train children who had the capacity to retain information. They would be given to the *Kahuna*, and taught to memorize entire genealogies, historical events that occurred and became the counselors to the Ali'i.**
9 Glossary: Term
10 Ancient name of Haleakalä as stated by the late Kahu David Ka'alakea
11 Glossary: Term

pōhaku (stone) to make their stone implements, or to *Kanu*[12] (bury) their dead. The royal remains were secreted in caves throughout the crater and surrounding area. Usually, the retainers that took the dead to their final resting place were sacrificed and buried with the *Ali'i*[13] (royalty). A specially chosen person was trusted with the location of the burials, and usually when he died, he took the secrets with him. He related to me that he remembered when he was a young boy going up to Haleakalā. The trips were a solemn occasion, and they would "walk feet" or go up on horseback. They only went there to hunt goats and pigs, and were not allowed to go everywhere because they were told that it was *kapu*[14] (sacred, forbidden) place. "Papa David", as he was well known, has passed away several years ago.

c. Ancient and modern use of Kolekole

<u>Ancient Use of Kolekole and Its Surrounding Area.</u>

For the ancient *Kanaka Maoli* (Aboriginal Hawaiian), Haleakalā and the Kolekole area were considered a *piko*[15] (the navel, or center of *Maui Nui a Kama*[16] - Greater Maui which includes Maui, Moloka'i, Lana'i and Kaho'olawe). It is a sacred place, one which our ancestors believed was a *Waoakua*[17] (a place were gods and spirits walk). Other *Kupuna*[18] (Elder) related that they were taught that when they went to Haleakalā, they would have to be very careful if they wanted to survive the trek to the summit, for they could be killed by the gods. They would have to wrap a *mau'ula'ili*[19] *(sysrinchium acre)* around their arms, and the acid from the iris plant branded their skin. This would indicate that they had, in fact, made the trek to the top of the mountain. On Maui, this plant is found near the summit of Haleakalā.

***Pele*[20], the goddess of fire (*Ka Wahine o ka lua* - the woman of the pit) is one of the most popular of the gods in ancient and modern times. Stories of her sightings abound, occurring both before and after volcanic eruptions. Sometimes, she appears as a beautiful woman, and other times an old "hag". There are many versions of the accounts about *Pele* in her travels to Hawai'i. Her family accompanied her on the voyage from Kahiki, including her brother, *Kamohoali'i*[21] (the great shark of Polynesia), and her other family members. The most famous were her youngest sisters, *Hi'iaka-ikapoli-O-pele*[22], the goddess of lightning and *Namakaokahaī,* the goddess of the sea. *Pele* was known to have been constantly**

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12 Glossary: Term
13 Glossary: Term
14 Glossary: Term
15 Glossary: Term
16 Glossary: Term
17 Glossary: Term
18 Glossary: Term
19 Glossary: Term
20 Handy, E.S. Craighill, et al. <u>Native Planters: In Old Hawaii – their life, lore and environment,</u> Bishop Museum Press, Honolulu, Hawaii, 1972: 336-337.
21 Beckwith 1970: 167-179
22 Hawaiian Legends Of Volcanoes, by William D. Westerville, 72-86

fighting, and when the lava of *Pele* would enter the sea, *Namakaokaha'i* would extinguish the fire as it entered the ocean.

According to our *Mo'olelo* about the travels of *Pele*, she went from Tahiti to Hawai'i in search of a home. After looking on each island, she finally found Haleakalā. Using her divining rod, *Pāoa,*[23] *Pele* dug a great quantity of lava and thru it out of her fire-pit. She and *Namakaokaha'i* fought from her home in Haleakalā (at the summit), down through Kahikinui. *Namakaokaha'i* tore the body of Pele and broke her lava bones into great pieces, which lie to this day along the seacoast of the district called Kahikinui. The masses of broken lava are called *Naiwi-o*-Pele [24](the bones of Pele). Some of her bones were buried in the pu'u called *Kaiwiopele* (which means the bones of *Pele*), in Haleakalā Crater.

That was the last time that *Pele* was a physical being. While her bones were being buried in the Pu'u in Haleakalā, her family looked across the *'Alanuihāhā* [25]Channel to the Island Of Hawai'i, and saw her spirit manifest there. They could see in the high mountains of Maunaloa and Maunakea, which was covered with snow, clouds of volcanic smoke tinged red from the flames of raging fire-pits below. The spirit of *Pele* was present. To this very day, *Pele* resides in Halema'uma'u Crater, on the island of Hawai'i.

There were numerous other gods and goddess that reside on the summit, in the crater and all around the Haleakalā Mountain. There is *Poli'ahu*[26], the goddess of snow, and *' Māui,* who is famous throughout the Pacific but more so to Haleakalā. (Refer to Traditional Practices Assessment report, In the Beginning, Page 4, and Para. 3) In preparing his cordage to "lasso" the sun, *Māui*[27] built a *heiau (*temple) on the ridge-top of Kapalaoa. When the Maui Space Surveillance Complex was built, they wanted to place a sensor on this ridge. They were informed that this *heiau* existed. Investigation by helicopter substantiated that the *heiau* is still intact on Kapalaoa Ridge within Haleakalā Crater. It is said that *Māui* stood with one foot on Kolekole and the other foot on Hanakauhi Peak[28] when he lassoed the Sun.

As mentioned in "Kū I Ka Mauna", Upright at the Mountain, December 2002, Traditional Practices Assessment for the Summit of Haleakalā, in the beginning of Page 4, it mentions about the Kanaka Maoli perception of Haleakalā. Kolekole was a *Wahi-Pana*[29], a very special religious place. It also was used by the Kahuna Po'o, who trained students in the arts, by passing on the enormous wisdom they possessed.

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[23] Glossary Term
[24] Glossary Term
[25] Glossary Term
[26] Glossary: Term
[27] Mäui snaring of the Sun is a Hawai'i-centric story, however Mäui was not only a Hawai'i demigod, and he was demigod of all of Polynesia. Therefore, Haleakalä is a pinnacle of power for all of Polynesia.
[28] Glossary Term
[29] Glossary Term

Modern use of Kolekole

A view of the entire 18.1 Acre Site that is being studied here is shown on page 18 of the Traditional Practices Assessment for the Summit of Haleakalā,. The saying, "A picture says a thousand words" holds true here because just by looking at the "Science City" complex, one can see the modern uses of Kolekole. A question which will be answered further on in this report is "How has the Kanaka Maoli been affected in terms of their Use and Access, and Religious, Spiritual, and Cultural Practices?", as noted in Act. 50 of the HRS.

d. Kolekole's relationship to surrounding area.

It is difficult to separate Kolekole from the rest of the summit of Haleakalā because of the fact that past accounts of its history is not only interrelated with other areas on the summit, but it includes the entire Haleakalā and the island of Maui. It also is related to the other islands in the Hawaiian chain, culturally and otherwise.

There is a stone on the north-east side of the crater rim, called *Pōhaku Palaha*[30], which is the beginning of the eight *Ahupua'a*[31] (land divisions) that surround the East Maui District.

II. Impact of facilities on Kolekole

The impact of facilities on Kolekole and the surrounding area started when the University of Hawai'i's Haleakalā High Altitude Observatory Site ("Science City") and communications facilities were constructed on Haleakalā some time ago. When this happened, it opened the door to more facilities being constructed (refer to Report #1, Traditional Practices Assessment, Page 16, picture of "Science City") at Kolekole.

a. How modern facilities impact cultural resources

Considering the amount of cultural history on Kolekole, as brought forth in this report and the Traditional Practices report, it is easy to surmise that the impact on the cultural resources by modern facilities built on Kolekole is traumatic at best, and devastating at worst, on the Kanaka Maoli who use this area to practice their culture in a spiritual manner. The disturbance by the buildings, and the activity that is going on, interferes with the quietness and solitude one should have when visiting a place like this for cultural purposes. It is like going into a church for prayer and meditation, then being interrupted by humming sounds coming from

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[30] Pöhaku Palaha is a stone on the beginning of the Kapalaoa Ridge of Haleakalä and from this stone originates the eight land division district around Haleakalä.

[31] Ahu Pua'a is a term for land division from the mountain to the sea. An "Ahu" stone alter and on the top would be placed the skull of a pig.

electronic equipment, and the bustle of human activity working around the telescopes and observatories in the area.

III. What cultural resources remain at Kolekole

The cultural resources remaining at Kolekole are limited because of the structures that were constructed. However, remnants of our past physical and spiritual culture have survived, and in some places remain intact.

Spiritual sensitivity can still be experienced because of the fact that one is at the highest point overlooking Maui and the rest of the Islands. Cultural sensitivity can still be enjoyed by touching the *''āina*[32] (provider of food and the mystical food for the Kanaka Maoli). Also, knowing that *Pele* created everything on Kolekole bestows a cultural sense of connection to the ancient gods and goddesses, and to the traditions of the past.

a. Predominate feature of Kolekole

The predominate feature of Kolekole is, of course, the Maui Space Surveillance Facility, which is the largest structure there. The "Science City" complex dominates the rest of the Kolekole area. Refer to page 16 of Report #1, High Altitude Observatory, "Overhead view of Kolekole, ("Science City") Haleakalā Island of Maui Hawai'i".

b. Passing knowledge to next generation.

Kolekole and the entire summit of Haleakalā is a very valuable asset to the Hawaiian culture, both physically and spiritually. Efforts have to be taken to set aside areas where Kanaka Maoli can worship, uninterrupted by the activities that are taking place at the astronomy facilities. By doing this, they can pass on the knowledge to the next generation.

IV. Long term method for preservation of Cultural Resources

Long term method for preservation of Cultural Resources should include the entire 18.1 acre site at Kolekole. For the Kanaka Maoli, the lava, cinders, dust, rocks, and boulders are all sacred to *Pele,* the Goddess of the Volcano. In fact, the Hawaiian word for lava is "Pele". Refer to first eight photographs in this report, showing the construction of the Faulkes Telescope, and it is clear how the Kanaka Maoli religious and cultural beliefs were completely ignored. There were no special prayers given when the hole for the platform was dug. The workers were not instructed to be culturally sensitive to the lava they dug up and the soil that they

[32] Glossary: Term

removed. There was no "asking" permission of the gods to dig into the soil, for the purpose of building a telescope to explore the universe.

<u>RULES FOR LONG TERM METHOD FOR PRESERVATION OF CULTURAL RESOURCES FOR ALL FACILITES PAST, PRESENT, AND FUTURE, ON KOLEKOLE, HALEAKALA.</u>

1….A Kanaka Maoli Cultural Specialist, who is both a Kūpuna (elder) and a Kahu (Reverend), and who is also aware of the spiritual and cultural protocol of the site, should be consulted and included in the first stages of the construction planning. That person would also monitor all ground alterations, renovations of buildings which increase existing footprints, and all phases of any new construction.

2….Cultural sites and other identified features found in the inventory survey should be marked as a cultural site and protected from inadvertent damage. Proper buffer zones should be created to protect these sites. It should also be placed on a centralized map, clearly delineated for future identification purposes.

3….All permanent employees working at Kolekole, both present and future, should attend "Sense of Place Classes" prior to working at the facilities. It could be in the form of a 1-hour video and reading prepared brochures which explain how culturally and spiritually important the summit is to the Hawaiian people.

4….A cultural inspection should be conducted of Kolekole 3 times a year.

5….Consultation with Kanaka Maoli in constructing a platform where cultural ceremonies, spiritual and otherwise, could be performed. This would be built <u>strictly</u> for Kanaka Maoli people. This idea was proposed when the Air force built their facilities, but so far it has not come to fruition.

6….These rules will be requirements specified in all land use agreements, leases, and memoranda.

<u>These rules would have to be strictly enforced by the University Of Hawai'i Institute of Astronomy (UH-IFA) because it is the responsible agency in charge of these lands according to the Executive Order of 1961. One must bear in mind that these lands are Ceded Lands and originally was owned by the Hawaiian Kingdom. Sec. 5-f of the Admissions Act (Statehood Act) specifically recognizes the Native Hawaiian as beneficiaries of these trust lands. More so, the Hawaiian Cultural and Spiritual beliefs should be adhered to and respected at the summit of Haleakalā.</u>

V. Mitigating impact of Summit

Numerous impacts have occurred on Kolekole, the summit of Haleakalā, due to the buildings and on going activities. The best method of controlling the impact would be to stop all construction and tear down all the existing buildings. Because of the caliber of these structures, it would be highly unlikely that this would ever happen.

To really mitigate the impacts that have happened to this site, there must be a stop to anymore construction on this 18.1 acre site. It is common sense that this suggestion is not going to occur because of the astronomical interest in building facilities on Haleakala, because of the optimum conditions Haleakala has compared to any other place in the world. For the Hawaiian people, it is just as important for cultural protocol to be observed. If this is so, then strong stringent rules have to be adopted, such as the above 7 conditions that are suggested. It has to appear on the building or extension plans, and must be adhered to by the contractors and developers that are involved in constructing these facilities. Only then can the future generations enjoy the spiritual and cultural attributes the summit has to offer, and it would be preserved forever.

SACRED NAMES ON HALEAKALĀ

The names of places, cones, vents, ridges and peaks are central to the history of Maui and the Native Hawaiian Culture. They mark time, legends, characters, and events of the primordial existence of the Kanaka Maoli.

- Puʻu ʻUlaʻula
  - Pu'u 'Ula'ula literally means red hill

- Kolekole
  - There are two versions of what Kolekole means: (1) One account explicates that Kolekole was named after the fish Kole. Kole's skin color is a rusty deep brown, almost like the cinders at Kolekole. (2) The second account states that Kolekole is the Hawaiian word for "talk story." Some believe that it was an area where Kahuna Po'o (Head Priests) would convene to discuss issues.

- Pākaoao
  - There is no literal translation for this inoa(name). However, one could surmise the intent of this specific name, and also, I believe that this is a fairly recent name. "Pāka" means park. "Ao" means light, day, dawn or clouds. Therefore, one could assume that Pākaoao means "Park of the dawn," or "Park of the clouds." It is with these translations that I surmise the meaning of the name of this park.

- Kalua o ka Ō`ō
  - Ka-Lua-O-Ka-'Ō'ō, this literally means "The pit of the digging stick."

- Kamoali`i
  - There is no direct translation for this word. I will offer two options: (1) the word could be spelt as such: Ka-Moa- Li'i . This literally means, "the small chicken." (2) the second of two translations could be spelt as such: Kāmoa-Li'i . This means, "Little Sāmoa."

- Pu`u o Pele
  - This literally means the "hill of Pele."

- Pu`u o Maui
  - Spelt: Pu'u-O-Māui. This means the "Hill of [the demigod] Māui."

- Ka Moa o Pele
  - This means, "The Chicken of Pele [Goddess of Fire]."

- Halāliʻi
  - There is no direct translation for the name of this crater that has any direct affiliation to this area. I will offer one such interpretation based on the translation of this word. (1) This word can be spelt: Halāli'i . This is the name of a pleasure

loving Ali'i on the island of Ni'ihau. (2) This word can also be spelt: Hala-li'i . This means small hala (pandanus tree). This may have grown either in the pit of the crater or the surrounding areas.

- Pu`u Naue
  - Pu'u Naue (or Nauwe) when spelt together, i.e. pu'unaue, means a division or section. When spelt as such: Pu'u-Naue, means "shaking hill."

- Pu`u Māmane
  - Spelt: Pu'u Māmane. Meaning: Māmane Tree Hill

- Pu`u Kumu
  - Meaning: Foundation Hill

- Pu`u Kauaua
  - There is no direct translation of this place. Pu'u Ka-Ua-Ua means "Rainy Hill." This one translation that I surmise would be best fitting.

- Pu`u Maile
  - Meaning: Maile Vine Hill

- Pu‘u ‘Alaea
  - Spelt: Pu'u-'Alaea Meaning: Ocherous Earth Hill.

- Pu`u o Li`i
  - There is no direct translation in written text. When translated in this fashion: Pu'u-O-Li'i, literally means: Hill of the Small.

- Pu`u Nianiau
  - Meaning: Peaceful Hill

- Pu‘u Lā‘ie
  - There is no meaning in written text for the name of this Pu'u (hill). However when translated as such: Pu'u Lā'ie, it means: "Hill of the 'ie'ie leaf."

- Kilohana
  - Meaning Lookout point, or best / superior.

- Kalahaku
  - Meaning: Proclaiming [the] Lord.

- Hōlua
  - Spelt: Hōlua. Meaning: Sled.

- Lele iwi

- Meaning: Bone altar (poetically, a symbol of disaster or anger.)

- Hale mauʻu
  - Spelt: Hale mau'u Meaning: Grass House.

- Kapalaoa
  - Ka-palaoa; the whale or the whale tooth: as in "Lei niho *palaoa*."

- Mauna Hina
  - Meaning: Gray Mountain

- Nā mana o ke Akua
  - Spelt: Nā-Mana-O-Ke-Akua. Meaning: the powers of the god.

- Honokahua
  - Meaning: Sites Bay

- Lāʻie
  - Spelt: Lā'ie. Meaning: The leaves of the 'ie'ie plant.

- Hanakauhi
  - Meaning: The cover bay

- Kalapawili
  - There is no direct translation for name of this wahi (place). However when broken down into: Kalapa-Wili; "kalapa" means "sulfur". "Wili" in this case could mean "spiral". Therefore, I would surmise that this is an area that may have had pockets of sulfur.

- Lau ʻulu
  - Spelt: Lau'ulu. Meaning: Breadfruit Leaf

- Pōhaku Pālaha
  - Spelt: Pōhaku Pālaha; Meaning: Flat Rock. Rock where the eight Ahūpuaʻa of west Maui originates.

- Pali kū
  - Spelt: Pali kū. Meaning: Vertical Cliff

- Wai kekeʻehia
  - There is no direct translation in written text. Based on this spelling: Wai-Keke'e-'Ehia, I would surmise the translation to be: "How many crooked streams?"

- Kukui
  - Meaning: (1)light, or (2)Candlenut Tree.

ARCHAEOLOGICAL OVERVIEW OF HALEKALĀ SUMMIT 18.1 ACRES AT KOLEKOLE, ("SCIENCE CITY").

In developing a general preservation plan for cultural resources, sites of historic and prehistoric significance were identified during the archeological inventory survey. Mr. Erik Frederickson of Xamanek Resources was interviewed on March 5, 2003, at 12:30pm. The meeting was held in my car, at the Pukalani Shopping Cent. After signing the Interview Form (which is attached here-to), the interview began.

Mr. Frederickson stated that he conducted the archeological inventory survey on this site, and that all of the sites that were found will be recommended for passive preservation in place. The most significant find was the possible burial site that is located on the Maalaea-Kahului side, down slope of the AEOS Air force complex.

The possible burial is a small platform, completely different from any other feature on the site. It is located in a complex structure, which includes a wind shelter, and two petroglyphs which are on the upslope. There are other features which are associated with this site in the surveyed area, and some were previously discovered. Most of the sites are wind shelters, indicating that the area was used a lot. These short-term temporary shelters were utilized for protection from the wind and cold. There was also a remnant of a possible trail on the southern side of the Air Force facilities.

These sites are unique in the sense that they were most likely used by persons who were involved in ceremonial activities. There were some remnants of coral in these sites, indicating that it was brought up to the summit for ceremonial purposes.

He went on to say that when a site is determined for preservation, S.H.P.D. will determine the type of preservation, the buffer zones that are to be constructed for protection, and signage if needed. This site, because of its density, should be totally preserved due to it's spiritual and cultural relationship to the host culture. He concluded by saying that his final report will reflect the comments made here.

ARCHAEOLOGICAL OBSERVATIONS OF HALEAKALĀ 18.1 ACRE SITE

There are 29 plus archaeological features presently on the site, not including the features that might have been destroyed by the past and present construction. Coupled with the spiritual and cultural history, which was recorded and passed down orally from one generation to the other, this site is the most sacred to the Kanaka Maoli, both past and present.

This 18.1 acre site significantly meets with the State Procedures for Historic Preservation Review (DLNR, 1966; Chapter 275). It also qualifies under the Federal Guide Lines of preservation. The archeological features far surpass the following criteria:

<u>Criterion "a"</u> **Be associated with events that have made an important contribution to the broad patterns of history; {please refer to Introduction of this report}**

<u>Criterion "b"</u> **Be associated with the lives of persons important in our past. {Please refer to Introduction of this report}**

<u>Criterion "c"</u> **Embody the distinctive characteristics of a type, period, or method of construction; represent the work of a master; or possess high artistic value; {please refer to the Archaeologist table, Item 3-T (d & e)2 petroglyph boulders}**

<u>Criterion "d"</u> **Have yielded, or is likely to yield, important information for research on prehistory or history; {refer to Introduction of this report and other documentation submitted}**

The archeology report, and information from Kūpuna and other informants gathered over the last 40 years, clearly associates Kolekole (summit) and all of Haleakalā Mountain as a special Hawaiian spiritual and cultural place for the Kūpuna that have passed on, the present population, and the future generations yet to come.

It is important that the remnants of the Hawaiian Culture be preserved, not only for the host culture of Hawaii, but for everyone that comes here to make Maui their home. The cultural and spiritual health of Maui depends on how we preserve our sacred and cultural sites.

On Kolekole("science city"), there has to be some balance, and the Kanaka Maoli have to be involved by having a seat at the table. Kanaka Maoli have to be involved in the planning, building, approving and care of this sacred site. The Hawaiian's values have to be recognized, and no matter how important Haleakalā is for astronomy or "National Defense", the spiritual and cultural essence should never be compromised. What has happened over the last several years, with broken promises, should not be allowed to continue. The number of archeological sites found on Kolekole substantiates the essence of this report.

CKM CULTURAL RESOURCES

Specializing in Cultural Impact Statements
(using State of Hawaii O.E.Q.C. methods),
Blessings, Weddings, Lectures
and Ho'oponopono

IMINA I KA NA'AUAO E PAHU IA MAKOU IMUA
(Seeking the knowledge to push us forward)

INTERVIEW FORM

NAME – PRINTED: Erik Frederiksen

SIGNITURE: Erik Frederiksen

ADDRESS: P.O. Box 880023 Pukalani, HI

TELEPHONE: 572-6118

PLACE OF INTERVIEW: Pukalani Shopping Center

DATE & TIME OF INTERVIEW: 3/5/03 at 1230 pm.

INTERVIEWER: Charles K. Maxwell Sr.

I understand that my statement will be used in a public document and it is my understanding that before it is published, I will have a chance to see it and make corrections if needed. INITIAL: EF

INTERVIEWERS SIGNITURE: [signature]
DATE & TIME: 3/5/03 1230 pm.

Kahu Charles Kauluwehi Maxwell, Sr.
157 Alea Place · Pukalani, Maui, HI 96768
Phone: (808) 572-8038 · Fax: (808) 572-0602 · Cell: 870-3345
Email: kale@moolelo.com · Website: www.moolelo.com

Shows excavation for Faulkes telescope foundation.

Concrete foundation, Faulkes Telescope

Shows the entire pit dug for the foundation.

Shows boom truck pouring concrete into form of platform.

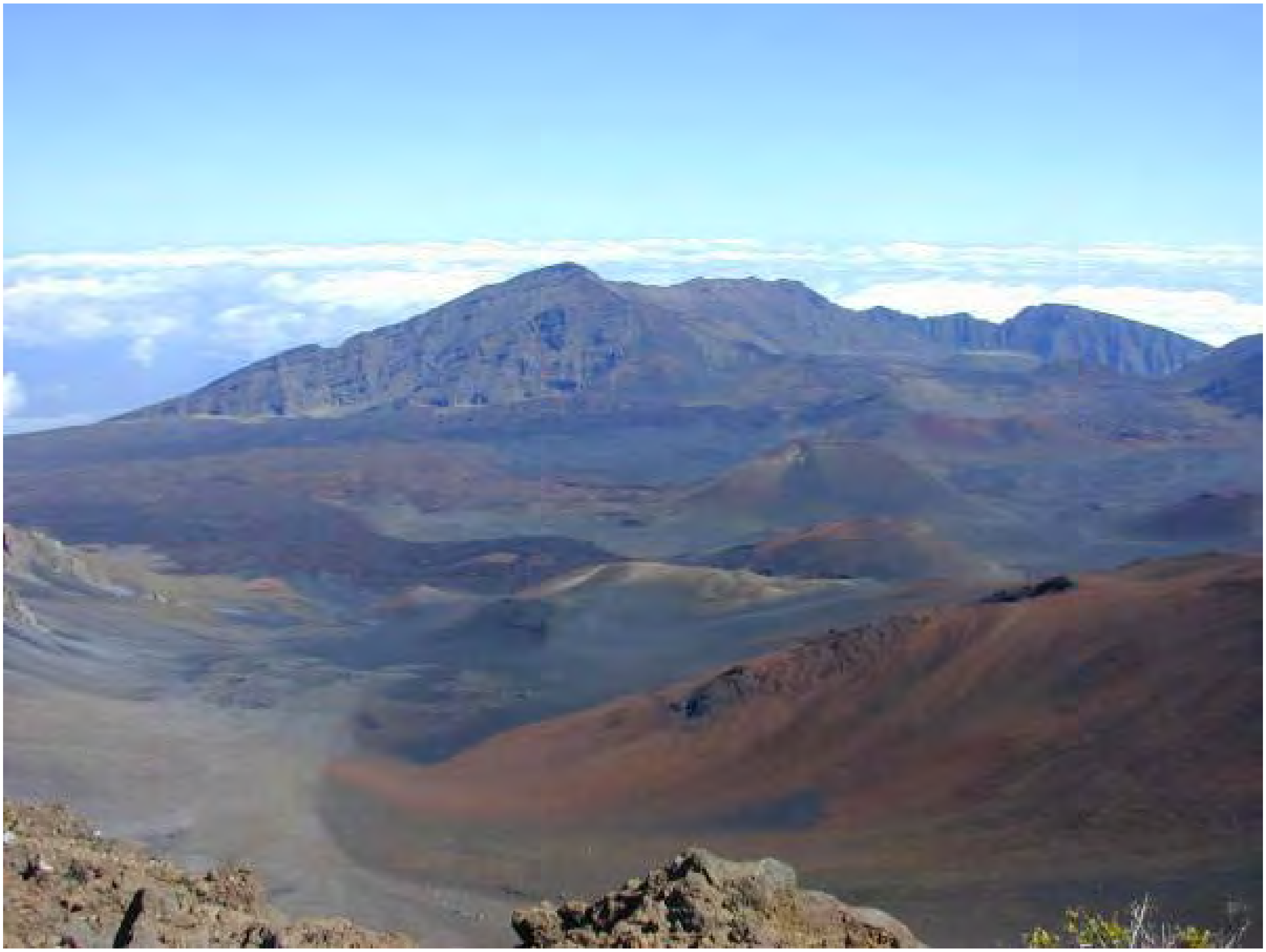
Shows structure with snow.

Construction of the foundation.

Charles Fein of F.C. Environmental and Dr. Faulkes, with telescope foundation in the background.

Concrete enclosure of Faulkes Telescope.

Workers constructing base of telescope in "pit".



Halehaku Overlook, shows the cinder cones (or Pu‘u). Names of Pu‘u can be obtained from “Sacred Names of Haleakalā”.

Ahinahina (Haleakalā silversword)
Argyroxiphium sandwicense* ssp. *Macrocephalum
Looking into crater towards Hana Mountain (Hanakauhi).

Silversword ending it's bloom with young plants growing on rim, overlooking Haleakalā Crater.

CONCLUSION – *EIA KA LĀ KAU:*

HIGH ALTITUDE OBSERVATORY
18.1 ACRE SITE, Tax Map Key 2-2-7-08
HALEAKALĀ, ISLAND OF MAUI, HAWAIʻI.

In Report #1, "Kū I Ka Mauna" (Upright at the Mountain), Traditional Practices Assessment submitted on December 2000, and this Report #2, "Kū I Ka Mauna" (Upright at the Mountain), Cultural Resources Evaluation, May 2003, the following summary is being submitted.

Kolekole, known as the summit of Haleakalā, or even "Science City" as it is sometimes referred to, is a very sacred place for the Kanaka Maoli, past and present. It is surprising, at best, that the buildings were even allowed to be built in this place that the Hawaiians call "*Wahi Pana*" (a legendary place). It was considered the *Piko* (navel), the center of Maui Nui O Kama (the greater Maui), and legends abound about the gods and goddesses that dwelled there in mythological times. These identities are still revered by the Kanaka Maoli of modern times. People from all over the world have felt the "essence" of Haleakala on their visits, and have documented in numerous publications their feelings of being "one with the gods" at the summit.

In a study published in May 2001 by KC Environmental, titled "Final Environmental Assessment Negative Declaration for the Faulkes Telescope Facility at Haleakala, Maui Hawaii", the last paragraph in Section 3.10 of the Traditional Practices Assessment mentions that; "The study did not identify impacts to burials, Hawaiian trails, hunting and gathering practices for plant or animal resources, religious sites, archeological sites or historic properties." The report determined a "finding of no significant impact".

Hawaiian's history, from the beginning of their ancient culture, shows that they consider lava, cinders, rocks and other material from the land sacred because it was created by *Pele*. That is why when a geothermal exploration team came to Maui to explore the possibility of drilling at several places around Mt. Haleakalā, there were protests by Native Hawaiians that did not want to see the drilling "disturb" the essence of *Pele*. The "essence" being the rock, cinders, and ash, which are the *Kinolau*(supernatural forms taken by *Pele*).

Photographs 1 to 10, which are attached to this report, shows how a backhoe has dug a pit of 20' deep, in a large diameter, consisting of volcanic rock, cinders and ash, the *Kinolau* of *Pele*. How can this action be interpreted as having "No significant impact", when it actually has the opposite effect. To add insult to injury, prayers were only offered during the ground breaking ceremonies. No Cultural protocol prayers were performed for "asking" permission from the ancient gods to

build the Faulkes Telescope. And, as construction continued, there was no reverence to the beliefs of the ancient and modern host culture of Hawai'i.

In his testimony, Erik Fredrickson of Xamanek Researches said that from his findings of the archaeological sites at Kolekole, he interprets this area as having a lot of sites and features for a small area, compared to the surrounding areas of Haleakalā. And, there were a lot of cultural and spiritual and ceremonial activities at the site.

In conclusion, it is of utmost importance that the suggestions made in the Introduction page of the report under the heading, <u>RULES FOR LONG TERM METHOD FOR PRESERVATION OF CULTURAL RESOURCES FOR ALL FACILITES PAST, PRESENT, AND FUTURE ON KOLEKOLE, HALEAKALĀ</u>, be brought to fruition. In this section, it outlines 7 procedures that should take place, and these recommendations would be a win-win situation for all involved. But, most importantly, it would establish a cultural protocol that would preserve the site, not only as a place for astronomy, but as a place where its Hawaiian Cultural aspects are ingrained in perpetuity.

GLOSSARY:

Kolekole – Land section in Kilohana and Mākena. There are two versions of what Kolekole means: (1) One account explicates that Kolekole was named after the fish, Kole. Kole‘s skin color is a rusty deep brown, almost like the cinders at Kolekole. (2) The second account stated that Kolekole is the Hawaiian word for "talk story". Some believe that it was an area where Kahuna Po‘o (Head Priests) would convene to discuss issues.

‘Āina – Land.

Ka wā kahiko – In the time of the traditional.

Pu‘u Honua – Place of refuge, sanctuary; a place of peace and safety.

‘Aumakua – Family or personal gods: Deified ancestors who might assume the shape of a shark (all islands except Kauai) owls, mud hens, octopuses, eels, almost all animals in Hawai‘i.

Ka po‘e Kahiko – People of old.

Mo‘olelo – Story, history, literature, legend, journal, essay, chronicle.

Pae’āina O Hawai‘i – Group of Hawaiian Islands; archipelago.

Kanaka Maoli – True aboriginal person.

Na Po‘o Kahuna – High Priest.

Kāhea – To call out.

Ao holo‘oko‘a – The Universe.

Kanu – To plant or bury.

Ali‘i – Hawaiian Royalty.

Kapu – Prohibition, taboo, "Keep out".

Piko – Navel; center.

Kupuna -Ancestor, generation, grandparent.

<u>Mau'ula'ili</u> (sysrinchium acre) – Native Iris, with long grass like leaves and small yellow flowers, found on Maui and Hawai'i above 2 thousand feet elevation.

<u>Pele</u> – Goddess of the volcano; Lava flow, volcano, eruption - all named for the Goddess Pele.

<u>Kamo'oali'i</u> – King of the Sharks; He led the *Pele* family from Kahiki to Hawai'i, ending up on Kaho'olawe Island.

<u>Hi'iaka-ikapoli-O-pele</u> – The youngest sister of Pele, and the god of thunder.

<u>Pāoa</u> – The divining rod by which Pele tested the suitability of areas for excavation on the island of Nihoa, at various places on O'ahu (Salt Lake, Punchbowl, Leahi, Makapu'u) and on Maui. Finally she planted the staff at Pana'ewa, Hawai'i, and it became a tree.

<u>'Alanuihāhā</u> – Channel between Maui and Hawai'i.

<u>Māui</u> – The demigod and trickster who snared the Sun, so that his mother's tapa cloth could dry.

<u>Poli'ahu</u> – The goddess of the snow.

<u>Wahi-Pana</u> - Sacred place; spiritual place.

<u>Pōhaku Palaha</u> - A stone located on the Kapalaoa Ridge of Haleakalā Crater, that is the beginning of the 8 land districts or Ahu-pua'a in the East Maui area.

<u>''Āina</u> - Land.

<u>**WORKS CITED:**</u>

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APPENDIX B

Supplemental Cultural Impact Assessment, May 2007

Supplemental Cultural Impact Assessment for the Proposed Advanced Technology Solar Telescope (ATST) at Haleakalā High Altitude Observatories Papa‘anui Ahupua‘a, Makawao District, Island of Maui

TMK: (2) 2-2-07:008

Prepared for

KC Environmental

and

The National Science Foundation (NSF)

Prepared by

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Cultural Surveys Hawai‘i, Inc.

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(Job Code: HALEA 2)

May 2007

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Management Summary

Report Reference	Supplemental Cultural Impact Assessment for the Proposed Advanced Technology Solar Telescope (ATST) at Haleakalā High Altitude Observatories Papa‘anui Ahupua‘a, Makawao District, Island of Maui TMK: (2) 2-2-07:008 (Dagan et al. 2007)
Date	May 2007
Project Number	CSH Job Code: HALEA 2
Project Location	Overall Location: Pu‘u Kolekole, Haleakalā High Altitude Observatories (TMK [2] 2-2-07:008), as depicted on the USGS 7.5 minute Topographic Survey Map, Portions of Kilohana Quadrangle and Lualailua Hills Quadrangle. Preferred ATST Site Location: Mees Solar Observatory Facility Alternate ATST Site Location: Reber Circle
Land Jurisdiction	State of Hawai‘i
Agencies	National Science Foundation (NSF) – Proposing Agency Association of Universities for Research in Astronomy (AURA) – Proposing Agency University of Hawai‘i Institute for Astronomy (UH IfA) – Managing Agency U.S. Environmental Protection Agency (EPA) – Federal Reviewing Agency U.S. Fish and Wildlife Services (USFW) – Federal Reviewing Agency Department of Land and Natural Resources, State Historic Preservation Division (DLNR/SHPD) – State Reviewing Agency State of Hawai‘i Office of Planning – State Reviewing Agency
Project Description	The National Science Foundation is proposing to build the Advanced Technology Solar Telescope (ATST) at the 18.166-acre Haleakalā High Altitude Observatories.
Project Acreage	0.60-acres
Region of Influence (ROI)	The area of direct affect is considered as the 0.60-acre site for the potential construction of the ATST. When contemplating both direct and indirect effects on the cultural and historic resources the ROI for this undertaking is defined as the entire summit area of Haleakalā.
Project Environmental Regulatory Context	As a federally funded project on state lands, this undertaking is subject to both Federal and State of Hawai‘i Environmental Regulations. With regard to Federal regulations, this undertaking is subject to the National Environmental Protection Act (NEPA) 40 Code of Federal Regulation [CFR} Part 1500-1508, as well as the National Science Foundation’s NEPA-implementing regulations 45 CFR Part 640. With regard to State of Hawai‘i Environmental Regulations, this undertaking is subject to Hawai‘i Administrative Rules (HAR) Title 11 Chapter 200-4(a) and Chapter 343 of the Hawai‘i Revised Statutes (HRS).

Consultation Results and Cultural Impact Recommendation	Based on the information gathered during the course of this study and presented in this report, the overwhelming evidence, from a cultural and traditional standpoint, points toward a significant adverse impact on Native Hawaiian traditional cultural practices and beliefs. This determination of significant adverse impact would apply to both the preferred Mees Location and the alternative Reber Circle location. To the majority of Native Hawaiians and non-Hawaiians who participated in the scoping, public comment, and overall Section 106 process, the proposed undertaking is unmitigable and therefore, following the "No Action" alternative and keeping both the Mees site and Reber Circle site in their current undeveloped state was strongly recommended. In the event that the proposed undertaking is approved and funding secured, it is highly recommended that more time for mitigative proposals be allotted and the development of working relationships with Native Hawaiian groups be actively pursued. As Haleakalā plays a central role in the history and culture of Maui Island *kanaka maoli* it is imperative that there be open lines of communication and that every effort is made to hear, understand, and respect the cultural concerns and beliefs of the community during the course of project construction, as well as throughout the operational time span of the facility itself.

Table of Contents

The missing pages are for the specific project this supplemental cultural impact assessment was originally intended for.

The intent of providing this Appendix for the Environmental Assessment is for its information content regarding Native Hawaiian cultural and traditional practices.

Missing pages are for the specific project this supplemental cultural impact assessment was originally intended for. The intent of providing this Appendix for the Environmental Assessment is for its information content regarding Native Hawaiian cultural and traditional practices.

List of Figures

List of Tables

Section 1 Introduction

1.1 Project Background

At the request of KC Environmental, and on behalf of the National Science Foundation, Cultural Surveys Hawaiʻi, Inc. conducted a Supplemental Cultural Impact Assessment (SCIA) for the Advanced Technology Solar Telescope (ATST) Project atop Puʻu Kolekole, within Papaʻanui Ahupuaʻa, Makawao District, Maui Island (Figure 1). The proposed action is for the construction, installation, and operation of the ATST at either the preferred Mees Location or alternate Reber Circle Location (see Figure 1) near the summit of Mauna Haleakalā and within the 18.166-acre University of Hawaiʻi Institute for Astronomy (IfA) Haleakalā High Altitude Observatories site (HO) [TMK (2) 2-2-07:008] (KC Environmental 2006:Section 1.1) (Figure 2).

This SCIA was performed in accordance with the guidelines for assessing cultural impacts as set forth by the Environmental Council of the Hawaii State Department of Health Office of Environmental Quality Control (OEQC) (Hawaii State Department of Health Office of Environmental Quality Control 1997) and is intended to supplement the existing Cultural Resource Evaluation (Maxwell 2006) included in the Draft Environmental Impact Statement (DEIS) for the proposed project (KC Environmental 2006). The primary purpose of this study was to widen community outreach and gather additional information on the traditional cultural property of Haleakalā as an additional means to assess the potential impacts of the proposed undertaking on Native Hawaiian traditional cultural practices and/or beliefs.

1.2 Scope of Work

The following scope of work served as the framework within which this study was conducted:

1. Additional background research regarding the historic preservation and OEQC regulatory framework for a project of this scope;
2. Substantial background research regarding the traditional and mythological setting for Mauna Haleakalā;
3. Additional background research, to supplement previously submitted materials, regarding the previous use, and modification of, the summit area;
4. Additional interviews or consultations which could include group meetings as well as formal and/or informal individual interviews (e.g. meetings with those living at Kahikinui, Kanaio, or Kaupō; consultation with Hawaiian cultural practitioners and organizations identified during the consultation process and commentary period; consultation with other parties to include the Friends of Haleakalā and other interested organizations);
5. An analysis and discussion of the criteria of eligibility of Haleakalā as a traditional cultural property (as mentioned in the October 23, 2006 State Historic Preservation Division/Department of Land and Natural Resources review letter, Log No. 2006-3502) will be analyzed, discussed and evaluated; and
6. Preparation of a supplemental report to include the findings from the additional background research, the results of additional community consultation, and an analysis of significance

and project effect in the context of the items listed above. This document would also address the review comments of the DEIS and incorporate the comments into the fabric of the report. All aspects of the cultural and historical significance of Haleakalā as a traditional cultural property will be considered in evaluating the project's cumulative impacts.

1.3 Environmental Setting

The proposed ATST Telescope site is within the 18.166-acre HO parcel and located near the summit of Haleakalā along the southwest rift ridge atop Puʻu Kolekole at approximately 9,940 feet above mean sea level (amsl). The tallest point of the mountain of Haleakalā is the top of a 300-foot tall cinder cone named named Puʻu ʻUlaʻula [Red Hill], located due east of Puʻu Kolekole, at 10,023 amsl.

1.3.1 Natural Setting

The natural landscape of the surrounding project area is dominated by hills of red cinder and basalt ejecta from eruptions that formed large cinder cones both within the crater and along rift zones to the northeast and southwest of the summit. Soils in the project area are classified as Cinder land ("rCl"), soils which predominate the landscape between 8,000 feet amsl to the summit. Cinder land is described as "areas of bedded magmatic ejecta" which display various shades of red, yellow, black or brown from the decomposition of iron oxide. Mixtures of volcanic cinder, ash and pumice found at the summit area are the result of eruptions of the cinder cones of Puʻu ʻUlaʻula [Red Hill], Puʻu Kolekole and Pakaʻoaʻo [White Hill]. The soil association found in the summit area is classified as "Rock land", and can be generally described as rough, mountainous land. The soil association is made up of areas where exposed rock covers 25 to 90 percent of the surface, wherein rock outcrops and shallow soils are the main characteristics. Although cinder land soils of the rock land association supports some vegetation, the primary land use is for wildlife habitat and recreational areas (Foote et al. 1972:29).

Rainfall at the summit of Haleakalā averages between 8 inches during the months of December-January, and 0-2 inches during June, for a yearly average between 30 and 55 inches (Giambelluca et al. 1986) and is vastly different than rainfall measured at the northeastern end of the crater, which can average as much as 180 inches per year (Juvik and Juvik 1998). The annual mean temperature (based on a standard 30-year period from 1961-1990) at the Haleakalā Research Station is 52.4˚F, with a yearly maximum temperature of 62.6˚F and a yearly minimum temperature of 44.1˚F (Sanderson 1993:51).

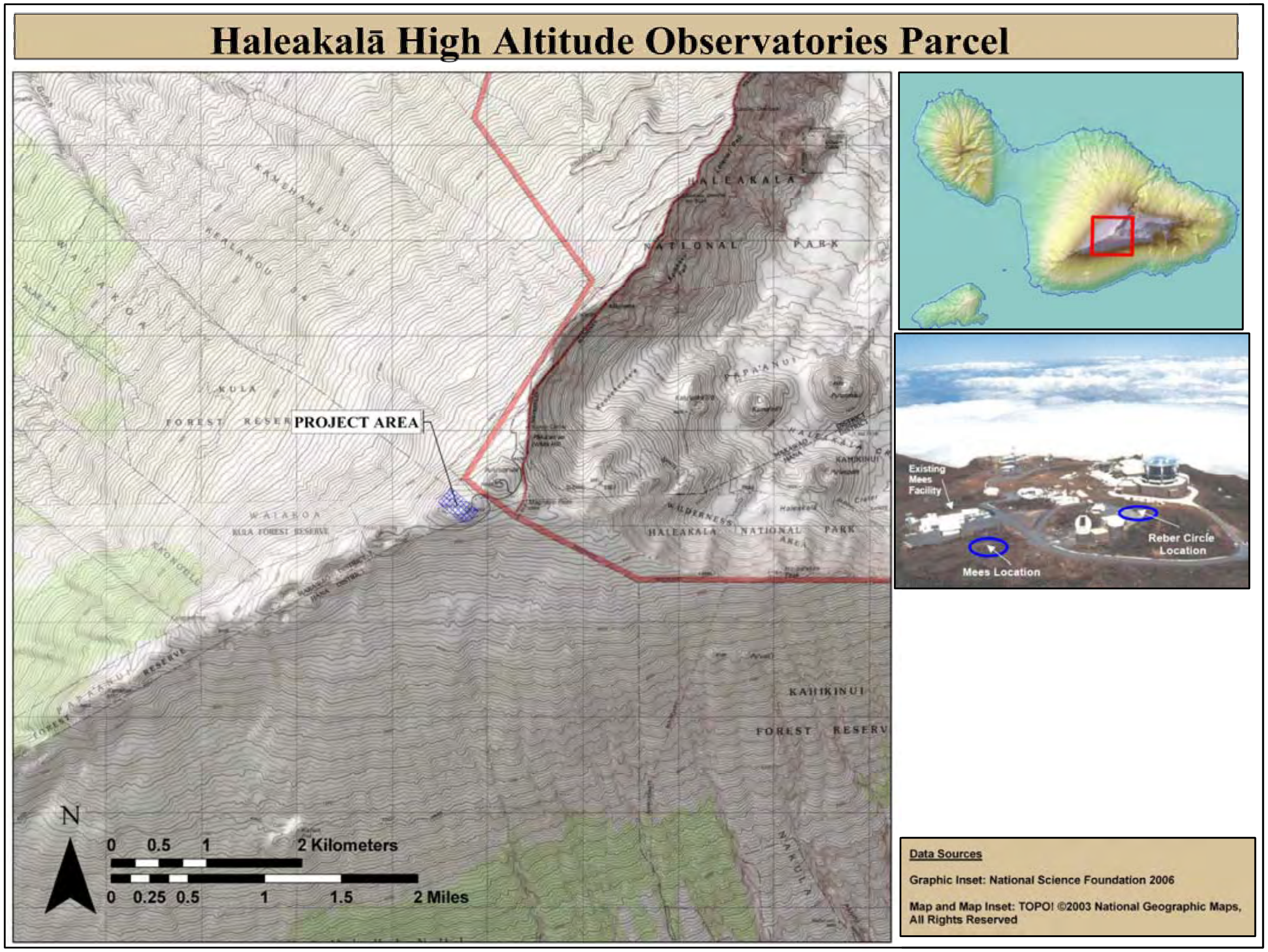

Figure 1. Portions Kilohana (1983) and Lualailua Hills (1983) 7.5-minute USGS topographic quadrangles with project location indicated by blue shaded area.

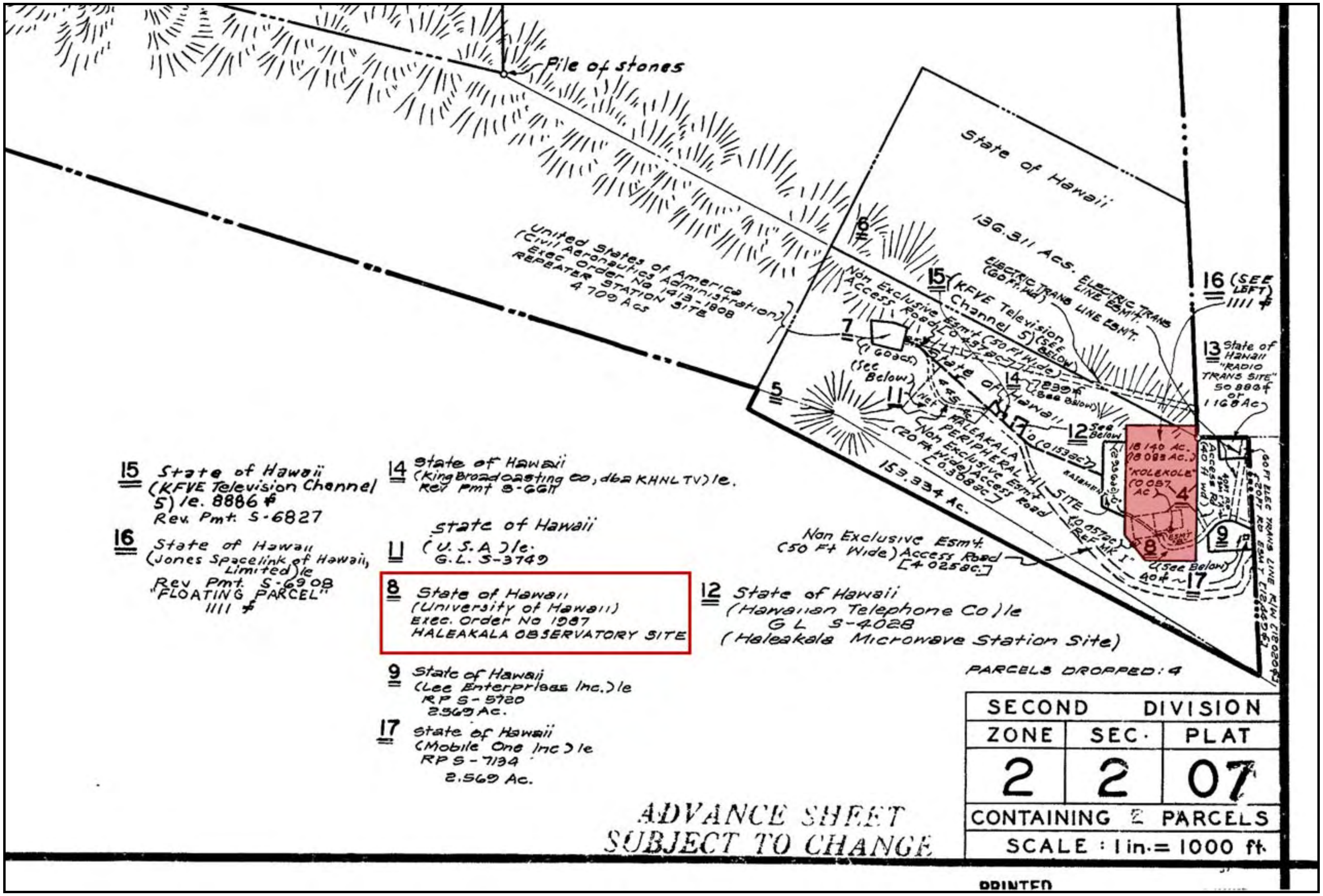

Figure 2. TMK (2) 2-2-07 showing loction of project area shaded in red

Plant cover within the project area is sparse (approximately 5-10% cover), consisting primarily of kūpaoa (*Dubautia menziesii*), a native plant of the daisy [Asteraceae] family. Other plants observed included an invasive perennial grass (*Deschampsia nubigena*) common to the high altitude environment, and a native species of grass, *pili uka* (*Trisetum glomeratum*). *Pūkiawe*, a native shrub (*Styphelia tameiameiae*), and a native daisy (*Tetramolopium humile*), were also observed (www.hear.org/starr/hiplants/). A complete listing of project area plants can be found in Appendix E (Botanical Survey), in the parent document prepared by KC Environmental (2006).

Several previous investigations of the avifauna observed at the Haleakalā National Park have documented the existence of endangered bird species that live at the summit area of the crater. A complete listing of the project area bird populations can be found in Appendix I (Petrel Monitoring Plan), in the parent document prepared by KC Environmental (2006).

1.3.2 Built Setting

To the north of the project area boundary, a paved road leads to the visitor observatory at the summit of Pu‘u ‘Ula‘ula . A paved and restricted-access roadway to the FAA and Hawaiian Telcom stations lies to the south of the project area. A visitor observatory is located on a secondary ridge of Pu‘u ‘Ula‘ula , overlooking the trailhead of Sliding Sands and the crater (to the east) and the as-built facilities of “Science City” (to the west).

The resident facilities of “Science City” are a mixture of defense structures maintained by subcontractors to the United States military, such as the AMOS Air Force Maui Optical Station, and scientific observatories operated by various countries, such as the MAGNUM 80-inch telescope operated by astronomers from Japan. The observatories at the summit of Haleakalā are coexistent with broadcast and relay substations for television and radio.

Section 2 Methods

2.1 Documentary Research

Historical documents, maps, online resources, and existing archaeological reports pertaining to the myths and legends of Mauna Haleakalā, prominent figures in traditional Hawaiian history, and historic properties were researched. Venues of research included the private collection of the authors, the State Historic Preservation Division, as well as maps on file at the Library of Congress.

2.2 Commmunity Consultation

The Office of Hawaiian Affairs, the Department of Hawaiian Homelands, the Maui/Lanai Islands Burial Council, the Maui County Cultural Resources Commission and members of other community organizations were contacted in order to identify potentially knowledgeable individuals with cultural expertise and/or knowledge of the study area. A discussion of the consultation process specific to the current study can be found in Section 6 Community Contacts and Consultations. Please refer to Table 13. Preliminary Results of Community Consultations for a complete list of individuals and organizations contacted for this study.

Section 3 Traditional and Historic Background

In order to gain an understanding of the importance and significance of Haleakalā, it is necessary to look at the symbology of the mountain, as well as the mountain's role in the history of Maui Island as a living entity. It has been said that the island of Maui was once known as Ihikapalaumaewa (Kamakau in Sterling 1989:2 and McGuire and Hammatt 2000). The name suggests a meaning of sacred reverence and respect (from *hōʻihi*). In former times, Maui was also known as Kūlua, a probable reference to the East and West Maui districts, which were separate polities by A.D. 1400-1500 (Sterling 1998:2; Kolb *et al*. 1997:16).

Traditionally, Maui Island was separated into 12 *moku*, or districts during the time of the *Aliʻi* Kakaalaneo and under the direction of the *Kahuna* Kalaihaʻohiʻa (Beckwith 1940:383). The western portion Maui Island, dominated by Mauna Eke, the range commonly referred to as the West Maui Mountains, was subdivided into three *moku*: Lāhaina, Kaʻanapali, and Wailuku. The eastern portion of Maui Island, dominated by Mauna Haleakalā, was subdivided into the remaining nine *moku*: Hāmākua Poko, Hāmākua Loa, Koʻolau, Hāna, Kīpahulu, Kaupō, Kahikinui, Honuaʻula, and Kula. There is a naturally circular stone plateau, referred to as Pālaha (Sterling 1998:3), along the summit of Haleakalā where one *ahupuaʻa* from each *moku*, with the exception of Hāmākua Poko, originate. Pōhaku Pālaha (Figure 3), as it is commonly known today, is located on the northeast edge of Haleakalā Crater, at Lauʻulu Paliku and is considered as the *piko* (navel or umbilical cord [Pukui and Elbert 1986]) of east Maui (Mr. Timothy Bailey, personal communication [Subsection 6.1.11]; see also Section 7.7 Pōhaku Pālaha-The Piko of East Maui).

Kapiʻioho Naone (in McGuire and Hammatt 2000) recalls a story told by Kupuna Pale, a Hawaiian woman that he cared for as a young boy. According to Naone, she always referred to Haleakalā as the entire mountain and to Halemahina as the West Maui mountains:

> (S)he would refer to Haleakalā as the house of the male and, this one over here as Halemahina, the house of the female or the house of the moon … The whole West Maui mountains, she considered the *piko ka honua*, the navel of the earth, the woman. She would tell me that Maui was lucky because Maui had a male and female — Maui was complete. It wasn't all male and it wasn't all female. It was complete. And, so we would talk about Haleakalā as the male part of the island … (Kapiʻoho Naone in McGuire and Hammatt 2000:Appendix B)

Sam Kaʻai (in McGuire and Hammmatt 2000:13) also indicated that Haleakalā was "male" and related that the best adze material comes from a cliff at Nuʻu where Māui's *ule* (penis) struck the side of the mountain

Figure 3. A portion of the Hawaiian Government Survey Map (Dodge 1885) showing Pōhaku Pālaha in relation to Puʻu Kolekole.

3.1 Traditional Accounts of Haleakalā

According to Abraham Fornander, the name "Halekalā" is said to be a "misnomer" and is incorrect: Aheleakala is the correct name (Fornander 1919, V, III: 536). He goes on to explain that Ahelekalā is:

> The ancient name of Maui's famous crater, which means, "rays of the sun," and it was these which the demigod Maui snared and broke off to retard the sun in its daily course so that his mother might be be able to dry her kapas. (Fornander 1918-1919:V:534-36)

Fornander (1918-1919:V: 538) further states that an informant, Lemuel K.N. Papa Jr., gives the correct name is Alehelā "on account of Māui's snaring the rays of the sun, where the word *‘alehe* is a variant form of *‘ahele.* Both words literally mean "to snare". "Haleakalā" refers to not only the literal meaning, but the fact that the sun's path passes through Haleakalā each morning, thus the common interpretation of the name, "house of the rising sun". Today, the practice of driving up to the summit of Pu‘u ‘Ula‘ula to see the sunrise, by both tourist and *kama‘āina*, serves to reinforce this perception of the name "Haleakalā".

Inez Ashdown (1971:68) disagrees with Fornander and writes that "Aleha-ka-lā" (Sun-snarer) is a more recent name attributed to the Māui traditions and Māui's feat of slowing the sun. She goes on to say that the name is really "Hale‘a-ka-lā" which refers to the "entire east mountain of Maui", while "Hale-a-ka-lā" is the peak over by Kaupō Valley. She writes:

> The proper name means Consecrated to, or by the sun and is poetically associated with Nā Mele o Nā Māhele of that mountain of legends and creation. (Ashdown 1971:68.)
>
> …or a sacred place of rejoicing because Wa-na-ao, the Dawn, brings the new day from that mountain mass. (Ashdown 1971:30)

Included in the first U.S.G.S survey of Haleakalā Caldera report was also a cultural analysis of the place name "Haleakala":

> Some of the white residents, learned in the native language, suggest that this name should be Hele-o-ka-lá, which means the trap in which the sun was caught. *Hale* means a house, but *hele* means a trap. The prepositions *a* and *o* both signify *of*, but the former implies an active relation of the *la*, or sun, while the latter implies a passive relation; that is to say, a-ka-la means that the sun did something – perhaps built the house or dwelt in it. But o-ka-la means that something was done to the sun. Now there is a well-known myth that Maui, the great hero and Ulysses of the Hawaiians, laid a snare for the sun and caught him, compelling him to make the daylight twelve hours long instead of eight (Dutton 1883:199).

The mountain of "Hale-a-ka-la" (terminology of Westervelt 1910) is the setting for the greatest deed of the legendary demi-god of Hawaiian literature, Māui. The myth depicting Māui's power over the travels of the sun is known throughout most of Polynesia, and although many of the details of Māui snaring the rays of the sun may be different (the composition of the snare, etc.), the importance of Māui capturing the sun as it rose in the east, from the underworld, is a universal detail. The many deeds of the demi-god Māui have become united into a continuous series, known universally to cultural anthropologists as the "Maui Cycle" (Luomala 1949).

Legends of the goddess Pele are also well known throughout Polynesia. In Rarotonga, Pere, the fire goddess, is the daughter of Mahuika, and it is from her that Māui (the demi-god of Hawaiʻi) obtains fire for his family. Pere is driven away from Raratonga by Mahuika, and she flees to Va-ihi (Hawaiʻi). In French Polynesia, Pere exists as the goddess of volcanoes, and in Aotearoa (New Zealand), she is known as Pele-honua-mea. In Hawaiʻi, Haleakalā was once her home, but she is now believed to reside on the island of Hawaiʻi, at the active volcanic vents of Kīlauea.

The traditional lore of Polynesia was recorded by a number of early visitors to the islands of the Pacific, and those traditions that include the Hawaiian demi-god Māui, the fire goddess Pele, and references to Mauna Haleakalā are summarized in the following table (Table 1).

Table 1. Summary of Traditions Related to Haleakalā

Legend	Source	Page No.	Synopsis
How Māui snared the sun	Armitage, George T. and Henry P. Judd (Ghost Dog and other Hawaiian Legends)	61	Reference to the sun rising over the Koʻolau Gap: ("He made a trip over the mountain ridges and across the plains until he came to Mount Haleakalā . He first saw the sun through the Koolau Gap and then, like a giant disc, it wheeled over the top of the black crater walls and thence up into the heavens.") Māui's grandmother was said to have lived in Haleakalā Crater, and baked bananas in an oven near a *wiliwili* tree where the sun would stop for a meal.
Māui snares the sun	Colum, Padraic	22,26	Māui observes the sun rising over Haleakalā through a break in the chasm sides. The correct name for the crater is given as "A-hele-a-ka-lā (rays of the sun)". As the sun comes through the chasm, it eats the bananas cooked by Māui's grandmother, who lives at Haleakalā. Māui forces an agreement with the sun, making longer days in the summer and shorter days in the winter.
How Māui snared the sun so that his mother's *kapa* could dry.	Colum, Padraic (Legends of Hawaiʻi)	47-52	A hele-a-ka-lā (rays of the sun) is given as the old name for Haleakalā. Maui's grandmother lives on the side of Haleakalā. The legend explains the longer days of summer and the shorter days of winter.
Legend of Māui snaring the sun	Fornander, Abraham (Fornander Collection of Hawaiian Antiquities and Folk-Lore	Vol. V: 536,538	Māui climbs Haleakalā to slow the sun and gives "Aheleakala" as the correct name of the mountain. Māui broke some of the sun's rays with a coconut husk snare. Fornander's informant, Lemuel K.N. Papa Jr. gives the correct name as "Alehela" for the mountain. The name given to the sun's rays which Māui found sleeping in a cave was "Moemoe".
Māui conquers the sun	Hapai, Charlotte ("Legends of the Wailuku")	4-6	Māui travels to Haleakalā from Rainbow Falls, outside of Hilo, to battle the sun. This account gives the explanation for shorter winter days and longer summer days.
Māui slows the sun	Lyons, Barbara ("Māui, The	15-19	From the tip of Mauna Kahalawai (the meeting place between heaven and earth) Haleakalā could be seen. Māui's

Legend	Source	Page No.	Synopsis
	Mischievious Hero”)		grandmother lives at the edge of the crater, near a *wiliwili* tree with red seeds.
How Māui snares the sun	Metzger, Berta (“Tales Told in Hawaii”)	81	Māui climbs Haleakalā to snare the sun.
Slowing the sun	Pukui, Mary Kawena (“Tales of the Menehune”)	19-21	Collected from Harriet Coan, island of Hawai‘i. The sun is described as rising through an opening in Haleakalā. The seasonal variation of summer/winter is explained.
How Maui slows the sun	Thrum, Thomas (“Hawaiian Folk Tales”)	31-33	Maui observes the sun rising directly over Haleakalā and battles it to allow his mother, Hina, to dry her *kapa*. The word for sun snarer is given as “Alehekalā”.
Māui destroys Kuna Loa	Armitage, George T. and Henry P. Judd (“Ghost Dog and other Hawaiian Legends”)	72-73	Māui rests near the *wiliwili* tree on Haleakalā and sees a warning cloud (“ao ‘ōpua”) over his mother’s cave.
Māui and Kuna Loa: the long eel	Colum, Padraic (“At the Gateways of the Day”)	34	From Haleakalā, Māui sees the warning cloud (“ao ‘ōpua”) over his mother’s cave in Wailuku.
Māui and the eel, Kuna Loa	Lyons, Barabara (“Māui, the Mischevious Hero”)	25-29	Māui makes the long trip to Haleakalā to visit his grandmother. From Haleakalā, he sees the danger signs of the “ao ‘ōpua”.
Kana, the youth who could stretch himself upwards	Colum, Padraic (“At the gateways of the Day”)	145	A “groove” was made in Haleakalā by Kana, as he stepped over the sea and mountain to reach his grandmother’s door on the island of Hawai‘i. The groove remains to this day.
Legend of Kana and Niheu	Fornander, Abraham	Vol. IV: 448	Kana bends himself over the top of Haleakalā, creating a groove in the mountain which “can be seen to this day”.
Story of the Great Flood	Fornander, Abraham	Vol. V: 526	A flood accompanied the arrival of Pele in Hawaiki [Hawai‘i] after she left Tahiti. Pele and her brothers and sisters went to live at Haleakalā, where she excavated the crater with her digging stick.
Pele and the Deluge (“Kai a Kahinali‘i”)	Thrum, Thomas (“Hawaiian Folk Tales”)	36-38	Pele travels to Hawai‘i in search of a new home. A flood accompanies her. The sea rises and only the tops of the highest mountains can be seen. Pele digs the crater of Haleakalā.
How Māui lifted the sky	Armitage, George and Henry P. Judd (“Ghost Dog and other Hawaiian Legends”)	49	Storms and storm clouds plague Haleakalā, forcing Māui to push them further skyward.
Māui lifts the sky	Lyons, Barbara (“Maui the Mischeivious Hero”)	7-9	Maui lifts the sky above Haleakalā.
Māui lifting the sky	Westervelt, W.D.	31	“Nevertheless dark clouds many times hang low along the

Legend	Source	Page No.	Synopsis
			eastern slope of Maui's great mountain-Haleakalā -and descend in heavy rains upon the hill Kauwiki; but they dare not stay, lest Maui the strong come and hurl them so far away that they cannot come back again”.
Māui fishes for an island	Armitage, George and Henry P. Judd (“Ghost Dogs and Other Hawaiian Legends”)	51	Mentions Haleakalā in the distance as Maui sets out to dislodge the islands from the hold of a supernatural being at the bottom of the ocean.
Maui fishing for the islands	Westervelt, W.D.	12	“The bottom of the sea began to move. Great waves arose, trying to carry the canoe away. The fish pulled the canoe two days, drawing the line to its fullest extent. When the slack began to come in the line, because of the tired fish, Maui called for the brothers to pull hard against the coming fish. Soon land rose out of the water. Maui told them not to look back or the fish would be lost. One brother did look back-the line slacked, snapped, and broke, and the land lay behind them in islands”.
Māui discovers the secret of fire	Armitage, George and Henry P. Judd (“Ghost Dogs and other Hawaiian Legends”)	66, 68	Māui sees smoke rising from the slopes of Haleakalā and discovers the secret of fire from the mudhens. The mudhens [ʻalae] have a red mark on their foreheads as punishment after they tried to trick Māui and not give up the secret of fire.
The secret of fire-making	Collected by Pukui, Mary Kawena (“Tales of the Menehune”)	26-32	From a translation by A.O. Forbes in Thrum’s “Hawaiian Annual”. Tells how man accidently discovered that the fire from lava could cook food (ʻulu, maiʻa), but did not know how to create it himself. Explained how the head of the mudhen was turned red.
Keoua, a story of Kalawao	Gowan, Herbert H. (“Hawaiian Idylls of Love and Death”)	106	Keoua goes to Kalawao, Kalaupapa (Molokaʻi) in search of his wife, Luka, a resident of the leper colony. The rising sun revealed “the majestic ridges of Haleakalā”.
The Tomb of Puʻupehe (A Lānaʻi legend)	Thrum, Thomas (“Hawaiian Folk Tales”)	181-185	The beauty of Puʻupehe was described: “Her glossy brown spotless body shone like the clear sun rising out of Haleakalā”.
Halemano and Princess Kama	Colum, Padraic (“At the Gateways of the Day”)	102	While at the grove at Ke-a-kui, Halemano makes a maile lei (a wreath) and describes Haleakalā: “like a painted cloud in the evening”.
Legend of Halemano	Elbert, Samuel H., editor, Selections from Fornander (1959)	266-68, 274	Halemano describes the sight of Haleakalā from Lele (Lahaina) on Maui as “like a painted cloud in the evening, as the other clouds drifted above it”.
Legend of Halemano	Fornander, Abraham	Vol. V: 238, 240	Halemano describes the sight of Haleakalā from Lele (Lahaina) on Maui as “though floating above the clouds”. The vision was enough to entice Halemano to travel to Kaupō and live there awhile.
The Jealous Wife	Metzger, Berta	81	The story of Aukele mentions Pele’s travels and her work at

Legend	Source	Page No.	Synopsis
	("Tales Told in Hawaii")		Haleakalā. Her fires were too small to heat the large crater, so she moved to Kīlauea.
The Legend of Puʻulaina	Fornander, Abraham	Vol. V: 534-36	Details the two ancient names of the mountain (Aheleakala and Alehela). "Formerly there was no hill there, but after Pele arrived, this hill was brought forth".
Hua, the unjust king, and the famine he caused	Skinner, Charles M. ("Myths and Legends of our New Possessions")	243	Luahoʻomoe of Hāna sent his two sons to live in Haleakalā to escape the wrath of Hua. Hua is cursed after the unjust death of Luahoʻomoe, and dies. The two sons meet a visiting chief from Oʻahu at Kaupō, and leave Haleakalā to form a new government in Hāna.
Travels of Pele and Hiʻiaka	Emerson, Nathaniel	XIV-XV	Pele made her home in Haleakalā but left because it was too large to keep warm. Pele fights with queen Namakaokahaʻi.
Travels of Pele and Hiʻiaka: "Legend of Aukelenuiaiku"	Fornander, Abraham	Vol IV: 104-106	Pele digs a pit at Haleakalā and starts her fires burning there. The battle with queen Namakaokahaʻi ends in Pele's death, but Pele returns as a spirit.
The Story of Pele and Hiʻiaka	Green, Laura ("Hawaiian Stories and Wise Sayings")	18-19	Reference to Pele's travels through the islands looking for a home and her short stay at Haleakalā.
Dwelling places of Pele	Lawrence, Mary Stebbins ("Stories of the Volcano Goddess")	63	Tells of Pele's travels in Hawaiʻi, and of her arrival at East Maui, whereupon she began building up the mighty crater of Haleakalā.
Pele goddess of the volcanoes	Nakuina ("Hawaii: Its People, Their Legends")	25	Tells of Pele's arrival at Haleakalā and her short stay there.
Pele and her fight with her sister, Namakaokahaʻi	Westervelt, W.D. ("Hawaiian legends of Volcanoes")	11	Pele dug the crater at Haleakalā with her pāoa, her special divining rod by which she tested the suitability of areas for excavation. Pele dies in the fight with Namakaokahaʻi and her torn body is thrown across the coastline of Kaupō at Kahikinui.
Legend of Kihapiʻilani	Fornander, Abraham	Vol. V: 180	Warfare in East Maui spreads to Haleakalā, where Piʻimaiwaʻa followed Hoʻolae until he caught him on the eastern side of the mountain of Haleakalā.
The Story of the ʻŌhelo	Fornander, Abraham	Vol. V: 576	Kaʻōhelo, one of Pele's sisters, dies, and a portion of her body was thrown over to Haleakalā. She is remembered in the volcanic areas of the islands of Hawaiʻi by the proliferation of *ʻōhelo* berry shrubs.
Description of the powers of the demi-god Māui, and his relationship to Haleakalā	Westervelt, W.D. ("Hawaiian Legends of Volcanos")	12	"One legend says that he crossed the channel, miles wide, with a single step. Another says that he launched his canoe and with a breath the god of the winds placed him on the opposite coast, while another story says that Māui assumed the form of a white chicken, which flew over the waters to Haleakalā."
Burials, relating to the dead in ancient	Fornander, Abraham	Vol. V: 572	"Here are the secret graves of wherein the chiefs of Nuʻu are buried, all on the side of Haleakalā."

Legend	Source	Page No.	Synopsis
times.			
Battle of the Alapa Regiment of Kalaniopuʻu	Fornander, Abraham	Vol IV: 286	The Alapa Regiment of Hawaiʻi's chief Kalaniopuʻu were annihilated at the Battle of Waikapū Commons, but not before they laid waste to Honuaʻula, an area of Maui described as "the rugged slope of Haleakalā".
Pele and the snow-goddess	Westervelt, W.D.	56	"Lilinoe was sometimes known as the goddess of the mountain Haleakalā. In her hands lay the power to hold in check the eruptions which might break forth through the old cinder cones in the floor of the great crater. She was the goddess of dead fires."

3.1.1 Legends of the Demi-god Māui as Related to Haleakalā

The Kumulipo is a cosmological chant, set down by David Kalakaua in 1856 and translated by his sister Queen Lydia Liliuokalani in 1897, which includes a vivid depiction of the creation of the world. Haleakalā is linked with a portion of the Kumulipo that includes the story of Māui's birth, his many deeds prior to his snaring of the sun, and the story of his death. The translation of the chant was accomplished. Bishop Museum researcher Katharine Luomala (1949) summarized the passage in this way:

> On his way to the island of Maui to the house of the sun, (Hale-a-ka-la) he was insulted by a man named Moemoe. After he snared the sun, slowed it up and made it agree to go more slowly for six months and fast the other six months, he returned to Moemoe whom he turned into stone (Luomala 1949:112).

This section of the Kumulipo chant also includes a hidden reference to Haleakalā. According to Westervelt (1910), Māui was told to search for a magical canoe bailer in the ocean off of the coast of Hāna. The bailer, once brought aboard his canoe, would be transformed into a beautiful mermaid. The Kumulipo's specific mention of "Kaʻuiki" is a reference to Hāna being a famous foothill of "Mauna Haleakalā ": the home of Māui before he ensnared the sun. Westervelt (1910) recorded this portion of the legend of Hina, mother of the demi-god, Māui, stating that the mermaid sought by Māui dwelt by the sea coast near "Kauiki, at the foot of the great mountain Haleakalā , House of the Sun", relating the two prominences of Kauiki and Haleakalā together (Westervelt 1910: 211).

Mauna Haleakalā played the pivotal role in the legend of Māui's snaring of the sun, providing Māui with the element of surprise and the elevation by which to capture the sun. No other island across Polynesia, with the exception of Aotearoa, had mountains tall enough to elicit a vision of a man standing level with the sun, straining to hold back the progress of its travel with an enchanted rope. Within Hawaiʻi, only the massive crater of Haleakalā appears as the underworld abyss from which the sun starts its westward journey each day.

3.1.1.1 A Description of the Demi-god Māui by Kalakaua (1888)

Although the chant of the Kumulipo is recited as a genealogical succession from the "era of the primeval night to the present, and intersperses the list with descriptive passages about the ancestors" (Luomala 1949:109), the longest passage in the Kumulipo is reserved for Māui, a man elevated to the rank of a god. King David Kalakaua collected the following anecdotal information about his ancestral demi-god:

> As told by tradition, the principal abode of the demi-god Maui was Hawaii, although his facilities for visiting the other islands of the group will be considered ample when it is stated that he could step from one to another, even from Oahu to Kauai, a distance of seventy miles. When he bathed – and bathing as one of his great delights – his feet trod the deepest basins of the oceans and his hair was moistened with the vapor of the clouds. It is related that at one time he reached and seized the sun, and held it for some hours motionless in the heavens, to enable his industrious spouse to complete the manufacture of a piece of ***kapa*** upon which she was engaged (Kalakaua 1888:502).

3.1.1.2 Stories Collected by Taylor (1870)

Aotearoa (New Zealand) has an especially rich collection of material about the demi-god Māui, and it is from this source that the best interpretation of Māui's deed, and the closest ties to Hawaiʻi are found.

The preservation of the myths of Aotearoa was undertaken in the 1860's by the English missionary Richard Taylor. Taylor had traveled to Aotearoa immediately following the bitterest fighting between the English military and Maori people, during which the "Maori Wars" [Nga Pakanga Nu Nui O Aotearoa, or "The Great Wars of Aotearoa] dispossessed the Maori people of vast tracts of their traditional cultural lands. The title of Taylor's book "Te Ika A Maui" literally translates as "The Fish of Maui", the original Maori name for the North Island of Aotearoa. The islands comprising Aotearoa, according to Maori traditions, were pulled up from the sea floor by a great fish hook commanded by the demi-god Māui.

In traditional stories told by the indigenous people who populate the islands of Aotearoa, myths describing the creation of the world and the origins of the Maori people share a common deity with the indigenous people of the islands of Hawaiʻi. Taylor's writings include legends that describe Māui, the great hero god of Maori legend. In these stories, Māui is represented as having the power to lengthen the day by beating the sun and rendering him lame. According to Taylor, the telling of this story was a figurative way of recording the fact that Polynesian migrations to the temperate zone of the islands of Aotearoa [New Zealand] from the tropical waters of Hawaiki [Hawaiʻi] had amplified the change in daylight hours, where the days are necessarily longer in Aotearoa.

Taylor's writings also documented myths of Māui's attempts to prolong man's life and destroy the power of death. Māui was said to have had the power to enter the underworld, and that he devised a plan to do so during the daylight hours, in order to cheat the power of the god of death. But his efforts to bring life to those already in the grave ended in tragedy for Māui. Instead of emerging from the underworld unscathed, Māui was tricked, and perished.

In the traditional stories of Māui in Aotearoa, his superhuman abilities were balanced by a small defect in his upbringing. As the grand hero of Maori mythology, he was given powers not unlike Achilles, where, because a tiny detail was overlooked, Māui grew up as a mortal being. The Maori people believed that after Māui was born, his mother [Taranga] cut off her long tresses of hair, wrapped Māui in them, and cast him into the sea. The winds and storms became his home:

> Wave-uplifting gales nursed him, and at last threw him up on the shore, where he was found by his great ancestor Tama-nui-ki-te-rangi, who carried him to his house and suspended him from the roof, that the smoke and warm air might restore him; thus he grew up and his mother called him Maui-tiki-tiki-a Taranga, or “Maui formed in the top-knot of Taranga”; his father Makea-tu-tara, at his baptism, omitted some of the Karakias [spells or incantations], and this caused Maui to be subject to death (Taylor 1870:124).

Māui was raised as the youngest of six children. A precocious child, he would wait until his five brothers had finished a day’s fishing: “he would then throw his hook into the water, and at one pull catch more fish than they had all taken together.” Secretly, Māui had taken the jaw-bone of his grandfather Muri Rangawhenua, made a fish-hook of it, and kept it concealed as a powerful spirit-hook.

One of Māui’s colossal works was tying the sun and moon together, so that having run their daily courses, they should return to their starting place. After Māui had forced the sun to travel more slowly across the sky, thus increasing the length of the day, his name came to mean “Tama-nui-te-ra”, or “the great man day”.

Hawaiki [Hawai‘i] were the islands seen as the cradle of Polynesia by the indigenous people of Aotearoa. From the original stories of the Maori come the legend that at one time, the *tuawhenua*, or the main land, was united all the way to Hawaiki [Hawai‘i] before Kupe came, cutting the land in two and allowing the sea to fill in between the two lands. Kupe was chief and master of the first canoe, named *Mataorua*, which brought the first migration from Hawai‘i to the islands of Aotearoa.

In the traditions of the Maori, the names of all seventeen canoes and the names of each prominent family making the journey to Aotearoa are sacred. The canoe that carried Māui, *Auraro tuia*, was said to have been crafted by the master builder Tutaranaki. In the list of the twenty-six generations of the Maori people, Māui is of the second generation, a demi-god ranked just below that of the father of man, Tiki. In the traditions of the Maori, Tiki took red clay and kneaded it with his own blood, and so formed the eyes and the limbs, and then gave the image breath. In this way, Tiki made man in the image of himself.

Hawai‘i is the name of the largest island in the Hawaiian Island Chain. In the language of Aotearoa, Hawai‘i is called *Hawaiki tawiti nui*, or the very distant Hawaiki. The legends of the migration of the Maori speak of *Hawaiki pata*, or nearer Hawaiki, (literally “the lesser isle”). This island, being smaller than Hawaiki, was the Maori name given to Tahiti. The legends speak of migrating islanders remaining in Tahiti until their numbers were too large for the size of the island, causing a further migrations to *Hawaiki i te moutere*; or, the other islands of Polynesia (Taylor 1870).

3.1.1.3 Legends Collected by Fornander (1919)

Fornander states, “No demigod of Hawaii figures so prominently in Polynesian mythology as does Māui, nor the hero of so many exploits throughout these islands. This accounts for the various localities claiming to be his birthplace.”

> Maui was the son of Hinalauae and Hina. Their residence was at Makaliua, above Kahaukuloa, and in a northerly direction from Lahainaluna (Fornander 1919, V, II: 536).

Māui was shown to have been mischievous even before his birth. The story of the unborn Māui leaving his mother's womb to see what there was of the world around him, was recorded by Fornander as a theme not often repeated in the lore of ancient Hawaiʻi. A group of fishermen on the coast of Kahakuloa saw a "handsome child" diving from the precipices into the waters of their fishing grounds, disturbing their ability to catch *uhu* (Scarus perspicillatus). Deemed a rascal, the boy was chased inland from the coast, where he hid behind a waterfall at the back of Makamakaʻole canyon. When Māui perceived that the chase had ended, he attempted to return to his mother's womb. But he was again seen, and chased to the village of Makaliua, at the home of his mother, Hina. Confronting Hina and Māui's father, Hinalauae, the fishermen spoke of the exploits of a boy who had just entered the house ahead of them. That is how it was known that Māui, the unborn child of Hina and Hinalauae, had left his mother's womb to pursue his own adventures (Fornander 1919,V,III, 536-538).

> The men went to seek a pig, a white chicken, black coconut, red fish, red *kapa* and *awa* root, and offered them as a sacrifice to the child. This act indicated that they recognized the godly character of the child.

As Māui grew to manhood, he felt sorry for his mother, because her *kapa* did not have enough time in a day to properly dry. He made plans to snare the sun so it would travel slower across the sky. He climbed Haleakalā to look for a suitable spot from which to perform this feat. At the cape of Hāmākua he saw *Moemoe* sleeping in the cave at Kapepeenui, and observed the spot that the sun rose at Hāna (Fornander 1919,V,III: 538). (Fornander notes, "Moemoe is a name given to the sun's rays which he finds at the cave. *Moemoe* means to lie down to sleep.")

> *Moemoe* called out sarcastically, "You can not catch the sun for you are a low down farmer." Maui answered, "When I conquer my enemy and satisfy my desire I shall kill you" (Fornander 1919,V,III: 538).

To complete his plans, Māui gathered coconut husk to braid his snare at Waiheʻe. He then proceeded along the Koʻolau ridge to a point upon Haleakalā where he lay in wait for the sun to arrive. Māui used his coconut husk snare to break off all of the strong rays of the sun, just as it passed directly overhead. The sun then promised to travel more slowly across the sky.

3.1.2 Legends of the Goddess Pele as Related to Haleakalā

3.1.2.1 The Arrival of Pele in Hawaiʻi by Kalakaua (1888)

In "The Legends and Myths of Hawaii" by King Kalakaua (1888), the origin of the goddess Pele is described. Kalakaua took pleasure in reminding the reader that, after more than sixty years of Christian teaching, offerings were still being made to Pele.

> Pele, the dreadful goddess of the volcanoes, with her malignant relatives, was added to the Hawaiian deities during the arrival of Paao, and temples were erected to her worship all over the volcanic districts of Hawaii (Kalakaua 1888:40).

3.1.2.2 Pele Legends Collected by Fornander (1919)

The legendary powers of Pele were such that lava was sent down from her mountains to punish those that had not paid her proper tribute. Kapapala challenged Pele to a *holua* sled race, and received a swift retribution from her in the "Legend of Kahawali" (Kalakaua 1888: 501-507). Her scorn turned living people into two ridges of the West Maui Mountains, and her jealousy turned her rival into Molokini island in the "Story of Puulaina" (Fornander 1919,V,III: 532). Pele's arrival at Aheleakala was further chronicled by Fornander:

> After this, Pele traveled until she came to Aheleakala, the large mountain of Maui at the rising of the sun (Fornander 1919, V, III: 536).

3.1.2.3 Pele Legends Collected by Westervelt (1916)

Pele, goddess of volcanoes, was the second daughter born of the Hawaiian god Ku (Kuwahailo) and the goddess Haumea. Thier first-born daughter was Na-maka-o-ka-hai , the goddess of the sea. Ellis (1826) described Pele's six Hiiaka sisters as various "cloud holders", who traveled with her, providing rains and winds (Westervelt 1916:15).

Na-maka-o-ka-hai 's husband, Aukelenuiaiku, took Pele and Hiiaka as his secret wives. Although Aukelenuiaiku was a great sorcerer, he could not deliver Pele and Hiiaka from the wrath of Na-maka-o-ka-hai . She drove them from their land, into the ocean, and pursued them to the Hawaiian Islands. Pele used her Paʻoa (digging tool) to try to build a home (fire pit) for herself on the island of Kauaʻi, but the angry Na-maka-o-ka-hai chased her from the island (Westervelt 1916:15). Pele struck her tool down into the earth of Oʻahu, but was again pursued by Na-maka-o-ka-hai .

Thus she passed along the coast of each island, the family watching and aiding until they came to the great volcano Haleakalā . There Pele dug with her Paoa, and a great quantity of lava was thrown out of her fire-pit. Na-maka-o-ka-hai saw enduring clouds day after day rising with the colors of the dark dense smoke of the underworld, and knew that her sister was still living. Pele had gained strength and confidence; therefore she entered alone into a conflict unto death.

The battle was fought by the two sisters hand to hand. The conflict lasted for a long time along the western slope of the mountain Hale-a-ka-la. Na-maka-o-ka-hai tore the body of Pele and broke her lava bones into great pieces which lie to this day along the seacoast of the district called Kahiki-nui. The masses of broken lava are called Na-iwi-o-Pele (The bones of Pele).

Pele was thought to be dead and was sorely mourned by the remaining brothers and sisters. Na-maka-o-ka-hai went off toward Nuu-mea-lani rejoicing in the destruction of her hated enemy. By and by she looked back over the wide seas. The high mountains of the island Hawaii, snow covered, lay in the distance. But over the side of the mountain known as Mauna Loa she saw the uhane, the spirit form of Pele in clouds of volcanic smoke tinged red from the flames of raging fire-pits below (Westervelt 1916:12-13).

3.1.2.4 A Description of the Powers of Pele by William Ellis (1826).

In 1823 the Reverend William Ellis, an English missionary, made an extended tour of the island of Hawaiʻi in order to ascertain the "religious state" of the inhabitants of the group. Having previously spent six years studying the Polynesians of the Society Islands [Tahiti], Ellis was struck by the fact that the dialect spoken by Hawaiians was very similar to the language of the Society Islanders, and that he was able to converse in a simple version of the Hawaiian language in a very short amount of time (Ellis 1826:18). In this way, Ellis was able to acquire information on the culture and traditions of Hawaiʻi with reasonable accuracy. As he made his way to witness an eruption of the volcano at Kīlauea, Ellis traveled from Kāʻu by way of Kapāpala, and accumulated native bearers and supplies required for weeks of travel (Ellis 1826:178).

His description of the volcanic activity of Kīlauea was highlighted by his gathering of many traditional stories of Pele, the Hawaiian mythological goddess thought to control the power of the volcano. Although Ellis did not investigate Haleakalā crater on Maui, his observations of the volcanic mountains of Hawaiʻi were discussed directly with American protestant missionaries serving at stations across the Sandwich Islands. His description of the lore of the volcano goddess Pele, including his account of Kapiolani's famous journey to challenge the supernatural powers of Pele (Ellis 1963:187), were of great interest to the American missionaries, who organized an expedition to the summit of Haleakalā six years later (see "An Expedition by Richards, Andrews and Green to the Summit of Haleakalā" in Section 3.3 below).

Ellis (1826:204) described the "superstitions" of the native Hawaiians in regard to offerings of an edible native plant, the *ʻōhelo* (*Vaccinium calycinum*). The origin of the use of the *ʻōhelo* was not transmitted to Ellis, but it was clear that Pele, goddess of the lava, required much in the way of ritual:

> As we passed along, we observed the natives, who had hitherto refused to touch any of the *ʻōhelo* berries, now gather several bunches, and, after offering a part to Pele eat them very freely. They did not use much ceremony in their acknowledgment; but when they had plucked a branch containing several clusters of berries, they turned their faces towards the place where the greatest quantity of smoke and vapour (sic) issued, and, breaking the branch they held in their hand in two, they threw one part down the precipice, saying at the same time, "*E* Pele, *eia ka ohelo ʻau; e taumaha aku wau ia oe, e ai hoi au tetahi*" [translated meaning] "Pele, here are your *ʻōhelos*: I offer some to you, some I also eat" (Ellis 1826:205-06).

As Ellis recorded the traditions surrounding the worship of Pele, he noted that the volcanic sites of Kīlauea, as well as the dormant cinder cones and mountain ranges throughout the islands of Hawaiʻi were considered sacred (Ellis 1826:204). He recorded stories telling of the common people being barred from entering the mountainous areas reserved for Pele (Ellis 1826:190) and her godlike brothers and sisters:

> They considered it the primeval abode of their volcanic deities. The conical craters, they said, were their houses, where they frequently amused themselves by playing at *Konane* [a game similar to checkers], the roaring of the furnace and the crackling of the flames were the *kani* of their *hura*, (music of their dance), and the red flaming surge was the surf wherein they played, sportively swimming on the rolling waves (Ellis 1826:216).

Ellis was also able to determine from his informants that the fires of the underworld had been burning from the beginning of time. He observed that the stories they told referred to a timeline that appeared to be ancient, or "*mai ka po mai*": from chaos 'till now. Other Polynesian societies which Ellis had spent years observing (Fitzpatrick 1986:85), referred to night as a chaotic state. The Hawaiian concept of the origin of the world, and of the time during which "almost all things therein [were made], the greater part of their gods not accepted", occurred during this night time. Ellis noted that Hawaiians referred to the present time as *ao marama*, the words for "day", or a state of light (Ellis 1826:216). He went on to describe the fires of the underworld, from which Pele derived her powers of creation and destruction:

> [Pele] had overflowed some part of the country during the reign of every king that had governed Hawaii. Kirauea [Kīlauea] had been burning ever since the island emerged from night, it was not inhabited till after the *Tai-a-kahina'rii*, sea of *Kahina'rii*, [the story of a great flood brought by Pele] or deluge of the Sandwich Islands. Shortly after that event, they say, the present volcanic family came from Tahiti, a foreign country, to Hawaii" (Ellis 1826: 216-217).

Ellis next recorded the principal gods inhabiting the mountains with Pele:

> The names of the principal individuals were: *Kamoho-arii*, the king Moho; *moho* sometimes means a vapour, hence the name might be the king of steam or vapour - *Ta-poha-i-tahi-ora*, the explosion in the place of life – *Te-ua-a-te-po*, the rain of night – *Tanehetiri*, husband of thunder, or thundering *tane* (Tane is the name of one of their gods, as well as the name of the principal god formerly worshipped by the Society islanders; [French Polynesians] in both languages the word also means a husband) – and *Te-o-ahi-tama-taua*, fire-thrusting child or war; these were all brothers, and two of them, Vulcan-like, were deformed, having hump-backs – Pele, principal goddess – *Makore-wawahi-waa*, fiery-eyed canoe breaker – *Hiata-wawahi-lani*, heaven rending cloud-holder – Hiata-noholani, heaven-dwelling cloud-holder – *Hiata-taarava-mata*, quick glancing eyed cloud-holder, or the cloud-holder whose eyes turn quickly and look frequently over her shoulders – *Hiata-hoi-te-pori-a-Pele,* the cloud-holder embracing or kissing the bosom of Pele – *Hiata-ta-bu-enaena*, the red-hot mountain holding or lifting clouds – *Hiata-tareiia*, the wreath or garland-encircled cloud holder – and *Hiata-opio*, young cloud-holder. These were all sisters, and, with many others in their train, on landing at Hawaii [from Tahiti], are said to have taken up their abode in Kirauea. Whenever the natives speak of them, it is as dreadful beings (Ellis 1826: 218).

Although Kīlauea Crater was represented as being the principal residence of Pele and her family, they had many other dwellings in different parts of the island, as well as on the other islands of Hawai‘i. Ellis noted that Pele frequently remained on the tops of the "snow-covered mountains" of Hawai‘i, a reference regarding the role that Haleakalā may have played in his account of the nature of Pele:

The religious significance of Pele and her powerful family was recorded as highly important to the inhabitants of Hawai‘i. The population was considered as bound to pay them tribute, or support their *heiaus*, and *kahu*, (devotees;) and whenever the chiefs or people failed to send the proper offerings, or incurred their displeasure by insulting them or their priests, or breaking the *tabu* (sacred restrictions) of their domains in the vicinity of the craters, Pele and her family would fill the crater of

> Kīlauea with lava, and cause the lava either to “spout” from that point, or cause lava to be sent by way of subterranean passages to other parts of Hawaiʻi. Ellis recorded native testimony that likened Pele and her spirit companions to warriors, who, when insulted, had “marched to some of their houses (craters) in the neighborhood where the offending parties dwelt, and from thence came down upon the delinquents with all their dreadful scourges” (Ellis 1826:219).

3.1.2.5 A Description of Pele’s Journey to Hawaiʻi by Forbes

In 1915, William A. Bryan adapted a compilation of Hawaiian myths and legends by Anderson Oliver Forbes for a book about the history of the Hawaiian Islands. A. O. Forbes was born at Kaawaloa in 1833, the son of Protestant Missionaries Cochrane and Rebecca Forbes. Educated at Punahou School and ordained as a minister at Princeton Theological Seminary in New Jersey, A. O. Forbes returned to the Hawaiian Islands in 1858, and spent the next 30 years preaching at Kaluaaha, Lahainaluna, and in Hilo. He is credited with publishing the earliest accounts of the deeds of Māui and the powers of Pele.

> In the beginning, there was born a most wonderful child called Pele. Hapakuela was the land of her birth, a far distant land out on the edge of the sky – away to the southwest. There she lived with her parents and her brothers and sisters as a happy child, until she had grown to womanhood when she fell in love and was married. Before long, her husband grew neglectful of her and her charms, and was enticed away from her and her island home. After a dreary period of longing and waiting for her lover, Pele determined to set out on the perilous and uncertain journey in quest of him (Bryan 1915: 89).

According to Forbes (Bryan 1915:89), the Polynesian goddess Pele then set out for the islands of Hawaiʻi, which at the time, were not islands at all, but were a group of “vast unwatered mountains standing on a great plain that has since become the ocean floor”. As Pele journeyed in search of her husband, “the waters of the sea preceded her, covering over the bed of the ocean. It rose before her until only the tops of the highest mountains were visible; all else was covered by the mighty deluge. As time went on, the water receded to the present level, and thus it was that the sea was brought to Hawaii-nei” (Bryan 1915: 91).

Pele’s first home in the Hawaiian Islands was said to have been Kauaʻi, followed by Kauhako crater on Molokaʻi, then Puʻulaina near Lahaina. According to Bryan (1915:91), Pele then made her way to Haleakalā, “where she hollowed out the mighty crater”. The story of her travels finally ends at Kīlauea Crater on Hawaiʻi.

3.1.3 Other Traditional Descriptions of Haleakalā

Writing of her childhood on the ranchlands of Haleakalā, Armine von Tempsky recorded a traditional story of the mountain in her 1940 book “Born in Paradise”:

> I listened avidly while Makalii told me about the cloud warriors, *Naulu* and *Ukiukiu* – trade-wind-driven clouds split by the height and mass of Haleakalā into two long arms. *Naulu* traveled along the southern flank of the mountain, *Ukiukiu* along the northern and they battled forever to possess the summit. Usually *Ukiukiu* was victorious, but occasionally *Naulu* pushed him back. Sometimes both Cloud Warriors

> called a truce and withdrew to rest, leaving a clear space between the heaped white masses of vapor looming against the blue of the sky. The space, Makalii told me, was called *Alanui O Lani* – the Highway to Heaven (von Tempski 1940:14).

The "Legend of Halemano" begins during the time that the kings of Puna and Hilo, on the island of Hawaiʻi, were competing for the affections of the most beautiful woman of Kapoho, named Kamalalawalu. Halemano, a young man from Waiʻanae, on the island of Oʻahu, had a dream that he would someday meet Kamalalawalu in Kaʻau, on his island. His dream became so vivid, and his love for her grew so strong, that he denied himself all food and drink and died (Fornander 1919,V,II: 230).

But Halemano had an older sister, named Laenihi, imbued with supernatural powers, and she restored life to him. When next Halemano fell asleep, he again dreamed of a meeting with the beautiful Kamalalawalu. During this dream, Halemano asked Kamalalawalu for her name and the name of the land in which she lived. He awoke and told these things to his sister. She set out for Hawaiʻi to bring Kamalalawalu to Halemano (Fornander 1919,V,II: 230).

While at Hawaiʻi, Laenihi fashioned a plan that would allow her brother to win Kamalalawalu for himself. This was done, and Kamalalawalu was brought to Oʻahu to live with Halemano. But Kamalalawalu's beauty could not be hidden, and the chief of Oʻahu, ʻAikanaka, demanded her presence before his court. This caused Kamalalawalu, Halemano, and his family to flee Oʻahu for Lele [Lahaina] on Maui. From Lahaina, they saw the top of Haleakalā as if it were floating above the clouds. Because of this vision, they set out to make their home at Kaupō, where they tilled the soil and grew their crops (Fornander 1919, V, II: 237-240).

In a separate legend, Kana, along with his brother, Niheukalohe, waged a series of battles against Kaupeepee on the island of Molokaʻi. The two brothers sought to avenge the kidnapping of their mother, Hina, and demolished the fortress of Haʻupu on Molokaʻi in the process. Kana attains legendary status in this story, by using his special powers to change his physical form. In the struggle against Kaupeepee, Kana realized that the mountain fortress of Haʻupu was anchored to the ocean floor by two turtles. Kana stretched his body over the backs of the two turtles, trying to break the great flippers that braced them to the bottom of the sea. The turtles struggled and arched their backs against Kana's ropelike body. Finally, faint from stretching, Kana planted his vast feet more firmly on the rocky shore of Molokaʻi, leaned across Maui, scoring a notch in Haleakalā Crater, and spun himself over the channel to Hawaiʻi. There, his grandmother Uli gave him food. Refreshed, Kana gathered his strength and crumpled the turtle's flippers, destroying the might of Haʻupu (Fornander 1919, V, III: 519).

3.1.3.1 A Description of the ʻUaʻu Bird in Kalakaua (1888)

A reference to the nesting habits of the *ʻUaʻu*, the Dark-Rumped Petrel, (*Pterodoma phaeopygia sandwichenesis*) was the focal point of a legend of Haleakalā and Hāna, recorded by King David Kalakaua. His account of the legend of Hua, King of Hāna, was included in his collection of "Legends and Myths of Hawaii", published in 1888.

> As tradition tells the story, Hua found occasion to order some *uwau*, or *uau*, to be brought to him from the mountains (Kalakaua 1888:160).

According to Kalakaua (1888), the *aliʻi-nui* of eastern Maui about A.D. 1170 was a reckless and war-like chief named Hua. Hua did not approve of a certain high-priest in his inner circle, and schemed of a way to slay the offending member of his court. Under false pretense, Hua gave specific orders for his bird-snarers to bring him some *‘Ua ‘u* birds from the uplands of Maui, and sought advice from the high-priest Luaho‘omoe as to their probable habitation.

Luaho‘omoe’s advice was for the hunting party to not venture into the mountainous region of Haleakalā, but instead to have the royal bird catchers set their snares by the seashore, where the birds were to be found during that season. Hua feigned that Luaho‘omoe had interfered with his wishes, and promised death to the high priest if his hunters were able to procure the birds in the uplands, as he had demanded.

Luaho‘omoe now understood the trap that had been set for him, and that Hua meant for him to die and for his family to be destroyed. He sent his two sons into a remote valley of Haleakalā, but was unable to inform others in his family before he was executed.

Immediately following the unjust death of the priest, an earthquake struck the *heiau* where his body was to be sacrificed, causing the remaining priests to flee in terror. Most of the people of the district fled to the uplands, chased by a hot and suffocating wind blowing from the south, drops of blood falling from the clouds, and the drying-up of all wells, springs and streams in the region.

Nothing would appease the gods that had been offended, and when Hua abandoned his desolate district on Maui and sailed to Hawai‘i, the drought followed him. After three years of wandering, he finally died of thirst and starvation.

One of Luaho‘omoe’s sons had a wife, who had been kept secretly away from the eyes of Hua. She lived in a secluded valley in the back of Hāna and, like all the other villagers, struggled to obtain water during the drought. Her name was Oluolu, and she waited patiently for her husband to return to her. Oluolu had a hidden mountain spring to sustain her and other *kuleana* members close to her (Kalakaua 1888:165).

The sons of Luaho‘omoe were seen in a vision by the high-priest of Waimalu, on Oahu, and he sailed for Maui to unite his powers with those of Luahoomoe’s sons, and bring an end to the drought, which had spread throughout the entire Hawaiian group. They met at Makena, erected an altar and prayed together to the gods. The rains came to all the islands, and Luaho‘omoe’s sons moved from Haleakalā to Hāna to serve as the new high-priests under the new regime (Kalakaua 1888: 173).

3.1.3.2 Haleakalā in Mele [music] and Oli [chants].

The following mele was composed by John Kapohakimohewa, and is entitled "Kilakila ʻO Haleakalā [Majestic Haleakalā] (http://www.kalena.com/huapala/Ki/Kilakila_Haleakalā .html).

Kilakila ʻo Haleakalā Kauhiwi nani o Maui Haʻaheo wale ʻoe Hawaiʻi Hanohano Maui nō ka ʻoe	Majestic Haleakalā Beautiful mountain of Maui Prized by you, Hawaiʻi Glorious Maui, is the very best
Kauhala o Kaʻaoʻao ʻIke aku iā Kilohana Kāua i ke one heʻe heʻe Me nā alanui kīkeʻekeʻe	Ka ao ao is our home That looks upon Kilohana You and I on the sliding sands And zigzagging pathways
Kau ana lā kau ana Kau ana ko ia ala maka ʻO ua lio holo peki Mea ʻole ko ia ala holo	Settling there, settling there That one's gaze is fixed Oh, that prancing horse Its gait is of no importance

A more complete list of songs and chants which depict stories of Haleakalā can be found in Appendix F of the DEIS.

3.2 Pre-Contact Setting

Religious pursuits and ceremonies were among the primary activities occuring atop Haleakalā during traditional Hawaiian times. The summit and crater of Haleakalā was considered a *wao akua* or distant mountain region, believed inhabited only by spirits (Pukui and Elbert 1986:382; see also Section 7.6 "Haleakalā as a Sacred Mountain" below).

As the elevation above 7,000 ft. would not have been well-suited for agriculture , the upper slopes of Haleakalā were likely used more for hunting and gathering by people who were recognized as specialists, as well as a travel route for messengers from the leeward to windward sides of the the mountain. Specialized activities such as bird hunting for food and feathers, timber harvesting for canoes and other household uses, plant gathering for medicinal and ceremonial uses, and quarrying of fine grained basalts for adze materials and possibly weapons such as sling stones where likely carried out.

The following shrubs are examples of what probably existed during pre-contact times. These vegetative types can still be found above the 7000 ft. elevation today: *māmane* (*Sophora chrysophylla), pūkiawe (Styphelia tameiameia), ʻaʻaliʻi (Dodonaea viscosa) ʻōhelo (Vaccinium reticulatum) ʻōhiʻia lehua (Metrosideros collina)* and, of course, the renown silversword or ʻ*āhinahina* (*Argyroxiphium sandwicense* subsp. *Macrocephalum*). Some of the native lobelias, which attract the native birds and the sandalwood would have grown there as well.

About the uplands, Handy and Handy (1972:276) note that "there never were extensive upland plantations here [Haleakalā] comparable to those on Hawaiʻi". They go on to say:

> Maui, despite the high mountains forming the west and east sections, had an even more extensive dry area than Hawaiʻi. All the country below the west and south slopes of Haleakalā specifically Kula, Honuaʻula, Kahikinui, and Kaupō in old Hawaiian times depended on the sweet potato. The leeward flanks of Haleakalā were not as favorable for dry or upland taro culture as were the lower forest zones on the island of Hawaiʻi. However, some upland taro was grown, up to an altitude of 3,000 feet (1972:276).

While on a survey of Maui, Handy and Handy also note that they found "groves of wild bananas … along the north, east, and south slopes of Haleakalā the gigantic volcanic cone of East Maui; sometimes there were extensive groves, as above Hāna Bay at Maui's easternmost point (Handy and Handy 1972:169). They also make a passing reference to the "tall luxuriant taro growing in forest humus or planted in decomposed lava on the slopes of Haleakalā ..." (Handy and Handy 1972:313). They are no doubt referring to the lower slopes of Haleakalā, below 3,000 ft.

3.3 Early Historic Era to the Late-1800's.

3.3.1 An Expedition by Missionaries William Richards, Lorrin Andrews and Jonathan S. Green to the Summit of Haleakalā (1828)

Lorrin Andrews and Jonathan F. Green, ordained missionaries, and Dr. Gerrit P. Judd, physician, were part of the third company of missionaries sent from New England to the Sandwich Islands by the American Board of Commissioners for Foreign Missions (ABCFM). They arrived in Honolulu on March 30, 1828 and visited William Richards in Lahaina, touring Maui that summer. On August 21, 1828, Richards, Andrews, Judd and Green made the first recorded ascent of Haleakalā (U.S. Department of Interior, National Park Service 2006).

The ascent was recorded by Gerrit Judd, and originally published by the Missionary Herald, a publication of the ABCFM in Boston. More recently, the narrative was made available in its entirety in "Hawaiʻi Nature Notes" (U.S. Department of Interior 2006, National Park Service).

Under the subheading "Ascent of an Extinguished Volcano", the narrative of Judd includes the first western description of the native Haleakalā silversword (*Argyroxiphium sandwicense* ssp. *macrocephalum*) and recounts the following:

> We rose early, and prepared for our ascent. Having procured a guide, we set out; taking only a scanty supply of provisions. Half way up the mountain, we found plenty of good water, and at a convenient fountain, we filled our calabash for tea. By the sides of our path, we found plenty of *ohelos*, and, occasionally, a cluster of strawberries. On the lower part of the mountain, there is considerable timber; but as we proceeded, it became scarce, and, as we approached the summit, almost the only thing, of the vegetable kind, which we saw, was a plant that grew to the height of six or eight feet, and produced a most beautiful flower. It seems to be peculiar to this mountain, as our guide and servants made ornaments of it for their hats, to

> demonstrate to those below, that they had been to the top of the mountain. [U.S. Department of Interior 2006, National Park Service]

The account continued with a description of the crater and of the cinder cones within. The spectacle of Haleakalā appeared to have mesmerized the missionaries much the same way that modern tourists view a sunrise or sunset from the summit:

> It was nearly 5 o'clock, when we reached the summit; but we felt ourselves richly repaid for the toil of the day, by the grandeur and beauty of the scene, which at once opened up to our view. The day was very fine. The clouds, which hung over the mountains on West Maui, and which were scattered promiscuously, between us and the sea, were far below us; so that we saw the *upper side* of them, while the reflection of the sun painting their verge with varied tints, made them appear like enchantment. We gazed on them with admiration, and longed for the pencil of Raphael, to give perpetuity to a prospect, which awakened in our bosoms unutterable emotions. On the other side, we beheld the seat of Pele's dreadful reign. We stood on the edge of a tremendous crater, down which, a single misstep would have precipitated us 1,000 or 1,500 feet. This was once filled with liquid fire, and in it, we counted sixteen extinguished craters. To complete the grandeur of the scene, Mouna Kea and Mouna Roa lifted their lofty summits, and convinced us, that, though far above the *clouds*, we were far below the feet of the traveller who ascends the mountains of Hawaii. By this time, the sun had nearly sunk in the Pacific; and we looked around for a shelter during the night. Our guide and other attendants we had left far behind; and we reluctantly began our descent, keeping along on the edge of the crater.

As the explorers searched along the southwest rim of the crater, they were able to find ancient rock shelters built, exactly as they assumed, by pre-contact Hawaiians:

> After descending about a mile, we met the poor fellows, who were hobbling along on the sharp lava, as fast as their feet would suffer them. They were glad to stop for the night, though they complained of the *cold*. We kindled a fire, and preparations were made for tea and lodgings. The former we obtained with little trouble. We boiled part of a chicken, roasted a few potatoes, and, gathering round the fire, we made a comfortable meal; but the place of lodging, we obtained with some difficulty. At length, we spread our mats and blankets in a small yard, enclosed, probably, by natives, when passing from one side of the island to the other. We were within twenty feet of the precipice, and the wind whistled across the valley, forcibly reminding us of a November evening in New England. The thermometer had fallen from 77 to 43 (the next morning, the thermometer stood at 40), and we shivered with the cold. The night was long and comfortless.

The next day, the 22nd of August, 1828, the explorers returned to view the interior features of the crater and described the Koʻolau and Kaupō Gaps:

> Early in the morning, we arose, and reascending the mountain, to its summit and contemplated the beauties of the rising sun, and gazed a while longer, on the scenery before us. There seemed to be but two places, where the lava had found a passage to the sea, and through these channels, it must have rushed with

> tremendous velocity. Not having an instrument, we were unable to acertain the height of the mountain. We presume it would not fall short of 10,000 feet. (This, I believe, is the height at which it has been generally estimated) The circumference of the great crater, we judged to be no less than fifteen miles. We were anxious to remain longer, that we might descend into the crater, to examine the appearance of things below, and ascend other eminences; but as we were nearly out of provisions, and our work but just commenced, we finished our chicken and tea, and began our descent.

3.3.2 The U.S. Navy Exploration of Haleakalā by Cmdr. Charles Wilkes (1841)

On February 15, 1841, a contingent from the U.S. Navy Exploring Expedition sailed from Hilo, Hawaiʻi to the island of Maui. Naturalist Charles Pickering, artist Joseph Drayton and botanist William D. Brackenridge had been sent to Lahaina to organize an expedition to climb "Mauna Haleakalā ". In Lahaina, the expedition was joined by the Reverend Lorrin Andrews, his son, four students from the Men's Seminary at Lahainaluna, and six *kanakas* [native bearers] to carry food. (Andrews had made the ascent thirteen years earlier) Traveling by way of Waikapū, they were joined by Reverend Edward Bailey, headmaster of the Wailuku Female Seminary. They spent the first night at the home of Lane and Minor, "two Bostonians", at a sugar plantation in Makawao (Wilkes 1852:167).

The next day, as the expedition gained altitude, they noted the changing forest features:

> The face of Mauna Haleakalā is somewhat like that of Mauna Kea; it is destitute of trees to the height of about two thousand feet; then succeeds a belt of forest, to the height of six thousand feet, and again, the summit, which is cleft by a deep gorge, is bare.
>
> Our party found many interesting plants as they ascended Mauna Haleakalā, among which were two species of Pelargonium [geranium], one with dark crimson, the other with lilac flowers; the Argyroziphium [*Argyroxiphium sandwicense*, subs. *Macrocephalum*, or Haleakalā silversword] began to disappear as they ascended, and its place was taken up by the silky species [*Artemisia mauiensis*, or ʻ*āhinahina*] which is only found at high altitudes. Near the summit they found shrubby plants, consisting of Epacris [*pūkiawe*], Vaccinium [ʻ*ōhelo*], Edwardsia [*māmane*], Compositae [*Dubautia plantagenia* or *na*ʻ*ena*ʻ*e*], and various rubiaceous plants (Wilkes 1852:170).

Having left the tree-line behind at 6,500 feet, the barren summit was attained and the winds were noted to have been driving with great velocity. The interior of the crater, as first viewed by the expedition, was completely concealed by clouds. The elevation reading by barometer was interpreted as 10,200 feet. Barometric readings were continued as the expedition descended into the crater:

> The crater of Haleakalā , if so it may be called, is a deep gorge, open at the north and east, forming a kind of elbow; the bottom of it, as ascertained by the barometer, was two thousand seven hundred and eighty-three feet below the summit peak, and two thousand and ninety-three feet below the wall. Although its sides are steep, yet a descent is practicable at almost any part of it. The inside of the crater was entirely

> bare of vegetation, and from its bottom arose some large hills of scoria and sand. Some of the latter of an ochre-red colour at the summit, with small craters in the centre (Wilkes 1852: 171).

Observations regarding the cultural significance of the crater were noted:

> All [of the interior features of the crater] bore the appearance of volcanic action, but the natives have no tradition of an eruption. It was said, however, that in former times the dread goddess Pele had habitation here, but was driven out by the sea, and then took up her abode in Hawaii, where she has ever since remained. Can this legend refer to a time when the volcanoes of Maui were in activity? Of the origin of the name Mauna Haleakalā , or the House of the Sun, I could not obtain any information. Some of the residents thought it might be derived from the sun rising over it to the people of West Maui, which it does at some seasons of the year (Wilkes 1852:171).

Botanist William D. Brackenridge, described a native species of flowering geranium known to Hawaiians as "*nohoanu*":

> Our gentlemen descended into the crater. The break to the north appears to have occasioned by the violence of volcanic action within. There does not appear any true lava stream on the north, but there is a cleft or valley which has a steep descent: here the soil was found to be of a spongy nature, and many interesting plants were found, among the most remarkable of which was the arborescent geranium [*Geranium cuneatum*] (Wilkes 1852:171).

Mapping the interior of the crater was undertaken by Joseph Drayton, an artist with the expedition. Although the resulting map was less than accurate (for example, the orientation of the Kaupō Gap was drawn too far to the east), it gave the world the first complete image of the immensity and layout of its features. Only three days were devoted to the study of the crater, but the drawing added greatly to the accumulating body of knowledge regarding Hawaiian volcanoes (Fitzpatrick 1986).

> Mr. Drayton made an accurate drawing or plan of the crater, the distances on which are estimated, but the many cross bearings serve to make its relative proportions correct. Perhaps the best idea that can be given of the size of this cavity, is by the time requisite to make a descent into it, being one hour, although the depth is only two thousand feet. The distance from the middle to either opening was upwards of five miles; that to the eastward was filled with a line of hills of scoria, some of them five or six hundred feet high; under them was lying a lava stream, that, to appearance, was nearly horizontal, so gradual was its fall (Wilkes 1852:171).

3.3.3 Government Survey of Haleakalā by William DeWitt Alexander (1869)

W.D. Alexander's father, William Patterson Alexander, an accomplished surveyor, used his son during his school vacations as an assistant surveyor. In 1869, W. D. Alexander combined this experience with his studies at Yale, and produced a "remarkable" map of the crater features of Haleakalā during a summer vacation:

> I have just been spending a summer vacation on Maui, and in the course of it made a careful survey of the great crater of Haleakalā . During the vacation I went three times to the summit. The first time I rode up from Makawao before sunrise, and spent about seven hours in collecting mineral specimens and plants, and forming a plan for the survey of the crater….On the morning of August 4th, I ascended the mountain again from Makawao, with five natives, and furnished with a superior theodolite [surveyor's transit], a dozen large bamboos for signal poles, a good tent, and provisions for a week. We spent seven days on the mountain and enjoyed almost uninterrupted fine weather (Moffat and Fitzpatrick 2004:16).

Alexander's map of Haleakalā was the first to document how dramatically magnetic north varied within a fairly short distance, which accounted for the poor quality of maps produced during the time of the Great Mahele. Observations made by W. D. Alexander were produced by rigorous surveying practices, which led to his appointment as surveyor general for the Kingdom of Hawaii in 1870 (Moffat and Fitzpatrick 2004:17).

3.3.4 An Ascent of Haleakalā by C.F. Gordon Cumming (1881)

A sightseeing trip through the ranchlands of Maui, including an ascent of the mountain of Haleakalā, was described in great detail by C.F. Gordon Cumming (1881). The journey described by Cumming required five days from leaving the island of Hawaiʻi to making the summit. Of scientific interest was Cumming's notion that the crater had been formed by a great explosive cataclysm, rather than by large flows of lava running at great velocity out through each of the two gaps leading to the sea, as proposed by Wilkes (1852), or by a cataclysmic collapse of the mountain-building cauldera, as would be put forward two years later by the investigation of the U.S. Coast and Geodetic Survey (Dutton 1883). All three of these theories would prove wrong, when the work of Stearns (1942) showed that the crater had been carved by hundreds of thousands of years of erosion.

The following excerpts describe the ascent of C.F. Gordon Cumming, as well as his initial impressions of the mountain:

> Next in interest to the active volcanoes of Hawaii is the vast crater known as Haleakalā , "the house of the sun." It occupies the whole summit of East Maui, which is one vast mountain-dome ten thousand feet in height, and is connected with West Maui by a low isthmus, which, as seen from the sea, presents an aspect of unmitigated and hideous barreness, while the mountain itself, presenting a sky-line almost as unbroken as that of Mauna Loa gives small indication of the marvels which lie concealed within it (Cumming 1881:272).

> I heard much that was intensely interesting concerning the early years of these islands; but one subject which, on Hawaii, is forever cropping up –namely, the wayward actions of the volcano – is here utterly lacking, for on Maui there is not the faintest suggestion of any living fire – no active crater, no solfataras, no mineral or warm springs, no steam jets. Indeed, the commonly accepted theory is that more than two thousand years have elapsed since the mighty outburst which shattered the huge mountain of Haleakalā, blowing off its entire summit as the steam might blow off the lid of a kettle. And such a lid! For the mighty cauldron in which such forces

worked is, by the lowest estimate, *twenty miles in circumference*, and upward of two thousand feet deep. It is a vast pit ten thousand feet above sea level. Looking up from the coast to the summit of that huge dome, we failed to discern the slightest dent which should betray the site of this vast crater (Cumming 1881:273).

At Haiku we found a native with horses to hire, and a store where we were able to lay in provisions, with which we filled saddle-bags lent us for the purpose. Two natives accompanied us as guides and helpers (Cumming 1881:274). The wiser travelers are those who, ascending from Makawao, make their arrangements for a night of camping out, which means sleeping in a large lava bubble that forms a cave, less than a mile from the summit. Those who prefer starting from Olinda, endeavor to be in the saddle by about 2 A.M., so as to reach the summit before sunrise, but we were far too weary to dream of such a thing. About 6 A.M., it suddenly cleared, and we hastened to prepare for the ascent. Fortunately, it is so gradual that there is not the slightest difficulty in riding the whole way. We passed a belt of pretty timber, and then rode over immense fields of wild strawberries, which unluckily were not in season. *Ohelos* and Cape gooseberries [*poha*] also abound.

Three hours steady ascent brought us to the lava bubble, where we saw evident traces of previous camping parties, and where our guide left us, while we filled our water-bottle at a spring a little further along the mountain-side. One mile more brought us to the summit. We had a momentary glimpse of a group of the cones, or rather secondary craters, rising from the bed of the great crater which lay extended at a depth of nearly half a mile below us – one, at least, of these cones attaining a height of seven hundred and fifty feet. There are sixteen of these minor craters, which elsewhere would pass as average hills, but which here are mere hillocks. Most of them are of very red lava, which has quite a fiery appearance in contrast with the blue-grey lava which forms the bed of the crater, and which is here and there tinged with vegetation. Indeed, we could discern tiny dots which we were assured were quite large trees, and at the further side there is fair camping-ground in the bed of the crater, with two springs of good fresh water [Paliku], where Professor W.D. Alexander told me he had spent considerable time, while preparing his admirable map of the crater. At certain spots is found a beautiful plant, known as the silver sword, which has the appearance of being made of finely wrought silver, and bears a blossom like a purple sunflower (Cumming 1881:274-275).

3.3.5 U.S. Geological Survey of Haleakalā by Clarence E. Dutton (1883)

The mountainous areas of each of the main Hawaiian Islands were surveyed by the U.S. Geological Survey early in 1881, with emphasis on the active volcanic region of the island of Hawaiʻi (Dutton 1883). Their survey of Haleakalā was accomplished by ascending the mountain, descending into the crater, and exiting by way of the Kaupō Gap.

The survey of the general characteristics of Haleakalā included comparisons with mountain-building and mountain-reducing processes observed on the island of Hawaiʻi. The Government Survey had assumed that the vast size of Haleakalā Crater was the result of a wholesale collapse of the caldera -- a structure original to the building of the mountain, but inherently unstable as caldera-filling lavas cooled and settled. The survey said:

> The general form and structure of Haleakalā are very similar to those of Mauna Kea and Mauna Loa. It has the same dome-like contour, and is apparently built in the same way, by the accumulation of lavas mingled with fragmental products. It has numerous cinder cones upon all parts of its surface, and though they are quite normal in form, none of them attain the large proportions of those seen upon Mauna Kea. But by far, the most striking feature of this mountain is seen upon its summit. The upper portion of the mountain contains a caldera suggestive of the same origin and mode of formation as that we have attributed to Kīlauea and Mokuaweoweo, but many times greater in extent (Dutton 1883:206).

The survey narrative continued by detailing the ascent with notes regarding vegetation. The existence and purpose of the Koʻolau and Kaupō gaps were described, and the location of Puʻu ʻUlaʻula as the true summit explained:

> Leaving Olinda, a faint trail winds up to the summit. As the summit is neared the vegetation steadily thins out, becoming very meager, and at last almost vanishing. We come upon the brink of the caldera very suddenly and without any premonition of its proximity. In an instant, as it were, a mighty cliff plunges down immediately before us, and the famous crater of Haleakalā is disclosed in all its majesty. Of all the scenes presented in these islands it is by far the most sublime and impressive. Its grandeur and solemnity have often been described, but the descriptions have not been overwrought (Dutton 1883:204).

> In two directions, eastward and southward, this vista of volcanic plain studded with cinder cones and streaked with black lava stretches off between Cyclopean walls and vanishes by descending the mountain slopes. The eastern passage is named the Koolau Gap. The southern passage is named the Kaupo Gap. The former descends upon the windward side of the island and resolves itself into a huge ravine, and becomes confounded with a medley of vast mountain gorges scoured by erosion and encumbered with an impenetrable forest jungle. The southern or Kaupo Gap descends into a drier region between the wind and lee, and the walls gradually dwindle until at last they vanish (Dutton 1883:205).

> The trail from Olinda reaches the crest of the wall a little more than two miles east of the coign [face], and in order to descend, it is necessary to skirt along the brink until the ciogn is reached. Everywhere a similar view is presented of the gulf below, but as we reach the angle other features are added to the scene. Right here stands a large cinder cone which forms the apex of the mountain [Puʻu ʻUlaʻula]. Its height is about 300 feet. From its summit, we may gain a magnificent view not only of the abyss below, but far away in the distance to the southeastward, of the domes of Mauna Loa, Mauna Kea, and Hualalai, projecting above the domain of the clouds (Dutton 1883:206).

At this point the narrative departs from all previous investigations, owing to geologic studies undertaken by the survey:

> The descent to the floor of the caldera is very easily effected here at the coign. A long slope leads downward, covered with fine lapilli and volcanic sand, into which the feet of the animals sink deeply. By zigzag courses the declivity may be made very easy and gentle. Reaching the plain below, all that is necessary to secure easy traveling is to avoid the fields of fresh lava which are generally found near the bases of the cinder cones. The eruptions of most recent date all appear to be of trivial volume, and contrast by their very insignificance with the mighty outpours of Mauna Loa. Here, too, may be seen admirable illustrations of the common fact that cinder cones are built after the lava has ceased to flow. The fresh sheets of basalt are clearly seen underlying the cones, which have evidently been built over them (Dutton 1883:208).
>
> At the mouth of the Kaupo Gap the floor of the caldera gradually bends downward and acquires a steeper declivity towards the sea. Here we come upon larger and rougher fields of basalt which look quite recent, though obviously older than the extremely fresh basalts which are spread about the bases of the cinder cones. Most of them have the form of *aa*, but are not nearly so rough as the great fields of Mauna Loa. Here and there patches of soil have accumulated in the swales, mosses have overgrown the clinkers, grass and scrubby vegetation have taken root among them. Our camp in Haleakalā was just at the opening of the Kaupo Gap, 7,600 feet above the sea, where the more rapid descent to the ocean begins (Dutton 1883:209).
>
> Reaching the sea-coast, we halted an hour for rest then moved onward parallel to the shore towards the east. Here is a well-built trail, without which travel would be impossible. The country in front of us is precisely similar to in its features to the Hamakua coast of Hawaii. It ends upon the sea in a vertical cliff, while the platform is sawed by cañons descending from the mountains. … Though all are extremely beautiful, there is one in particular which seems to surpass all the others. It is named the Waialua Valley. The surrounding walls, 500 to 600 feet high, are carved into pediments of fine form and overlain with a vegetation so dense, rich, and elegant that the choicest green of our temperate zone is but the garb of poverty in comparison (Dutton 1883:210).
>
> Long after nightfall we rode up to a fine mansion where dwelt the proprietor of the Hana plantation and received memorable hospitality. We had descended that day from the caldera of Haleakalā 7,600 feet above us, and had ridden and walked 20 miles more up and down, I know not how many cañon walls. (Dutton 1883:211).

3.4 The Project Area in the Twentieth Century

3.4.1 Geological Survey by Harold T. Stearns (1942)

Geologist Harold T. Stearns began a comprehensive survey of the island of Maui to document ground-water resources in 1932. The survey was carried on intermittently until 1942, during which time Stearns was assisted in the field for two years by H.A. Powers, and for a year by Gordon A. Macdonald for the East Maui portion of the study (Stearns 1942:14). Stearns made the first detailed study of the geology of Haleakalā, being the first to scientifically show that the summit depression of Haleakalā was of erosional origin, a concept suggested earlier by Whitman Cross, in his paper “Lavas of Hawaii and their relations”, written for the U.S. Geological Survey in 1915.

Stearns described the processes by which the crater was formed from the original volcanic eruptions that built the enormous mountain of Haleakalā (Stearns 1942:61). He estimated that the original height of the mountain had been at least a thousand feet taller that its’ present height of 10,000 feet. Heavy rainfall in both the Keʻanae and Kaupō regions of the mountain began to carve away two valleys, soon joined by erosional valleys at Kīpahulu and Waihoʻi (Stearns 1942:61).

Changes in the level of the ocean caused the deep stream valleys to partially “drown”, causing widening of the valleys, and huge deposits of alluvium to be deposited along the drowned valley walls. At a time when the sea level was near its’ present point, Kaupō Valley experienced an cataclysmic mudflow, sweeping everything in its’ path to the ocean, and creating the Kaupō Gap. Although the geologic signs of such a catastrophe had not been found at Keʻanae, Stearns theorized that the same type of event probably occurred to create the Koʻolau Gap. Stearns also stated:

> Haleakalā would now have at least 5 or perhaps 7 large permanent rivers had not the ancient valleys been deeply buried by thick mud flows, alluvial deposits, and hundreds of feet of highly permeable Hana lavas. Only long expensive tunnels can tap these buried rivers (Stearns 1942:90).

Following a period of accelerated erosion, owing to the valley openings toward the sea below, deep amphitheater-shaped cliff-lines at the head of both the Keʻanae and Kaupō valleys carved their way further toward the summit of Haleakalā. Renewed volcanic activity produced lines of cinder cones across the crater floor and along the outer slopes at rift zones where new lava could force its way to the surface (Stearns 1942:72). Stearns found evidence that powerful earthquakes may have been the triggering force for landslides that carved gaps, and created rift zones that criss-crossed the summit of Haleakalā (Stearns 1942:59).

During Stearns investigation of the interior of the crater, he noted various geologic structures associated with the volcanic forces that built the cinder cones. In addition, he reviewed notes by Frank Hjort, ranger-in-charge at Haleakalā National Park, who had conducted an investigation of the “Bottomless Pit”. Within the pit, which actually measured 75 feet deep, Hjort had observed the existence of sealed jars containing the umbilical cords of infants (Stearns 1942:100).

3.4.2 Military Use of the Haleakalā National Park

Prior to World War II, the United States military sought sites for “unspecified defense installations” at the summits of both Mauna Loa and Haleakalā. On April 29, 1941, the War Department was granted a special use permit by the U.S. Department of the Interior to utilize a six-acre portion of the summit at Puʻu ʻUlaʻula , adjacent to lands located just outside of the boundary of Haleakalā National Park at Kolekole (Jackson 1972:130). At the time of the Pearl Harbor attack, December 7, 1941, the Puʻu ʻUlaʻula installation was not operational. Just prior to the Battle of Midway, in June, 1942, U.S. Army radar and communications equipment at

Haleakalā was finally ready. Technical design problems caused intermittent radar failures until March, 1943, when the facility was operationally abandoned.

Although the public had been barred from access to the summit under Martial Law, following the outbreak of WWII, partial access to the National Park occurred in October 1942, with full access returned to the public in February 1943 (Jackson 1972:131).

In November, 1943, new plans for defense construction at Haleakalā were drawn up by the military, with construction commencing May 1944. The peak of Puʻu ʻUlaʻula was leveled off, and a series of 90-foot tall radio masts were installed at the crater summit (Jackson 1972:131).

Throughout the "War Years" of WWII, various areas of the island of Maui were utilized either as military bases or as military training areas. The trails across the crater of Haleakalā were deemed ideal for long-distance training marches. Between 1942 and 1945, various units of the U.S. Army Infantry's 27th Division, 40th Division, 33rd Division, and 98th Division, as well as units of the U.S. Marine Corps' Fourth Marine Division, could be found making their way across the shifting cinders of the crater floor (Mary Cameron-Sanford, personal communication, 2007).

By 1945, a second defense installation adjacent to Puʻu ʻUlaʻula, at Kolekole, was in operation. Although the end of the war rendered the Haleakalā facilities obsolete, the remnant radio masts remained an eyesore until they were finally removed by the military in 1950. The U.S. Air Force maintained a loose "caretaker status" over the abandoned military buildings at the summit until 1955, when the University of Hawaiʻi was granted permission from the federal government to pursue solar studies from the existing military buildings (Jackson 1972:132).

Between 1956 and 1958, a number of unused buildings were removed by the U.S. Air Force. At that time, the Department of the Navy was conducting a project related to the atomic bomb tests in the South Pacific (Jackson 1972:134). In 1959, the Hawaiʻi Air National Guard requested construction be undertaken at the summit for new communications and radar equipment, but the request was argued in Washington D.C., with astronomy researchers and the military at odds about the location of various facilities at the summit. Negotiations were not completed until 1964, when it was decided that Puʻu ʻUlaʻula would be cleared of all former military debris, and that all future use of the summit would either be relegated to Kolekole (the present-day "Science City") or just below Hosmer's Grove: both outside lands maintained by the National Park Service (Jackson 1972:134-140).

Table 2. Development Timeline atop Haleakalā

DATE	EVENT
circa 1600	Road through crater floor from Kaupō to Keʻanae built by Kihaapiʻilani.
1841	First scientific descent into crater (Wilkes Expedition, U.S. Navy).
1866	Samuel Clemens (Mark Twain) at summit of Haleakalā
1894	C. W. Dickey Summit Rest House completed.
1916	Haleakalā National Park established: 19,276 acres
1921	First archaeological study of Haleakalā by Emory
1925	First telephone service from Olinda to Summit Rest House.
1935	Construction and paving of first road to the summit completed.

DATE	EVENT
1936	Summit visitor observatory completed below White Hill.
1937	Kapalaoa, Hōlua and Palikū cabins on crater floor completed.
1940	Three U.S. Navy aircraft crash in formation at Polipoli.
1942	WWII radio and radar antennas constructed at summit.
1964	“Science City” astronomical observatories established at Kolekole
1976	U.S. Wilderness Act adds 5,500 acres to Haleakalā National Park
1992	Noise regulations move helicopter flights out of Haleakalā Crater.
Present	Haleakalā National Park: 31,083 acres total, 24,719 in wilderness. Haleakalā High Altitude Observatories: 18.166 acres total

Section 4 Archaeological Research

4.1 First Archaeological Survey of Haleakalā by Emory (1921)

Kenneth P. Emory (1921) conducted the first archaeological survey of the interior of Haleakalā, and performed excavations to explore construction methods and record cultural deposits associated with various stone structures found within the crater. Emory and his team of researchers made a survey of the apex of the mountain, including the area within the proposed ATST site. This summary of Emory’s landmark work details all excavations undertaken, as well as all features noted either by Emory, or his fellow researchers. Of the sixteen larger cinder cones identified across the floor of the crater, Emory determined that twelve contained stone structures. The architecture of each group was named for the prominent cinder cone it was resident in, and a summary of archaeological activities performed at each group is listed below:

4.1.1 Haleakalā Group

The Haleakalā group of archaeological features was recorded at the highest points of Haleakalā, which Emory noted consisted of two peaks and a high connecting ridge on the south rim of the crater. The largest stacked-basalt structure in the entire crater region was documented at the top of “Summit Number 1” [Pu‘u ‘Ula‘ula] (Emory 1921:19). Emory recorded the structure as a *heiau*, with base measurements of 57 ft (feet) by 36 ft, extending lengthwise along the ridge. The support walls were measured at heights of 18 ft (on its eastern-facing side), 12 ft (west), 6 ft (north), and 15 ft (south). The top measured 24 by 15 feet and consisted of two level spaces, the easternmost measuring 6 feet square and raised 6 inches taller than the level to the west. A wall several feet thick separated the two levels, which included an additional platform measuring 15 ft long and 6 ft wide extending out towards the crater from the easternmost wall. This portion of the platform was noted by Emory to “almost overhang the rim of the crater”. Although two survey cairns (dating either to the U.S. Geological Survey of 1883, or W.D. Alexander’s Government Survey of 1869) were noted to have been erected on a portion of the eastern platform, the majority of the *heiau* structure appeared well preserved (Emory 1921:20). Emory noted that ten sling-stones (water-worn pebbles) were recorded at the structure.

Just east of Pu‘u ‘Ula‘ula , in a dip of the ridge, a large rectangular stacked-basalt stone shelter measuring 27.5 ft long, 8 ft wide to the east, 3 ft wide to the west, with walls averaging 2 ft high (measured on the inside), was recorded. Two fireplace features 9 ft apart and 2 ft square were noted. The easternmost fireplace was excavated, within which Emory noted “one inch of solid earth covering seven inches of white ash”. The excavation of the second fireplace revealed “two inches of soil covering small pieces of burnt wood”. In a location below the large shelter, Emory also noted four or five smaller shelters, which he described as “in ruins” (Emory 1921:19). A number of nearby shelters were described by Emory:

> Half an hour’s walk farther along the crest of the ridge, brought us to another rectangular shelter, 6½ feet wide and 13½ feet long, with walls 3 feet high. Among the scattered rocks of the enclosure, a fireplace, 3 feet square, was found against the south wall. Other smaller shelters lie on the nearby slope. Fifty yards east in the lowest part of the ridge between the summits of Haleakalā Mountain we

> discovered a platform with a flat stone-paved top, 4½ by 8 feet, and 34 inches high, extending east and west. A few small shelters in ruins lie 50 yards beyond, one a small wall a foot high around the mouth of a cave (Emory 1921:19).

Emory recorded a stacked-basalt platform at the very top of the summit opposite Puʻu ʻUlaʻula, which he termed "Summit Number 2" [Kolekole Hill]. The platform measured 20 ft long by 4 ft wide, with the tallest portion of the base facing east ("towards the crater") measuring 3 ft in height. Emory noted a survey cairn erected on the east end of the platform. Emory described six small nearby shelters as "in ruins". In the vicinity of the Puʻu ʻUlaʻula platform and shelters, Emory located five sling-stones and two pieces of marine branch coral. Emory's survey of the west slope of Puʻu ʻUlaʻula noted 25 stone shelters, and in the vicinity between Puʻu ʻUlaʻula and Kolekole Hill, the survey noted a group of 8 or 9 stone shelters with "a great many small *ahus* (Emory 1921:19).

Other structures on the rim described by Emory included two stacked-basalt platforms located on the north rim of the crater during an exploration of the region from Hanakauhi to Palaha. The first platform was described as "merely a pavement of smooth rocks measuring 6 ft by 18 ft overlooking Kalua o Umi". The second platform, located on the summit of Hanakauhi, was described as "completely in ruins". According to Emory:

> Our attention was first directed to this platform by the following remark made in the Coast and Geodetic Survey records of the station. For Hanakauhi, "Station Mark: a pillar of stone 10 feet high *on an ancient platform*, maliciously demolished in 1884 (Emory 1921:20).

> The summit of White Hill is completely covered with large, strongly constructed shelters. Just west of the summit cairn a crevice in a small cliff is sealed by stones and cement. On the ground ten feet away is a table composed of four large, flat stones one on top of the other with cement in between. These are the work of W. D. Alexander during his survey of Haleakalā and together with the large stone corral near by, should not be confused with Hawaiian structures in the crater (Emory 1921:20).

4.1.2 Puʻu Naue Group

Located in a 250-foot tall cinder cone in the center of the floor of Haleakalā Crater, pre-contact historic properties resident consisted of a complex of three stacked-basalt terraced platforms. The north platform was described by Emory to have been "in ruins". The south platform, which was described as a rectangular platform measuring 26 ft (feet) long by 16 ft wide by 2 ft high, was pit-excavated to a depth of four feet. The excavation produced no "shells, artifacts, nor skeletal material". The east platform, a polygon that measured 12 ft by 12 ft by 15.5 ft by 11 ft, was trench-excavated, but no cultural deposits were found (Emory 1921:4).

4.1.3 Burial *Ahu* in Kamoa O Pele

Located on the floor of the crater of Kamoa O Pele, a cinder cone close to the cinder cone Puʻu Naue, was a pre-contact stacked-rock cairn (*ahu*) constructed to protect an individual burial (Emory 1921:5). After removing the basalt construction to ground level, a rectangular stone base measuring 6.5 feet by 5.5 feet was discovered. Further excavation revealed a human skeleton placed face downward. The excavation located two sticks of “Mamani” wood [mamane] on either side of the remains; determined to have once been the frame of a stretcher used to convey the body to the burial site. Further examination located fragments of a decayed calabash [gourd]. A skull and jaw were found in good condition with the teeth exhibiting slight decay (two of which were observed to have been lost during life), but lower body bones were in an advanced state of decay. Skeletal remains were determined to have been of a Polynesian female, aged thirty-five years (Emory 1921:6).

Following the excavations, the burial pit was refilled, and the *ahu* rebuilt to its original height. A profile drawing revealed that the skeletal remains were arrayed with the feet facing north. The entire skeleton had been laid flat, with the leg bones folded almost to the shoulder, and hands laid across the back. To Emory, the method of burial appeared, “grasshopper fashion” (Emory 1921:6).

4.1.4 Halāliʻi Group

A cinder cone adjoining Kamoa O Pele, named Halāliʻi, included two craters separated by a wall of consolidated cinder material one hundred feet high. Using an approach from the spatter cone named Pa Puaʻa O Pele, located between Kamoa O Pele and Halāliʻi, access to a three-tiered stacked basalt terrace 36 feet long was made. The uppermost step dropped one foot to the next level, which was 26 inches wide. The next drop was 1.5 feet to a step 26 inches wide, and the final drop was two feet to a step 26 inches wide. Standing at this terrace brought into view all the other structures investigated within Halāliʻi Crater (Emory 1921:7).

Other structures investigated within Halāliʻi Crater included:

> A suspected terrace covered by slide of cinders. A wall 25 feet long by two feet high could be discerned, but excavation was not possible.
>
> A terraced platform 13 by 16 feet was excavated, but no cultural deposits were found.
>
> A complex of three stacked-basalt terraces: the topmost terrace measuring 14 ft long by 5.5 ft wide by 1.8 ft tall; the middle terrace measuring 12 ft long by 5.5 ft wide by 3.5 ft tall; and the bottom terrace measuring 9.5 ft long by 5.5 ft wide by 2.5 ft tall. On a level near the surface of the top terrace, Emory found fragments of various human skeletal remains, including an adult tooth and a skull. Emory noted, “There was a stone to the east of the skull, and a small stone resting on top of it (Emory 1921:9).
>
> A complex of five stacked-basalt terraces: the topmost terrace measuring 11 ft long by 7.3 ft wide by 2 ft tall; the second terrace measuring 18 ft long by 3 ft wide by 6 ft tall; the middle terrace measuring 15 ft long by 7 ft wide by 4 ft tall; the fourth terrace measuring 9.5 ft long by 5 ft wide by 1.3 ft tall; and the bottom terrace measuring 12 ft long by 5 ft wide by 2 ft tall.
>
> Emory’s excavation notes of the topmost terrace included:
>
> We recovered bones of an adult female and a child of four years of age within the space of the top terrace but also deep enough to have been in the fourth terrace. The skull of the woman was missing, but the jawbone in good preservation lay right side up 17 inches below the surface and 36 [inches] from the front wall of the fourth terrace. No teeth were found. Some of the molars had evidently been lost in life. Ribs

> and isolated vertebrae extended the width of the grave to the cliff where we found the entire skeleton of the child buried 32 inches deep, turned slightly to its left side, the head towards the northeast. A toe bone was found five feet away, buried one foot under the east end of the platform, and some of the smaller bones were only one foot under the surface and next to the front wall (Emory 1921:10).
>
> There was very coarse gravel about the bones and large stones on all sides of them. In examining the bones from this terrace, Mr. Sullivan found an extra femur of a child about three years of age. It is difficult to account for the absence of the long bones of the adult, which were searched for most thoroughly. Either they had been removed before the rest of the skeleton had been deposited, or the grave had been opened and the missing parts removed. I think the latter explanation the more plausible, for none of the bones were broken and some of the rib bones and vertebrae were in their appropriate position (Emory 1921:10).
>
> While filling in the top terrace we started the sand sliding from above and brought to view several small bleached fragments of bone and a large, badly weathered jawbone with the teeth remaining in it. Bones of the same skeleton were found by digging along the edge of the dike and a pelvic bone was recovered from from a crevice in the cliff a foot and a half under the sand. By the side of it were fragments of decayed wood, probably mamani, and bits of calabash or gourd. The bones were those of a man about sixty years of age and well above the average height. Only a few teeth were left on the lower jaw; the skull and long bones were missing (Emory 1921:10).

Although Emory noted that excavation of the middle terrace “revealed nothing”, his notes regarding the fourth terrace include a description of a small sub-terrace, measuring 4 ft by 2 ft by 5 ft tall. Following the recovery of two beach pebbles that Emory interpreted as sling stones, he commenced further excavation:

> Against the cliff wall, 34 inches beneath the surface of the terrace, a rib bone was found. After some difficult excavation in sliding gravels, we found a small skull, face down, slightly turned to the south, and below this a smaller skull filled with broken bones, and then a third very small skull and jaw. Scattered bones were also found. The largest skull was that of a man about sixty years of age who had lost during life most of his molar and premolar teeth. The other skulls were those of a child of four and a child of three years of age. All were of a pure Hawaiian type. (Emory 1921: 11).

4.1.5 Pa Puaʻa o Pele Group

A stone structure was observed fifteen yards east of the spatter cone structure of Pa Puaʻa o Pele, measuring 9 ft long by 5 ft wide. The structure, interpreted by informants as a burial containing two men and a woman who, “scratched the sacred sands and were lost in the descending fog and perished”, was excavated. A slingstone was lodged in the corner of the structure and five others were scattered about it, but no cultural deposit was revealed. Emory noted 50 *ahus* around Pa Puaʻa o Pele; none half as large as the burial *ahu* in Kamoa o Pele and some consisting of only three stones one on top of the other (Emory 1921:12).

4.1.6 Hanakauhi Group

Emory relied on the testimony of Robert T. Aitken for information regarding a set of structures resident at Hanakauhi Valley. Three stacked-basalt platforms and two stacked-basalt *ahus* were observed “in a little pocket lying between Mamani and Kumu Hills”. The three platforms, which were situated respectively in the south, east, and north parts of the valley were notable for volcanic “bombs” [cobble-sized basalt ejecta with a characteristic teardrop shape: first described as a “bombe de roulement” by J. D. Dana, Manual of Geology, 4th ed.,1894:287] used in the construction. The isolated south platform was bordered by a wall less than 2 feet high, forming a rectangle 15 ft by 7 ft. The east platform was recorded as poorly preserved, and the north platform was noted with a secondary wall. The two *ahus* were recorded thus:

> Near the entrance to Hanakuhi Valley are two solidly built *ahus* constructed of unmarked local stones. The north ahu measures 5 by 7 feet and the south *ahu* 5½ by 9 feet; both are 2½ feet high and lie east and west. By standing on them the three platforms in the valley can be seen and the approach to the valley watched (Emory 1921:13).

4.1.7 Mamani Group

A group of eleven stacked-basalt platforms, some of which were examples with features new to Emory and his team, were recorded at the foot of Mamani crater, at a cinder cone named Kalua Mamani by native informants. A small terraced platform was noted on the west slope of Mamani crater, at the base of the cinder cone. It measured 12.5 ft by 4.5 ft by 1.5 ft high, oriented northeast/southwest. This platform was noted as “very similar to the lower terraces of the north and south Hanakauhi platforms, and its dimensions were the same as the east platform” (Emory 1921:14).

An unusual square platform, located 200 ft southwest of the terraced platform described above, had been constructed on a raised knoll. It measured 4.5 ft on its north side, 6 ft on the south, 4.5 ft on the east and 6 ft on the west. It measured 1.5 ft high on the north and west, and 2.5 ft high on the east and south, with shelves 2 ft wide.

A structure comprised of slabs of *aa* clinker, stacked 1.5 ft tall in the form of a rectangle, was located 150 ft west of the square structure described above. The construction measured 3.5 ft by 7 ft. This structure, and subsequent structures described below, were located on loose cinder at the edge of an old lava flow issuing from a volcanic vent dubbed “Dante’s Inferno” by Emory. The structures were recorded in an orientation parallel to the edge of the lava flow: extending in a line northeast to southwest.

At a location 100 ft further toward the southwest, a stacked-basalt structure was recorded that differed markedly from previously recorded structures. The structure was constructed in a T-shape, the “T” measuring 3 ft square, joined eastward to a platform measuring 15 ft long by 5 ft wide by 2 ft high.

Located 130 ft further to the southwest, a platform measuring 19.5 ft long by 3.5 ft wide by 2 ft high was recorded.

Located 200 ft to the south, an area measuring 6 ft square and less than a foot high, was described as "paved with stones". The stones were removed "to make sure that they concealed no crack or opening in the lava". No cultural deposits were found.

The last of the related structures was located 100 ft eastward on the very edge of the *aa* flow. The structure was described as a platform measuring 3 ft by 5 ft by 3 ft high.

4.1.8 Kihapiʻilani Road

The southern portion of the *aa* clinker flow from Dante's Inferno was traversed by an ancient Hawaiian road. Emory was able to trace its course over the *aa* flow, but lost it where it crossed the loose cinders. It measured 6 to 8 ft wide and was paved with blocks of *aa* basalt. According to Emory's informants, the road was supposed to have gone around the base of Mamani Hill, through the Hanakauhi Valley, above Mauna Hina cone, and along the Kalapawili Ridge to the pond Wai Ale on the outside slope of Haleakalā, where Kihapiʻilani was said to have built a dam to hold the waters of the pool. Emory's informants stated that water-worn pebbles had been found above Mauna Hina and along Kalapawili Ridge (Emory 1921:15).

4.1.9 "Dante's Inferno" Group

Located along an *aa* clinker flow from the volcanic vent, pre-contact historic properties resident consisted of a complex of three stacked-basalt terraced platforms. The first two structures, the east and west platforms were recorded 36 feet apart. The east platform measured 14 ft long by 3.5 ft wide by 1.5 ft high. The west platform measured 10 ft long by 5 ft wide by 2 ft high. Located 75 feet northwest of the east platform, a structure recorded as the northwest platform was measured as 8 ft long by 3.5 ft wide by 1 ft high (Emory 1921:15).

4.1.10 Keahuokaholo Group

A stacked-basalt structure, described by Emory as a "curved stone wall" was recorded at Keahuokaholo, at a point where a ridge of red cinder emanating from Puʻu Maui crossed the Halemauʻu trail at the midpoint of the Koʻolau Gap. Near this point and alongside of the trail was a curved stone wall that measured 34 ft long by 4.5 ft wide by 3.5 ft high. The red cinder had drifted to a height that nearly covered the middle of the construction. One hundred and fifty feet southeast of the wall was an *ahu* measured 3 by 4 feet (Emory 1921:16).

At the ridge of Keahuokaholo, between 40 and 50 stacked-basalt *ahu* were recorded within a radius of one hundred yards. East of the entrance of the trail from Halāliʻi, 28 stone shelters were noted. Within the shelters, a total of 15 water-worn pebbles were collected. Five had been laid together next to a ruined shelter. Emory noted as many *ahus* and shelters north of the entrance as south of it. A stacked-basalt platform noted at the north entrance measured 9 ft by 3.5 ft by 1.5 ft high.

Another 50 small *ahus* were located at the west border of Keahuokaholo. Ruins of a platform were noted 100 ft to the south and another, measuring 3.5 ft by 12 ft, was located 300 ft to the northeast on the edge of a ravine. Located 200 ft further northeast a large flat rock, 3 ft high, was covered by a single layer of rough stones.

A few hundred yards from Keahuokaholo on the Leleiwi trail, a stacked basalt platform 3.5 ft wide and 12 ft long, built of thin slabs of *aa* clinker, was recorded. A half-mile further, the lava tube known as the Long Cave was noted, as were 3 associated large stone sleeping shelters. Dr. George Aiken, Mr. Walter Walker and Emory followed the cave for three-quarters of a mile without reaching its end. Upon exiting the cave, Emory described a most unique site within the crater of Haleakalā:

> A short distance north of the Long Cave is the pit, Na Piko Haua, 10 feet deep and 15 feet in diameter, in which we found tucked away in crevices the umbilical cords of Kaupo babies. Some of the cords were in colored cloth wrapped with the hair of the child's mother, and others were preserved in small glass bottles; the presence of the recently hidden cords testifies to the strength of superstition among present-day natives. I have heard two explanations of this custom. Mr. Poouahi, from Kaupo, whose own cord is hidden here, claims that placing the cord out of danger of destruction protects the child from becoming a thief. The other explanation is from George Aiken, who at one time saw an old native throw a collection of navel strings into the Bottomless Pit, Kawilinau, exclaiming, "To make the child strong." Probably, these spots are sacred (Emory 1921:17).

4.1.11 The ʻŌʻŌ Group

A complex of three large stacked-basalt terraces located at the uppermost cinder cone on the Sliding Sands trail was recorded. The topmost terrace measured 38 ft long by 22 ft wide by 6 ft tall; the middle terrace measured 22.5 ft long by 15 ft wide by 4 ft tall; and the bottom terrace measured 20.5 ft long (at the front), 22 ft long (at the back) by 13.5 ft wide by 5 ft tall. Emory noted that all three terraces were in ruins (Emory 1921:17).

4.1.12 Keoneheʻeheʻe Trail Group

Although in ruins, the original form of the east terraced platform of the Keoneheʻeheʻe group, north of Puʻu o Pele, on the south side of the trail, was recognizable. Emory likened the platform features observed at Keoneheʻeheʻe to those in Hanakauhi Valley. The most prominent stacked-basalt platform measured 13 ft long by 4 ft wide (east), 6 ft wide (west) by 1 ft tall (Emory 1921:17).

4.1.13 Wai Kapalaoa Shelters

Emory's description of the features of Kapalaoa include:

> At the foot of Puu Maile and opposite the spring, Kapalaoa, I counted over 50 stone shelters in clusters of 3 to 10, and found pebbles lying on the sand about Kahuinaokeone, but none among the Kapalaoa shelters. I do not think the shelters can be considered fortifications; they are not in strategic positions; and are too low for a man to hide behind and defend himself while throwing sling-stones. As sleeping shelters they would serve tolerably well in clear weather, and isolated ones on the floor of the Crater have been so used even recently. The group of shelters at Kapalaoa and Keahuokaholo are large enough to serve as sleeping quarters for 150 to 200 men (Emory 1921:18).

4.1.14 Hunter’s Cave Terraces

According to testimony by Robert T. Aitken, a large hunter’s cave located under the east rim of the small crater known as Kalua o Aawa, half-way up the north wall of the crater of Haleakalā , was sealed over by a rockslide in 1918. The cave contained terrace construction similar to features observed on the crater floor (Emory 1921:18).

4.1.15 Lā‘ie Group

Four platforms, having their long dimensions east and west, were recorded by Emory on the margin of the Kalua o ‘Umi lava flow, between Lā‘ie Cave and the upper trail to Lā‘ie. Each stacked-basalt platform was about 50 feet apart, and measured three feet high. The first platform measured 3 ft by 6 ft; the second 4 ft by 6ft; the third 3 ft by 6 ft; and the fourth 3 ft by 5 ft (Emory 1921:18)

4.2 Other Archaeological Studies

Winslow Metcalf Walker, in his survey report entitled the *Archaeology of Maui* (Walker 1931), discusses a *heiau* on Summit 1 (named Haleakalā) on the southern ridge of Haleakalā Crater in the neighboring *moku* of Kahikinui. A trail from the Nu‘u district, discussed in Emory's report, leads to the same peak on which the *heiau*, identified as Kemanono by Emory (Heiau site 229; State site 50-50-16-3626; Bishop Museum number MH-41), is located.

In 1963, Lloyd J. Soehren conducted *An Archaeological Survey of Portions of East Maui* (Soehren 1963). This report calls Emory's work "extensive", and focuses on the structural and functional interpretations of the sites within and around the perimeter of Haleakalā Crater. Based on an early radiocarbon date obtained from Holua Cave (located along the Halemau‘u Trail on the north side of the interior of the crater), Soehren suggests this region was being used prior to 1000 A.D. The Haleakalā region is described as being primarily used as a traveling route from one side of the island to the other, although Soehren also mentions bird hunting, and place of refuge for war victims as possible uses. He points toward the numerous *ahu* and stone shelters as evidence for cairns, markers, shrines and wind breaks associated with traveling. Several archaeological sites were ascribed with such traditional Hawaiian practices as umbilical cord offerings, ritual and family burial rites and the collection of raw materials for adze making (Soehren 1963: 111-116).

Paul Rosendahl (1978) completed an archaeological reconnaissance for the proposed Haleakalā Highway Realignment Corridor. He reported 7 sites along the highway realignment corridor including cave shelters, a platform, cairns and walled shelters (Rosendahl 1978: 4). None of the sites found is in the present project area.

In 1991, J.C. Chatters conducted a cultural resource inventory and evaluation for 7.7 acres associated with the expansion of the Maui Space Surveillance Site located in Science City (Chatters 1991). Chatters identified four archaeological sites at the proposed location for MSSS expansion, Sites 50-50-11-2805 through 50-50-11-2808. The recorded sites consist of 23 shelters and a wall segment. A slingstone was found at site 50-50-11-2807 and a limpet shell was identified at site 50-50-11-2808 (Chatters 1991:13). Archaeological sites identified along the summit region were interpreted as pre-contact temporary shelters made by travelers passing through the region. No further archaeological work was recommended for the expansion of the MSS Site as the proposed construction would not affect the newly recorded sites.

An archaeological inventory survey was conducted in Papaʻanui by Xamanek Researches (E. Fredericksen et al. 1996) for the then proposed GTE Hawaiian Telephone Haleakalā Fiber Optics Ductline, Phase III project corridor. A total of four historic properties were identified as a result of this study, none of which were found in the surveyed portion of Papaʻanui Ahupuaʻa.

Field inspections of localities at Haleakalā for the installation of Remote Weather Stations included one locality within Papaʻanui Ahupuaʻa (Folk and Hammatt 1997). A low L-shaped wall was identified on the north slope of Hanakauahi and interpreted as a temporary shelter or hunting blind for goat hunters.

An archaeological inventory survey was conducted by Cultural Surveys Hawaii, Inc. (Bushnell and Hammatt 2000) in anticipation of the construction of the privately funded Faulkes Telescope. A total of two archaeological sites, State Inventory of Historic Places (SIHP) Numbers 50-50-11-4835 and -4836, were identified during the course of the inventory survey. SIHP -4835 consisted of two rock enclosures interpreted as trash burning pits associated with the military use of Kolekole. SIHP -4836 consisted of three terrace features, two enclosed and leveled areas, and one wall segment interpreted as pre-contact temporary habitation shelters.

As a part of the Long-Range Management Plan for the University of Hawaii Institute for Astronomy High Altitude Observatories, Xamanek Researches (E. Fredericksen and D. Fredericksen 2003) conducted an archaeological inventory survey of the entire 18.166-acre parcel. This inventory survey resulted in the identification of six new historic properties (SIHP Nos. -5438 through -5443), as well as additional documentation of previously recorded historic properties (SIHP Nos -2805 through -2808 and -4836), Approximately 80% of the newly identified features were interpreted as temporary habitation sites and/or wind shelters while two features consisted of petroglyph depictions and one site consisted of a possible burial feature. Finally, a late historic era former radio telescope facility built in 1952 was also recorded during the inventory process.

Based on the overall findings of the above archaeological studies, it appears that the principal site types at Haleakalā such as trails, platforms, adze quarries, caves, temporary shelters and cairns, seem to be associated with topographic or geomorphic locations (Chatters 1991). Platforms related to traditional Hawaiian ceremony are predominantly found along the crater floor and at high promontory locations. Caves are often found on the crater rim. Temporary shelters built against rock outcrops or boulders are found scattered along the crater rim and within the crater, but are concentrated on the leeward sides of cinder cones such as Pakaoao. Cairns or *ahu* are scattered over Haleakalā.

Missing pages are for the specific project this supplemental cultural impact assessment was originally intended for.

The intent of providing this Appendix for the Environmental Assessment is for its information content regarding Native Hawaiian cultural and traditional practices.

Section 7 Traditional Cultural Practices

In this section, cultural practices, traditional and modern day, have been extracted from the public testimonies, formal letters, and from the community counsultation process. The practices and beliefs presented here are derived from common themes that presented themselves throughout the above processes (Section 5 Scoping Meetings and Section 106 Testimony; Section 6 Community Contacts and Consultations) as well as additional background research. Excerpts from McGuire and Hammatt (2000), Maxwell (2002, 2003, 2006), Xamanek Researches, LLC (2006), KC Environmental (2005) have also been included in these summaries.

7.1 Gathering for Plant Resources

Plants along the upper elevations and summit of Haleakalā include *'ōhelo* berries, *lehua*, *'a'ali'i*, *pūkeawe*, *pōpolo*, *māmane* and various species of fern. *'Ōhelo* berries (*Vaccinum sp.*) were traditionally offered to Pele (see Section 3.1.2.4 A Description of the Powers of Pele by William Ellis (1826).) by those who frequented the upper elevations of the mountainous regions. Currently, as in traditional times, upland hikers and those in transit would often pick these berries as a food resource when found ripe (Abbott 1992:44).

Pūkiawe (*Syphelia tameiameiae*) (Abbott 1992:126) and *lehua* blossoms were often used for lei making. Kumu Hula Hokulani Holt-Padilla (McGuire 2000: 60) describes collecting *pūkeawe, lehua*, *māmane* as well as other plants and flowers.

The trunks and branches of the *'a'ali'i* (*Dodonaea viscosa*) and *māmane* (*Sophora chrysophylla*) were traditionally harvested and used for *hale*, or house, posts (Abbott 1992: 68). Present day efforts have revived the construction of traditional structures, however, it is unknown at this time whether these plants are actively harvested along the upper elevations for modern *hale* construction. Traditional use of *māmane* for weaponry, particularly spears, was also common during the time period before western contact (Abbott 1992:110). While there are modern craftsmen of traditional weapons practicing their art, it is unknown if timber from the *māmane* tree are being actively harvested for this specific purpose along the upper elevations of Haleakalā.

Pōpolo (*Solanum americanum*) leaves were often used in *la'au lapa'au*, or Hawaiian medicinal practices, for alleviating sore tendons, muscles, and joints (Abbott 1992:98). There are indications that this plant continues to be gathered along the upper elevations.

Although no gathering of plant resources occurs in the proposed ATST locations, the community consultation process revealed that traditional gathering for plant resources continues today in the upper elevations surrounding Haleakalā summit. Mr. Kawika Davidson recalls that traditionally only certain parts of the upper forest could be accessed. In the past as well as at present, *kumu hula* and *hula* students go to the upper forested areas to collect flowers and plants for *lei* and adornments. There are cultural concerns about the possibility of the contamination of the plant resources via hazardous materials that may potentially result from the operations of ATST.

7.2 Traditional Hawaiian Sites

In the most recent archaeological study, Xamanek Researches, LLC (2006) completed a field inspection of the proposed primary location and the alternate location for ATST. Six newly identified sites which inculde a total of 30 individual features were recorded. There are a total of 12 archaeological sites that have been assigned SIHP numbers in the OH parcel, with a total of 51 traditional Hawaiian features. Archaeological sites include: temporary habitation sites, petroglyphs, terraces, rock walls, a potential burial, undetermined rock piles, and a foot path.

Different archaeological sites, including an adze quarry, were also mentioned in the testimonies and community consultations. Mr. Tim Bailey also makes mention of a *heiau* above Kapalaoa.It is clear that the 18 acre parcel in study was an important place for Hawaiian living in precontact times. The large number of remnant archaeological sites indicates that the area was used and therefore held significance during traditional times.

7.3 Traditional Hawaiian Birth and Burial Practices

The crater floor, as well as the summit area, is known to be a place where people went not only to bury their dead but also to place the umbilical cords of their infants. During his survey of the crater floor, Kenneth Emory noted a pit where the umbilical cords or *piko* were found in sealed jars and there are indications that the practice continues to the present time. With regards to burial practices, there was mention of burial sites/caves in the crater throughout the public comment period, as well as a possible burial feature within the 18.166-acre HO (E. Fredericksen and D. Fredericksen 2003). Through these actions it is clear that Haleakalā plays a vital role in the life cycle of Native Hawaiian people who were and continue to be *ma‘a* (familiar or accustomed) to this place.

7.4 Native Hawaiian and Contemporary Hunting Practices

The Hawaiian Dark-rumped Petrel (*Petrodroma phaeopygia sandwichensis*) known as the *‘Ua‘u*, is an endangered species whose breeding grounds are found only in the main Hawaiian Islands (Day *et al.* 2005: i). On Maui their nesting sites are located at the summit of Haleakalā and throughout the crater. The highest known concentration of burrows is located at the inner western rim of the crater. There are approximately 27 known active burrows surrounding the proposed Mees site location (Kathleen Bailey, per telephone conversation April 1, 2007).

The Hawaiian Almanac of 1902 published by Thomas Thrum, the 1902 included a description by ornithologist H.W. Henshaw of the *‘ua‘u*:

> The natives inform me that the *‘ua‘u* is common on the fishing grounds, some five to ten miles off the windward side of Hawaii. The natives reported that the birds formerly nested in great numbers in the lava between Mauna Kea and Mauna Loa.
>
> It is said that years ago the nestlings of the ‘ua‘u were considered a great delicacy, and were tabooed for the exclusive use of the chiefs. Natives were dispatched each season to gather the young birds which they did by inserting into the burrows a long stick and twisting it into the down of the young which then were easily pulled to the surface (Henshaw 1902:120, italics added).

Mr. Tim Bailey stated that he too knows of this use of the *‘ua‘u*. He explained that a mother *‘ua‘u* is known as a *kaini* and Hawaiian bird hunters were careful to avoid killing the *kaini* as they were needed to raise their young. In addition to being a prized food source, *‘ua‘u* were also hunted for their feathers. The *‘ua‘u* were the *hō‘ailona*, or the insignia, of some *ali‘i*, and thus, used by them in personal adornments such as capes. Certain *ali‘i* might be identified, not only by the pattern in his or her feather cape, but also by the type of feathers and the distinct color of the feathers. *‘Ua‘u* feathers were also used as adornments on *hula* and *lua* instruments. Because of of the birds’ migratory nature, following the seasons, *‘ua‘u* feathers might have been used to represent the season in which they appear. Lastly, *‘Ua‘u* were considered *‘aumakua*, a family or personal god (Pukui and Elbert 1986), who acted as a guardian. Today, it is illegal to harm or kill the *‘ua‘u* as they are an endangered species and are protected by State and Federal laws.

Concern for the *‘ua‘u* was raised throughout the testimonies. Mr. Ki‘ope Raymond stressed that the ‘Ua‘u is an *‘aumakua* or family god and an endangered species. There is concern is that these endangered birds may be displaced, harmed or killed during construction as their burrows are near the proposed site. Mr. Leslie Kuloloio says of the ‘Ua‘u, “[t]hat represents old Hawai‘i” (Table 3). Mr. Tim Bailey voices his concern about the ‘Ua‘u and the Native bat, *‘ōpe‘ape‘a* (Table 3).

Hunting practices are ongoing in the upland areas that border the National Park. The hunting of deer, goats, pigs, pheasant, chukar partridges, francolin and other game birds has become a culturally supported subsistence practice. In addition to subsistence hunting, feathers from some game birds are highly prized for their use in hatbands.

It was found that the Skyline Trail has been used by generations of hunters for access to the upper reaches of the Kula Forest Reserve. Another favorite hunting area is the Kahikinui Forest Reserve. This forest reserve is located along the southern park boundary and is managed by Living Indigenous Forest Ecosystem, (LIFE), a non-profit organization which works to keep feral animals and invasive species out of the reserve in an effort to help support the native forest. LIFE works in cooperation with Kahikinui Game and Land Management, a group allowed into the reserve to hunt feral animals.

7.5 *Wahi Pana* (Storied Place)

Historical research, public testimonies and community consultations confirm that Haleakalā is a well known *wahi pana*. Its legendary status is not only known in Hawai‘i but throughout Polynesia. It is at Haleakalā that one of the greatest deeds performed by the demi-god Māui occurred, and although there are several variations of the legend of Māui snaring the sun, most Polynesians are familiar with the tale. Traditional accounts of Māui’s deeds are found in the Richard Taylor compilation and it is in these collections that are found the closest ties with the Maori people of Aotearoa (see Section 3.1.1.2 Stories Collected by Taylor (1870)).

Evidence of Māui’s importance resurfaces in several testimonies. Ms. Uilani Kapu explains that people come from Aotearoa to visit Haleakalā for spiritual purposes (Table 11). Mr. Edwin Lindsey describes the Maori people of Aotearoa and their belief that Māui pulled their home, Aotearoa, up from the sea. He explains, “It [Haleakalā/Māui] is a spiritual entity that crisscrosses and has deep spiritual meaning to cultures not only here…but throughout Polynesia” (Table 3). Mr. Tom Cannon briefly relates the legend of Māui snaring the sun to slow it in its path across the sky, so his mother would have more time to dry her *kapa* (Table 11). Ms. Leslie Ann Bruce states, “…as we all know, [Haleakalā] has mythological significance of the highest value. It is a storied place for the island’s namesake, Māui, who has Pan Pacific importance to many

Polynesian cultures in addition to Hawaiian culture" (Table 10). Regarding Haleakalā's interconnectedness with different places on Maui Island, Mr. Kiope Raymond notes the significance of Paeloko, a coconut grove located at Waiheʻe, that provided the the coconut fibers or sennit Māui used to make the lasso or cordage that snared the sun (Section 7). In his interview with Ms. Kaʻohulani McGuire, Mr. Kapiʻioho Lyons Naone mentions hearing people talk about Kaʻuiki, the birthplace of Maui (2000: 85).

While all volcanic craters were once the dwelling place of the fire goddess Pele, Haleakalā is also the site of an epic battle between Pele and her eldest sister Namakaokahaʻi (see Section 3.1.2 Legends of the Goddess Pele as Related to Haleakalā). It is along the slopes and within the crater of Haleakalā where Pele lost the physical battle to Namakaokahaʻi and where the bones of her physical form are scattered far and wide. It is in the aftermath of this battle that Pele takes her spiritual form and finds her final home within Kilauea on the island of Hawaiʻi.

7.6 Haleakalā as a Sacred Mountain

According to historical research, testimonies, formal letters and community consultations, Haleakalā is considered to be a sacred place. The overall feeling is that the construction of the proposed ATST atop Haleakalā is viewed as the desecration of a sacred mountain that will have a negative impact on Hawaiian culture and on the scenic properties of Haleakalā. This theme was repeated throughout the meetings in formal letters and in the community consultation process. Individuals stated that they go the summit area for spiritual and ceremonial purposes, to pray, and to find solitude and solace and to remain in contact with the gods and ancestors. Mr. Bill Evanson explains: "… [l]ots of people appreciate open space, as our island becomes more developed, those are the places we go to seek refuge and get spiritual replenishment" (Table 11). In his testimony Mr. Michael Howden explains that Puʻu Kolekole is a sacred, "place of prayer and inner attunement…." "It's a place sacred for ceremony" (Table 10). Mr. Kiʻope Raymond states: "I am a Native Hawaiian who does attach religious and cultural significance to Haleakalā I will be negatively affected and offended by the proposed undertaking of the Advanced Technology Solar Telescope" (Table 6. Mayor Hannibal Tavares Community Center - March 28, 2006). Mr. Edwin Lindsey describes his feelings on the sacredness of Haleakalā, "[w]hen a culture depends on these natural wonders of their environment for survival and reverence communications to a power higher than themselves, all care must be given to this practice. Haleakalā is noted throughout Polynesia as one of a most sacred area. There are stories, legends, events, but most important, prayers by generations of *Kahunas*. As many visitors can testify there is a life force within these rocks that have influenced their lives" (Table 12). Mr. Sam Kaʻai makes the statement: "sacred mountains are praying places." He goes on to explain that it is hard to pray when you have helicopters flying overhead, thousands of cars and tourists, and large telescopes all around your praying place (Section 7). Individuals contacted during the community contact process overwhelming share this view.

The summit area is referred to as *wao akua.* This has been described in the testimonies and community consultations to mean, the realm of the gods, where the gods dwell, and a place for the gods. One example as stated by Mr. Lui Hokoana (in Table 7. Paūkukalo Community Center - May 1, 2006): "I was taught to revere the mountain because it is a place where the gods dwell." Pukui and Elbert define *wao akua* as, "[a] distant mountain region, believed inhabited only by spirits (*akua*); wilderness, desert." (1986; 382). It is an area that is described to have been *kapu* in traditional times, to all but *aliʻi*, *kahuna* and their *haumana*. In an interview with Kahu

Maxwell (2006:24), Ms. Hokulani Holt-Padilla describes Haleakalā to be wao akua. She explains: "…and so as a Wao Akua, that is where the gods live and whenever we go as humans, we must go in a sense of humbleness and in a sense of asking and in a sense of not disturbing unduly…" She goes on: "[w]e will come and go the mountain will remain, it is greater than all of us." This idea is another sacred aspect of Haleakalā.

Testimonies describe the cinder and rock of Haleakalā as being the *kino lau* or the physical, body form of Pele. The excavation required for the proposed ATST is thought of as digging into Pele, into her *kino lau*. This is believed to be a desecration of Pele and, therefore, a desecration of one of the sacred aspects of the mountain.

In the most extreme testimonies the proposed construction of ATST and the existing structures at Puʻu Kolekole are described as the "rape" of Haleakalā. Mr. Edwin Lindsey states, "…in rape there's no concurrence (Table 7. Paūkukalo Community Center - May 1, 2006)." He goes on in a separate testimony, "I refuse to have Haleakalā prostituted for the sake of this project. You cannot take advantage of Haleakalā and throw ideas out to what is sacred" (Table 7. Paūkukalo Community Center - May 1, 2006). He feels there is nothing one can do to lessen or mitigate the impacts of this type of action. His intense feelings about Haleakalā are shared by Ms. Suzanne Burns who explains: "I feel like my mountain [is] a rape victim and we're asking the friends of the rapist to stop raping our mountain, and they're saying, 'Oh, by the way, do you mind if we rape it one more time?' That's what it feels like" (Table 11).

As is apparent, this topic is one that evokes strong emotions throughout the Hawaiian community. In another testimony, Ms. Leslie Ann Bruce describes how she feels, "[p]eople I know on the island, including myself, feel hurt, offended and invaded by outsiders' intrusions on our *wahi pana*, our sacred places, that lose their pristine character and cultural significance by being used for large, obtrusive structures that obliterate the emptiness we value so highly on our mountain top" (Table 10).

Testimonies reveal a deep sense of a protective nature over Haleakalā and the idea that it is the Hawaiian people's *kuleana* or responsibility to properly care for Haleakalā, not just for themselves but for future generations. This theme repeats itself throughout the meetings. Mr. Tom Cannon states: "I feel that there is no more culturally significant place in Maui County, in the U.S., or in Polynesia than the summit of Haleakalā" (Table 11). Ms. Mikahala Helm describes this by stating, "[s]ome of us strongly feel that it is our responsibility to have a legacy for our children and the children's children, all the generations to come. And we feel it so deeply, that it is not our role to come here and give you proposals on what we can do to mitigate. But it is our role to strengthen what it is we want to do to avoid it being built here at all" (Table 6. Mayor Hannibal Tavares Community Center - March 28, 2006).

7.7 Pōhaku Pālaha-The Piko of East Maui

Throughout the community consultation process this point, or rock, as it was commonly called, was mentioned several times. Although not all who mentioned this point knew its name, all recalled that it was a significant.

Mr. Timothy Bailey and Mr. Leslie Kulolio described it well when explaining the thought behind the name Pōhaku Pālaha. The name is said to represent the *he'e*, or octopus, particularly how the *heʻe* clings on to a rock when hiding or when being hunted and how its eight tentacles spread out over the rock. Mr. Bailey further elaborates that the mouth, its center, representing the *piko,* locks onto the rock making it extremely difficult to pry loose, "its pōhaku pālaha" or stuck flat to the rock, he explains. Like the tentacles of the *heʻe* spread out over a rock, Pōhaku Pālaha is the rock, the *piko,* from which the eight *moku* of east Maui fan out. In his cultural resource evaluation, Maxwell (2003:4) speaks also of the Kolekole area being the *piko* of Maui Nui a Kama (Maui, Molokaʻi, Lanaʻi, and Kahoʻolawe). These two ideas may well be one in the same.

7.8 Cultural Practices

It is not unusual in the Hawaiian culture, and in other cultures, that individuals keep specific cultural rituals and ceremonies secret. This may be for personal reasons or a matter of having the responsibility of maintaining the integrity of a particular ceremony or ritual. As a result of this, testimonies do not reveal many specific cultural practices. Instead of actual descriptions of ceremonies the consensus derived from the testimonies is that Haleakalā is a sacred mountain and that people go there for spiritual reasons and for ceremonies. This must be accepted on that basis alone. Kahu Maxwell explains this as well; he states: "[i]n the past it was not proper to talk about the sacred practices that occurred on Halekala…" (2002:23). Today, he says, more people are sharing their *mo'olelo*. Even so, testimonies and community consultations show great caution is taken in sharing one's knowledge. Of the few examples given in testimonies, a known ritual performed atop Haleakalā is the calling of the sun, in chanting, E ala e, as the sun rises. Melia explains that once a year and sometimes once a month her family goes to Haleakalā to "…greet our ancestors, our *kupuna* and also [greet] the sun…" She continues, "[w]e like to go up to that mountain and say *a ala ai* [*e ala e*]…" (Table 7. Paūkukalo Community Center - May 1, 2006). The following is the entire chant and its English translation from Maxwell (2006):

E ala e	Rise
Ka lā I kahikina	The sun at the east
I ka moana	At the ocean
Ka moana hōhonu	At the deep ocean
Piʻi ka lewa	As it climbs
Ka lewa nuʻu	To the highest
I kahikina	In the east
A I ka lā	Is the sun
E ala e	Rise

In her formal interview with Ms. Kaʻohulani McGuire (2000:53), Ms. Hokulani Holt-Padilla described visiting Haleakalā on a regular basis, often during the summer and also when it snowed. She explains that it used to snow more regularily on Haleakalā than it does now. Ms. Holt-Padilla remembers being required by her grandmother to have a moment of "respectful silence" while at the summit (McGuire 2000:54). Ms. Holt-Padilla also mentions the deity Lilinoe, the goddess of the heavy mists, who resided at Haleakalā (McGuire 2000:55). Ms. Holt-Padilla goes on to descibe an *ʻawa* ceremony she performs at an old ohia tree at the park. She explains that she goes to this tree to pay her respects and honor that tree (McGuire 2000: 60).

Ms. Roselle Bailey describes another traditional practice atop Haleakalā and its use as a calendar. She explained that Hawaiians tracked the path of the sun by observing the shadows on the crater floor. Both Ms. Bailey and Mr. Kaʻai describe that the solstices and equinoxes were times of special significance at the summit. Ms. Bailey stated that on the solstice the suns rays hit

Puʻukukui directly. Mr. Kaʻai explained that on the summer solstice priests or *kahuna* went to Paʻa Kea, described to be a rock or rock mound near the summit, to pray. Ms. Bailey states that the proposed ATST must not interfere with this use of Haleakalā Crater as a calendar. In addition, there are two *ahu* near the proposed project area at Puʻu Kolekole, one which faces west called Hinalaʻanui, and one which faces east called Pāʻele Kū Ai I Ka Moku. These *ahu* are described in (Maxwell 2006; 43-45).

Mr. Kapiʻioho Lyons Naone was also interviewed by Ms. McGuire (2000) and shared his knowledge about the Hawaiian significance of the solstices. He explained that growing up in Kipahulu he followed the traditional moon calendar and according to the moon calendar, the solstices were honored times of the year, they were referred to as *hālāwai*:

> …the meeting or zenith, when the sun was directly overhead, when we have the greatest amount of *hā* (spiritual breath or strength that comes from above). And, it was always believed that every *heiau* had its *ʻanuʻu* (tower within the heiau) tower, of which there was the the calabash bowl underneath and when the sun came directly overhead and there was no shadow, that was the most spiritual time of the *heiau*. And, that's also the most spiritual time of each mountain (McGuire 2000: 72).

Mr. Naone's grandmother explained to him that this time, the *hālāwai*, was a very sacred time (McGuire 2000: 72). Mr. Naone goes on to describe a *puʻu* known as Iwilele, or more commonly, Leleiwi. He describes this *puʻu* as being located near Science City and gives the following description of its significance to the *hālāwai*:

> There is a place we call Iwilele. It's where the bones of the ancestors or the spirits of the ancestors fly. The two important places that I recognize are Leleiwi and Kianiau, because of the *hālāwai* or the "meeting"—the zenith—when the sun is directly overhead and you cannot see your shadow. We call this the *hālāwai* or the "meeting". Everything "meets" there. The way I looked at it, Leleiwi or Iwilele, was that point—like a *leina* (jumping-off place for spirits) which was the opening into *pō* (realm where spirits go after physical death) that the spirits jumped into. Kianiau is very close to Iwilele. Those are the two places that I recognize as the important places duringg the *hālāwai*. The *hālāwai* is in the month of Ikiiki, about the middle of May, probably about the 25^{th}, or 27^{th} of May. It's not the same every year—it changes each year. That would be the time of *kau* (summer), when the sun is moving up towards the northern-most point. Then, it comes up and it stops over Mokumanamana, Necker Island, and it stays ther for just a few days before it starts moving back down the island chain. Then it passes over us again, in the middle of Kaʻaona, which is around July 15, 16, or 17—around there somewhere. It's really hard to say exactly which day because it changes from year to year. Those are the times when the sun passes directly overhead on Maui. And, to me, those are the two most important times on Haleakalā, as well as Halekiʻi/Pihanakalani Heiau (McGuire 2000: 72).

Therefore, the significance of the solstices is as Mr. Naone describes:

> We have to honor the sun for reaching its northernmost point and call it to come back and acknowledge its responsibility, acknowledgd its journey up to here. It stops there and then it starts to come back. So, it the solstice, we're honoring the fact that the sun has made its journey and the sun has allowed us to do our farming, our harvesting

> and whatever we need to do. And, when it comes down and it reaches its southernmost point, we honor it for that. That's what we do during the solstice (McGuire 2000: 75).

Although Mr. Naone knows that the observation of the *hālāwai* occured on other prominent mountains such as Halemahina (an old reference to the West Maui Mountains), Mauna Kea and Mauna Loa, he explains that he only goes to Haleakalā to observe the *hālāwai*. He takes an offering or *hoʻokupu* and sometimes an *ʻumeke* or calabash bowl and describes sitting there, "with a sense of 'sitting with the ancestors'" (McGuire 2000: 73). Mr. Naone describes chanting and simply being there at that moment, the sun having reached its zenith and, essentially, trying to do what his ancestors have done for generations (McGuire 2000: 73).

Ms. Holt-Padilla also goes to Haleakalā in observance of the solstices. She describes Haleakalā's coldness as a value that makes it special during winter solstice. It's also a time when not many other people are around. She describes it as a time when the air is thin and your body can experience the cold. Ms. Holt-Padilla describes the significance in just being there; at the same place her ancestors went to observe the summer and winter solstice (McGuire 2000: 61).

Kahu Maxwell states that there are cultural ceremonies that continue to take place within the 18-acre University of Hawaii parcel, but does not go into detail about those ceremonies (Table 3).

7.9 Impacts on Viewplane

In her interview with Ms. McGuire, Ms. Hokulani Holt-Padilla describes that one needs an uninterrupted view to make an emotional and physical connection to the place of importance. Without an uninterrupted view, the connection cannot be made, and this interferes with the *mana* of a place (McGuire 2000: 57). Ms. Holt-Padilla goes on to describe that it is the environment -- the trees, the rocks; the animals, the rain, the mists, the clouds, the ocean -- which Hawaiians worship. This is where the gods live and it is from the environment that Hawaiian comes. She explains:

> When you need to give offerings at a *koʻa* so that you can have an abundance of fish, you need to be out there to talk about how the ocean is, how the sky is, where it is located and who you are trying to access because it is the environment that we are trying to access and we are trying to bring life to it and, therefore, it will bring life to us (McGuire 2000: 58).

Mr. Hinano Rodrigues also explains that "[t]o many Kanaka Maoli, the very onobstructed view of the *mauna* itself, is a part of their dialy religious observations" (Section 7). Mr. Naone touches on the importance of an unobstructed viewplane in the Hawaiian culture. He describes that he does feel that it is culturally inappropriate to have things, such as buildings, obstructing the view, but he explains that it is more important that structures do not prevent the flow of *mana*. "So, I guess, what I'm saying is just the fact that there's something built and it's in sight, is it really blocking the flow, the movment of the spirits? I would be more concerned if there was an ancient trail there and the structure blocked that trail" (McGuire 2000: 85).

In reference to the Faulkes telescope he continues:

> And, if it's just the fact that it's in view, personally, it wouldn't be objectionable to me. What I'm saying is, I'm sure the observatories are important. There's knowledge we're gaining from it. Yet, we hope and wish that they would be very sensitive to our

> cultural beliefs. Cultural assessment studies at least forces developers to be aware of our beliefs. Am I totally objecting to Science City being up there? No, I'm not. Would I prefer that they not be up there? Yes. But, I have no real strong objection to something being built up there as long as cultural aspects are always taken into consiceration—that we're not prevented from practicing what we believe in (McGuire 2000: 86).

Additionally, there are two *ahu* near the proposed project area at Pu‘u Kolekole, one which faces west called Hinala‘anui, and one which faces east called Pā‘ele Kū Ai I Ka Moku. These *ahu* are described in (Maxwell 2006: 43-45). Mr. Ki‘ope Raymond explains that a 360-degree viewplane from each *ahu* is important and presently the proposed ATST would be constructed less than 100 feet from the eastern *ahu* (Table 11).

The visibility of the proposed ATST, its white color particularly, concerns several individuals giving testimony. People feel it will be an eyesore and they would like to change the color to brown or a color that might not been seen as easily. Mr. Leslie Kuloloio voices his concerns regarding the color of the proposed ATST (Table 3). Mr. and Mrs. Pali want all efforts to be made to change the color in order to make ATST less visible (Section 7). It appears that people cannot accept the NSF statement that nothing can be done about the color. It is hard for people to understand why an entity that can create a huge solar telescope cannot figure out a way to make it a color besides white. There is the feeling in the testimonies that this can be done and people want this done at whatever the cost would be.

Many feel that the visability of ATST will also take away from the wilderness aspect of the greater Haleakalā area. Echoing many others, Mr. Brian Jenkins explains that ATST will have a "tremendous negative impact on that sense of wildness that is currently enjoyed. This negative visual impact will also affect much on the Skyline Trail and views from the Upper Waiohuli Trial in the Kula Forest Reserve" (Section 7). In an overall sense, the size and white color of the ATST, as well as the day-to-day operation of the facility clearly present a negative cumulative impact on the viewplane.

7.10 Ceded Lands and Sovereign Identity

The Paūkukalo meetings saw a large Native Hawaiian turnout and from the transcripts it is clear that tensions were high, people were emotional and the meeting overall became unorganized. This resulted in people voicing their concerns on impulse and because of this, the transcriber was not able to get everyone's name. As noted in a speakers testimony, individuals left this meeting out of frustration without giving testimony (Table 7. Paūkukalo Community Center - May 1, 2006).

Much of the Paūkukalo testimonies reflect concerns over ownership of the land at the proposed site and at the summit area in general. There are concerns that these are ceded lands and that Native Hawaiians are the only ones with a true right to the lands. Several individuals would not go any further into discussion with NSF for this reason. Mr. Oliver Dukelow states, "[b]efore we can discuss anything, I would like to see your title to that land" (Table 7. Paūkukalo Community Center - May 1, 2006). There were some who explained that they did not recognize United States law at all and accused the presenter of, "…belligerently occupying this place." This individual went on to say, "Your law does not apply here. The superior law of the land is the domestic law that applies here, the *kumukānāwai*. The *kumukānāwai,* what's going on up there is not supposed to happen. So what I'm saying is that what are you doing here? What are you doing here?" (Table 7. Paūkukalo Community Center - May 1, 2006). Kahu Maxwell attempts to explain the situation that existed at this meeting:

> …hundreds of years of oppression of our people. When Captain Cook came in 1778, the missionaries came in 1820, the land put into sugar and pineapple; Hawaiians culture were turned around. ...It's the land that was taken away in 1893 and was controlled by Leleo Kalani. They made it into trust lands, then they had also government lands, but nobody has clear title of this land. You guys got to realize this (Table 7. Paūkukalo Community Center - May 1, 2006).

The feeling of the Hawaiian sovereignty movement is reflected in this statement made by an audience speaker: "…We are not under US law. We are an independent nation. We have never relinquished our nationhood. There is someone sitting in our seat of government. His name is Sam. We would like to ask him to leave so that we can fill our own seat with our own people" (Table 7. Paūkukalo Community Center - May 1, 2006). Mr. Kapali Keahi also touched on this theme, addressing the panel; he stated: "…it's not a good time for you guys. It's never going to be. As long as that flag is is waving, it's never going to be one good time for you guys. And we can say this now in this day and time because, well, your predecessors, your ancestors wen' shut our people up. And the only reason why America is here is because of the military." It is clear that there is a population that believes Hawaiʻi is a sovereign nation.

Feelings of mistrust and frustration towards the government and its processes such as Section 106 are reflected in statements made by Ms. Roselle Bailey and Mr. Sam Kaʻai. Ms. Bailey and others are not convinced that ATST isn't a covert military operation. She expresses the concerns of many when she suggests that the entire state might be put in danger. Ms. Bailey's frustration is equally apparent with the section 106 process. She refers to section 106 as "foreign law" and describes how wrong it is to ask the Hawaiian people to, in essence, prove their beliefs in order to maintain the integrity of a site they consider sacred.

Sharing his skepticism with the section 106 process, Mr. Kaʻai explains that it's not worth sharing cultural knowledge anymore because, he says, "no one listens" (Section 6.1.9). He has noticed that studies such as this one don't make a difference in the outcome of a project, therefore he and other cultural practitioners would rather not waste their time sharing what they know.

7.11 Haleakalā as a Traditional Cultural Property

A traditional cultural property (TCP) "can be defined generally as one that is eligible for inclusion in the National Register of Historic Places because of its association with cultural practices or beliefs of a living community that are (a) rooted in the community's history and (b) important in maintaining the continuing cultural identity of the community" (National Register Bulletin No. 38). Based on the background research and community consultation conducted for this study, public testimony resulting from the Section 106 process, and the above discussion on traditional cultural practices, it is unquestionably clear that the caldera and summit of Haleakalā is a Native Hawaiian traditional cultural property with Pan-Polynesian significance.

In a letter from the State Historic Preservation Division, Mr. Peter Young states, "Haleakalā Summit unquestionably represents a Traditional Cultural Property" (Table 12). In their review, the Cultural Resource Commission states, "The proposed telescope is not consistent with the designation of the summit of Haleakalā as a Traditional Cultural Place or Property (TCP) and its eligibility for listing on the National Register of Historic Places” (Table 12).

Missing pages are for the specific project this supplemental cultural impact assessment was originally intended for.

The intent of providing this Appendix for the Environmental Assessment is for its information content regarding Native Hawaiian cultural and traditional practices.

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APPENDIX C

Archeological Field Inspection, January 2005

An Archaeological Field Inspection of the Primary and Alternate Locations for the planned Advanced Technology Solar Telescope (ATST) Facility, located within the 18.1-acre parcel Science City complex, Haleakala Crater, Papa`anui *Ahupua`a*, Makawao District, Maui Island (TMK: 2-2-07: portion of 8)

Prepared for:

Charlie Fein, PhD
KC Environmental, Inc.
Makawao, Maui

Prepared by:

Xamanek Researches, LLC
Pukalani, Hawaii
Erik M. Fredericksen

2 January2005

Figure 1: Location of the project area, Haleakala, Maui.

INTRODUCTION

Xamanek Researches[1] carried out an archaeological inventory survey of the Science City parcel in the fall of 2002. This 18.1-acre project area, which lies near the summit of Haleakala, is located in Papa`anui *ahupua`a*, Makawao District, Maui (TMK: 2-2-07: Portion of 8). The inventory survey report was approved by the State Historic Preservation Division (SHPD) in a 10 July 2003 review letter (SHPD DOC NO: 0307MK03). The study area contains several existing observatories and other structures that have been constructed at different times over the years. Current plans call for the construction of an Advanced Technology Solar Telescope (ATST) facility at one of two locations within the subject parcel.

A total of six previously unidentified sites were located during our archaeological inventory survey, and we also carried out additional work on previously identified sites that are contained within the subject parcel (see Table 1). The newly identified sites have been designated SIHP[2] No. 50-50-11-5438 through 5443. In addition, further documentation was obtained for previously identified Sites 2805 through 2808, per discussions with Dr. Melissa Kirkendall, SHPD staff archaeologist for Maui. Finally, a trail remnant was located at the previously recorded Site 4836 and given a feature number (F).

The bulk (80%+) of the features in newly identified Sites 5438-5442 consist of temporary habitation areas or wind shelters. Two features in Site 5440 are petroglyph images (Features F and G), and one is interpreted as a possible burial (Feature D). Site 5441 contains two small platforms that are thought to have possible ceremonial functions. Site 5443 consists of the remnants of a former radio telescope facility, known as Reber Circle that was built in 1952, and subsequently dismantled due to signal interference.

All of the newly identified sites and Feature F of Site 4836 as well as the previously recorded sites in the Science City project area retain their significance ratings under at least Criterion “d” for their information content under Federal and State historic preservation guidelines. The possible burial—Feature D, and the petroglyph Features F and G of Site 5440, as well as Site 5441 and Feature F of Site 4836 also qualify for cultural significance under Criterion “e”. Finally, it is important to note that all of the sites with the exception of Site 5443 that are located in Science City represent a remnant of a Native Hawaiian cultural landscape. Because Haleakala is noted for its ceremonial

[1] Xamanek Researches was converted to Xamanek Researches, LLC, a Hawaii-based Limited Liability Company, in February 2005. The earlier inventor survey and the current field inspection study have been undertaken on behalf of KC Environment, Inc

[2] SIHP = **S**tate **I**nventory of **H**istoric **P**laces

and traditional importance to the Native Hawaiian people, the entire Science City site complex may well qualify for importance under additional significance criteria as well.

Mitigation Recommendations

There were two main mitigation recommendations that were set forth for the Science City project area at the conclusion of the 2002-2003 inventory survey. Given the possibility that future construction actions may occur in the Science City project area, in-place passive preservation was recommended for all of the identified sites within the project area, with the possible exception of Reber Circle (Site 5443).[3] Precautionary archaeological monitoring was recommended during any future construction activities in the general vicinity of any of the previously identified sites, to help avoid inadvertent impacts. Data recovery was the recommended mitigation for the Reber Circle site remnant in the event that project plans called for its removal. Xamanek Researches, LLC conducted field inspections of the two proposed locations for the planned construction of the Advanced Technology Solar Telescope (ATST) during December 2005. The two possible locations included an area to the northeast of the existing Mees Solar Observatory (primary) and Reber Circle (alternate) on Pu`u Kolekole (see Figure 2).

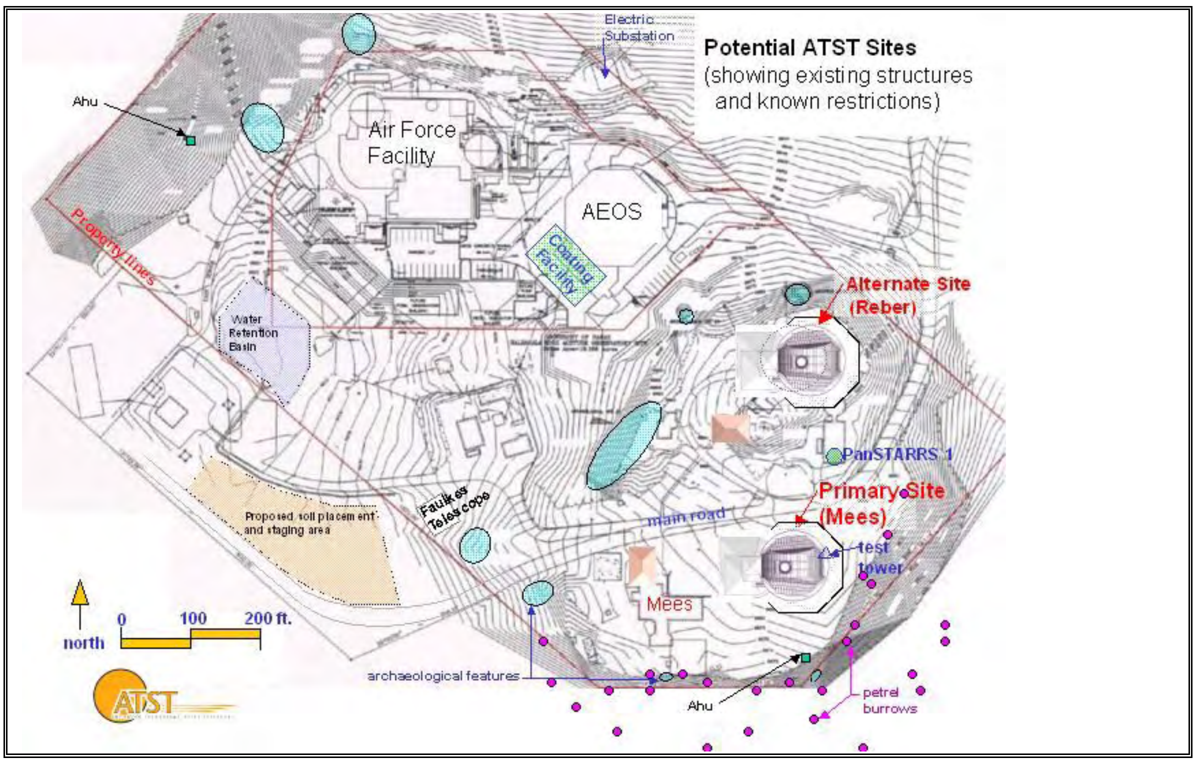

Figure 2: Potential ATST site location map, including primary Mees and alternate Reber Circle sites.

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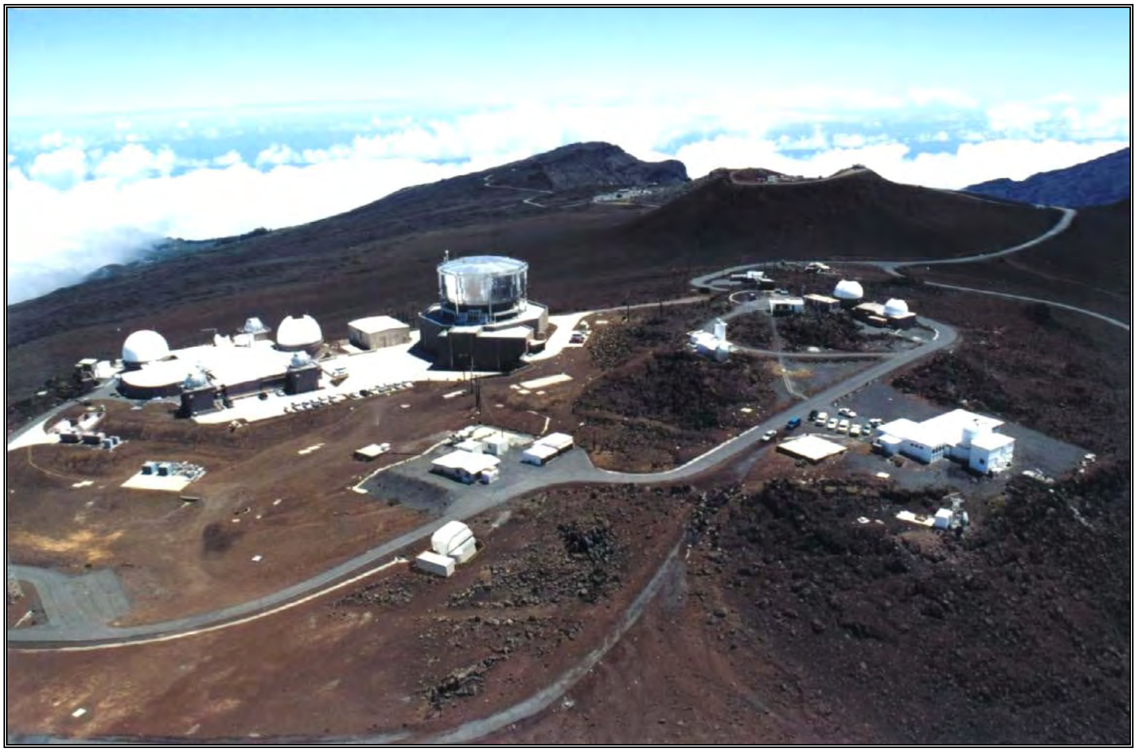
[3] A Preservation Plan is currently under preparation; a Burial Treatment Plan for Feature D of Site 5440 will be prepared at a later date, following consultation with the Maui/Lana`i Islands Burial Council.



Photograph 1: Aerial view of Science City complex—Haleakala Crater—looking north. Reber Circle is visible in upper center right of photograph; Primary Mees site at center right.

THE STUDY AREA

The 18.1-acre “Science City” parcel is located near the summit of Haleakala in Papa`anui *ahupua`a*, Makawao District, on the island of Maui. Papa`anui is a discontinuous *ahupua`a* that extends from the shore at Makena, and runs upslope to Keonehulu summit (c. 4000 feet AMSL) where it terminates. The *ahupua`a* then continues from Pu`u Keokea (c. 7500 feet AMSL) to the crater rim of Haleakala, across the crater floor and ends at Pahaku Pahala on the northeastern rim above Paliku (Bushnell and Hammatt, 2000, p. 7). The USGS Makena quadrangle map is not clear as to the *makai* boundaries between Papa`anui and other *ahupua`a*. Cordy (1978) suggests that there were only 2 *ahupua`a* in the Makena area—Ka`eo and Papa`anui, and that other place names refer to *`ili* of these two land divisions.

Natural History

The soils in the overall Science City project area are classified as Cinder Land (rCl), and consist of areas of bedded magnetic ejecta associated with cinder cones. They are a mixture of cinders, pumice, and ash, and range in color from black, red, yellow to brown. These materials have jagged edges and a glassy appearance and show little or no evidence of soil development (Foote, et al., p. 29; Plate 117).

The overall parcel ranges in elevation from just over 10,000 feet AMSL on Pu`u Kolekole to a low of about 9,840 feet AMSL along its southeastern boundary. The high elevation of the Science City parcel gives the project area a sub-alpine climate, which influences the environment of the summit area. The following information is drawn from the Environmental Assessment document that was prepared for the Advanced Electro-Optical System (AEOS) facility (Belt Collins Hawaii, March 1994). Precipitation at the Maui Space Surveillance Site (MSSS) facility averages 25 inches per year, with the bulk of the rainfall occurring during November through May. Average annual temperatures near the summit range from 42 degrees F in the winter to 50 degrees F in the summer. Daily temperature ranges can be more extreme, with occasional sleet, snow, and hail fall occurring from December to February. Wind patterns are dominated by the northeast trade winds, which typically are most persistent from March to November. Southeasterly or Kona winds occur during the winter months and tend to bring clear weather to the summit. Sustained winds of 50 miles or more per hour can occur every month of the year. The maximum wind speed recorded at the summit is in excess of 125 miles per hour. The strongest winds typically occur during the winter and are associated with North Pacific storm systems that pass over the island chain.

Vegetation present in the project area is sparse—5 to 10% cover. A botanical survey carried out in April of 2000 (Char & Associates) on a c. 1.5 acre portion of the 18.1-acre current project area listed low shrubs of *kupaoa* (Dubautia menziesii), and scattered clumps of Deschampsia nubigena. The former (an endemic member of the daisy family) has stiff, upright branches with yellowish, daisy-like clusters arranged in compact clusters. The later is an endemic, perennial grass which forms rounded tufts, 6 to 12 inches tall with flowering stalks up to 2 feet in height. It is the most commonly found grass at this elevation.

Other plants, fewer in number, include hairy cat's ear (Hypochoeris radicata), another endemic member of the daisy family—Tetramoloium numile—a rounded dwarf shrub 3 to 10 inches across with whitish hairs and clusters of white flowers, a single shrub of indigenous *pukiawe* (Styphelia tameiameiae), and several clumps of mountain *pili* (Trisetum glomeratum)—an endemic perennial grass. No endangered silversword were noted during this 2000 survey, but were found in earlier surveys (U.S. Air Force 1991), and at the AEOS Telescope site (Belt Collins and Associates 1994). Three cultivated silversword plants were noted adjacent to the AEOS parking lot during the previous inventory survey. There were no endemic plants located at the Reber Circle location at the time of our 2005 field inspection.

PREVIOUS ARCHAEOLOGICAL WORK ON SITES WITHIN THE SCIENCE CITY PARCEL

There were two archaeological surveys that had been conducted in portions of the project area, prior to the Xamanek Researches 2002-2003 inventory survey. The first of these archaeological studies was carried out in 1990 and consisted of a reconnaissance survey (Chatters, 1991). Cultural Surveys Hawaii, Inc. conducted the second study, an archaeological inventory survey, in 1998 (April 2000). The results for each of these earlier projects are summarized below (see Appendix A—Table 1).

The first study, which consisted of an archaeological reconnaissance survey, was carried out by Pacific Northwest Laboratory on behalf of the U.S. Air Force for the expansion of the Maui Space Surveillance Site or MSSS (Chatters, 1991). During the course of this walkover, four archaeological sites were identified, primarily along the western side of Kolekole Hill. These features included 23 temporary shelters and a short, low wall. These wind shelters were typically constructed against the existing rock outcrop of the hill. The sites were designated SIHP No. 50-50-11-2805 through 2808. One sling stone was found on the floor of Feature J at Site 2807. In addition, one *opihi* (Cellana spp.) shell was noted on the surface of the Feature B floor of Site 2808. There was no subsurface investigation carried out, and only Site 2805 was mapped (Ibid.,). Per discussions with Dr. Melissa Kirkendall of the SHPD Maui office, we carried out additional inventory level documentation at these sites.

The second study was carried out by Cultural Surveys Hawaii, Inc., in conjunction with the planned construction of the Faulkes Telescope facility. This more recent project located two previously unidentified sites—4835 and 4836. Both of these sites were constructed against an exposed rock outcrop. Site 4835 consists of 2 features—both historic rock enclosures filled with burned remnants of modern refuse—obviously historic trash burning pits. The authors suggest that these may have been used initially by the U.S. Army during the war, and later by University of Hawaii workers later on.

Site 4836 consists of 3 terraces, a rock enclosure, 2 leveled areas and a rock wall—all constructed against an exposed rock outcrop.[4] Five of the features are interpreted as temporary shelters, while the 2 leveled areas were of indeterminate usage.

[4] Xamanek Researches identified a trail remnant at the previously recorded Site 4836 during our inventory survey in 2002. This feature had not been noted in Bushnell and Hammatt, 2000. We subsequently recorded this feature per the direction of Dr. Melissa Kirkendall, SHPD staff archaeologist, and Mr. Charles Kauluwehi Maxwell, Chair of the Maui/Lanai Islands Burial Council. This trail remnant was assigned a feature number (F).

Although one test unit did not reveal any precontact cultural materials, their construction is consistent with precontact structures used for temporary shelters in other areas of Haleakala Crater (Bushnell and Hammatt, 2000, pp. 16-19). The University of Hawaii Institute for Astronomy opted to preserve both of the sites.

Xamanek Researches carried out an inventory survey of the entire 18.1 acre parcel in 2002-2003 (Fredericksen and Fredericksen, April 2003). A total of six previously unrecorded sites (50-50-11-5438 through 5443) were located during the course of this inventory survey. These sites consist of wind shelters, two petroglyph images, a possible burial feature, and an historic foundation—Reber Circle. Supplemental information was obtained from Sites 2805-2808 per discussions with Dr. Melissa Kirkendall of the SHPD Maui office. In addition, a trail segment was recorded at Site 4836 and designated as Feature F. Several isolated pieces of coral were noted in the southeastern portion of the c. 18-acre study area, but not assigned a formal site number, because the coral pieces were not weathered. A possible site—consisting of several pieces of coral in a boulder—was plotted on the project map, but was determined to lie off the project area.

Field inspections of primary and alternate ATST locations

Xamanek Researches, LLC conducted separate field inspections of the two proposed locations for the ATST facility, per the request of Charlie Fein, PhD of KC Environmental, Inc. These inspections were conducted in early December 2005. Follow-up investigations were undertaken in mid-December of both locations. The results of our field inspections and follow up work are presented below.

Primary ATST location—Mees

The proposed primary location for construction of the ATST facility is situated c. 30 meters to the northeast of the existing Mees Solar Observatory (refer to Figure 3). This portion of the Science City parcel contains three relatively recently constructed information gathering towers (Photographs 2-7). Inspection of the surface area in the vicinity of the towers indicates that this portion of the Science City parcel was previously impacted by earthmoving activities associated with the construction of the existing access road, the tower structures, as well as the Mees Solar Observatory, which was built in 1964.[5] Pushed rocks, push piles, and old cleared areas (bulldozed) were noted in the vicinity of the towers (see Photographs 2, 4 and 5). This portion of the project area contains three features that are interpreted as relatively recent additions/modifications (see Photographs 2, 6 and 8).

[5] My father, Walter Mailand Fredericksen (deceased), worked as a laborer and mason during the construction of the Mees Solar Observatory and other buildings that were built during 1964-65 in the Science City complex, prior to accepting a teaching position at Maui Community College.

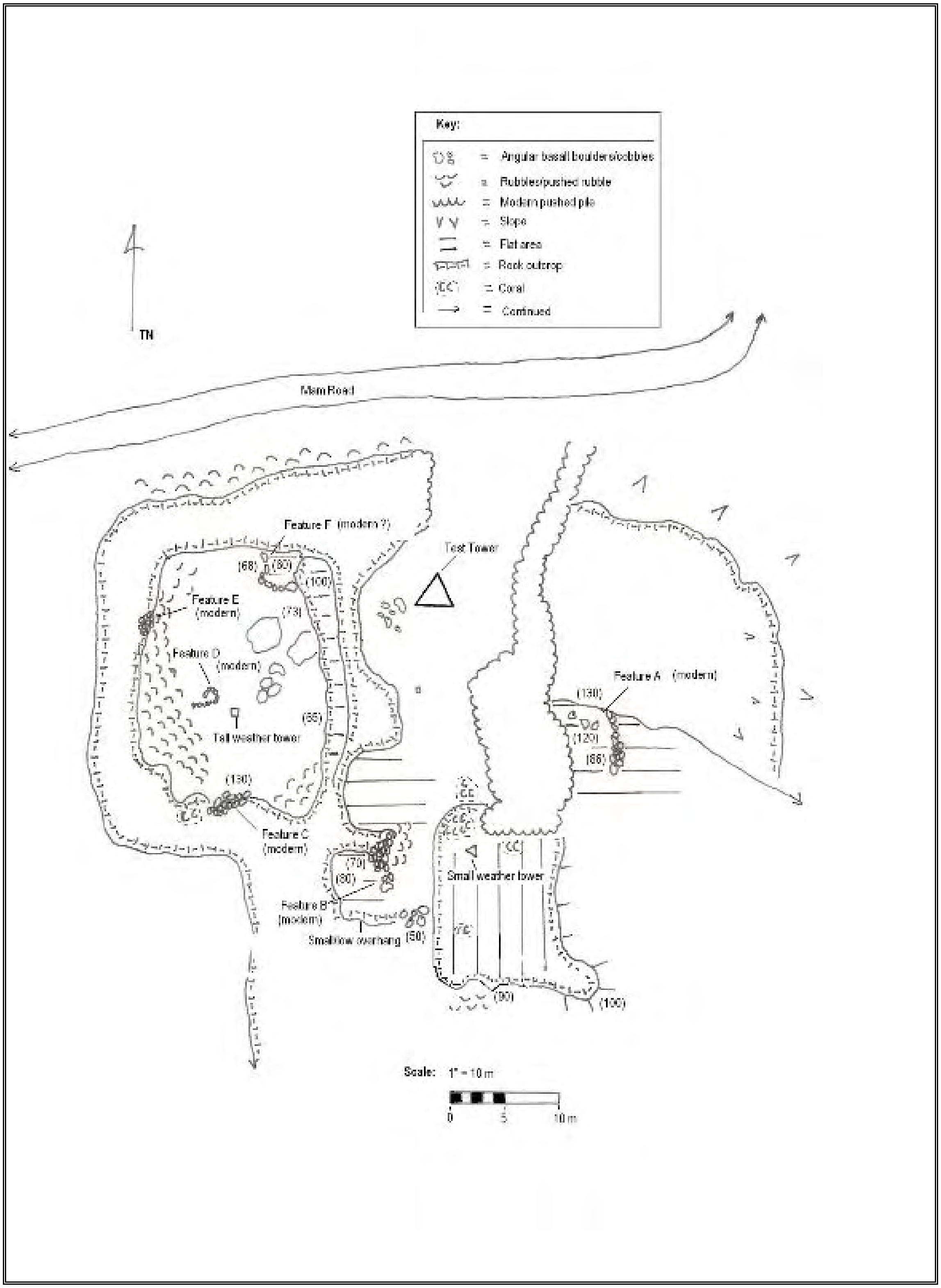
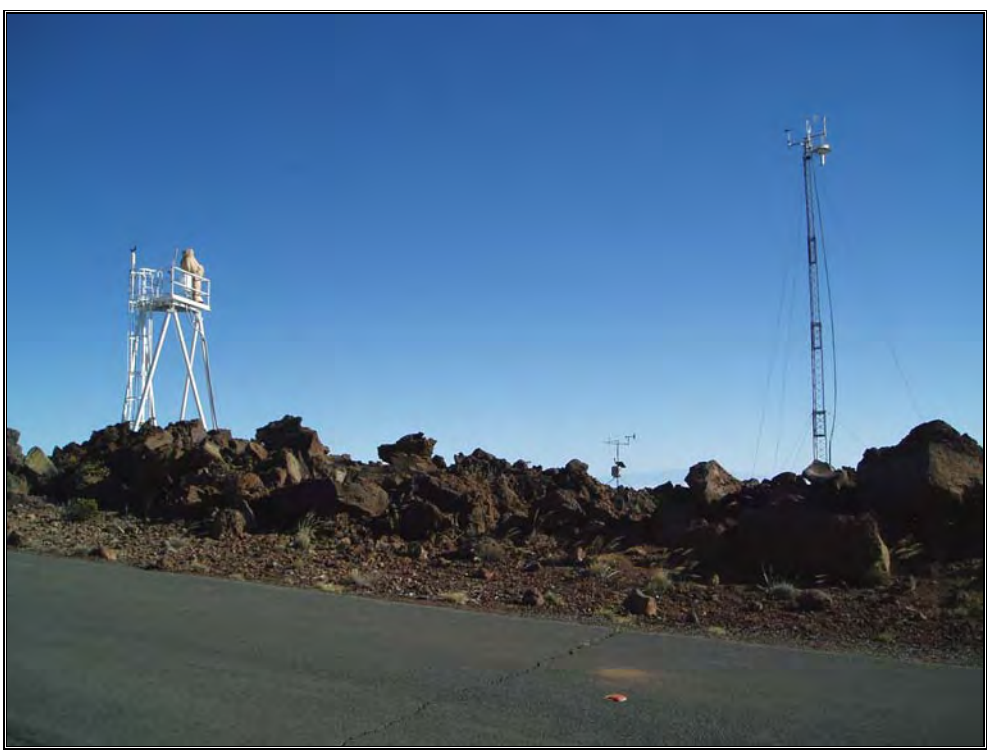
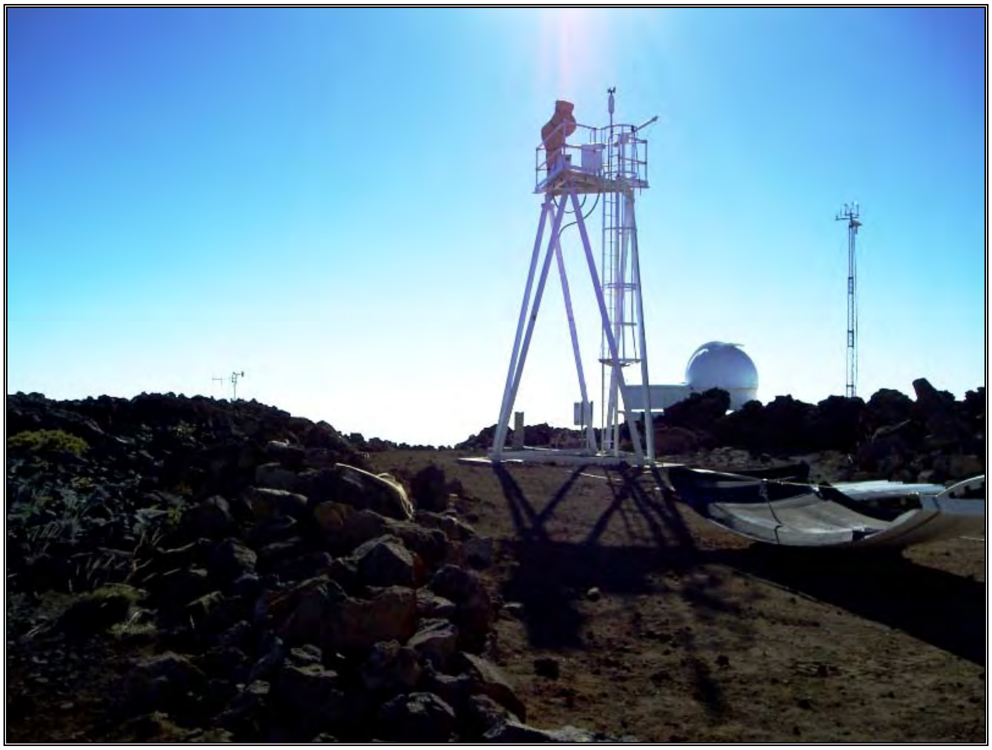


Figure 3: Plan view of the Primary Mees location for the ATST, Haleakala.

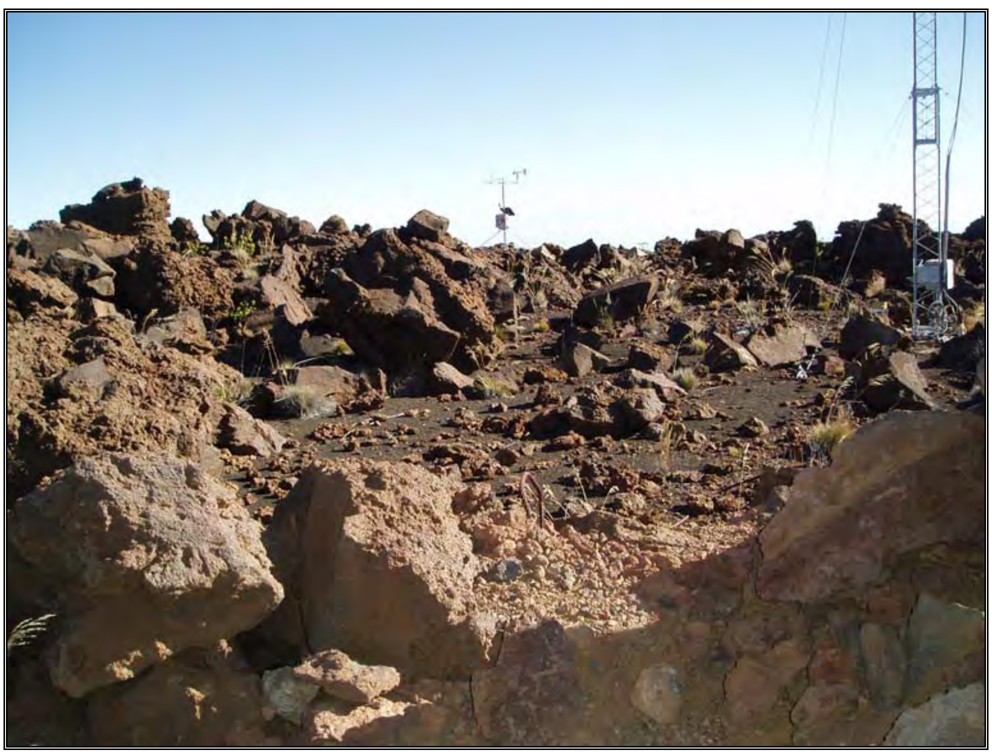
Photograph 2: General view to the northwest of Pu`u Kolekole (center right) from the preferred site location for the ATST; weather tower at left; cleared area at center right.



Photograph 3: View to the southeast of test tower (left), small weather tower (center), and tall weather tower (right).

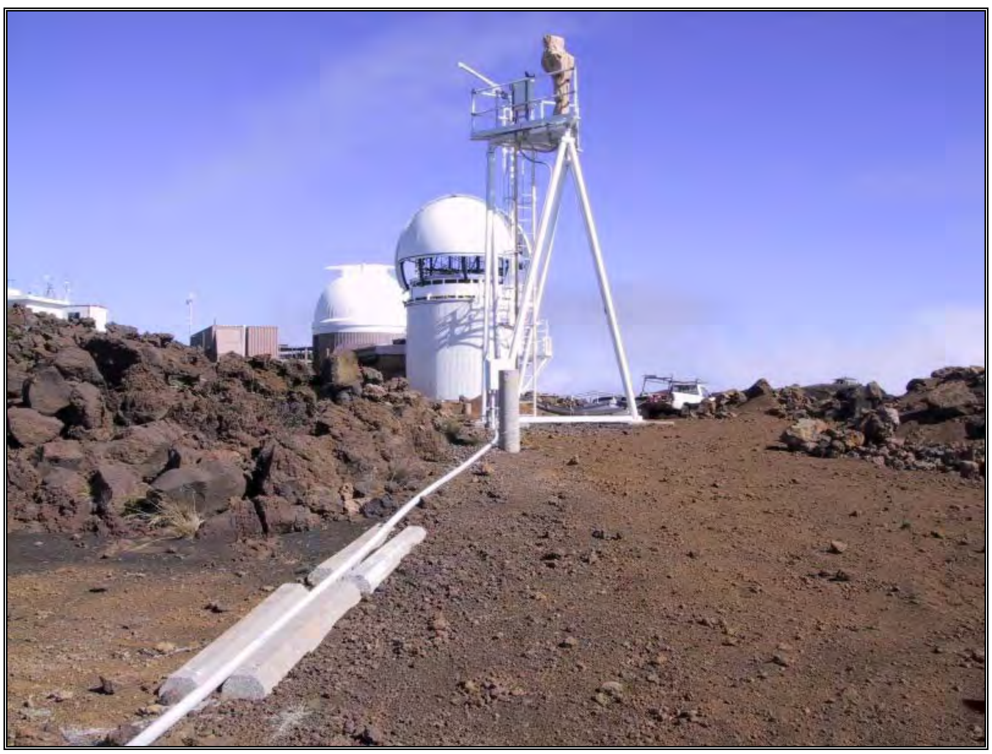


Photograph 4: View to the southwest of the data tower and weather tower (right), note push pile at left and construction materials at right; Mees Observatory is in the background.



Photograph 5: General view of relatively recent pushed material.

Photograph 6: General view of relatively recently modified area—center. Small weather tower located in upper center.



Photograph 7: View to the northwest across the Primary Mees location, test tower in foreground, PanSTARRS 1 in center background.

Photograph 8: View to the east of a relatively recently deposited rock pile.

Discussion

All of the features noted within the proposed ATST Mees location are interpreted as recent modifications. Rocks noted in the construction of these features/modifications were not weathered like those contained in the many sites and features that have been previously documented on the Science City project area. The features within the Primary Mees location for the ATST were not recorded during our earlier 2002-2003 inventory survey, because they were considered to be relatively recent additions in a previously disturbed area. In closing, it is important to note that portions of the Primary Mees location have been previously impacted by earthmoving activities associated with the construction of the paved access road, as well as the Mees Solar Observatory, and the three towers.

Reber Circle (Site 50-50-11-5443); alternate ATST location

This site remnant lies at the peak of Pu`u Kolekole, and is known as Reber Circle (see Figures 2 and 3; Photographs 8-13). Site 5443 qualifies for significance under federal and state historic preservation guidelines Criterion "a" because of its association with mid-20th century scientific studies at Haleakala, and under Criterion "d" for its information content. This site remnant consists of a concrete and rock foundation that was part of the former radio telescope facility that was constructed in 1952 by Grote Reber. This facility apparently did not function well, because of signal interference (personal communication with Charlie Fein). The bulk of this structure was dismantled about 18 months after the facility was completed. This site is composed of a concrete and rock foundation that is c. 25 meters in diameter, the outer rim of which is up to 1 meter in width and c. 80 cm in height (Figure 3). Approximately 40% of the structure has been impacted by previous earthmoving activities, and the site is in fair to poor condition. This previously identified site lies in the alternate location for the ATST.

The summit of Pu`u Kolekole contains two older buildings (i.e. constructed in the mid-1960s), a relatively recently constructed rock pile, and a surface scatter of water worn coral with “beach” glass, likely deposited in the mid-1960s.[6] All of these features are interpreted as modern features and have not been assigned SIHP site numbers.

[6] Some of the concrete utilized in the construction of the older buildings contains pieces of fragmented marine shell and coral pieces in its matrix. It is postulated that the remaining scatter of water worn coral, shell and beach glass is associated with construction activities associated with the older buildings on the *pu`u*.

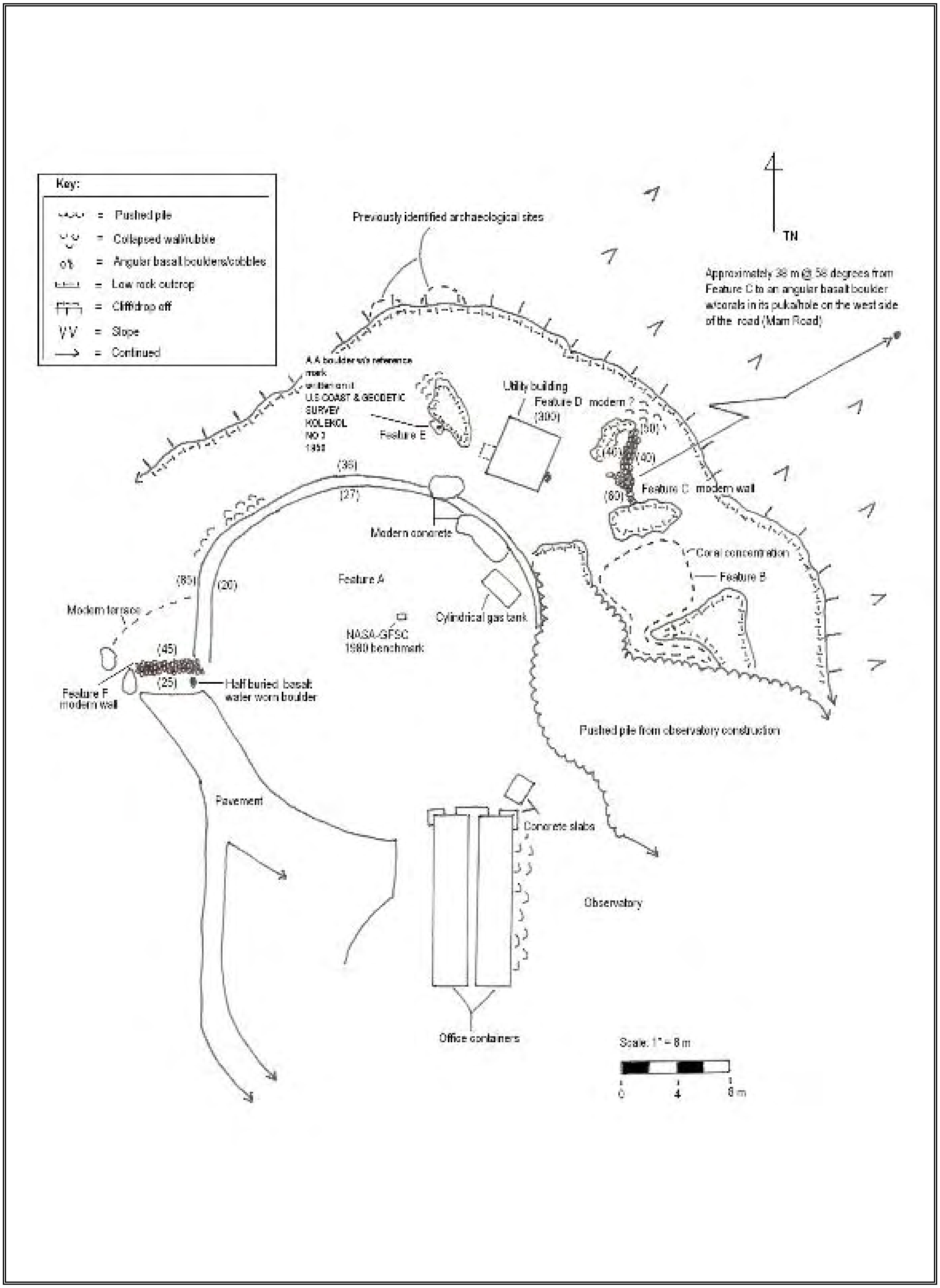


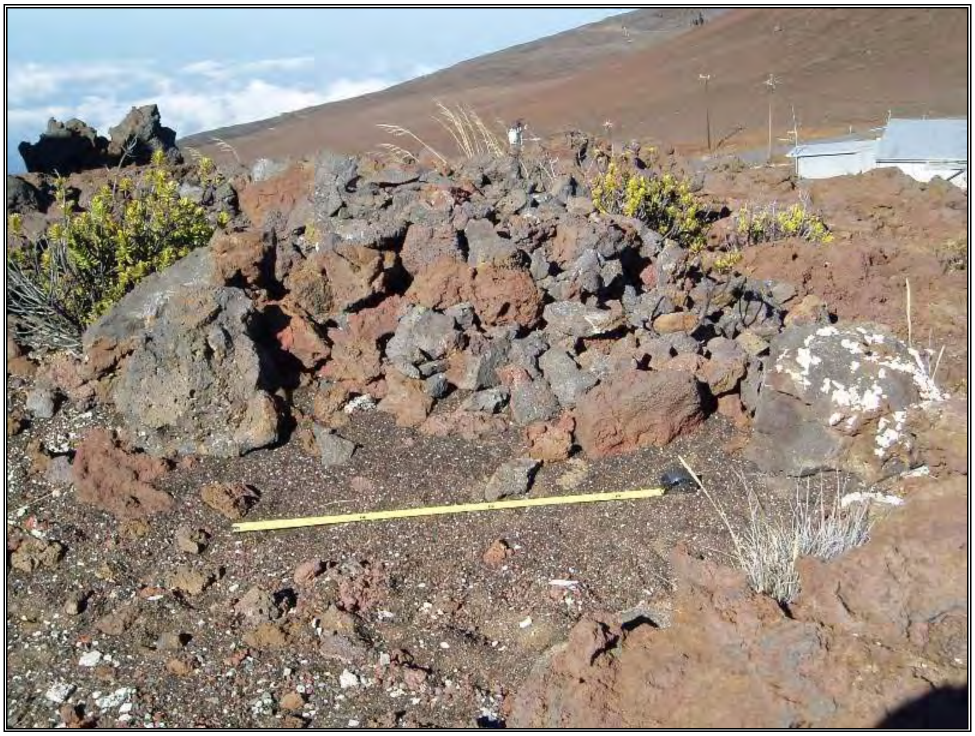
Figure 3: Plan view of Pu`u Kolekole with Reber Circle (Site 5443) and other features. Updated map prepared by Jonas Madeus in December 2005.

Photograph 9: General view to the north across Reber Circle—Site 5443.

Photograph 10: View to the northwest across a newer section of rock wall that was added to Reber Circle (right) at an unknown date.

Photograph 11: View of a Reference Mark—US Coast & Geodetic Survey marker (dated 1950).

Photograph 12: General view to the north of Reber Circle of an older mid-1960s antenna building (see Figure 3 for location of this structure).



Photograph 13: View to the northeast of a relatively recent rock pile near antenna building.

Photograph 14: General view of modern (c. mid-1960s) coral scatter (with beach glass) near antenna/utility building.

Discussion

The bulk of the features noted within the proposed ATST Reber Circle location, with exception of this early radio-telescope site remnant, are interpreted as recent modifications. Rocks noted in the construction of these more recent features/modifications were not weathered like those contained in the many sites and features that have been previously documented. These features within the Reber Circle alternate location were not recorded during our 2002-2003 inventory survey, because they were also considered to be relatively recent additions. It is, once again, important to note that portions of the Pu`u Kolekole alternate location have been previously impacted by earthmoving activities associated with the construction of a paved access road, as well as the Site 5443 facility and the two mid-1960s buildings. In closing, it should be stressed that the Reber Circle is not a favored ATST location from a Native Hawaiian perspective (personal communication, Kahu Charles Maxwell). Given the number of remaining sites that have been located within the overall Science City parcel, it is **highly** probable that Pu`u Kolekole was a culturally significant location in precontact times.

SUMMARY AND CONCLUSIONS

The Science City parcel was clearly an important cultural area for precontact Native Hawaiians. The number of remaining sites clearly indicates the cultural significance of this portion of Maui in precontact times.[7] In closing, should an ATST facility be constructed within the subject parcel, it is recommended that the Primary Mees location be chosen. While both locales have been previously disturbed, the Kolekole Hill location (Reber Circle) was likely an important cultural area in precontact times. The placement of a large ATST complex on this *pu`u* would have negative cultural impacts.

[7] The author estimates that up to 50% of the parcel has been impacted by previous earthmoving activities associated with the development of the Science City complex.

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APPENDIX A—TABLE 1
SUMMARY OF SITES STUDIED IN 2002-2003 INVENTORY SURVEY

TABLE 1 SUMMARY OF SITES—SCIENCE CITY

SIHP[8] Site Number	Features	Description	Function	Age	Remarks
5438	A	Wind shelter	Temporary habitation	Precontact-post-contact	Partial rock wall enclosure in lee of vertical escarpment
	B	Terrace/Wind shelter	Temporary habitation	Precontact-post-contact	Crude terrace built at leeward base of vertical escarpment
	C	Terrace-like Wind shelter	Temporary habitation	Precontact-post-contact	Small terrace-like level area w/ low escarpment along NE edge
	D	Terrace-like Wind shelter	Temporary habitation	Precontact-post-contact	Small terrace-like level area w/ crude stacking along northern edge
	E	Terrace-like Wind shelter	Temporary habitation	Precontact-post-contact	Small terrace-like level area w/ vertical escarpment at SE edge
	F	Rock pile	Undetermined/ Possible clear pile	Precontact-post-contact	Rock pile with associated level area
5439	A	Rock Shelter	Temporary habitation	Precontact-post- contact	Marginal shelter restricted overhang
	B	Rock shelter	Temporary habitation	Precontact-post- contact	Marginal shelter restricted overhang
	C	Wind shelter	Temporary habitation	Precontact—post-contact	Low rock wall built on windward side of level area
	D	Wind shelter	Temporary habitation	Precontact-post-contact	Crude rock arrangement around level area
	E	Wind shelter C-shape	Temporary habitation	Precontact-post-contact	Low rock wall wrapping windward side of level area
	F	Wind shelter C-shape	Temporary habitation	Precontact-post-contact	Low rock wall wrapping windward side of level area
	G	Rock pile	Undetermined	Precontact-post-contact	Rock pile in crevice between boulders
	H	Wind shelter C-shape	Temporary habitation	Precontact-post-contact	Small level area with stacking along windward edge
	I	Wind shelter C-shape	Temporary habitation	Precontact-post-contact	Small level area in lee of boulders, crude stacking on windward edge
	J	Wind shelter	Temporary habitation	Precontact-post-contact	Small level area in lee of boulders w/ crude stacking in crevice

[8] **SIHP** = **S**tate **I**nventory of **H**istoric **P**laces. Site numbers prefaced by 50-50-11- 50=State 0f Hawaii, 50=Maui,11=Kilohana quadrangle.

TABLE 1 CONT.

	K	Wind shelter	Temporary habitation	Precontact-post-contact	Level area in lee of boulders w/ crude stacking and alignment.
	L	Wind shelter C-shape	Temporary habitation	Precontact-post-contact	Small level area w/ crude wall along windward edge
	M	Wind shelter C-shape	Temporary habitation	Precontact-post-contact	Small level area w/ crude wall along windward edge
5440	A	Wind shelter Enclosure	Temporary habitation	Precontact-post-contact	Relatively substantial rock wall enclosing two small level areas.
	B	Wind shelter C-shape	Temporary habitation	Precontact-post-contact	Rock wall arcing around windward edge of level area abutting outcrop
	C	Wind shelter natural terrace	Temporary habitation	Precontact-post-contact	Relatively large level area in lee of escarpment w/ crude rock alignments
	D	Platform	Potential burial	Precontact-post-contact	Cobble concentration delineated by boulder alignments on two sides
	E	Wind shelter C-shape	Temporary habitation	Precontact-post-contact	Small level area in lee of boulders w/ added crude stacking
	F	Petroglyph	Rock art/ceremonial	Precontact-post-contact	Triangular torso human image on boulder
	G	Petroglyph	Rock art/ceremonial	Precontact-post-contact	Turtle image on boulder
5441	A	Terrace	Temporary habitation?	Precontact-post-contact	Small level area on east facing slope w/ rough alignment along leading edge
	B	Terrace	Temporary habitation?	Precontact-post-contact	Small level area on east facing slope w/ rough alignment along leading edge
5442	Single	Rock wall partial enclosure	Temporary habitation	Precontact-post-contact	Small level area w/ stacked rock wall tied in w/ existing boulders
5443	Single	Foundation	Former radio telescope Foundation—Reber Circle	1952	Circular concrete foundation
2805	Single	Wind shelter	Temporary habitation	Precontact-Post-contact	Partial enclosure, crude wall in lee of escarpment
2806	Single	Wind shelter	Temporary habitation	Precontact	Partial enclosure, rough wall in lee of escarpment
2807	A	Wind shelter	Temporary habitation	Precontact-post-contact	Level area with boulder alignment on windward edge
	B	Wind shelter	Temporary habitation	Precontact-post-contact	Level area w/ rock pile
	C	Wind shelter (C-shape)	Temporary habitation	Precontact-post-contact	Level area w/ upright slabs on windward edge
	D	Wind shelter (C-shape)	Temporary habitation	Precontact-post-contact	Level area w/ boulder alignment on wind edge
2807	E	Wind shelter	Temporary habitation	Precontact-post-contact	Level area in lee of outcrop
	F	Wind shelter	Temporary habitation	Precontact-post-contact	Level area w/ linear clearing pile

TABLE 1 CONT.

	G	Wind shelter	Temporary habitation	Precontact-post-contact	Level area on slope in lee of outcrop w/ modified outcrop
	H	Wind shelter	Temporary habitation	Precontact-post-contact	Level area on slope in lee of outcrop
	I	Wind shelter	Temporary habitation	Precontact-post-contact	Level area w/ minimal stacking on windward edge
	J	Wind shelter	Temporary habitation	Precontact-post-contact	Crude rock wall partially encloses small level area
	K	Wind shelter	Temporary habitation	Precontact-post-contact	Crude rock wall built along wind edge of a cleared level area
	L	Wind shelter/terrace	Temporary habitation	Precontact-post-contact	Natural terrace in lee of slope cleared of rock
	M	Wind shelter	Temporary habitation	Precontact-post-contact	Level area on slope with boulder alignment
	N	Wind shelter	Temporary habitation	Precontact-post-contact	Level area in lee of modified outcrop
	O	Wind shelter	Temporary habitation	Precontact-post-contact	Level area in lee of boulder w/ crude stacking on perimeter
	P	Wind shelter	Temporary habitation	Precontact-post-contact	Level area w/ altered crude stacking on perimeter
2808	A	Wind Shelter	Temporary habitation	Precontact-post-contact	Level area w/ rubble on windward edge
	B	Wind shelter	Temporary habitation	Precontact-post-contact	Level area w/ stacked rock on windward edge
	C	Wind shelter	Temporary habitation	Precontact-post-contact	Level area w/ boulders on windward edge
4836	F	Path	Pedestrian traffic	Precontact-post-contact	Pathway w/ boulder alignment at edge

APPENDIX D

Archeological Recovery Plans

(1) **Data Recovery Plan for Site 50-50-11-5443 (Reber Circle), December 2005**
(2) **“Science City” Preservation Plan, March 2006**

LINDA LINGLE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

PETER T. YOUNG
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COMMISSION ON WATER RESOURCE MANAGEMENT

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BOATING AND OCEAN RECREATION
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CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

June 14, 2006

Mr. Erik Fredericksen
Xamanek Researches
P.O. Box 880131
Pukalani, Hawai'i 96788

LOG NO: 2006.1881
DOC NO: 0606MK16
Archaeology

Dear Mr. Fredericksen:

SUBJECT: National Historic Preservation Act (NHPA) Section 106 Review – Data Recovery Plan for SIHP 50-50-11-5443 Located on the 18.1 Acre Parcel Known as Science City
Papa'anui Ahupua'a, Makawao District, Island of Maui
TMK: (2) 2-2-007: portion 008

Thank you for the opportunity to review this data recovery plan received by our office on February 5, 2006 (Fredericksen 2006, *An Archaeological Data Recovery Plan for Site 50-50-11-5443, located on the 18.1 acre parcel known as Science City, Haleakala Crater, Papa'anui Ahupua'a, Makawao District, Maui Island [TMK 2-2-07: portion of 8)*...Xamanek Researches, LLC, ms.

An archaeological inventory survey was conducted on the Science City parcel in the fall of 2002 by Xamanek Researches (LOG NO: 2003.1138/DOC NO: 0307MK03). During the survey, six previously unidentified historic properties were identified within the project area. SIHP 50-50-11-5438 through 5442 consist of temporary habitations, wind shelters (C-shapes), two (2) small terrace features, petroglyphs and a remnant of a 1952 radio telescope facility foundation (SIHP 50-50-11-5443). We concurred with the mitigation recommendations made in the archaeological inventory survey report that in-place passive preservation is appropriate for the present. We also agreed that any future construction activities should be archaeologically monitored. Data recovery was recommended in the event that SIHP 50-50-11-5443, the Reber Circle remnant in the event that project plans necessitated its removal.

This plan has been developed in the event that Pu'u Kolekole, is selected as the construction site for the Advanced Technology Solar Telescope (ATST). The plan will only be implemented if that is the case. Otherwise, passive preservation for Reber Circle/Pu'u Kolekole sites will remain the recommended mitigation.

SIHP 50-50-11-5443, the radio telescope facility foundation is the focus of the data recovery proposed here. The proposed research questions will acceptably provide documentation on the facility. Chronology and function for Reber Circle will be established, as well as term of function. Oral history will assist in documentation of the original appearance and condition of the facility.

Erik Fredericksen
Page 2

Necessary data recovery work includes HABS/HAER level documentation. Additional data recovery work will include interviews and a photograph search to document the area pre-Reber Circle facility.

The data recovery plan is acceptable. Should you have any questions, please contact Dr. Melissa Kirkendall of the State Historic Preservation Division, Maui Section, at (808) 243-5169.

Aloha,

Peter Young, Chair
State Historic Preservation Officer

MK:kf

c: Bert Ratte, DPWEM, County of Maui
Michael Foley, Director, Dept. of Planning, 250 S. High Street, Wailuku, HI 96793
Maui Cultural Resources Commission, Dept. of Planning, 250 S. High Street, Wailuku, HI 96793

An Archaeological Data Recovery Plan for Site 50-50-11-5443 18.1-acre parcel known as Science City, Haleakala Crater, Papa`anui *Ahupua`a*, Makawao District, Maui Island (TMK: 2-2-07: portion of 8)

Prepared for:

Charles Fein, PhD
KC Environmental, Inc.
Makawao, Maui

Prepared by:

Xamanek Researches, LLC
Pukalani, Hawaii
Erik M. Fredericksen

28 December 2005

Figure 1: Location of the project area, Haleakala, Maui.

INTRODUCTION

Xamanek Researches[1] carried out an archaeological inventory survey of the Science City parcel in the fall of 2002. This 18.1 acre project area, which lies near the summit of Haleakala, is located in Papa`anui *ahupua`a*, Makawao District, Maui (TMK: 2-2-07: Portion of 8). The inventory survey report was approved by the State Historic Preservation Division (SHPD) in a 10 July 2003 review letter (SHPD DOC NO: 0307MK03). The study area contains several existing observatories and other structures that have been constructed at different times over the years.

A total of six previously unidentified sites were located during the archaeological inventory survey. These sites have been designated SIHP[2] No. 50-50-11-5438 through 5443. In addition, further documentation was obtained for previously identified Sites 2805 through 2808, per discussions with Dr. Melissa Kirkendall, SHPD staff archaeologist for Maui. Finally, a trail remnant was located at the previously recorded Site 4836 and given a feature number (F).

The bulk (80%+) of the features in newly identified Sites 5438-5442 consist of temporary habitation areas or wind shelters. Two features in Site 5440 are petroglyph images (Features F and G), and one is interpreted as a possible burial (Feature D). Site 5441 contains two small platforms that are thought to have possible ceremonial functions. Site 5443 consists of the remnants of a former radio telescope facility, known as Reber Circle that was built in c. 1952, and subsequently dismantled due to signal interference.

All of the identified sites and Feature F of Site 4836 as well as the previously recorded sites in the Science City project area retain their significance ratings under at least Criterion “d” for their information content under Federal and State historic preservation guidelines. The possible burial—Feature D, and the petroglyph Features F and G of Site 5440, as well as Site 5441 and Feature F of Site 4836 also qualify for cultural significance under Criterion “e”. Finally, it is important to note that all of the sites with the exception of Site 5443 that are located in Science City represent a remnant of a Native Hawaiian cultural landscape. Because Haleakala is noted for its ceremonial and traditional importance to the Native Hawaiian people, the entire Science City site complex may well qualify for importance under additional significance criteria as well.

[1] Xamanek Researches was converted to Xamanek Researches, LLC, a Hawaii-based Limited Liability Company, in February 2005.
[2] SIHP = **S**tate **I**nventory of **H**istoric **P**laces

Mitigation Recommendations

Two main mitigation recommendations were made for the Science City project area at the conclusion of the 2002-2003 inventory survey. Given the possibility that future construction actions may occur in the Science City project area, in-place passive preservation was recommended for all of the identified sites within the project area, with the possible exception of Reber Circle (Site 5443).[3] Archaeological monitoring was recommended during any future construction activities in the general vicinity of any of the previously identified sites, to help avoid inadvertent impacts. Data recovery was the recommended mitigation for the Reber Circle site remnant in the event that project plans called for its removal. The following data recovery plan has been prepared, should Pu`u Kolekole be chosen as the construction site for the Advanced Technology Solar Telescope (ATST).[4]

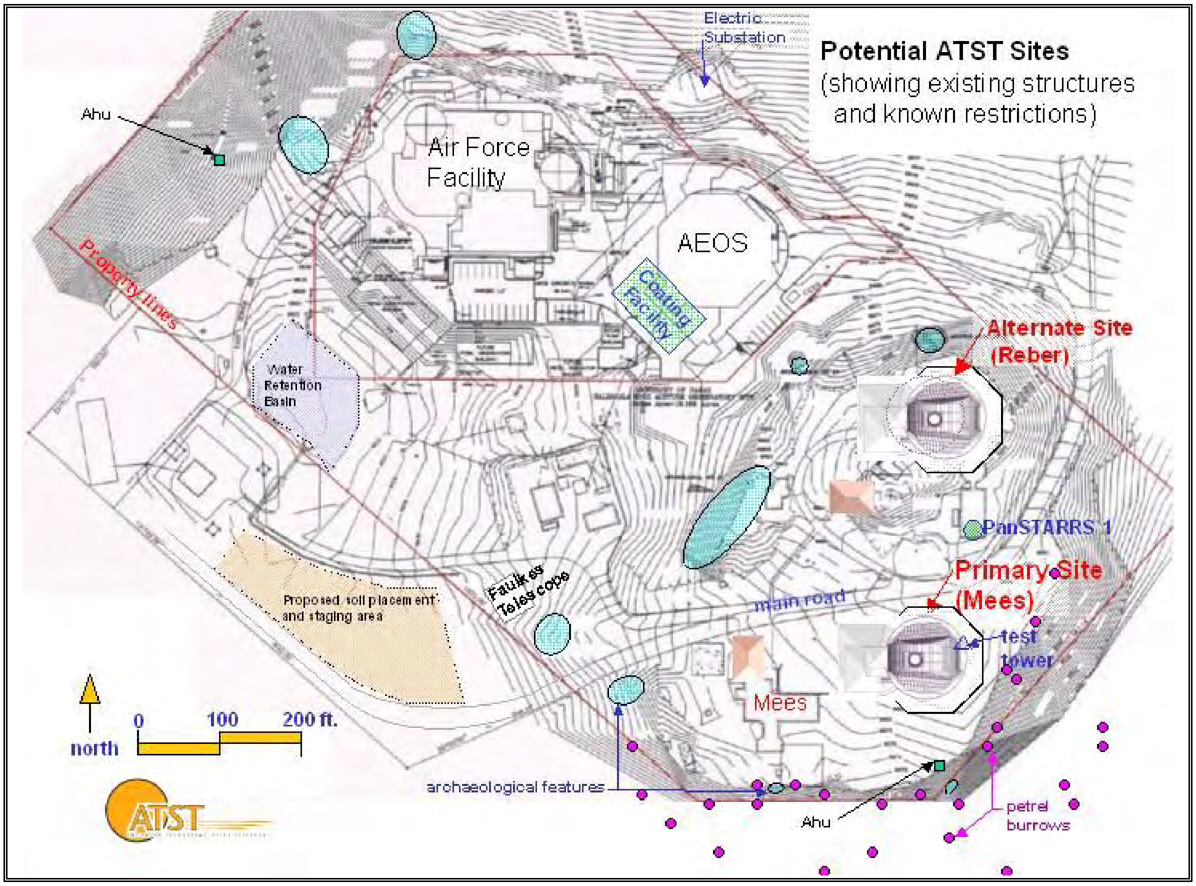

Figure 2: Potential ATST site location map, including alternate Reber Circle site.

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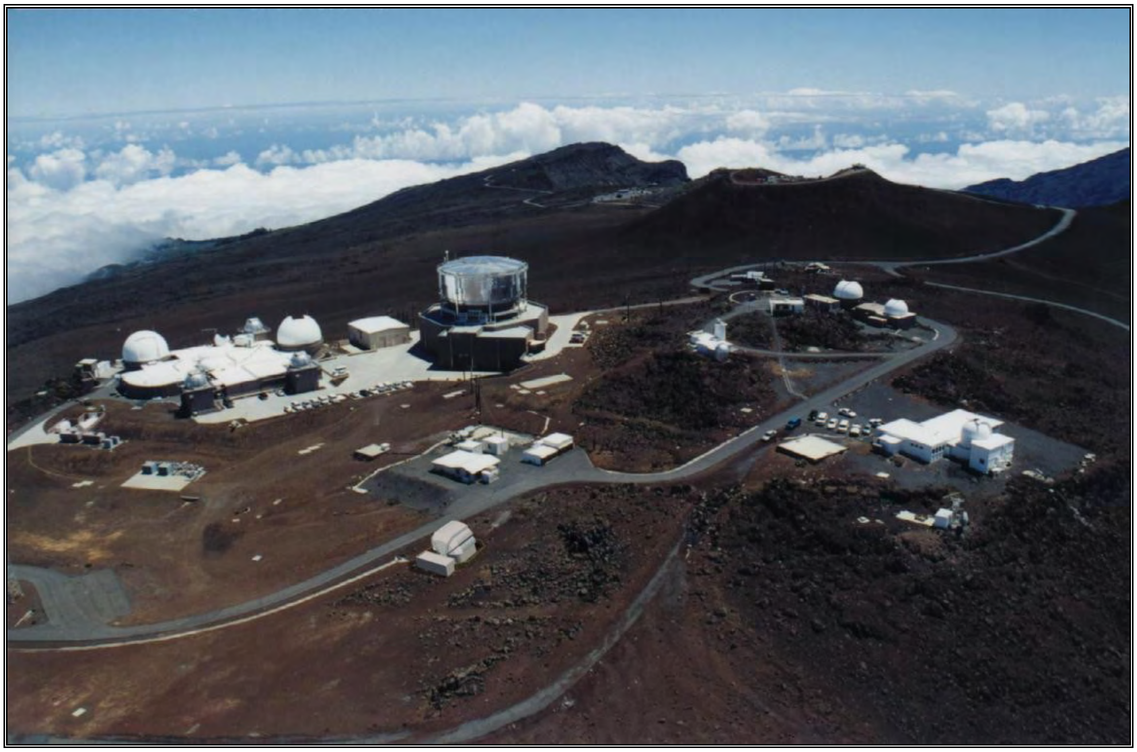
[3] A Preservation Plan is currently under preparation; a Burial Treatment Plan for Feature D of Site 5440 will be prepared at a later date, following consultation with the Maui/Lana`i Islands Burial Council.
[4] Pu`u Kolekole is the alternate site location for the ATST.



Photograph 1: Aerial view of Science City complex—Haleakala Crater—looking north. Reber Circle is visible upper center right of photograph.

THE STUDY AREA

The 18.1-acre "Science City" parcel lies near the summit of Haleakala in Papa`anui *ahupua`a*, Makawao District, Maui. Papa`anui is a discontinuous *ahupua`a* that extends from the shore at Makena, and runs upslope to Keonehulu summit (4000 feet AMSL) where it terminates. It then continues from Pu`u Keokea (7500 feet AMSL) to the crater rim, across the crater floor and ends at Pahaku Pahala on the northeastern rim above Paliku (Bushnell and Hammatt, 2000, p. 7). The USGS Makena quadrangle map is not clear as to the *makai* boundaries between Papa`anui and other *ahupua`a*. Cordy (1978) suggests that there were only 2 *ahupua`a* in the Makena area—Ka`eo and Papa`anui, and that other place names refer to *`ili* of these two land divisions.

Natural History

The soils in the overall Science City project area are classified as Cinder Land (rCl), and consist of areas of bedded magnetic ejecta associated with cinder cones. They are a mixture of cinders, pumice, and ash, and range in color from black, red, yellow to brown. These materials have jagged edges and a glassy appearance and show little or no evidence of soil development (Foote, et al., p. 29; Plate 117).

The overall parcel ranges in elevation from just over 10,000 feet AMSL on Pu`u Kolekole to a low of about 9,840 feet AMSL along its southeastern boundary. The high elevation of the Science City parcel gives the project area a sub-alpine climate, which influences the environment of the summit area. The following information is drawn from the Environmental Assessment document that was prepared for the Advanced Electro-Optical System (AEOS) facility (Belt Collins Hawaii, March 1994). Precipitation at the Maui Space Surveillance Site (MSSS) facility averages 25 inches per year, with the bulk of the rainfall occurring during November through May. Average annual temperatures near the summit range from 42 degrees F in the winter to 50 degrees F in the summer. Daily temperature ranges can be more extreme, with occasional sleet, snow, and hail fall occurring from December to February. Wind patterns are dominated by the northeast trade winds, which typically are most persistent from March to November. Southeasterly or Kona winds occur during the winter months and tend to bring clear weather to the summit. Sustained winds of 50 miles or more per hour can occur every month of the year. The maximum wind speed recorded at the summit is in excess of 125 miles per hour. The strongest winds typically occur during the winter and are associated with North Pacific storm systems that pass over the island chain.

Vegetation present in the project area is sparse—5 to 10% cover. A botanical survey carried out in April of 2000 (Char & Associates) on a c. 1.5 acre portion of the 18.1-acre current project area listed low shrubs of *kupaoa* (Dubautia menziesii), and scattered clumps of Deschampsia nubigena. The former (an endemic member of the daisy family) has stiff, upright branches with yellowish, daisy-like clusters arranged in compact clusters. The later is an endemic, perennial grass which forms rounded tufts, 6 to 12 inches tall with flowering stalks up to 2 feet in height. It is the most commonly found grass at this elevation.

Other plants, fewer in number, include hairy cat's ear (Hypochoeris radicata), another endemic member of the daisy family—Tetramoloium numile—a rounded dwarf shrub 3 to 10 inches across with whitish hairs and clusters of white flowers, a single shrub of indigenous *pukiawe* (Styphelia tameiameiae), and several clumps of mountain pili (Trisetum glomeratum)—an endemic perennial grass. No endangered silversword were noted during this 2000 survey, but were found in earlier surveys (U.S. Air Force 1991), and at the AEOS Telescope site (Belt Collins and Associates 1994). Three cultivated silversword plants were noted adjacent to the AEOS parking lot during the previous inventory survey. There were no endemic plants located within Reber Circle at the time of our field inspection.

PREVIOUS ARCHAEOLOGICAL WORK ON SITES WITHIN THE SCIENCE CITY PARCEL

There were two archaeological surveys that had been conducted in portions of the project area, prior to our 2002-2003 inventory survey. The first of these archaeological studies was carried out in 1990 and consisted of a reconnaissance survey (Chatters, 1991). Cultural Surveys Hawaii, Inc. conducted the second study, an archaeological inventory survey, in 1998 (April 2000). The results for each of these earlier projects are summarized below.

The first study, which consisted of an archaeological reconnaissance survey, was carried out by Pacific Northwest Laboratory on behalf of the U.S. Air Force for the expansion of the Maui Space Surveillance Site or MSSS (Chatters, 1991). During the course of this walkover, four archaeological sites were identified, primarily along the western side of Kolekole Hill. These features included 23 temporary shelters and a short, low wall. These wind shelters were typically constructed against the existing rock outcrop of the hill. The sites were designated SIHP No. 50-50-11-2805 through 2808. One sling stone was found on the floor of Feature J at Site 2807. In addition, one *opihi* (Cellana spp.) shell was noted on the surface of the Feature B floor of Site 2808. There was no subsurface investigation carried out, and only Site 2805 was mapped (Ibid.,). Per discussions with Dr. Melissa Kirkendall of the SHPD Maui office, we carried out additional inventory level documentation at these sites.

The second study was carried out by Cultural Surveys Hawaii, Inc., in conjunction with the planned construction of the Faulkes Telescope facility. This more recent project located two previously unidentified sites—4835 and 4836. Both of these sites were constructed against an exposed rock outcrop. Site 4835 consists of 2 features—both historic rock enclosures filled with burned remnants of modern refuse—obviously historic trash burning pits. The authors suggest that these may have been used initially by the U.S. Army during the war, and later by University of Hawaii workers.

Site 4836 consists of 3 terraces, a rock enclosure, 2 leveled areas and a rock wall—all constructed against an exposed rock outcrop.[5] Five of the features are

[5] Xamanek Researches identified a trail remnant at the previously recorded Site 4836 during our inventory survey in 2002. This feature had not been noted in Bushnell and Hammatt, 2000. We subsequently recorded this feature per the direction of Dr. Melissa Kirkendall, SHPD staff archaeologist, and Mr. Charles Kauluwehi Maxwell, Chair of the Maui/Lanai Islands Burial Council. This trail remnant was assigned a feature number (F).

interpreted as temporary shelters, while the 2 leveled areas were of indeterminate usage. Although one test unit did not reveal any precontact cultural materials, their construction is consistent with precontact structures used for temporary shelters in other areas of Haleakala Crater (Bushnell and Hammatt, 2000, pp. 16-19). The University of Hawaii Institute for Astronomy opted to preserve both of the sites.

Xamanek Researches carried out an inventory survey of the entire 18.1 acre parcel in 2002-2003 (Fredericksen and Fredericksen, April 2003). A total of six previously unrecorded sites (50-50-11-5438 through 5443) were located during the course of this inventory survey. These sites consist of wind shelters, two petroglyph images, a possible burial feature, and an historic foundation—Reber Circle. Supplemental information was obtained from Sites 2805-2808 per discussions with Dr. Melissa Kirkendall of the SHPD Maui office. In addition, a trail segment was recorded at Site 4836 and designated as Feature F. Several isolated pieces of coral were noted in the southeastern portion of the c. 18-acre study area, but not assigned a formal site number, because the coral pieces were not weathered. A possible site—consisting of several pieces of coral in a boulder—was plotted on the project map, but was determined to lie off the project area.

Site 50-50-11-5443

This site remnant lies at the peak of Pu`u Kolekole, and is known as Reber Circle (Photographs 1-4). Site 5443 qualifies for significance under federal and state historic preservation guidelines Criterion “a” because of its association with mid-20th century scientific studies at Haleakala, and under Criterion “d” for its information content. This site consists of a concrete and rock foundation that was part of the former radio telescope facility that was constructed in 1952 by Grote Reber. This facility apparently did not function well, because of signal interference. The bulk of the structure was dismantled about 18 months after the facility was completed. This site remnant is composed of a concrete and rock foundation that is c. 25 meters in diameter, the outer rim of which is up to 1 meter in width and c. 80 cm in height (Figure 3). Approximately 40% of the structure has been impacted by previous earthmoving activities, and the site is in fair to poor condition. This previously identified site lies in the alternate location for the planned ATST.

Photograph 2: General view to the northwest of Pu`u Kolekole (center right) from the preferred location of the ATST.

Photograph 3: General view to the north across Reber Circle—Site 5443.

Photograph 4: View to the northwest across a newer section of rock wall that was added to Reber Circle (right) at an unknown date.

Photograph 5: View of a Reference Mark—US Coast & Geodetic Survey disc (dated 1950).

Photograph 6: General view to the north of Reber Circle of an older mid-1960s antenna building (see Figure 3 for location of this structure).

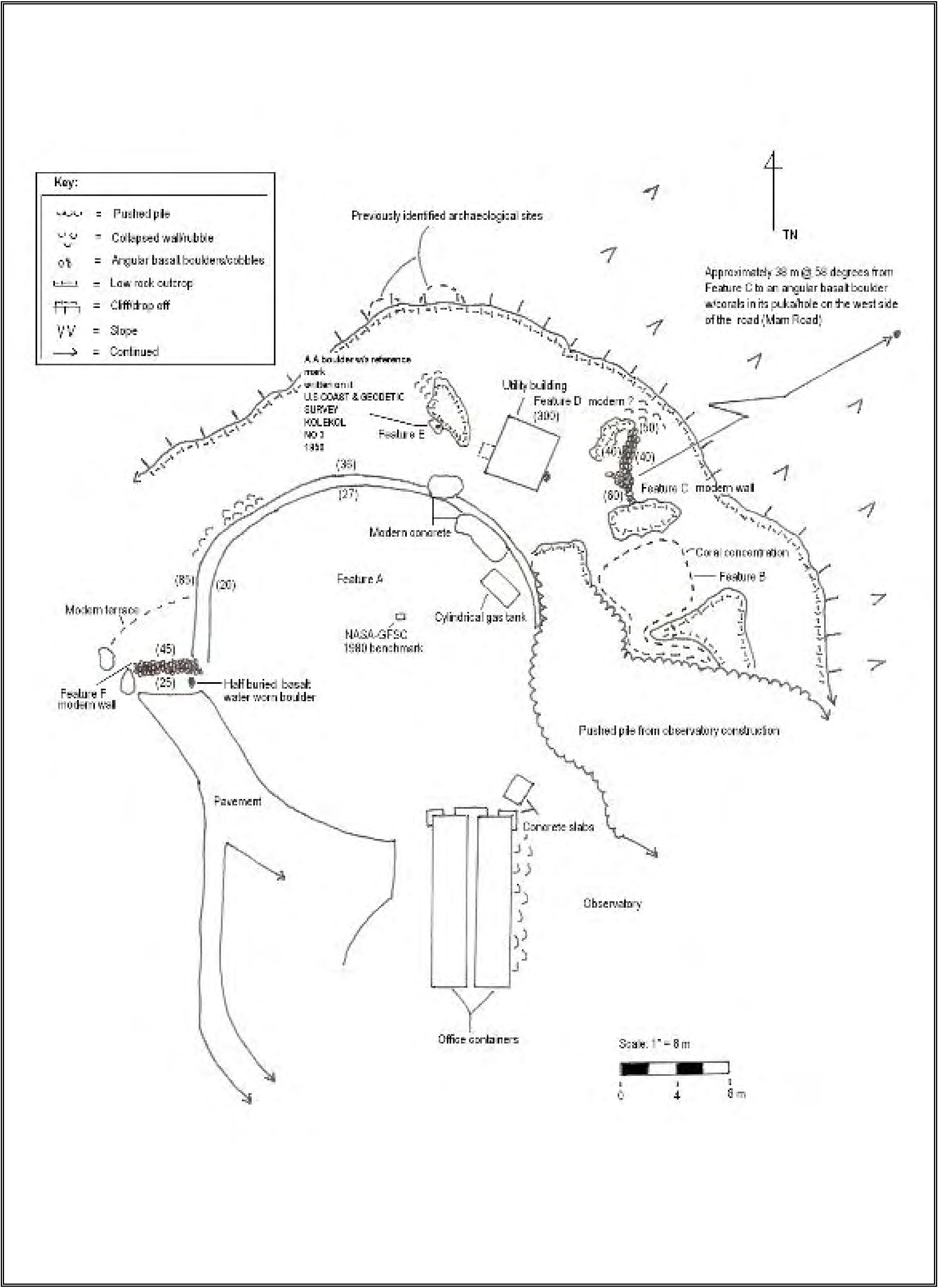


Figure 3: Plan view of Pu`u Kolekole with Reber Circle (Site 5443) and other features. Updated map prepared by Jonas Madeus in December 2005.

DATA RECOVERY STRATEGY

Research Questions

As noted earlier in this plan, should Reber Circle be chosen as the construction site for the planned ATST facility, data recovery work will be necessary. Based on our previous research, the current condition of Reber Circle, and discussions with Dr. Melissa Kirkendall, SHPD Maui staff archaeologist, we propose the following research questions:

1. When precisely was Reber Circle constructed and for what purpose(s). How long did it function?

2. What did the facility originally look like? Are there people in the community that have "institutional" memory/photographs of the facility?

3. What was the original condition of Pu`u Kolekole prior to construction of Reber Circle?[6]

Information needed to address research questions

We propose the following data collection approach to address the above research questions:

1. Undertake HABS and HAER level documentation of Reber Circle, to include large format photographs of the existing structure, and further research on the facility.

2. Interview knowledgeable individuals and search for old photographs of the area prior to construction of the Reber Circle facility.

[6] Given the number of previously identified indigenous sites within the Science City project area, there is a very real possibility that Pu`u Kolekole was also utilized by Native Hawaiians.

Methods

Conventional methods of data collection and recordation will be utilized during our data recovery program. These methods will conform to the Department of the Interior and National Park Service HABS and HAER standards.

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ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

July 10, 2006

Mr. Erik Fredericksen
Xamanek Researches
P.O. Box 880131
Pukalani, Hawai'i 96788

LOG NO: 2006.2287
DOC NO: 0606MK44
Archaeology

Dear Mr. Fredericksen:

SUBJECT: National Historic Preservation Act (NHPA) Section 106 Review – Preservation Plan for Eleven Sites at Science City, Haleakala Papaanui Ahupua'a, Makawao District, Island of Maui
TMK: (2) 2-2-007: por. 008

Thank you for the opportunity to review and comment on this preservation plan received by our staff April 6, 2006 (Fredericksen 2006, *An Archaeological Preservation Plan for an 18.1 Acre Parcel Known as Science City, Haleakala Crater, Papaanui Ahupua'a, Makawao District, Maui Island [TMK 2-2-007: por 008])*...Xamanek Researches, LLC, ms. An archaeological inventory survey was conducted on the subject parcel in 2002, and was reviewed and accepted by our office (DOC NO: 0307MK03). We agreed that the distribution of these features and sites across the cultural landscape of Haleakala has the potential to yield additional information, and should be passively preserved. In addition, SHPD concurred with precautionary monitoring as mitigation during any construction that might occur in the subject area.

The preservation plan provides details for 11 historic properties; SIHP 50-50-11-5438-5443 with 30 component features, SIHP 50-50-11-2805-2808 with 21 features, and SIHP 50-50-11-4835 and 4836 with eight (8) features. The sites and component features consist of temporary habitations, wind shelters (C-shapes), two (2) small terrace features, petroglyphs and a remnant of a 1952 radio telescope facility foundation, and Feature D at SIHP 5440 is interpreted as a possible burial.

Short-term and interim preservation measures include the removal of non-native plants (flush cutting) and erection of orange plastic construction fencing as a protection measure during construction activities. All operating facilities within the Science City project area should maintain copies of the overall project map that clearly depict site locations.

Long term preservation will be accomplished via passive "as is" protection. No access trails are planned to the sites. Limited access provisions are provided, although no formal access is recommended. Buffers for each site and feature are depicted in the preservation plan and are acceptable. No landscaping is detailed, with the exception of the aforementioned removal of non-native plants. No signage is recommended. Two (2) *ahu* or ceremonial markers have been constructed under the direction of Mr. Charles Kauluwehi Maxwell, with adjacent well-marked trails to the *ahu*.

Mr. Erik Fredericksen
Page 2

The Preservation Plan is acceptable. The State Historic Preservation Division (SHPD) will await the submittal of a Burial Treatment/Preservation Plan for Feature D at SIHP 50-50-11-5440. If you have any questions, please contact Dr. Melissa Kirkendall of SHPD, Maui Section, at (808) 243-5169.

Aloha,

for Peter Young, Chair
State Historic Preservation Officer

MK:kf

c: Bert Ratte, DPWEM, County of Maui, FAX 270-7972
Michael Foley, Director, Dept. of Planning, FAX 270-7634
Maui Cultural Resources Commission, Dept. of Planning, 250 S. High Street, Wailuku, HI 96793

An Archaeological Preservation Plan for an 18.1-acre parcel known as Science City, Haleakala Crater, Papa`anui *Ahupua`a*, Makawao District, Maui Island (TMK: 2-2-07: por. of 8)

Prepared for:

Charles Fein, PhD
KC Environmental, Inc.
Makawao, Maui

Prepared by:

Xamanek Researches, LLC
Pukalani, Hawaii
Erik M. Fredericksen

30 March 2006

ABSTRACT

Xamanek Researches[1] carried out an archaeological inventory survey of the Science City parcel in the fall of 2002. This 18.1 acre project area lies near the summit of Haleakala, and it is located in Papa`anui *ahupua`a*, Makawao District, Maui (TMK: 2-2-07: Portion of 8). The study area contains several existing observatories and other structures that have been constructed at different times over the years.

A total of six previously unidentified sites were located during the archaeological inventory survey. These sites were designated SIHP[2] No. 50-50-11-5438 through 5443. In addition, further documentation was obtained for previously identified Sites 2805 through 2808, per discussions with Dr. Melissa Kirkendall, SHPD staff archaeologist for Maui. Finally, a trail remnant was located at the previously recorded Site 4836 and given a feature number (F). Our inventory survey report was approved by the State Historic Preservation Division (SHPD) in a 10 July 2003 review letter (SHPD DOC NO: 0307MK03).

Two mitigation recommendations were made for the Science City project area at the conclusion of the inventory survey. Given the possibility that future construction actions may occur in the Science City project area, in-place passive preservation was recommended for the identified sites that are contained in the study area.[3] The second mitigation recommendation called for precautionary monitoring to occur should any future construction activities take place on the parcel.[4] The following preservation plan has been prepared in order to help ensure the long-term integrity of the cultural resources that have been identified within the Science City parcel (TMK: 2-2-07: Portion of 8).

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[1] Xamanek Researches was converted to Xamanek Researches, LLC, a Hawaii-based Limited Liability Company, in February 2005.

[2] SIHP = **S**tate **I**nventory of **H**istoric **P**roperties

[3] A Burial Treatment Plan for Feature D of Site 5440 will be prepared at a later date, following consultation with the Maui/Lana`i Islands Burial Council.

[4] A general monitoring plan for the Science City parcel will be submitted to the SHPD for review and comment at a later date.

Map 1: Location of the project area, Science City, Haleakala, Maui.

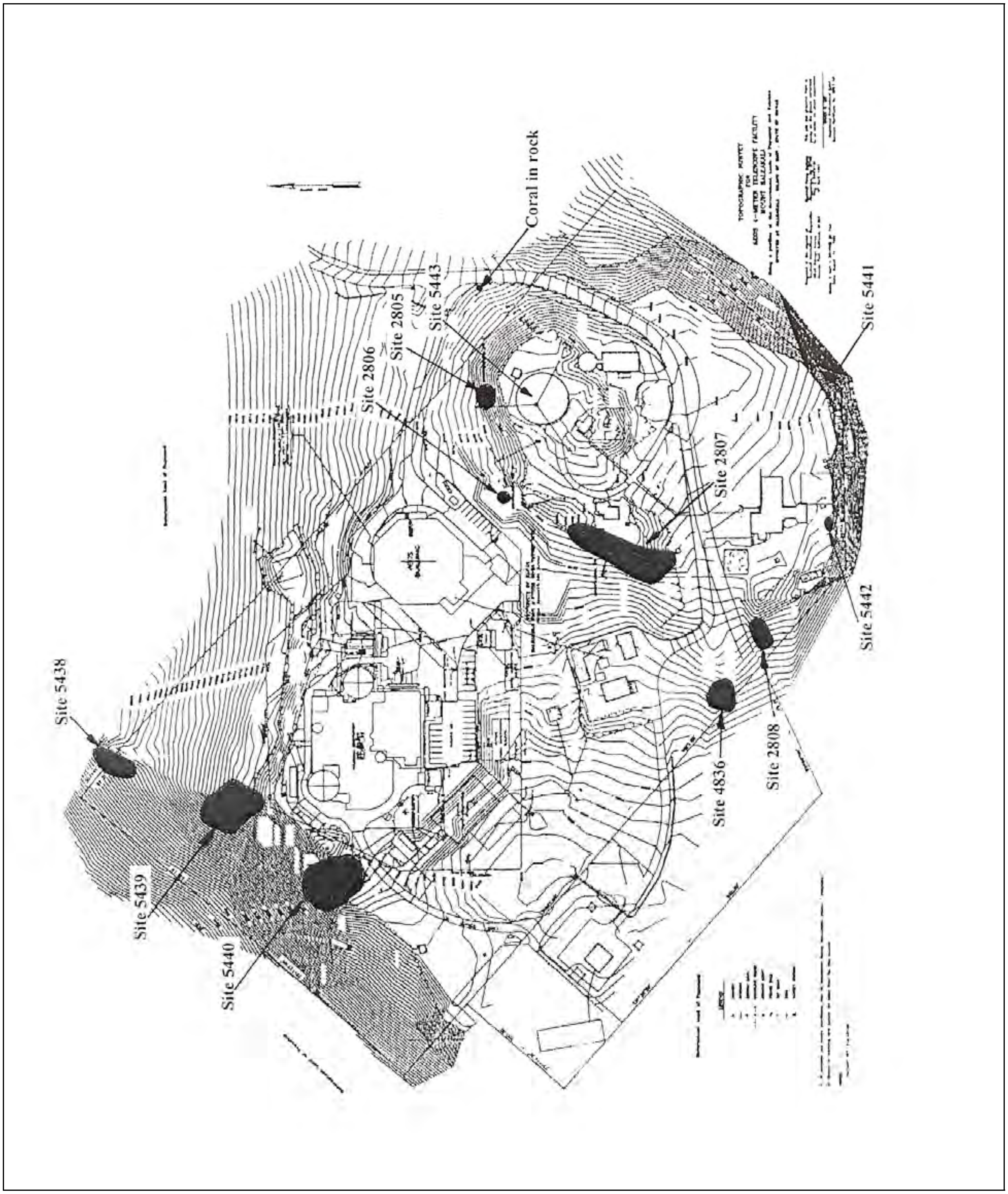

Figure 1: Plan view of the Science City project area with site locations.

INTRODUCTION

Xamanek Researches[5] carried out an archaeological inventory survey of the Science City parcel in the fall of 2002. Two previous studies had been carried out in portions of this scientific complex, and had identified five archaeological sites. However, there had not been a comprehensive inventory survey of the entire 18.1-acre parcel. This 18.1 acre project area, which lies near the summit of Haleakala, is located in Papa`anui *ahupua`a*, Makawao District, Maui (TMK: 2-2-07: Portion of 8). The inventory survey report was approved by the State Historic Preservation Division (SHPD) in a 10 July 2003 review letter (SHPD DOC NO: 0307MK03). The study area contains several existing observatories and other structures that have been constructed at different times over the years.

A total of six previously unidentified sites were located during the archaeological inventory survey. These sites have been designated SIHP[6] No. 50-50-11-5438 through 5443. In addition, further documentation was obtained for previously identified Sites 2805 through 2808, per discussions with Dr. Melissa Kirkendall, SHPD staff archaeologist for Maui. Finally, a trail remnant was located at the previously recorded Site 4836 and given a feature number (F).

The bulk (80%+) of the features in newly identified Sites 5438-5442 consist of temporary habitation areas or wind shelters. Two features in Site 5440 are petroglyph images (Features F and G), and one is interpreted as a possible burial (Feature D). Site 5441 contains two small platforms that are thought to have possible ceremonial functions. Site 5443 consists of the remnants of a former radio telescope facility, known as Reber Circle that was built in 1952, and subsequently dismantled due to signal interference.

All of the newly identified sites and Feature F of Site 4836 as well as the previously recorded sites in the Science City project area retain their significance ratings under at least Criterion “d” for their information content under Federal and State historic preservation guidelines. The possible burial—Feature D, and the petroglyph Features F and G of Site 5440, as well as Site 5441 and Feature F of Site 4836 also qualify for cultural significance under Criterion “e”. Finally, it is important to note that all of the sites with the exception of Site 5443, and, possibly, Site 4835 that are located in Science City represent a remnant of a Native Hawaiian cultural landscape. Because Haleakala is noted for its ceremonial and traditional importance to the Native Hawaiian people, the

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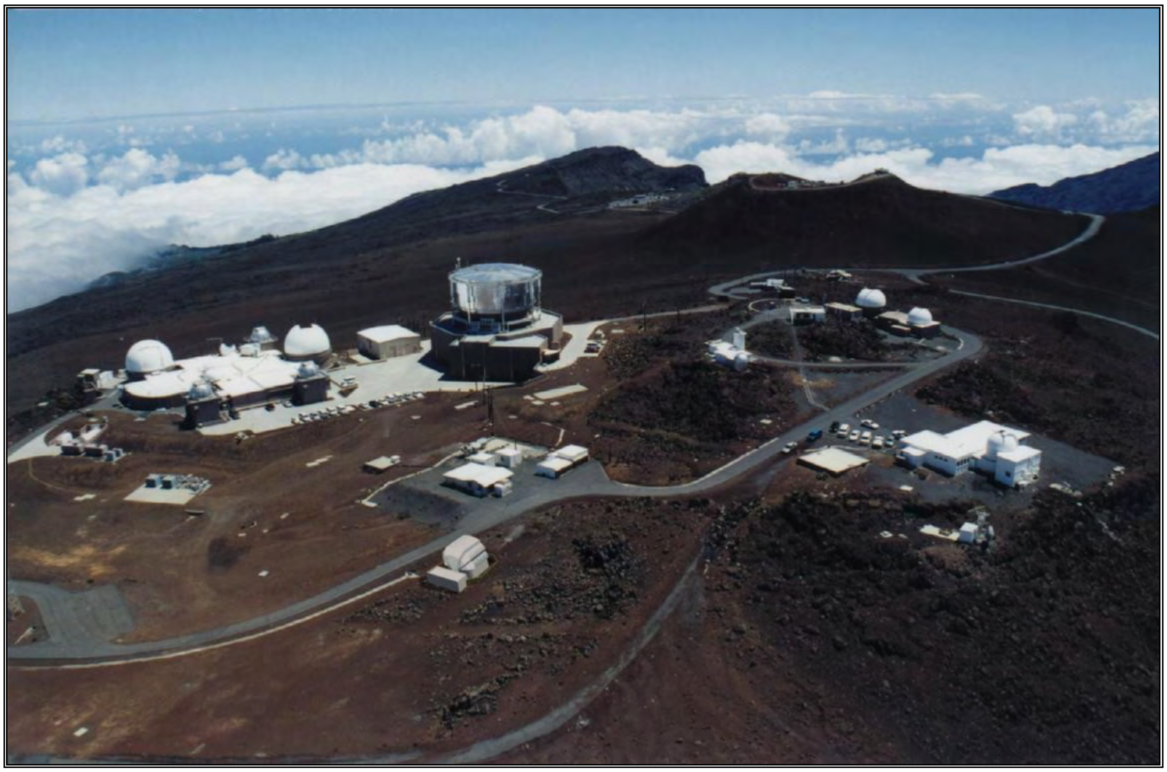
entire Science City site complex may well qualify for importance under additional significance criteria as well.

Two mitigation recommendations were made for the Science City project area at the conclusion of the inventory survey. Given the possibility that future construction actions may occur in the Science City project area[7], in-place passive preservation was recommended for the identified sites that are contained in the study area.[8] The second mitigation recommendation called for precautionary monitoring to occur should any future construction activities take place on the parcel.[9] The following preservation plan has been prepared in order to help ensure the long-term integrity of the various cultural resources that are contained within the Science City parcel.[10]



Photograph 1 – Aerial view of Science City complex—Haleakala Crater—looking north.

[7] At the writing of this Preservation Plan, the Advanced Technology Solar Telescope (ATST) appears to be slated for construction near the existing Mees Solar Observatory facility.
[8] A Burial Treatment Plan for Feature D of Site 5440 will be prepared at a later date, following consultation with the Maui/Lana`i Islands Burial Council.
[9] A general monitoring plan for the Science City parcel will be submitted to the SHPD for review and comment.
[10] It appears that Reber Circle—Site 5443, may be dismantled, possibly to restore Pu`u Kolekole for Native Hawaiian cultural purposes. In the event that it is determined that this site will be destroyed, a data recovery plan (Fredericksen, December 2005) for the site has been submitted to the State Historic Preservation Division for review and comment.

**Photograph 2 – Close-up view of observatories—view to the northwest.
Camera view is from Pu`u Kolekole.**

Photograph 3 – AEOS facility from near Pu`u Kolekole—view to the north.

Photograph 4 – Faulkes Telescope—view to the southwest.

THE STUDY AREA

The 18.1-acre parcel lies near the summit of Haleakala in Papa`anui *ahupua`a*, Makawao District, Maui. Papa`anui is a discontinuous ahupua`a that extends from the shore at Makena, and runs upslope to Keonehulu summit (4000 feet AMSL) where it terminates. It then continues from Pu`u Keokea (7500 feet AMSL) to the crater rim, across the crater floor and ends at Pahaku Pahala on the northeastern rim above Paliku (Bushnell and Hammatt, 2000, p. 7). The USGS Makena quadrangle map is not clear as to the *makai* boundaries between Papa`anui and other *ahupua`a*. Cordy (1978) suggests that there were only 2 *ahupua`a* in the Makena area—Ka`eo and Papa`anui, and that other place names refer to *`ili* of these two land divisions.

Natural History

The soils in the project area are classified as Cinder Land (rCl), and consist of areas of bedded magnetic ejecta associated with cinder cones. They are a mixture of cinders, pumice, and ash, and range in color from black, red, yellow to brown. These materials have jagged edges and a glassy appearance and show little or no evidence of soil development (Foote, et al., p. 29; Plate 117).

The project area ranges in elevation from just over 10,000 feet AMSL on Pu`u Kolekole to a low of about 9,840 feet AMSL along its southeastern boundary. The high elevation of the Science City parcel gives the project area a sub-alpine climate, which influences the environment of the summit area. The following information is drawn from the Environmental Assessment document that was prepared for the Advanced Electro-Optical System (AEOS) facility (Belt Collins Hawaii, March 1994). Precipitation at the Maui Space Surveillance Site (MSSS) facility averages 25 inches per year, with the bulk of the rainfall occurring during November through May. Average annual temperatures near the summit range from 42 degrees F in the winter to 50 degrees F in the summer. Daily temperature ranges can be more extreme, with occasional sleet, snow, and hail fall occurring from December to February. Wind patterns are dominated by the northeast trade winds, which typically are most persistent from March to November. Southeasterly or Kona winds occur during the winter months and tend to bring clear weather to the summit. Sustained winds of 50 miles or more per hour can occur every month of the year. The maximum wind speed recorded at the summit is in excess of 125 miles per hour. The strongest winds typically occur during the winter and are associated with North Pacific storm systems that pass over the island chain.

Vegetation found in the project area is sparse—5 to 10% cover. A botanical survey carried out in April of 2000 (Char & Associates) on a 1.5 acre portion of the 18.1-acre current project area listed low shrubs of *kupaoa* (Dubautia menziesii), and scattered clumps of Deschampsia nubigena. The former (an endemic member of the daisy family) has stiff, upright branches with yellowish, daisy-like clusters arranged in compact clusters. The later is an endemic, perennial grass which forms rounded tufts, 6 to 12 inches tall with flowering stalks up to 2 feet in height. It is the most commonly found grass at this elevation.

Other plants, fewer in number, ainclude hairy cat's ear (Hypochoeris radicata), another endemic member of the daisy family—Tetramoloium numile—a rounded dwarf shrub 3 to 10 inches across with whitish hairs and clusters of white flowers, a single shrub of indigenous *pukiawe* (Styphelia tameiameiae), and several clumps of mountain pili (Trisetum glomeratum)—an endemic perennial grass. No endangered silversword were noted during this 2000 survey, but were found in earlier surveys (U.S. Air Force 1991), and at the AEOS Telescope site (Belt Collins and Associates 1994). Three cultivated silversword plants were noted adjacent to the AEOS parking lot during the previous inventory survey.

PREVIOUS ARCHAEOLOGICAL WORK ON SITES WITHIN THE SCIENCE CITY PARCEL

There were two archaeological surveys that had been conducted in portions of the project area, prior to our 2002-2003 inventory survey. The first of these archaeological studies was carried out in 1990 and consisted of a reconnaissance survey (Chatters, 1991). Cultural Surveys Hawaii, Inc. conducted the second study, an archaeological inventory survey, in 1998 (April 2000). The results for each of these earlier projects are summarized below.

The first study, which consisted of an archaeological reconnaissance survey, was carried out by Pacific Northwest Laboratory on behalf of the U.S. Air Force for the expansion of the Maui Space Surveillance Site or MSSS (Chatters, 1991). During the course of this walkover, four archaeological sites were identified, primarily along the western side of Kolekole Hill. These features included 23 temporary shelters and a short, low wall. These wind shelters were typically constructed against the existing rock outcrop of the hill. The sites were designated SIHP No. 50-50-11-2805 through 2808. One sling stone was found on the floor of Feature J at Site 2807. In addition, one *opihi* (Cellana spp.) shell was noted on the surface of the Feature B floor of Site 2808. There was no subsurface investigation carried out, and only Site 2805 was mapped (Ibid.,). Per discussions with Dr. Melissa Kirkendall of the SHPD Maui office, we carried out additional inventory level documentation at these sites.

The second study was carried out by Cultural Surveys Hawaii, Inc., in conjunction with the planned construction of the Faulkes Telescope facility. This more recent project located two previously unidentified sites—4835 and 4836. Both of these sites were constructed against an exposed rock outcrop. Site 4835 consists of 2 features—both historic rock enclosures filled with burned remnants of modern refuse—obviously historic trash burning pits. The authors suggest that these may have been used initially by the U.S. Army during the war, and later by University of Hawaii workers later on.

Site 4836 consists of 3 terraces, a rock enclosure, 2 leveled areas and a rock wall—all constructed against an exposed rock outcrop.[11] Five of the features are

[11] Xamanek Researches identified a trail remnant at the previously recorded Site 4836 during our inventory survey in 2002. This feature had not been noted in Bushnell and Hammatt, 2000. We subsequently recorded this feature per the direction of Dr. Melissa Kirkendall, SHPD staff archaeologist, and Mr. Charles Kauluwehi Maxwell, Chair of the Maui/Lanai Islands Burial Council. This trail remnant was assigned a feature number (F).

interpreted as temporary shelters, while the 2 leveled areas were of indeterminate usage. Although one test unit did not reveal any precontact cultural materials, their construction is consistent with precontact structures used for temporary shelters in other areas of Haleakala Crater (Bushnell and Hammatt, 2000, pp. 16-19). The University of Hawaii Institute for Astronomy opted to preserve both of the sites.

As noted earlier, Xamanek Researches carried out an inventory survey of the entire 18.1 acre parcel in 2002-2003 (Fredericksen and Fredericksen, April 2003) [Figure 2]. A total of six previously unrecorded sites (50-50-11-5438 through 5443) were located during the course of this inventory survey. These sites consist of wind shelters, two petroglyph images, a possible burial feature, and an historic foundation—Reber Circle. Supplemental information was obtained from Sites 2805-2808 per discussions with Dr. Melissa Kirkendall of the SHPD Maui office. In addition, a trail segment was recorded at Site 4836 and designated as Feature F. Several isolated pieces of coral were noted in the southeastern portion of the c. 18-acre study area, but not assigned a formal site number, because the coral pieces were not weathered. A possible site—consisting of several pieces of coral in a boulder—was plotted on the project map, but was determined to lie off the project area. Each of the previously unidentified sites is summarized below.

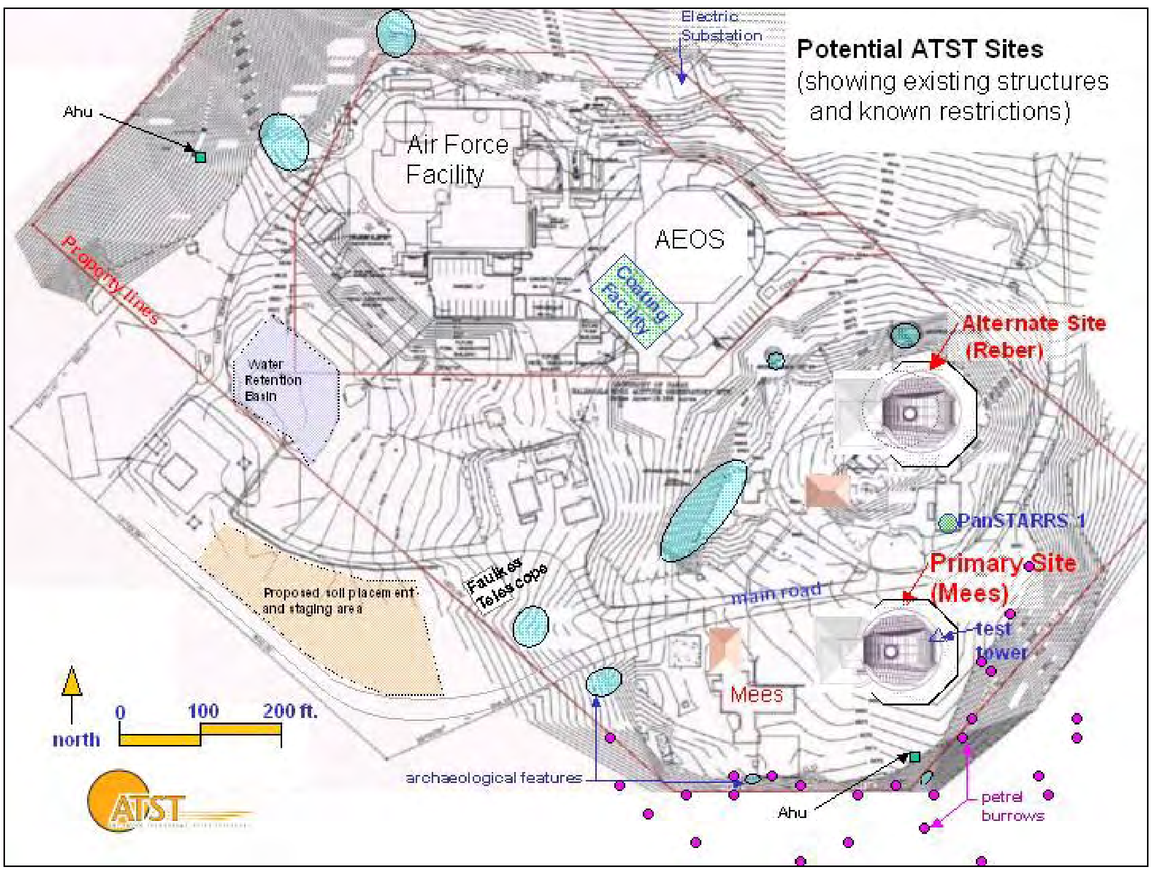


Figure 2: Potential ATST site location map, including approximate locations of identified cultural resources.

Site 5438 [Figure 3]

This site is located near the northwestern corner of the rectangular project area, and lies down slope (north) of the MSSS Facilities. The average elevation of this site is 9880 ft AMSL, and it lies approximately 20 meters in elevation below the crest of the Science City complex. The entire area is covered with *a'a* cobbles, boulders and cinder with large weathered lava flow outcrop. Observed vegetation consisted of a few clumps of unidentified bunch grass and scattered *kupaoa* (Dubautia menziesii.) plants. Overall site dimensions are c. 20 meters NE/SW by 10 meters NW/SE. Site 5438 is composed of two semi-enclosures or wind shelters (Features A and F), and 4 terrace/platforms (Features B through E). The bulk of these structures are composed of *a'a* cobble and boulder layers/walls that range from 1 to 6 courses in height (i.e. up to 90 cm tall). All of these features are interpreted as temporary habitation areas that provided shelter from the wind, which can be quite cold in the evening and early morning hours.[12] The terrace/platforms are on the lee of a small *pu'u* and have low or no walls.

The surface inspection of this site yielded isolated pieces of modern materials such as tin foil, paper, plastic and metal. One test unit was utilized to assess subsurface conditions at this site. This site is interpreted as a temporary habitation area that was mainly used for shelter on an intermittent basis. While there were no indigenous material culture remains located during the surface inspection of this site or during testing, it is nevertheless interpreted as a probable precontact cultural resource that has been utilized in more recent times.

[12] The project area occasionally freezes, and frost was noted on the project area on several days during the inventory survey. In addition, the summit area received a light snowfall during the winter of 2001 and 2002.

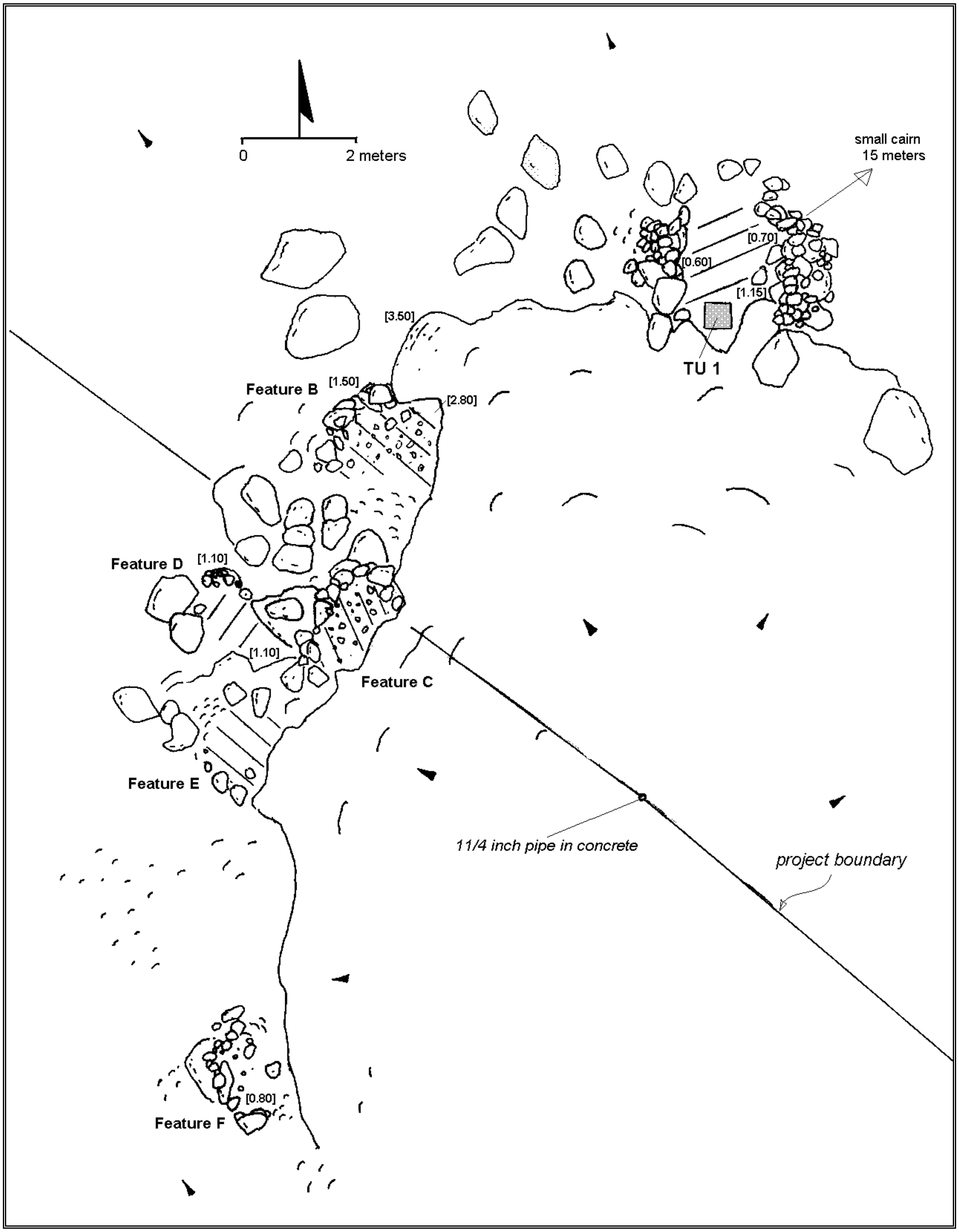


Figure 3 – Plan view of Site 5438.

Site 5439 [Figures 4-6]

Site 5439 is located between 30 and 80 meters down slope (north) of the main portion of the MSSS complex, and c. 15 meters to the southwest of Site 5438. Site 5439 is primarily situated along the crest and down the western flank of a sharp ridge that drops down from the summit in a northerly direction. Overall site dimensions are c. 49 meters N/S by 31 meters E/W. The elevation of this site ranges from about 9,930 ft AMSL to c. 9,860 ft AMSL. Several large, weathered lava flow sections are surrounded by talus boulders, with areas of loose rubble and cinders on the moderately steep slope. Loose cinder and rubble occur in pockets and over the level areas of the various features within this site. Several apparent electrical cables transit the central portion of this site. The only vegetation noted in the site area consisted of scattered *kupaoa* shrubs and isolated bunch grass.

The site complex consists of 22 features (A-M). These features include 2 rock wall shelters that incorporate small overhangs referred to as dew shelters in this report (Features A and B), 10 rock wall shelters (Features C through M), and 1 possible shelter remnant (rock pile). Two of the rock wall shelters (Features F and L) are C-shapes, while the remaining ones consist of various shapes. As with Site 5438**,** these features are interpreted as temporary habitation areas that provided shelter from the elements—especially the wind. The two "dew" shelters (Features A and B) would also have provided some protection from mist and dew. All of the structures are roughly constructed of *a'a* cobbles and boulders that range from 20-80 cm in height (1 to 5 stone courses).

Our surface inspection primarily revealed modern material remains such as plastic, what appeared to be discarded roofing material, metal, paper, and some possible insulation material. However, one weathered coral fragment was found on the floor of Feature A, and a weathered piece of marine shell (Cypraea spp.) was located at Feature B. These cultural materials are tentatively interpreted as indigenous rather than modern remains.

Two test units were excavated at this site in order to assess subsurface conditions. There were no portable remains other than a few small pieces of coral found in Layer I of TU 1. The general lack of material culture remains suggests that at least the two tested features do not appear to have been used for extended periods of time. As with Site 5438, Site 5429 is interpreted as a complex of wind shelters that were likely used in precontact as well as post-contact times.

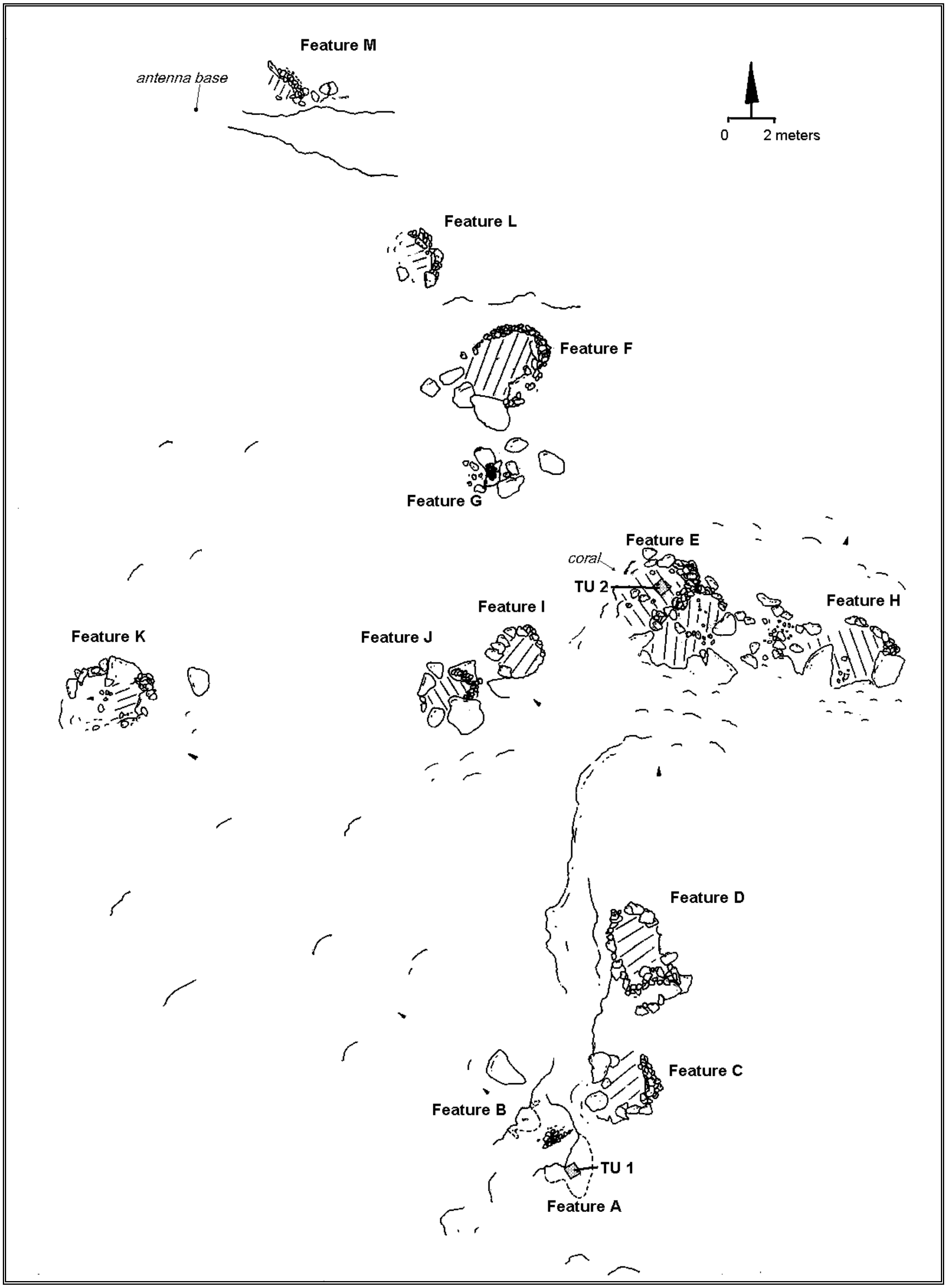


Figure 4 - Plan view of Site 5439.

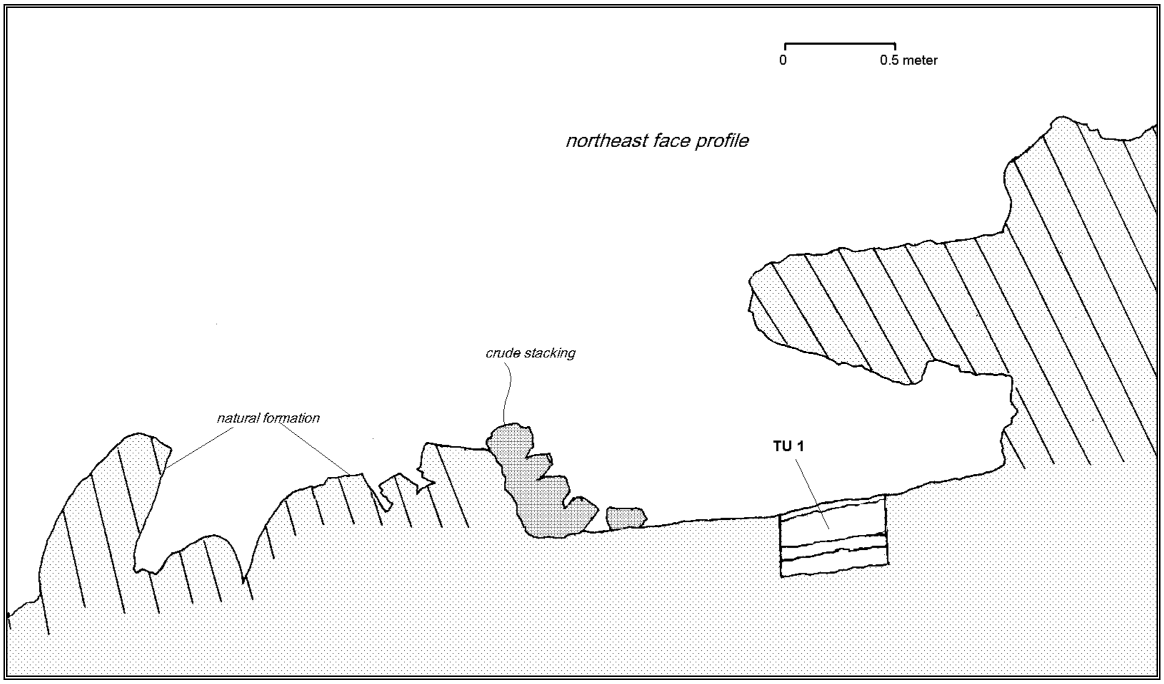


Figure 5 – Northeast face profile of Feature A, Site 5439—showing TU 1.

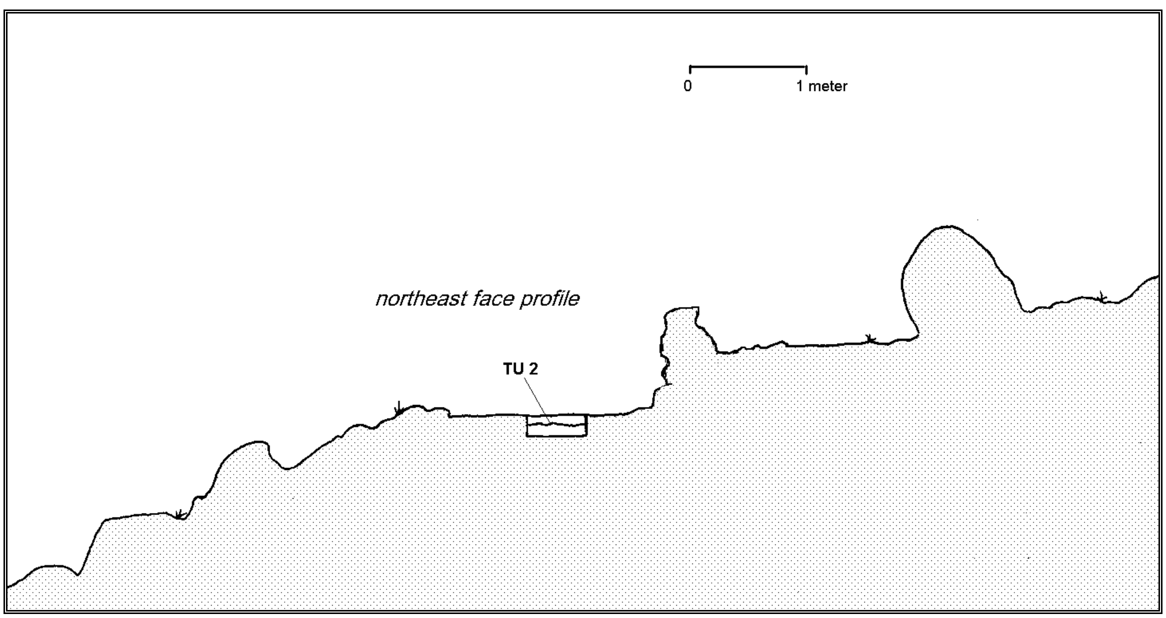


Figure 6 – Northeast face profile of Feature E, Site 5439—showing TU 2.

Site 5440 [Figures 7-14]

Site 5440 is located in the northwestern portion of the project area, near the upper reach of a northwest-facing slope. This temporary habitation site lies to the southwest of Site 5439, and just down slope from the graded area of the Haleakala Observatory facility. This part of the study area ranges from between 9,910 ft to 9,950 ft AMSL. The general slope is covered with large sections of weathered lava flow that are surrounded by talus boulders and areas of loose rubble and cinder. The southeastern-most portion of this site lies c. 7 meters northwest of the paved access service road to the Haleakala Observatory building. The only vegetation observed in the site area consisted of scattered *kupaoa* plants and clumps of bunch grass.

The overall dimensions of Site 5440 are c. 34 meters N/S by 24 meters E/W. This site complex includes four wind shelters (Features A-C and E), a possible burial (Feature D), and two petroglyph images (Features F and G). The wind shelters are roughly built with *a'a* cobbles and boulders, and include two C-shapes (Features B and E). The walls of these shelters range from 30-120 cm in height. The Feature B C-shape also contains a small dew shelter at its southwestern end. This small sheltered space consists of a lava slab that has been placed over a gap between two outcrops of lava. Feature D consists of a low platform that lies at the base of a small overhang. This low platform measures 160 by 100 cm. by 15 cm high and is interpreted as a possible burial.[13] Features F and G are composed of petroglyph images that have been pecked into the faces of 2 boulders. Feature F is composed of an angular human figure and Feature G appears to represent an unfinished turtle image. The former image is well proportioned and in good condition, while the latter one is somewhat vague and not deeply pecked into the surface of the rock face. Two test units were utilized to investigate subsurface conditions at Features A and B of Site 5440. Neither of these units yielded cultural materials.

The overall site consists primarily of wind shelters. Site 5440 is tentatively interpreted as a precontact cultural resource that may contain a burial feature. While the two petroglyph images do not appear to be appreciably weathered, their relative age remains somewhat uncertain.

[13] This feature was not tested per the request of Mr. Charles Kauluwehi Maxwell, Chair, Maui/Lana`i Islands Burial Council.

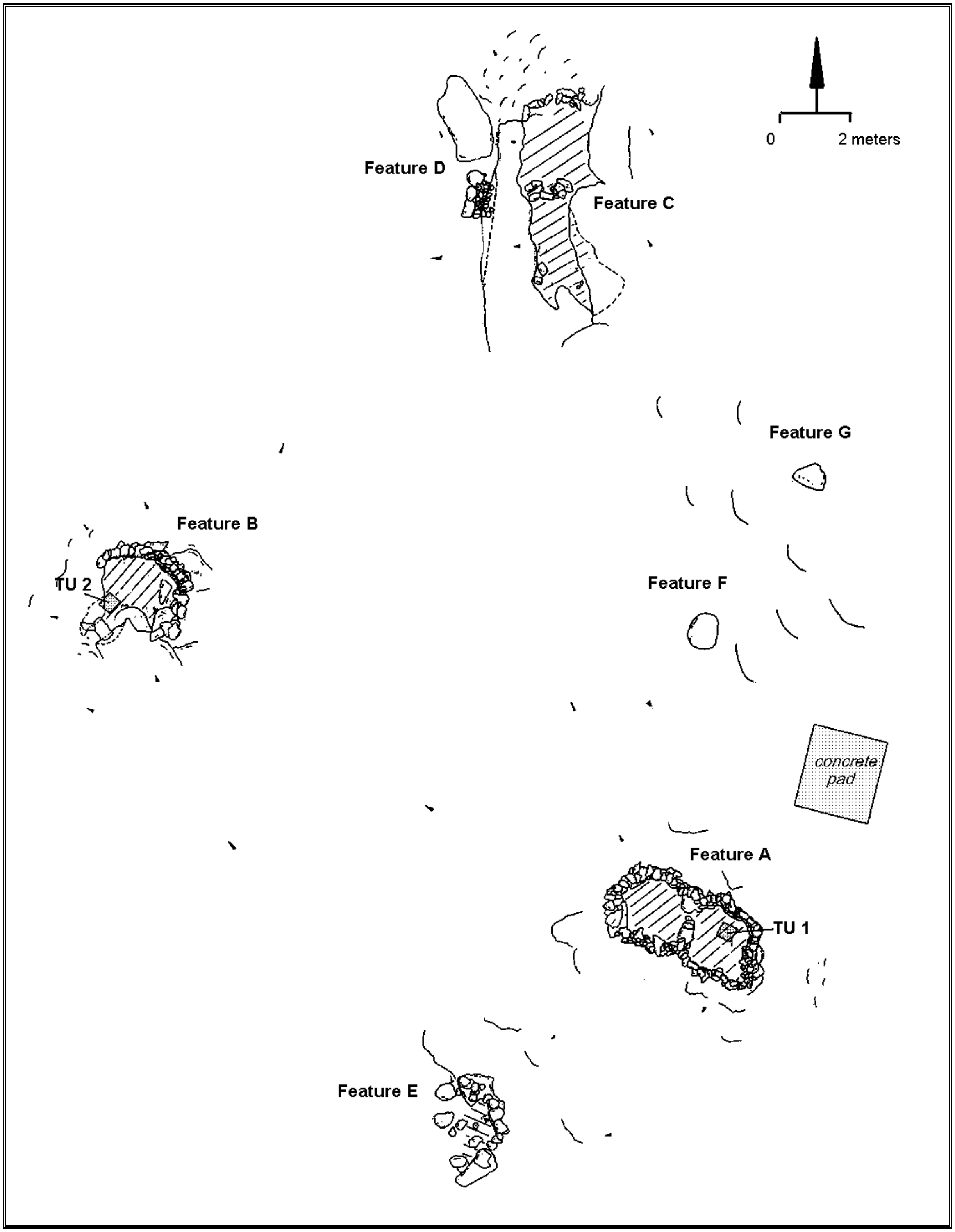


Figure 7 – Plan view of Site 5440.

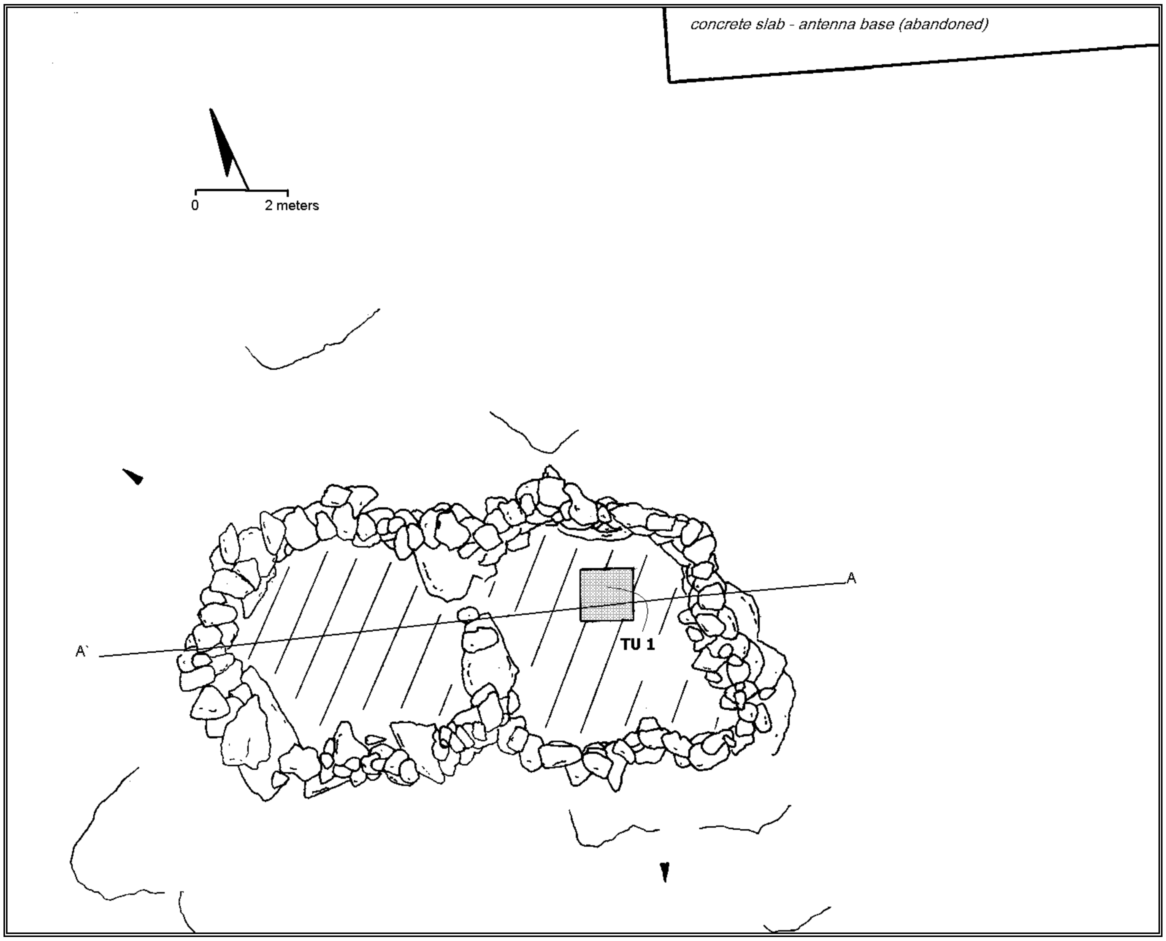


Figure 8 – Plan view of Feature A, Site 5440.

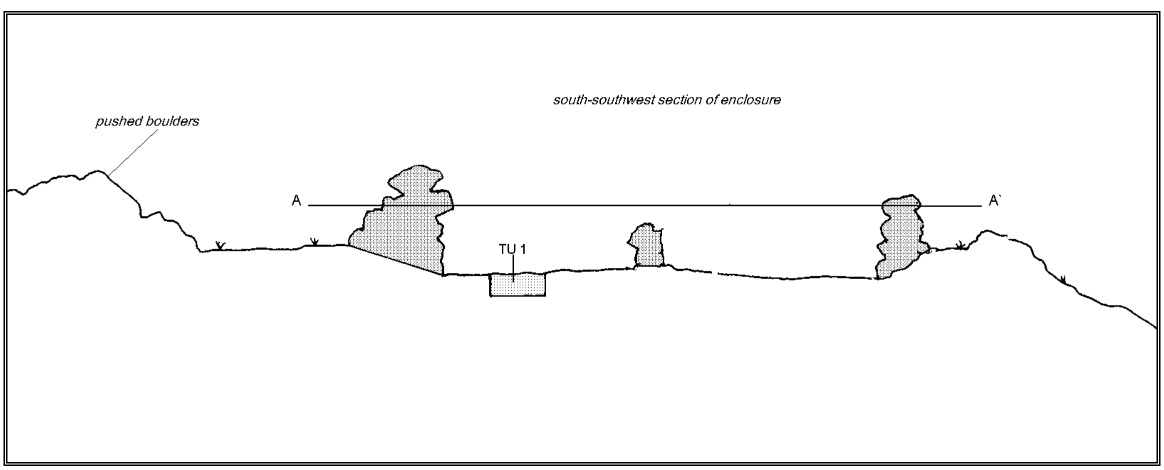


Figure 9 – South-southwest profile of Feature A, Site 5440.

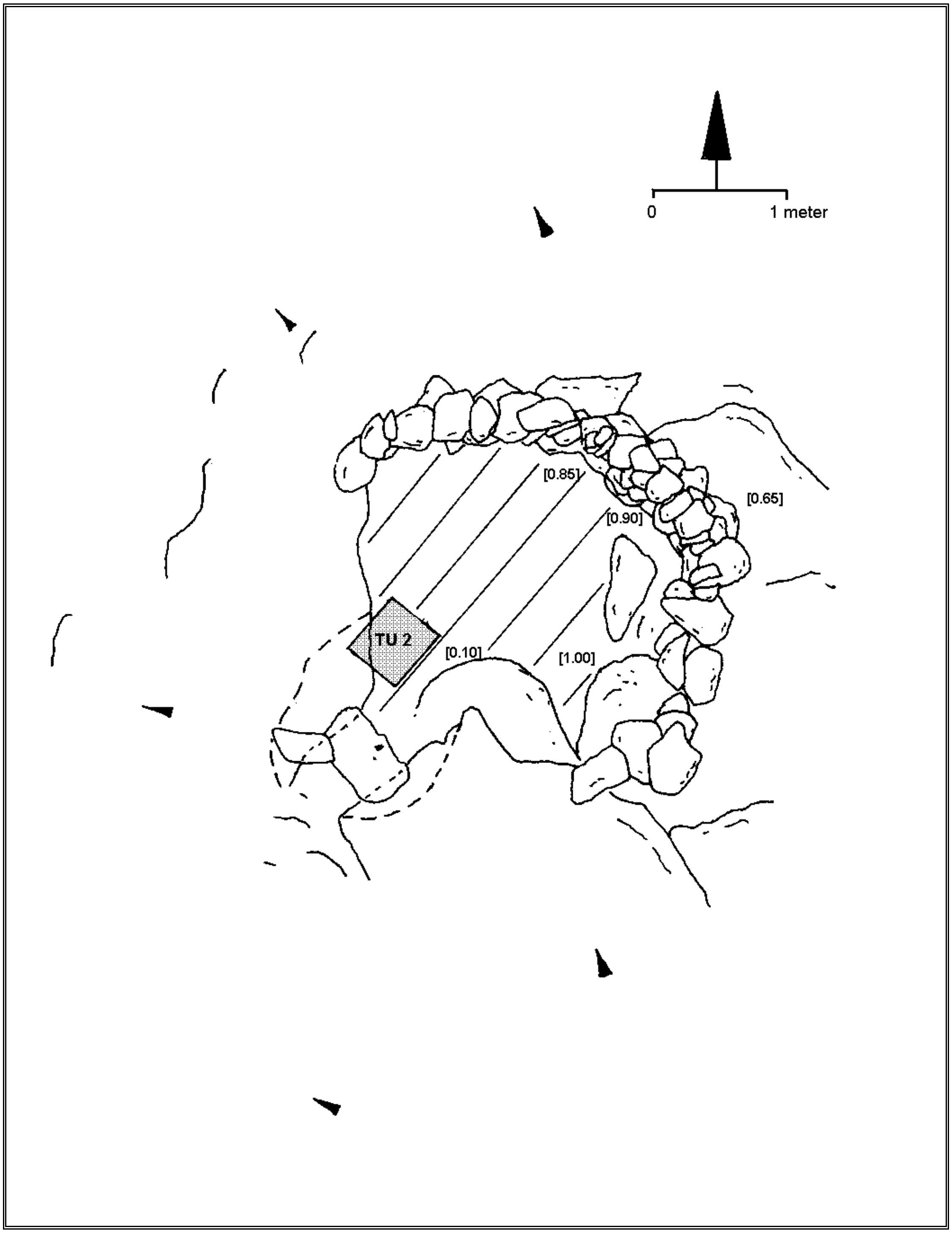


Figure 10 – Plan view of Feature B, Site 5440.

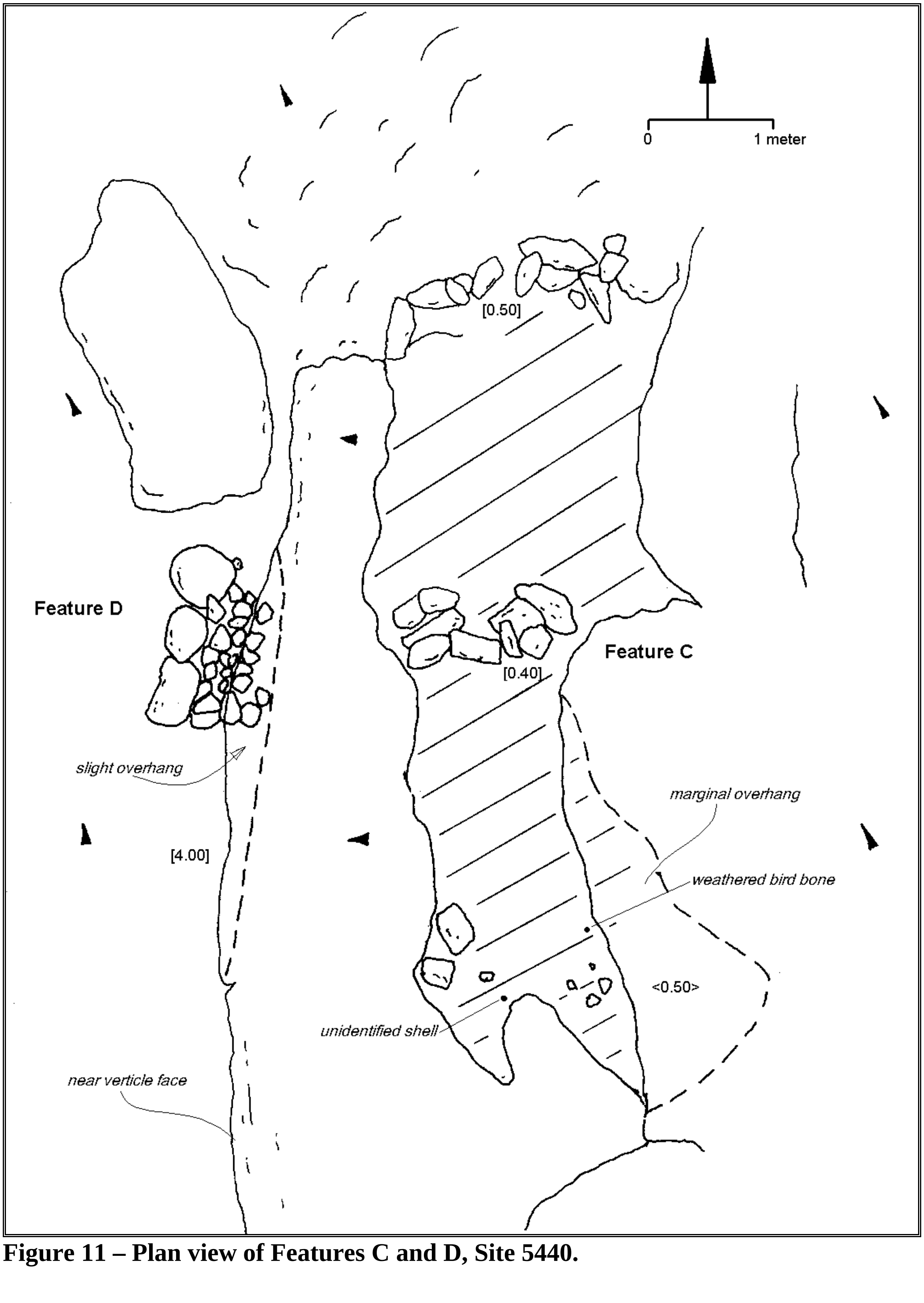


Figure 11 – Plan view of Features C and D, Site 5440.

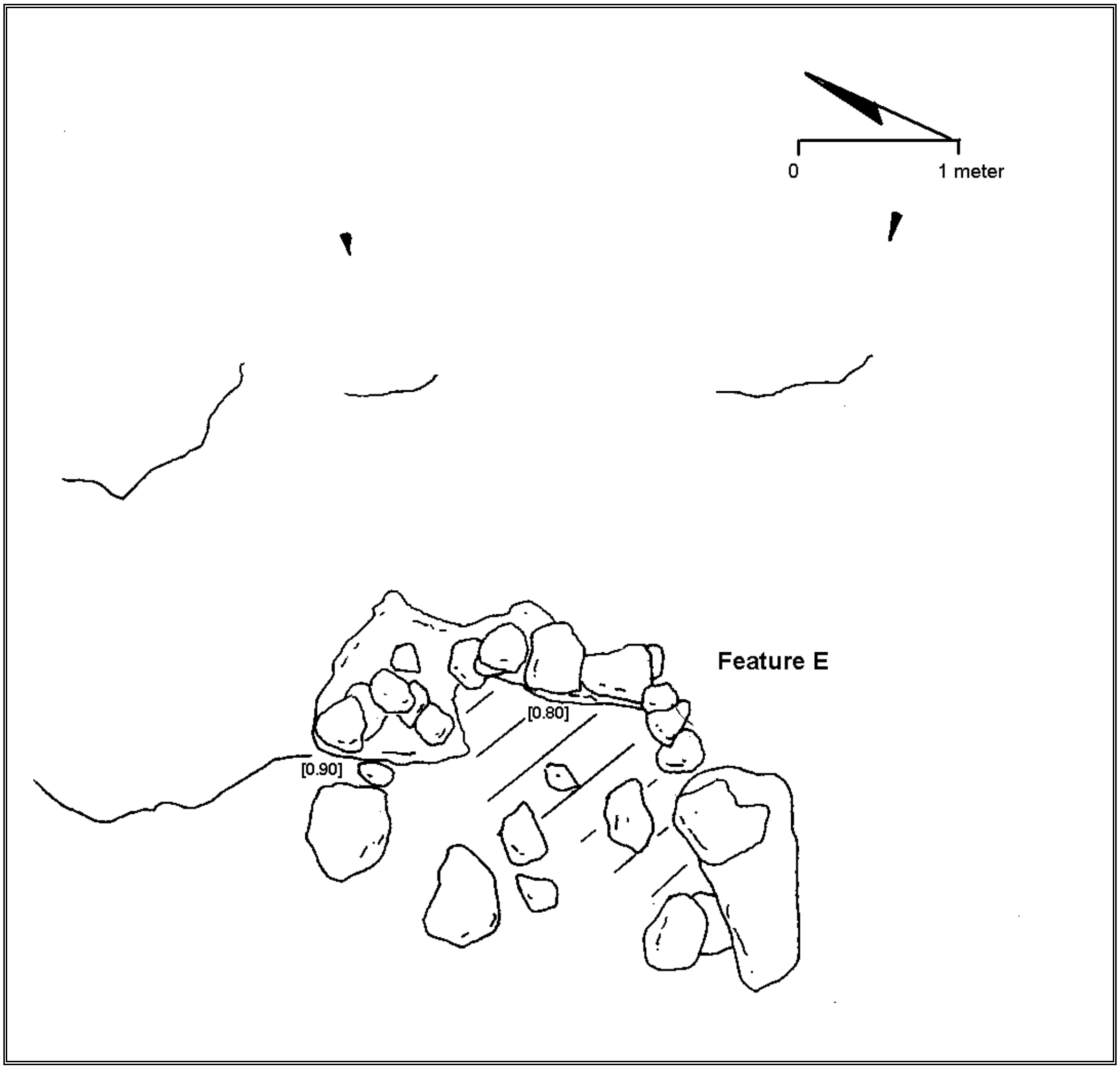


Figure 12 - Plan view of Feature E, Site 5440.

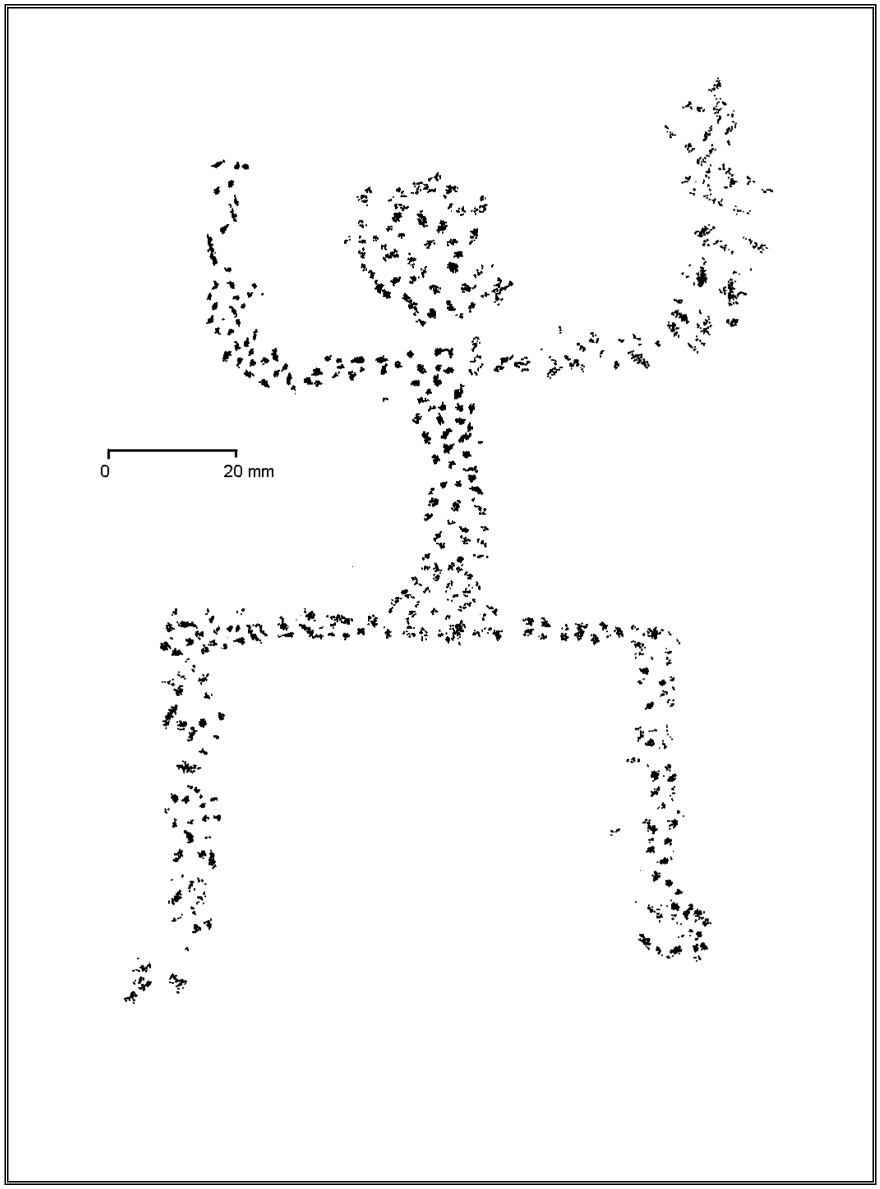


Figure 13 - Drawing of Feature F petroglyph, Site 5440.

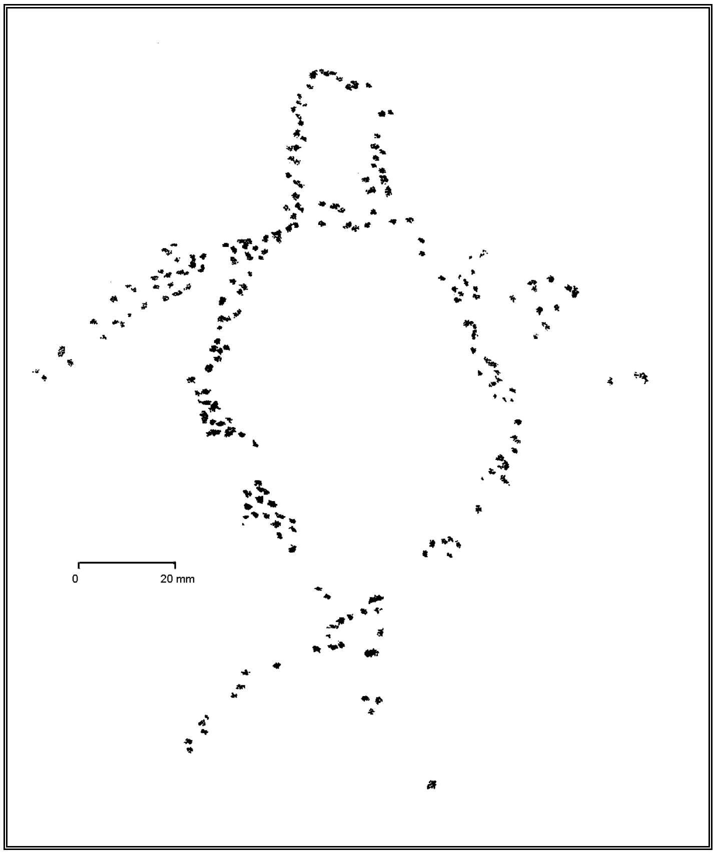


Figure 14 – Drawing of Feature G petroglyph, Site 5440.

Site 5441 [Figure 15]

Site 5441 lies along the southern project boundary c. 5 meters northeast of southeastern-most ¾" pipe corner marker. The site is located at the base of a c. 9-meter high escarpment that lies just to the north of the boundary. The terrain slopes steeply to the southeast from the base of this escarpment. The general area is covered with large talus boulders and loose rubble. Observed endemic plants included *ohelo'ai* (Vaccinium reticulatum) and *kupaoa*. In addition, isolated clumps of unidentified bunch grass were noted.

The overall dimensions of Site 5441 are 4.25 meters in length NE/SW by 1.75 meters width NW/SE. This site consists of two small terrace features that are situated along the base of the escarpment to the southeast of the University of Hawaii Mees Solar Observatory. This site is located in the southeastern portion of the project area, in the near vicinity of the parcel boundary. Both terraces have small oval level areas and minimal stacked rock arrangements on their leading southeastern edges. The features face out to the southeast with a commanding view of the island of Hawai`i.

These two terrace features are located in an exposed portion of the overall project area and do not appear to represent temporary wind shelters. While there was no subsurface excavation carried out at this site, it is tentatively interpreted as a possible ceremonial area. This somewhat speculative assessment is based on the orientation of the two features to the Big Island.

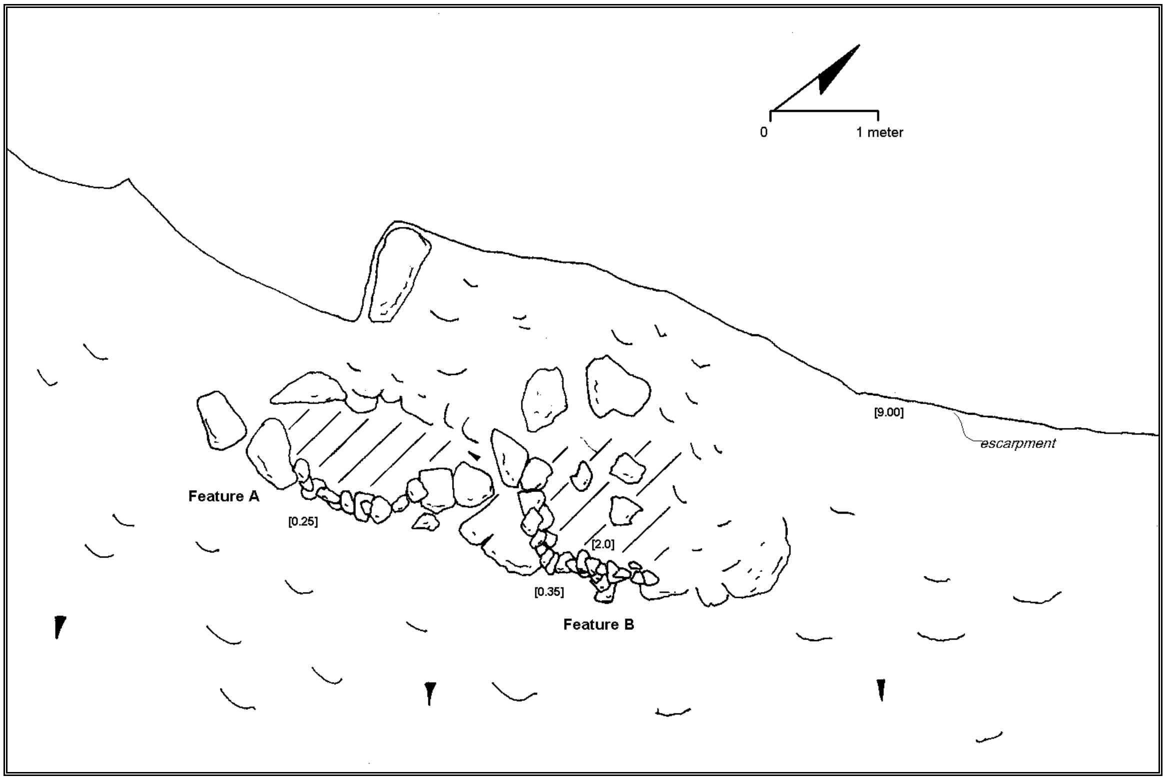


Figure 15 – Plan view of Site 5441.

Site 5442 [Figure 16]

This single component site is situated at the southern edge of the Mees Solar Observatory grade at an elevation of about 9,955 ft AMSL. Site 5442 lies c. 6 meters south of the southwestern corner of the observatory building and about 3 meters north of the upper edge of an approximately 9 meter high escarpment that rims the project area on this portion of the parcel. Evidence of previous bulldozing activities is visible in the immediate vicinity of this site. Previous earthmoving activities associated with the construction of the nearby observatory appear to have impacted the southern edge of this feature. Numerous pushed *a'a* boulders are clustered in close proximity to this site. This location affords a commanding view of the island of Hawaii. Flora present in this portion of the project area includes sparse amounts of *na` ena`e*, nonnative grasses and scattered weeds.

This site consists of a partial rock enclosure that lies at the periphery of a previously graded area to the southeast of the Mees Solar Observatory. The intact portion of this enclosure measures 4.5 meters in length E/W by 3.25 meters in width N/S by a maximum wall height of 0.85 meter. This structure appears to have been partly rebuilt in the relatively recent past. One coral cobble was noted just outside of this enclosure, along with modern materials such as pieces of concrete, metal and bottle glass. There was no subsurface testing carried out at this site. This site is interpreted as a wind shelter that appears to have been modified in relatively recent times.

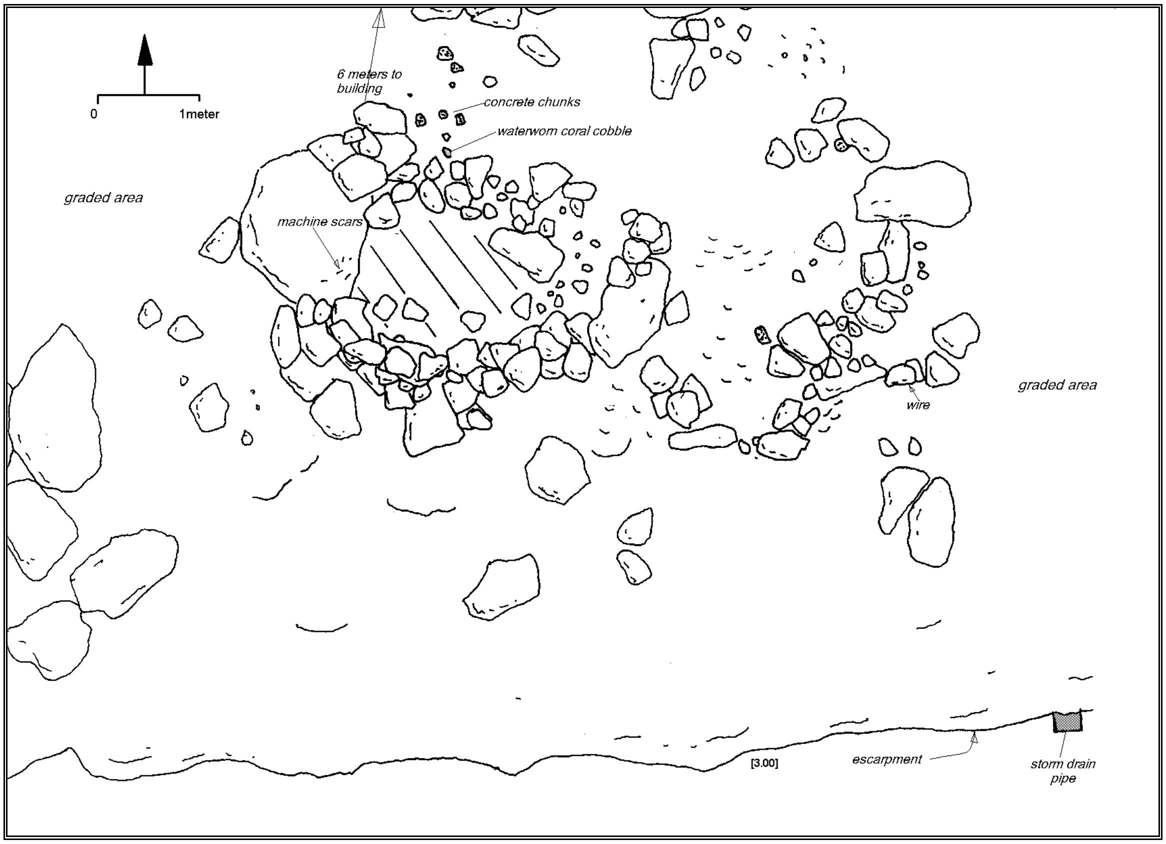


Figure 16 – Plan view of Site 5442.

Site 5443 [Figure 17]

This site remnant lies on the peak of Pu`u Kolekole, and is known as Reber Circle. Site 5443 consists of a concrete and rock foundation that was part of the former radio telescope facility that was built in 1951-1952 by Grote Reber. This facility apparently did not function well, because of signal interference. The bulk of the structure was dismantled about 18 months after the facility was completed. This site is composed of a concrete and rock foundation that is c. 25 meters in diameter, the outer rim of which is up to 1 meter in width and c. 80 cm in height. Approximately 40% of the structure has been impacted by previous earthmoving activities, and the site is in fair to poor condition.

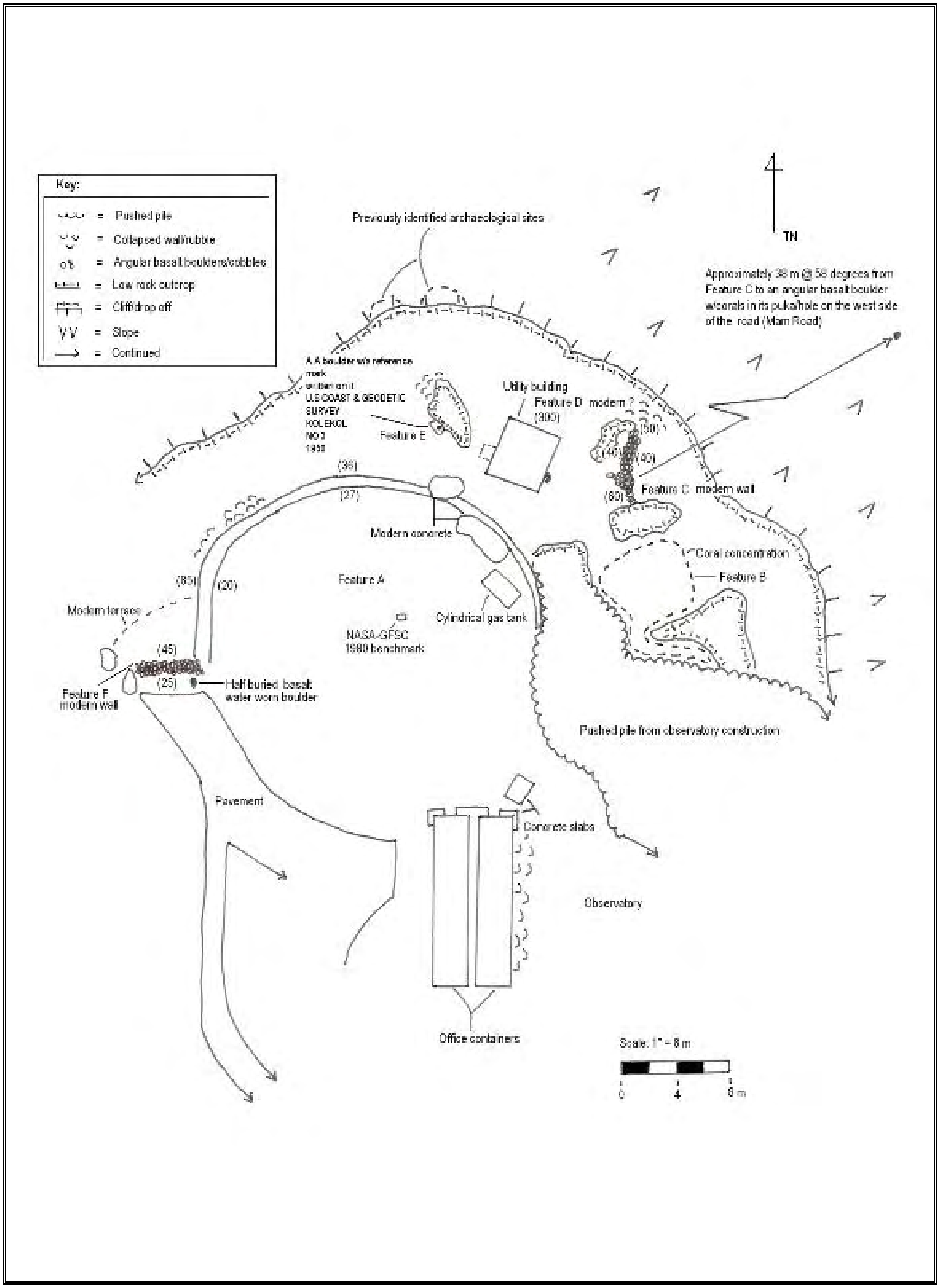


Figure 17 - Plan view of Site 5443.

Sites 50-50-11-2805-2808

As previously mentioned in this report, this site complex was previously documented by Chatters in 1991. During the course of this earlier work, which consisted of a walkover, four archaeological sites were identified, primarily along the western side of Kolekole Hill. These features included 23 temporary shelters and a short, low wall. These wind shelters were typically constructed against the existing rock outcrop of the hill.[14] The various sites are discussed below.

Site 2805 [Figure 18]

This rock wall shelter is located on the northern rocky slope of the uppermost rise of Pu`u Kolekole and c. 41 meters due north of the Kolekole triangulation station that lies at the summit. The site lies at an elevation of about 9,990 feet AMSL. The area around the site is covered with *a'a* talus boulders and cobbles. Observed vegetation in the general site area included scattered *kupaoa* shrubs and isolated clumps of nonnative grasses. The overall dimensions of this site are 3.50 meters N/S by 2.50 meters E/W by up to 1.18 meters in maximum wall height.

Site 2805 consists of a short roughly stacked rock wall section that forms a shallow arch around the western edge of a small level area that measures 2.50 meters in length NE/SW by 1.0 meter in width NW/SE. The feature is set against the base of a low basalt face. The wall is constructed of 3-6 courses of vertically stacked angular *a'a* cobbles and boulders. This site was first interpreted as a wind shelter in the 1990 reconnaissance survey.

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[14] Pipe fencing (without mesh) was installed around these sites in the 1990s, in order to help delineate them. However, there was typically less than a 1 m buffer around the sites. This fencing was recently removed, at the request of Mr. Charles Kauluwehi Maxwell, Project Cultural Consultant.

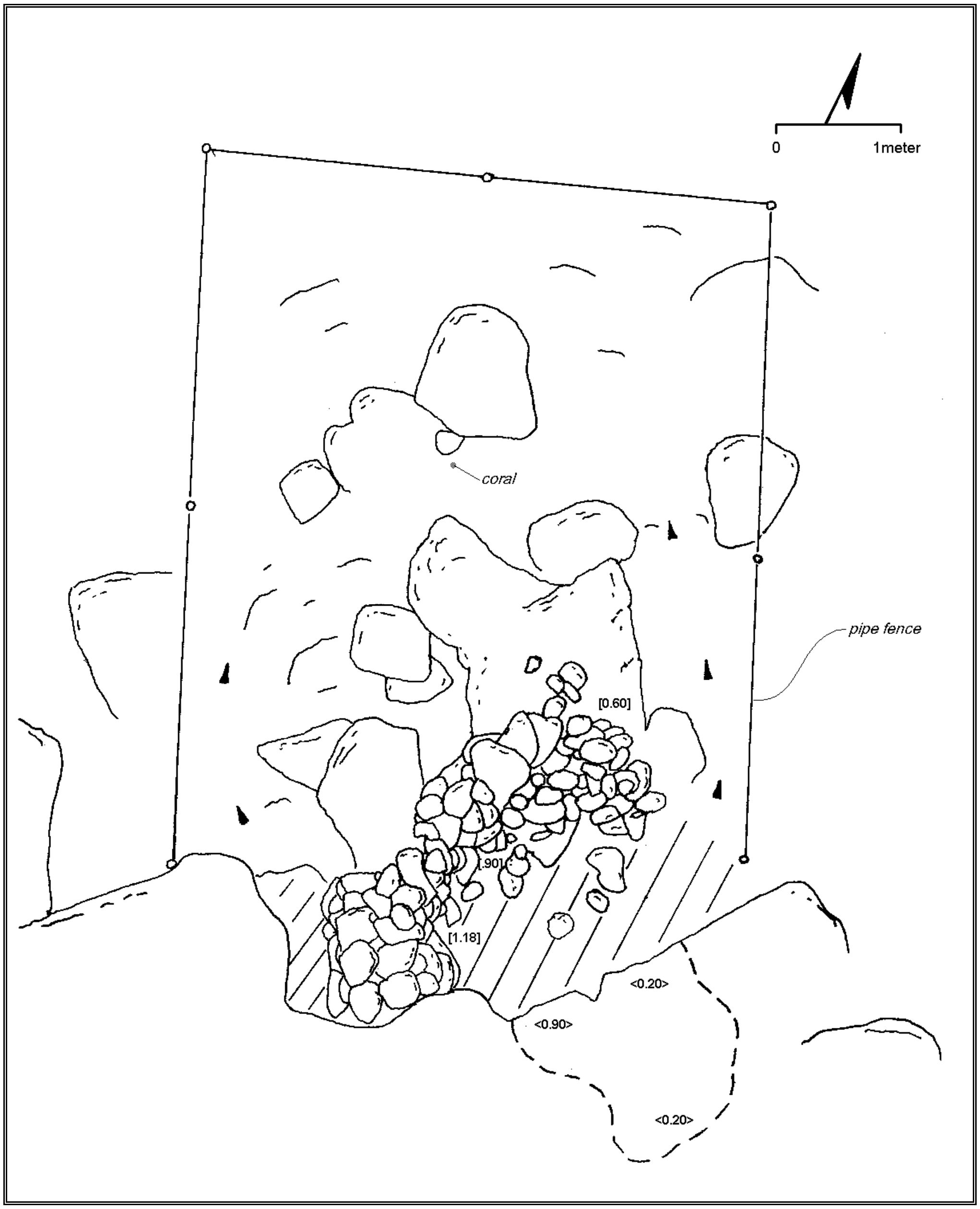

Figure 18 – Plan view of Site 2805.

Site 2806 [Figure 19]

This site is located within the Science City complex on the northwestern facing slope of the uppermost rise of Pu`u Kolekole, and some 48 meters northwest of the Kolekole triangulation station at the summit. The AEOS building lies c. 35 meters to the northwest. The area surrounding the site is covered with large *a'a* boulders that have broken off from a c. 3-meter high vertical basalt face that is upslope of Site 2806.

Site 2806 consists of a rough rock alignment with minimal stacking of 1-2 courses of angular *a'a* boulders and cobbles. This partial enclosure measures 2.50 meters E/W in length by 2.20 meters N/S in width by 0.30 meter in maximum wall height. One piece of branch coral was noted c. 3 meters to the east of the site. This site is also a wind shelter.

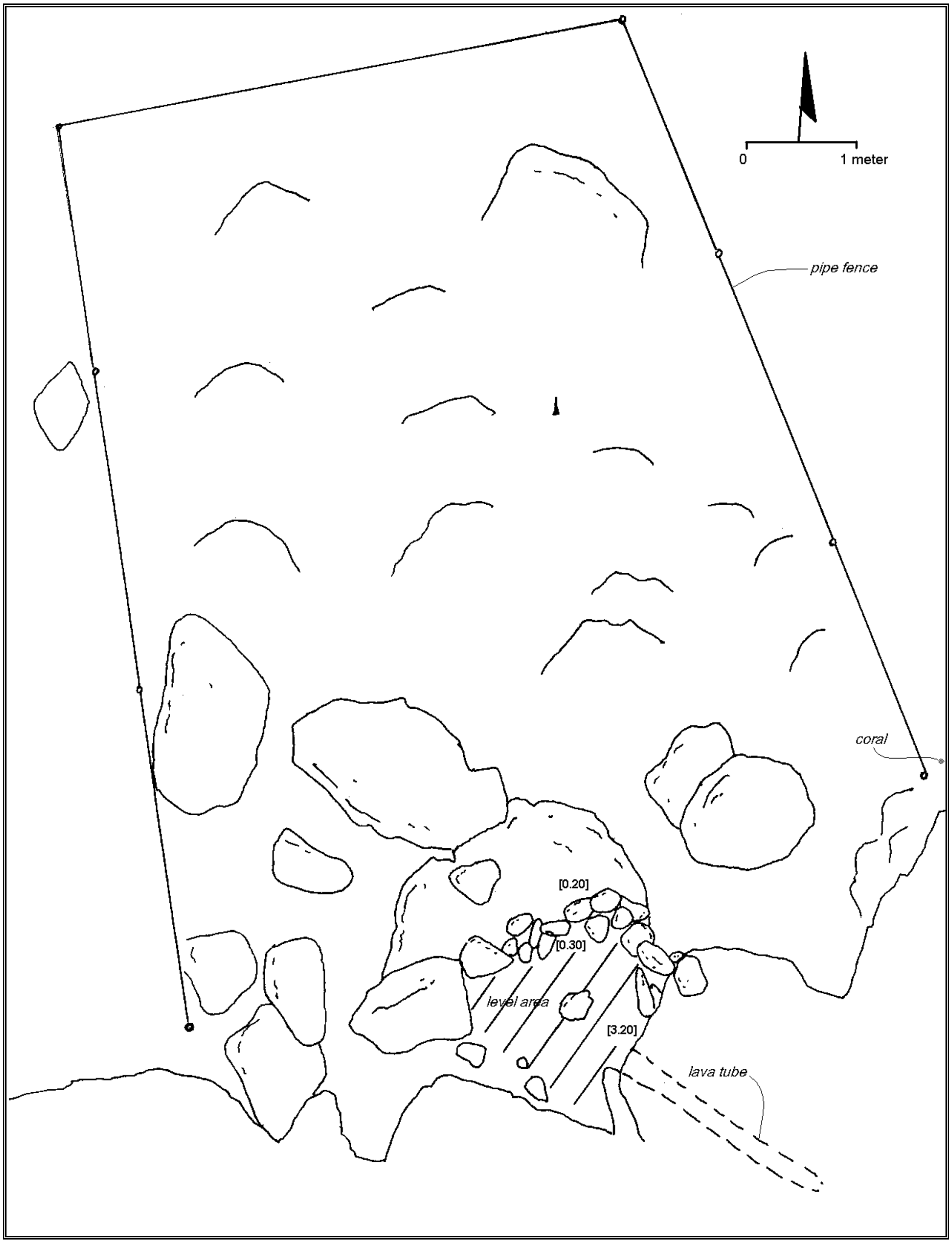

Figure 19 – Plan view of Site 2806.

Site 2807 [Figure 20]

Site 2807 is located approximately 48 meters to the west of the Pu`u Kolekole summit and the triangulation station. This site is situated on the very rocky WNW facing slope directly east of another telescope facility. The site lies at an elevation that ranges from about 9,980 feet AMSL near the crest of Pu`u Kolekole to 9,960 AMSL at the base of the slope. The only vegetation noted in the vicinity of the site consisted of scattered *na'ena'e* shrubs and nonnative bunch grasses. Modern material culture remains noted on the surface included broken bottle glass, metal, plastic and wood.

This site consists of 16 (Features A-P) separate level areas, each of which has some form of rock modification. The modifications consist of simple rock alignments or roughly stacked low walls. Some of the features resemble terraces with minor modifications along the western or down-slope edge of the level areas. Others features along the base of the slope have been partially encircled by rock alignments. A few of the features have marginal overhangs near the edge of the level areas. Many of the features are within 2 meters of one another. The overall dimensions of this site are c. 48 meters N/S in length by 20 meters E/W in width. A sling stone that was noted in Feature J during the earlier reconnaissance survey was not relocated. This site is interpreted as a complex of wind shelters. This site is tentatively interpreted as a precontact temporary wind shelter complex, portions of which may well have been utilized in post-contact times.

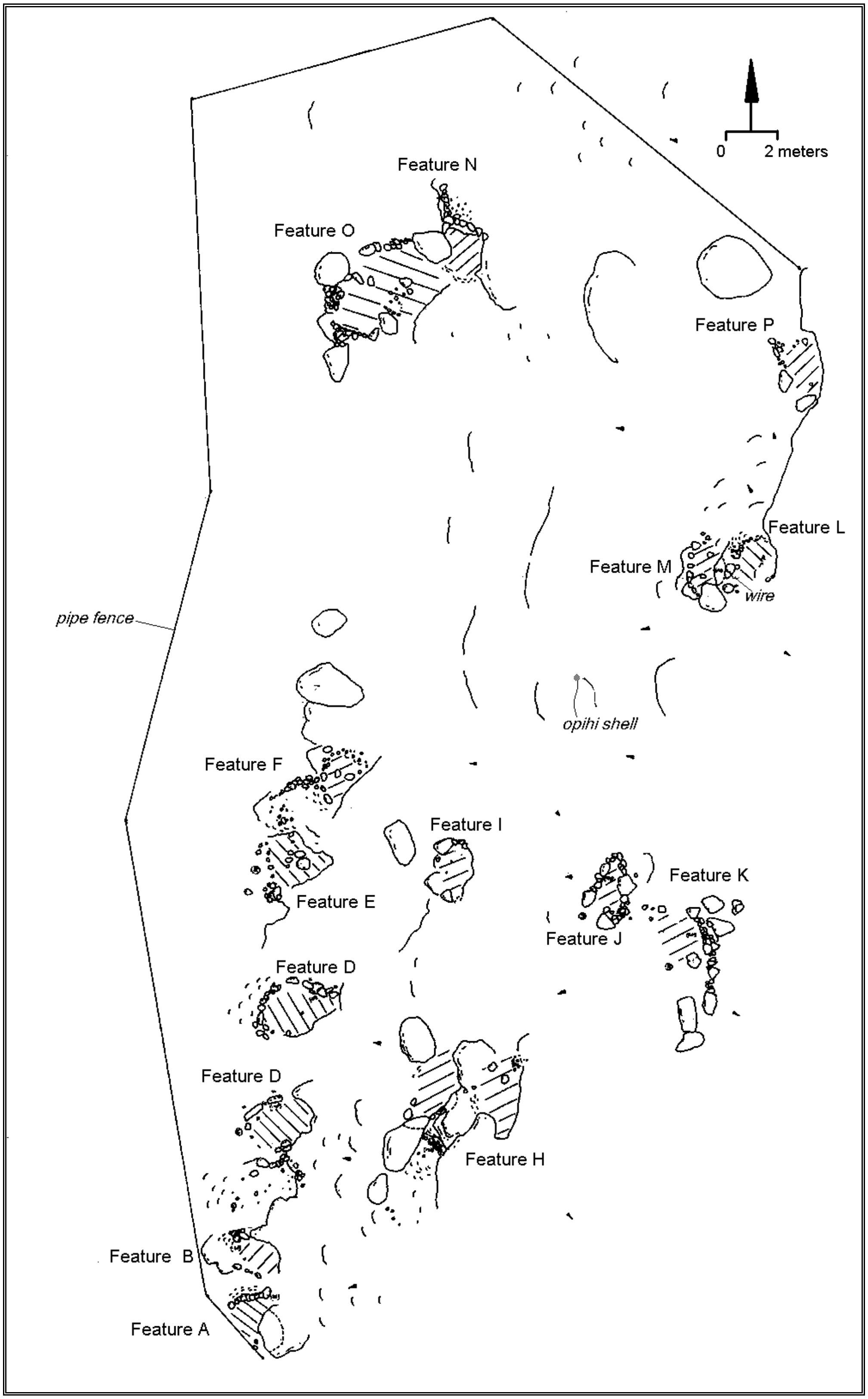

Figure 20 - Plan view of Site 2807.

Site 2808 [Figure 21]

Site 2808 (Features A-C) is located near the base of the western slope of the prominent rocky hill that lies directly to the west of the Mees Solar Observatory. This site lies at about 9,960 feet AMSL. The surrounding terrain consists of an exposed and weathered *a'a pu`u* that is covered with talus boulders and rubble. Vegetation noted in the area consisted of scattered *na'ena'e* and *kupaoa* shrubs.

This site is composed of three small level areas that have apparently been cleared of loose rock. Each of these has some type of rock modification in the form of walls or simple clear piles apparently designed to create a place to rest out of the wind. Overall site dimensions are c. 13 meters NE/SW by 7 meters NW/SE. Given the location of this site, it is also interpreted as a wind shelter complex that was possibly first utilized in precontact times.

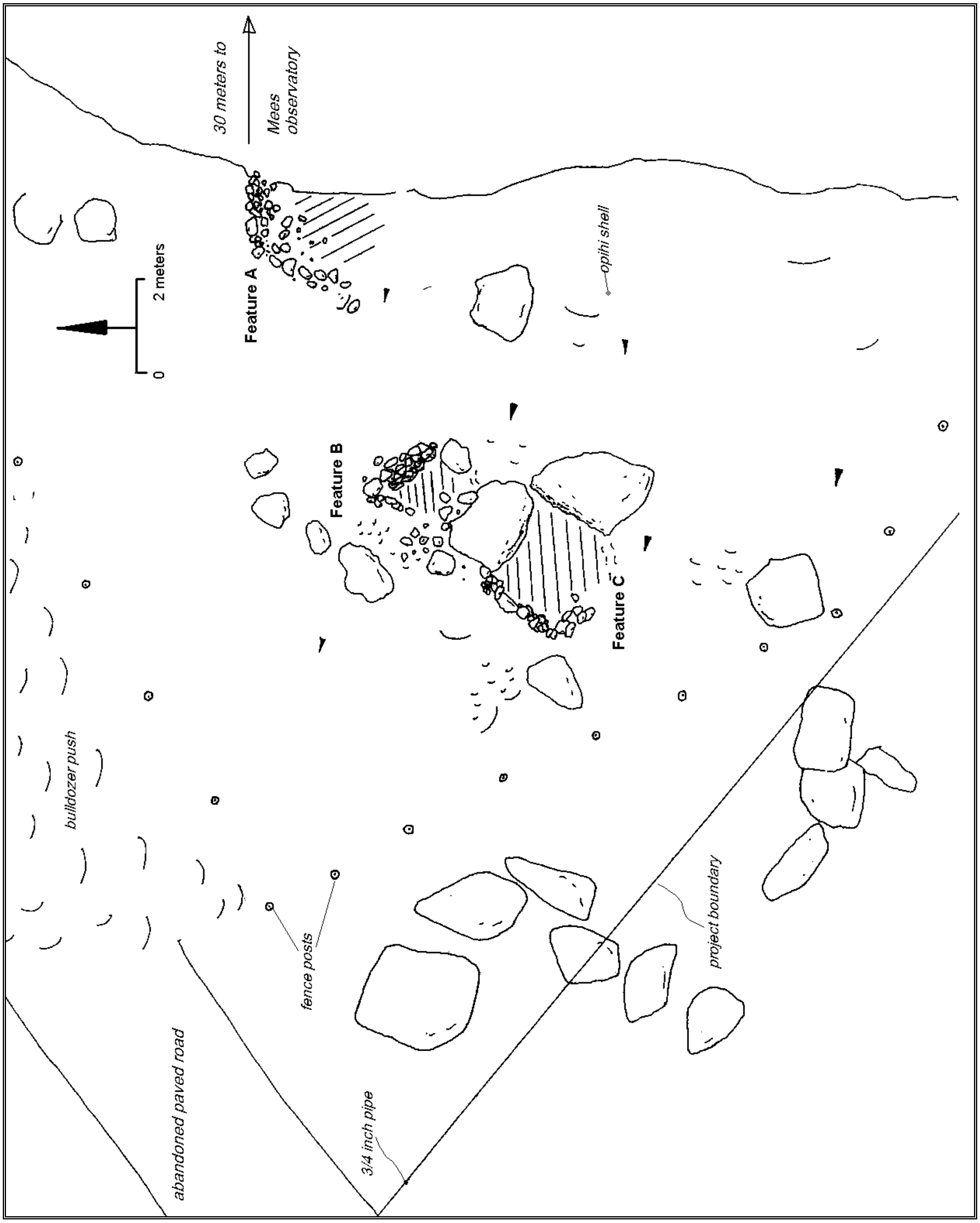

Figure 21 – Plan view of Site 2808.

Site 4835 and Site 4836 [Figure 22]

The previously documented portion of Site 4836 consists of 5 features (A-E) that are interpreted as wind shelters. These features, along with Site 4835[15] lie around the base of a small *pu`u*. An additional feature, a probable trail segment remnant, was noted adjacent to the previously identified Site 4836. Given its proximity to the site, this trail has been designated Feature F.

Feature F consists of a pathway that has been purposefully cleared of rock. Numbers of large cobbles and small boulders averaging 50-60 cm across are roughly aligned along the southern edge of the pathway for much of its length. This feature runs in an east/west direction along the southern edge of Site 4836. The path becomes apparent c. 4 meters to the south of Feature C of Site 4836. The eastern end of the path appears to have been impacted by the construction of an abandoned paved access road. Feature F is c. 22 meters in length E/W by an average of 1.10 meters in width N/S. This feature is in generally good condition, although its eastern and western ends were likely altered by previous earthmoving activities.

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[15] Both Sites 4835 and 4836 were fully documented in the CSH 2000 survey, and were not intensively reexamined in our inventory survey. Site 4835 consists of two small burn pits, and is interpreted as a post-contact (possible World War II era or later) site.

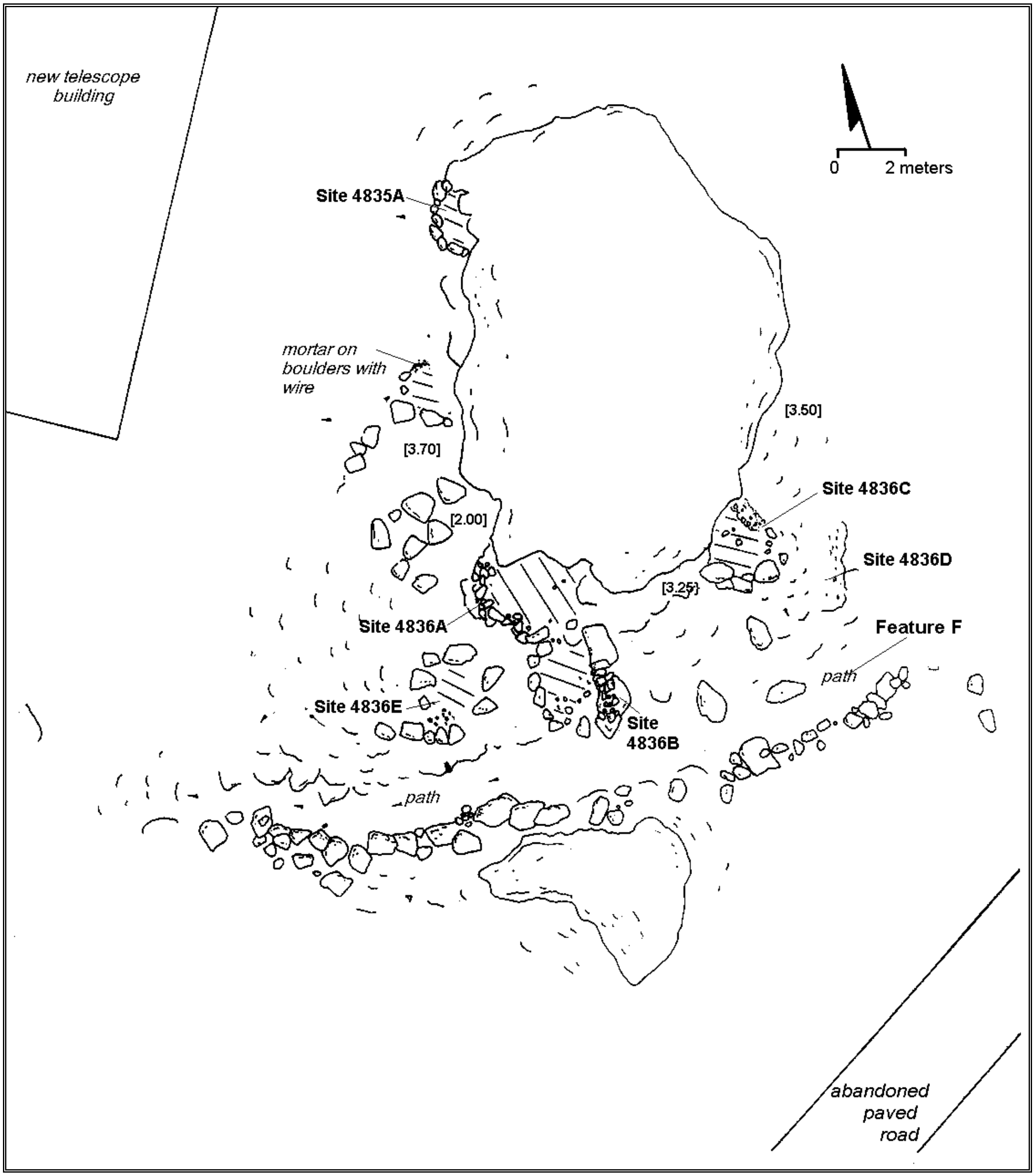

Figure 22 – Plan view of Sites 4835 and 4836 (including Feature F path of Site 4836).

TABLE 1
Proposed Site Buffers for Science City Project

SIHP[16] Site Number	Features	Description	Function	Draft Buffer Area (meters)	Remarks
5438	A	Wind shelter	Temporary habitation	5	Partial rock wall enclosure in lee of vertical escarpment
	B	Terrace/Wind shelter	Temporary habitation	5	Rough terrace built at leeward base of vertical escarpment
	C	Terrace-like Wind shelter	Temporary habitation	5	Small terrace-like level area w/ low escarpment along NE edge
	D	Terrace-like Wind shelter	Temporary habitation	5	Small terrace-like level area w/ crude stacking along northern edge
	E	Terrace-like Wind shelter	Temporary habitation	5	Small terrace-like level area w/ vertical escarpment at SE edge
	F	Rock pile	Undetermined/ Possible clear pile	5	Rock pile with associated level area
5439	A	Rock Shelter	Temporary habitation	5	Marginal shelter restricted overhang
	B	Rock shelter	Temporary habitation	5	Marginal shelter restricted overhang
	C	Wind shelter	Temporary habitation	5	Low rock wall built on windward side of level area
	D	Wind shelter	Temporary habitation	5	Crude rock arrangement around level area
	E	Wind shelter C-shape	Temporary habitation	5	Low rock wall wrapping windward side of level area
	F	Wind shelter C-shape	Temporary habitation	5	Low rock wall wrapping windward side of level area
	G	Rock pile	Undetermined	5	Rock pile in crevice between boulders
	H	Wind shelter C-shape	Temporary habitation	5	Small level area with stacking along windward edge
	I	Wind shelter C-shape	Temporary habitation	5	Small level area in lee of boulders, crude stacking on windward edge
	J	Wind shelter	Temporary habitation	5	Small level area in lee of boulders w/ crude stacking in crevice
	K	Wind shelter	Temporary habitation	5	Level area in lee of boulders w/ crude stacking and alignment.
	L	Wind shelter C-shape	Temporary habitation	5	Small level area w/ crude wall along windward edge
	M	Wind shelter C-shape	Temporary habitation	5	Small level area w/ crude wall along windward edge

[16] **SIHP** = **S**tate **I**nventory of **H**istoric **P**laces. Site numbers prefaced by 50-50-11- 50=Stare 0f Hawaii, 50=Maui; 11 = Kilohana quadrangle.

Table 1 cont.

5440	A	Wind shelter Enclosure	Temporary habitation	5	Relatively substantial rock wall enclosing two small level areas.
	B	Wind shelter C-shape	Temporary habitation	5	Rock wall arcing around windward edge of level area abutting outcrop
	C	Wind shelter natural terrace	Temporary habitation	5	Relatively large level area in lee of escarpment w/ crude rock alignments
	D	Wind shelter C-shape	Temporary habitation	5	Small level area in lee of boulders w/ added crude stacking
	E	Platform	Possible burial	10	Cobble concentration delineated by boulder alignments on two sides
	F	Petroglyph	Rock art/ceremonial	5	Triangular torso human image on boulder
	G	Petroglyph	Rock art/ceremonial	5	Turtle image on boulder
5441	A	Terrace	Temporary habitation? Possible ceremonial?	5	Small level area on east facing slope w/ rough alignment along leading edge
	B	Terrace	Temporary habitation? Possible ceremonial?	5	Small level area on east facing slope w/ rough alignment along leading edge
5442	Single	Rock wall partial enclosure	Temporary habitation	5	Small level area w/ stacked rock wall tied in w/ existing boulders
5443	Single	Foundation	Former radio telescope foundation	NA	Circular concrete foundation
2805	Single	Wind shelter	Temporary habitation	5	Partial enclosure, crude wall in lee of escarpment
2806	Single	Wind shelter	Temporary habitation	5	Partial enclosure, rough wall in lee of escarpment
2807	A	Wind shelter	Temporary habitation	5	Level area with boulder alignment on windward edge
	B	Wind shelter	Temporary habitation	5	Level area w/ rock pile
	C	Wind shelter (C-shape)	Temporary habitation	5	Level area w/ upright slabs on windward edge
	D	Wind shelter (C-shape)	Temporary habitation	5	Level area w/ boulder alignment on wind edge
2807	E	Wind shelter	Temporary habitation	5	Level area in lee of outcrop
	F	Wind shelter	Temporary habitation	5	Level area w/ linear clearing pile
	G	Wind shelter	Temporary habitation	5	Level area on slope in lee of outcrop w/ modified outcrop
	H	Wind shelter	Temporary habitation	5	Level area on slope in lee of outcrop
	I	Wind shelter	Temporary habitation	5	Level area w/ minimal stacking on windward edge
	J	Wind shelter	Temporary habitation	5	Crude rock wall partially encloses small level area
	K	Wind shelter	Temporary habitation	5	Crude rock wall built along wind edge of a cleared level area
	L	Wind shelter/terrace	Temporary habitation	5	Natural terrace in lee of slope cleared of rock

Table 1 cont.

	M	Wind shelter	Temporary habitation	5	Level area on slope with boulder alignment
	N	Wind shelter	Temporary habitation	5	Level area in lee of modified outcrop
	O	Wind shelter	Temporary habitation	5	Level area in lee of boulder w/ crude stacking on perimeter
	P	Wind shelter	Temporary habitation	5	Level area w/ altered crude stacking on perimeter
2808	A	Wind Shelter	Temporary habitation	5	Level area w/ rubble on windward edge
	B	Wind shelter	Temporary habitation	5	Level area w/ stacked rock on windward edge
	C	Wind shelter	Temporary habitation	5	Level area w/ boulders on windward edge
4835	A	Trash pit	Burn pits	5	Possible WWII era, modern trash observed
	B	Trash pit	Burn pits	5	Possible WWII era, modern trash observed
4836	A	Enclosure	Temporary habitation	5	Level area with some stacked rocks
	B	Rock wall with level area	Temporary habitation	5	Level area with a wall of stacked rocks
	C	Terrace/enclosure	Temporary habitation	5	Level area with a wall of stacked rocks
	D	Terrace/level area	Temporary habitation?	5	Level area with little modification
	E	Terrace	Temporary habitation	5	Level area with some single low stacking
	F	Path	Pedestrian traffic	5	Pathway w/ boulder alignment at edge

TABLE 2
Proposed Mitigation Treatment for Archaeological Sites within the Science City Project Area

SIHPSite 50-50-11-	Significance Criterion[17]	Site Type/Function (No. of Features)	Proposed Mitigation Treatment (Comments)
5438	d	Semi-enclosure, 4 terrace features and 1 possible rock pile (6)	Passive Preservation
5439	d	Two rock shelters, 11 rock wall shelters or C-shapes (13)	Passive Preservation
5440	d, e	Two rock wall enclosures, 1 terrace-like feature, 1 small platform-like feature (possible burial), 1 rock wall shelter or C-shape, and 2 petroglyphs on boulders (7)	Passive Preservation
5441	d, e	Two terrace features (2) at base of escarpment—both face the island of Hawai`i	Passive Preservation
5442	d	Semi-enclosure (1)	Passive Preservation
5443	a, d	Radio telescope facility remnant-Reber Circle	Passive Preservation or data recovery
2805	d	Rock wall shelter (1)	Passive Preservation
2806	d	Rock wall shelter (1)	Passive Preservation
2807	d	Rock wall shelters and prepared level areas w/ modification or alignments (16)	Passive Preservation
2808	d	Prepared level areas w/ modified outcrops or clear piles (3)	Passive Preservation
4836	d, e	Prepared level areas w/ modified outcrops and low walls, trail (6)	Passive Preservation

[2]Criterion: a = associated with events that have made an important contribution to our island's history; b = associated with the lives of persons important in our past; c = embodies the distinctive characteristics of a type, period, or method of construction; represents the work of a master; or possesses high artistic value; d = has yielded or is likely to yield information important for research on pre- or post-contact history; e = has an important traditional cultural value to the native Hawaiian people or another ethnic group in Hawaii.

PRESERVATION PLAN FOR SITES CONTAINED WITHIN THE SCIENCE CITY PROJECT AREA

The plan outlined here follows suggestions in the SHPD rules (HAR Title 13, Subtitle 6, Chapter 148, pp. 2-5).

Identification of Site(s) to be preserved

Ten of the 11 sites are recommended for passive "as is" preservation on the Science City parcel. These various cultural resources include: 1) Sites 50-50-11-2805 through 2808; 2) Sites 4835 and 4836; and 3) Sites 5438 through 5443. The first group of sites was identified in a 1991 archaeological reconnaissance survey of a portion of the project area (Chatters, 1991). All of these sites are interpreted as wind shelters of various shapes and sizes. As noted earlier in this preservation plan, we carried out additional inventory level documentation at these sites per discussions with Dr. Melissa Kirkendall of the SHPD Maui office.

The second study was conducted by Cultural Surveys Hawaii, Inc., in conjunction with the planned construction of the now-built Faulkes Telescope facility (Bushnell and Hammatt, 2000). This more recent project identified two previously unrecorded sites—4835 and 4836, with a total of seven features. Site 4836 consists of 3 terraces, a rock enclosure, 2 leveled areas and a rock wall—all constructed against an exposed rock outcrop.[18] Five of the features are interpreted as temporary shelters, while the 2 leveled areas were of indeterminate usage.

As noted earlier, Xamanek Researches carried out an inventory survey of the entire 18.1 acre parcel in 2002-2003 (Fredericksen and Fredericksen, April 2003). A total of six previously unrecorded sites (50-50-11-5438 through 5443) were located during the course of this most recent inventory survey. These sites consist of wind shelters, two petroglyph images, a possible burial feature, and an historic foundation of an old radio telescope facility—Reber Circle. Supplemental information was obtained from Sites 2805-2808 per discussions with Dr. Melissa Kirkendall of the SHPD Maui

[18] Xamanek Researches identified a trail remnant at the previously recorded Site 4836 during our inventory survey fieldwork in 2002. This feature had not been previously noted in Bushnell and Hammatt, 2000. We subsequently recorded this feature per the direction of Dr. Melissa Kirkendall, SHPD staff archaeologist, and Mr. Charles Kauluwehi Maxwell, Chair of the Maui/Lanai Islands Burial Council. This trail remnant was assigned a feature number (F).

office. In addition, as noted above, a trail segment was recorded at Site 4836 and designated as Feature F.

The various preservation actions for the Science City parcel are discussed below.

Preservation Tasks

Recommended mitigation measures for the above sites consist of passive "as is" preservation. While many of these sites separately have limited interpretive value, they as a group represent a relatively intact portion of the cultural landscape of a portion of Haleakala. However, given the cultural sensitivity of the area as well as various security issues, there are no identification signs proposed for the sites that are located within the Science City project area**.** The following preservation measures have been developed in consultation with Dr. Melissa Kirkendall, SHPD Maui staff archaeologist, and the project's Cultural Specialist, Mr. Charles Kauluwehi Maxwell.

Short-term and interim preservation measures

To help ensure protection of the cultural features in close proximity to the research facilities and during possible future construction of the proposed Advanced Technology Solar Telescope (ATST) project, it is recommended that the following actions be taken.

- It is recommend that any invasive nonnative plants be removed (i.e. flush cut) from the recommended site preservation buffer areas and the roots left in place to rot. This methodology will help minimize potential disturbance to the sites slated for preservation.

- Given that the sites discussed in this preservation plan are contained in portions of Science City that are typically somewhat isolated from existing structures, the probability of future disturbance appears to be relatively low. However, due care should be exercised by the staff of the Air Force Facility, in order to avoid inadvertent impacts to components of Sites 5439 and 5440, which are located down slope from these installations. During our earlier inventory survey, we noted some apparent construction debris that may have covered one or more features down slope from these facilities. In addition, Site 5441 lies at the base of an escarpment that is near the potential impact area for the ATST facility, which may be built in the future. Again, due care should be exercised in the event that this facility is situated near the UH Mees Solar Observatory. Finally, Site 5442, in particular, is located in close proximity to this facility, and due care should be exercised during ongoing operations.

- In the event that Reber Circle (Site 5443) is dismantled, and Pu`u Kolekole is restored to its natural state, it will be necessary to ensure that debris does not inadvertently roll down slope onto portions of Sites 2805 and 2806. Some sort of construction fencing and/or dirt barrier should be installed upslope from these sites prior to any earthmoving activities in this portion of the Science City project area.

- It is recommended that all of the facilities have a copy of the overall project map that includes the locations of various cultural resources that have been identified within the Science City project area. This will help ensure that sites are not inadvertently impacted by actions associated with any of these facilities.

Long-term preservation

As noted earlier in this Plan, all sites are recommended for passive "as is" preservation. There is no planned access trail to any of the following sites anticipated at present. Recommended long-term actions for each of these sites are listed below:

Site 5438 (refer to Figure 3)

1. This complex of wind shelters and a possible rock clear pile is located near the northwestern corner of the rectangular project area, and lies down slope (north) of the AEOS Facility. Site 5438 is composed of two semi-enclosures or wind shelters (Features A and F), and 4 terrace/platforms (Features B through E). No signage is envisioned for this site at this time, due to cultural and security concerns.

2. Provisions for limited access to the general site area will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. At this time, no landscaping actions are recommended for the site, except for the possible removal (via flush cutting) of any invasive plant species that may be in the area or become established in the future. .

4. A c. 5-meter (15-foot) preservation area buffer around the perimeter of this site complex is recommended.

Site 5439 (refer to Figure 4)

1. This site complex consists of 22 features (A-M). These features include 2 rock wall shelters that incorporate small overhangs referred to as dew shelters in this report (Features A and B), 10 rock wall shelters (Features C through M), and 1 possible shelter remnant (rock pile). This site lies down slope (north) of the Air Force Facilities. No signage is envisioned for this site at this time, due to cultural and security concerns.

2. Provisions for access to the general site area will be made for native Hawaiian members of the community who wish to visit it for traditional cultural

purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the possible removal (via flush cutting) of invasive non-native plant species within the site preservation area.

4. A preservation area buffer of c. 5 meters (15 feet) is recommended for this site.

Site 5440 (refer to Figure 7)

1. This complex includes four wind shelters (Features A-C and E), a possible burial (Feature D), and two petroglyph images (Features F and G). This site also lies down slope (north) of the Air Force Facilities. No signage is envisioned for this site at this time, due to cultural and security concerns.

2. Provisions for limited access to this site will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the removal (via flush cutting) of invasive, non-native plant species from within the site preservation area.

4. A preservation area buffer of c. 5 meters (15 feet) is recommended for the bulk of this site. However, a buffer of c. 10 meters (30 ft) is suggested for Features D (possible burial), and Features F and G (petroglyphs).

Site 5441 (refer to Figure 15)

1. Site 5441 lies along the southern project boundary c. 5 meters northeast of southeastern-most ¾” pipe corner marker. This site consists of two small terrace features that are situated along the base of the escarpment to the southeast of the University of Hawaii Mees Solar Observatory. No signage is envisioned for this site at this time, due to cultural and security concerns.

2. Provisions for limited access to this site will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the removal (via flush cutting) of invasive, non-native plant species from within the site preservation area.

4. A preservation area buffer of c. 5 meters (30 feet) is recommended for this isolated site.

Site 5442 (refer to Figure 16)

1. This single component site consists of a walled wind shelter. It is situated near the southern corner of the UH Mees Solar Observatory and lies at the edge of a high escarpment at an elevation of about 9,955 ft AMSL. No signage is envisioned for this site at this time, due to cultural and security concerns.

2. Provisions for limited access to this site will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the removal (via flush cutting) of invasive, non-native plant species from within the site preservation area.

4. A preservation area buffer of c. 5 meters (15 feet) is recommended for this site.

Site 2805 (refer to Figure 18)

1. This rock wall shelter is located on the northern rocky slope of the uppermost rise of Pu`u Kolekole and c. 41 meters due north of the Kolekole triangulation station that lies at the summit. The site lies at an elevation of about 9,990 feet AMSL. Site 2805 consists of a short roughly stacked rock wall section that forms a shallow arch around the western edge of a small level area. No signage is envisioned for this wind shelter at this time, due to cultural and security concerns.

2. Provisions for limited access to this site will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the removal (via flush cutting) of invasive, non-native plant species from within the site preservation area.

4. A preservation area buffer of c. 5 meters (15 feet) is recommended for this site.

Site 2806 (refer to Figure 19)

1. This site is located within the Science City complex along the northwestern facing slope of the uppermost rise of Pu`u Kolekole, and some 48 meters northwest of the Kolekole triangulation station at the summit. The AEOS building lies c. 35 meters to the northwest. This partial enclosure is also interpreted as a wind shelter, and no signage is envisioned for this feature, because of cultural and security concerns.

2. Provisions for limited access to this site will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the removal (via flush cutting) of invasive, non-native plant species from within the site preservation area.

4. A preservation area buffer of c. 5 meters (15 feet) is recommended for this site.

Site 2807 (refer to Figure 20)

1. Site 2807 is located approximately 48 meters to the west of the Pu`u Kolekole summit and the triangulation station. This complex is situated on the very rocky WNW facing slope directly east of another telescope facility. The site lies at an elevation that ranges from about 9,980 feet AMSL near the crest of Pu`u Kolekole to 9,960 AMSL near the base of its slope. This complex consists of 16 (Features A-P) separate level areas, each of which has some form of rock modification. These various features are interpreted as wind shelters, and no signage is envisioned for this site, because of cultural and security concerns.

2. Provisions for limited access to this site will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the removal (via flush cutting) of invasive, non-native plant species from within the site preservation area.

4. A preservation area buffer of c. 5 meters (15 feet) is recommended for this site.

Site 2808 (refer to Figure 21)

1. Site 2808 consists of Features A-C, which are interpreted as wind shelters. This site is located near the base of the western slope of the prominent rocky hill that lies directly to the west of the UH Mees Solar Observatory. This site lies at about 9,960 feet AMSL. The site is composed of three small level areas that have apparently been cleared of loose rock. Each of these has some form of rock modification (i.e. walls or simple clear piles). No signage is envisioned for this feature, because of cultural and security concerns.

2. Provisions for limited access to this site will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the removal (via flush cutting) of invasive, non-native plant species from within the site preservation area.

4. A preservation area buffer of c. 5 meters (15 feet) is recommended for this site.

Site 4836[19] (refer to Figure 22)

1. The previously documented portion of Site 4836 consists of 5 features (A-E) that are interpreted as wind shelters. These features, along with Site 4835 lie around the base of a small *pu`u*. An additional feature, a probable trail segment remnant, was noted adjacent to the previously identified Site 4836. Given its proximity to the site, this trail has been designated Feature F. Feature F consists of a pathway that has been purposefully cleared of rock. As with all of the other sites in the Science City project area, no signage is envisioned for this feature, because of cultural and security concerns.

2. Provisions for limited access to this site will be made for native Hawaiian members of the community who wish to visit it for traditional cultural purposes. No formal access for the general public is envisioned for this site at this time, due to cultural and security concerns.

3. No landscaping recommendations are proposed at this time other than the removal (via flush cutting) of invasive, non-native plant species from within the site preservation area.

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[19] Site 4835 consists of two burn pits (possible WWII era and later). This site lies in close proximity to Site 4836. It is not discussed in this section, because of its possible more recent origin. However, the UH Institute of Astronomy has already agreed to preserve it. As a result, this site will be passively preserved along with Site 4836.

4. A preservation area buffer of c. 5 meters (15 feet) is recommended for this site.

Perpetual Maintenance and Access

It is anticipated that the preservation areas of the sites discussed in this plan will have minimal maintenance requirements, given the high altitude of the Science City project area. However, in the event that invasive plants become established within the project area, hand clearing (i.e. flush cutting) is recommended.

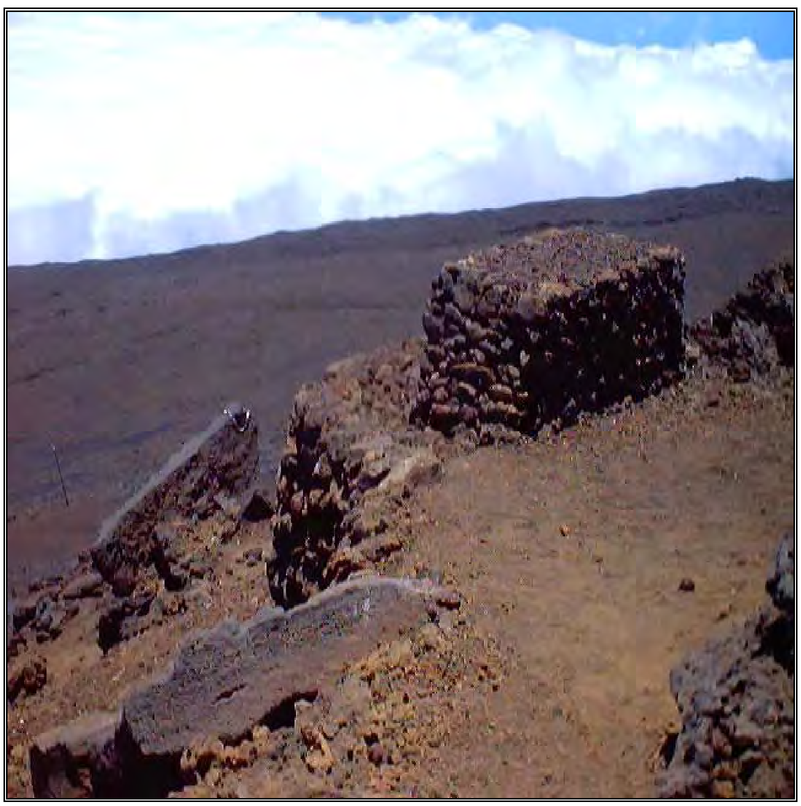
Signage

As previously noted, there is no signage is recommended for individual sites discussed in this preservation plan. While all of the sites will be placed in passive “as is” preservation, it is felt that signage could potentially draw unwanted attention to these sites, possibly causing negative impacts and/or security concerns. As noted previously, the project’s Cultural Specialist, Mr. Charles Kauluwehi has indicated that because of the cultural sensitivity of these sites signage is inappropriate. Finally, there are security issues that have been raised by personnel at some of the facilities (AEOS, in particular).

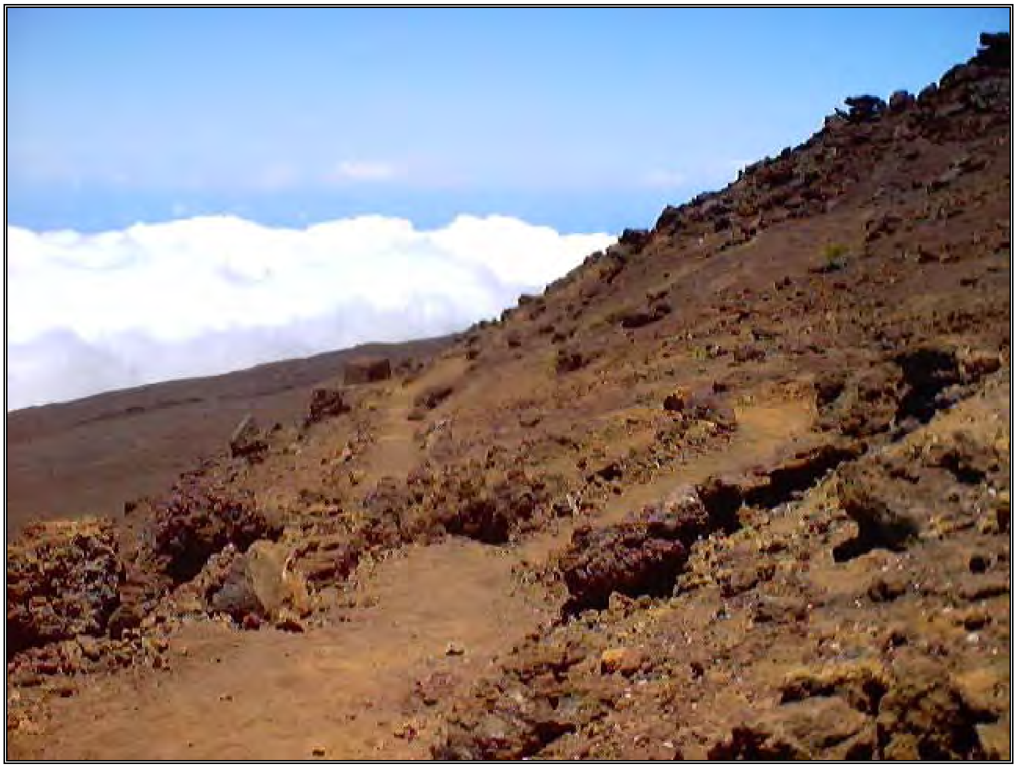
Placement of two *Ahu*

At the writing of this plan, two *ahu* have been constructed at essentially opposite sides of the Science City project area (see Figure 2, Photographs 5-7). Both *ahu* are very well fashioned from *a`a* lava rock. These ceremonial markers were constructed at the direction of the project’s Cultural Specialist, Mr. Charles Kauluwehi Maxwell. Both structures were placed in portions of the project area where no cultural resources were present. Well marked trails lead to each overlook. The western *ahu* faces the West Maui Mountains and is located well west of Site 5440. The eastern *ahu* is located at the top of the escarpment that rises above Site 5441, and has a commanding view of the island of Hawai`i.

Photograph 5 – View of the East *Ahu*, Site 5441 lies at the base of this c. 9 meter high escarpment.



Photograph 6 – View of the West *Ahu*, Site 5440 lies to the east of this marker.


Photograph 7 – View of the access trail to the West *Ahu* (visible in center left), Site 5440 lies to the east of the marker.

SUMMARY AND CONCLUSIONS

As previously noted in this plan, a total of 12 sites are slated for preservation within the Science City project area. Of these, the majority of sites and features consists of wind shelters, along with two petroglyph images (Features F and G of Site 5440), a possible burial (Feature E of Site 5440), and two possible ceremonial platforms (Ste 5441). Passive as-is preservation is recommended for all of the above sites except for the remnant of Reber Circle (Site 5443), which was largely demolished in the 1950s. There is no signage proposed for any of the sites within the Science City parcel (TMK: 2-2-07: portion of 8). As previously noted, there is no signage is recommended for individual sites discussed in this preservation plan. It is felt that signage could potentially draw unwanted attention to these sites, possibly causing negative impacts and/or security concerns. As mentioned earlier in this plan, the project's Cultural Specialist, Mr. Charles Kauluwehi has indicated that because of the cultural sensitivity of these sites signage is inappropriate. In addition, there are security issues that have been raised by personnel at some of the scientific facilities (AEOS, in particular) regarding the potential for inadvertently drawing members of the general public into a security area.

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APPENDIX E

Arthropod Assessments

(1) Updated Arthropod Inventory and Assessment, December 2005
(2) Supplemental Arthropod Sampling, March 2007
(3) Arthropod Inventory and Assessment, HALE and HO, July 2009

(1) UPDATED ARTHROPOD INVENTORY AND ASSESSMENT AT THE HALEAKALĀ HIGH ALTITUDE OBSERVATORIES MAUI, HAWAI`I

Advanced Technology Solar Telescope Primary and Alternative Sites

December 2005

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UPDATED ARTHROPOD INVENTORY AND ASSESSMENT AT THE HALEAKALĀ HIGH ALTITUDE OBSERVATORIES MAUI, HAWAI`I

Advanced Technology Solar Telescope Primary and Alternative Sites

December 2005

I. TABLE OF CONTENTS

II. EXECUTIVE SUMMARY

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 3,055-m (10,023-ft) at its summit on Pu`u `Ula`ula. Near the summit is a volcanic cone known as Kolekole with some of the best astronomy viewing in the world. In 1961, an Executive Order of Hawai`i Governor Quinn established the Haleakalā High Altitude Observatories (HO) Site, sometimes referred to as "Science City". The site is managed by the University of Hawai`i.

The summit of Haleakalā is also the home to unique cultural and natural resources. Important cultural places and sites are found here that are spoken of in numerous Hawaiian mele (songs), oli (chants) and legends (NPS 2005). Arthropods occur near the summit of Haleakalā in an aeolian ecosystem that was once considered lifeless.

The National Science Foundation has proposed the development of the Advanced Technology Solar Telescope (ATST) within the 18-acre University of Hawai`i Institute for Astronomy HO site. The ATST represents a collaboration of 22 institutions, reflecting a broad segment of the solar physics community. The proposed ATST project would be the largest and most capable solar telescope in the world. It would be an indispensable tool for exploring and understanding physical processes on the Sun that ultimately affect Earth.

An inventory and assessment of the arthropod fauna at the HO site was conducted in 2003 as part of the Long Range Development Plan (LRDP) (http://www.ifa.hawaii.edu/haleakala/LRDP/) for the Haleakalā High Altitude Observatories. KC Environmental, Inc. managed the environmental and cultural surveys and prepared survey-based recommendations for the IfA committee responsible for long range development planning.

Pacific Analytics, LLC was contracted to update the 2003 inventory and assessment of the arthropod fauna at the ATST proposed primary and alternative sites within the Haleakalā High Altitude Observatories Site.

The goal was to describe the arthropod fauna at the two proposed ATST sites, and identify Hawaiian native arthropod species or habitats, if any, that could be impacted by construction or operation of the ATST. The information provided in this report will be used to make sound, considered decisions regarding the placement and development of the proposed ATST project, based on the best scientific information available.

This report is the result of arthropod sampling at the proposed ATST primary site, east of the existing Mees Solar Observatory facility, and the alternative site, at Reber Circle, both within the HO site. This report contains sampling methodology, site description, discussion of findings, and an extensive Bibliography.

III. INTRODUCTION

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 3,055-m (10,023-ft) at its summit on Pu`u `Ula`ula. Near the summit is a volcanic cone known as Kolekole with some of the best astronomy viewing in the world. In 1961, an Executive Order of Hawai`i Governor Quinn established the Haleakalā High Altitude Observatories (HO) Site, sometimes referred to as "Science City". The site is managed by the University of Hawai`i.

The highest elevations of Haleakalā were once considered largely lifeless with only sparse vegetation, but biologists have discovered a diverse fauna of resident insects and spiders there that are found nowhere else in the world (Medeiros and Loope 1994). These arthropods inhabit unique natural habitats on the bare lava flows and cinder cones. Feeding primarily on windblown organic material, they form an aeolian ecosystem.

The term aeolian has generally been used to describe ecosystems on snow, ice, meltwater, and barren rock, but in Hawai`i it has been used to characterize non-weathered lava substrates, mostly but not exclusively found at high elevations (Howarth 1987, Medeiros and Loope 1994).

On Haleakalā, aeolian and sub-aeolian ecosystems begin at about 2,300-m (7,546-ft) elevation in the cinder-dominated habitat inside the crater, and at around 2,600-m (8,530-ft) on the older western slope of the volcano, and extend up to the summit at 3,055-m (10,023-ft). Climate conditions are extreme, with widely varying diurnal temperatures and little precipitation. Solar radiation can be intense, and the conditions often affect visitors not accustomed to high elevations.

The Haleakalā aeolian ecosystem is extremely xeric, caused by relatively low precipitation, porous lava substrates that retain negligible amounts of moisture, little plant cover, and high solar radiation. The dark, heat-absorbing cinder provides only slight protection from the extreme temperatures. Thermal regulation and moisture conservation are critical adaptations of arthropods that occur in this unusual habitat.

Vegetation covers less than 5% of the open ground, and food is apparently scarce. Wind-assisted diurnal movement and seasonal migrations of insects from the surrounding lowlands are the primary source of food for the resident scavenger and predator arthropods in this remarkable ecosystem. Aeolian ecosystems are not unique to Haleakalā in Hawai`i. Similar ecosystems also occur on Mauna Kea and Mauna Loa on the Island of Hawai`i (Howarth and Montgomery 1980). Each volcano has its own unique aeolian fauna that exploit the windblown organic material.

The National Science Foundation has proposed the development of the Advanced Technology Solar Telescope (ATST) within the 18-acre University of Hawai`i Institute for Astronomy HO site. The ATST represents a collaboration of 22 institutions, reflecting a broad segment of the solar physics community. The proposed ATST project would be the largest and most capable solar telescope in the world. It would be an indispensable tool for exploring and understanding physical processes on the Sun that ultimately affect Earth.

An inventory and assessment of the arthropod fauna at the HO site was conducted in 2003 as part of the Long Range Development Plan (LRDP) for the Haleakalā High Altitude Observatories. KC Environmental, Inc. managed the environmental and cultural surveys and prepared survey-based recommendations for the IfA committee responsible for long range development planning.

Pacific Analytics, LLC was contracted to update the inventory and assessment of the arthropod fauna at the ATST proposed primary and alternative sites within the HO site. Pacific Analytics personnel have extensive experience with ecological research, wildlife inventory, monitoring, and consulting. Pacific Analytics personnel have many years of professional experience in tropical and temperate ecosystems, including natural resource inventory and monitoring, forest and riparian entomology, endangered species research, mitigation, and habitat management, forensic entomology, integrated pest management, and land management.

Sampling of arthropod habitats was approved in a permit obtained from the Department of Land and Natural Resources (DLNR) issued in September, 2005. Sampling began on September 30, 2005 and was completed on October 30, 2005.

The intended purpose of this study is to update the baseline survey of resident invertebrates conducted in 2003, and to gather reliable scientific information about the current status of arthropods and other invertebrates at the proposed ATST primary and alternative sites within the HO site.

This study provides a means of gathering information that can be used to protect the native Arthropod species during development and operation of observatory facilities. This study supports astronomy programs at the Haleakalā High Altitude Observatories Site by promoting the good stewardship of the natural resources located there.

IV. PROJECT DESCRIPTION

The Project consists of six tasks. The tasks were:

Task I) Survey the site to determine habitats of interest and the special collecting methods that may be deployed.

Task II) Install five pitfall traps on each of the proposed ATST primary and alternative sites.

Task III) Collect under rocks, on vegetation, in leaf litter, and in special habitats (e.g., for ground dwelling arthropods).

Task IV) Retrieve material from pitfall traps after operating for one month.

Task V) Identify and curate of collected specimens.

Task VI) Prepare a Final Report of Findings.

Review the previous inventories and assessments,

Discuss the current status of resident Arthropods on the proposed ATST primary and alternative sites ,

Compare the current status to the findings of the 2003 inventory,

List any species of concern or special interest,

V. METHODS

Site Description

The Haleakalā High Altitude Observatories (HO) site is located on Kolekole Hill. The site is at 3,052-m (10,012-ft) above sea level, adjacent to Pu`u `Ula`ula, also known as Red Hill, the highest elevation on Maui, 3,055-m (10,023-ft).

The 7.3-ha (18.1-ac) site was established in 1961, and the first telescope, the Mees Solar observatory was dedicated in 1964. The site now consists of five telescope facilities.

The proposed ATST primary site is approximately 0.24-ha (0.60-ac) of undeveloped land located east of the existing Mees Solar Observatory facility. The proposed alternative site is at Reber Circle, a previously developed site located north of the existing MAGNUM telescope facility.

Annual precipitation at these sites averages 1,349.2-mm (53.14-in), falling primarily as rain and mist during the winter months from November through April. Snow rarely falls at the site.

Monthly mean temperatures range from 10˚C (50˚F) in February to 14˚C (57˚F) in July and August. The average high is 18.5˚C (62.5˚F), and the average low is 7.3˚C (44.8˚F). Daily temperatures can range from below freezing at night to near 80˚F (27˚C) during the day. In June, the average high temperature is 18˚C (65˚F), and the average low temperature is 8˚C (47˚F) (Weather.com website).

The prevailing Northeast trade winds occur a majority of the time between May and November and over 60% of the time the rest of the year (ATST website).

Sampling

Prior to sampling, reports and publications of previous arthropod surveys and studies were examined to determine the best approach to sample the site. Two reports (Beardsley 1980 and Medeiros and Loope 1994) were extremely useful because they are specific to the site and nearby crater. Particular attention was given to the Arthropod Inventory and Assessment conducted in 2003 (Pacific Analytics 2003).

After reviewing historical reports it was decided that ethylene glycol pitfall traps, foliage beating, and visual searching would be the most efficient methods to inventory arthropods at this site.

Light-trapping at night was considered for sampling nocturnal arthropod species, but was rejected because of the potential for disturbance to nearby active petrel nests. Searches for noctural arthropods using red-light headlamps was also considered. It was decided that while there is a potential to observe some noctural species using this method, most would be captured by pitfall traps that would be open continuously for one month.

Pitfall Traps

The selection of a trapping technique used in a study needs to be carefully considered. If the target species of the trapping system are rare or important for another reason (i.e., endangered, keystone species, etc.) live-trapping should be considered. Entomologists have long believed that they can sample without an impact on the population being sampled. It has been assumed that collecting makes only a small impact on the populations of interest. While that assumption remains to be tested, responsible entomologists consider appropriate trapping techniques to ensure survival of local populations of interest.

There have been some concerns expressed about insects living in the ground and the small amount of information known about their distribution at the site. Most of the open ground is scoria, cinder, lapilli, and ash. A large percentage of this substrate is composed of ash and sand-sized particles. When a hole is dug in this kind of substrate, the sides quickly collapse and fill in the hole. Pitfall traps were used to sample this habitat type. It is unlikely that abundant and active ground-dwelling arthropods would not be collected in these traps. Even when arthropods live in the ground, they generally must come to the surface to feed. When they do, they should be captured by the pitfall traps.

Because sampling was to occur for only one month, ethylene glycol traps were used to sample the arthropod ground fauna. Ethylene glycol pitfall traps are cups placed into the ground so that the lip of the cup is level with the substrate. A small amount of ethylene glycol is placed into the trap to kill and preserve specimens that fall into the traps. Ethylene glycol is used because it has a low evaporation rate and because it prevents specimen decomposition during the sampling period. Additionally, it is easily cleaned from the specimens.

Catches in pitfall traps record the activity of ground-active arthropods. The more active the organism, the more likely it is to fall into a trap (Greenslade 1964, Luff 1975, Adis 1979, Baars 1979, Spence and Niemelä 1994). Pitfall trapping gives a reliable estimate of the relative densities of active adult species (Baars 1979, Rieske and Raffa 1993), although the method may not be useful for estimating absolute densities of species (Briggs 1960, Greenslade 1964, Adis 1978, Baars 1979, Desender and Maelfait 1983, Waage 1985). Luff et al. (1989) concluded that analysis of pitfall trap data collected under standardized conditions could lead to meaningful results.

The results of sampling depend largely on the species being sampled and the density of traps at the site. The target of pitfall trapping in this study was ground-active arthropod species. The sampling goal was to place five traps in each of the proposed ATST sites. Ten pitfall traps were set at the site on September 30, 2005, sampling representative habitat at each site. The locations of the pitfall traps are reported in Figure 1.

Protocol for Setting Traps

Habitat was accessed with a minimum of disturbance to the habitat and cinder slopes. Care was taken to prevent creation of new trails or evidence of foot traffic. A map of significant historic and cultural sites was provided by KC Environmental, Inc., and sampling near these sites was avoided. Petrel nesting sites were also identified during a site review, and no traps were set within the nesting area.

Sampling stations were selected in suitable habitat (Step 1). Traps were installed at each sampling station by carefully digging into the cinder, disturbing only the amount of cinder necessary to set up the trap (Step 2). A 355-ml (12-oz) plastic cup was inserted into the hole so that the top of the cup was slightly below the existing surface (Step 3). The hole around the cup was refilled with the cinder that was removed from the hole and a 10-cm (4-in) apron of local ash and small-sized cinder was created around each trap (Step 4). The apron allows arthropods to easily walk into the traps.

Traps were set by pouring about 15-ml (0.5-oz) of ethylene glycol (antifreeze) into the cups (Step 5). Flagging tape to mark the locations was wrapped around cap rocks, ten to fifteen inches in diameter. The cap rocks were then placed over each trap such that the entire trap was shaded from sunlight (Step 6).

Traps were installed on September 30, 2005, and were checked over the next two days to determine if they were capturing a large amount of arthropods. This was done to ensure that traps would not have a serious impact on resident arthropods. Traps were collected on October 29, 2005. The contents of the traps were screened to remove the ethylene glycol, and dead arthropod specimens were collected in vials filled with alcohol. The ethylene glycol was deposited at a local auto parts store for recycling. The ground around the traps was restored to near original condition.

Setting a pitfall trap near Reber Circle.

Setting an Ethylene Glycol Pitfall Trap

Step 1
Select Sampling Site

Step 2
Dig a hole for the trap cup

Step 3
Install 12 oz. plastic cup

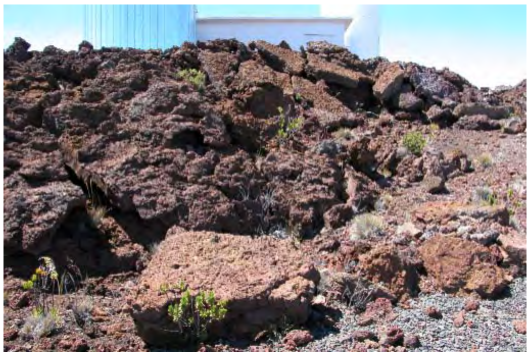
Step 4
Refill hole and create apron

Step 5
Pour in 15 ml of Ethylene glycol

Step 6
Emplace Cap Rock

Trap Locations

An effort was made to sample representative examples of all habitat types on each of the proposed sites.



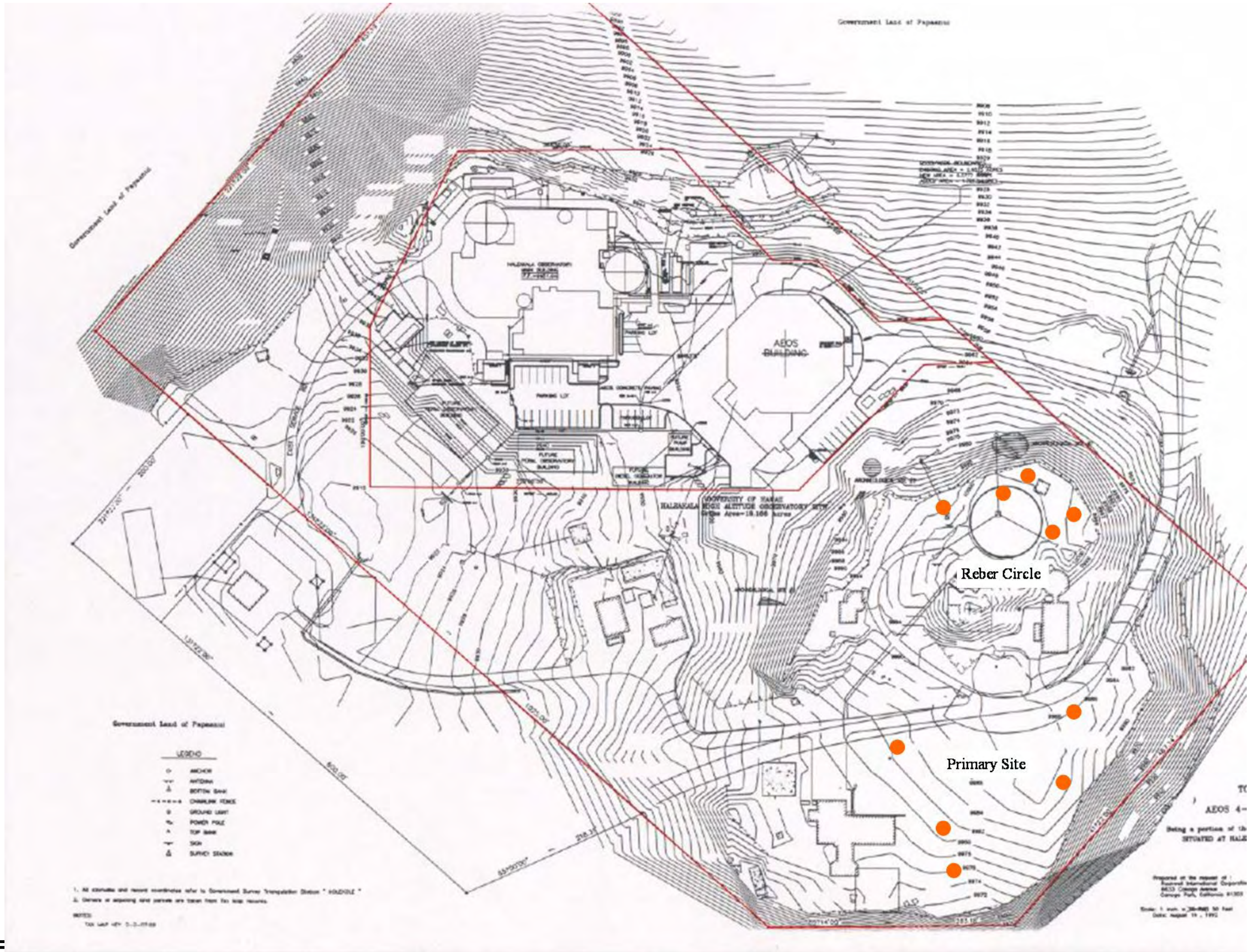
Aa flow near Reber Circle forms a rocky cliff face.

The surface of the substrate on much of the HO site consists of broken fragmental ankaramite lavas and spatter, such as scoria, cinder, and lapilli, with blankets of cinder and ash (Bhattacharji 2003). In some areas, aa lava flows of picrite basalt form large rock outcrops.

The habitat east of the Mees Observatory is different than that found on most of the rest of the HO site, being relatively level ash and cinder with an abundance of blocky scoria and cinder. There is sparse vegetation cover. Traps were placed near vegetation to maximize sampling potential.

Habitat at the proposed primary ATST site east of the Mees Observatory facility.

The Reber Circle site is highly disturbed, and previously developed. The substrate within the circle is compacted cinder and ash. The area surrounding the site has sparse vegetation cover and little potential arthropod habitat. Traps were set in areas near potential arthropod habitats to maximize sampling potential.



Government Land of Papaanui
AEOS BUILDING
Reber Circle
Primary Site
Government Land of Papaanui
LEGEND

Trapping Precautions
Cultural and Historic Sites

Care was taken to avoid archeological sites. These sites have cultural and historical significance and precautions were made to prevent their disturbance. Traps were not placed in or near these sites.

Habitat was accessed with a minimum of disturbance to the habitat and cinder slopes. Care was taken to prevent creation of new trails or evidence of foot traffic. A map of significant historic and cultural sites was provided by KC Environmental, Inc.

Some sites were marked with white flagging and others were delineated with metal fencing to prevent disturbance.

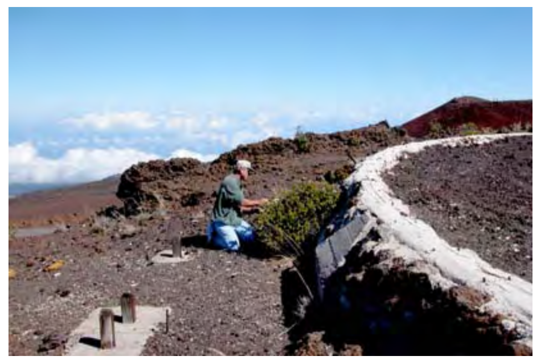
Sensitive Nesting Sites

Care was also taken to avoid disturbing nesting petrels. These endangered birds dig into the cinder to make burrows for nesting. Nesting is seasonal and was occurring during the arthropod sampling. A map of active petrel nests was prepared by Haleakalā Park Service staff, and used to ensure that arthropod sampling was not conducted in these sensitive areas.

Other Sampling

Visual Observations and Habitat Collecting Under Rocks

Approximately six hours were spent sampling under rocks, in leaf litter, and on foliage to locate and collect arthropods at each site.



Sampling foliage adjacent to Reber Circle.

Collecting on Foliage

The vegetation type at this site is an *Argyroxiphium/Dubatia* alpine dry shrubland (Starr and Starr, 2005). Foliage of various common plant species was sampled by beating sheet. A one-meter square beating sheet was placed under the foliage being sampled and the branch was hit sharply three times using the handle of a collecting net.

Na`ena`e, *Dubautia menziesii,* was sampled using a beating sheet.

Plants sampled using a beating sheet included na`ena`e (*Dubautia menziesii*), pukiawe (*Styphelia tameiamieae*), ohelo (*Vaccinium reticulatum*), and others.

Pukiawe, *Styphelia tameiameiae*, was sampled using a beating sheet.

Grasses, such as pili uka (*Trisetum glomeratum*) and Hairgrass (*Deschampsia nubigena*), were also sampled using a beating sheet. The beating sheet was placed next to and under the grass clump and the stems were brushed by hand to remove arthropods. Common plants and grasses were also sampled using a sweep net.

Hairgrass, *Deschampsia nubigena*, and other grasses were sampled with a beating sheet.

Plant species that were relatively less abundant were sampled with special techniques so as not to disturb their growth. Sampling was conducted by carefully inspecting the plants for arthropods.

Mosses and lichens were visually inspected for arthropods that may be restricted to these species. These species occurred in rock crevices, small caves, or under overhangs, where they were protected for strong sunlight. Care was taken to avoid disturbing their habitats.

Vegetation was sampled on September 29-30, 2005 and again on October 29-30, 2005. Arthropod specimens were collected and stored in vials of 70% ethyl alcohol.

Quantification and Curation

The contents of the traps were cleaned in 70% ethyl alcohol and placed in separate vials for each trap. After quantifying the trap captures, the specimens were sorted into the morphospecies for identification. Hard-bodied species, such as beetles, true bugs, large flies and wasps were mounted on pins, either by pinning the specimen or by gluing the specimens to paper points. Pinned specimens were placed into Schmidt boxes. Soft-bodied specimens, such as immature stages, spiders, Collembola, Psyllids, Aphids, small flies and wasps, and millipedes and centipedes, were stored in vials filled with 70% ethyl alcohol.

Identification

References for general identification of the specimens included Fauna Hawaiiensis (Sharp (ed) 1899-1913) and the 17 volumes of Insects of Hawaiʻi (Zimmerman 1948a, 1948b, 1948c, 1948d, 1948e, 1957, 1958a, 1958b, 1978, Hardy 1960, 1964, 1965, 1981, Tentorio 1969, Hardy and Delfinado 1980, Christiansen and Bellinger 1992, Liebherr and Zimmerman 2000, and Daly and Magnacca 2003). Other publications that were useful for general identification included The Insects and Other Invertebrates of Hawaiian Sugar Cane Fields (Williams 1931), Common Insects of Hawaiʻi (Fullaway and Krauss 1945), Hawaiian Insects and Their Kin (Howarth and Mull 1992), and An Introduction to the Study of Insects Sixth Edition (Borror, Triplehorn, and Johnson 1989).

For specific groups specialized keys were necessary. Most of these had to be obtained through library searches. Keys used to identify Heteroptera included those by Usinger (1936, 1942), Ashlock (1966), Beardsley (1966, 1977), and Gagné (1997). Keys used to identify Hymenoptera included Cushman (1944), Watanabe (1958), Townes (1958), Beardsley (1961, 1969, 1976), Yoshimoto and Ishii (1965), and Yoshimoto (1965,a, 1965b).

Species identification of those specimens identified to genus or species level are unconfirmed and subject to change after comparison to specimens in museums.

In many cases changes in family and generic status and species synonymies caused species names to change from those in the keys. Species names used in this report are those listed in Hawaiian Terrestrial Arthropod Checklist Third Edition (Nishida 1997).

VI. RESULTS AND DISCUSSION

General Observations

The primary site has had minimal previous disturbed from construction. Vegetation occurred in the areas largely undisturbed. It was in these areas where arthropods were most abundant.

About eighty percent of the Reber Circle site has been previously disturbed by construction. Native vegetation occurs only at the north and east portions of this site. Arthropods were most abundant near this vegetation, but some were collected in pitfall traps from the compacted and disturbed areas.

A majority of the arthropod specimens were collected in pitfall traps and on foliage. Only a small number of specimens were collected from under rocks or through general collecting. A total of twenty arthropod species were collected representing sixteen families in nine orders.

Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in nearly all pitfall traps. They appeared abundantly as adults and juveniles.

Lycosid spider, *Lycosa hawaiiensis*, abundant at the two sites.

This spider is the predominant predator of the arthropod fauna at the site (Medeiros and Loope 1994). This spider was also commonly observed in visual habitat searches under rocks and on open ground.

True bugs and leafhoppers were abundant on the vegetation at both sites. These endemic species have been reported from the HO site in previous surveys.

Other arthropods occurred in low abundance including small ground beetles and spiders, Collembola, and flies. The arthropod fauna collected during this study will be discussed according to their taxonomic groups.

Previous Studies

The summit of Haleakalā has been sampled by several entomologists. Some of the first specimens known from there were collected by the Reverend Thomas Blackburn over 100 years ago. Near the beginning of the twentieth century, R.C.L. Perkins sampled the upper reaches of Haleakalā. During the first half of the century other entomologists who sampled Haleakalā included O.H. Swezey who recorded host plant information for many insect species, E.C. Zimmerman who collected information for the Insects of Hawaiʻi series and studied the flightless lacewings of Haleakalā, and D.E. Hardy who worked extensively with the Diptera (flies) found there.

Entomological studies continued in the 1960's when John Beardsley (1966) investigated species of *Nysius* that were disrupting operation of the Haleakalā Observatory. In that study Beardsley collected fifty-one insect species from 36 families in nine orders from malaise traps on Pu`u Kolokole.

In 1980, John Beardsley completed his basic inventory of the insects of the Haleakalā National Park crater district for the Cooperative National Park Resources Studies Unit of the University of Hawaiʻi at Manoa. This was the first published report of a thorough inventory of the upper portion of Haleakalā listing the species collected. Three hundred and eighty-nine species of insects representing ninety families from thirteen orders were collected from the Crater District in this study. About 60% of the species were believed to be endemic to Hawaiʻi, and 83 species (21%) were determined to be endemic to Haleakalā.

A previous review of the arthropod fauna at the Haleakalā High Altitude Observatories Site before the current study occurred in 1994 (Medeiros and Loope 1994). The study was limited to the proposed Air Force Construction Site. The number of species collected is not listed in that report. The report concluded "The study site is basically a typical but somewhat depauperate example of the Haleakalā aeolian zone."

The last inventory of arthropods at the HO site was conducted in 2003 (Pacific Analytics). In that study, fifty-eight arthropod species were identified from the facility, twenty-nine that are indigenous to Hawai`i. This current survey is a site-specific update to that study.

Current Survey

Of the twenty arthropod species collected during this study, at least half are indigenous Hawaiian species. All but one of the species collected have been previously reported from upper elevations on Haleakalā.

Class Arachnida

Order Araneae
Spiders

Lycosidae – Wolf Spiders

Lycosa hawaiiensis Simon

This large endemic wolf spider, *Lycosa hawaiiensis* Simon, was frequently encountered when searching under rocks and collecting at the site. Adults and juveniles also occurred in pitfall traps, averaging a combined fourteen specimens per trap (~ 6.9 adults and 7.5 juveniles). This is more than were captured during the 2003 inventory (combined average of ~10 lycosids per trap). The increased abundance may be due to seasonal differences. Sampling in 2003 was conducted during the summer months when the spiders may be less active.

Adults of this large predator can reach up to 2 inches (5 cm) in length. Juveniles that appeared in traps were as small as 1 cm in length. To protect themselves from the climatic extremes, Lycosids construct burrows under rocks by cementing leaves and wind-blown detritus together with silk (Medeiros and Loope 1994). During favorable conditions, these spiders emerge from their burrows to hunt for prey.

The wolf spider are most commonly found under rocks in open cinder habitat. They occur down to 7,875 ft (2,400 m) on Haleakalā, and are also found on Oahu and Hawaiʻi.

Linyphiidae – Sheet-web Spiders

Unknown species

Spiders of the family Linyphiidae were also observed on the site. Linyphiid spiders are small, usually less then 2 mm in length, and are difficult to see during visual reconnaissance. Only five species of these spiders are reported from Maui, 3 endemic and two nonindigenous (Nishida 1997).

Ten individuals were collected in pitfall traps, and none were observed during habitat searches. They were also relatively rare during the 1994, and 2003 surveys (Medeiros and Loope, Pacific Analytics 2003), and their status is unchanged. This group of spiders is not well studied and little is known about their distribution and abundance.

Class Chilopoda - Centipedes

Centipedes are elongate, flattened arthropods with 15 or more pairs of legs, one pair per body segment. They occur in a variety of habitats, where they feed on spiders and insects. There are 24 species of centipedes reported in Hawai'i, only one from Maui, the nonindigenous, *Mecistocephalus spissus* Wood (Nishida 1997). Nine specimens of centipedes were collected in this study. Because of a lack of taxonomic keys, they were not identified. Five specimens of the same species were found in traps during the 2003 inventory.

Class Diplopoda - Millipedes

Millipedes are elongate, wormlike arthropods with 30 or more pairs of legs, two pair per body segment. Millipedes are scavengers and feed on decaying plant material. There are 25 species known in Hawai'i, 8 on Maui.

Two specimens of millipedes were collected in pitfall traps during this study. Because of a lack of taxonomic keys, they were not identified. Thirty specimens were collected during the 2003 inventory, generally from the northern sections of the HO site.

Class Insecta
Order Coleoptera
Beetles

Beetles are the most diverse group of arthropods in Hawai'i. There are 1,983 species of beetles reported in Hawai'i (Nishida 1997), 544 on Maui (B.P. Bishop Museum 2002).

Five species of beetles were found during this study, one endemic to Hawai'i. In his 1980 study, Beardsley reported 45 species from the Crater District of Haleakalā, including 29 endemic species. In previous arthropod surveys at the Haleakalā High Altitude Observatories Site, fewer than 10 species were reported, only one of which is endemic (Medeiros and Loope 1994, Pacific Analytics 2003).

<u>Carabidae – Ground Beetles</u>

Bembidion molokaiense (Sharp)

This endemic species was identified during the 2003 inventory, and was also recorded from Haleakalā in 1980 near the Kuiki Trail at 6,400 ft (1,950 m). Five specimens of this species were collected, only one was collected in 2003. Identification

The other endemic carabid beetle identified in 2003, *Blackburnia rupicola* (Blackburn), did not occur during this inventory. It was uncommon during the 2003 survey, occurring only twice from the northern areas of the HO site.

Coccinellidae – Ladybird Beetles

Coccinella septempunctata L.

This non-indigenous beetle was purposely introduced as a biocontrol for aphids. Four individuals were collected from Na`ena`e on the Reber Circle site.

Cryptophagidae – Silken Fungus Beetles

Cryptophagus sp.

No species of this family are known to be indigenous to Hawai`i. This genus is cosmopolitan in distribution. These small beetles feed on fungi, decaying vegetation, and similar materials, and usually occur in decaying vegetable matter. One specimen was collected from a pitfall trap, and represents the first record of this genus in Hawai`i.

Lathridiidae - Minute Brown Scavenger Beetles

Aridius notifer (Westwood)

Only one specimen of this non-indigenous beetle was collected. It occurs on other main islands in Hawai`i and is not considered a pest. This specimen represents a new record for the upper elevations of Haleakalā.

Staphylinidae – Rove Beetles

Unknown species

Three individuals of this species occurred in pitfall traps. They appear to be in the subfamily Aleocharinae, a difficult taxonomic group. Species of this group in Hawai`i are adventive, cosmopolitan, and common.

Order Collembola - Springtails

Collembola are small, insect-like arthropods. They are abundant and ubiquitous, exceeding all other insects in numbers of individuals (Christiansen and Bellinger 1992). Most species are detritivors and few are pests. One hundred and sixty-nine species of Collembola are found in Hawai'i, sixty on Maui (Nishida 1997).

Because of their small size (0.25–6-mm), Collembola are seldom observed or reported. Only three were trapped in pitfalls at the primary site, but 40 were found in pitfalls at Reber Circle representing at least two species. In 1980, five species of Collembola were reported from the Crater District of Haleakalā. In 2003 Collembola were abundant in pitfall traps, occurring in the hundreds in some locations, especially on the outer northwest slopes of Pu`u Kolekole, but uncommon in the southern part of the HO site.

Order Diptera -Flies

In previous studies on Haleakalā , more than 115 species of flies were recorded (Beardsley 1980, Medeiros and Loope

1994, Pacific Analytics 2003). Only a few of those species were recorded near the summit of the volcano.

During this study, five species of flies were captured. The most abundant were nonindigenous humpbacked flies (Phoridae). These flies develop in dead organic materials, especially decaying vegetation. It is likely that these flies are blown to the HO site by diurnal winds from the surrounding lowlands.

Calliphoridae – Blue Bottle Flies

Calliphora vomitoria (L.)

This non-indigenous fly is widespread throughout the World. It occurs on all the main islands of Hawai`i at higher elevations. It is one of the largest species of this family, commonly ovipositing on meat and other organic matter (Hardy 1981).

Phoridae – Humpbacked Flies

Megaselia setaria (Malloch)

This fly is an immigrant from Guam, and has been recorded from Kauai, Oahu, and Maui.

Sarcophagidae - Flesh Flies

Blaesoxipha plinthopyga (Wiedemann)

This non-indigenous species scavengers on dead animal material. Individuals are abundant around the leach field on the northeast portion of the HO site.

Sciaridae - Dark-winged Fungus Gnats

Bradysia sp.

There are five species of this genus that occur on Maui, two endemic, and three adventive. All five occur on other main islands and are not rare.

Tipulidae - Craneflies

Limonia hawaiiensis (Grimshaw)

This endemic species is common on all the main islands of Hawai`i (Hardy 1960).

Order Heteroptera - True Bugs

The order Heteroptera contains 408 species in Hawai'i, 304 of which are endemic. Most species feed on plants, inserting their straw-like mouth parts into the plant to extract the juices. Some species are predaceous.

Forty species of true bugs were recorded during the 1980 Crater District inventory on Haleakalā, but most occurred well below the summit area. Eight species of true bugs were recorded during the investigation conducted on the Haleakalā High Altitude Observatories Site in 1966. Of these six species, only three actually are residents of the site (Beardsley 1966). In the 2003 inventory, eight true bugs were identified, all endemic.

In the current study, three species of true bugs, all endemic to Hawai'i , were found in pitfall traps and on plants.

Lygaeidae – Seed Bugs

Nysius nemorivagus White

This endemic species of true bug was common at both sites on *Dubautia menziesii*. Three individuals were captured in pitfall traps. This species is known to accumulate in large aggregations at the site and can disrupt observatory operations (Beardsley 1966). It was abundant during the 2003 survey.

Lygaeidae, *Nysius nemorivagus* White, were common on foliage at the sites.

Nysius lichencola Kirkaldy

This endemic species was described from specimens that were collected on Haleakalā above 2,133-m (7,000-ft). Only one specimen was collected.

Miridae – Plant Bugs

Orthotylus sp.

This nearly cosmopolitan genus contains a larger number of described species in Hawai`i than any other genus of endemic Miridae.

Order Homoptera
Psyllids, Aphids, and Hoppers

The order Homoptera is another large and diverse group of insects. There are 695 species of Homoptera found in Hawai'i, 386 considered endemic (Nishida 1997). All species feed on plant juices and like the Heteroptera, they use their straw-like mouthparts to feed.

In the 1980 insect inventory of the Crater District of Haleakalā, 44 species of Homoptera were found on various plants, but only nine species occurred above 8,000 ft. In his investigation in 1966, Beardsley (1966) found only two species of Homoptera at the Haleakalā High Altitude Observatories Site. Nine species of Homoptera were identified in the 2003 inventory.

Cicadellidae - Leafhoppers

Nesophrosyne sp.

Two adult specimens of this endemic genus were collected from pitfalls, but immatures were abundant on *Dubautia menziesii*, and in pitfalls.

Order Hymenoptera - Bees and Wasps

Bees and wasps are common in Hawai'i. There are 1,270 species that occur in Hawaiʻi. Of these species, 652 are endemic to Hawaiʻi that consist largely of small parasitic wasps, mud-daubers, and yellow-faced bees. The yellow-faced bees (family Colletidae) are important pollinators of native plants (Howarth and Mull 1992). Many of the nonindigenous species were purposely released for biological control of agricultural pests.

Another important group of Hymenoptera are the ants (family Formicidae). There are no endemic ants in Hawaiʻi, but at least forty-four species that now occur here. All were accidentally transported to Hawaiʻi where they have become a major threat to native arthropods. No ants were found during this study, and none were reported in previous studies.

Only one species of Hymenoptera were collected during this study, a very small parasitic wasp. Hymenoptera were relatively uncommon at the site, a similar finding as that recorded in 1994 (Medeiros and Loope). In an earlier investigation (Beardsley 1966), 12 species of Hymenoptera were collected at the site, mostly small parasitic wasps. Most of the species are not likely residents of the site and probably are carried by winds from lower elevations. The status of this group is largely unchanged since 1966.

Order Lepidoptera
Moths and Butterflies

There are 1,148 species of moths and butterflies found in Hawaiʻi, a majority (957) of which are endemic. Many of the endemic species are small moths with a wingspan of less than 1 cm (Howarth and Mull 1992).

Endemic Lepidoptera in Hawaiʻi have made a remarkable feeding adaptation. In most of the World, butterfly and moth larvae are plant feeders. In Hawaiʻi several species of butterflies and moths have been found to be insectivorous. Larvae of some forest inch worms (family Geometridae) species are ambush predators that blend imperceptibly into their surroundings. Small hairs and nerves on their backs indicate the presence of prey. In a fraction of a second the caterpillar can snap backward and grab its meal with pincer-tipped forelegs.

In higher elevations, larvae of some moths may feed on wind-blown lowland arthropods that become moribund as nighttime temperatures drop. They may also eat the leaves of the few plants that occur in their habitat.

Noctuidae – Noctuid Moths

Agrotis sp.

Caterpillars of this genus were captured in pitfall traps, averaging less than one per trap during the study. This is about the same capture rate measured in the 2003. survey.

Not more than 6 species of Lepidoptera have been reported from Pu`u Kolekole during previous studies (Beardsley 1966, 1980, Medeiros and Loope 1994). No specimens of the Haleakalā flightless moth were collected at either site. Adults of this species appeared in pitfall traps during the 2003 survey in low abundance at locations near the current study areas. The lack of occurrence in this survey may be due to seasonal variation in activity and abundance.

Summary of the Arthropod Fauna

The arthropods species that were collected during this study were typical of what has been found during previous studies. No species were found that are locally unique to the site. Nor were any species found whose habitat is threatened by normal observatory operations.

The diversity of the arthropod fauna at the Haleakalā High Altitude Observatories Site is somewhat less than what has been reported in adjacent, undisturbed habitat. This could be expected given the fact that about 40% of the site is occupied by buildings, roads, parking areas, and walkways. Also, much of the ground surrounding the buildings is disturbed and compacted from observatory operations. However, the undisturbed habitat on the site that was sampled has an arthropod fauna generally similar to what could be expected from other sites on the volcano with similar undisturbed habitat.

While development of the site has impacted the availability of some habitat locally, it has only affected a small amount of the available habitat on the volcano overall. The 7.3-ha (18.1-ac) facility occupies less than one percent of similar habitat available on the volcano (MacDonald 1978). The undisturbed portions of the Haleakalā High Altitude Observatories Site is representative of the surrounding habitat on Haleakalā.

The two proposed ATST sites represent an even smaller portion of the habitat overall on Haleakalā. The Reber Circle site was previously developed and has very sparse vegetation to support arthropods. The ground here is largely compacted, and lacks the structure necessary for most ground-dwelling arthropods. Only the surrounding, undisturbed areas contains habitats in which arthropods can survive. The diversity and abundance of arthropods at this site is very low.

The primary proposed ATST site east of the existing Mees Solar Telescope facility is largely undisturbed. Native vegetation is more abundant here, and the undisturbed nature of the substrate provides excellent microhabitats for arthropods. The diversity and abundance of arthropods here is greater than that of the Reber Circle site, but is low compared to the HO site in general and to the surrounding undisturbed habitats found elsewhere on Haleakalā.

Most of the arthropods collected during this study were largely associated with the vegetation at the site. Development of either of the proposed sites for the ATST will diminish only slightly the presence of the native vegetation in the general area of the HO, and therefore not threaten the persistence of any arthropod species found at the sites. The vegetation cover at these sites is only a small portion of the overall habitat available elsewhere on Haleakalā.

Only a few exclusively ground-dwelling species were found during this study. These include the wolf spider, ground beetle, and Collembola. These species make their home under rocks and in crevices and do not burrow into the cinder substrate. No obvious threats to these species survival were evident at either of the proposed ATST sites, although development of the primary site will displace some arthropod habitat.

One of the biggest concerns of past evaluations was the presence of ants. None were found during this study, but ants are reported from nearby National Park facilities. With some practical precautions, the site should remain ant free.

Other alien arthropod species also have the potential to impact the native ecosystem. No obviously threatening alien species were found during this study and with similar precautions as those used for ants, none should be introduced by the ATST observatory construction or operation. The harsh environment of this aeolian ecosystem should make it difficult for most alien species to establish populations.

Comparison of the results of this update to the 2003 Arthropod Fauna survey

Fewer species of arthropods were identified in this survey than were reported in the 2003 survey. This was probably due to restricting the sampling to a smaller area, the two proposed ATST sites. These two sites contain fewer microhabitats than can be found at the HO facility overall.

The trap capture rates of the species collected were similar to those from traps in similar locations during the 2003 survey, although some seasonal variation was evident. Evidently the construction activity in the adjacent areas has not impacted the arthropod fauna, except where habitat was removed.

It is unlikely that development of either of the proposed ATST sites will have an serious impact to arthropod species that occur at the sites beyond the limits of the HO facility.

The development of the ATST facility will diminish a small amount of arthropod habitat, including the presence of native plants, and thereby reduce native arthropod species diversity and abundance at the proposed ATST sites, but is not likely to have a direct impact on the persistence of arthropod species on Haleakalā.

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(2) SUPPLEMENTAL ARTHROPOD SAMPLING

AT THE

HALEAKALĀ HIGH ALTITUDE OBSERVATORIES

MAUI, HAWAI`I

Advanced Technology Solar Telescope

Primary and Alternative Sites

March 2007

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SUPPLEMENTAL ARTHROPOD SAMPLING AT THE HALEAKALĀ HIGH ALTITUDE OBSERVATORIES MAUI, HAWAI`I

Advanced Technology Solar Telescope Primary and Alternative Sites

March 2007

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II. EXECUTIVE SUMMARY

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 3,055-m (10,023-ft) at its summit on Pu`u `Ula`ula. Near the summit is a volcanic cone known as Kolekole with some of the best astronomy viewing in the world. In 1961, an Executive Order of Hawai`i Governor Quinn established the Haleakalā High Altitude Observatories (HO) Site, sometimes referred to as "Science City". The site is managed by the University of Hawai`i.

The summit of Haleakalā is also the home to unique cultural and natural resources. Important cultural places and sites are found here that are spoken of in numerous Hawaiian mele (songs), oli (chants) and legends (NPS 2005). Arthropods occur near the summit of Haleakalā in an aeolian ecosystem that was once considered lifeless.

The National Science Foundation has proposed the development of the Advanced Technology Solar Telescope (ATST) within the 18-acre University of Hawai`i Institute for Astronomy HO site. The ATST represents a collaboration of 22 institutions, reflecting a broad segment of the solar physics community. The proposed ATST project would be the largest and most capable solar telescope in the world. It would be an indispensable tool for exploring and understanding physical processes on the Sun that ultimately affect Earth.

An inventory and assessment of the arthropod fauna at the HO site was conducted in 2003 as part of the Long Range Development Plan (LRDP) (http://www.ifa.hawaii.edu/haleakala/LRDP/) for the Haleakalā High Altitude Observatories.

The 2003 arthropod inventory and assessment was updated in December 2005. The goal was to describe the arthropod fauna at the two proposed ATST sites, and identify Hawaiian native arthropod species or habitats, if any, that could be impacted by construction or operation of the ATST.

Through a desire to have a comprehensive arthropod inventory and in response to comments submitted for the ATST Draft Environmental Impact Statement, supplemental sampling for arthropods at the sites was conducted in March 2007. The goal was to detect additional species that may have been missed during previous samplings. This additional survey, including night sampling, covers a seasonal component not included in the two previous studies.

III. INTRODUCTION

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 3,055-m (10,023-ft) at its summit on Pu`u `Ula`ula. Near the summit is a volcanic cone known as Kolekole with some of the best astronomy viewing in the world. In 1961, an Executive Order of Hawai`i Governor Quinn established the Haleakalā High Altitude Observatories (HO) Site, sometimes referred to as "Science City". The site is managed by the University of Hawai`i.

The highest elevations of Haleakalā were once considered largely lifeless with only sparse vegetation, but biologists have discovered a diverse fauna of resident insects and spiders there that are found nowhere else in the world (Medeiros and Loope 1994). These arthropods inhabit unique natural habitats on the bare lava flows and cinder cones. Feeding primarily on windblown organic material, they form an aeolian ecosystem.

The term aeolian has generally been used to describe ecosystems on snow, ice, meltwater, and barren rock, but in Hawai`i it has been used to characterize non-weathered lava substrates, mostly but not exclusively found at high elevations (Howarth 1987, Medeiros and Loope 1994).

On Haleakalā, aeolian and sub-aeolian ecosystems begin at about 2,300-m (7,546-ft) elevation in the cinder-dominated habitat inside the crater, and at around 2,600-m (8,530-ft) on the older western slope of the volcano, and extend up to the summit at 3,055-m (10,023-ft). Climate conditions are extreme, with widely varying diurnal temperatures and little precipitation. Solar radiation can be intense, and the conditions often affect visitors not accustomed to high elevations.

The Haleakalā aeolian ecosystem is extremely xeric, caused by relatively low precipitation, porous lava substrates that retain negligible amounts of moisture, little plant cover, and high solar radiation. The dark, heat-absorbing cinder provides only slight protection from the extreme temperatures. Thermal regulation and moisture conservation are critical adaptations of arthropods that occur in this unusual habitat.

Vegetation covers less than 5% of the open ground, and food is apparently scarce. Wind-assisted diurnal movement and seasonal migrations of insects from the surrounding lowlands are the primary source of food for the resident scavenger and predator arthropods in this remarkable ecosystem. Aeolian ecosystems are not unique to Haleakalā in Hawai`i. Similar ecosystems also occur on Mauna Kea and Mauna Loa on the Island of Hawai`i (Howarth and Montgomery 1980). Each volcano has its own unique aeolian fauna that exploit the windblown organic material.

The National Science Foundation has proposed the development of the Advanced Technology Solar Telescope (ATST) within the 18-acre University of Hawai`i Institute for Astronomy HO site. The ATST represents a collaboration of 22 institutions, reflecting a broad segment of the solar physics community. The proposed ATST project would be the largest and most capable solar telescope in the world. It would be an indispensable tool for exploring and understanding physical processes on the Sun that ultimately affect Earth.

An inventory and assessment of the arthropod fauna at the HO site was conducted in 2003 as part of the Long Range Development Plan (LRDP) for the Haleakalā High Altitude Observatories. KC Environmental, Inc. managed the environmental and cultural surveys and prepared survey-based recommendations for the IfA committee responsible for long range development planning.

The 2003 arthropod inventory and assessment was updated in December 2005. The goal was to describe the arthropod fauna at the two proposed ATST sites, and identify Hawaiian native arthropod species or habitats, if any, that could be impacted by construction or operation of the ATST.

Comments submitted for the ATST Draft Environmental Impact Statement suggested that important and unique special status species in the summit area may not have been represented in earlier arthropod collections and reports of the proposed sites. Supplemental sampling was proposed in order to satisfy this concern and to obtain a more complete inventory of species at the sites, especially night sampling for nocturnally active species. In additional, this supplemental sampling encompasses a seasonal component not included in the previous two inventories.

Sampling of arthropod habitats was approved in a permit obtained from the Department of Land and Natural Resources (DLNR) issued in February, 2005. Sampling began on March 17, 2007 and was completed on March 20, 2007.

The intended purpose of this study is to gather reliable scientific information about the species of arthropods at the proposed ATST primary and alternative sites within the HO site that are active at night and might not have been detected during the previous two surveys. Additionally, sampling was conducted during daylight hours to capture seasonal variation of the arthropod fauna.

This study completes a comprehensive Arthropod species inventory at the proposed sites and provides valuable information that will be used during development and operation of observatory facilities. This study supports astronomy programs at the Haleakalā High Altitude Observatories Site by promoting the good stewardship of the natural resources located there.

IV. PROJECT DESCRIPTION

The Project consists of five tasks. The tasks were:

Task I) Sample the proposed ATST primary and alternative sites using special techniques for nocturnal species. This includes attracting flying arthropods with UV and other lights deployed at night, and nighttime ground and foliage searching.

Task II) Install five pitfall traps on each of the proposed ATST primary and alternative sites.

Task III) Collect under rocks, on vegetation, in leaf litter, and in special habitats (e.g., for ground dwelling arthropods).

Task IV) Identify and curate of collected specimens.

Task V) Prepare a Final Report of Findings.

V. METHODS

Site Description

The Haleakalā High Altitude Observatories (HO) site is located on Kolekole Hill. The site is at 3,052-m (10,012-ft) above sea level, adjacent to Pu`u `Ula`ula, also known as Red Hill, the highest elevation on Maui, 3,055-m (10,023-ft).

The 7.3-ha (18.1-ac) site was established in 1961, and the first telescope, the Mees Solar observatory was dedicated in 1964. The site now consists of five telescope facilities.

The proposed ATST primary site is approximately 0.24-ha (0.60-ac) of undeveloped land located east of the existing Mees Solar Observatory facility. The proposed alternative site is at Reber Circle, a previously developed site located north of the existing MAGNUM telescope facility.

Annual precipitation at these sites averages 1,349.2-mm (53.14-in), falling primarily as rain and mist during the winter months from November through April. Snow rarely falls at the site.

During the four days of sampling temperatures ranged from 2˚C (36˚F) at night to 12˚C (54˚F) during the day. Wind speed ranged from 14 m/s at night to 1 m/s during the day. The moon was in the New Moon phase when sampling began on March 17 and a waxing crescent first appeared on March 20.

Sampling

Prior to sampling, reports and publications of previous arthropod surveys and studies were examined to determine the best approach to sample the site. Particular attention was given to the Arthropod Inventory and Assessment conducted in 2003 (Pacific Analytics 2003) and the Updated inventory and assessment of the two proposed ATST sites (Pacific Analytics 2005).

The selection of a trapping technique used in a study needs to be carefully considered. If the target species of the trapping system are rare or important for another reason (i.e., endangered, keystone species, etc.) live-trapping should be considered. Entomologists have long believed that they can sample without an impact on the population being sampled. It has been assumed that collecting makes only a small impact on the populations of interest. While that assumption remains to be tested, responsible entomologists consider appropriate trapping techniques to ensure survival of local populations of interest.

Pitfall Traps

Because sampling was to occur for only four days, ethylene glycol traps were used to sample the arthropod ground fauna. Ethylene glycol pitfall traps are cups placed into the ground so that the lip of the cup is level with the substrate. A small amount of ethylene glycol is placed into the trap to kill and preserve specimens that fall into the traps. Ethylene glycol is used because it has a low evaporation rate and because it prevents specimen decomposition during the sampling period. Additionally, it is easily cleaned from the specimens.

Five pitfall traps were installed an each of the two sites being considered for the proposed ATST. Traps were installed and set on March 17, 2007 and closed on March 20, 2007.

Light Sampling

Night sampling was conducted using lights and a collecting sheet. A sheet was hung on a rope and a UV light was suspended in the middle of the sheet. During windy conditions the sheet was placed on the ground and held down with rocks. The light was turned on after sunset, and allowed to attract night-flying insects for at least two hours. Insects that landed on the sheet were collected with an aspirator or sweep net.

Each of the proposed ATST sites was sampled each night, March 17-20 (four nights).

Light sampling at Reber Circle.

Light sampling on a windy night adjacent to the MEES observatory.

Visual Observations

Approximately eight hours were spent during daylight sampling under rocks, in leaf litter, and on foliage to locate and collect arthropods at each site.

Approximately 6 hours were spent after sunset sampling foliage and under rocks and visually observing the ground and nearby vertical surfaces for arthropods. The sampling sites were illuminated using a headlamp.

Curation

The contents of the traps were cleaned in 70% ethyl alcohol and placed in vials. The specimens were sorted into the morphospecies for identification. Hard-bodied species, such as beetles, moths, true bugs, flies, and wasps were mounted on pins, either by pinning the specimen or by gluing the specimens to paper points. Pinned specimens were placed into Schmidt boxes. Soft-bodied specimens, such as spiders and caterpillars were stored in vials filled with 70% ethyl alcohol.

Identification

References for general identification of the specimens included Fauna Hawaiiensis (Sharp (ed) 1899-1913) and the 17 volumes of Insects of Hawaiʻi (Zimmerman 1948a, 1948b, 1948c, 1948d, 1948e, 1957, 1958a, 1958b, 1978, Hardy 1960, 1964, 1965, 1981, Tentorio 1969, Hardy and Delfinado 1980, Christiansen and Bellinger 1992, Liebherr and Zimmerman 2000, and Daly and Magnacca 2003). Other publications that were useful for general identification included The Insects and Other Invertebrates of Hawaiian Sugar Cane Fields (Williams 1931), Common Insects of Hawaiʻi (Fullaway and Krauss 1945), Hawaiian Insects and Their Kin (Howarth and Mull 1992), and An Introduction to the Study of Insects Sixth Edition (Borror, Triplehorn, and Johnson 1989).

For specific groups specialized keys were necessary. Most of these had to be obtained through library searches. Keys used to identify Heteroptera included those by Usinger (1936, 1942), Ashlock (1966), Beardsley (1966, 1977), and Gagné (1997). Keys used to identify Hymenoptera included Cushman (1944), Watanabe (1958), Townes (1958), Beardsley (1961, 1969, 1976), Yoshimoto and Ishii (1965), and Yoshimoto (1965a, 1965b).

Species identification of those specimens identified to genus or species levels are unconfirmed and subject to change after comparison to specimens in museums.

In many cases changes in family and generic status and species synonymies caused species names to change from those in the keys. Species names used in this report are those listed in Hawaiian Terrestrial Arthropod Checklist Third Edition (Nishida 1997).

VI. RESULTS AND DISCUSSION

Observations

The primary site has had minimal disturbance from previous construction. Vegetation in this area is largely undisturbed.

About eighty percent of the Reber Circle site has been disturbed by previous construction. Native vegetation occurs only at the north and east portions of this site.

Nineteen species of arthropods were detected during the sampling. Twelve of the detected species are thought to be endemic to Hawai`i. Night sampling yielded only one species not detected during the daylight hours, a noctuid moth.

Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in pitfall traps at both sites being considered for the proposed ATST. They were less abundant than during the two previous arthropod inventories, occurring in only two pitfall traps. Several juvenile spiders were observed during daytime sampling. *Lycosa hawaiiensis* is the predominant predator of the arthropod fauna in from the crater district of Haleakalā (Medeiros and Loope 1994). This spider is also known from the islands of Oahu and Hawai`i.

Juvenile centipedes were observed under rocks. Centipedes are elongate, flattened arthropods with 15 or more pairs of legs, one pair per body segment. They occur in a variety of habitats, where they feed on spiders and insects. There are 24 species of centipedes reported in Hawaiʻi, only one from Maui, the non-indigenous, *Mecistocephalus spissus* Wood (Nishida 1997). Because of a lack of taxonomic keys for juvenile stages, the centipedes observed during this study were not identified.

Eight species of true bugs and leafhoppers were detected on the vegetation at the sites; seven of the species are endemic to Hawai`i. All eight of these species have been reported from the HO site and surrounding habitats in previous surveys.

The endemic plant bug (family Miridae) *Trigonotylus hawaiiensis* (Kirkaldy) was collected from the native grasses at the Mees site. This species can be very abundant on grasses, and occurs everywhere in suitable habitats from the coast to

10,000 feet (Perkins 1913, Zimmerman 1948), and on all the main Hawaiian Islands except Molokai. This species was present in low abundance.

The endemic plant bug *Engytatus hawaiiensis* (Kirkaldy) was abundant on *na`ena`e* (*Dubautia menziesii* (A. Gray) D. Keck). This insect was first described from specimens collected in the Haleakalā Crater (Zimmerman 1948) and is also known from the islands of Oahu, Molokai and Hawai`i.

The endemic seed bug (family Lygaeidae) *Nysius coenosulus* (Stål) was very abundant on *pukiawe* (*Styphelia tameiameiae* (Cham. & Schlechtend.) F. V.Muell.) and less common on *na`ena`e*. This insect is known from all but one of the major islands, and uses a wide variety of plants as hosts.

An endemic seed bug of the genus *Neseis ochriasis* Usinger was collected in leaf litter under *pukiawe*. This species was not abundant, occurring under only about ten percent of the plants sampled.

Another potentially endemic species of seed bug was found *pukiawe*. Only one specimen of this species was found and may be a vagrant from the surrounding lowlands.

Two species of stink bugs (Pentatomidae) were collected from the Mees site. The largest is the introduced green stink bug, *Nezara viridula* (Linnaeus). One specimen of the endemic *Oechalia similes* Usinger was collected. This species endemic predator is known only from Maui and occurs in low abundance above 4,500 feet (Zimmerman 1948).

One species of leafhopper (family Delphacidae), *Nesosydne osborni* Muir was collected from *pukiawe*. This endemic insect was common on *na`ena`e* and *pukiawe*. It occurs throughout the Haleakalā crater region.

Other arthropods occurred in low abundance including small ground beetles and spiders, Collembola, and flies. The arthropod fauna collected during this study will be discussed according to their taxonomic groups.

Beetles are the most diverse group of arthropods in Hawaiʻi. There are 1,983 species of beetles reported in Hawaiʻi (Nishida 1997), 544 on Maui (B.P. Bishop Museum 2002).

Three species of beetles were found during this study, at least one from the genus *Mecyclothorax* is endemic to Hawaiʻi. Specimens of this species were found in leaf litter under *na`ena`e*, and were not abundant.

A rove beetle (family Staphylinidae) was also detected in low abundance. Species of this group in Hawai`i are adventive and cosmopolitan in distribution. One species of Coccinellidae, *Olla v-nigrum* (Mulsant) was found on *pukiawe*. This species was purposely introduced in Hawai`i as a biological control agent.

Collembola are small, insect-like arthropods. They are abundant and ubiquitous, exceeding all other insects in numbers of individuals (Christiansen and Bellinger 1992). Most species are detritivors and few are pests. One hundred and sixty-nine species of Collembola are found in Hawaiʻi, sixty on Maui (Nishida 1997).

Because of their small size (0.25–6-mm), Collembola are seldom observed or reported. In 2003 Collembola were abundant in pitfall traps, occurring in the hundreds in some locations, especially on the outer northwest slopes of Pu`u Kolekole, but uncommon in the southern part of the HO site. During the current study Collembola were observed under rocks and in leaf litter in low abundance.

In previous studies on Haleakalā, more than 115 species of flies were recorded (Beardsley 1980, Medeiros and Loope 1994, Pacific Analytics 2003). Only a few of those species were recorded near Pu`u Kolekole.

During this study, two species of flies were observed. The Blue Bottle Fly, *Calliphora vomitoria* (L.) was seen in low abundance. This non-indigenous fly is widespread throughout the World. It occurs on all the main islands of Hawai`i at higher elevations.

One specimen of *Drosophila melanogaster* Miegen was collected from *pukiawe*. This small fruit fly is an adventive species, not native to Hawaiʻi.

Bees and wasps are common in Hawaiʻi. There are 1,270 species that occur in Hawaiʻi. Of these species, 652 are endemic to Hawaiʻi that consist largely of small parasitic wasps, mud-daubers, and yellow-faced bees. The yellow-faced bees (family Colletidae) are important pollinators of native plants (Howarth and Mull 1992). Many of the non-indigenous species were purposely released for biological control of agricultural pests.

One species of yellow-faced bee (family Colletidae) was collected during this study, *Hylaeus nivicola* Meade-Waldo. These bees are important pollinators of native plants, and occur in low abundance in higher elevations where vegetation is scarce.

One species of parasitic wasp was collected during this study. Hymenoptera were relatively uncommon at the site, a similar finding as that recorded in 1994 (Medeiros and Loope). In an earlier investigation

(Beardsley 1966), 12 species of Hymenoptera were collected at the site, mostly small parasitic wasps. Most of the species are not likely residents of the site and probably are carried by winds from lower elevations. The status of this group is largely unchanged since 1966.

No ants were found during this study, and none were reported in previous studies.

There are 1,148 species of moths and butterflies found in Hawaiʻi, a majority (957) of which are endemic. Many of the endemic species are small moths with a wingspan of less than 1 cm (Howarth and Mull 1992).

In higher elevations, larvae of some moths may feed on wind-blown lowland arthropods that become moribund as nighttime temperatures drop. They may also eat the leaves of the few plants that occur in their habitat.

Only one species of moth came to lights during night sampling, *Agrotis baliopa* Meyrick. This moth is known only from the islands of Maui and Hawaiʻi. Little is known about this species, even its host plant is unknown (Zimmerman 1958). Its type locality is 6,000 feet on Haleakalā.

One caterpillar was found in a pitfall trap. It appears to be a noctuid, or closely related group. The caterpillar was found at the primary site near the Mees observatory.

Night sampling, using attracting lights, and intensive searching for foliage and ground dwelling arthropods yielded only one new species to the arthropod inventory, the noctuid moth mentioned in the previous paragraph. Foliage sampling at night detected only species that were active and common during daylight hours, and ground searching found no active species.

Summary of the Arthropod Fauna

The arthropods species that were collected during this study were typical of what has been found during previous studies. No species were found that are locally unique to the proposed sites. Nor were any species found whose habitat is threatened by normal observatory operations. Species that were detected during this and the previous assessment of the proposed ATST sites were those that occur over the larger Haleakalā, or have wider distributions on Maui and other islands in the Hawaiian chain.

Comments submitted for the ATST Draft Environmental Impact Statement suggested that important and unique special status species in the summit area may not have been represented in earlier arthropod collections and reports of the proposed sites. The supplemental sampling summarized in this report did not identify any species listed as endangered or threatened, candidate species for listing, or any species of concern.

Night sampling detected only one species not captured in the previous two assessments of the HO facility, an endemic noctuid moth. Overall arthropod diversity was low during this study, likely due to seasonal factors.

The diversity of the arthropod fauna at the Haleakalā High Altitude Observatories Site is somewhat less than what has been reported in adjacent, undisturbed habitat. This could be expected given the fact that about 40% of the site is occupied by buildings, roads, parking areas, and walkways. Also, much of the ground surrounding the buildings is disturbed and compacted from observatory operations. However, the undisturbed habitat on the site that was sampled has an arthropod fauna generally similar to what could be expected from other small habitat patches on the volcano with similar undisturbed habitat.

While development of the site has impacted the availability of some habitat locally, it has only affected a small amount of the available habitat on the volcano overall. The 7.3-ha (18.1-ac) facility occupies less than one percent of similar habitat available on the volcano (MacDonald 1978). The undisturbed portions of the Haleakalā High Altitude Observatories Site are representative of the surrounding habitat on Haleakalā.

The two proposed ATST sites represent an even smaller portion of the habitat overall on Haleakalā. The Reber Circle site was previously developed and has very sparse vegetation to support arthropods. The ground here is largely compacted, and lacks the structure necessary for most ground-dwelling arthropods. Only the surrounding, undisturbed areas contain habitats in which arthropods can survive. The diversity and abundance of arthropods at this site is very low.

The primary proposed ATST site east of the existing Mees Solar Telescope facility is relatively undisturbed. Native vegetation is more abundant here, and the relatively undisturbed nature of the substrate provides microhabitats for arthropods. The diversity and abundance of arthropods here is greater than that of the Reber Circle site, but is low compared to the HO site in general and to the surrounding undisturbed habitats found elsewhere on Haleakalā. This is likely due to a scarcity of vegetation.

Most of the arthropods collected during this study were largely associated with the vegetation at the site. Development of either of the proposed sites for the ATST will diminish only slightly the presence of the native vegetation in the general area of the HO, and therefore not threaten the persistence of any arthropod species found at the sites. The vegetation cover at these sites is only a small portion of the overall habitat available elsewhere on Haleakalā.

Only a few exclusively ground-dwelling species were found during this study. These include the wolf spider, ground beetles, centipede, and Collembola. These species make their home under rocks and in crevices and do not burrow into the cinder substrate. No obvious threats to these species survival were evident at either of the proposed ATST sites, although development of the primary site will displace some arthropod habitat.

One of the biggest concerns of past evaluations was the presence of ants. None were found during this study, but ants are reported from nearby National Park facilities. With some practical precautions, the site should remain ant free.

Other alien arthropod species also have the potential to impact the native ecosystem. No obviously threatening alien species were found during this study and with similar precautions as those used for ants; none should be introduced by the ATST observatory construction or operation. The harsh environment of this aeolian ecosystem should make it difficult for most alien species to establish populations.

It is unlikely that development of either of the proposed ATST sites will have a serious impact to arthropod species that occur at the sites beyond the limits of the HO facility.

The development of the ATST facility will diminish a small amount of arthropod habitat, including the presence of native plants, and thereby reduce native arthropod species diversity and abundance at the proposed ATST sites, but is not likely to have a direct impact on the persistence of arthropod species on Haleakalā.

The results of the arthropod survey indicate there are no special concerns or legal constraints related to invertebrate resources in the project area. No invertebrate species listed as endangered, threatened, or that are currently proposed for listing under either federal or State of Hawai'i endangered species statutes were found at the project site (DLNR 1997, Federal Register 1999, 2005).

Table 1. Species List of Arthropods collected during March 2007 sampling.

Order	Family	Genus	Species	Authority	Status
Araneae	Lycosidae	Lycosa	hawaiiensis	Simon	endemic
Coleoptera	Coccinellidae	Olla	v-nigrum	(Mulsant)	purposely
Coleoptera	Staphylinidae		sp.		unknown
Coleoptera	Carabidae	Mecyclothorax			endemic
Diptera	Calliphoridae	Calliphora	vomitoria	Linnaeus	introduced
Diptera	Drosophilidae	Drosophila	melanogaster	Meigen	adventive
Heteroptera	Lygaeidae	Neseis	ochriasis	Usinger	endemic
Heteroptera	Lygaeidae	Nysius	coenosulus	Stål	endemic
Heteroptera	Lygaeidae		sp.		endemic?
Heteroptera	Miridae	Engytatus	hawaiiensis	(Kirkaldy)	endemic
Heteroptera	Miridae	Trigonotylus	hawaiiensis	(Kirkaldy)	endemic
Heteroptera	Pentatomidae	Nezara	viridula	Linnaeus	introduced
Heteroptera	Pentatomidae	Oechalia	similis	Usinger	endemic
Homoptera	Delphacidae	Nesosydne	osburni	Muir	endemic
Hymenoptera	Braconidae		sp.		unknown
Hymenoptera	Colletidae	Hylaeus	nivicola	Meade-Waldo	endemic
Lepidoptera	Noctuidae	Agrotis	baliopa	Meyrick	endemic
Collembola					endemic?
Geophilomorpha?			sp.		juvenile

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(3) ARTHROPOD INVENTORY AND ASSESSMENT AT THE HALEAKALĀ NATIONAL PARK ENTRANCE STATION AND AT THE HALEAKALĀ HIGH ALTITUDE OBSERVATORIES MAUI, HAWAI`I

In Support of the Advanced Technology Solar Telescope Environmental Impact Analysis Process

JULY 2009

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ARTHROPOD INVENTORY AND ASSESSMENT AT THE HALEAKALĀ NATIONAL PARK ENTRANCE STATION AND AT THE HALEAKALĀ HIGH ALTITUDE OBSERVATORIES MAUI, HAWAI`I

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II. EXECUTIVE SUMMARY

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 3,055-m (10,023-ft) at its summit on Pu`u `Ula`ula. Near the summit is a volcanic cone known as Kolekole with some of the best astronomy viewing in the world. The summit of Haleakalā is also the home to unique cultural and natural resources. Important cultural places and sites are found here that are spoken of in numerous Hawaiian mele (songs), oli (chants) and legends (NPS 2005). Arthropods occur near the summit of Haleakalā in an aeolian ecosystem that was once considered virtually lifeless. The subalpine shrubland within the Haleakalā National Park is also host to a wide variety of indigenous species. Because these areas remain fairly intact, they represent important habitat for unique and highly adapted native arthropod species (Loope and Medeiros 1994).

The National Science Foundation (NSF) has proposed the development of the Advanced Technology Solar Telescope (ATST) within the 18-acre University of Hawai`i Institute for Astronomy High Altitude Observatories (HO) site. The ATST represents a collaboration of 22 institutions, reflecting a broad segment of the solar physics community. The proposed ATST project would be the largest and most capable solar telescope in the world. It would be an indispensable tool for exploring and understanding physical processes on the Sun that ultimately affect Earth. The proposed ATST Project would be contained within a 0.74 acre site footprint (FEIS, 2009) in the HO site.

The current configuration of the existing entrance station for Haleakalā National Park (HALE) has been identified as a restriction to wide truck loads necessary during construction of the ATST. Loads up to about 33 feet wide would be required to move telescope components to the ATST site. The HALE entrance station currently provides one paved driving lane approximately 12 feet wide on both the entrance and exiting sides. HALE staff has identified a mutually preferred option to temporarily widen and improve the shoulder of the entry on the uphill side of the entrance station to accommodate the large loads. The provision of wide-load truck access at the HALE entrance station would require mitigations related to that project, as described in Section 4.18.5 of the Final Environmental Impact Statement (2009). The proposed mitigation includes protection of habitat for biological resources and HALE infrastructure. Additional information about arthropods that may occur near the entrance station is necessary to understand potential impacts, if any, due to the proposed road modifications made there.

An inventory and assessment of the arthropod fauna at the proposed ATST sites was conducted in 2005 with supplemental sampling in 2007. The goal of this study was to inventory the arthropod fauna near the entrance station and at the proposed ATST sites, identify Hawaiian native arthropod species or habitats, if any, that could be adversely affected by construction or operation of the ATST, and provide a seasonal component of baseline information that may be used for proposed programmatic monitoring.

III. INTRODUCTION

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 3,055-m (10,023-ft) at its summit on Pu`u `Ula`ula. Near the summit is a volcanic cone known as Kolekole with some of the best astronomy viewing in the world. In 1961, an Executive Order of Hawai`i Governor Quinn established the Haleakalā High Altitude Observatories (HO) Site, sometimes referred to as "Science City". The site is managed by the University of Hawai`i.

The highest elevations of Haleakalā were once considered largely lifeless with only sparse vegetation, but biologists have discovered a diverse fauna of unique resident insects and spiders (Medeiros and Loope 1994). These arthropods inhabit unusual natural habitats on the bare lava flows and cinder cones. Feeding primarily on windblown organic material, they form an aeolian ecosystem.

The term aeolian has generally been used to describe ecosystems on snow, ice, meltwater, and barren rock, but in Hawai`i it has been used to characterize non-weathered lava substrates, mostly but not exclusively found at high elevations (Howarth 1987, Medeiros and Loope 1994).

On Haleakalā, aeolian and sub-aeolian ecosystems begin at about 2,300-m (7,546-ft) elevation in the cinder-dominated habitat inside the crater, and at around 2,600-m (8,530-ft) on the older western slope of the volcano, and extend up to the summit at 3,055-m (10,023-ft). Climate conditions are extreme, with widely varying diurnal temperatures and little precipitation. Solar radiation can be intense, and the conditions often affect visitors not accustomed to high elevations.

The Haleakalā aeolian ecosystem is extremely xeric, caused by relatively low precipitation, porous lava substrates that retain negligible amounts of moisture, little plant cover, and high solar radiation. The dark, heat-absorbing cinder provides only slight protection from the extreme temperatures. Thermal regulation and moisture conservation are critical adaptations of arthropods that occur in this unusual habitat.

Vegetation covers less than 5% of the open ground, and food is apparently scarce. Wind-assisted diurnal movement and seasonal migrations of insects from the surrounding lowlands are the primary source of food for the resident scavenger and predator arthropods in this remarkable ecosystem. Aeolian ecosystems are not unique to Haleakalā in Hawai`i. Similar ecosystems also occur on Mauna Kea and Mauna Loa on the Island of Hawai`i (Howarth and Montgomery 1980). Each volcano has its own unique aeolian fauna that exploit the windblown organic material.

An inventory and assessment of the arthropod fauna at the HO site was conducted in 2003 as part of the Long Range Development Plan (LRDP) for the Haleakalā High Altitude Observatories. This inventory and assessment was updated in December 2005 to provide a more detailed description of the arthropod fauna at the two proposed ATST sites, and identify Hawaiian native arthropod species or habitats, if any, that could be impacted by construction or operation of the ATST. In an effort to be complete, supplemental sampling was conducted in 2007 to provide a seasonal component and additional nighttime sampling not included in the previous two inventories.

The subalpine shrubland within the Haleakalā National Park is also host to a wide variety of indigenous arthropod species (Krushelnycky et al. 2007). The vegetation here covers most of the open ground, mostly with *pūkiawe* (*Styphelia tameiameiae*), *ōhelo* (*Vaccinium reticulatum*), and occasional *mamane* (*Sophora chrysophylla*) trees and *Coprosma* shrubs, with native and alien grasses growing between. Precipitation in the form of rainfall and fog is frequent, with about 70 inches falling throughout the year (Giambelluca et al. 1986).

Because the areas proposed for development remain fairly intact, they represent important habitat for unique and highly adapted native arthropod species (Loope and Medeiros 1994). Sampling of arthropod habitats was approved in a permit obtained from the Department of Land and Natural Resources (Permit # FHM09-188) and the National Park Service (Permit # HALE-2009-SCI-0007), both issued in June, 2009. Sampling began on June 19, 2009 and was completed on June 26, 2009.

The intended purpose of this study is to gather reliable scientific information about the current status of arthropods and other invertebrate species near the HALE entrance station and at the proposed ATST primary and alternative sites within the HO site that would be used to assess the potential impacts, if any, due to construction of the proposed ATST.

This study provides a means of gathering information that can be used to establish a baseline for proposed programmatic monitoring of native arthropod and invertebrate species over the next ten years as part of the proposed ATST Project mitigation measures described in Section 4.18.3 of the FEIS. This study supports natural resource management programs at Haleakalā National Park and is consistent with the Long Range Development Plan for the Haleakalā High Altitude Observatories Site (HO) by promoting the good stewardship of the natural resources located there.

IV. METHODS

Description of study area

The Haleakalā High Altitude Observatories (HO) site is located on Kolekole Hill. The site is at 3,052-m (10,012-ft) above sea level, adjacent to Pu`u `Ula`ula, also known as Red Hill, the highest elevation on Maui, 3,055-m (10,023-ft). The 7.3-ha (18.1-ac) site was established in 1961, and the first telescope, the Mees Solar observatory was dedicated in 1964. The site now consists of five telescope facilities.

The proposed ATST primary site is on undeveloped land located east of the existing Mees Solar Observatory facility. The proposed alternative site is at Reber Circle, a previously developed site located north of the existing LURE/PS-1 facility.

Annual precipitation at these sites averages 1,349.2-mm (53.14-in), falling primarily as rain and mist during the winter months from November through April. Snow rarely falls at the site.

The Haleakalā National Park Entrance Station is at about 2,072 m (6,800 ft) on the western slope of Haleakalā. Sampling locations were determined with guidance and cooperation from HALE personnel. Annual precipitation here averages 1,750 mm (70 in), falling primarily as rain and mist during the winter months from November through April.

Procedures

The selection of a trapping technique used in a study was carefully considered. When the target species of the trapping system are rare or important for other reasons (i.e., endangered, keystone species, etc.) live-trapping should be considered. Entomologists have long believed that they can sample without an impact on the population being sampled. It has been assumed that collecting makes only a small impact on the populations of interest. While that assumption remains to be tested, responsible entomologists consider appropriate trapping techniques to ensure survival of local populations of interest. The sampling methods that were used during this study are similar to those used during the 2007 arthropod inventory conducted on the western slope of Haleakalā and were reviewed by HALE natural resource staff modified according to their comments.

Pitfall Traps

After consultation with HALE natural resources staff, twelve pitfall traps were installed (eight below the road and four above the road) near the HALE entrance station. Nine pitfall traps were installed at the proposed ATST sites (five at the Mees site and four at the Reber Circle site). The traps (300 ml [10 oz], 80 mm diameter cups) were filled with soapy water solution as preservative. Concerns about endangered native birds precluded the use of ethylene glycol. The traps were spaced at least 2 m apart, and left open for one week. It was decided that pitfall traps would not be baited around the rim with blended fish because they might attract birds. This is a trapping method similar to that used during the 2007 arthropod survey conducted in 2007 (Krushelnycky et al. 2007).

Care was taken to avoid archeological sites. These sites have cultural and historical significance and precautions were made to prevent their disturbance. Traps were not placed in or near these sites. A map of significant historic and cultural sites within 50 feet of the road corridor was used to avoid such sites. Habitat was accessed with a minimum of disturbance to the habitat. Care was also taken to prevent creation of new trails or evidence of foot traffic.

Care was also taken to avoid disturbing nesting petrels and other wildlife species. The endangered petrels dig into cinder to make burrows for nesting. Incubation of fledglings was underway and all efforts were made to avoid active nests. Pitfall traps are placed below ground and covered with a heavy cap rock. This makes it very unlikely that petrels could access the traps.

Light-Trapping

Sampling for nocturnal insects is vital to understanding the complete faunal presence. Some insects are only active and moving around at night. Many insects have a nocturnal activity cycle to evade birds, and to locate certain food sources. Night collecting is important in environments like dry locations where insects may choose this strategy to avoid desiccation. Thyrocopa moths, for example, have been seen at lights in restrooms at the HALE Visitor Center, at 9,740 ft.

Battery-powered ultraviolet light traps were operated near the entrance station and at the ATST sites. The traps consisted of a 3.5 gallon polypropylene bucket, a smooth surface funnel, a 22 watt Circline blacklight tube mounted on top of vanes under an aluminum lid that directs light downwards. The effective range of the 22 watt lamp is less than 100 feet, and traps were always located more than 100 feet from the nearest petrel burrow. Light traps will be run every night for seven nights (a total of 14 trap nights).

Other light sampling at night

Night collecting can be aided by a UV light source. An ultraviolet blacklight was placed on top of a white sheet and arthropods that were attracted to the light were collected as they are observed.

Small handheld ultraviolet blacklights were also used for additional sampling for foliage and ground-dwelling arthropods.

Visual Observations and Habitat Collecting Under Rocks and in Leaf Litter

Time was spent sampling under rocks, in leaf litter, and on foliage to locate and collect arthropods at each sampling station. Hand picking, while sorting through leaf litter and bunch grasses, and searching beneath stones was the most effective sampling for litter and soil associated forms.

Collecting on Foliage

Foliage of various common plant species was sampled by beating sheet. A one-meter square beating sheet or insect net was placed under the foliage being sampled and the branch hit sharply three times using a small plastic pipe. After the initial collection the foliage was beat again to dislodge persistent individuals. Care was taken to avoid sensitive plants and to leave all vegetation intact.

Nets

Aerial nets and sweep nets were used as necessary to capture flying insects and arthropods that occur on grasses.

Collections

Arthropods that appear in traps were stored and later mounted for identification. Arthropods that are observed during hand collecting and netting were collected only as necessary to provide voucher specimens.

Curation

The contents of the traps were cleaned in 70% ethyl alcohol and placed in vials. The specimens were sorted into the morphospecies for identification. Hard-bodied species, such as beetles, moths, true bugs, flies, and wasps were mounted on pins, either by pinning the specimen or by gluing the specimens to paper points. Pinned specimens were placed into Schmidt boxes. Soft-bodied specimens, such as spiders and caterpillars were stored in vials filled with 70% ethyl alcohol.

Identification

Specimens were mounted and identified to the lowest taxonomic level possible within the time frame of the study. Many small flies and micro-Hymenoptera were sorted to morpho-species and will be sent to reliable experts for identification. Identification of arthropods is difficult, even for experts. More time needs to be allotted for this necessary task in all arthropod inventory projects. All specimen identifications are provisional until they can be confirmed by comparison to museum specimens or by group/taxon experts.

References for general identification of the specimens included Fauna Hawaiiensis (Sharp (ed) 1899-1913) and the 17 volumes of Insects of Hawaiʻi (Zimmerman 1948a, 1948b, 1948c, 1948d, 1948e, 1957, 1958a, 1958b, 1978, Hardy 1960, 1964, 1965, 1981, Tentorio 1969, Hardy and Delfinado 1980, Christiansen and Bellinger 1992, Liebherr and Zimmerman 2000, and Daly and Magnacca 2003). Other publications that were useful for general identification included The Insects and Other Invertebrates of Hawaiian Sugar Cane Fields (Williams 1931), Common Insects of Hawaiʻi (Fullaway and Krauss 1945), Hawaiian Insects and Their Kin (Howarth and Mull 1992), and An Introduction to the Study of Insects Sixth Edition (Borror, Triplehorn, and Johnson 1989).

For specific groups specialized keys were necessary. Most of these had to be obtained through library searches. Keys used to identify Heteroptera included those by Usinger (1936, 1942), Ashlock (1966), Beardsley (1966, 1977), and Gagné (1997). Keys used to identify Hymenoptera included Cushman (1944), Watanabe (1958), Townes (1958), Beardsley (1961, 1969, 1976), Yoshimoto and Ishii (1965), and Yoshimoto (1965a, 1965b).

Species identification of those specimens identified to genus or species levels are unconfirmed and subject to change after comparison to specimens in museums.

In many cases changes in family and generic status and species synonymies caused species names to change from those in the keys. Species names used in this report are those listed in Hawaiian Terrestrial Arthropod Checklist Third Edition (Nishida 1997).

Schedule/Start and End dates

Sampling was conducted over eight days and nights in June 2009, starting on June 19, 2009 and ending on June 26, 2009. Sampling typically began at 9:00 am and run until about 2:00 pm. A break was taken to prepare for night sampling which resumed at 8:00 pm and continued until midnight. It is estimated that approximately seventy person hours were spent sampling during the day and fifty person hours after dark. Pitfall traps were open for 147 trap nights, and light traps were deployed for 21 trap nights. Three days was allocated for mounting and identification.

V. LITERATURE SUMMARY

The summit of Haleakalā has been sampled by several entomologists. Some of the first specimens known from there were collected by the Reverend Thomas Blackburn over 100 years ago. Near the beginning of the twentieth century, R.C.L. Perkins sampled the upper reaches of Haleakalā. During the first half of the century other entomologists who sampled Haleakalā included O.H. Swezey who recorded host plant information for many insect species, E.C. Zimmerman who collected information for the Insects of Hawaiʻi series and studied the flightless lacewings of Haleakalā, and D.E. Hardy who worked extensively with the Diptera (flies) found there.

Entomological studies continued in the 1960's when John Beardsley (1966) investigated species of Nysius that were disrupting operation of the Haleakalā Observatory. Beardsley collected fifty-one insect species from 36 families in nine orders from malaise traps on Pu\`u Kolokole in that study.

In 1980, John Beardsley completed his basic inventory of the insects of the Haleakalā National Park crater district for the Cooperative National Park Resources Studies Unit of the University of Hawaiʻi at Manoa. This was the first published report of a thorough inventory of the upper portion of Haleakalā listing the species collected. Three hundred and eighty-nine species of insects representing ninety families from thirteen orders were collected from the Crater District in this study. About 60% of the species were believed to be endemic to Hawaiʻi, and 83 species (21%) were determined to be endemic to Haleakalā.

An inventory of arthropods of the west slope shrubland and alpine ecosystems of HALE was conducted in 2007 (Krushelnycky et al.). The investigators collected a total of 60,146 individual arthropods in the course of the inventory. Of these, 11,086 (18.4%) were mites (Acari), mealybugs (Hemiptera: Pseudococcidae), or parasitic wasps (Hymenoptera), and were not further identified. The remaining arthropods represented a total of 257 taxa in 17 orders.

The HO property adjacent to HALE has been studied several times. The first review of the arthropod fauna at the HO site occurred in 1994 (Medeiros and Loope 1994). The study was limited to the proposed Air Force Advanced Electro-Optical System (AEOS) Construction Site. The number of species collected is not listed in that report. The report concluded "The study site is basically a typical but somewhat depauperate example of the Haleakalā aeolian zone."

An inventory of arthropods at the HO site was conducted in 2003 (Pacific Analytics 2003). In that study, fifty-eight arthropod species were identified from the facility, twenty-nine that are indigenous to Hawai\`i. Finally, an ATST site-specific update to that study was conducted in 2005 (Pacific Analytics 2005) and a supplemental sampling specifically for the purpose of night sampling was conducted in March 2007 (Pacific Analytics 2007). During June 2009, additional sampling was conducted at HO to further supplement the first three collections, including nighttime samples.

VI. RESULTS AND DISCUSSION

Observations

High Altitude Observatories ATST Sites

The Mees site has had minimal disturbance from previous construction. Vegetation in this area is largely undisturbed and is a mix of native and non-native species. About eighty percent of the Reber Circle site has been disturbed by previous construction. Native vegetation occurs only at the north and east portions of this site.

Sixty-two species of arthropods were collected at the two sites and around the HO facility. Night sampling was fairly effective. Two species of endemic moths were collected in the light traps and a few specimens of the Haleakalā flightless moth (*Thyrocopa apatela*) were found on rocks. They did not appear to be attracted to the lights. An *Agrotis* moth larva was observed foraging at night. *Nysius* (true bugs) species were resting between *Dubautia* leaves and under shrubs, but appeared to be active when disturbed, even at low nighttime temperatures.

Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in pitfall traps at both ATST sites. Several juvenile spiders were observed during daytime sampling. *Lycosa hawaiiensis* is the predominant predator of the arthropod fauna in from the crater district of Haleakalā (Medeiros and Loope 1994). This spider is also known from the islands of Oahu and Hawai`i. They were observed to be especially active during the day.

The pitfall traps also captured several noctuid larvae (caterpillars). Two *Agrotis* moth species were captured in the light traps and these caterpillars may be their larvae. One specimen of the endemic carabid beetle, *Mecyclothorax* sp., was found in the pitfall traps. They are not abundant at the sites although several were found searching under rocks and leaf litter.

The most effective sampling method was foliage beating and searching. Small centipedes and millipedes were found, presumably indigenous species. Twelve species of beetles were found, four that are endemic to Hawai`i. The most interesting of these are the previously mentioned *Mecyclothorax*, and two species of long horn beetles of the genus *Plagithmysus*. *Mecyclothorax* populations appear to be impacted when alien predators are introduced to their habitats (Liebherr and Krushelnycky 2007) and their conservation is considered important. The two species of long horn beetles are considered rare and are infrequently collected.

Thirteen species of flies were collected, only two endemic to Hawai`i. Of interest were the specimens of native fruit flies (Tephritidae). These flies are often important pollinators of native plants and may be important in preserving native ecosystems. These flies were uncommon on *pūkiawe* likely feeding on nectar. The non-indigenous flies are common in the lowlands surrounding Haleakalā and may be blown up to the HO site by wind.

The most abundant insects were the seed bugs of the genus *Nysius*. These bugs were especially common on *pūkiawe* and *ōhelo*. These insects are known to have huge population explosions and sometimes interfere with observatory operations (Beardsley 1966). Three species of the endemic plant hoppers of the genus *Nesosydne* were collected. These species are more abundant in lower elevations but appear to be breeding at the HO sites as juveniles were also collected.

Eleven species of Hymenoptera were found. Except for the European honeybee and native *Hylaeus* bee, they were all small parasitic wasps. These kinds of wasps have been released throughout Hawai`i as biological control agents and whether they are breeding at the high elevations of Haleakalā remains to be investigated.

One of the biggest concerns of past evaluations was the presence of ants. None were found during this study, but ants are reported from nearby National Park facilities. With some practical precautions, the site should remain ant free.

Other alien arthropod species also have the potential to impact the native ecosystem. No obviously threatening alien species were found during this study and with similar precautions as those used for ants; none should be introduced by the ATST observatory construction or operation. The harsh environment of this aeolian ecosystem should make it difficult for most alien species to establish populations.

The development of the ATST facility would diminish a small amount of arthropod habitat, including the presence of native plants, and thereby reduce native arthropod species diversity and abundance at the proposed ATST sites, but would not likely to have a direct impact on the persistence of arthropod species on Haleakalā.

Haleakalā National Park Entrance Station Site

The area surrounding the HALE entrance station is largely native shrubs and grasses and occasional trees. The widening project will require some fill to be brought in, but will displace only a small amount of habitat.

Sixty species of arthropods were observed near the entrance station. The light traps were highly effective at collecting night-flying moths. Fourteen species of moths were collected, ten endemic to Hawai`i. None of these species have a restricted distribution and are all considered common.

The same two species of centipede and millipede were found that were collected at the HO sites. Eight species of beetles were seen, including an endemic species of carabid, *Mecyclothorax*. This was the only endemic species, the rest being introduced non-indigenous species.

A non-indigenous earwig was common in the area, and this species is also common throughout Hawai`i. Seven species of flies were collected, the only native one being a fruit fly of the genus *Trupanea*. As mentioned above, these species can be important pollinators of native plants.

Thirteen species of true bugs (Heteroptera and Homoptera) were found. Most of these are endemic species that are common and widely distributed in Hawai`i. The most interesting was the native stinkbug, *Oechalia pacifica*. This genus of stinkbug is being threatened by the introduction of biological control species, especially those released for the introduced green stink bug. The species that occurs near the entrance station also occurs on Kauai, Oahu, Molokai, and Lanai.

Fourteen species of Hymenoptera were collected at the entrance station, including two species of endemic bees of the genus *Hylaeus*. Both species appear to be limited to habitats on Haleakalā. These species may also be important pollinators of native plant species. Two ant species were collected near the entrance station. Ants represent one of the biggest threats to native arthropods. Much research has been conducted trying to discover a method of controlling these serious pests. Care must be taken during construction to prevent further introductions or spreading of these ants.

Besides the ants, there were no seriously threatening non-indigenous species of arthropods and none should be introduced by ATST development if precautions are followed to prevent their release. The development at the entrance station will displace only a small amount of habitat, most already disturbed by previous park development activities.

Arthropods are seasonal and their abundance and even presence varies throughout the year. The sampling conducted during this inventory is reflective of the time of year it was performed, and is reflective of only the sites surveyed, and thus should not be extrapolated to areas beyond those boundaries. More seasonal sampling would be necessary to establish a complete baseline of current conditions. This study does contribute an important seasonal component to the inventory of the ATST and HO sites, but is only a snapshot of the arthropod fauna at the HALE entrance station. A comprehensive monitoring program will consider seasonal variation when it is implemented.

The results of this arthropod survey indicate there are no special concerns or legal constraints related to invertebrate resources in the project areas. No invertebrate species listed as endangered, threatened, or that are currently proposed for listing under either federal or State of Hawai'i endangered species statutes were found at the project site (DLNR 1997, Federal Register 1999, 2005).

VII. RECOMMENDATIONS

ALIEN ARTHROPOD CONTROL

Analysis of Potential Impacts

Arthropods, segmented animals with hard exoskeletons and jointed appendages, are the most diverse group of animals on earth today. Arthropods are insects, spiders, centipedes, and crustaceans, and are found in all habitats from the bottom of the oceans to the tops of the highest mountains. Arthropod species introduced outside their natural range represent a threat to natural systems because they can deplete native arthropod food resources and prey on native species, sometimes driving natives to extinction. Alien species that successfully establish populations within the Haleakalā High Altitude Observatories Site could out-compete or exclude native species, such as the Haleakalā Flightless Moth, lycosid wolf spider, and other native resident arthropods.

Alien species are those that occur outside of their natural range. Accidentally introduced alien arthropods arrive in the United States at the rate of about 11 new species per year (Sailer 1983). It has been estimated that more than 3,200 alien arthropods have been accidentally or intentionally introduced in Hawai‘i (Howarth and Mull 1992). About 2,500 of these species have established resident populations. Alien arthropods appear in virtually every Hawaiian habitat from sea level to the summits of the highest mountains.

Many insect introductions are regarded as beneficial (i.e., honeybees and biological control agents), but some are feared as potentially dangerous (i.e., ants, spiders, and wasps). The populations of some introduced species have reached destructive numbers and caused serious environmental damage to natural areas. The decline of Hawaiian endemic arthropod populations, resulting from accidental introduction of alien arthropods is well documented (Howarth 1985).

One destructive alien species that has been reported in low numbers near Pu`u Kolekole is the yellowjacket (Vespula pensylvanica). It appeared in low numbers during the 1994 arthropod study of the Air Force Facility. While none were found during the current study, the species can become abundant seasonally in September through November (Medeiros and Lope 1994).

This predator arrived in Hawai‘i in 1977 on imported Christmas trees (Gambino et al. 1990). It quickly became established and spread to all of the main islands. In some places the increasing yellowjacket population corresponded to an alarming decline in many native arthropods vulnerable to the new predator (Gambino et al. 1990). Current yellowjacket populations are too low at the Haleakalā High Altitude Observatories Site to contribute to the decline of native arthropod. If yellowjacket numbers increase at the site, however, native populations could be impacted.

Ants are another group of alien species that have impacted native Hawaiian arthropod populations. Forty-four ant species, none of which are native, have been recorded in the Hawaiian Islands. All were accidentally introduced. Ants can have a devastating impact on the native fauna and flora. Hawai‘i's endemic arthropods never evolved adaptations such as mimicry, or secretions to avoid predation by ants, as is commonly observed with arthropods from areas where ants occur naturally. The establishment of ants within the Haleakalā High Altitude Observatories Site could result in the reduction and possible elimination of many native arthropods.

Perhaps the greatest alien threat to native arthropods is the Argentine ant, (*Linepithema humile*). Although they are relatively small (even for ants), the Argentines nevertheless are quite prolific. Colonies create anywhere from 20 to 100 queens, each producing vast numbers of eggs that keep the colony growing and expanding. In order to feed all the ants that build up in a single colony, Argentine ants utilize and monopolize every available food resource. Vulnerable food resources include not only the wind-borne food of the naturally occurring species, but also the resident native arthropods themselves. Especially vulnerable to ants are the small, immature, nymph stages or instars of native arthropods.

The Argentine ant occurs in several areas in Hawai‘i, including high elevation sites such as Haleakalā National Park on Maui, Hawai‘i Volcanoes National Park, and up to 8,500 feet on Mauna Kea. No Argentine ants were found during this study and the Haleakalā High Altitude Observatories Site is believed to be currently free of ants (Medeiros and Loope 1994).

Other ant species of concern are the big-headed ant, (*Pheidole megacephala*), the long-legged ant, (*Anoplolepis longipes*), the fire ants, (*Solenopsis geminata* and *S. papuana*), and the black house ant, (*Ochetellus glaber*). All these species are present on the Island but have never been reported to occur on the Haleakalā High Altitude Observatories Site.

Alien spiders are another potential threat to the resident native arthropods. The South American hunting spider, (*Meriola arcifera*) has been collected near observatories on Mauna Kea. While its method of introduction is unconfirmed, its occurrence has been linked to observatory operations by some environmental groups. It does not build webs but instead hunts on the surface and interstitial spaces of the cinder cones. The hunting spider is large enough to capture many of the native arthropods at the Haleakalā High Altitude Observatories Site, should it occur there, and can potentially reduce their population.

The probability for the introduction of a serious predator is small. It is important, however, to prevent the establishment of alien species in the sensitive high elevation habitats. Alien arthropod control is therefore an essential consideration during future observatory construction and operation.

Alien Arthropod Control Recommendations
The following actions are recommended to prevent the establishment of alien arthropods on the Haleakalā High Altitude Observatories Site. If these recommendations are followed, no significant impact to native arthropod populations should occur as a result of alien arthropod introductions during the construction and/or operation of the observatories at the site.

The 2005 Institute for Astronomy Long Range Development Plan (LRDP) the Haleakalā Observatories (HO) (http://www.ifa.hawaii.edu/haleakala/LRDP/) was created to provide a structure for sustainable, focused management of the resources and operations of the HO, in order to protect historic/cultural resources: e.g. archaeology sites, traditional cultural practices, to protect natural resources, protect and enhance education and research. Many of these protection measures are already incorporated into the LRDP and in the ATST FEIS are repeated here to emphasize their importance.

Recommendation 1
As required by the LRDP, earthmoving equipment should be free of large deposits of soil, dirt and vegetation debris that could harbor alien arthropods.

(a) Pressure-wash to remove alien arthropods.

Alien arthropods can arrive at the site by two general pathways. First, alien species already on the Island can spread to new localities. Second, alien species can arrive with shipping crates and containers. In order to block the first pathway, heavy equipment, trucks, and trailers should be pressure-washed before being moved to the site.

Earthmoving equipment and large vehicles and trailers often sit at storage sites for several days or weeks between jobs. Most of these storage sites are located in industrial areas and usually support colonies of ants and other alien arthropods. These species often use stored equipment as refuges from rain, heat, and cold. Ants will colonize mud and dirt stuck to earthmoving equipment and could then be transported to uninfested areas. Spiders occupy stored equipment, looking for food or escaping predation by hiding in protected niches. Once transported to the site, these species could migrate to surrounding habitat.

Pressure-washing of equipment before transportation to the site will remove dirt and mud and wash away ants, spiders and other alien arthropods, thereby reducing the chances of transporting these species to the site area.

(b) As required by the LRDP, Inspect large trucks, tractors, and other heavy equipment before entering Haleakalā National Park.

Tractor-trailer rigs, earthmoving machinery, and other heavy equipment should be inspected before Haleakalā National Park. Inspection should be recorded a log book kept at the site.

Recommendation 2
As required by the LRDP, all construction materials, crates, shipping containers, packaging material, and observatory equipment should be free of alien arthropods when delivered to the site.

(a) Inspect shipping crates, containers, and packing materials before shipment to Hawai‘i

Alien arthropods can be transported to Hawai‘i via crates and packaging. Only high quality, virgin packaging materials should be used when shipping supplies and equipment. Pallet wood should be free of bark and other habitat that can facilitate the transport of alien species. Federal and Hawai‘i State agricultural inspectors do not currently check all imported non-food items for alien arthropods. Haleakalā National Park resource managers should communicate to shippers, and suppliers the environmental concerns regarding alien arthropods, and inform them about appropriate inspection measures to ensure that supplies and equipment shipped to Hawai‘i are free of alien arthropods at the points of departure and arrival.

Shipping containers should be inspected and any visible arthropods removed. Construction of crates immediately prior to use will prevent alien arthropods from establishing nests or webs. Cleaning containers just prior to being loaded for shipping will also eliminate alien arthropod infestations.

After arrival in Hawai‘i, crates or boxes to be transported to the site should be inspected for spider webs, egg masses, and other signs of alien arthropods. Arthropods are small and easily overlooked during hectic assembly and packaging activity off-island. Many arthropods could escape detection during shipping inspections. Re-inspection prior to transport to the site should reduce the potential for undetected arthropods reaching the construction site.

(b) Inspect construction materials before entering Haleakalā National Park.

Alien arthropods already resident in Hawai‘i are capable of hitchhiking on construction material such as bricks and blocks, plywood, dimension lumber, pipes, and other supplies. Precautions should be taken to ensure that alien arthropods are not introduced to the Haleakalā High Altitude Observatories Site.

Construction materials should be inspected before transport to the construction site. If any alien arthropods are discovered, the infestation should be removed prior to transport. Infestations of ants can be removed using pressure-washing. Infestations of spiders can be removed using brooms, vacuum cleaners, or other similar methods. Pesticide use on materials to be transported to the site should be avoided.

Recommendation 3
As is currently being done at the site, outdoor trash receptacles should continue to be secured to the ground, have attached lids and plastic liners, and collected frequently to reduce food availability for alien predators.

Readily available food supplies can facilitate the establishment of alien arthropods at the Haleakalā High Altitude Observatories Site. Sanitary control of food and garbage will prevent access to food resources that could be used by invading ants and yellowjackets.

Refuse containers should be heavy and secured to the ground. Heavy, hinged lids will prevent wind dispersal of garbage. Refuse should be collected on a regular basis before containers are completely full or overflowing. This could entail collection several times a week, particularly in eating areas and during periods of heavy use of the area.

Containers should be regularly washed using steam and/or soap to reduce odors that attract ants. Plastic bag liners should be used in all garbage containers receiving food to control leaking fluids.

Recommendation 4
As described in Section 4.18.5 of the FEIS, a biological monitor will be employed during construction and programmatic arthropod sampling will be done in accordance with the schedule shown in Section 4.18.3. Monitoring for new alien arthropod introductions should be conducted during any construction activities. Any populations detected during monitoring would be eradicated.

Monitoring for alien populations is relatively easy and inexpensive to conduct. Baited traps have been shown to detect alien populations before they reach damaging proportions.

(a) Ant eradication

Sticky traps designed to capture ants should be deployed immediately after any ants are detected. Persistence of ant detections is indicative of larger infestations, and should prompt a search for and eradication of colonies. Bait and chemical control should be employed only when absolutely necessary and only by a certified pest control professional. In no case should pesticides be applied on or near native arthropod habitat.

(b) Alien spider eradication

Alien spider webs should be removed when detected. Native lycosid wolf spiders do not make webs. Native sheet-web spiders make tiny webs under the cinder surface. Only alien spiders make large spider webs on the Haleakalā High Altitude Observatories Site. Sweeping such webs away with a broom disrupts alien spider food capture success and destroys egg masses.

TRASH CONTROL

Analysis of Potential Impacts
Construction activity may generate a considerable amount of waste debris. Typically construction debris is disposed of in “roll-off” containers that are periodically picked up and emptied at a landfill. Large “roll-off” containers can accommodate debris generated over several days of

construction. Debris disposed of in these containers consists of wood, scrap insulation, packaging material, waste concrete, and various other construction wastes.

High winds at the site can extract construction debris from the containers and disperse the material into adjacent arthropod habitat. Unsecured building materials and equipment on-site is also susceptible to wind dispersal. The construction trash and building material is not believed to significantly impact native arthropod species, but the collection of the wind-blown material could potentially disturb their habitat (e.g., Howarth et al. 1999).

Trash Control Recommendations

Recommendation 5
Construction trash containers should be tightly covered to prevent construction wastes from being dispersed by wind. This would be accomplished during construction of ATST by Best Management Practices.

Covering containers will decrease the amount of construction debris that could be blown onto adjacent native arthropod habitat. “Roll off” containers can be equipped with tarps held securely with cables. Containers should be collected on a regular basis before they are completely full or overflowing. This could entail collection several times a week, particularly during periods of heavy use.

Recommendation 6
Construction materials stored at the site should be covered with tarps, or anchored in place, and not be susceptible to movement by wind.

Construction materials and supplies should be prevented from being blown into native arthropod habitat by covering them with heavy canvas tarps, using steel cables, attached to anchors that are driven into the ground.

Construction materials at the site should be tied down or otherwise secured during high winds and at close of work each day. Securing materials will reduce the chances of debris being blown off the site into native arthropod habitat. Preventing debris from blowing around and off the site will reduce costs and the potential habitat disturbance necessary to retrieve the items.

Recommendation 7
As required by the LRDP, outdoor trash receptacles should be secured to the ground and have attached lids. Workers and visitors to the Haleakalā High Altitude Observatories Site unfortunately often bring trash with them. Lunch bags, film canisters, wrappers, etc. can be easily blown into arthropod habitat. Receptacles should be provided to eliminate the dispersal of this kind of trash. The receptacles should be heavy and have attached lids so that they do not become flying objects in the high winds at the site.

Recommendation 8

If construction materials and trash are blown into native arthropod habitat, they should be collected with a minimum of disturbance to the habitat.

Despite efforts to prevent wind-blown construction materials and trash, some debris could end up in native arthropod habitat. Retrieving this debris from sensitive areas should be done carefully and with minimum disturbance. Small pieces of debris should be allowed to blow out of habitat to spots where they can be collected safely. Larger debris should be removed with minimum disturbance to slope stability and structure. Methods for removal may vary depending on the material and its location. Contractors should be educated about appropriate debris retrieval methods.

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APPENDIX A

SPECIES LIST

The following list is the provisional identifications of specimens collected during the sampling described in this report. All identifications are provisional and may change when compared to museum specimens or from comments by taxonomic experts.

SPECIES LIST

								Location	
Class	Order	Family	Genus	Species	Subspecies	Authority	Status	HES	HO
Insecta	Coleoptera	Anobiidae	Xyletobius				endemic		X
Insecta	Coleoptera	Apionidae	Exapion	ulicis		(Forster)	non-indigenous	X	
Insecta	Coleoptera	Carabidae	Mecyclothorax	spp.			endemic	X	X
Insecta	Coleoptera	Carabidae	Trechus				non-indigenous	X	
Insecta	Coleoptera	Cerambycidae	Plagithmysus	dubautianus		Gressit and Davis	endemic		X
Insecta	Coleoptera	Cerambycidae	Plagithmysus	railliardiae		(Perkins)	endemic		X
Insecta	Coleoptera	Chrysomelidae	Altica	carinata		(Germar)	non-indigenous	X	X
Insecta	Coleoptera	Coccinellidae	Diamus	notescens		(Blackburn)	non-indigenous		X
Insecta	Coleoptera	Coccinellidae	Hippodemia	convergens		Gurein-Meneville	non-indigenous	X	X
Insecta	Coleoptera	Coccinellidae	Olla	v-nigrum		(Mulsant)	non-indigenous		X
Insecta	Coleoptera	Coccinellidae	Scymnus	loewii		Mulsant	non-indigenous	X	
Insecta	Coleoptera	Coccinellidae	Scymnus	sp.			non-indigenous		X
Insecta	Coleoptera	Coccinellidae	SP1				non-indigenous		X
Insecta	Coleoptera	Curculionidae	Pantomorus	cervinus		(Boheman)	non-indigenous	X	
Insecta	Coleoptera	Nitidulidae	Carpophilus	hemipterus		(Linnaeus)	non-indigenous		X
Insecta	Coleoptera	Staphylinidae	Philonthus	sp.				X	
Insecta	Coleoptera	Staphylinidae	Tachyporus	sp.					X
Insecta	Dermaptera	Forficulidae	Forficula	auricularia		Linnaeus	non-indigenous	X	
Insecta	Diptera	Calliphoridae	Calliphora	vomitoria		(Linnaeus)	non-indigenous		X
Insecta	Diptera	Calliphoridae	Lucilia	sericata		(Meigen)	non-indigenous	X	
Insecta	Diptera	Calliphoridae	SP1					X	
Insecta	Diptera	Muscidae	SP1						X
Insecta	Diptera	Muscidae	SP2						X
Insecta	Diptera	Muscidae	SP3						X
Insecta	Diptera	Muscidae	SP4					X	
Insecta	Diptera	Pipunculidae	Pipunculus	sp.			endemic		X
Insecta	Diptera	Sepsidae	Sepsis	thoracica		(Robineau-Desvoidy)	non-indigenous	X	X
Insecta	Diptera	SP1						X	X
Insecta	Diptera	Syrphidae	Allograpta	exotica		(Weidemann)	non-indigenous		X
Insecta	Diptera	Syrphidae	Allograpta	obliqua		(Say)	non-indigenous		X

SPECIES LIST

								Location	
Class	Order	Family	Genus	Species	Subspecies	Authority	Status	HES	HO
Insecta	Diptera	Syrphidae	Copestylum	sp.			non-indigenous		X
Insecta	Diptera	Syrphidae	Toxomerus	marginatus		(Say)	non-indigenous		X
Insecta	Diptera	Tachinidae	SP1				non-indigenous	X	X
Insecta	Diptera	Tephrytidae	Trupanea	sp.			endemic	X	X
Insecta	Heteroptera	Lygaeidae	Geocoris	pallens		Stål	non-indigenous	X	
Insecta	Heteroptera	Lygaeidae	Nysius	coenosulus		Stål	endemic	X	X
Insecta	Heteroptera	Lygaeidae	Nysius	communis		Usinger	endemic	X	X
Insecta	Heteroptera	Lygaeidae	Nysius	lichenicola		Kirkaldy	endemic	X	X
Insecta	Heteroptera	Lygaeidae	Nysius	palor		Ashlock	endemic		X
Insecta	Heteroptera	Lygaeidae	Nysius	terrestris		Usinger	endemic	X	X
Insecta	Heteroptera	Miridae	Engytatus	hawaiiensis		(Kirkaldy)	endemic		X
Insecta	Heteroptera	Miridae	Hyalopeplus	pelucidus		Stål	endemic		X
Insecta	Heteroptera	Miridae	Orthotylus	sp.1			endemic		X
Insecta	Heteroptera	Miridae	Orthotylus	sp.2				X	
Insecta	Heteroptera	Miridae	Psallus	sp.			endemic	X	X
Insecta	Heteroptera	Miridae	Sarona	sp.			endemic		X
Insecta	Heteroptera	Miridae	SP1					X	
Insecta	Heteroptera	Miridae	Trigonotylus	hawaiiensis		(Kirkaldy)	endemic		X
Insecta	Heteroptera	Pentatomidae	Nezara	viridula		Linnaeus	ohelo		X
Insecta	Heteroptera	Pentatomidae	Oechalia	pacifica		(Stal)	endemic	X	X
Insecta	Homoptera	Aphididae	SP1					X	
Insecta	Homoptera	Cercopidae	Clastoptera	xanthocephala		Germar	non-indigenous	X	
Insecta	Homoptera	Cicadellidae	SP1					X	
Insecta	Homoptera	Delphacidae	Nesosydne	geranii		(Muir)	endemic		X
Insecta	Homoptera	Delphacidae	Nesosydne	sp. 1			endemic		X
Insecta	Homoptera	Delphacidae	Nesosydne	sp. 2			endemic		X
Insecta	Homoptera	Delphacidae	SP1					X	
Insecta	Homoptera	Psyllidae	Trioza	ohiacola		Crawford	endemic		X
Insecta	Hymenoptera	Apidae	Apis	mellifera		Linneaus	non-indigenous	X	X
Insecta	Hymenoptera	Braconidae	Meteorus	laphygmae		Viereck	non-indigenous	X	

SPECIES LIST

								Location	
Class	Order	Family	Genus	Species	Subspecies	Authority	Status	HES	HO
Insecta	Hymenoptera	Colletidae	Hylaeus	melanothrix		(Perkins)	endemic	X	
Insecta	Hymenoptera	Colletidae	Hylaeus	nivicola		Meade-Waldo	endemic	X	X
Insecta	Hymenoptera	Colletidae	Hylaeus	sp.			endemic	X	
Insecta	Hymenoptera	Formicidae	Hypoponera	opaciceps		(Mayr)	non-indigenous	X	
Insecta	Hymenoptera	Formicidae	Linepithema	humile		(Mayr)	non-indigenous	X	
Insecta	Hymenoptera	Ichneumonidae	Diplazon	laetatorius		(Fabricius)	non-indigenous		X
Insecta	Hymenoptera	Unknown 1							X
Insecta	Hymenoptera	Unknown 2							X
Insecta	Hymenoptera	Unknown 3							X
Insecta	Hymenoptera	Unknown 4						X	X
Insecta	Hymenoptera	Unknown 5							X
Insecta	Hymenoptera	Unknown 6							X
Insecta	Hymenoptera	Unknown 7							X
Insecta	Hymenoptera	Unknown 8						X	
Insecta	Hymenoptera	Unknown 9						X	
Insecta	Hymenoptera	Unknown 10						X	
Insecta	Hymenoptera	Unknown 11						X	
Insecta	Hymenoptera	Unknown 12						X	
Insecta	Hymenoptera	Unknown 13						X	
Insecta	Hymenoptera	Vespidae	Odynerus				endemic		X
Insecta	Isopoda	Porcellionidae	Porcellio	scaber		Latreille	non-indigenous	X	X
Insecta	Lepidoptera	Cosmopterigidae	Hyposmocoma	sp.1			endemic		X
Insecta	Lepidoptera	Cosmopterigidae	Hyposmocoma	sp.2			endemic	X	
Insecta	Lepidoptera	Crambidae	Eudonia	sp.			endemic		
Insecta	Lepidoptera	Crambidae	Udea	pyranthes		(Meyrick)	endemic		
Insecta	Lepidoptera	Geometridae	Scotorythra	sp.			endemic		
Insecta	Lepidoptera	Lycaenidae	Udara	blackburni		(Tuely)	endemic		X
Insecta	Lepidoptera	Noctuidae	Agrotis	biliopa		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Agrotis	epicremna		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Agrotis	giffardi (or mesotoxa)			endemic		

SPECIES LIST

								Location	
Class	Order	Family	Genus	Species	Subspecies	Authority	Status	HES	HO
Insecta	Lepidoptera	Noctuidae	Agrotis	mesotoxa		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Agrotis	perigramma		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Agrotis	xiphias		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Ascalapha	odorata		(Linnaeus)	non-indigenous	X	
Insecta	Lepidoptera	Noctuidae	Megalographa	biloba		(Stephens)	non-indigenous		
Insecta	Lepidoptera	Noctuidae	Peridroma	albiorbis		Zimmerman	endemic		
Insecta	Lepidoptera	Noctuidae	Peridroma	cinctipennis	albostigma	(Warren)	endemic		
Insecta	Lepidoptera	Noctuidae	Peseudaletia	unipunctata		(Haworth)	non-indigenous		
Insecta	Lepidoptera	Oecophoridae	Thryocopa	apatela		(Walsingham)	endemic		X
Insecta	Lepidoptera	Pterophoridae	Stenoptilodes	littoralis	rhynchophora	(Meyrick)	non-indigenous		X
Insecta	Lepidoptera	Sphingidae	Agrius	cingulata		(Fabricius)	non-indigenous	X	
Chilopoda	Lithobiomorpha	Lamyctes	sp.1					X	X
Diplopoda	Julida	SP1						X	X

APPENDIX F

Geological Survey of HO, 2002

Geological Survey of the University of Hawaii Haleakala Observatories at Haleakala Summit Region, East Maui, Hawaii

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Table of Contents

1.0 *Executive Summary*

The project area (18±1acres) of the University of Hawaii's (UH) Haleakala Observatories on the summit region is located primarily in the crater area of the Kolekole cinder cone volcano. A detailed field geological survey of this area was undertaken in order to map the various rock types of the Kolekole cinder cone at the UH site. Standard field geological methods were employed. Detailed geological maps were constructed based on field identification of various rocks at different outcrops (rock exposures), and megascopic and microscopic examinations and measurements of the strike (the direction in which the rock outcrop extends) and dip (slope). Based on the field measurements of geological structures at various outcrops along the rim and inside the crater area, the structure of the Kolekole cinder cone volcano was deciphered.

The strikes and dip measured at various outcrops on the western, northwestern, eastern and southern rims of the Kolekole seem to indicate that the Kolekole is an asymmetric cinder cone whose slopes are steeper at the western and northwestern rims; the eastern and southern rims slope more gently.

The Kolekole cinder cone is located at the summit area (northeastern end) of the Southwest Rift Zone, which is a part of the triple junction rifts on the island of East Maui with the Haleakala volcano at its center. The Southwest Rift Zone is characterized by a large number of volcanoes of which the Kolekole cinder cone is one. The Kolekole volcano shows the initial phase of post-shield alkaline volcanism (magmatism) following the development of (shield phase) Haleakala volcanism and an intervening period of quiescence.

The Kolekole cinder cone is composed primarily of various types of ankaramite lava, spatter and cinder on the surface. The ankaramite lavas show a deep-crustal magma (lava) source for the Kolekole cinder cone. The large volume of phenocrysts (large crystals) in ankaramite lavas and the highly vesicular nature of lavas in the crater and rims of the Kolekole indicate rapid eruptions of lavas from deep sub-surface magma (molten rock)-chambers under high volatile pressures which degassed rapidly. The rims of the Kolekole were built up quickly by rapid surges of phenocryst-bearing lavas, especially at the western and northwestern margins.

Layers of ankaramite lavas and pyroclastic materials (broken fragmental lavas such as scoria, cinder, lapilli and volcanic ash) in alternate sequence in the crater area indicate repeated eruptions. The presence of thick layers of limonite (iron hydro-oxide due to water action) in sub-surface ankaramite lava flows also indicates intervals of both weathering and quiescence between eruptions.

The presence of a large number of spheroidal volcanic bombs near the crater areas and the large dimensions of these bombs (2-6 feet in diameter of phenocryst-bearing ankaramite lava bombs) indicates that enormous hydroexplosions (vapor explosions) occurred during the eruptions at which time large pyroclastic materials were extruded with degassing. Such explosive eruptions appear to have occurred during the end phase of the eruptions as indicated by the abundance of such materials in the lava fields surrounding the Kolekole volcano.

The central crater of the Kolekole is ponded with ankaramite lava flows, spatter and pyroclastic ejecta. Below this is a basal, horizontal zone of polygonal to sub-columnar phenocryst-rich lava. This is the likely site of a major vent. A secondary vent is present at Site B (Figure 4) where the soil is highly weathered to limonite and shows a prominent depression. The ground surrounding this site (Site B) is covered with pyroclastic ejecta.

2.0 Introduction

At the invitation of the KC Environmental, Inc., Makawao, HI, a detailed geological survey was conducted of the approximately 18±1 acre University of Hawaii (UH) Haleakala Observatories (HO) near the summit of the Haleakala volcano, Maui (Figure 1). The primary objective of this geological survey was to determine the various rock types and structural characteristics of the Kolekole cinder cone at the UH site, as well as its adjacent area.

2.1 Project Area Description

The project area (18±1 acres of UH land) on the Kolekole cinder cone along the southwest rift zone of the Haleakala summit area is about 0.5 miles southwest of the Haleakala National Park's Red Hill Overlook (Figure 1). The land is located within the Forest Reserve and the general subzone of the State Conservation District, having been conveyed to UH in 1961 by Governor's Executive Order (EO) 1987. Contained within this 18±1 acre area, the major UH facilities at HO are: the Mees Solar Observatory, the LURE Lunar and Satellite Ranging Facility and the recent Faulkes Telescope Facility (FTF) (in its final stage of construction). Other facilities within HO include the Cosmic Ray Neutron Monitor Station operated in association with the University of Chicago's Enrico Fermi Institute. All of these facilities, and the AEOS 3.67-meter telescope site to the north and the other Air Force's facilities to the west, lie within the Kolekole cinder cone crater. Much of this area has been bulldozed and flattened for the construction of various telescope and support facilities. Approximately 10 acres lie undeveloped outside of the telescope observatory facilities. Undeveloped areas are mostly at the western and northern portions where the rim of the volcano and the lava fields slope steeply, although they gradually flatten out with distance.

2.2 Scope of Work and Methods

A detailed field geological survey of 18±1 acres of Haleakala Observatories was undertaken in order to map the various rock types of the Kolekole cinder cone volcano on which the UH site resides. Standard field geological methods using a Brunton Compass, a field measuring tape, a hand lens, a field camera (for photographic records), etc., were employed. Detailed maps (Figures 4, 5 and 6) were constructed. These were based on field identification of various rocks at different outcrops and megascopic and microscopic examinations and measurements of the strike (the direction in which the rock outcrop extends) and dip (slope). Based on the field measurements of geological structures at various outcrops along the rim and inside the cone, the structure of the Kolekole cinder cone was deciphered (Figure 7).

In the Kolekole cinder cone volcano, individual eruptive units and their stratigraphical relationships can only be deciphered broadly. Individual outcrops at various sites (Figures 4, 5 and 6) show records of important geological features. Various types of ankaramite lava (the main lava type at the UH sites) were mapped in several areas (A, D, D_1, E, H, and I, Figures 5 and 6) where they are well exposed. However, the gradational nature of the individual lava types (Figures 5 and 6) and their boundaries can not be mapped in exact detail. Only at the Faulkes Observatory site (E) can the general stratigraphy of individual lava flows and pyroclastic ejecta be established (from an excavation site where a log of lava flows and pyroclastic ejecta up to a depth of ≈34 feet are recorded).

3.0 Geological Study

3.1 Geological Setting of Project Area

The project area (18±1 acres) of HO on the summit region of Haleakala is located primarily in the crater area of the Kolekole cinder cone volcano (Figures 1 and 2 and Picture 1). The project area on Kolekole (marked yellow in figures 1 and 3 and the rectangular area in Picture 1) is within the Haleakala volcano, which is located in the central region of the triple junction rift zone (marked by the hatched circle in Figure 2). This area of Haleakala has been considered the focal region of the mantle hot spot where the Southwest Rift Zone, the East Rift Zone and the North Rift Zone meet. Haleakala developed as a shield volcano over the hot spot, similar to the volcanoes on the island of Hawaii (i.e., Mona Loa, Mauna Kea, etc.) with frequent eruptions of shield-building lava derived from partial melting in the hot spot region. As the island of Maui (including Haleakala) moved off the hot spot, lavas from later volcanoes along its rift zones became increasingly alkaline (Macdonald and Katsura, 1964; Clague and Dalyrimple, 1987), culminating in differentiated alkalic lava flows (such as ankaramite, olivine-basalt lavas, etc.,) which comprised the post-shield stage of volcanism. During this stage, the vents of the Kula and Hana volcanic series (Figure 2) developed along the North Rift, East Rift and Southwest Rift Zones. These rift zones, like many others in the Hawaiian volcanoes (e.g., the active Kilauea East Rift Zone on the island of Hawaii) are potentially weak, extensional zones in the upper crust. They show large numbers of volcanic vents (Figure 2 and Picture1). Each rift zone is characterized by parallel fissures of varying length, width and depth. These become major eruptive passages, and along these passages, major volcanic centers develop. The Kolekole cinder cone volcano is one such volcanic center which developed in the Southwest Rift Zone, along with many others (Picture 1A and 1B).

3.2 Southwest Rift Zone and Volcanism

The Southwest Rift Zone is a part of the triple junction rifts of East Maui, which has Haleakala at the center (Figure 2). The Southwest and East Rift Zones are almost on a straight line. Large numbers of older Kula (green circles) and younger Hana (red crosses) volcanic vents (Figure 2) developed along both the Southwest and East Rift Zones. Younger Hana lava flows are exposed in wide areas of these two rift zones (Figure 3). These Hana lava flows may cover older Kula flows along the rift zones and their surrounding slopes (Figure 3). An aerial view of the region shows a large number of volcanoes along the Southwest Rift Zone. Some are paired volcanoes. The axis of the Southwest Rift Zone shows splayed branching at the southwestern and western ends. Volcanoes develop over wide areas at the western end of the splayed branches of the rift, which is common in many rift zones (Picture 1B). (Bhattacharji and Koide, 1987).

3.2.1 Volcanism of the Southwest Rift Zone

Stearns and Macdonald (1942) have distinguished the deposits of older Honomanu (shield), Kula (post-shield) and Hana (rejuvenated) volcanics of East Maui. Within each series they defined the areal extent covered by lava flows, cinder cones and ash deposits of various stages of volcanism on East Maui (Figure 3).

The major and trace element chemistry of lavas from the Kula and Hana volcanics overlap, and presently there is no method of distinguishing all Hana from all Kula lavas on the basis of major and trace element chemistry (Bergmanis, et al., 2000). So far, no Kula-age rocks have been dated along the Southwest Rift Zone.

Existing data suggest that there is no systematic temporal or spatial variation in the composition of the Hana lavas from the Southwestern Rift Zone and they cannot always be distinguished from Kula lavas. Most evolved lavas have erupted from the middle of the rift zone, although the composition of lava on-axis and off-axis groups overlaps. Relatively unfractionated lavas have erupted from all parts of the rift zone.

3.2.2 Kula and Hana Volcanism

A recent study made along the Southwest Rift Zone (Bergmanis, et. al., 2000) has shown that the Hana series of volcanics (rejuvenated stage) have occurred repeatedly during the last~4800 years. There have been at least six eruptions within the past ~960 years. These volcanic activities on the Southwest Rift Zone during the past ~4800 years occurred in three episodes, each lasting as long as 1,000 years separated by quiescent periods of ~500-800 years. Most recent volcanism on the Southwest Rift Zone occurred on the southwestern and western slopes between 1750 and 1790 (Stearns and Macdonald, 1942; Picture 1B). However, recent C14 dating of charcoal below these lava flows indicates that these lavas (Picture 1B) may be as old as 1600-1450 years (Sinton, 2002, personal communication). More recent relatively high eruption frequency from a quasi-steady state deep crustal magma reservoir(s) indicates that the Southwest Rift Zone is potentially an *active volcanic rift zone*. Hence, volcanoes on the Southwest Rift Zone can only be considered active volcanoes which can erupt again in the near future (Sinton, personal communication, 2002).

The older Kula volcanoes (age: 0.93-0.36 million years, Chen, et.al., 1991) belong to the post-shield phase and are most extensive on East Maui (Figures 2 and 3). Kula volcanics are characterized by a large areal extent of cinder cones, lava flows and ash deposits. The lava flows are primarily alkaline basalts (basanite, Hawaiite, olivine basalts (ankaramite, etc.).

3.3.1 Kolekole Volcanism

Kolekole cinder cone lavas are primarily ankaramite and olivine basalts. The lavas are agglutinated with spatter and, in most outcrops, are vesicular and aa—types. However, they are very rich in phenocrysts of augite (pyroxene) and olivine. In many respects these ankaramite lavas are similar to the Kula lavas, but are chemically indistinguishable from the Hana lavas of the Southwest Rift Zone. Detailed geochemical analyses and age dating are essential to determine the affinity of these Kolekole ankaramites with Kula or Hana lavas as well as the timing of Kolekole lava eruptions.

The surface of Kolekole is covered mostly by layers of cinders and volcanic pyroclastics of various sizes. The thickness of the pyroclastic cinder, ash and spatter on different slopes of the volcano varies greatly. A large portion of these materials is altered to hematite and limonite on the surface.

3.3.2 Other Geological Processes

The erosion that produced the Haleakala crater also destroyed the top of the mountain. At the end of the Kula volcanism, the Haleakala volcano rose to a summit more than 3,000 feet higher than the present crater rim (Stearns and Macdonald, 1942)—a summit undoubtedly studded with large cinder cones and resembling in profile that of present day Mauna Kea. These erosions produced the Kaupo and Koolau gaps (Figure 3) leading out of the crater, which are the upper parts of stream-cut canyons, now partly filled with lava flows of the younger Hana volcanic series. Since the last eruptions, the surface of the volcanoes in the rift zones have been continuously eroded by surface processes of mechanical (variation of daily and seasonal temperature) and chemical (primarily water action) weathering.

3.4 Geological Structure and Structural Features

Based on field mapping and measurements of dips (slope of the rock layer from the horizontal surface) and strikes (direction of extension of rock outcrops) at various sites (described in section 3.4.1), the structure of the Kolekole cinder cone is reconstructed. Although the northern, eastern and southern rims are disturbed and were flattened during the construction of roads and telescope observatory sites, there are several critical outcrops at the rims of the Kolekole (Pictures 10, 11, and 12) which allow us to reconstruct its shape and structure.

Strikes and dips measured as various outcrops on the western, northwestern, eastern and southern rims of the Kolekole (Pictures 10, 11 and 12) seem to indicate that the Kolekole is an asymmetric cinder cone whose slopes are steeper at the western and northwestern rims; the eastern and southern rims slope more gently. Because the northern rim was disturbed during the 1960's construction of the Air Force's telescope observatory facilities, accurate measurements of the rim structure there are not possible.

In general, the western rim of the Kolekole is steep at the rim boundary (dip: 50°-55° W) but becomes gentler (40°-45° W) with distance. However, the steeper slope of Kolekole at the western boundary extends for a considerable distance until it merges at the adjacent cinder cone (Picture 10).

The eastern slope of Kolekole dips at a gentler angle (≈20°25° E, average dip), and this slope extends for a considerable distance (Picture 11B) until it merges with the adjacent cinder cone (Picture 11A). On the eastern slope, the ankaramite lava outcrops show rotation in opposing directions (Picture 11C).

The northern rim (north of the Air Force's observatories) is thin and flattened over a considerable distance. However, the dip at the rim is approximately 30°-35° N which becomes much gentler (10°-15° N) within a short distance (Picture 8A).

The southern boundary (Picture 12), starting from the Mees Observatory site, is steep at the rim (Picture 12B, right end). Although the surface here is irregular due to broken ankaramite lava blocks, the average dip of the rim is 30°-35° S which gradually becomes gentler (20°-25° S) at the southern end. The gentle slope of composite lava flows continues for a considerable distance (Picture 12B). On the slope, composite lava flows are agglutinated with spatter and cinder (Picture 12C).

In summary, the rims of the Kolekole cinder cone are steeper at the western and northwestern ends and are more gradual at the eastern and southern ends. Much of the northern slope shows a gentler incline.

The central crater of Kolekole is flattened where all of the observatory sites are located. This area of Kolekole is ponded with ankaramite lava flows, spatter and pyroclastic ejecta. At Site A, as well as at Sites I and H (Figure 4), ankaramite lava is ponded with a basal, horizontal zone of polygonal to sub-columnar, phenocryst-rich lava. This lava zone grades gradually upwards into a highly vesicular, a-a type ankaramite lava whose thickness ranges from a few feet (2 to 3 feet) at Site A to almost 25 feet at Site I (Pictures 7E and 7F).

Near Site E (Figures 4 and 5) and at the Faulkes Observatory site (under construction/Pictures 3A and 3B), ankaramite lava of various thicknesses alternate with pyroclastic materials (scoria, ash, cinder, etc.) up to a depth of ≈34 feet, indicating a series of eruptions alternating with lava and pyroclastic materials being spewed from a nearby major vent (most likely located at Site A).

Another probable site of a secondary vent is at B where the soil is highly weathered to limonite and shows a prominent depression. Surrounding Site B and near Sites C, G and F (Figures 4, 5 and 6) the ground is covered with pyroclastic ejecta (Picture 5A, 5B and 5C). The most probable sources of such ejecta (especially large volcanic bombs and lapilli) are vents B and A, situated nearby.

3.5 Geological Characteristics of the Site

Sites A and A_1

Site A is located on lava slopes of ankaramite type, containing various proportions of olivine and pyroxene crystals. This gives the lava a binding property similar to concrete-cement containing fine-grained gravel. In this site the lava flows are of variable thickness with an approximate total thickness of 20-25 feet. The lava surface is generally undulating and rough where the flow is highly vesicular (frothy) and contains lava tubes of various sizes, or where it is broken into blocks or ropes. However, the massive lava below the spatter, highly vesicular and tubular zone (several inches to several feet deep) is generally flat-lying or gently dipping in Site A. The highly vesicular and tubular top surface is considerably fractured and jointed. It contains vertical joints, as well as horizontal and inclined joints (linear fractures) in several rock exposures. These two varieties in the upper several feet of ankaramite lava are agglutinated with spatter and cinder.

At depth, several feet below the spatter ankaramite lava (at Site A) one encounters less consolidated, sub-columnar, horizontal lava flow. It is important to note that the vesicularity and concentration of tubular structures in the upper horizon of ankaramite lava flows vary greatly, especially at Site A and in the sub-columnar horizon. The areas A and A_1 surrounding Sites H and I are ponded with a number of highly vesicular ankaramite lava and pyroclastic ejecta.

Site B

Site B is located in a large, shallow depression covered with iron-rich (limonite) soil on the surface. The shape and size of the depression indicate that it is possibly the neck of a collapsed volcanic vent. The concentration of a large number of bombs in adjacent Sites C and G (Figures 4 and 5) indicate that they may have been derived from Site B vent eruptions. This vent occurring on the Rift Axis is a weak site for end-phase explosive eruptions.

Site C

Site C, located between Sites B and A, is covered on the surface by large spheroidal bombs, cinders and spatters possibly derived from B-vent eruptions (Figure 5). Massive to vesicular ankaramite lava flows on the southern side of Site C show many disturbed structures.

Sites D and D_1

Highly vesicular phenocryst-bearing unaltered ankaramite lava occurs at Sites D and D_1. The unaltered phenocrysts of augite (pyroxene) and olivine are abundant (close to 30-35 percent). Most of the lava at Site D_1 is sub-columnar ankaramite and shows sub-parallel layers of vesicles, indicating a lateral flow of highly vesicular lava. Vertical and horizontal joints are common in these flows. The presence of abundant phenocrysts indicates a sub-crustal deep magma source of alkaline ankaramite lava and a rapid surge of magma from a deep-seated magma-chamber(s) under high volatile pressure (see Pictures 7A-7D).

Sites E and E_1

Massive ankaramite lava at Sites E and E_1 (near Faulkes Observatory site and its eastern end) show highly vesicular, a-a type lava which is rich in augite and olivine phenocrysts. The presence of abundant phenocrysts (≈35-40 percent) indicates a rapid surge of partly crystallized magma under high volatile pressure from sub-surface magma chamber(s) through a nearby vent (possibly the vent at A). Ankaramite lava after consolidation shows the development of inclined sheet joints at low (30°-35° NE to 50°-55° NE) as well as at high angles (60°-70° NW) in opposing rock exposures. This indicates that there was a rotation of lava blocks at some stage after the consolidation of lava near the vent area due to the fluctuation in pressure. The lavas here are agglutinated with spatter and cinder (Pictures 3A and 4A-4D).

Site F

Site F, located north of Site G, is floored by cinders and some spatter ankaramite lava. Much of the cinder at the northern end was probably spewed from the main vent (at A) or sub-vent to the east (Figure 6). The area east of Site F is slightly depressed, indicating the probable presence of a sub-vent (V) in this area. Large spheroidal bombs (2-6 feet in diameter, Picture 8A) and other pyroclastic materials occur at this and nearby sites.

Site G

A flat-lying area, northwest of Site A, Site G is covered on the surface with bombs, cinders and spatter lava. A small exposure of massive to vesicular ankaramite lava indicates the likely occurrence of a flat-lying platform below the loose boulder ejecta. However, the thickness of the massive lava platform is likely to be less than that of Site A.

Sites H and I

Sites H and I are characterized by well-exposed polygonal to sub-columnar lava horizons which are broken into large blocks along vertical and horizontal joints. This near-horizontal ankaramite lava is phenocryst rich and highly vesicular (Pictures 6 and 7). This basal zone of lava flows is ponded over the crater area whose center is near A. The upper horizon of the ankaramite lava is vesicular a-a type and is agglutinated with spatter and in some outcrops with cinder as well. The lava bed dips at a low angle (15°-20° E) and indicates the direction of the lava flows to be towards the eastern slope of Kolekole cinder cone (Pictures 6A-6B).

3.5.1 Significance of the Kolekole Cinder Cone

1.0 The Kolekole cinder cone volcano shows the initial phase of post-shield alkaline volcanism (magmatism) following the development of (shield phase) Haleakala volcanism. There had been an intervening period of quiescence; denudation eroded several thousand feet of Haleakala and produced several deep canyons.

2.0 Ankaramite and olivine ((picro-)basalt) show a deep crustal magma (lava) source for the Kolekole cinder cone.

3.0 The large volume of phenocrysts of augite (pyroxene) and olivine in ankaramite lavas, and the highly vesicular nature of lavas in the crater and rims of the Kolekole indicate rapid eruptions of lavas from deep sub-surface magma-chambers under high volatile pressures which degassed rapidly. The rims of the Kolekole were built up quickly by rapid surges of phenocryst-bearing lavas at the western and northwestern margins.

4.0 Layers of ankaramite lavas and pyroclastic material (scoria, volcanic ash, cinder, lapilli, etc.) in alternate sequence in areas A and E indicate that repeated eruptions took place in the crater (vent) area. The presence of thick layers of limonite in sub-surface ankaramite lava flows also indicates intervals of both weathering and quiescence.

5.0 The presence of large numbers of spheroidal bombs near the crater areas (areas such as B, C, G, etc.) and the large dimensions of these bombs (2-6 feet in diameter of phenocryst-bearing ankaramite lava bombs) indicate that enormous hydroexplosions occurred during the eruptions at which time pyroclastic materials were extruded with degassing. Such explosive eruptions appear to have occurred during the end phase of the eruptions.

6.0 During the last phase of the eruptions, pyroclastic materials (primarily cinder, scoria and ash) were ejected. This is indicated by the abundance of such materials in the lava fields surrounding the Kolekole volcano.

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5.0 Glossary of Terms

A A. Lava with a rough clinkery surface.

ASH. Fine-grained volcanic ejecta, of sand or dust size.

AUGITE. A variety of the dark mineral pyroxene containing calcium, magnesium, iron, aluminum, silicon, and oxygen.

BASALT. A dark heavy lava rock, rich in iron and magnesium and comparatively poor in silicon. The common lava of Hawaii.

BLOCKS. Angular volcanic ejecta larger than 1.5 inches across, solid when thrown out.

BOMBS. Rounded, flattened, or irregular fragments of volcanic ejecta, molten when thrown out, and larger than 1.5 inches in diameter.

CALDERA. A volcanic crater more than 1 mile in diameter.

CINDER. Irregular, spongy fragments of lava, of bomb or lapillus size, thrown out by volcanic explosions. They are usually solid when they strike the ground.

CINDER CONE. A cone-shaped cinder hill which has piled up around a volcanic vent.

COLUMNAR JOINTING. Cracking of lava rock into pencil-shaped fragments (in dikes) or column-like structures (in thick flows or ponded lava lakes).

CRATER. A bowl-shaped depression usually found in the top of a volcanic cone.

EJECTA. Fragments thrown out, or ejected, by volcanic explosion.

FISSURE. A crack in the rocks of the earth's crust. Such cracks often guide rising magma to the surface, where it flows out in fissure eruptions.

HAWAIITE. A variety of andesitic lava in which the feldspar is predominantly andesine.

HYDROEXPLOSION. A steam explosion caused by contact of water with magma or hot rock.

IGNEOUS ROCK. Rock formed by solidification of magma or lava.

INCLUSIONS. Fragments of solid rock brought up from depth by rising magma, and left frozen into lava flows or bombs.

INTRUSIVE ROCK. A rock formed by magma solidifying beneath the earth's surface.

Glossary of Terms

LAPILLI. Volcanic ejecta from about 0.25 to 1.5 inches across (singular: lapillus).

LAVA. Hot liquid rock at or close to the earth's surface, and its solidified products.

LAVA TUBE. A natural lava tunnel through which the form of a flow was fed, and left empty when the last of the lava drained out.

MAGMA. Hot liquid rock.

MAGMA CHAMBER. Chamber or large subsurface reservoir where molten rock material collects and forms crystals upon cooling and solidification.

OLIVINE. A green mineral composed largely of magnesium, iron, silicon, and oxygen.

PAHOEHOE. Lava with a smooth or ropy-appearing surface.

PUMICE. A froth of volcanic glass; very vesicular cinder.

PYROXENE. A group of dark-colored minerals composed largely of silicon, magnesium, iron, and oxygen, with varying amounts of calcium and aluminum.

RIFT. A fracture in the earth's crust.

RIFT ZONE. A highly fractured belt on the flank of a volcano along which most of the eruptions take place.

ROPY LAVA. Same as Pahoehoe lava.

SCORIA. Slaggy, porous, spongy-appearing ejecta; cinder.

SHIELD VOLCANO. A volcano having the shape of a very broad, gently sloping dome.

SPATTER. Volcanic ejecta thrown out in a very fluid condition. The fragments remain partly fluid when they strike the ground, so that they flatten out and often stick together.

SPATTER CONE. A cone built by the accumulation of spatter.

TUFF. Consolidated volcanic ash.

VENT. An opening through which volcanic material reaches the surface.

VESICULAR. Having vesicles.

VESICLE. A bubble hole formed by gas in lava.

6.0 *Notes*

HAWAIIAN ROCK TYPES

Hawaiian rock types can be arranged in two general series (or suites), the tholeiitic and the alkalic. The thloeiitic series comprises the following rocks, arranged in order from most basic (magnesium– and iron-rich) to most acid (silica-rich): oceanite, tholeiitic olivine basalt, tholeiitic basalt, tholeiitic quartz basalt, rhyodacite. The alkalic series similarly consists of: ankaramite, alkalic olivine basalt, alkalic basalt, hawaiite, mugearite, trachyte. The nephelinites and basanites are even more strongly alkalic than the rocks of the main alkalic series, and form a group more or less by themselves. Within each of the principal series, the variations among the rock types can be accounted for largely by fractional crystallization—a process of separation of crystals formed in early stages of consolidation of the magma that leaves a liquid residue with a composition different from that of the original magma.

ROCK TYPES OF MAUI (HALEAKALA VOLCANO)

Ankaramite—a rock containing abundant phenocrysts of black augite and green olivine in a fine-grained dark matrix. Feldspar, which makes up less than one-third of the total rock, is mostly in the matrix. With a decrease in the abundance of phenocrysts the rock grades into the alkalic olivine basalts (defined below). Together with oceanite, ankaramite is also referred to by the more general name *picrite-basalt*.

Basalt—a rock composed almost wholly of calcic plagioclase feldspar and pyroxene, fine grained and usually dark colored. Two general varieties are recognized in Hawaii: *tholeiite*, or *tholeiitic basalt*, which is relatively rich in silica and poor in the alkalies (sodium and potassium), and in which the pyroxene is partly or largely pigeonite containing little calcium or aluminum; and *alkalic basalt*, which is comparatively poor in silica and rich in alkalies, and in which the pyroxene is generally augite containing calcium and aluminum. Both tholeiitic and alkalic basalts commonly contain olivine, often as phenocrysts, and they may also contain phenocrysts of plagioclase feldspar or pyroxene.

Hawaiite—an andesitic rock composed largely of andesine (plagioclase feldspar containing between 50 and 70 percent albite) and pyroxene, generally with some olivine. Hawaiite grades on the one hand into alkalic olivine basalt and on the other into mugearite.

Mugearite—an andesitic rock resembling hawaiite but in which the feldspar is oligoclase (plagioclase containing 70 to 90 percent albite). Mugearite grades on one side into hawaiite and on the other into trachyte.

Oceanite—a basaltic rock containing very abundant (more than 35 percent) olivine phenocrysts. A variety of picrite-basalt, it grades into the olivine basalts.

Olivine basalt—a basalt containing a moderate amount (5 percent or more) of olivine. Olivine basalts may be either tholeiitic or alkalic.

7.0 Figure Descriptions

1. The project area—18± 1 acres of University of Hawaii land used for satellite tracking and observatory sites west of Red Hill and Magnetic Peak in the Haleakala summit area. The area mapped for the geology of the Kolekole cinder cone volcano is shown in the yellow rectangle.

2. Map of Haleakala volcano on East Maui showing the Southwest, East and North Rift Zones. The axes of three rift zones are shown on the map. The center of the triple junction of rift zones (hatched circle) is at the Haleakala Summit area. The Southwest Rift and the East Rift axes are in a slightly curved line. Vents of the Kula (circles) and Hana (crosses) Volcanic Series are shown on the map. (After Stearns and Macdonald, 1942).

3. Geological map of the Island of Maui showing areas of lava flows and pyroclastic deposits. The Kolekole cinder cone volcanic area is shown in the yellow rectangle. (After Bergmanis, et al., 2000)

4. Geological map showing areas of ankaramite lava (1) and cinder (2) on 18±/1acres of UH site and its surroundings on the Kolekole cinder cone Volcano. Probable location of the rift axis of the Southwest Rift Zone is shown. Sites A-I are mapped for geological rock types and their structural features.

5. Detailed geological map of types of ankaramite lavas for Sites—A, A_1, D, D_1, E, H and I. Sites B, C, G and F are mapped for various types of pyroclastic ejecta.

6. Enlarged geological map for the sites shown in Figure 5, showing types of ankaramite lava at various locations.

7. Schematic cross-section of the geological structure of the Kolekole cinder cone along $X\text{-}X^1$ (in Figure 5).

7.2 Picture (Photograph) Descriptions

Picture 1.

A. Aerial view of the cinder cone volcanoes along the Southwest Rift Zone. Probable location of the rift axis (from NE to SW) is shown. The area mapped for the geology of the UH site ($18\underline{+}1$ acres) is shown in the rectangular area on the Kolekole cinder cone volcano. Note the splay branching of the rift axis at the western end which allows spreading of the volcanic activity over a wider zone along the splay branching of the Rift.

B. Cinder cone volcanoes at the western end of the Southwest Rift Zone spread over wide areas: In the foreground are broken blocks of vesicular basaltic lava from the 1750/1790 (still questionable) eruptions at the western end of the Southwest Rift Zone. The reddish color is due to the alternation of basaltic a-a lava to hematite.

Picture 2.

A. Highly vesicular ankaramite lava at Sites A and A_1. The lava is frothy and friable where vesicle concentration is high. Vertical joints (on the left side) break the lava into blocks. The compressive and shearing strengths of such vesicular lava are low.

B. Highly vesicular spatter, ankaramite lava with lava tubes (dark areas in the foreground) and open cavities. On the surface the lava shows a ropy structure in places.

C. Large open lava tubes and fissures in highly vesicular ankaramite lava at the southern end of the Sites A and A_1 and at the southwest end of the LURE Observatory.

D. The ankaramite lava at the southern and southwestern ends of Site A (see Figure 4) showing vertical and inclined lava tubes on a disturbed, undulating surface. This section of lava is highly porous and permeable and easily breaks up into small fragments due to very low compressive and shearing strengths.

E. Sub-columnar, polygonal and rectangular blocks in ankaramite lava at the southern end of Site A and at the southern and eastern ends of the UH LURE Observatory site. The ankaramite lava is almost horizontal on the surface and has broken into large blocks. This thermally cooled ankaramite lava is the basal part of a lava flow which was ponded over vent area A and was covered quickly by spatter lava flows on the surface (see Figure F).

Picture (Photograph) Descriptions

F. Highly vesicular spatter with vertical and horizontal joints over the sub-columnar ankaramite lava. This lava flow at the eastern end of Site A and the LURE Observatory site is inclined at an angle (20°-25° NE) showing the general direction of lava flow at the eastern end of the Kolekole cinder cone volcano.

Picture 3. (Sites E and E_1)

A. Exposure of ankaramite lava east of the Faulkes Telescope Observatory Site (under construction) at Site E showing inclined sheet joints and broken ankaramite boulders in the foreground. The ground is covered with cinders and other pyroclastic ejecta.

B. Close-up view of ankaramite lava showing a weathered upper horizon of broken lava fragments and boulders. Well-developed high angle (60°-70° NW) sheet and near vertical extension joints are common at Sites E and E_1 (east and south of Foukes Observatory Site). Several exposures south of the site (E_1) also show sheet joints dipping at a shallower angle in the opposite direction (50°-55° to 30°-35° NE) indicating a possible rotation of blocks after the consolidation of ankaramite lava blocks. Here vesicular and tubular lava are covered with layers of spatter and cinder.

Picture 4. (Sites E, E_1 and A_1)

A. Close-up view of the massive ankaramite lava at Sites E and E_1, showing phenocrysts of augite (pyroxene) embedded in the lava. Phenocryst-bearing lavas are layered and partly altered to limonite. The hammer gives the scale.

B. Ankaramite lava boulders on the cinder bed at the north and northeastern sides of Sites E and A. In the background is an exposure of spatter lava with thin layers of cinder on the surface.

C. Vesicular, tubular ropy lava east of Site E and near site A_1. The ropy lava is highly vesicular and covered with spatter and cinder.

D. Highly vesicular ropy and a-a lavas showing near-vertical joints. These lavas are altered to limonite. Adjacent cinders (on the right side) are highly altered to hematite and limonite.

Picture (Photograph) Descriptions

Picture 5 (Sites C, G and F)

A. Different types of pyroclastic ejecta at Sites C, G and F. Most of these sites have been flattened and bulldozed.

Top: (i). Volcanic lapilli with phenocrysts of augite and olivine.
(ii). Volcanic bomb of olivine basalt.

Bottom: (i). Angular cinder cone and broken cinder block
(ii). Vesicular rod
(iii). Polygonal sub-columnar rod with phenocrysts of augite
(iv). Spheroidal, olivine basalt bomb.

The scale gives the size of the individual pyroclastic ejecta.

B. Large spheroidal volcanic bomb at Site G. The average size is about 2 feet in diameter. Some are as large as 4 to 5 feet in diameter. The pen on the surface of the bomb (8 inches in length) gives the scale.

C. Broken fragmental cinders and bombs at Site C. The cinders and volcanic ashes are generally altered to hematite and limonite. Red pen (7 inches in length) gives the scale.

Picture 6 (Sites H and I)

A. Well-developed polygonal, sub-columnar joints at the basal zone of ankaramite lava at Sites H and I, east of LURE and Mees Observatories. This sub-columnar ankaramite lava zone extends further south up to the boundary of the UH land.

B. Highly vesicular thin spatter over the broken fragmental sub-columnar lava east of LURE Observatory. The sub-columnar lava is generally broken into square or rectangular blocks by two sets of vertical joints. This lava bed dips at a low angle (15°to 20° E) showing the direction of lava flow towards the eastern slope of Kolekole cinder cone volcano.

C. Close-up view of well-developed polygonal and sub-columnar joints in ankaramite lava at Site H. Vertical and horizontal joints and fractures are common. This basal zone of ankaramite lava flow at Sites H and I is highly vesicular and contains phenocrysts of augite (pyroxene).

Picture (Photograph) Descriptions

D. Horizontal, irregular fractures in a sub-columnar block of ankaramite lava at Site H. The pen (8 inches in length) gives the scale. Such sub-parallel horizontal sheet joints (fractures) develop due to the release of gases from sub-horizontal vesicles filled with gases driving lava consolidation.

E. Highly vesicular, ankaramite lava with spatter above the sub-columnar zone (C & D). The thickness of this lava flow is between 5 and 30 feet at Sites H and I. The scale is indicated by the red pen (8 inches in length) as well the by the strike of the rock exposure.

F. The contact zone of sub-columnar and overlying vesicular ankaramite lava at Site I. The contact is marked by the red pen.

Picture 7 (Site D$_1$)

A. Highly vesicular, sub-columnar ankaramite lava at the northern end of the Airforce Telescope Observatory. This lava flow is similar to the lava flow at Sites I and H and the lava flow east of LURE Observatory (see Picture 6D). Elongated vesicles are arranged in sub-parallel layers. Vertical and horizontal joints are common in this lava flow. The pencil (8 inches in length) gives the scale.

B. Spheroidal and elliptical vesicles in the ankaramite lava on the north and northwestern sides of the Air Force Telescope and AEOS Observatories in the UH land area.

C. Phenocryst-bearing ankaramite lava showing large areas of elongated vesicles (the 8-inch pen gives the scale).

D. Highly crystalline, phenocryst-bearing, unaltered ankaramite lava at Site D$_1$. The unaltered phenocrysts of augite (pyroxene) and olivine are abundant (≈30 to 35 percent). A rapid surge of magma from subsurface magma chamber(s) under high gas pressure may have given rise to the extensive phenocryst-bearing lava flow on the north and northwestern sides of Kolekole Volcano.

Picture 8 (Site F and the Northern Rim of Kolekole)

A. Large spheroidal bombs (2 to 6 feet in diameter) and other pyroclastic materials on the spatter lava and cinder bed north of the AEOS Observatory. In the background near the observatory is an outcrop of broken ankaramite lava with spatter.

Picture (Photograph) Descriptions

B. A close-up, megascopic view of the ankaramite lava showing a large volume of pyroxene phenocrysts in unaltered lava at this site. The pen (8 inches in length) gives the scale. Such phenocryst-bearing lava indicates rapid surges of magma from a deep-seated (magma) chamber(s) at the northern, western, eastern and southern ends of the Kolekole volcano.

Picture 9 (Western Rim of the Kolekole Cinder Cone)

A. An outcrop of Ankaramarite lava along the western and northwestern rim of Kolekole. Here and in the background lava and cinder have weathered to hematite. The ankaramite lava is rich in pyroxene and olivine phenocrysts. The strike of this outcrop is N 85° W and the dip is 50°-55° W. This high angle dip makes the western boundary very steep and allows the lava to flow to a great distance and merge with the adjacent volcano. Vertical extension joints are common.

B. Highly vesicular ankaramite lava outcrop showing steep dip (50°-60° W). The lava is highly altered in places and is covered by hematite-bearing pyroclastics.

Picture 10 (West to Northwestern rim of Kolekole)

A. Ankaramite lava outcrop at the western and northwestern rim of Kolekole.

B. Steeply dipping ankaramite lava flow (50°-55° NW) in the foreground (near the rim) and the more gently dipping (20°-25° NW) lava flow at the northwestern boundary. The slope of the lava flow becomes gentle with distance. The cinder surface is altered to reddish hematite.

C. Phenocryst-bearing, vesicular ankaramite lavaalong the northern and northwestern rim of the cinder cone. The phenocrysts are olivine and augite (pyroxene). This ankaramite lava along the northwestern rim of Kolekole typically contains 30-40 percent phenocrysts.

Picture (Photograph) Descriptions

Picture 11 (Eastern Rim of Kolekole Cinder Cone)

A. In the foreground is broken fragmental ankaramite lava and volcanic ejecta. In the background is the adjacent cinder cone volcano of the Southwestern Rift Zone.

B. Outcrops of broken, fragmental ankaramite lava with spatter showing the gentle dip (20°-25° E) of the lava flow.

C. The eastern end of the Kolekole cinder cone showing several exposures of ankaramite lava on the slope. The nearest lava exposure is highly vesicular with a ropy structure, lava tubes and cavities. The rock outcrops closer to the road are also ankaramite lava with spatter. The outcrop of ankaramite (on the right) dips west (inward) (20°-28° NW) while the other exposure on the left dips eastward. The change in the direction of lava blocks on the slope of the volcano indicates a rotation of consolidated lava blocks with subsequent lava flows on the eastern slope of the Kolekole volcano.

Picture 12 (Southern Rim of the Kolekole Cinder Cone)

A. Broken, fragmental, sub-columnar ankaramite lava field at the southern slope of Kolekole (south of Mees Observatory).

B. Profile of the southern slope of Kolekole showing a steep dip of 30°-33° S at the upper end (right side) which gradually becomes 20°-22° S with distance on the southern slope of the volcano. Lava on the southern slope extends a considerable distance.

C. Ankaramite lava flow with spatter and cinder on the top surface showing composite lava flows and cinder on the southern slope of the volcano. Volcanic ejecta and lava flows are altered to hematite and limonite.

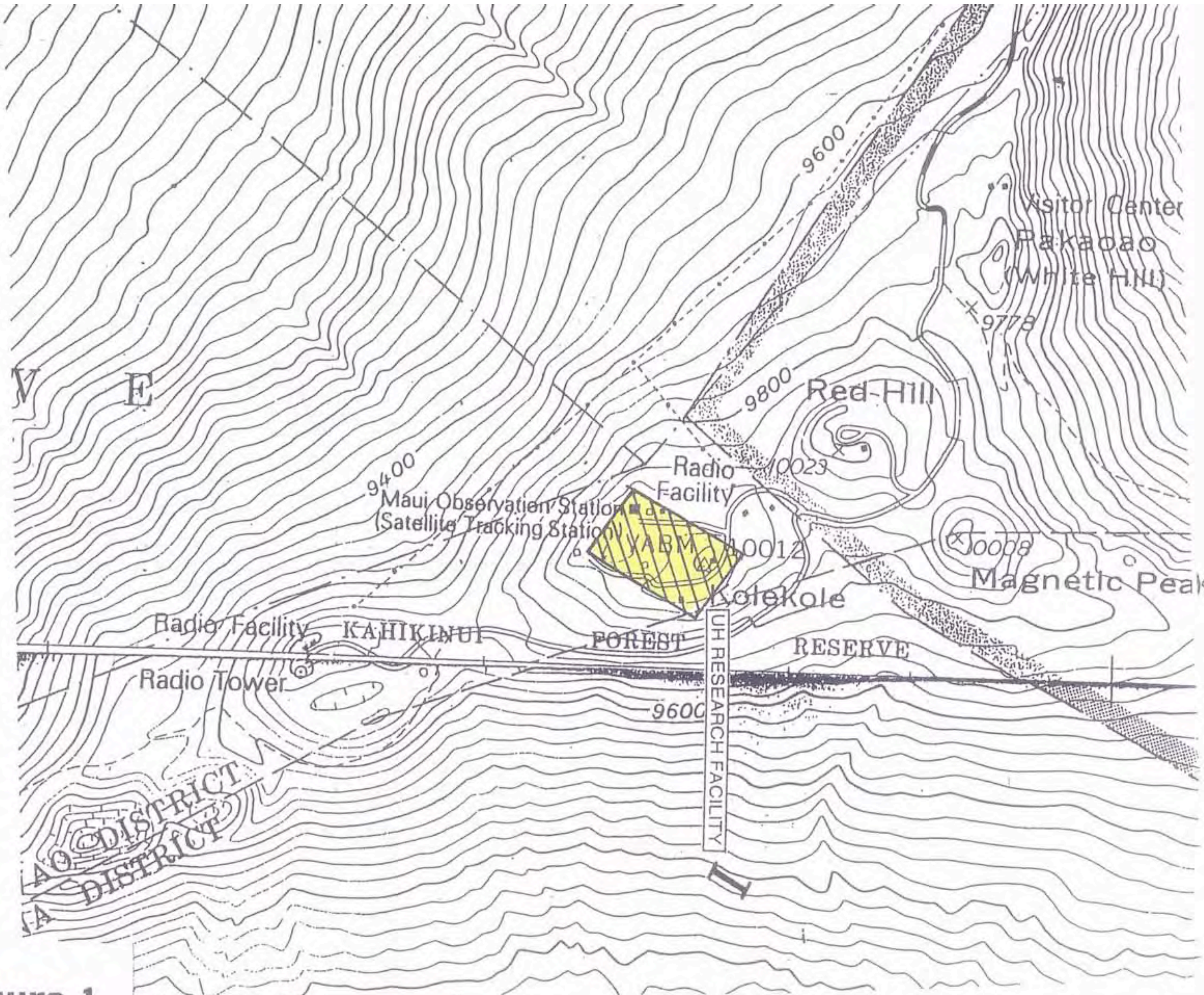
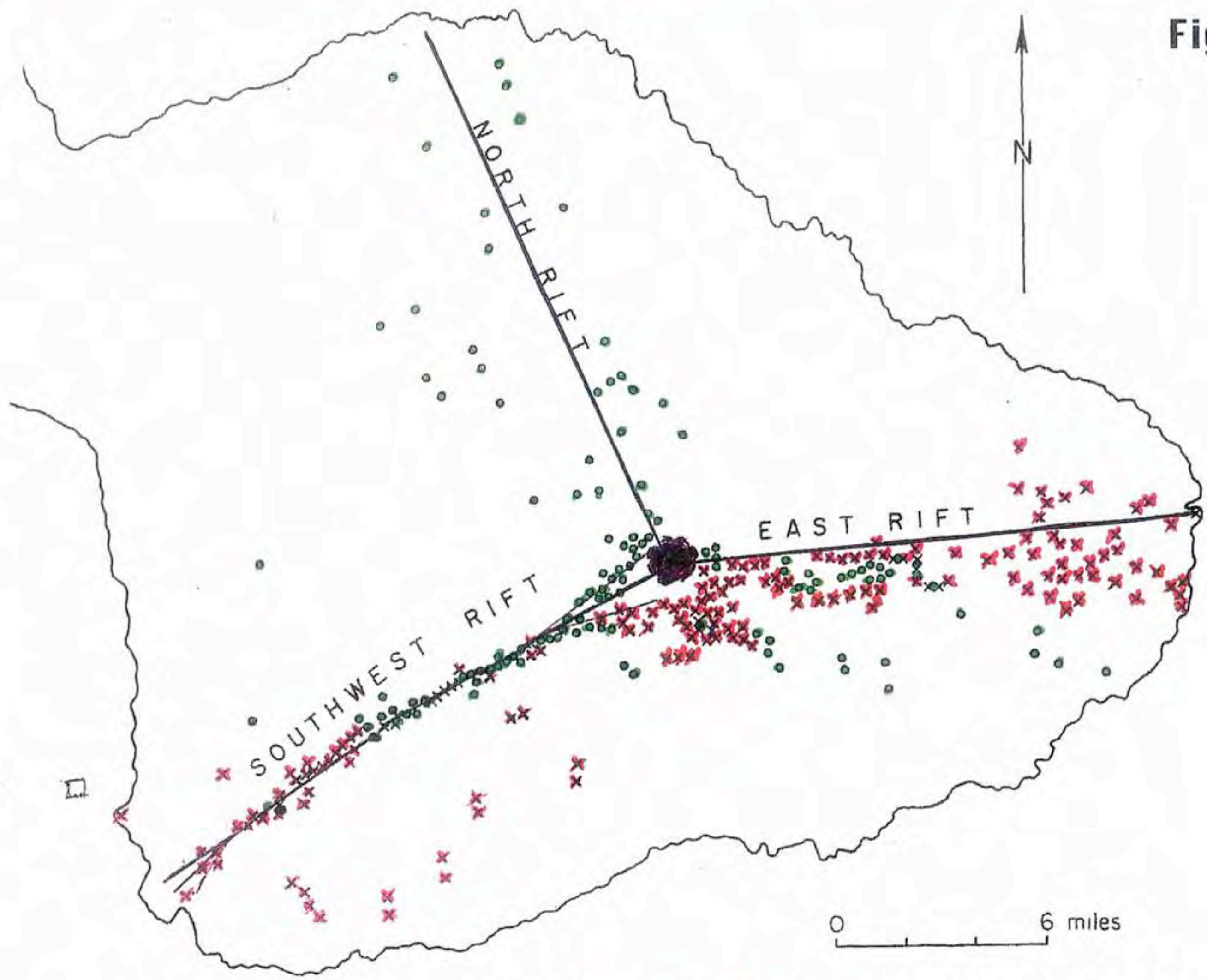


Figure 1

HALEAKALA OBSERVATORIES

Figure 2



Map of Haleakala volcano, showing vents of the Kula (*circles*) and Hana (*crosses*) Volcanic Series. Molokini Islet is a tuff cone on the southwest rift zone of Haleakala. (After Stearns and Macdonald, 1942.)

Figure 3

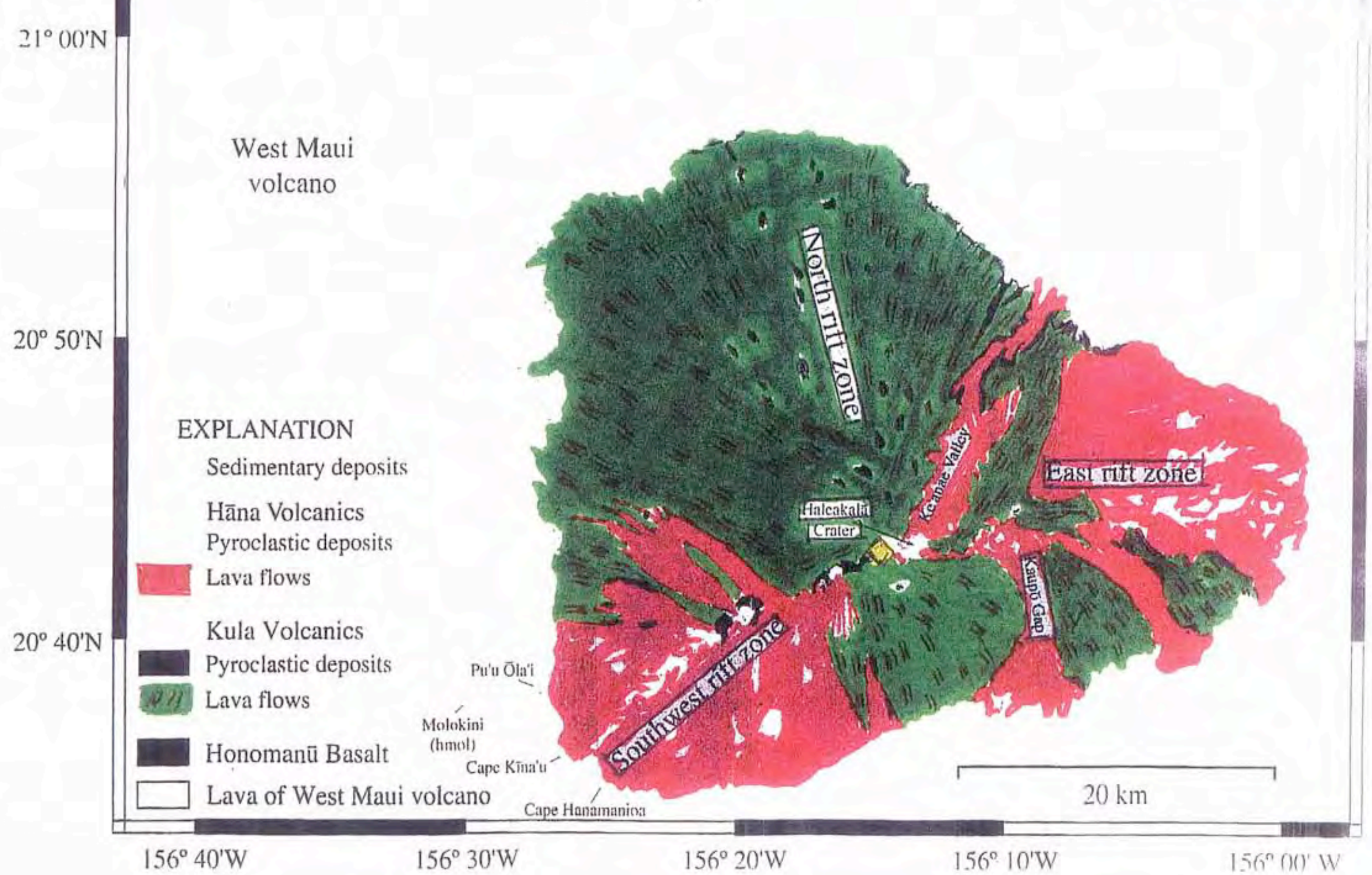

21° 00'N
20° 50'N
20° 40'N
West Maui
volcano
EXPLANATION
Sedimentary deposits
Hāna Volcanics
Pyroclastic deposits
Lava flows
Kula Volcanics
Pyroclastic deposits
Lava flows
Honomanū Basalt
Lava of West Maui volcano
North rift zone
East rift zone
Southwest rift zone
Haleakalā Crater
Keanae Valley
Kaupō Gap
Pu'u Ōla'i
Molokini
(hmol)
Cape Kīna'u
Cape Hanamanioa
20 km
156° 40'W
156° 30'W
156° 20'W
156° 10'W
156° 00' W

Figure 4

GEOLOGICAL MAP OF HALEAKALA OBSERVATORIES

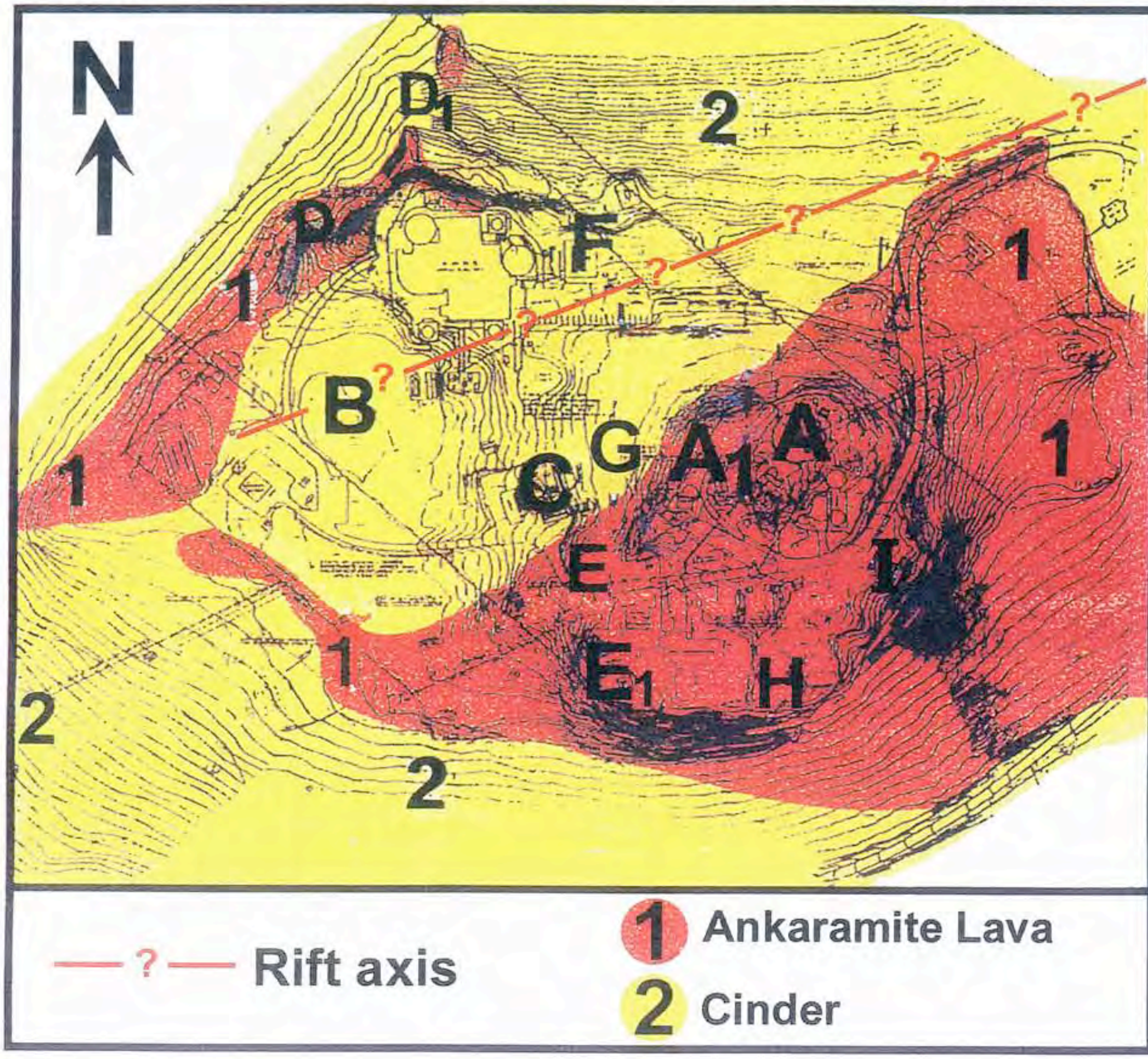
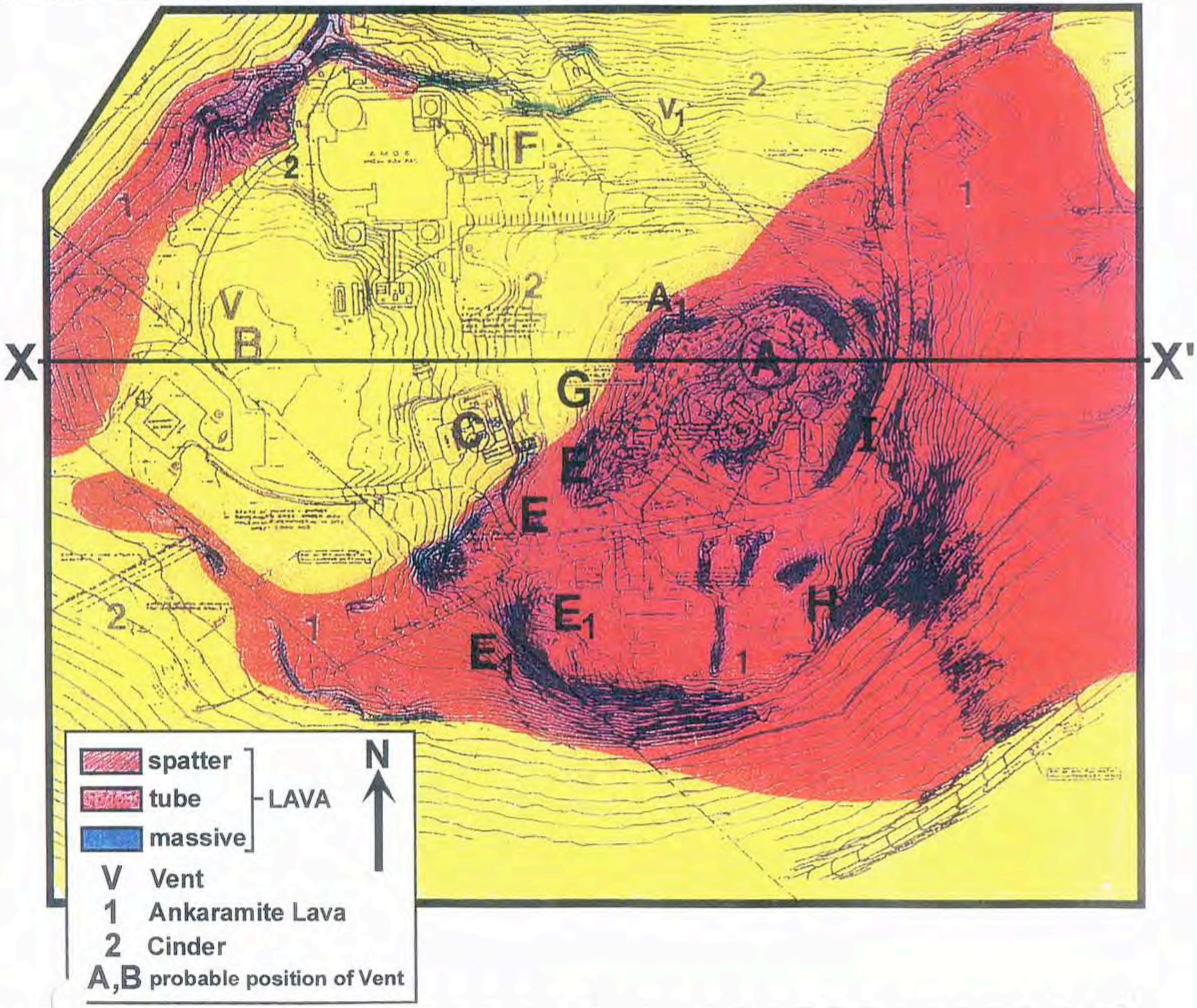
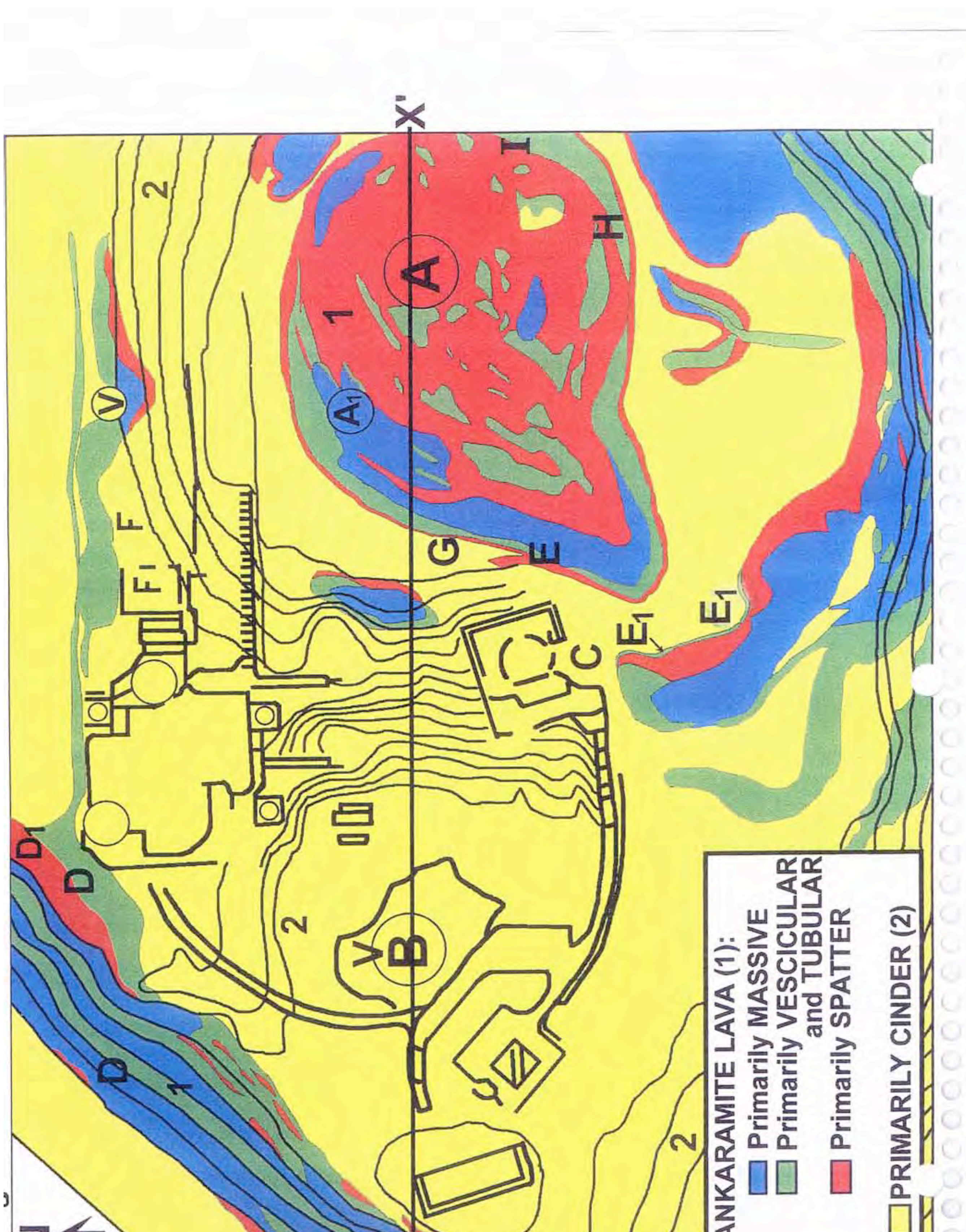


Figure 5 DETAILED GEOLOGICAL MAP OF HALEAKALA OBSERVATORIES

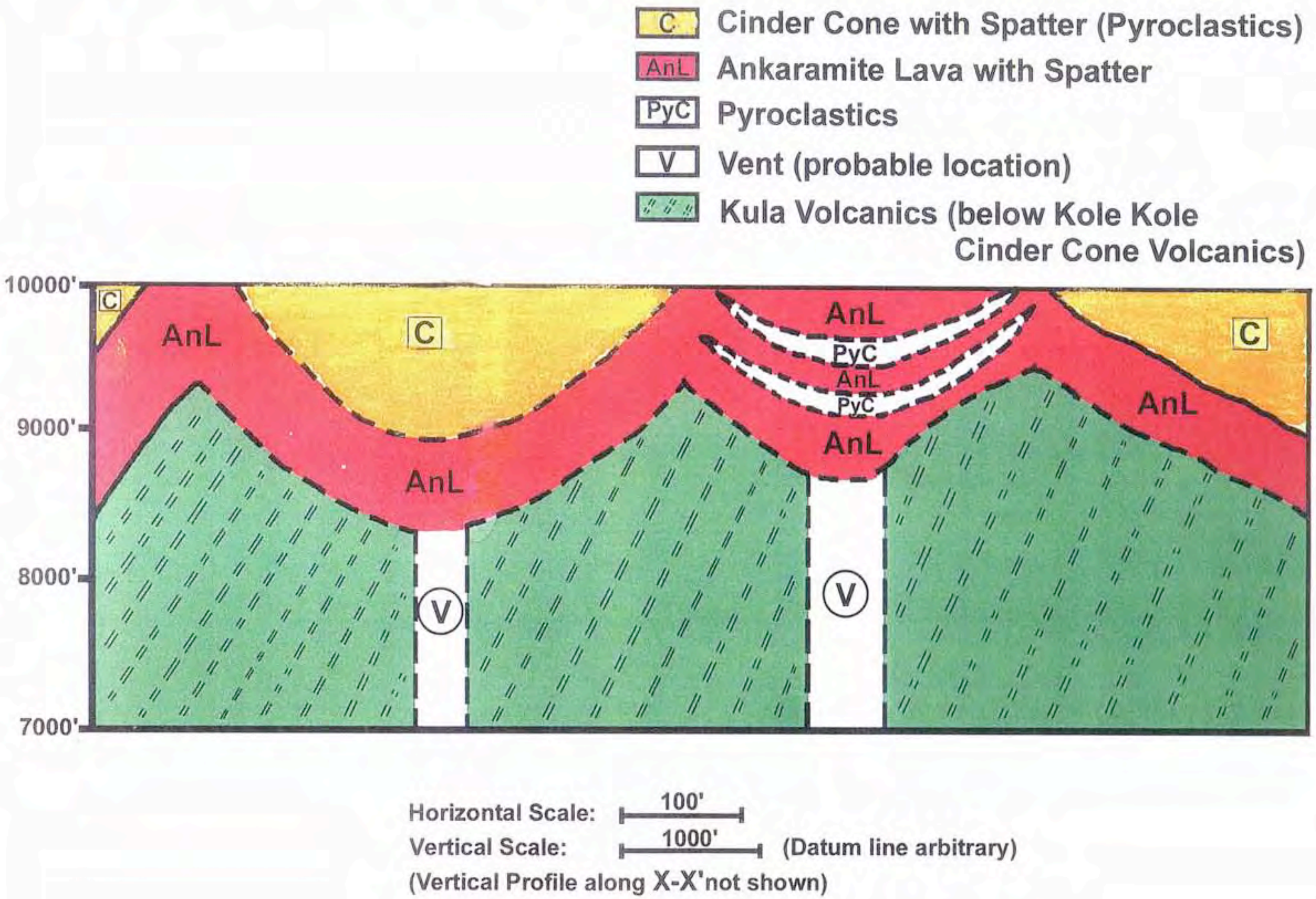




APPENDIX F: GEOLOGICAL SURVEY, 2002

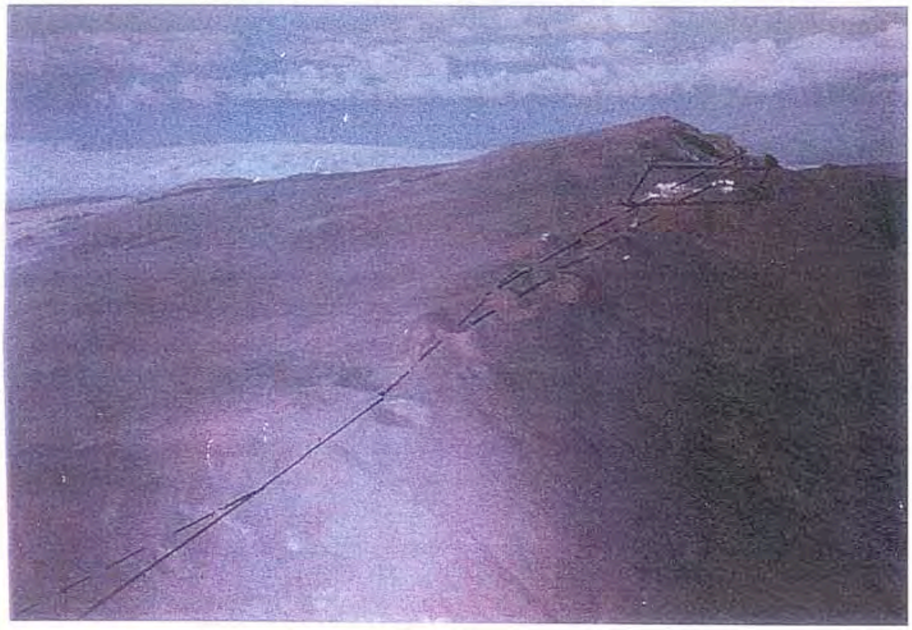
Figure 7

SCHEMATIC CROSS-SECTION OF GEOLOGIC STRUCTURE ALONG X-X'



Picture 1

1A



1B

Picture

A

B

C

Pictur

D

E

F

Picture 3

3A

3B

Picture 4

4A

4B

4C

4D

Picture 5

5A

5B

5C

Picture 6

6A

6B

6C

6D

6E

6F

Picture 7

7A

7B

7C

7D

Picture 8

8A

8B

Picture 9

9A

9B

Picture 10

10A

10B

10C

Picture 11

11A

11B

11C

Picture 12

12A

12B

12C

APPENDIX G

Soils Investigation, May 2005

REPORT
SOILS INVESTIGATION

PROPOSED
ADVANCED TECHNOLOGY SOLAR TELESCOPE
HALEAKALA OBSERVATORY

HALEAKALA, MAUI, HAWAII

for

AURA, INC.

Project No. 05951-FM
May 25, 2005

ISLAND GEOTECHNICAL ENGINEERING, INC.
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May 25, 2005
Project No. 05951-FM

Association of Universities for Research in Astronomy, Inc.
Sponsored Projects Office
950 North Cherry Avenue
Tucson, Arizona 85719

The attached report presents the results of a soils investigation at the site of the proposed Advanced Technology Solar Telescope (ATST) to be located at Haleakala Observatory in Maui, Hawaii.

A summary of the findings is as follows:

1) Six (6) test borings were drilled to depths of 28.5 to 37.5 feet below the existing grade. Borings 1 through 5 were performed within the envelope of the proposed ATST enclosure structure & Boring 6 was performed on the west side of the proposed ATST support operations building.

   In general, Borings 1 through 5 disclosed the ATST enclosure structure site to be overlain with 5 to 21 feet of loose to very dense GRANULAR soils which consist of GRAVELS & SANDS in varying proportions. The GRANULAR soils were underlain with soft to moderately hard BASALT ROCK to the final depths of the borings at 28.5 to 30 feet below existing grade. No groundwater was observed in Borings 1 through 5.

   Boring 6 (performed on the west side of the proposed ATST support operations building) encountered different subsurface conditions than Borings 1 through 5. Boring 6 encountered moderately dense SAND with silt & gravel from the surface to a depth of 1.5 feet below existing grade followed by moderately dense GRAVEL with sand to a depth of 5 feet below existing grade followed by loose GRAVEL with sand to a depth of 33.5 feet below existing grade followed by moderately dense material to the final depth of the boring at 37.5 feet below existing grade where a hard layer was encountered that was believed to be ROCK. Groundwater was observed in Boring 6 at a depth of 15 feet below existing grade.

2) From the information provided, it is desired to place the telescope pier on a mat foundation and the enclosure structure on drilled shafts. This report addresses

(continued) these two types of foundations along with the foundation for the support building.

3) Moderately hard to hard BASALT ROCK was encountered in Test Borings 1 through 5 at depths of 5 to 21 feet below existing grade. Excavation into this rock will be difficult to accomplish and will likely require heavy equipment or hoeramming for removal.

Details of the findings and recommendations are presented in the attached report.

This investigation was made in accordance with generally accepted engineering procedures and included such field and laboratory tests considered necessary for the project. In the opinion of the undersigned, the accompanying report has been substantiated by mathematical data in conformity with generally accepted engineering principles and presents fairly the design information requested by your organization. No other warranty is either expressed or given.

Respectfully submitted,

ISLAND GEOTECHNICAL ENGINEERING, INC.

Charles K. Biegel, P.E.
President

CHARLES K. BIEGEL
REGISTERED
PROFESSIONAL
ENGINEER
No. 7568-C
HAWAII, U.S.A.

This work was prepared by me
or under my supervision.

TABLE OF CONTENTS

INTRODUCTION

This investigation was made for the purpose of obtaining information on the subsurface conditions from which to base recommendations for foundation design for the proposed ATST at Haleakala facility to be located in Haleakala, Maui, Hawaii. The location of the site, relative to the existing streets and landmarks, is shown on the Vicinity Map, Plate 1.

SCOPE OF WORK

The services included drilling 6 test borings to depths of 28.5 to 37.5 feet below existing grade, obtaining samples of the underlying soils, performing laboratory tests on the samples, and performing an engineering analysis from the data gathered. In addition, a spectral analysis of surface waves (sasw) geophysical survey was performed along with on-site soils resistivity testing. In general, the following information is provided for use by the Architect and/or Engineer:

1. General subsurface conditions, as disclosed by the test borings.
2. Physical characteristics of the soils encountered.
3. Recommendations for foundation design, including bearing values, embedment depth and estimated settlement.
4. Recommendations for placement of fill and backfill.
5. Special considerations.

PLANNED DEVELOPMENT

From the information provided, the project will consist of constructing a 4 meter telescope facility on the site. The telescope enclosure structure has a roof that opens for telescope viewing. When completed, the top of the enclosure structure will be approximately 137 feet above ground level. It is desired to have the foundation system for the telescope pier separate from the foundation system for the enclosure structure in order to minimize the effects of the vibrations produced by the enclosure structure on the telescope foundation. Estimated load for the telescope is 6,680,000 pounds and estimated load for the enclosure structure is 1,544,000 pounds. Another foundation will be needed for the Support Building for the telescope which will have maximum spot footing loads of 100,000 pounds and a typical spot footing load of 50,000 pounds.

SITE CONDITIONS

Surface

The property is located adjacent to, and to the northeast of, the existing MEES observatory in Haleakala, Maui, Hawaii.

At the time of the field investigation, the site was covered with bare soil which consisted of sand, gravel, cobbles and boulders.

From the topographic map provided by Akamai Land Surveying, Inc. (see Plate 2), the existing elevations at the site range from 9,979 feet at the southwest corner of the proposed ATST Support Operations Building to 9,990 feet at the north/northeast side of the proposed ATST Telescope Enclosure Structure. The elevations shown on the boring logs of this report were provided by Akamai Land Surveying, Inc who were on-site during the drilling of our test borings.

Subsurface

The subsurface conditions at the site were explored by drilling 6 test borings to depths of 28.5 to 37.5 feet below existing grade. Borings 1 through 5 were performed within the envelope of the proposed ATST enclosure structure & Boring 6 was performed on the west side of the proposed ATST support operations building. The location of the test borings are shown on the Plot Plan, Plate 2. It should be noted that a Boring 7 is also shown on Plate 2; Boring 7 was performed by IGE for another project and is located off of the ATST site but is attached to this report for informational purposes only. A detailed log of each test boring is presented in the Appendix to this report; the blowcounts shown on the boring logs are the blowcounts required to drive a 2 inch (outer diameter) sampler into the ground with a 140 pound hammer dropped from a height of 30 inches.

In general, Borings 1 through 5 disclosed the ATST enclosure structure site to be overlain with 5 to 21 feet of loose to very dense GRANULAR soils which consist of GRAVELS & SANDS in varying proportions. The GRANULAR soils were underlain with soft to moderately hard BASALT ROCK to the final depths of the borings at 28.5 to 30 feet below existing grade. No groundwater was observed in Borings 1 through 5.

Boring 6 (performed on the west side of the proposed ATST support operations building) encountered different subsurface conditions than Borings 1 through 5. Boring 6 encountered moderately dense SAND with silt & gravel from the surface to a depth of 1.5 feet below existing grade followed by moderately dense GRAVEL with sand to a depth of 5 feet below existing grade followed by loose GRAVEL with sand to a depth of 33.5 feet below existing grade followed by moderately dense material to the final depth of the boring at 37.5 feet below existing grade where a hard layer was encountered that was believed to be ROCK. Groundwater was observed in Boring 6 at a depth of 15 feet below existing grade.

Pictures of the ROCK CORES that were obtained from the test borings are attached on Plates 19 thru 22. The specimens in these pictures are approximately 2.38 inches in diameter.

No groundwater was encountered in Borings 1 through 5 but was encountered in Boring 6 at a depth of 15 feet below existing grade.

From the USDA Soil Conservation Service "Soil Survey of the Islands of Kauai, Oahu, Maui, Molokai and Lanai, State of Hawaii", the site is located in an area designated as Cinder land (rCl). Cinder land consists of areas of bedded magmatic ejecta associated with cinder cones. It is a mixture of cinders, pumice and ash. These materials are black, red, yellow, brown, or variegated in color. They have jagged edges and a glassy appearance and show little or no evidence of soil development. Cinder land occurs on the islands of Maui and Oahu. On Maui, it is mainly at elevations between 8,000 and 10,000 feet, in the Haleakala National Park. (USDA, 1972, pp. 29 and Plate 117).

From a report by S. Bhattacharji entitled Geological Survey of the University of Hawaii Haleakala Observatories at Haleakala Summit Region, East Maui, Hawaii, the site is in a Ankaramite Lava area. This site is characterized by well-exposed polygonal to sub-columnar lava horizons which are broken into large blocks along vertical and horizontal joints. This near-horizontal ankaramite lava is phenocryst rich and highly vesicular. This basal zone of lava flows is ponded over the crater area whose center is near A. The upper horizon of the ankaramite lava is vesicular a-a type and is agglutinated with spatter and in some outcrops with cinder as well. The lava bed dips at a low angle (15°-20° E) and indicates the direction of the lava flows to be towards the eastern slope of the Kolekole cinder cone.

Geology

The island of Maui is a volcanic doublet formed when lavas from Haleakala ponded against the older West Maui Mountains. The development of the island above sea level is believed to have occurred between late Pliocene and Pleistocene time (approximately 1 to 12 million years ago).

The site is located atop the Haleakala Volcano. The volcano was built over three rift zones that trend north, southwest and east. These rift zones are studded with large cinder cones. The lava flows making up the main mass of the mountain is known as the Honomanu Volcanic Series which consists of thin-bedded pahoehoe and aa lava flows. Above the Hononamu volcanics is the Kula Volcanic Series which consists of thicker andesitic aa flows. Most of the lava flows dip about 12 degrees. Along the southwest and east rift zones only, the volcano is capped with the Hana volcanic series (Stearns, 1966).

Fresh to slightly weathered pahoehoe flows generally have a relatively smooth, billowy or ropy surface. The vesicles in pahoehoe flows usually have a fairly regular spheroidal shape. Lava tubes and pressure domes are common in this type of flow.

Fresh to slightly weathered aa flows are characterized by very rough, spiny or rubbly surfaces. The clinkery surface covers a massive, relatively dense rock interior (commonly known as blue rock). Vesicles within the rock mass are generally irregular in shape.

CONCLUSIONS AND RECOMMENDATIONS

General

Based on the findings and observations, it is concluded that the site may be developed for the intended use.

Special Considerations

Moderately hard to hard BASALT ROCK was encountered in Test Borings 1 through 5 at depths of 5 to 21 feet below existing grade. Excavation into this rock will be difficult to accomplish and will likely require heavy equipment or hoeramming for removal.

Mat Foundation for the Telescope Pier

A 3-dimensional Finite Element Analysis was performed using the Winkler Soil Model to estimate the settlement of a concrete mat foundation. The following values were used in the analysis:

Mat diameter:	84 feet
Mat thickness:	24 inches
Poisson's ratio of the subgrade soil:	0.35
Modulus of elasticity of the subgrade soil:	484,000 psf
Modulus of vertical subgrade reaction of soil:	230 pci
Structural Load (distributed uniformly):	6,680,000 pounds

The minimum embedment depth of the mat footing shall be 24 inches below the lowest adjacent compacted grade (measured to bottom of footing).

A model of the 84-foot diameter mat showing the estimated settlement is presented on Plate 25. The calculated settlement at the center of the mat is 0.1804 feet (2.1") and the settlement at the edge of the mat is 0.1202 feet (1.4").

Settlement is dependent on the stiffness of the soil and the rigidity of the mat. The above calculated settlement values are based on a 24 inch thick concrete mat and granular subgrade soil under the mat. The test borings indicate that the thickness of the granular soil (and the depth to ROCK) beneath the telescope varies. In areas where ROCK is at a shallower depth, the settlement of the mat will likely be less. The differential settlement may in turn increase or decrease depending on the depth to the ROCK under the mat.

Due to the granular nature of the on-site soils, the majority of the settlement of the structures will occur during project construction.

Prior to constructing the mat slab, subgrade soil under the mat should be compacted with a vibratory compaction machine weighing not less than 20,000 pounds; compaction should continue until a dense/unyielding surface has been achieved as determined by the project geotechnical engineer.

Backfill around the perimeter of all footings should be mechanically compacted to a minimum of 90 percent of the maximum dry density as determined by the ASTM D 1557 test procedure.

It should be noted that at the time this report was written, a structural engineer was not a part of the design team for this project. Once a structural engineer has completed the foundation design, this office should be retained to review the project blueprints.

Drilled Shafts for the Telescope Enclosure Structure

From the information provided, 12 drilled shafts will be required to support the telescope enclosure structure. Each drilled shaft will have a vertical load of 155,000 pounds and a shear load at the shaft head of 50,000 pounds. A moment at the shaft head was not provided.

For the above design loads, the minimum recommended drilled shaft diameter is 3 feet. The minimum recommended embedment depth for the drilled shaft is 21 feet below existing grade.

The allowable bearing capacity for a drilled shaft may be determined by combining the side friction with the end bearing. For the proposed 21 foot deep drilled shaft, the side friction may be assumed as 400 pounds per square foot of sidewall area. The end bearing (at 21 feet below existing grade) may be assumed as 100,000 pounds per square foot.

The test borings indicate the depth to ROCK varies from 5 to 21 feet below existing grade. Therefore, two analysis were performed for drilled shafts on this site: one analysis was performed assuming granular soils to 21 feet below existing grade (see Plate 23 for results) and another analysis was performed assuming granular soils to 5 feet below existing grade with ROCK from 5 feet to 21 feet below existing grade (see Plate 24 for results). Lateral deflection at the shaft head ranged from 0.4 inches for the granular soil model to 0.02 inches for the ROCK model. It is likely that each of the 12 drilled shafts will fall somewhere in between these two models.

It is estimated that settlement of a 36 inch diameter drilled shaft embedded at least 21 feet below existing grade will be less than 1/4 inch.

Foundation for the Support Building

Based on the topographic map provided and information from the project architect, a portion of this building will require fill in order to reach finished grade. Prior to constructing the support building pad, the existing ground under the building pad should be compacted with a vibratory compaction machine weighing not less than 20,000 pounds. Compaction should continue until a dense/unyielding surface has been achieved as determined by the project geotechnical engineer.

For footings bearing on firm on-site soil or properly compacted imported structural fill, an allowable bearing value of 2,500 psf may be used. The minimum footing embedment depth shall be 18 inches below the lowest adjacent compacted grade (measured to bottom of footing).

An allowable bearing value of 6,000 psf may be used for footings bearing on the underlying moderately hard to hard BASALT ROCK.

For footings located adjacent to new or existing utility trenches, the bottom of the footing shall be deepened below a 1 horizontal to 1 vertical plane projected upwards from the edge of the utility trench.

For footings located on or adjacent to slopes, the footing shall be deepened such that there is a minimum horizontal distance of 10 feet from the edge of the footing to the slope face.

The bearing value is for dead plus live loads and may be increased by one-third for momentary loads due to wind or seismic forces. If any footing is eccentrically loaded, the maximum edge pressure shall not exceed the bearing pressure for permanent or for momentary loads.

All loose and disturbed soil at the bottom of footing excavations shall be removed to firm soil or the disturbed soil shall be compacted prior to laying of steel or placing of concrete. The bottom of all footings should be mechanically compacted to a minimum of 95 percent of the maximum dry density as determined by the ASTM D 1557 test procedure.

Backfill around the perimeter of all foundations should be mechanically compacted to a minimum of 90 percent of the maximum dry density as determined by the ASTM D 1557 test procedure.

Site grading should be designed to prevent ponding of water adjacent to slab and footing areas.

Settlement of Support Building Footings

Under the fully applied recommended bearing pressure, it is estimated that settlement of footings up to 7 feet square bearing on firm on-site soils or properly compacted fill will be less than ½ inch.

For footings bearing on the underlying BASALT ROCK, it is estimated that settlement will be less than 1/4 inch.

Differential settlement between footings will vary according to the size, bearing pressure and bearing material of the footing.

Lateral Resistance

For resistance of lateral loads, such as wind or seismic forces, an allowable passive resistance equivalent to that exerted by a fluid weighing 300 pounds per cubic foot may be used for footings, or other structural elements, provided the vertical surface is in direct contact with undisturbed soil or properly compacted fill.

Frictional resistance between footings and the underlying on-site soils may be assumed as 0.5 times the dead load. Frictional resistance between footings and the underlying ROCK may be assumed as 0.6 times the dead load. Lateral resistance and friction may be combined.

Retaining Walls

Foundations for retaining walls shall be designed as per the foundation section of this report.

Retaining wall backfill shall consist of imported or on-site granular soil (1.5" minus, well graded). For backfill material within a 1H:2V plane projected upwards from the bottom edge of the retaining wall footing, the following active earth pressures may be used for design of free-standing retaining walls:

Backfill Slope	Horizontal Component	Vertical Component
Level Backfill	30 pcf	0
3H:1V Backfill	35 pcf	10 pcf
2H:1V Backfill	40 pcf	20 pcf

Free-standing walls are defined as walls that are allowed to rotate between 0.005 to 0.01 times the wall height. The rotation of the wall away from the backfill develops "active earth pressures". If the wall is not allowed to move as in the case of basement walls or walls that are restrained at the top, the soil pressure that will develop is known as an "at rest" pressure; for restrained walls, the above active earth pressures shall be increased by 50 percent for "at-rest" conditions.

For granular retaining wall backfill, the top 1 foot of the backfill shall be "capped" with an impervious clay or silt type soil, or capped by an impervious surface such as concrete or asphaltic concrete.

Drainage for the retaining wall backfill shall be accomplished by providing 4-inch diameter weepholes spaced 8-feet on-center (horizontally as well as vertically) or by using a minimum 4-inch diameter perforated PVC footing drain pipe. A 2-foot thick layer of crushed gravel, which is wrapped with geotextile filter fabric, shall be placed above the pipe; the crushed gravel shall be continuous from weephole to weephole, or in the case of a footing drain pipe, laid throughout the full length of the pipe. Geotextile fabric shall be AMOCO 4545 or similar.

The backfill for the retaining wall shall be properly compacted in accordance with the Site Preparation and Grading section to this report. Site grading should be designed to drain surface water away from the backfill area.

The above active pressures do not include surcharge loads such as footings located within a 45 degree plane projected upwards from the heel of the footing, fine-grained soils as backfill, and/or from hydrostatic pressures. If such conditions occur, the active pressure shall be increased accordingly.

Slabs-on-Grade

Slab-on-grade construction shall be in accordance with Plate A of this report. Site grading should be designed to prevent ponding of water adjacent to slab and footing areas.

Slopes

Cut and fill slopes shall not exceed 2 horizontal to 1 vertical. Exposed slopes shall be covered as soon as practical after construction to minimize erosion.

Fill slopes shall be constructed by overfilling and cutting back to compacted soil.

Resistivity Testing

The Four Pin test method (a.k.a. Wenner 4 Pin Method) was used to determine the resistivity at the site. A Nilsson 400 resistance meter was used along with 5/16" diameter by 30" long stainless steel pins.

In general, the test is conducted by spacing the 4 pins an equal distance from each other (in a straight line) and then driving the pins into the ground. The 4 pins are connected to the resistance meter using No.16 AWG, 105 strand copper wire with pvc insulation. The resistance reading is then taken from the meter and a calculation is made to determine the resistivity. Adjustments to the pin spacing are made to determine the resistivity for various depths.

Resistivity readings were taken in two directions on the site as shown on Plate 2A. The locations of the two lines (labeled east/west and north/south) were determined in the field by the fact that these two lines did not contain ROCK/BOULDERS on the surface of the site, thereby, enabling our field crew to hammer the stainless steel pins into the ground. The results of the Resistivity Test are as follows:

Location	Depth	Resistivity (ohm/cm)
East/West Line	20'	5,745,000
East/West Line	15'	4,883,250
East/West Line	10'	4,404,500
East/West Line	5'	1,819,250
North/South Line	20'	3,447,000
North/South Line	15'	3,734,250
North/South Line	10'	4,021,500
North/South Line	5'	4,213,000

Site Preparation and Grading

It is recommended that the site be prepared in the following manner:

1. All vegetation, weeds, brush, roots, stumps, rubbish, debris, soft soil and other deleterious material shall be removed and disposed of off-site.

2. In areas to receive fill and at finished subgrade in cut areas, the exposed surface shall then be moisture conditioned to near optimum moisture and then compacted (with a compaction machine weighing not less than 20,000 pounds) to at least 95 percent of the maximum dry density as determined by the ASTM D 1557 test procedure. If soft or loose spots are encountered, the loose/soft areas shall be removed to firm material and the resulting depression shall be filled with properly compacted fill.

3. Where fill is placed on existing ground that is steeper than 5 horizontal to 1 vertical, the existing ground surface shall be benched into firm soil as the fill is placed.

4. Fill and Backfill in Structural Areas: Structural areas shall be defined as areas beneath and 3 feet beyond the edges of the structures.

   Structural fill and backfill material shall consist of 1.5 inch minus granular material which is well-graded & free of organics and debris and is non-expansive.

Each layer of structural fill and backfill material shall be placed in lifts not exceeding 6 inches in compacted thickness. Each layer of structural fill and backfill shall be thoroughly compacted prior to placing of any subsequent lifts. Structural fill and backfill shall be compacted to at least 95 percent of the maximum dry density. The maximum dry density shall be determined by the ASTM D 1557 test procedure.

5. <u>Fill and Backfill in Non-Structural Areas:</u> Non-structural areas shall be defined as areas beyond 3 feet from the edge of any structure.

Non-structural fill and backfill material shall consist of material which is free of organics and debris. In the upper 3 feet from finished grade, the fill and backfill material shall be less than 3 inches in greatest dimension. Below 3 feet from finished grade, the fill material shall be less than 24 inches in greatest dimension, provided there is sufficient fines to fill the interstices. The on-site soils are acceptable for use as non-structural fill provided the above size requirements can be met.

Each layer of non-structural fill and backfill material shall be placed in lifts not exceeding 12 inches in compacted thickness. Each layer of non-structural fill and backfill shall be thoroughly compacted prior to placing of any subsequent lifts. The top 2 feet of non-structural fill and backfill shall be compacted to at least 90 percent of the maximum dry determined by the ASTM D 1557 test procedure. Non-structural fill and backfill below 2 feet from finished grade shall be compacted to at least 85 percent of the maximum dry density as determined by the ASTM D 1557 test procedure.

6. Backfill Behind Retaining Walls Retaining wall backfill shall be defined as backfill that extends from the stem of the retaining wall to 6 inches beyond the heel of the wall footing or the footing excavation line, whichever is greater.

All retaining wall backfill material shall consist of material that is in accordance with the project plans and specifications and meets the design criteria of the structural engineer.

Each layer of backfill shall be placed in layers not exceeding 6 inches in compacted thickness. Each layer of backfill shall be thoroughly compacted prior to placing of any subsequent lifts. All retaining wall backfill shall be compacted to at least 90 percent of the maximum dry density as determined by the ASTM D 1557 test procedure. Retaining wall backfill that will support structures or roadways shall be placed and compacted in accordance with the above requirements for Fill and Backfill in Structural Areas. The appropriate size compaction equipment should be used to avoid damaging the retaining wall.

7. During construction, drainage shall be provided to prevent ponding of water adjacent to or on foundation areas. Ponded areas shall be drained immediately or water pumped out without damaging adjacent structures and property. If water accumulation softens the subgrade materials, the affected soils shall be removed and replaced with properly compacted fill.

It is particularly important to see that all fill and backfill soils are properly compacted in order to maintain the recommended design parameters provided in this report.

ON-SITE OBSERVATION

During the progress of construction, so as to evaluate general compliance with the design concepts, specifications and recommendations contained in this report, a representative from this office should be present to observe the following operations:

1. Site preparation.
2. Placement of fill and backfill.
3. Footing excavations and drilled shaft excavations.

REMARKS

For cultural sensitivity reasons, clearing existing surface rocks on the proposed ATST telescope pad with a bull-dozer and doing test borings where the surface rocks are now located was not possible at the time this investigation was performed. The test borings that were performed are in locations that were accessible with minimal disturbance. If it is desired to more accurately predict mat settlement or the subsurface conditions at the telescope facility, additional test borings can be performed upon request.

The conclusions and recommendations contained herein are based on the findings and observations made at the exploration locations. If conditions are encountered during construction which appear to differ from those disclosed by the exploration, this office shall be notified so as to consider the need for modifications.

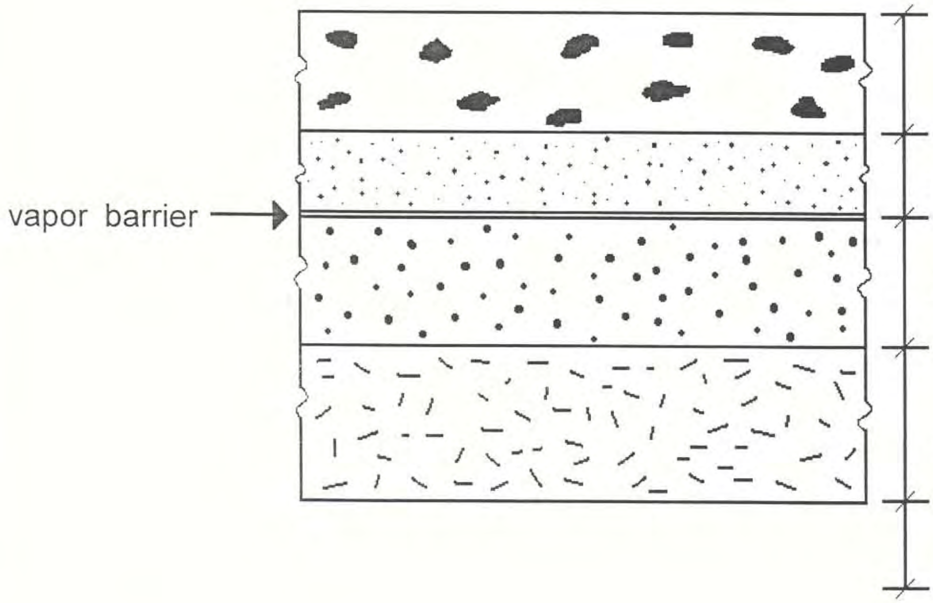
It should be noted that at the time this report was written, a structural engineer was not involved in the project. When the final design of all the structures has been completed, this office should be retained to review the project blueprints.

This report has been prepared for the exclusive use of AURA, Inc. and their respective design consultants. It shall not be used by or transferred to any other party or to another project without the consent and/or thorough review by this facility. Should the project be delayed beyond the period of one year from the date of this report, the report shall be reviewed relative to possible changed conditions.

Samples obtained in this investigation will deteriorate with time and will be unsuitable for further laboratory tests within one (1) month from the date of this report. Unless otherwise advised, the samples will be returned to the site under the supervision of the project cultural monitor.

The following are included and complete this report:

SLAB-ON GRADE DETAIL



Notes:

1. The subgrade soil should be non-expansive material. The subgrade soil should be moisture conditioned to within 3 percent of optimum moisture content and compacted to a minimum of 95% of the maximum dry density, as determined by the ASTM D 1557 test procedure.

2. The UTB (Untreated Base Course gravel) shall be compacted to a minimum of 95% of the maximum dry density as determined by the ASTM D 1557 test procedure.

3. The #3 fine gravel shall be compacted by means of a vibratory plate compactor making a minimum of 4 passes.

4. The SAND shown above is for concrete curing purposes and should be moist prior to placement of the concrete. In the event the slab designer eliminates the 2 inches of sand, the UTB thickness should be increased to 8 inches.

5. The concrete thickness, reinforcing and curing compound recommendations are to be provided by others.

6. Exterior slabs may eliminate the #3 fine gravel, vapor barrier and sand; concrete may be placed on 6 inches of UTB.

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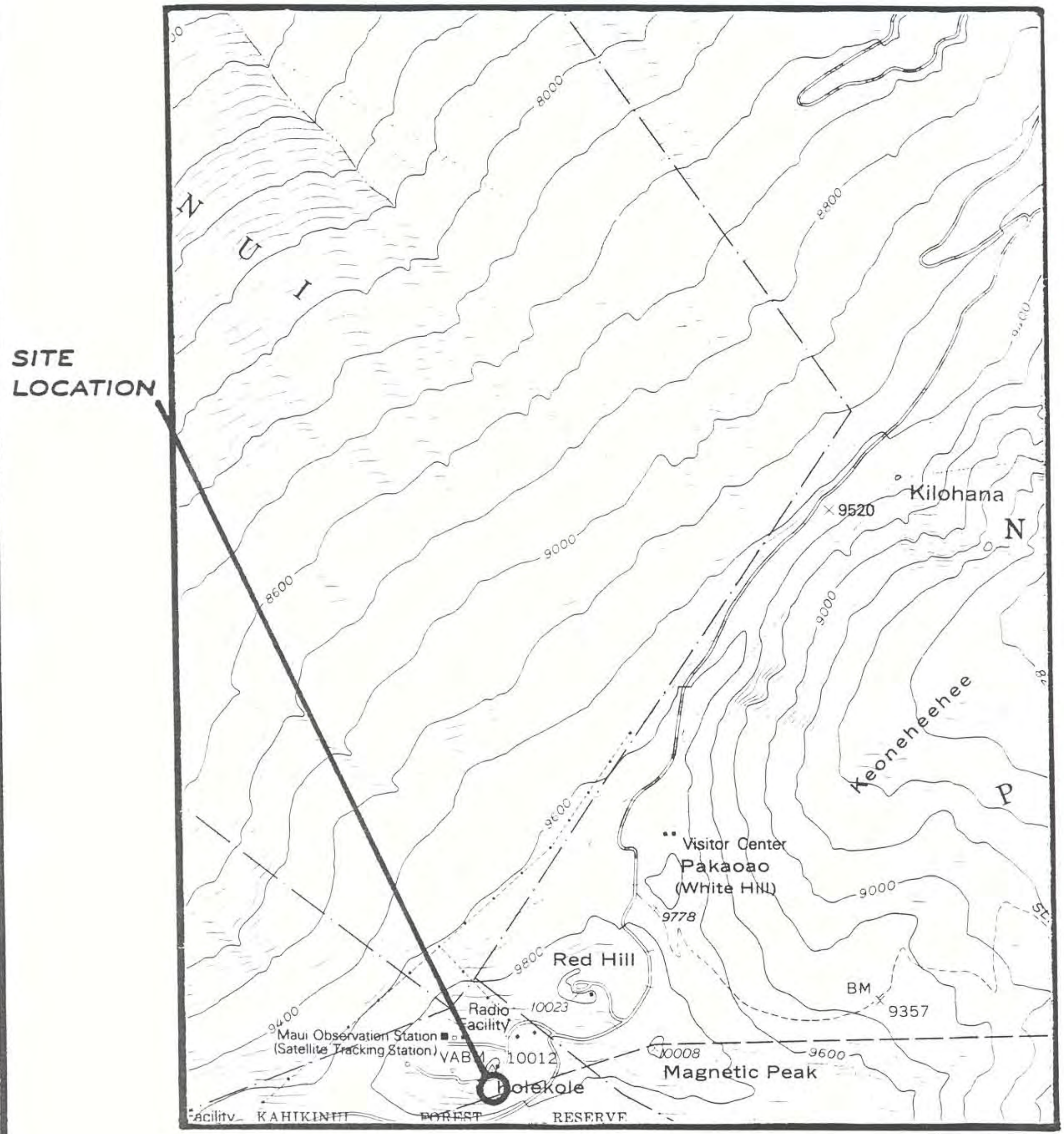
VICINITY MAP



REFERENCE:

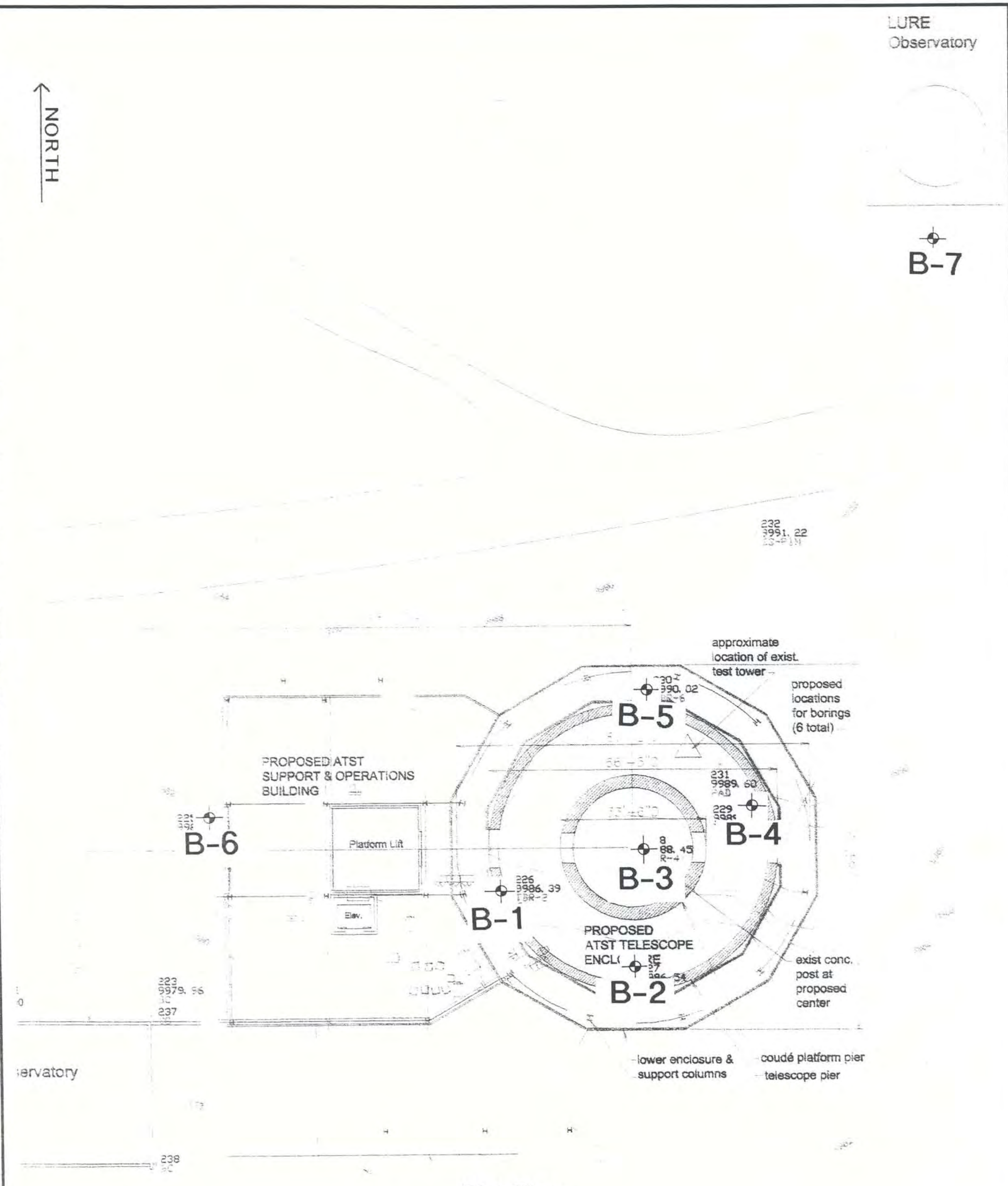
USGS TOPOGRAPHIC MAP
KILOHANA QUADRANGLE

Dated: 1983

ATST AT HALEAKALA

ISLAND GEOTECHNICAL ENGINEERING, INC.
Geotechnical Consultants

PROJECT NO.	05951-FM
DATE	Apr. 2005
SCALE	1" = 2000'
PLATE	1



Plot Plan

Scale: 1" = 30' (±)

Project: ATST AT HALEAKALA

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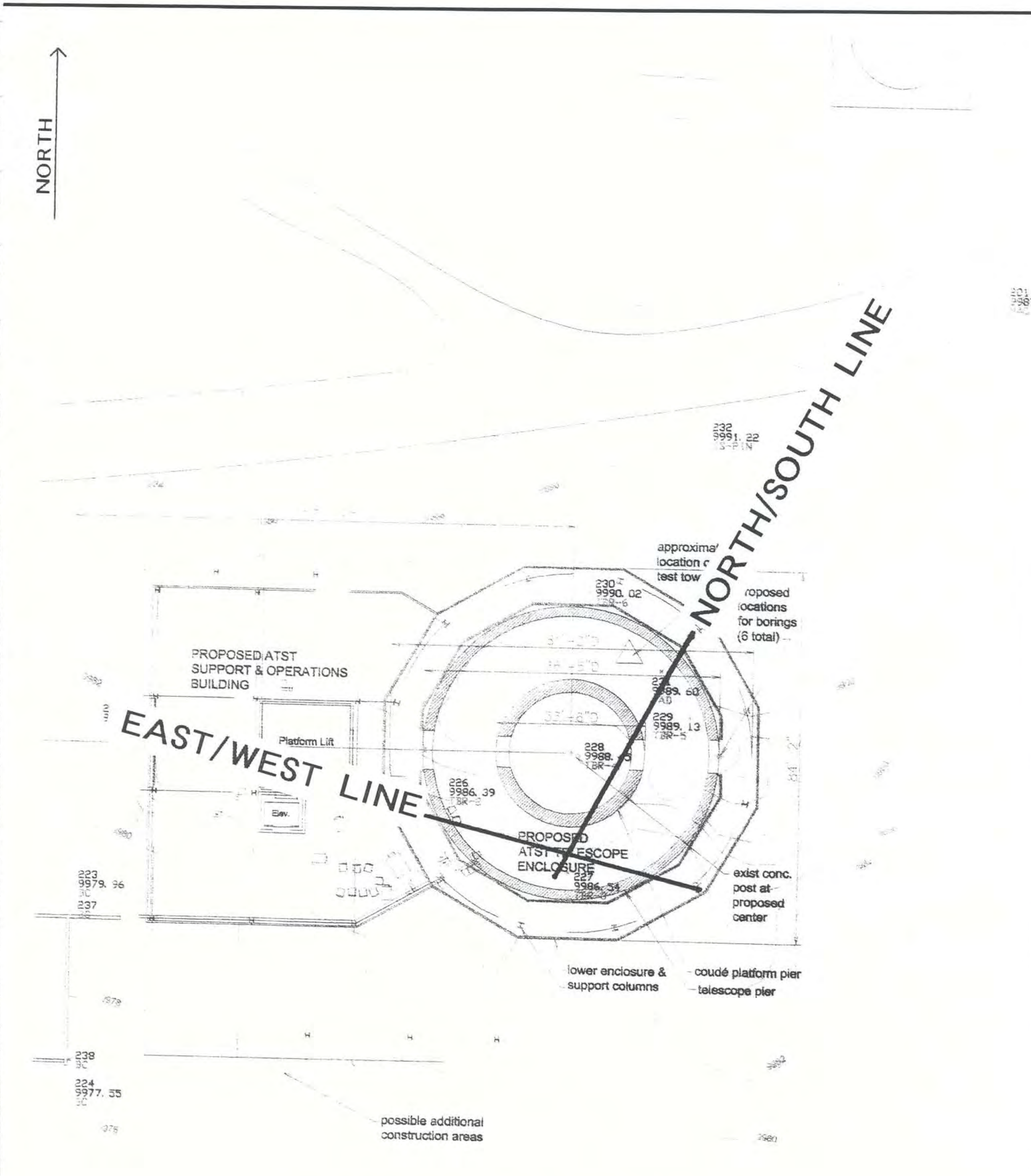
ISLAND GEOTECHNICAL ENGINEERING, INC.

PLATE 2



SASW & RESISTIVITY TESTING PLAN

Scale: 1" = 30' (±)

Project: ATST AT HALEAKALA

Project No.: 05951-FM

ISLAND GEOTECHNICAL ENGINEERING, INC.

PLATE 2A

APPENDIX

FIELD INVESTIGATION AND LABORATORY TESTING

FIELD INVESTIGATION

General

The field investigation consisted of performing explorations at the locations shown on the Plot Plan. The method used for the exploratory work is shown on the respective exploration log. A description of the various method or methods used is presented below.

Test Borings Using Truck-Mounted Drilling Equipment

Truck-mounted borings are drilled using a gas-powered drilling rig. The hole is advanced using continuous flight augers, wash boring and/or NX coring.

Auger drilling is used in soils where caving does not occur. The augers are 4-1/2 inch diameter continuous helical flight augers with the lead auger having a head equipped with changeable cutting teeth. Soil cuttings are brought to the surface by the continuous flights. After the bore hole is advanced to the required depth and cleaned of cuttings by additional rotation of the augers, the augers are retracted for soil sampling or in-situ testing.

In soils where caving of the bore hole occurs, the hole is advanced by wash boring or hollow-stem augering. Wash boring consists of advancing steel casing by rotary action and water pressure to flush the soil from the casing. The lead section of the casing is equipped with a carbide or diamond casing bit. After the casing has been advanced to the required depth, soil samples are obtained through the inside of the casing. Hollow-stem drilling consists of advancing the hole with 7-5/8 inch outside diameter and 4-1/4 inch inside diameter augers. The leading drill bit is connected to drilling rods through the central portion of the auger. At the required sampling depth, the interior drill rods and lead bit are removed, and the soil sample is taken by driving a sampler through the "hollow" section of the augers.

Coring is used for hard formations such as rock, coral or boulders. The core barrel, consisting of a 5-foot long double tube, hardened steel barrel with either a carbide or diamond bit, is attached to drilling rods and set on the hard formation. The core barrel is advanced through the formation by rotation of the core barrel. Water is used to flush out the cuttings. Upon completion of the core run, the sample is removed from the core barrel and inspected. The total core recovery length and the sum of all intact pieces over 4-inch in length are measured. The length of core recovery divided by the length of the core run is the recovery ratio. The combined length of the 4-inch or longer pieces divided by the length of core run is the Rock Quality Designation (RQD). The values provide an indication of the quality of the formation.

Test Borings Using Portable Drilling Equipment

In areas inaccessible to truck-mounted equipment, portable drilling equipment is used to drill the test boring. The boring is advanced by either 1) continuous drive sampling or by 2) using a small gas-powered drill rig with continuous flight augers, wash boring or NX coring.

Soil samples are obtained with a tripod and cathead assembly using soil sampling methods described below.

Test Pits Using Excavators/Backhoes

Test pits are excavated using a excavator or backhoe. Material excavated from the pit and the sides and bottom of the pit are visually inspected and a continuous log of the hole is kept.

Explorations Using Hand Tools

In inaccessible areas requiring only shallow explorations, borings and test pits are made using hand equipment. Borings are drilled using hand augers. Test pits are excavated using hand tools. Cuttings from the boring and/or pit are inspected and visually classified.

Soil Sampling

Relatively undisturbed samples of the underlying soils are obtained from borings by driving a sampling tube into the subsurface material using a 140-pound safety hammer falling from a height of 30 inches. Ring samples are obtained using a 3-inch outside diameter, 2.5 inch inside diameter steel sampling tube with an interior lining of one-inch long, thin brass rings. The tube is driven approximately 18 inches into the soil and a section of the central portion is placed in a close fitting waterproof container in order to retain field conditions until completion of the laboratory tests. Standard Penetration Test (SPT) values and disturbed soil samples are obtained with a 2-inch (outside diameter) split-barrel sampler instead of the 3-inch sampler. The number of blows required to drive the sampler into the ground is recorded at 6-inch intervals. The blow count for the last 12-inches is shown on the boring logs.

From test pit excavations, relatively undisturbed soil samples are obtained by pushing the 3 inch outside diameter sampling tube (mentioned above) into the ground with the backhoe bucket. In addition, undisturbed bulk samples are retained from cohesive type soil formations and disturbed bulk samples are retained from friable and cohesionless soil formations.

The soil samples are visually classified in the field using the Unified Soil Classification System. Samples are packed in moisture proof containers and transported to the laboratory for testing.

Dynamic Cone Penetrometer (DCP)

There are two types of DCP test used in the field. One test is generally used for pavement design and the other test is generally used for foundation design.

The DCP test for pavement design is an in-place test generally performed on the near surface soils. The DCP consist of a steel rod with a steel cone attached to one end which is driven into the soil by means of a sliding hammer. The angle of the cone is 60 degrees. The depth of the cone penetration is recorded at selected penetration or hammer drop intervals. The standard DCP test is designed to penetrate soils to a total depth of 1 meter (39.4 inches), however, extension rods may be used to reach greater depths. The recorded data from the DCP test can be converted to CBR values for use in pavement design.

The DCP test for foundation design (aka Wildcat DCP) is used to evaluate the consistency of the subsurface soils to depths of 25 feet. The test is performed by driving a 1.4 inch diameter (10 square centimeter area) steel cone (cone is connected to 1.1" diameter steel rods) into the ground using a 35 pound slide hammer that is dropped from a height of 15 inches. The number of blows required to drive the steel cone 10 centimeters is recorded and the process is continued until the desired depth is reached.

LABORATORY TESTING

General

Laboratory tests are performed on various soil samples to determine their engineering properties. Description of the various tests are listed below.

Unit Weight and Moisture Content

The in-place moisture content and unit weight of the samples are used to correlate similar soils at various depths. The sample is weighed, the volume determined, and a portion of the sample is placed in the oven. After oven-drying, the sample is again weighed to determine the moisture loss. The data is used to determine the wet-density, dry-density and in-place moisture content.

Direct Shear

Direct shear tests are performed to determine the strength characteristics of the representative soil samples. The test consists of placing the sample into a shear box, applying a normal load and then shearing the sample at a constant rate of strain. The shearing resistance is recorded at various rates of strain. By varying the normal load, the angle of internal friction and cohesion can be determined.

Consolidation Test

Consolidation tests are performed to obtain data from which time rates of consolidation and amounts of settlement may be estimated. The test is performed by placing a specimen in a consolidation apparatus. Loads are applied in increments to the circular face of a one (1) inch high sample. Deformation or changes in thickness of the specimen are recorded at selected time intervals. Water is introduced to or allowed to drain from the sample through porous disks placed against the top and bottom faces of the specimen. The data is then used to plot a stress-volume strain curve which is used in estimating settlement.

Expansion Index Test

Expansion Index of fine-grained soils is determined in accordance with ASTM D 4829-88 test procedure. The soil specimen is compacted into a metal ring so that the degree of saturation is between 40 and 60 percent. The specimen and the ring are placed in a consolidometer. A vertical confining pressure of 1 psi is applied to the specimen and then the specimen is inundated with water. The deformation of the specimen is recorded for 24 hours. The data is used to determine the expansion potential of the soil.

One-Dimensional Swell Test

Another procedure for determining the expansion potential of fine-grained soils is ASTM D 4546-90 (Method B) test procedure. The soil specimen is compacted into a 2.5 inch diameter (1 inch height) metal ring using a 10 pound hammer. The specimen and the ring are placed in an expansion apparatus. A vertical confining pressure of 155 psf is applied to the specimen and then the specimen is inundated with water. The deformation of the specimen is recorded for 24 hours.

This test is similar in principle to the Expansion Index Test (see above) with the primary difference being the soil specimen in the One-Dimensional Swell Test is usually compacted to a higher dry density than the Expansion Index and, therefore, generally produces a higher degree of expansion.

Classification Tests

The soil samples are classified using the Unified Soil Classification System. Classification tests include sieve and hydrometer analysis to determine grain size distribution, and Atterberg Limits to determine the liquid limit, plastic limit and plasticity index.

California Bearing Ratio Test

California Bearing Ratio (CBR) tests are performed on materials to determine the bearing strength of the soil for determination of pavement sections. The sample is compacted into a 6-inch diameter mold in 5 equal layers. Each layer is compacted with a 10-pound hammer falling from a height of 18-inches, with each layer receiving 56 blows. The mold is then placed in a water bath for 4-days and the vertical swell is measured under a surcharge weight of 10 pounds. After the soaking period, the sample is placed in a CBR apparatus that has a 3-square inch penetrometer. The penetrometer is pressed vertically into the soil at constant strain and the loads required to press the penetrometer are recorded. A plot of the load-strain relationship is made to determine the CBR value.

Maximum Dry Density/Optimum Moisture Content

The maximum dry density and optimum moisture content of the material is determined in accordance with the ASTM D1557-91 test procedure. The sample is compacted into a mold in 5 equal layers using a 10 pound hammer falling from a height of 18 inches. The diameter of the mold is either 4-inches or 6-inches depending on the proportion of gravel in the sample. The sample is compacted at various moisture contents to develop a compaction curve for the soil. The curve is usually bell-shaped with a peak indicating the maximum dry density and optimum moisture content.

Penetrometer Test

Penetrometer tests are performed on clayey soils to determine the consistency of the material and an approximate value of the unconfined compressive strength.

Torvane

Torvane tests are used to determine the approximate undrained shear strength of clayey soils.

The torvane apparatus consists of a torque device with a small diameter plate that has vanes situated perpendicular to the plate. The vanes are pushed into the soil and torque is applied until failure occurs. The torque required to cause failure is converted to approximate undrained strength of the soil.

LOG OF BORING NO. 1

EQUIPMENT USED: Mobile B-59

DATE DRILLED: March 8, 2005

ELEVATION: 9986.39

DEPTH OF BORING (FT.): 30

DEPTH OF GROUNDWATER: unknown

DEPTH (FT.)	GRAPHIC SYMBOL	SOIL CLASSIFICATION	DESCRIPTION	SAMPLE	BLOWS/FOOT	COLOR	CONSISTENCY	MOISTURE	DRY DENSITY (PCF)	MOISTURE CONTENT (% OF DRY WT.)	PENETROMETER (TSF)
0		SM	silty SAND	■	50/ 6"	dark brown	mod. dense	moist	78.2	18.0	
		SP-SM	SAND with silt, gravel and cobbles			brown	very dense			11.4	
4											
		rock	BASALT ROCK			gray brown	mod. hard rock with zones of soft rock & cinder				
8			Core Run from 5' to 10': Rec. = 45% RQD = 33%								
12			Core Run from 10' to 15': Rec. = 31% RQD = 11%								
16			Core Run from 15' to 20': Rec. 51% RQD = 33%								
							soft rock or cinder zone				
20							mod. hard rock with zones of soft rock & cinder				
			Core Run from 20' to 25': Rec. = 40% RQD = 26%								
24											
			Core Run from 25' to 30': Rec. = 70% RQD = 20%								
28							soft rock or cinder zone				
			END OF TEST BORING								

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PLATE 3

LOG OF BORING NO. 2

EQUIPMENT USED: Mobile B-59

DATE DRILLED: March 9, 2005

ELEVATION: 9986.54

DEPTH OF BORING (FT.): 30

DEPTH OF GROUNDWATER: unknown

DEPTH (FT.)	GRAPHIC SYMBOL	SOIL CLASSIFICATION	DESCRIPTION	SAMPLE	BLOWS/FOOT	COLOR	CONSISTENCY	MOISTURE	DRY DENSITY (PCF)	MOISTURE CONTENT (% OF DRY WT.)	PENETROMETER (TSF)
0		SM	silty SAND		22	brown	mod. dense	moist	95.7	10.4 20.7 23.3	
		GP-GM	silty GRAVEL with sand and cobbles								
4											
					50/ 6"		very dense			18.3	
8											
						reddish brown					
12		rock	BASALT ROCK Core Run from 11.5' to 15': Rec. = 37% RQD = 29%		31/ 5"	gray brown	mod. hard rock with zones of soft rock & cinder			15.8	
16			Core Run from 15' to 20': Rec. = 67% RQD = 52%								
20			Core Run from 20' to 25': Rec. = 57% RQD = 41%								
24							soft rock or cinder zone				
28			Core Run from 25' to 30': Rec. = 58% RQD = 25%				mod. hard rock with zones of soft rock & cinder				
			END OF TEST BORING								

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PLATE 4

LOG OF BORING NO. 3

EQUIPMENT USED: Mobile B-59

DATE DRILLED: March 10, 2005

ELEVATION: 9988.45

DEPTH OF BORING (FT.): 28.5

DEPTH OF GROUNDWATER: unknown

DEPTH (FT.)	GRAPHIC SYMBOL	SOIL CLASSIFICATION	DESCRIPTION	SAMPLE	BLOWS/FOOT	COLOR	CONSISTENCY	MOISTURE	DRY DENSITY (PCF)	MOISTURE CONTENT (% OF DRY WT.)	PENETROMETER (TSF)
0		GP-SP	SAND with gravel and GRAVEL with sand (alternating layers)		25 53 24 23 31	dark brown	mod. dense	moist	86.1	16.1 28.8 6.2	
4		SP-SM	poorly graded SAND with silt		17 37 48	dusky red	dense			16.2	
8					96	dark reddish brown	very dense				
		SW-SM	well-graded SAND with silt and gravel		58	reddish black				13.1 15.8	
12		rock	BASALT ROCK		30/ 3"	gray brown	mod. hard rock with zones of soft rock & cinder			1.0	
16											
20							soft rock or cinder zone				
24							mod. hard rock with zones of soft rock & cinder				
28			END OF TEST BORING								

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PLATE 5

LOG OF BORING NO. 4

ELEVATION: 9989.13

EQUIPMENT USED: Mobile B-59

DEPTH OF BORING (FT.): 30

DATE DRILLED: March 11, 2005

DEPTH OF GROUNDWATER: unknown

DEPTH (FT.)	SOIL CLASSIFICATION	DESCRIPTION	BLOWS/FOOT	COLOR	CONSISTENCY	MOISTURE	DRY DENSITY (PCF)	MOISTURE CONTENT (% OF DRY WT.)	PENETROMETER (TSF)
0	SM	silty SAND with gravel		dark brown to brown	loose	moist to very moist	88.5	21.5	
	GP	GRAVEL with sand	18		mod. dense			41.0	
						moist		23.6	
4									
			7					26.3	
8									
					very dense				
			64					14.7	
12									
		---boulder (12" diameter)							
				dark reddish gray	mod. dense				
16			23					5.5 14.0	
20									
			25/ 6"					4.9 7.8	
	rock	BASALT ROCK		gray brown	mod. hard rock with zones of soft rock & cinder				
24		Core Run from 21' to 25': Rec. = 97% RQD = 83%							
28		Core Run from 25' to 30.5': Rec. = 88% RQD = 69%							
		END OF TEST BORING							

PROJECT NAME: ATST AT HALEAKALA

PROJECT NO.: 05951-FM

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PLATE 6

LOG OF BORING NO. 5

EQUIPMENT USED: Mobile B-59

DATE DRILLED: March 11, 2005

ELEVATION: 9990.02

DEPTH OF BORING (FT.): 30

DEPTH OF GROUNDWATER: unknown

DEPTH (FT.)	SOIL CLASSIFICATION	DESCRIPTION	BLOWS/FOOT	COLOR	CONSISTENCY	MOISTURE	DRY DENSITY (PCF)	MOISTURE CONTENT (% OF DRY WT.)	PENETROMETER (TSF)
0	SP	SAND with gravel		dark brown	loose	moist	82.5	6.5	
	GP	GRAVEL with sand	8	dusky red					
				dark reddish brown				23.3	
4									
				black				20.8	
			25/ 3"		dense			18.4 13.7	
8	rock	BASALT ROCK Core Run from 8' to 10': Rec. = 83% RQD = 44%	50/ 3"	gray brown	mod. hard rock with zones of soft rock & cinder			1.8	
12		Core Run from 10' to 15': Rec. = 53% RQD = 30%							
16		Core Run from 15' to 20': Rec. = 35% RQD = 25%							
20		Core Run from 20' to 25': Rec. = 44% RQD = 34%							
24					soft rock or cinder zone				
					mod. hard rock				
28		Core Run from 25' to 30': Rec. = 30% RQD = 14%			soft rock or cinder zone				
					mod. hard rock				
		END OF TEST BORING							

PROJECT NAME: ATST AT HALEAKALA

PROJECT NO.: 05951-FM

ISLAND GEOTECHNICAL ENGINEERING, INC.

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PLATE 7

LOG OF BORING NO. 6

ELEVATION: 9983.11

EQUIPMENT USED: Mobile B-59

DEPTH OF BORING (FT.): 37.5

DATE DRILLED: March 14, 2005

DEPTH OF GROUNDWATER: 15 feet

DEPTH (FT.)	SOIL CLASSIFICATION	DESCRIPTION	BLOWS/FOOT	COLOR	CONSISTENCY	MOISTURE	DRY DENSITY (PCF)	MOISTURE CONTENT (% OF DRY WT.)	PENETROMETER (TSF)
0	SP-SM	SAND with silt and gravel	12	brown	mod. dense	mod. moist to moist	88.7	16.6 19.6 17.6	
	GP	GRAVEL with sand							
4			6	weak red to reddish brown	loose			27.0 21.8	
8			9			very moist		30.3 35.6	
12				reddish brown					
16			6			sat.		21.9	
20			7					23.9	
24			8	dusky red		very moist to sat.		20.9	
28									
	??	PROBE from 30' to 37.75'		??	loose	??			

PROJECT NAME: ATST AT HALEAKALA

PROJECT NO.: 05951-FM

ISLAND GEOTECHNICAL ENGINEERING, INC.

Geotechnical Consultants

PLATE 8

LOG OF BORING NO. 6

ELEVATION: 9983.11

EQUIPMENT USED: Mobile B-59

DEPTH OF BORING (FT.): 37.5

DATE DRILLED: March 14, 2005

DEPTH OF GROUNDWATER: 15 feet

DEPTH (FT.)	GRAPHIC SYMBOL	SOIL CLASSIFICATION	DESCRIPTION	SAMPLE	BLOWS/FOOT	COLOR	CONSISTENCY	MOISTURE	DRY DENSITY (PCF)	MOISTURE CONTENT (% OF DRY WT.)	PENETROMETER (TSF)
32					7						
					14						
					42		mod. dense				
					27						
36					22						
					33						
			END OF TEST BORING REFUSAL with PROBE: BASALT ROCK?		50/ 5"		hard				
40											
44											
48											
52											
56											
60											

PROJECT NAME: ATST AT HALEAKALA

PROJECT NO.: 05951-FM

ISLAND GEOTECHNICAL ENGINEERING, INC.

Geotechnical Consultants

PLATE 8

LOG OF BORING NO. 7

ELEVATION: see Plate 2

EQUIPMENT USED: Mobile B-59

DEPTH OF BORING (FT.): 15

DATE DRILLED: March 21, 2005

DEPTH OF GROUNDWATER: unknown

DEPTH (FT.)	GRAPHIC SYMBOL	SOIL CLASSIFICATION	DESCRIPTION	SAMPLE	BLOWS/FOOT	COLOR	CONSISTENCY	MOISTURE	DRY DENSITY (PCF)	MOISTURE CONTENT (% OF DRY WT.)	PENETROMETER (TSF)
0		GP	GRAVEL with sand and silt		52/ 9"	dark brown	very dense	moist			
		rock	BASALT ROCK Core Run from 1.25' to 5': Rec. = 71% RQD = 51% Core Run from 5' to 10': Rec. = 37% RQD = 27%		39/ 3"	gray brown	mod. hard rock with zones of soft rock & cinder				
		GP-SP	GRAVEL/SAND		14		mod. dense				
		rock	BASALT ROCK				mod. hard rock				
			END OF TEST BORING								

Depth scale: 0, 4, 8, 12, 16, 20, 24, 28

PROJECT NAME: ATST AT HALEAKALA

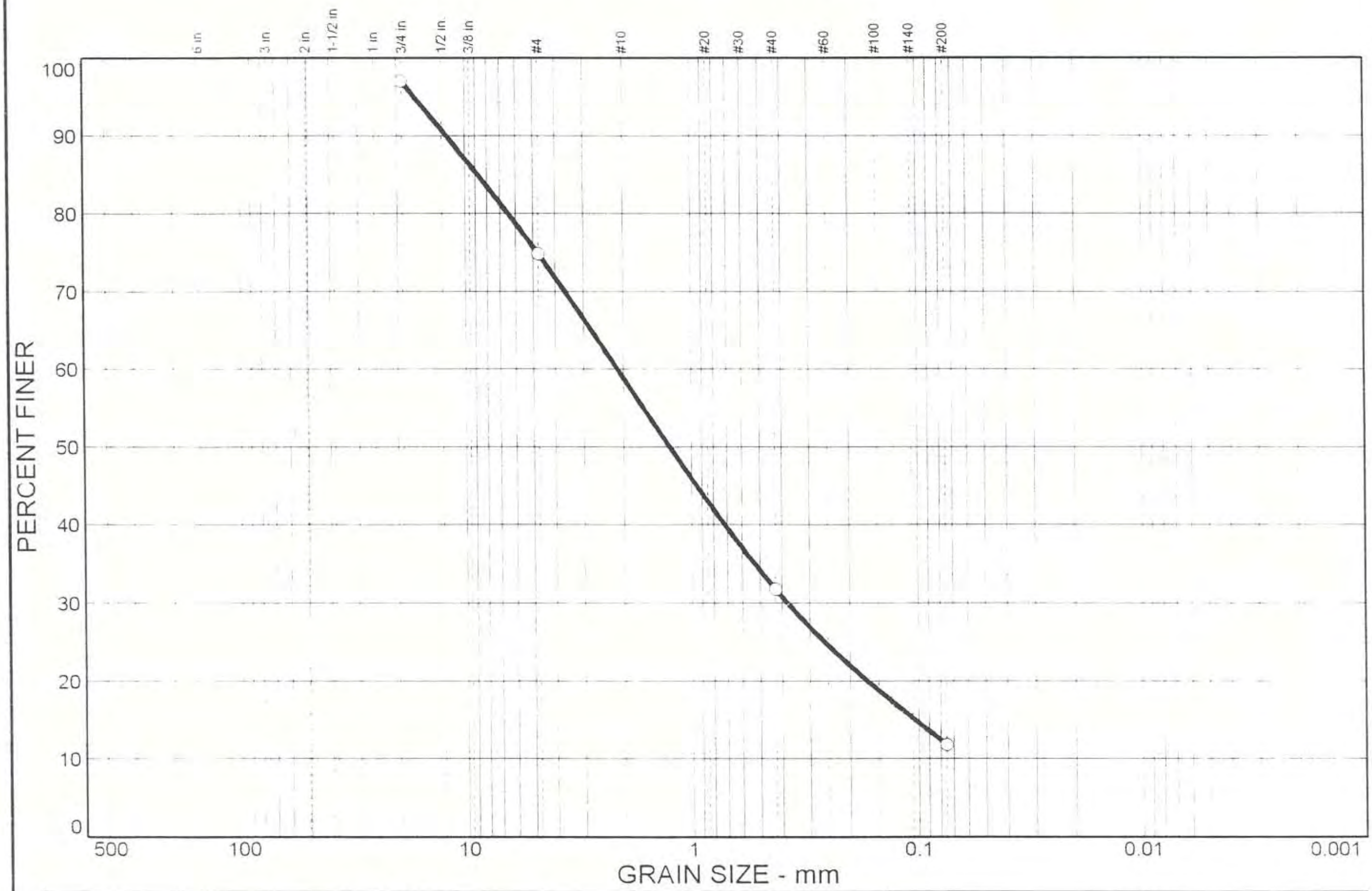
PROJECT NO.: 05951-FM

ISLAND GEOTECHNICAL ENGINEERING, INC.

Geotechnical Consultants

PLATE 9

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
		22.2	15.9	27.2	19.9	11.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	97.0		
#4	74.8		
#40	31.7		
#200	11.8		

* (no specification provided)

Soil Description

dark reddish brown poorly graded SAND with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.77 D_{60}= 2.12 D_{50}= 1.25
D_{30}= 0.378 D_{15}= 0.104 D_{10}=
C_u= C_c=

Classification

USCS= SP-SM AASHTO= A-1-b

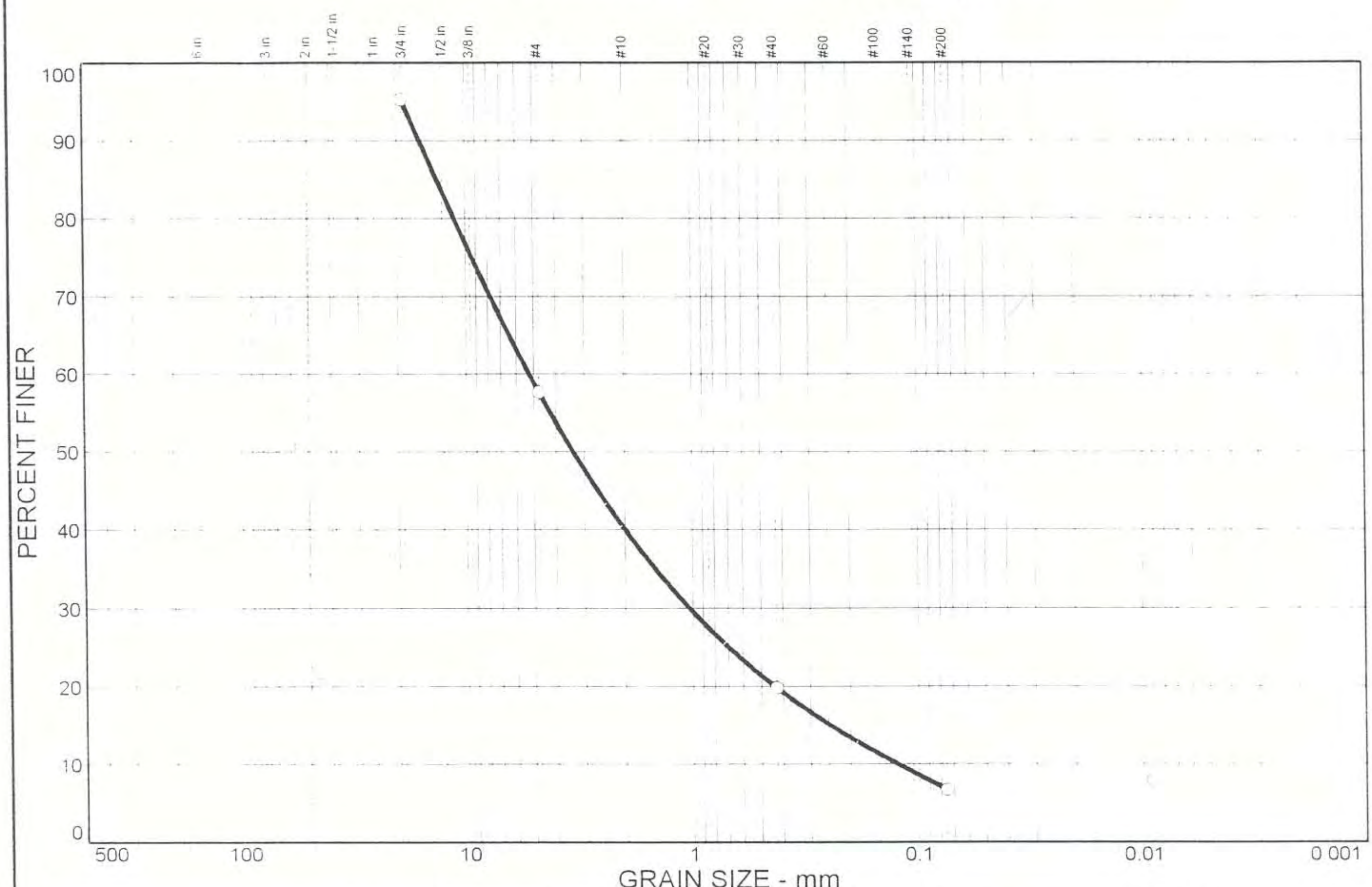
Remarks

Sample No.: 4 **Source of Sample:** Boring #3 **Date:** 4-6-05
Location: Boring #3 **Elev./Depth:** 5.5'

Island Geotechnical Engineering, Inc.

Client:
Project: ATST at Haleakala
Project No: 05951-FM **Plate** 10

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
		37.6	17.5	20.3	13.1	6.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	95.2		
#4	57.6		
#40	19.8		
#200	6.7		

* (no specification provided)

Soil Description

dark reddish brown well-graded SAND with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 13.4 D_{60}= 5.25 D_{50}= 3.37

D_{30}= 1.04 D_{15}= 0.245 D_{10}= 0.124

C_u= 42.50 C_c= 1.65

Classification

USCS= SW-SM AASHTO=

Remarks

Sample No.: 7 Source of Sample: Boring #3 Date: 4-6-05

Location: Boring #3 Elev./Depth: 10.5'

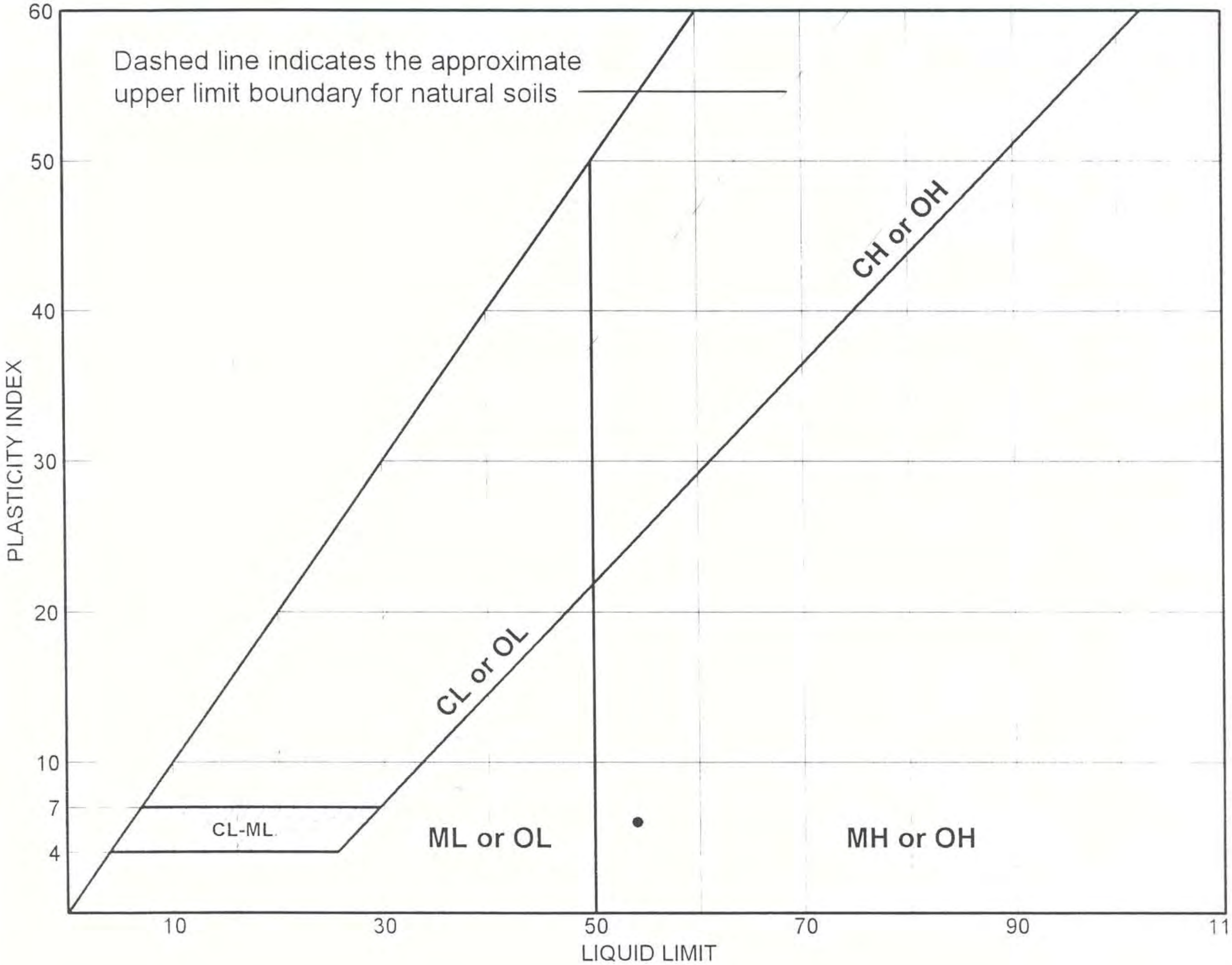
Island Geotechnical Engineering, Inc.

Client:

Project: ATST at Haleakala

Project No: 05951-FM Plate 11

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Boring #1	1	25'	31.3	48	54	6	MH

LIQUID AND PLASTIC LIMITS TEST REPORT

Island Geotechnical Engineering, Inc.

Client:

Project: ATST at Haleakala

Project No.: 05951-FM **Plate** 12

Unconfined Compressive Strength of Intact Rock Core Specimens

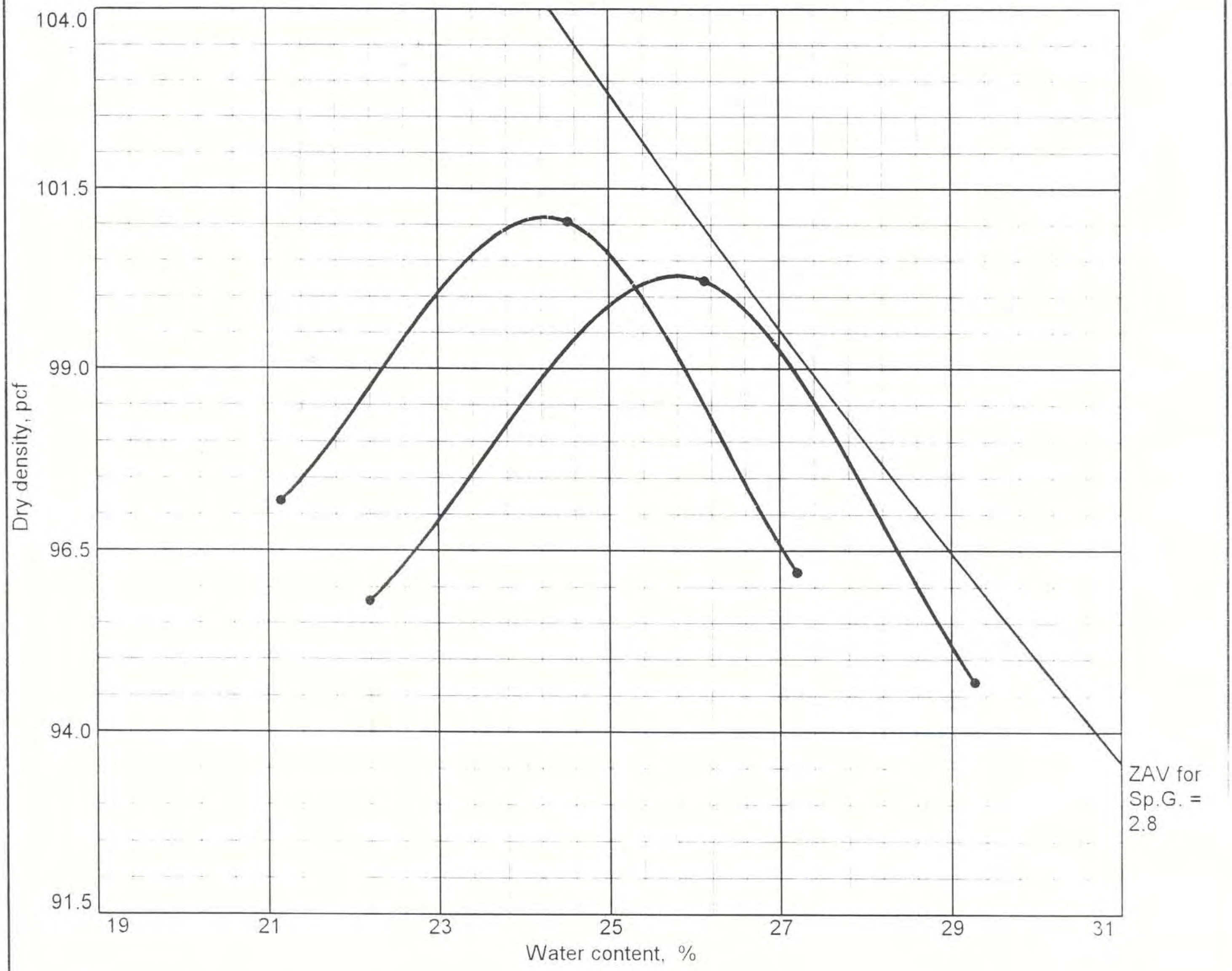
Boring	Sample Depth (feet)	Strength (PSF)
1	15 to 20	377,720
2	16 to 18	556,062
4	25 to 30	387,107
5	12 to 14	506,864

Notes:
A) All rock core specimens are 2.38 inch diameter.
B) Test performed in accordance with ASTM D 2938.

Project: ATST AT HALEAKALA   Project No.: 05951-FM

ISLAND GEOTECHNICAL ENGINEERING, INC.   PLATE 13

MAXIMUM DRY DENSITY TEST



Test specification: ASTM D 1557-91 Procedure C Modified
Oversize correction applied to each point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/4 in.	% < No.200
	USCS	AASHTO						
0-.75'	SM (Estimate)		28.5	3.04	nonplastic	nonplastic	14.6	

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 101 pcf	100 pcf	dark reddish brown silty SAND
Optimum moisture = 24 %	26 %	

Project No. 05951-FM
Project: ATST at Haleakala

• **Location:** Boring 2

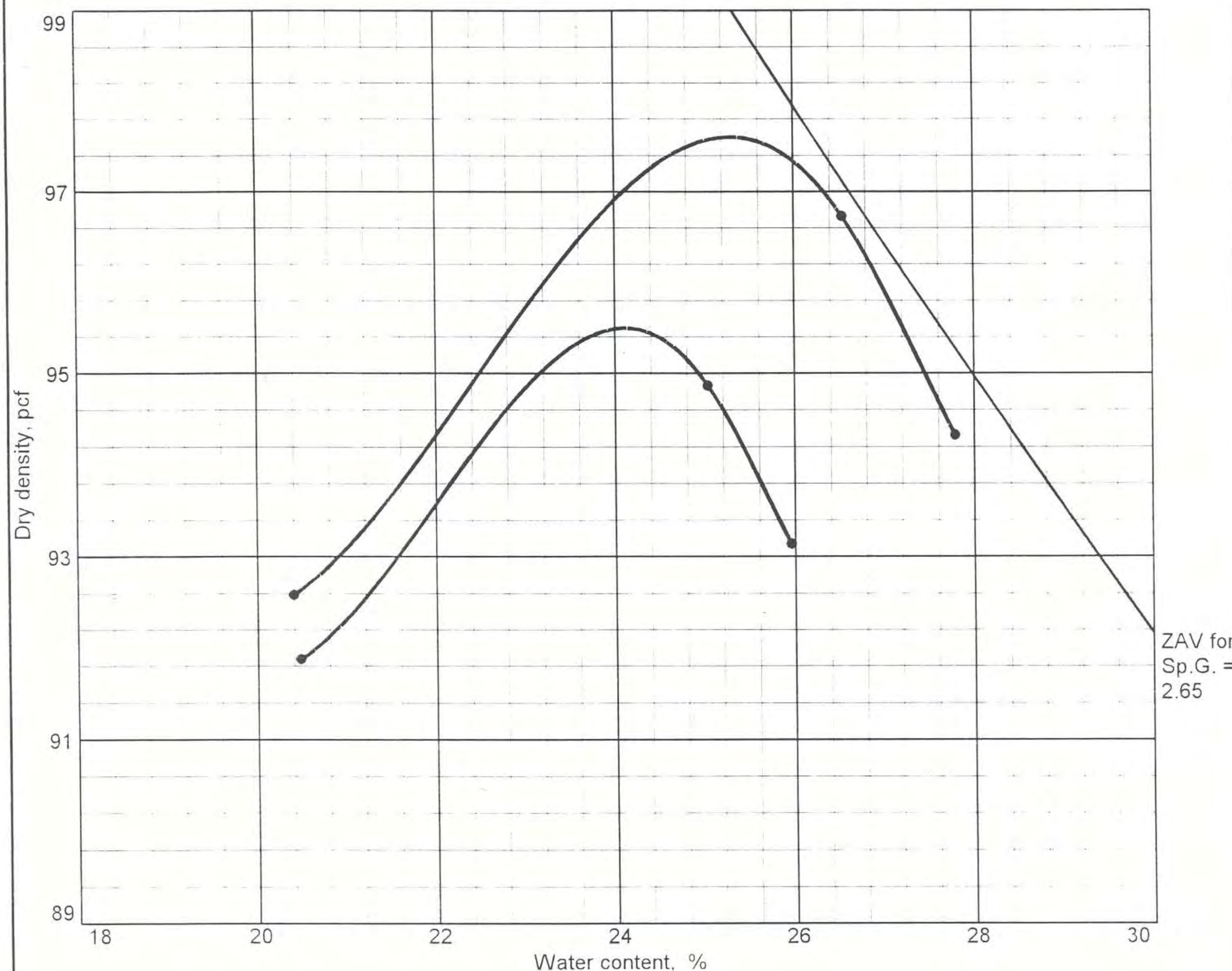
Remarks:
1) Date:April 2005
2) BSG = 1.70, Absorption = 15.1

MAXIMUM DRY DENSITY TEST

Island Geotechnical Engineering, Inc.

Plate 14

MAXIMUM DRY DENSITY TEST



Test specification: ASTM D 1557-91 Procedure C Modified
Oversize correction applied to each point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/4 in.	% < No.200
	USCS	AASHTO						
0 to 1'	SM (Estimate)		28.9	3.09	nonplastic	nonplastic	25.8	

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 95 pcf	98 pcf	dark reddish brown silty SAND with gravel
Optimum moisture = 24 %	25 %	

Project No. 05951-FM
Project: ATST at Haleakala

● **Location:** Boring #3

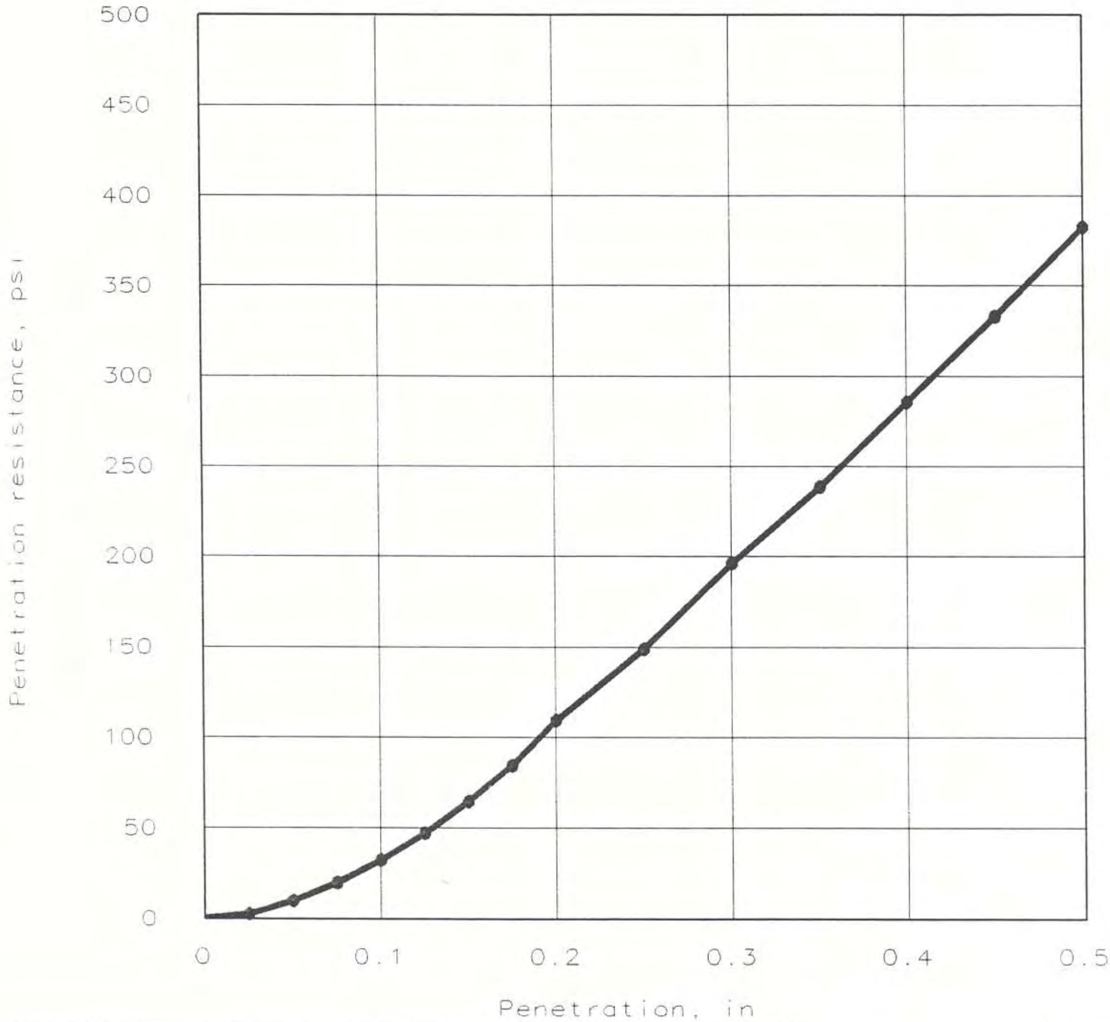
Remarks:
1) Date April 2005
2) BSG = 1.44, Absorption = 20.7

MAXIMUM DRY DENSITY TEST

Island Geotechnical Engineering, Inc.

Plate 15

BEARING RATIO TEST REPORT



	Molded			Soaked			CBR. (%)		Lin.	Pen.	Swell
	Dens	% max	moist	Dens.	% max	moist	0.1 in	0.2 in	Cor.	Sur.	%
1 ●	95.6	95.6	26.6%	95.6	95.6	28.5%	8.1	11.2	0.070	12.64	0.0
2 ▲											
3 ■											

MATERIAL DESCRIPTION	USCS	Max. dens.	Opt. w.c.	LL	PI
dark reddish brown silty SAND	SM (Est)	100	26	np	np

Project No: 05951-FM

Project: ATST at Haleakala

Location: Boring 2 at 0 to -.75' Exist

Date: April 2005

BEARING RATIO TEST REPORT

ISLAND GEOTECHNICAL ENGINEERING, INC.

Test Descr./Remarks:

ASTM D 1883-92

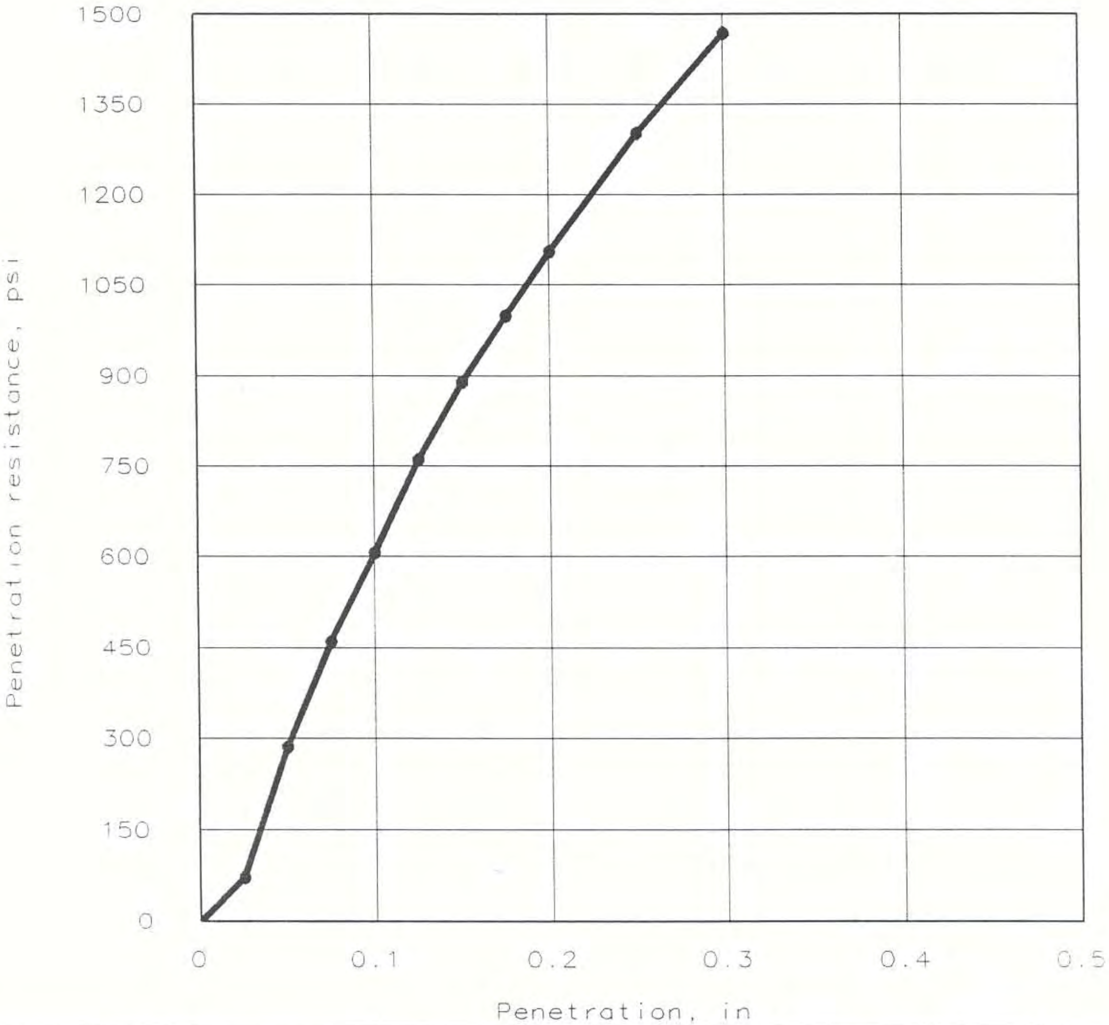
10 lb Hammer

Test performed on portion passing the 3/4" sieve.

14.6% was ret. 3/4"

Plate No: 16

BEARING RATIO TEST REPORT



	Molded			Soaked			CBR, (%)		Lin.	Pen.	Swell
	Dens.	% max	moist	Dens.	% max	moist	0.1 in	0.2 in	Cor.	Sur.	%
1 ●	95.4	97.3	26.8%	95.4	97.3	26.0%	60.6	73.7	0.00	12.58	0.0
2 ▲											
3 ■											

MATERIAL DESCRIPTION	USCS	Max. dens.	Opt. w.c.	LL	PI
dark reddish brown silty SAND with gravel	SM (Est)	98	25	np	np

Project No: 05951-FM
Project: ATST at Hakeakala
Location: Boring 3 at 0 to -1.0' Exist

Date: April 2005

BEARING RATIO TEST REPORT

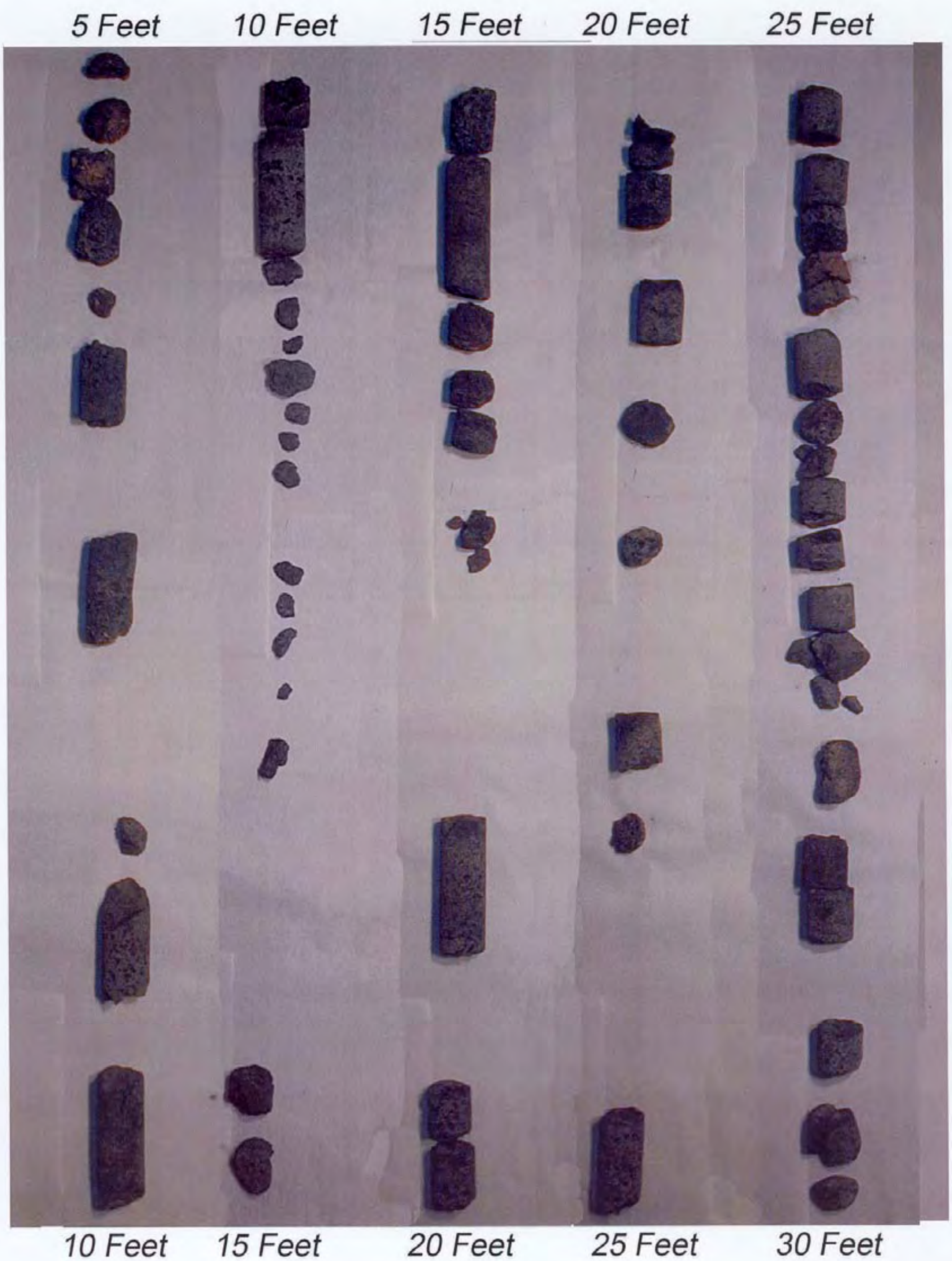
ISLAND GEOTECHNICAL ENGINEERING, INC.

Test Descr./Remarks:
ASTM 1883-92
10 lb. Hammer
Test performed
on portion passing
the 3/4" sieve.
25.8% was ret. 3/4"

Plate No. 17

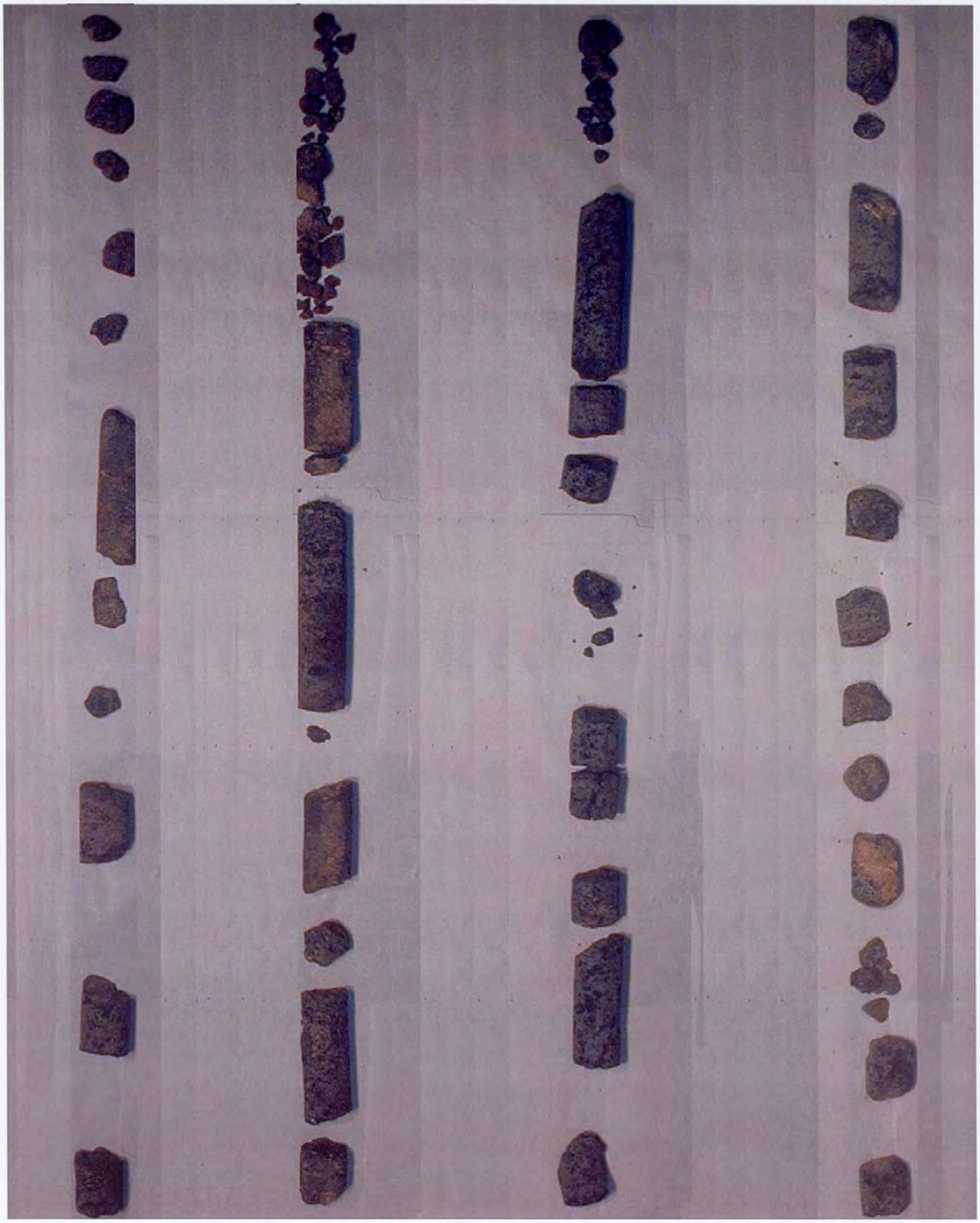
Miscellaneous Test Results

Test Description	Location	Depth	Results
Specific Gravity (ASTM D 854)	Boring 2	0 to 0.75'	3.04
Specific Gravity (ASTM D 854)	Boring 3	0 to 1.0'	3.09
Bulk Specific Gravity Of Coarse Aggregate (ASTM C 127)	Boring 2	0 to 0.75'	BSG = 1.70 Absorption = 15.1%
Bulk Specific Gravity Of Coarse Aggregate (ASTM C 127)	Boring 3	0 to 1.0'	BSG = 1.44 Absorption = 20.7%
pH of Soil (AASHTO T 289)	Boring 1	0 to 0.5'	6.86
pH of Soil (AASHTO T 289	Boring 2	0 to 0.75'	6.92
pH of Soil (AASHTO T 289	Boring 3	0 to 1.0'	6.98



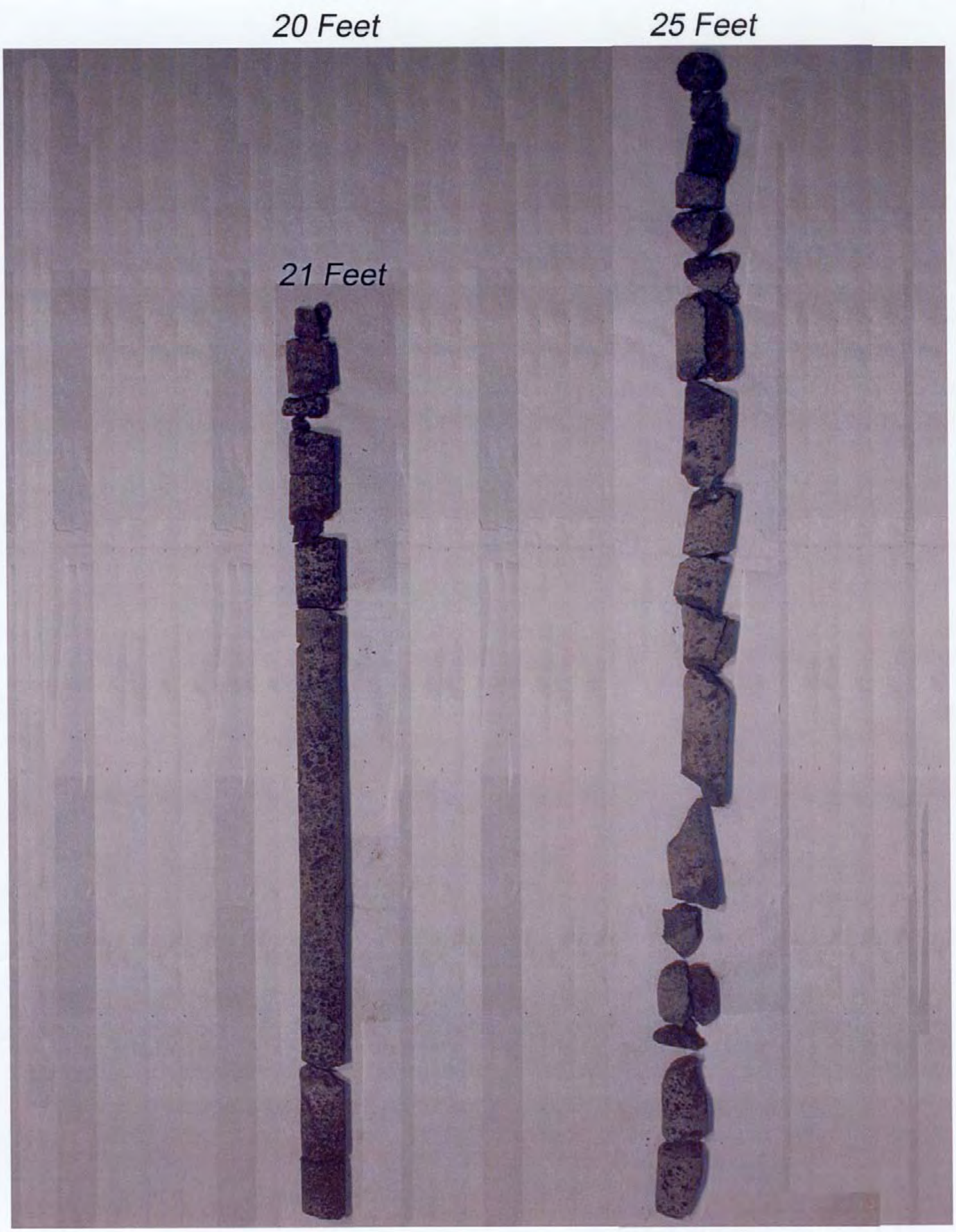
ATST at Haleakala **Boring 1** **Plate 19**

10 Feet | 15 Feet | 20 Feet | 25 Feet

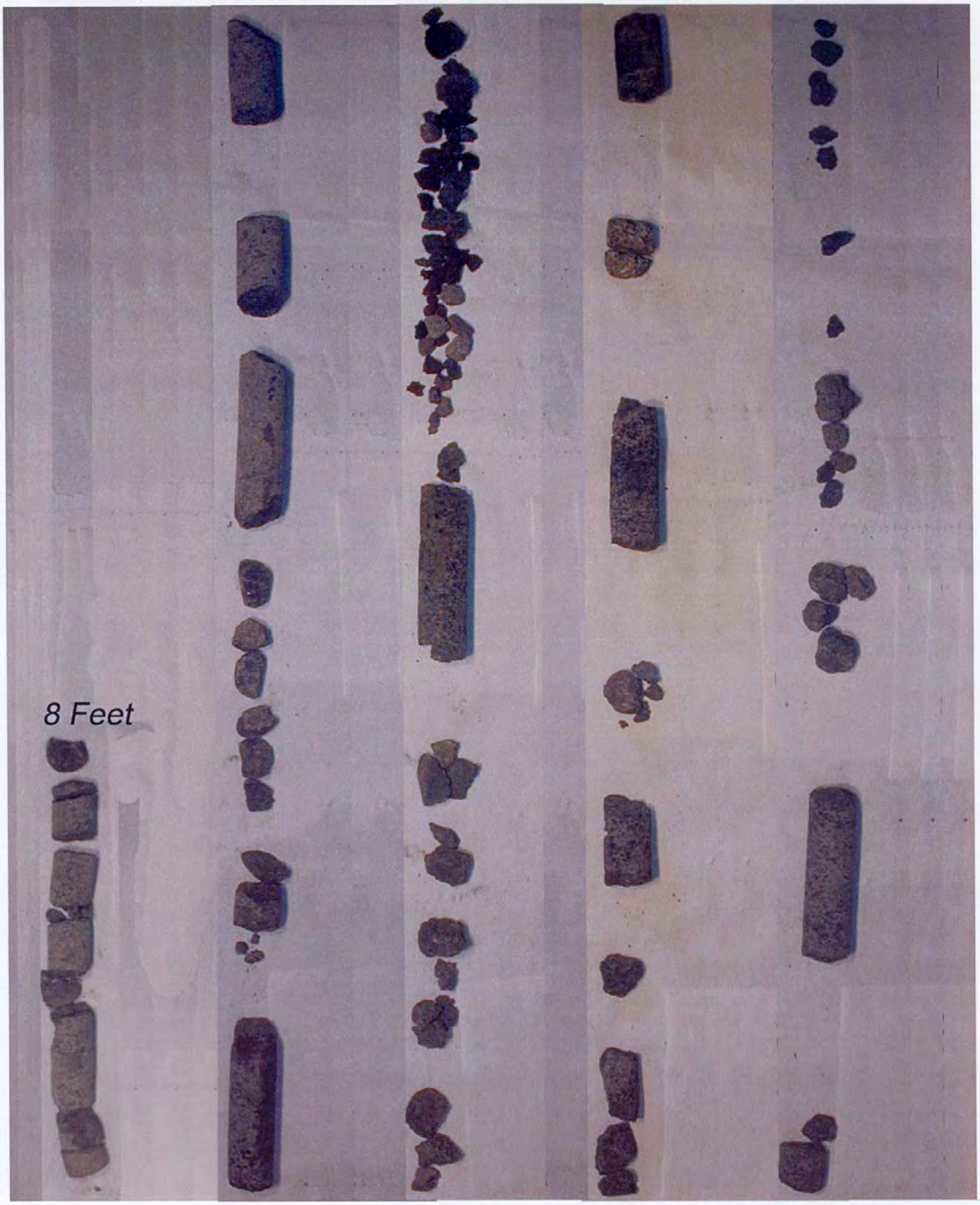


15 Feet | 20 Feet | 25 Feet | 30 Feet

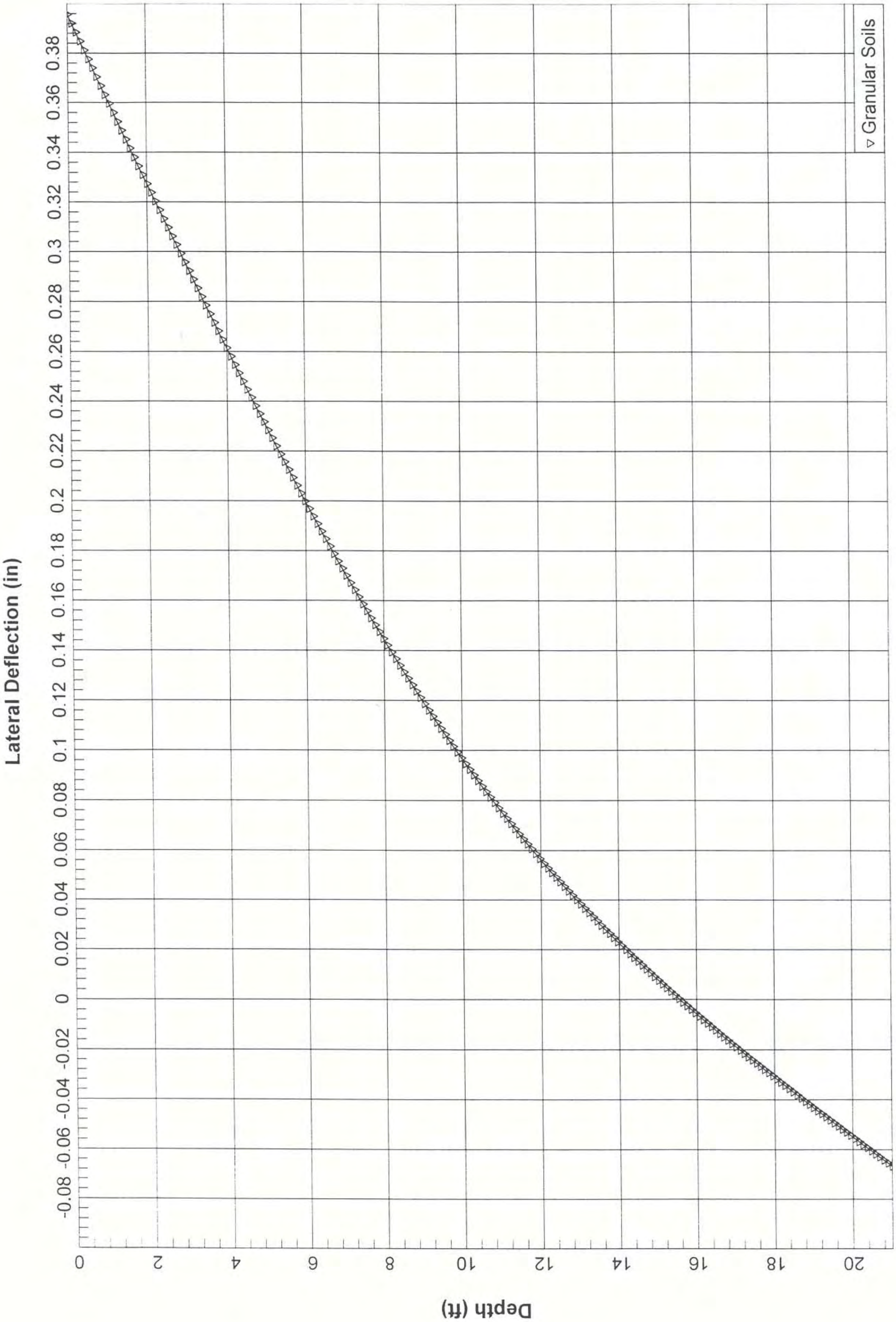
ATST at Haleakala **Boring 2** **Plate 20**



ATST at Haleakala **Boring** 4 **Plate** 21

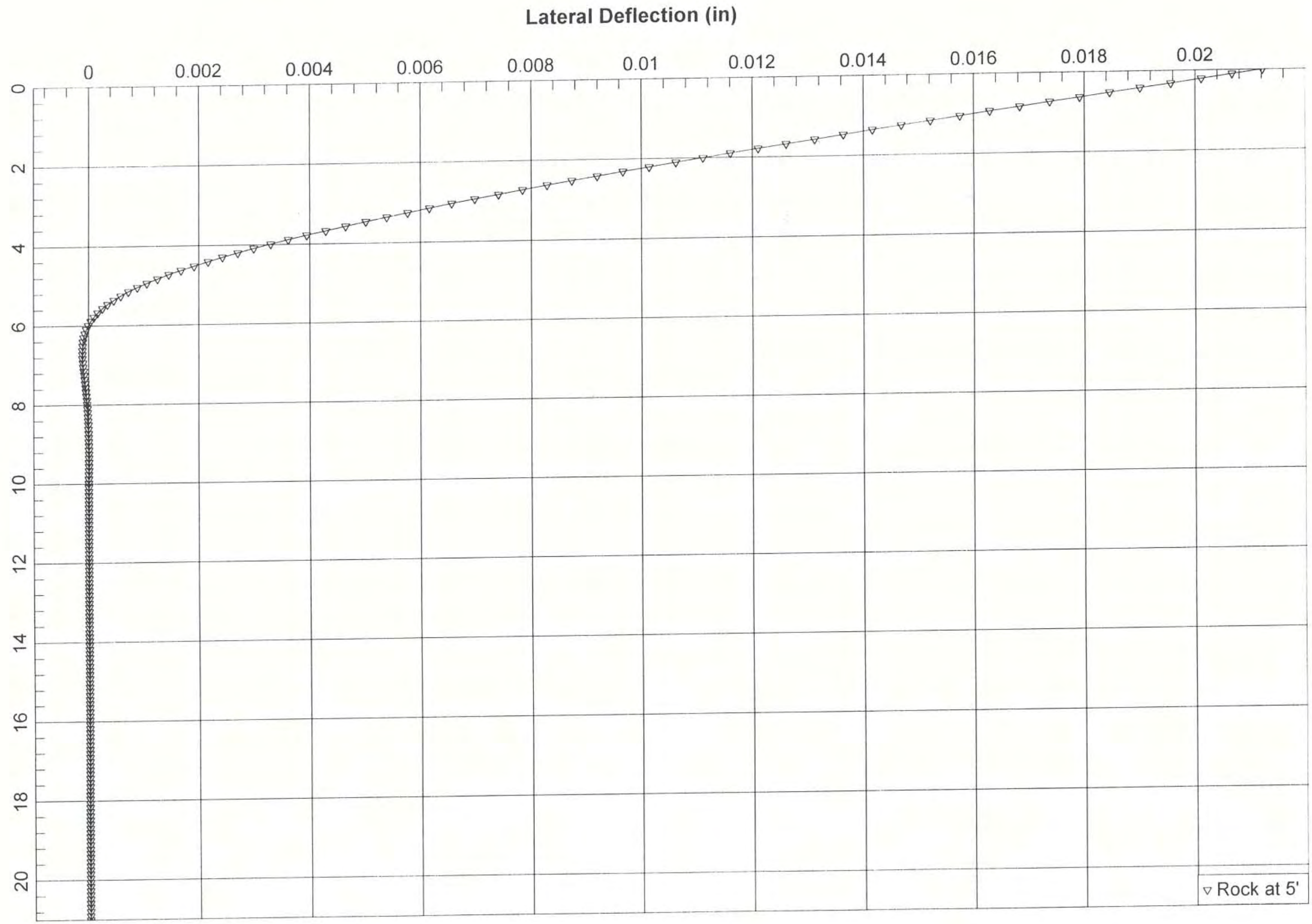


ATST at Haleakala **Boring** 5 **Plate** **22**



ATST at Haleakala: 36 inch diameter x 21 feet long drilled shaft in granular soils

Plate 23



ATST at Haleakala: 36 inch diameter x 21 feet long drilled shaft with rock at 5 feet below grade

Plate 24

ATST AT HALEAKALA 84' DIAMETER MAT

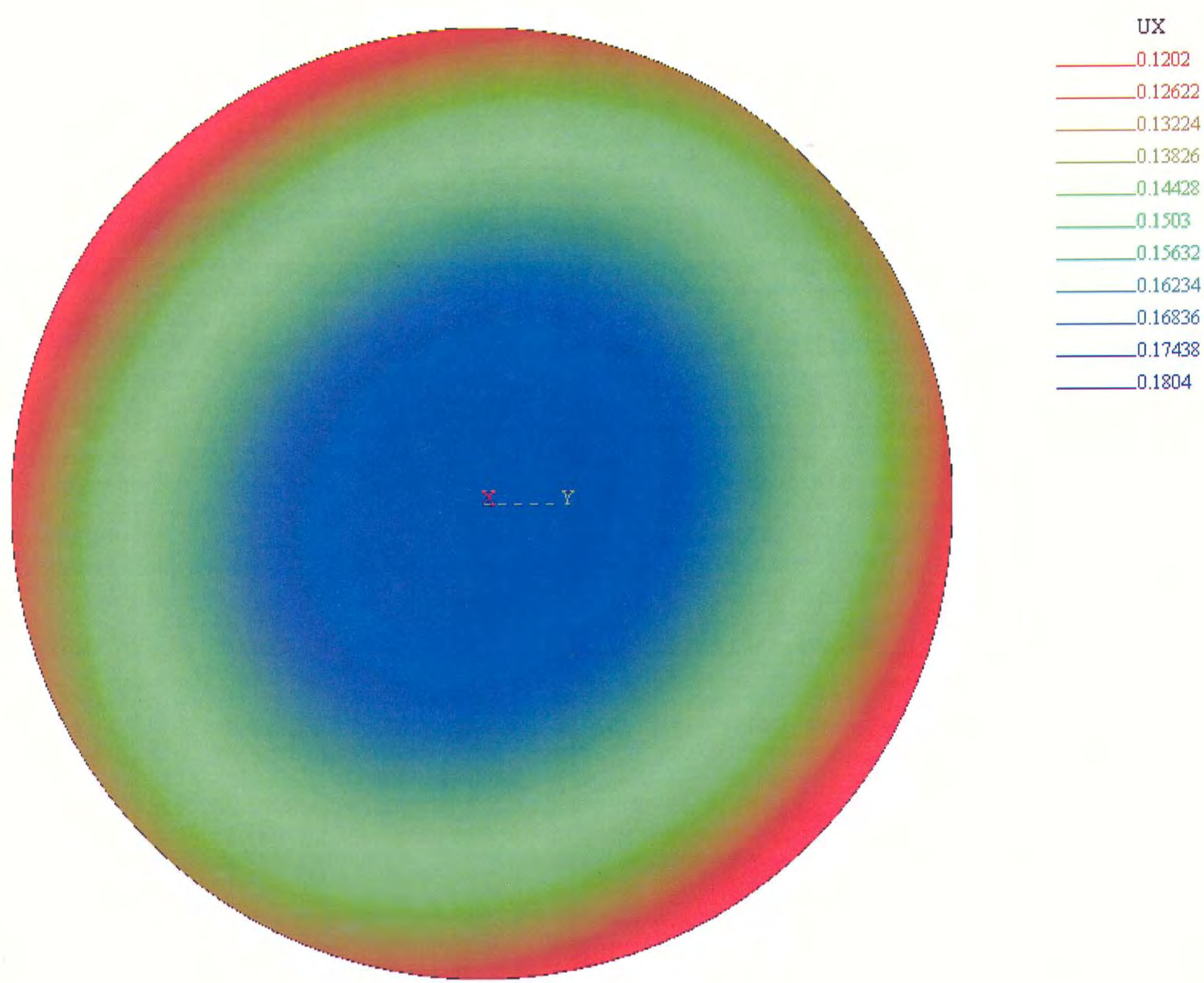


Plate 25

GEOPHYSICAL ENGINEERING INVESTIGATION
SUBSURFACE SEISMIC VELOCITY PROFILE
ATST AT HALEAKALA VOLCANO OBSERVATORY SITE
MAUI, HAWAII

Prepared for:

Island Geotechnical Engineering, Inc.
222-A Kawaipuna Place
Wailuku, Maui, Hawaii 96793

Attn: Mr. Charles Biegel
Ofc: 808/243-9355
Fax: 808/244-8997

Olson Engineering Job No. 1706
May 4, 2005

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

This report presents the results of Spectral Analysis of Surface waves (SASW) geophysical surveys performed along two lines at the site of the proposed ATST Observatory on Haleakala Volcano, Maui, Hawaii. The field investigation was performed by Mr. Larry D. Olson, Principal Engineer of Olson Engineering, Inc., on March 7, 2005 for Island Geotechnical Engineering, Inc (ISLAND). Field assistance and boring logs were provided by Mr. Charles Biegel of ISLAND. The main objective of the investigation was to obtain the shear wave seismic velocity profiles of the soil and rock at the proposed ATST site and provide recommendations for other related dynamic properties of the soil and rock.

SASW Field Investigation. The SASW field investigation was conducted along two lines from east to west (Site 1 E-W) and north to sourth (Site 2 N-S) on the site. Sources of energy for SASW tests ranged from a small 4 lb hammer and a 9.7 lb sledgehammer for shorter geophone receiver spacings to dropping a large boulder from a Caterpillar 226B Loader bucket for the longest spacings. Receivers used in this survey consisted of a pair of 4.5 Hz geophones for the shorter spacings, and a pair of 1 Hz geophones for the longer spacings.

SASW Velocity Profile and Seismic Moduli Results. The SASW and seismic moduli results are tabulated in Tables I and II below for the E-W and N-S sites, respectively, for the SASW layer modeling results for the soil and volcanic cinder/rock materials (see Island Geotechnical Report for subsurface findings). The experimental velocity dispersion curve and the theoretical model dispersion curves are plotted in Figs. 7 and 8 for the E-W and N-S sites, respectively. The dispersion curve plot presents depth versus surface wave velocity (Vs). The E-W site was found to have somewhat slower velocities and corresponding lower moduli than the N-S site (seismic shear and Young's Moduli values are plotted versus theoretical SASW layer model depths in Figs. 9 and 10). Dynamic foundation design should consider the SASW and boring results in dynamic and seismic analyses for the proposed observatory. Damping ratios were estimated based on the results of the boring logs for the soils and basalt rock.

Table I - Forward Model SASW Profile and Seismic Moduli for Site 1 E-W									
Layer No.	Layer Thickness (ft)	Poisson's Ratio	Unit Weight (lb/ft^3)	Mass Density (lb/ft^3/g)	S-Wave Velocity Vs (fps)	P- Wave Velocity Vp (fps)	Shear Modulus (G) x 10^6 (psf)	Young's Modulus (E) x 10^6 (psf)	Damping Ratio Suggested Values
1	1	0.35	100	3.11	520	1083	0.84	2.27	0.04
2	1	0.35	100	3.11	670	1395	1.39	3.76	0.04
3	0.5	0.35	110	3.42	900	1874	2.77	7.47	0.03
4	3	0.35	100	3.11	480	999	0.72	1.93	0.04
5	3	0.35	110	3.42	550	1145	1.03	2.79	0.04
6	10	0.35	150	4.66	700	1457	2.28	6.16	0.04
7	10	0.35	150	4.66	800	1665	2.98	8.05	0.03
8	10	0.33	150	4.66	850	1688	3.37	8.95	0.03

Table II - Forward Model SASW Profile and Seismic Moduli for Site 2 N-S									
Layer No.	Layer Thickness (ft)	Poisson's Ratio	Unit Weight (lb/ft^3)	Mass Density (lb/ft^3/g)	S-Wave Velocity Vs (fps)	P- Wave Velocity Vp (fps)	Shear Modulus (G) x 10^6 (psf)	Young's Modulus (E) x 10^6 (psf)	Damping Ratio Suggested Values
1	0.18	0.35	100	3.11	370	641	0.43	1.15	0.04
2	1.6	0.35	100	3.11	470	814	0.69	1.85	0.04
3	2.7	0.35	100	3.11	480	999	0.72	1.93	0.04
4	12.9	0.3	130	4.04	1500	2806	9.08	23.62	0.03
5	1.4	0.25	120	3.73	420	874	0.66	1.77	0.04
6	1	0.3	125	3.88	800	1497	2.48	6.46	0.04
7	3	0.3	125	3.88	1000	1871	3.88	10.09	0.03
8	18	0.25	150	4.66	1400	2425	9.13	22.83	0.03
9	20	0.25	150	4.66	3000	5196	41.93	104.81	0.02

2.0 SPECTRAL ANALYSIS OF SURFACE WAVES (SASW) METHOD

A detailed outline of the SASW evaluation method along with the theoretical background used in the geophysical engineering investigation is given below. The method was applied to generate a single SASW profile for each of the Site 1 East-West and Site 2 North-South survey lines. The survey line locations are sketched in the ISLAND site boring plan in their Geotechnical Report for this project..

2.1 Elastic Stress Wave Relationships

The following equations from elastic theory illustrate the relationships between shear moduli (G), mass density (ρ, total unit weight divided by gravitational acceleration), shear wave velocity (Vs), Young's modulus of elasticity (E), Poisson's ratio (ν), compressional wave velocity (Vp), and constrained modulus (M):

Direct P- or S- Wave Velocity: $Vp = D / tp$ or $Vs = D/ts$ (1)

Shear Modulus: $G = \rho\ Vs^{**}2$ (2)

Young's Modulus: $E = 2\ (1+\nu)\ \rho\ Vs^{**}2 = \rho\ Vp^{**}2\ [(1+\nu)(1-2\nu)/(1-\nu)]$ (3)

Constrained Modulus: $M = \rho\ Vp^{**}2$ (4)

Poisson's Ratio: $\nu = [0.5\ (Vp/Vs)^{**}2 - 1]/[(Vp/Vs)^{**}2 - 1]$ (5)

P- and S-wave Velocities: $Vp = Vs\ [2(1-\nu)/(1-2\nu)]^{**}0.5$ (6)

where D = Distance, tp = P-wave travel time and ts = S-wave travel time.

Values of these parameters determined from seismic measurements (SASW measurements) represent the material behavior at small shearing strains, i.e. strains less than 0.001 percent. Thus, moduli calculated from compression, shear or surface wave velocities represent the maximum moduli of materials because of their low strain levels. It should be noted that the measurement of the surface wave velocity, also called Rayleigh wave velocity, is actually performed in the SASW test. Surface wave velocity (V_R) in a homogeneous half-space is related to shear wave velocity by:

$$V_R \sim 0.9\ Vs \quad (7)$$

(The exact equation is given in numerous geophysical textbooks)

Using the shear wave velocity data, the shear modulus (G), constrained modulus (M), Youngs Modulus (E), and Poisson's ratio (ν) for a given depth can be calculated by using the above equations in conjunction with estimated densities for the soil and rock materials encountered in the Island borings.

2.2 Spectral Analysis of Surface Waves (SASW) Method

The SASW method is based upon measuring surface waves propagating in layered elastic media and is illustrated in Fig. 1. The ratio of surface wave velocity to shear wave velocity varies with Poisson's ratio. However, reasonable estimates of Poisson's ratio and mass density for soils and other materials can normally be made with only a small effect on the accuracy of the determined shear wave velocity profile. Knowledge of the shear wave velocity combined with reasonable estimates of mass density of the material layers allows calculation of shear moduli for low-strain amplitudes.

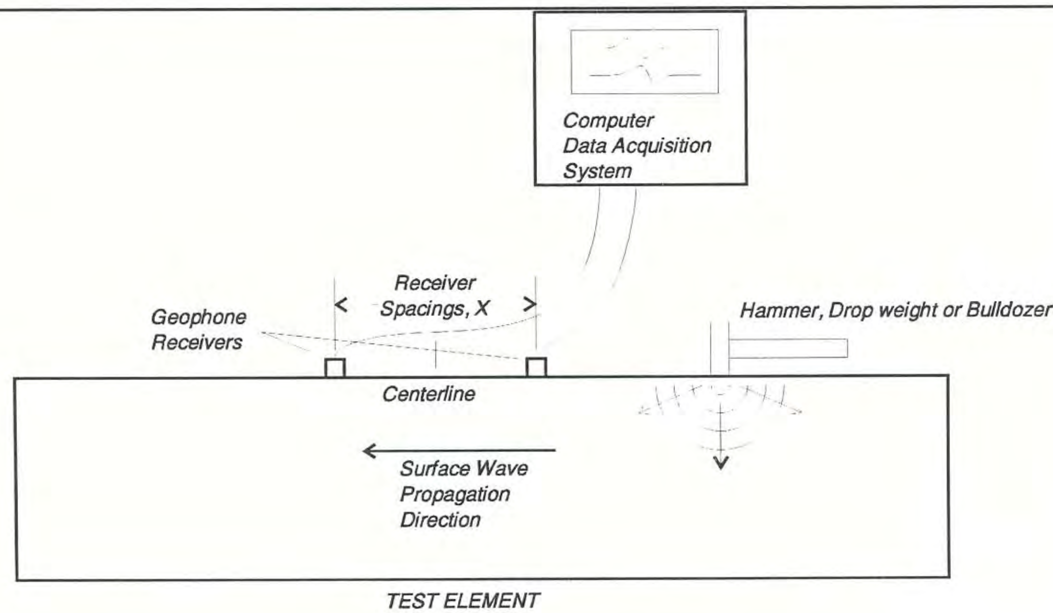


Fig. 1 - Field Arrangement of Source, Receivers and Recording Equipment for Typical SASW Testing

Surface wave (also termed Rayleigh; R-wave) velocity varies with frequency in a layered system with differing velocities. This variation in velocity with frequency is termed dispersion. A plot of surface wave velocity versus wavelength is called a dispersion curve.

The SASW tests and analyses are generally performed in three phases: (1) collection of data in situ; (2) construction of an experimental dispersion curve from the field data; and (3) inversion (forward modeling) of the theoretical dispersion curve, if desired, to match theoretical and experimental curves so that a shear wave velocity versus depth profile can be constructed. Wavelength (λ), frequency (f), and wave velocity (Vr), are related as follows:

$$Vr = f^*\lambda \tag{8}$$

Surface wave dispersion can be expressed in terms of a plot of surface wave velocity versus wavelength. This type of plot is used in this report.

<u>2.2.1 Collection of SASW Field Data.</u> The SASW field tests for this investigation consisted of vertically impacting the test surface to generate surface wave energy at various frequencies that were transmitted through the test material. Hammer blows from 4 lb and 9.7 lb sledgehammers and a large rock dropped by a Caterpillar 226B Loader bucket were used to generate the energy, with smaller hammers used to produce shorter wavelength, higher frequency energy for close receiver spacings (2-16 ft) and the large boulder dropped from the loader was used at the longer spacings of 32 and 64 feet. The approximately 600 lb boulder dropped from the loader bucket was used to generate longer wavelengths and sample deeper into the subsurface.

Two vertical geophone receivers were evenly spaced on the surface in a line with the impact point as illustrated in Fig. 1. Photographs of the equipment used in the project are presented below in Figs. 2-5. A pair of 4.5 Hz geophones were used for spacings of 2 to 8 feet, while a pair of 1-Hz geophones were used for all longer spacings. The geophones were used to monitor the passage of the surface wave energy as illustrated on Fig. 1. To obtain increasingly deeper data, several tests with different receiver spacings were performed by doubling the distance between the receivers about an imaginary centerline between the receivers. The impacts were applied typically at each end of a given receiver spacing, with the distance from the impact point to the closest receiver equal to 1/2 of that of the receiver-to-receiver spacing.

An Olson Instruments Freedom Data PC with a data acquisition card was used to digitize the analog receiver outputs and record the signals for spectral (frequency) analyses. The phase information of the transfer function (cross power spectrum) between the two receivers for each frequency was the key spectral measurement. All field data was recorded on the computer hard drive for later analysis.

Fig. 3 - Freedom Data PC for SASW Surveys

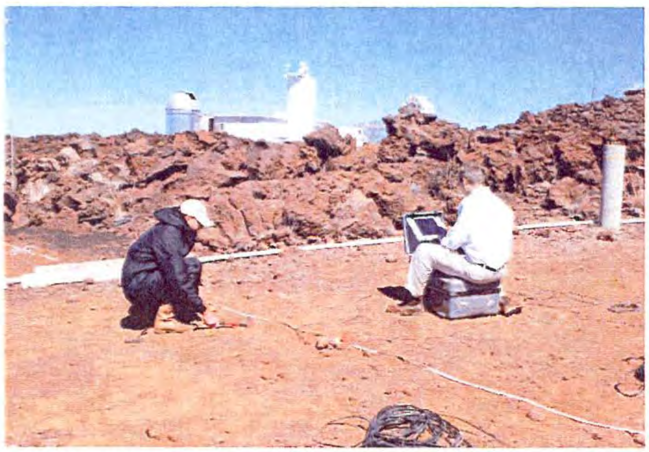


Fig. 2 - SASW on Site 1 E-W with 4 lb Hammer and 4.5 Hz Geophone Pair (orange)

Fig. 4 - Dropping Rock for SASW Survey on Site 2 N-S with 1 Hz Geophone Pair (silver)

Fig. 5 - Caterpillar 226B Loader dropping ~600 lb Boulder for SASW tests

2.2.2 SASW Experimental Dispersion Curve Processing. An example SASW record showing one of the two geophone receiver responses in the time domain and the averaged calculations of coherence (values close to 1 indicate good quality data) and phase versus frequency are shown in the top, middle and bottom trace plots in Fig. 6 below. A total of -360 degrees of phase difference represents one cycle for one wavelength (receiver spacing of 8 ft in this case for Fig. 6) and shows the difference in phase between the surface wave arrival at the second receiver away from the ground impact to the receiver closest to the impact. Examination of Fig. 6 shows that -360 degrees of phase occurred at about 47 Hz, so applying Eq. (8), the surface wave velocity for an 8 ft wavelength is about 384 ft/s. The experimental dispersion curve is developed from the field phase data from a given site by knowing the phase (ϕ) at a given frequency (f) and then calculating the travel time (t) between receivers of that frequency/wavelength by:

$$t = \phi / 360*f \qquad (9)$$

Surface wave velocity (Vr) is obtained by dividing the receiver spacing (X) by the travel time at a frequency:

$$Vr = X / t \qquad (10)$$

The wavelength (λ) is related to the surface wave velocity and frequency as shown in equation 8. By repeating the above procedure for any given frequency, the surface wave velocity corresponding to a given wavelength is evaluated, and the dispersion curve is determined. The phase data was viewed on the PC data acquisition system in the field to ensure that acceptable data was being collected. The phase data was then returned to our office for processing. The phase of the cross power spectrum (transfer function) between the two receivers and the coherence function were used in creating the dispersion curves discussed in Section 3.

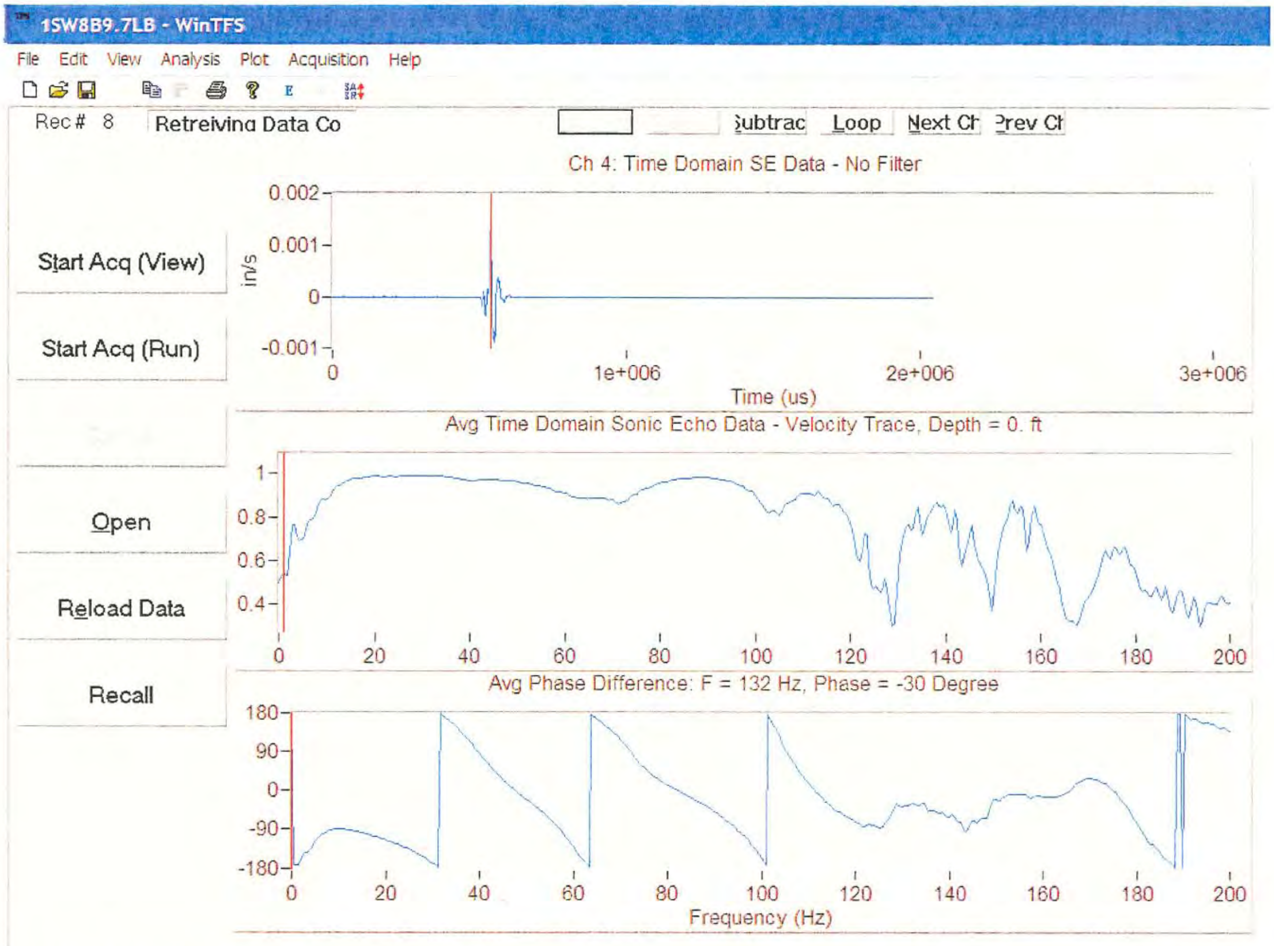


Fig. 6 - Example SASW Geophone Response (top trace), Coherence (middle trace) and Phase (bottom trace) Plots for 8 ft Receiver Spacing and West Traveling Wave at Site 1 E-W

After masking of all forward and reverse phase record pairs from each receiver spacing, an experimental field dispersion curve is developed that is the plot of surface wave velocity versus wavelength. We used a University of Texas at Austin program called WINSASW to mask the phase data and generate the experimental field dispersion curve on IBM compatible PC's.

2.2.3 SASW Theoretical Modeling Processing. To determine the shear wave velocity profile from the "apparent" velocities of the dispersion curve, analytical modeling is necessary. This analytical process was performed for the site surveyed during this investigation. The analytical modeling used herein is a forward modeling process that is iterative and involves assuming a shear wave velocity profile and constructing a theoretical dispersion curve. The experimental (field) and theoretical curves are compared, and the assumed theoretical shear wave velocity profile is adjusted until the two curves match. The interactive computer algorithm for both 2-dimensional and 3-dimensional analyses have been developed by Dr. Jose Roesset and his colleagues at the University of Texas at Austin to compute a theoretical dispersion curve based upon an assumed shear wave velocity and layer thickness profile. These algorithms have been in use for some time and have produced reasonable accuracy when comparing velocities determined with the SASW and seismic crosshole or downhole methods. The results of the theoretical modeling are discussed below.

2.2.4 SASW Method References.

1. M.F. Aouad, "Evaluation of Flexible Pavements and Subgrades Using the Spectral Analysis of Surface Waves Method", Dissertation Submitted in Partial Fulfillment of the Doctor of Philosophy Degree, The University of Texas at Austin, 1993.
2. S. Nazarian and K.H. Stokoe, II, In Situ Determination of Elastic Moduli of Pavement Systems by SASW Method (Practical Aspects), Report 368-1F, Center For Transportation Research, The University of Texas at Austin, 1985.
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4. Roesset, J.M., D.W. Chang and K.H. Stokoe, "Comparison of 2-D and 3-D Models for Analysis of Surface Waves Tests", Proceedings, Fifth International Conference on Soil Dynamics and Earthquake Engineering, Karlsruhe, Germany, 1991, pp. 111-126

5. Andrus, R.D., K.H. Stokoe and J.A. Bay, "In Situ Vs of Gravelly Soils Which Liquified", Proceedings, Tenth World Conference on Earthquake Engineering, Madrid, Spain, July 1992.

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3.0 SASW RESULTS

The results of the SASW experimentally and theoretical modeled surface wave velocity dispersion curves are plotted for Site 1 E-W and Site 2 N-S in Figs. 7 and 8, respectively. These plots show surface wave velocity in feet per second (ft/s) on the top horizontal axis versus wavelength (feet) on the vertical axis. Note that both the experimental (unconnected symbols) and theoretical modeling (symbols connected by a line) curves for both sites are very similar, indicating the relatively close match between the models and the field conditions.

The shear wave velocity layer profile comes from the surface wave velocity based on forward modeling to match the experimental dispersion curves (Figs. 7 and 8). The results of the modeling in terms of shear and compression wave velocities and layer thicknesses are plotted graphically in Figs. 9 and 10 for Site 1 E-W and Site 2 N-S, respectively. The shear wave velocity layer profiles, Poisson's ratios and corresponding seismic moduli and damping ratios are presented for Site 1 E-W and Site 2 N-S in Tables I and II, respectively.

Comparisons of the velocity dispersion curves and theoretical shear wave velocity profiles presented in Figs. 7-10 indicates that Site 2 is significantly faster in velocity than Site 1. Also, there are layers of high velocity materials surrounded by slower velocity materials at shallow depths, although velocity does increase with longer wavelenghths that penetrated into the volcano rock. This variation is likely due to a local velocity variation in the soil/rock of the volcanically deposited materials. Such variation was also encountered in the ISLAND geotechnical borings which were provided to us.

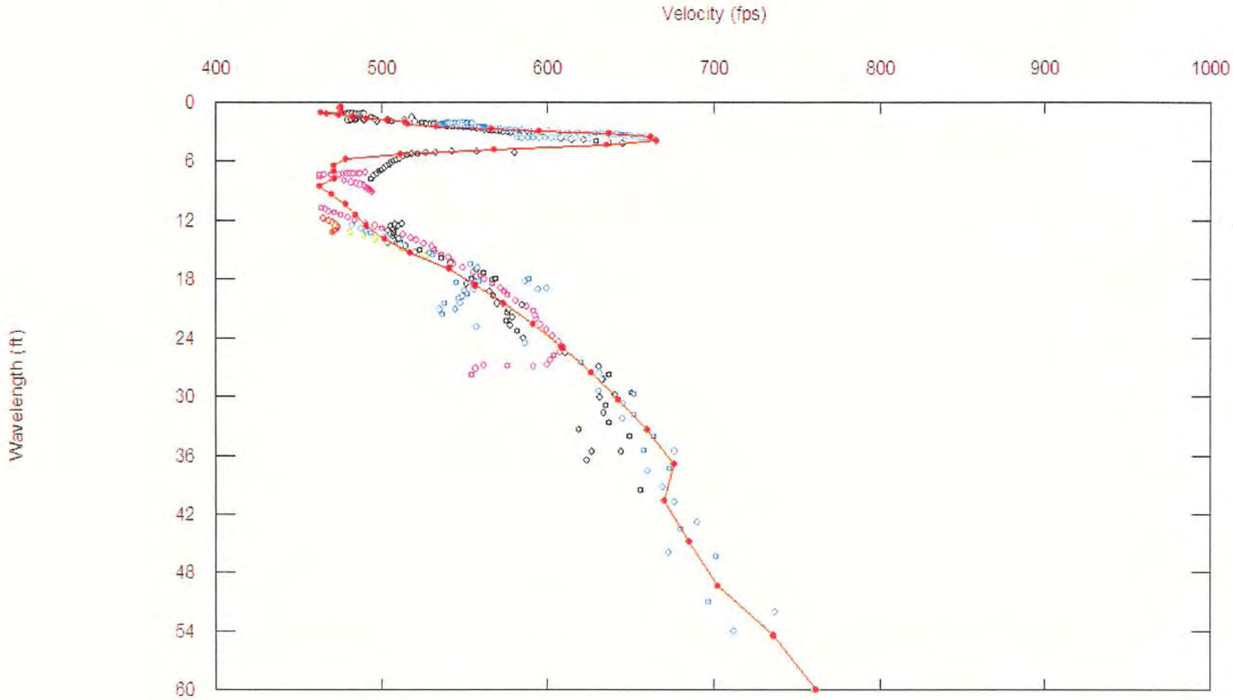

Fig. 7 - Site 1 E-W SASW Experimental (symbols) and Theoretical (symbols with line) Velocity Dispersion Curve Results

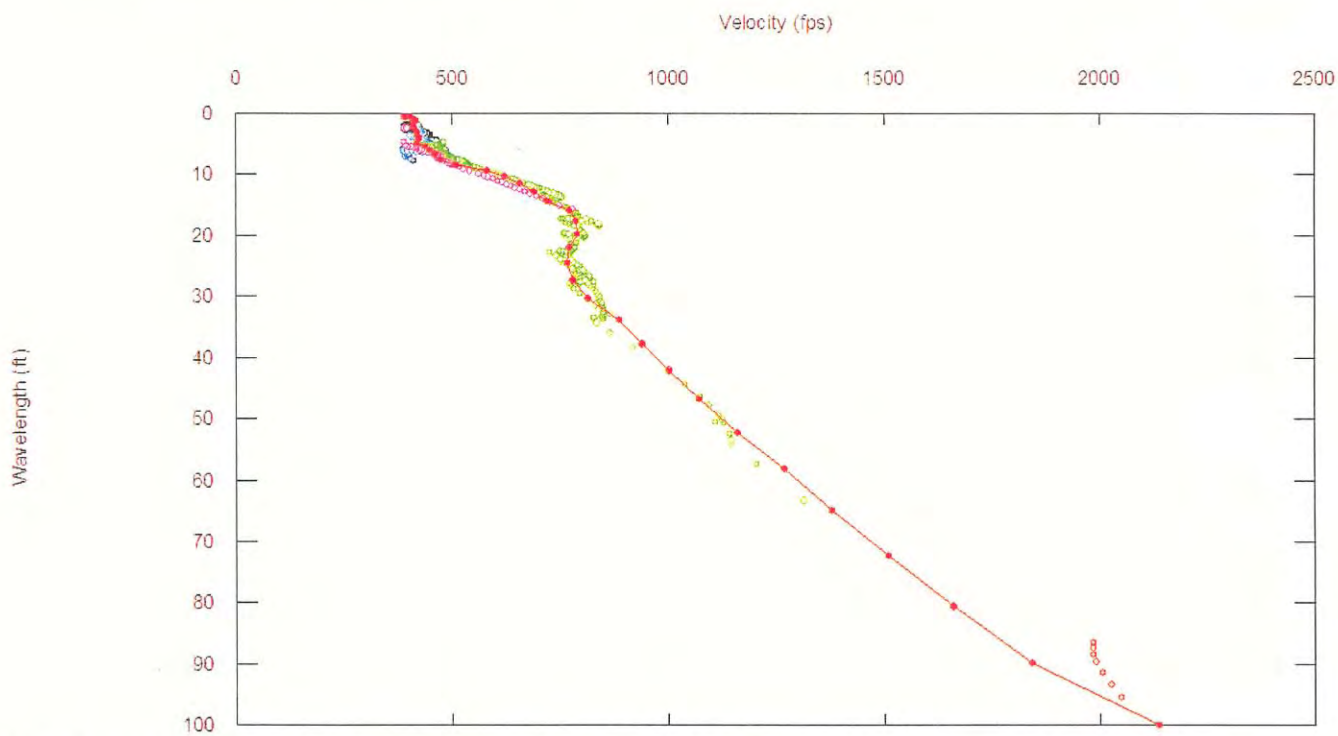

Fig. 8 - Site 2 N-S SASW Experimental (symbols) and Theoretical (symbols with line) Velocity Dispersion Curve Results

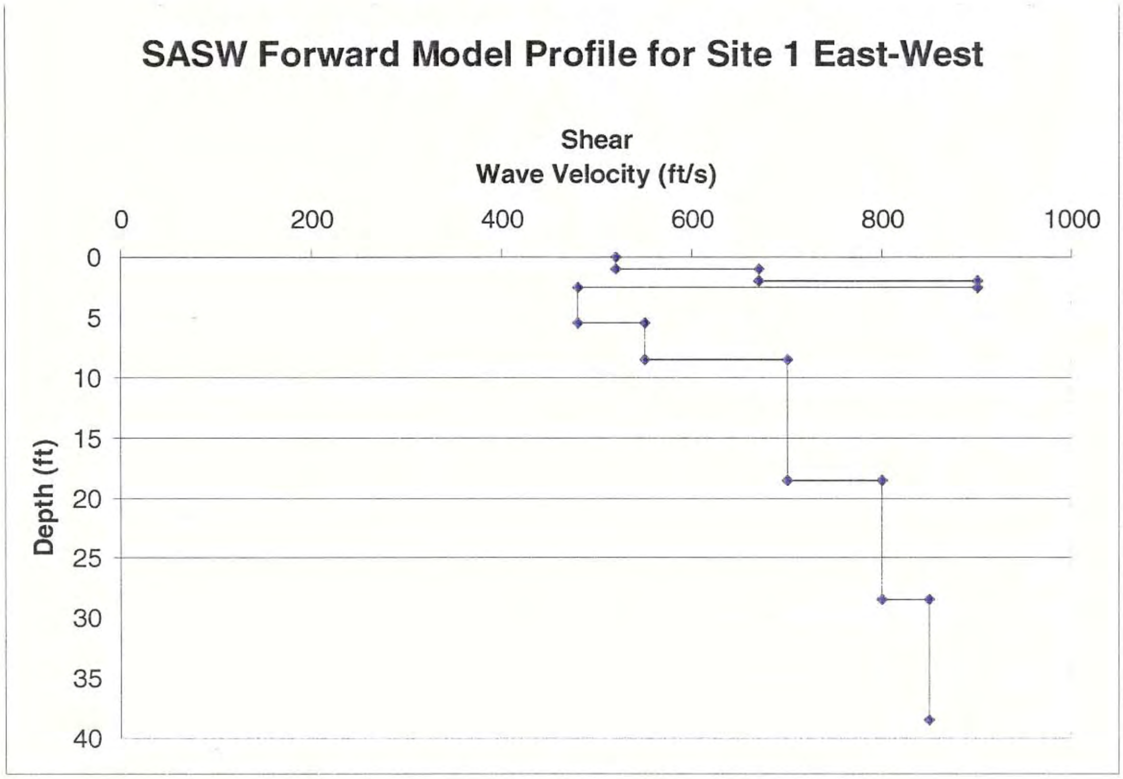

Fig. 9 - Site 1 E-W SASW Theoretical Shear Wave Velocity Profile

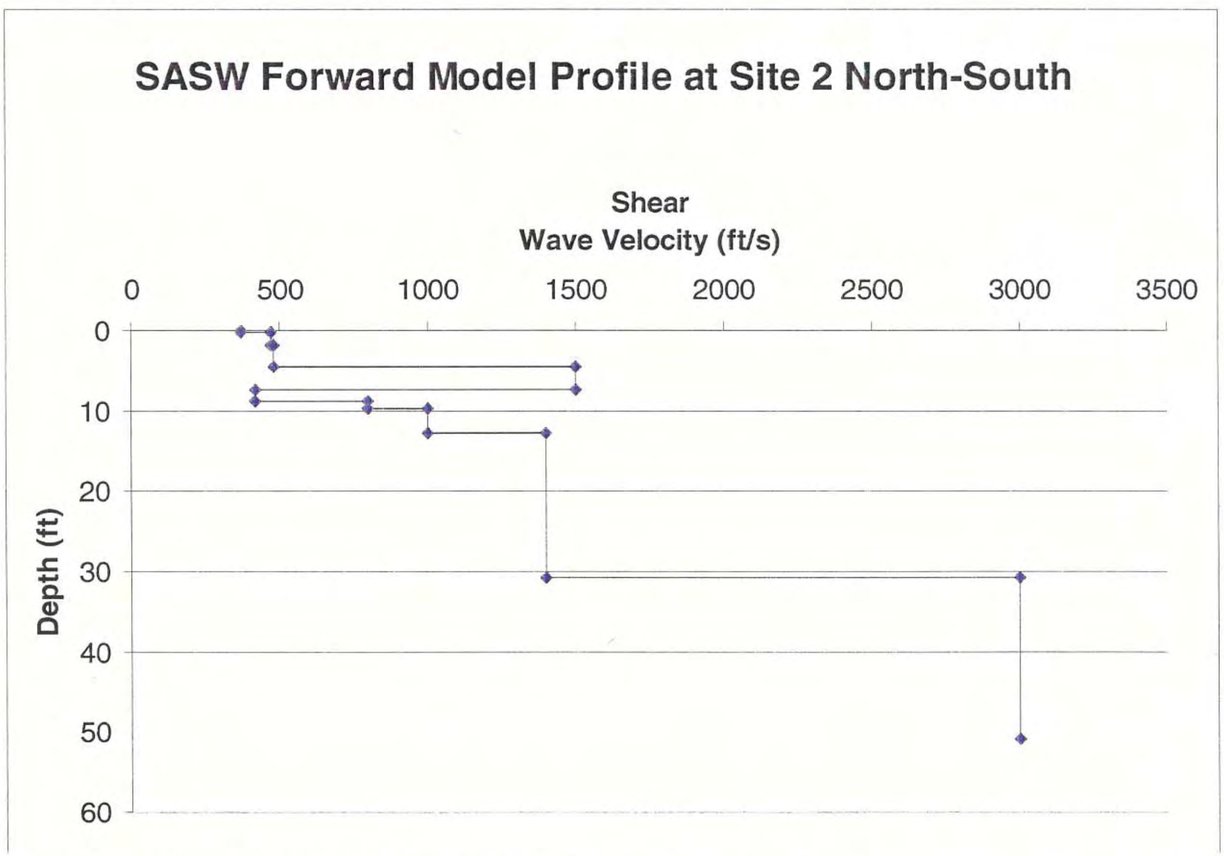

Fig. 10 - Site 2 N-S SASW Theoretical Shear Wave Velocity Profile

4.0 CLOSURE

The field portion of this investigation was performed in accordance with generally accepted testing procedures. If additional information is developed that is pertinent to the findings of this investigation, or we can provide any additional information, please call.

Respectfully submitted,

OLSON ENGINEERING, INC.

Larry D. Olson, P.E.
Principal Engineer

(2 copies mailed, 1 copy faxed)

APPENDIX H

Movement of Hawaiian Petrels Near USAF Facilities Near the Summit of Haleakalā, Maui Island, Fall 2004 and Spring 2005

MOVEMENTS OF HAWAIIAN PETRELS NEAR USAF FACILITIES NEAR THE SUMMIT OF HALEAKALA, MAUI ISLAND, FALL 2004 AND SPRING 2005

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APPENDIX H:
MOVEMENT OF HAWAIIAN PETRELS

EXECUTIVE SUMMARY

- The endangered Hawaiian Petrel or 'Ua'u (*Pterodroma sandwichensis*) breeds only in the Main Hawaiian Islands, where it is protected as an endangered species at both State and Federal levels. Its center of nesting abundance is the summit of Haleakala, on Maui Island.
- The USAF Air Force Research Laboratory (AFRL) of Kirtland AFB, New Mexico, conducts astronomical and satellite research at the Maui Space Station Complex (MSSC), near the summit of Haleakala. To understand the MSSC's affected environment better, AFRL contracted ABR to conduct a radar and visual study of the movements of Hawaiian Petrels that were nesting near the summit of Haleakala. We conducted these studies in the fall of 2004 (during late chick-rearing and early fledging) and the summer of 2005 (during late egg-laying and early incubation).
- The objective of this study, which both ornithological radar and visual sampling techniques, was to determine movement patterns of Hawaiian Petrels near the summit of Haleakala, including spatial movement patterns, temporal movement patterns, and flight altitudes.
- We recorded 518 targets on surveillance radar over 16 nights of sampling in fall 2004 and 355 targets over 16 nights of sampling in summer 2005. We recorded 72 targets on vertical radar over 14 nights of sampling in fall 2004 and 47 targets over 16 nights of sampling in summer 2005. We recorded 0 Hawaiian Petrels during visual sampling over 14 nights of sampling in fall 2004 and 107 Hawaiian Petrels over 15 nights of sampling in summer 2005.
- Movement rates varied between seasons, among sites, and among nights. The overall mean movement rate was 13.6 ± SE 3.5 radar targets/h in fall 2004 and 10.5 ± 3.2 targets/h in summer 2005.
- Mean movement rates at three of four individual sites were similar between fall 2004 and summer 2005. Mean movement rates were consistently low at the MSSC and the Gate/Observatory sites in both seasons and were consistently high at the Visitor's Center in both seasons, reflecting the heavy use of this latter area by nesting and displaying birds. In contrast, mean movement rates at the FAA Saddle Site varied wildly between seasons, being four times higher in fall 2004 than in summer 2005.
- Nightly activity patterns of petrel movements around the summit of Haleakala varied within nights and between seasons. During both fall 2004 and summer 2005, movement rates increased dramatically immediately after it became completely dark, resulting in a sharp increase in the number of targets detected within the first hour of complete darkness. In fall 2004, movement rates remained high during the entire evening's sampling period (to about midnight), once birds arrived at the mountain summit, whereas movement rates in summer 2005 were high for the first two hours after darkness, then decreased steadily until the end of the evening's sampling period (about midnight).
- Spatial patterns of movements qualitatively were similar between seasons, although there were a few differences. The one exception was that the number of targets crossing the Northwestern Slope to/from the crater declined from fall to spring.
- Flight directions suggested distinctly southwesterly patterns of movement, all of which were nearly identical among strata and between seasons, in the three broad geographic strata near the summit of Haleakala. Flight directions also suggested distinct patterns of movement across the ridge sections near the summit of Haleakala, suggesting movement northwesterly to southwesterly across the ridge; again, patterns were nearly identical between seasons.
- The mean flight velocity of Hawaiian Petrels as measured on surveillance radar was 37.7 ± SE 0.3 mi/h. Almost 77% of the radar targets flew 30–44 mi/h, and ~87% flew 30–49 mi/h; in contrast, <3% of targets flew <30 mi/h. Mean velocities recorded near the summit of Haleakala in this study were similar to those recorded on Maui in previous years and to those recorded on other Hawaiian Islands.

- Flight behaviors differed significantly in frequency between seasons. In fall 2004, straight-line, directional flight occurred >99% of the time, with erratic flight occurring 0.2% of the time and circling behavior not recorded. In contrast, in summer 2005, straight-line flight occurred ~74% of the time, whereas erratic flight occurred ~23% of the time and circling behavior occurred ~2% of the time. All three behaviors showed significant seasonal differences, indicating a significant increase in the frequency of erratic and circling behaviors and a concomitant decrease in the frequency of straight-line flight from fall to summer.
- The mean minimal flight altitude of all targets recorded on vertical radar was 175 ± SE 14 m above ground level [agl] overall; however, it was significantly higher in fall 2004 (239 ± 19 m agl) than in summer 2005 (79 ± 13 m agl). Of the five environmental factors examined in a model-selection process (season as a covariate and four weather factors), only season and wind speed significantly affected flight altitude. Flight altitudes averaged 155 m higher in fall than in summer and averaged 64 m higher when wind speeds were >10 mi/h than when they were ≤10 mi/h.
- Seasonal differences in the vertical distribution of flight altitudes followed the same pattern as mean flight altitudes in each season, with flight altitudes in fall significantly higher than altitudes in summer. In fall 2004 (summer 2005), 13.0% (80.5%) of all targets flew 1–100 m agl, 47.8% (90.2%) flew 1–200 m agl, 76.8% (95.1%) flew 1–300 m agl, 88.4% (97.6%) flew 1–400 m agl, and 94.2% (100.0%) flew 1–500 m agl. Hence, the greatest seasonal difference occurred in the lowest 200 m (and especially the lowest 100 m) of the air column, with a much higher percentage of birds flying at low altitudes in summer than in fall.
- We also calculated the mean minimal flight altitude of all Hawaiian Petrels seen flying inland or seaward on Kauai in 1992–2002 and compared them with our pooled Maui vertical radar data from 2004–2005. Birds on Kauai flew at a mean altitude of 236.8 ± SE 8.5 m agl, or ~30% higher than what we recorded in this study. On Maui (Kauai), 38.2% (36.7%) of all Hawaiian Petrels flew 1–100 m agl, 63.7% (56.7%) flew 1–200 m agl, and 83.7% (74.2%) flew 1–300 m agl. Patterns for both locations suggest that the number of Hawaiian Petrels in the air column decreases logarithmically with increasing height above ground.
- We detected no Hawaiian Petrels visually in fall 2004. In summer 2005, we detected 107 Hawaiian Petrels, all at the Visitor's Center. The timing of movements was similar to that for movements detected with radar at this site, in that we saw or heard no petrels until after the point of complete darkness. Hawaiian Petrels occasionally were heard calling and seen flying 4–8 m above the parking lot of the Visitor's Center, usually beginning within 10 min of complete darkness. Birds also were heard calling while flying, and some were heard calling from nesting crevices on the ground.
- The mean minimal flight altitude of Hawaiian Petrels seen flying near the Visitor's Center was 12.4 ± SE 1.6 m agl. Over three-fourths (~79%) of the petrels flew ≤15 m agl, suggesting that many of the birds in this location were flying at altitudes so low that they would not have been detected by the radar at all times.
- There was a significant difference in behavior between what petrels were doing in the area as a whole and what the subset that we were able to detect visually was doing. At the Visitor's Center area the radar data indicated that ~82% of the radar targets were flying with straight-line behavior, ~16% flew erratically, and ~2% flew by circling. In contrast, the visual data indicated that ~13% of the birds (essentially equal to radar targets) flew with straight-line behavior, ~2% flew erratically, and ~85% flew by circling.
- Many of the patterns we saw in this study matched what is known about the biology of Hawaiian Petrels. Breeding adults and non-breeding subadults and adults are active in the summer, when the displaying non-breeders

are active and fly erratically and circle the colonies at low altitudes; in contrast, only adults visit the colonies during the fall, when they simply fly in and land at burrows to feed young. We suspect that fewer birds were seen on the radar in the vicinity of the MSSC than near the Crater because the crater is much more active for breeding and displaying birds than is that part of the colony along the southwestern ridge (i.e., that ridge on which the observatories and the FAA Site sit).

- The flight-direction analyses and the maps of target locations suggested that petrels flying upslope from the southeastern side of the island generally flew toward the southwest as they approached the summit of the mountain. They crossed the ridge between the Southeastern and Northwestern slopes in many locations (over both saddles and pu'us). Birds on the Northwestern Slope also flew strongly toward the southwest, with many of those birds coming out of the Crater. This spatial movement pattern is different from what we expected, in that we expected that there would be movement in both directions over the ridge and along the northwestern slope, with birds flying to and from the Crater. Although this pattern of movement was pronounced, we cannot explain with confidence at this time why it was the way it was and why it differed from our expectation.
- The consistency of flight velocities implies that there is an optimal flight speed of these birds, based on wing-loading and wing-shape characteristics, that rarely is changed.
- Seasonal differences in flight altitudes also reflected seasonal differences in colony attendance of non-breeding birds, in that altitudes were significantly lower in the summer than in the fall.

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ACKNOWLEDGMENTS

We thank the USAF Air Force Research Laboratory of Kirtland AFB, NM, for funding the study. The funding and project were managed by Boeing LTS of Kihei, HI; we especially thank Stephan Shimko and the security personnel (Al, Catherine, Chester, and Kekealani) of that organization for invaluable support and assistance at the Maui Space Science Complex. The USFWS, Honolulu, HI, loaned us the Furuno radar; we especially thank Holly Freifeld of that organization for arranging the MOU that allowed us to use the radar. The NPS, Haleakala National Park, provided access and research permits for working in the park, stored the radar unit and batteries for us, and provided observers on some nights; we especially thank Cathleen Bailey of that organization for support, insights into the biology of petrels, and helping to provide the research permit. John Medeiros of the State of Hawaii DLNR generously provided a location for us to assemble the radar in 2004. At ABR, Thomas P. DeLong provided contractual and fiscal assistance; Todd J. Mabee provided the latest version of his vertical radar mount; Will P. Lentz and Dorte Dissing conducted the GIS analyses; and Allison L. Zusi-Cobb made the GIS maps. Stephan Shimko of Boeing LTS reviewed and improved this report.

INTRODUCTION

The endangered Hawaiian Petrel or 'Ua'u (*Pterodroma sandwichensis*) breeds only in the Main Hawaiian Islands (Simons and Hodges 1998), where it is protected as an endangered species at both State and Federal levels. Its center of nesting abundance is near the summit of Haleakala, on Maui Island. Because of the introduction of mammalian and avian predators and avian malaria, extensive habitat alteration and degradation, and other factors (reviewed in Day et al. 2003b), populations of this species have declined dramatically in historical times. In addition, this species is susceptible to mortality caused by collision with powerlines and other tall structures (Hodges 1992) and to mortality caused by light attraction and grounding (Reed et al. 1985, Simons 1985, Telfer et al. 1987, Gassmann-Duvall et al. 1988, Simons and Hodges 1998). The small population size of Hawaiian Petrels and documented recent population declines of the related Newell's Shearwater ('A'o; *Puffinus auricularis newelli*) in the Main Hawaiian Islands (Day et al. 2003b; also see Ainley et al. 2001) have increased concern about the long-term fate of this species. In addition, between 1990 and 1992, Hawaiian Petrels were found dead as a result of collision-caused mortality near the summit of Haleakala (Hodges 1992), so any structures high on Haleakala may put this species at risk of collision, and other human activities may have negative effects on this species in its largest known nesting colony.

The USAF Air Force Research Laboratory (AFRL) of Kirtland AFB, New Mexico, conducts astronomical and satellite research at the Maui Space Station Complex (MSSC), near the summit of Haleakala. To understand the MSSC's affected environment better, AFRL contracted ABR to conduct a radar and visual study of the movements of Hawaiian Petrels that were nesting near the summit of Haleakala and especially near the MSSC. We conducted these studies in the fall of 2004 and the summer of 2005, during two important periods in the natural history of these birds. The fall sampling was conducted to collect data during the late chick-rearing and early fledging periods, and the summer sampling was conducted to collect data during late egg-laying and the early incubation period.

The objective of this study was to determine movement patterns of Hawaiian Petrels near the summit of Haleakala, including spatial movement patterns, temporal movement patterns, and flight altitudes. This work was conducted with both ornithological radar and visual sampling techniques. Ornithological radar, in particular, has been highly useful for studying movements of Hawaiian Petrels and Newell's Shearwaters on Kaua'i Island (Cooper and Day 1995, 1998; Day and Cooper 1995; David et al. 2002; Day et al. 2002c, 2003b), Moloka'i Island (Day and Cooper 2002), Hawai'i Island (Day et al. 2002a, 2002b, 2003a, 2003c; Day and Cooper 2003a, 2003b, 2003c, 2004c; Day and Rose 2004), and Maui Island (Day and Cooper 1999, 2004a, 2004b; Cooper and Day 2003, 2004). Additional research on Hawaiian Petrels on Maui has been conducted by Simons (1984, 1985), Hodges (1994), and Hodges and Nagata (2001).

STUDY AREA

This research was conducted near the summit of Haleakala, Maui Island (Fig. 1). Haleakala is a large extinct volcano that forms all of East Maui, rising to 10, 023 ft in elevation. The summit itself consists of several pu'us (small cinder cones) of various heights between ~9,700 ft and 10, 023 ft; however, the largest structure near the summit is Haleakala Crater itself. At this elevation, vegetation is very sparse and consists of scattered small shrubs and small herbaceous plants, with scattered Hawaiian silverswords (*Argyroxiphium*); however, the dominant feature is bare lava cinders. Because of the high elevation, winds often are high and temperatures often are cool, especially at night. The other main feature of the summit of Haleakala is the complex of astronomical observatories that are concentrated along the rim of the pu'u known as Kolekole. In addition, there also is a Federal Aviation Administration (FAA) facility located on the pu'u to the southwest of the MSSC and a small television transmitter facility immediately northeast of the main entrance to the MSSC.

The research was conducted at four sampling sites each in fall 2004 and summer 2005, with three of the sites sampled in both seasons (Fig. 1).

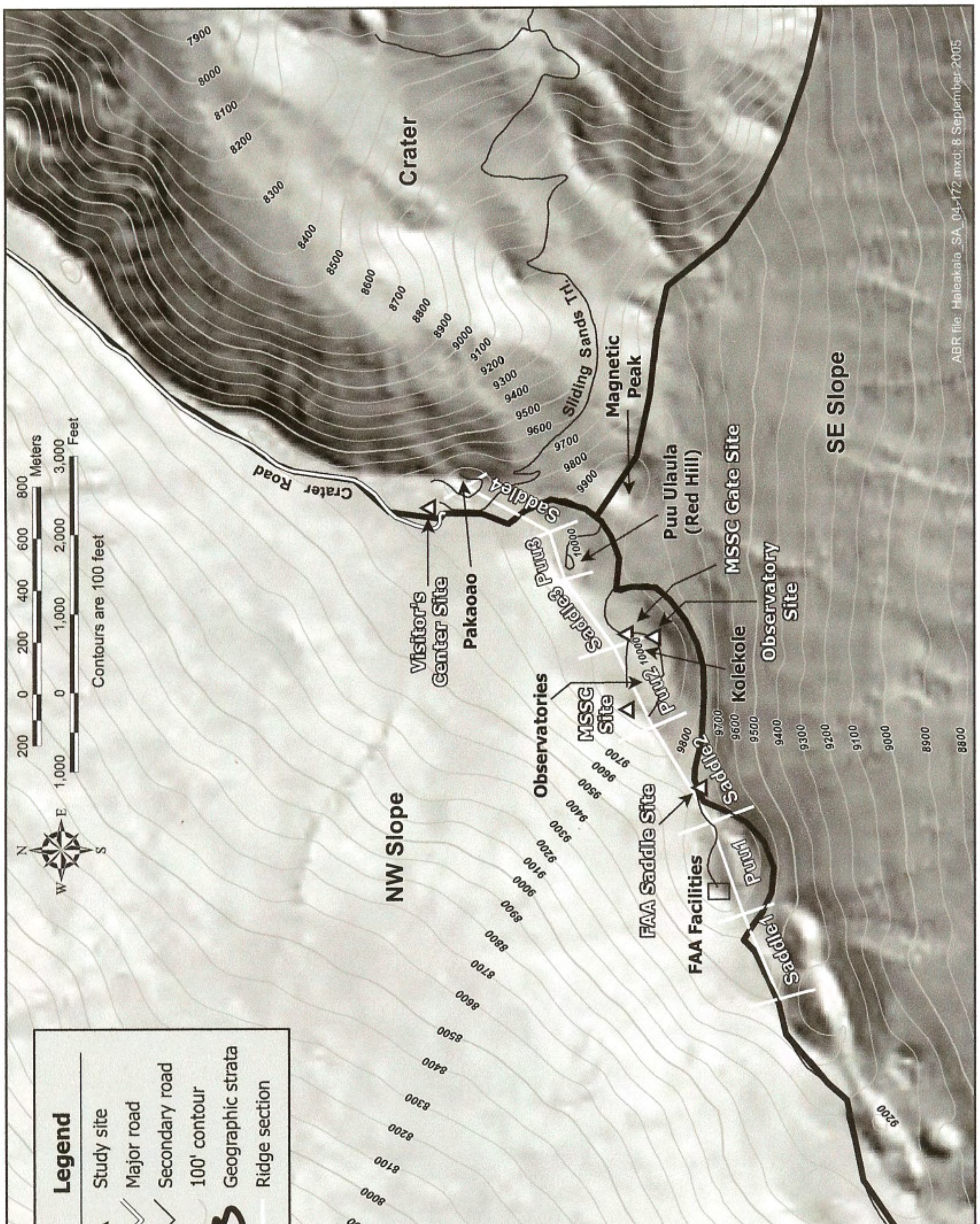

Figure 1. Study area and sampling sites near the summit of Haleakala, Maui Island, Hawaii, fall 2004 and spring 2005. Also shown are the locations of the three geographic strata and the seven ridge-crossing segments used in some analyses.

Because the radar operates only in line-of-sight operation, the irregular topography near the summit prevented us from collecting all of our data at one site. The MSSC Site (20°42.5'N 156°15.5'W) was located in the rear parking lot of the MSSC; it was used to sample movements along the Northwestern Slope, where some Hawaiian Petrels are known to nest (C. N. Bailey, Haleakala National Park, Makawao, HI, unpubl. data); its elevation was 3,026 m. The Visitor's Center Site (20°42.9'N 156°15.1'W) was located near the entrance to the parking lot for the Visitor's Center that overlooks Haleakala Crater; it was used to sample movements along the edge of the Crater (where the largest number of Hawaiian Petrels is known to nest; Hodges, unpubl. data) and the Northwestern Slope to a location southwest of the FAA site, along which Hawaiian Petrels are known to nest (Hodges, unpubl. data). Its elevation was 2,966 m. The FAA Saddle Site (20°42.3'N 156°15.7'W) was located to the southwest of the MSSC Site, in the saddle between Kolekole and the unnamed pu'u on which the FAA facilities are located; it was used to sample movements along the Southeastern Slope (where some Hawaiian Petrels are known to nest; Hodges, unpubl. data) and through the saddle itself. Its elevation was 2,959 m. The Security Gate Site, which (20°42.5'N 156°15.3'W) was located just inside the Main Gate of the MSSC, was sampled only in fall 2004; it was used to sample movements along the Northwestern and Southeastern slopes, along the southern edge of the Crater, and in the saddle between Kolekole and Pu'u 'Ula'ula. Its elevation was 3,033 m. The Observatory Site (20°42.4'N 156°15.4'W), which was sampled only in summer 2005, replaced the Security Gate Site and was located nearby; it sampled all of the above areas except for the Northwestern Slope. Its elevation was 3,043 m.

METHODS

We collected data on the movements, behavior, and flight altitudes of Hawaiian Petrels on 16 nights in September 2004 and 16 nights in May 2005 (Tables 1 and 2). We sampled with ornithological radar for ~5 h/night, from near sunset to the middle of the night. We also used visual equipment (both 10X binoculars before darkness and a night-vision scope with a 5X eyepiece or night-vision goggles with a 1X eyepiece after darkness) to try to locate and identify birds and other organisms that were flying. These samples covered the evening peak of activity (Day and Cooper 1995), plus additional sampling time when few birds were flying.

We collected data during 30-min sampling sessions that consisted of 25 min of data collection, followed by a 5-min break to collect weather data and to give observers a short break. Each 25-min sample was divided into a 15-min sample of surveillance radar, a 1-min break to switch the orientation of the radar mount into vertical position, and a 9-min sample of vertical radar. In contrast, the visual sampling was conducted continuously during the entire 25-min period. Actual lengths of sampling sessions were 2–25 min for surveillance radar data because some time was lost when precipitation obscured significant portions of the radar screen; in addition, we did not conduct vertical sampling during all 25-min sessions. For vertical radar data, actual lengths of sampling sessions were 2–9 min, with one 25-min session being used for experimentation and training purposes; some sessions were shorter than 9 min because heavy rain made sampling impossible. For visual data, actual lengths of sampling sessions were 10–25 min, because heavy rain and/or fog made sampling impossible.

We recorded the following weather and environmental data at the beginning of each radar or visual sampling session:

- ordinal wind direction (10 categories)—north, northeast, east, southeast, south, southwest, west, northwest, variable/ erratic, none (calm);
- wind speed (to nearest 8 km/h [5 mi/h]);
- cloud cover (to the nearest 5%);
- ceiling height (10 categories)—0 m agl, 1–50 m, 51–100 m, 101–150 m, 151–500 m, 501–1,000 m, 1,001–2,500 m, 2,501–5,000 m, >5,000 m, clear sky;
- minimal horizontal visibility in a cardinal direction (7 categories)—0–50 m, 51–100 m, 101–500 m, 501–1,000 m, 1,001–2,500 m, 2,501–5,000 m, >5,000 m;

Table 1. Activities and sampling effort for sampling near the summit of Haleakala, Maui Island, fall 2004. Sampling effort is presented as time of sampling (*n* samples).

		Sampling effort (*n*)			
Date	Site	Surveillance radar	Vertical radar	Visual	Comments
2 SE	–	– (0)	– (0)	– (0)	R. Day and J. Parrett arrive.
3 SE	–	– (0)	– (0)	– (0)	Set up and test radar; select sites; coordinate with Boeing personnel.
4 SE	MSSC	1900–1930, 2000–2200 (5)	1930–2000 (1)	– (0)	Clear and sunny; winds light; insect activity low-moderate; 1 owl-like target.
5 SE	MSSC	1800–2000 (4)	– (0)	– (0)	Windy and clear; insect activity low; 0 owl-like targets; battery failure—rest of sampling cancelled.
6 SE	MSSC	1930–2200 (5)	– (0)	1800–1930, 2200–2230 (4)	Light winds; few clouds; insect activity moderate; 0 owl-like targets.
7 SE	MSSC	1830–2300 (9)	1830–2300 (9)	1800–2300 (10)	Partly cloudy and cool; winds light; lightning over the ocean, far away; insect activity moderate; 0 owl-like targets.
8 SE	MSSC	2030–2300 (5)	2030–2300 (5)	2030–2300 (5)	R. Burgess arrives in evening, so first part of sampling missed; cool and windy; insect activity low; 1 owl-like target.
9 SE	MSSC	1900–0000 (10)	1900–0000 (10)	1940–0000 (9)	R. Day leaves; light winds; insect activity moderate; ~1 owl-like target.
10 SE	MSSC	1830–2330 (10)	1830–2330 (10)	1820–2330 (11)	Winds moderate; one session in wet fog; windy early, then calming a bit; insect activity not noted; 1 owl-like target.
11 SE	Visitors' Center	1830–2330 (10)	1830–2100, 2200–2330 (8)	2300–2330 (1)	Heavy fog and rain squalls all evening, causing cancellation of some samples; insect activity low; many bird targets, including owl-like targets.
12 SE	Visitors' Center	1830–2330 (10)	1830–2330 (10)	1830–2330 (3)	Foggy evening, so few visual sessions possible; fog turns heavy and wet late in evening; insect activity low; several owl-like targets.
13 SE	Visitors' Center	1830–1930, 2030–2330 (7)	1830–1900, 2030–2100, 2200–2300 (4)	1830–2330 (0)	Another foggy, misty night with some session lost; variable winds, decreasing; insect activity low; 3–5 owl-like targets.
14 SE	Visitors' Center	1830–2330 (10)	1830–2330 (10)	1845–2330 (10)	Clear and windy, with winds increasing during the evening; insect activity low; owl-like targets not noted.

Table 1. Continued.

Date	Site	Sampling effort (*n*)			Comments
		Surveillance radar	Vertical radar	Visual	
15 SE	Visitors' Center	1830–2330 (10)	1830–2330 (10)	1830–2330 (10)	Clear with light winds; many petrels, insect activity low; owl-like targets not noted.
16 SE	FAA Saddle	1845–2330 (10)	1900–2330 (9)	1840–2330 (9)	Low fog at first; later, clear sky; NPS observers assist; many petrels, insect activity very low; owl-like targets not noted.
17 SE	FAA Saddle	1830–2330 (10)	1830–2330 (10)	180–2330 (11)	Short periods of low fog in saddle, but Visitors' Center and northern side of volcano foggy all night; NPS observers assist; insect activity moderate; 5–6 owl-like targets.
18 SE	Security Gate	1850–2300 (8)	1900–2030, 2130–2230 (5)	1850–2300 (6)	Late start due to access delay; fog and rain move in, ending sampling at 2300; insect activity low; 1 owl-like target.
19 SE	Security Gate	1900–2330 (9)	1900–2330 (9)	2030–2330 (6)	Late start due to access delay; foggy early in evening, clearing a bit with scattered fog later in evening; insect activity zero; a few owl-like targets.
20 SE	–	– (0)	– (0)	– (0)	Disassemble and pack radar for storage; ship some equipment off-island.
22 SE	–	– (0)	– (0)	– (0)	R. Burgess and J. Parrett depart.

Table 2. Activities and sampling effort for sampling near the summit of Haleakala, Maui Island, spring 2005. Sampling effort is presented as time of sampling (*n* samples).

		Sampling effort (*n*)			
Date	Site	Surveillance radar	Vertical radar	Visual	Comments
1 MY	–	– (0)	– (0)	– (0)	R. Day and A. Gall arrive.
2 MY	–	– (0)	– (0)	– (0)	Set up and test radar; security briefing and logistics coordination at MSSC.
3 MY	MSSC	1920–2330 (8)	2130–2330 (4)	– (0)	Finish radar assembly; clear and sunny with light winds; insect activity moderate; ~2 owl-like targets.
4 MY	MSSC	2000–2330 (7)	2000–2330 (7)	1900–2000 (2)	Clear with light winds; insect activity low–moderate, declining after ~2230; 1–2 owl-like targets.
5 MY	MSSC	1900–2330 (9)	1900–2330 (9)	1900–2100, 2200–2300 (6)	Clear with light winds; insect activity low–moderate, declining after ~2200; 1–2 owl-like targets.
6 MY	MSSC	1900–0000 (10)	1900–0000 (10)	1900–0000 (10)	Clear with light winds that increased late in the evening; cold; insect activity low; 2 owl-like targets.
7 MY	Visitors' Center	1900–2330 (9)	1900–2330 (9)	1900–2330 (9)	Clear with winds 8–15 mi/h; cold; insect activity low; 1–2 owl-like targets.
8 MY	Visitors' Center	1900–2200 (6)	1900–2200 (6)	1900–2200 (6)	Foggy with drizzly rain; winds 5–12 mi/h; cold; insect activity low; 0 owl-like targets; abandoned sampling at 2200 because of poor conditions—even unable to conduct visual sampling.
9 MY	Visitors' Center	1900–2330 (9)	1900–2330 (9)	1900–2330 (9)	Clear and cold; winds 8–12 mi/h; insect activity low; 1–2 owl-like targets.
10 MY	Visitors' Center	1900–2300 (8)	1900–2300 (8)	1900–2300 (8)	Clear and cold with light winds; insect activity low, increasing to low–moderate after 2030; 1–2 owl-like targets.
11 MY	FAA Saddle	1900–2330 (9)	1900–2330 (9)	1900–2330 (9)	Clear and cool with light winds; insect activity moderate; 6 owl-like targets.
12 MY	FAA Saddle	1900–2330 (9)	1900–2330 (9)	1900–2330 (9)	Clear and cool with moderate winds; insect activity low–moderate, decreasing later in evening; ~3 owl-like targets.
13 MY	FAA Saddle	1900–2330 (9)	1900–2330 (9)	1900–2330 (9)	R. Burgess arrives; mostly clear (patchy fog at times) and cool; winds 15–25 mi/h; insect activity low; ~6 owl-like targets.
14 MY	FAA Saddle	1900–2300 (8)	1900–2300 (8)	1900–2300 (8)	Clear and cool; winds 35–40 mi/h, but only ~20 mi/h down in the saddle itself; insect activity very low; ~2 owl-like targets.

Table 2. Continued.

Date	Site	Sampling effort (*n*)			Comments
		Surveillance radar	Vertical radar	Visual	
15 MY	Observatory	1900–2330 (9)	1900–2330 (9)	1900–2330 (9)	R. Day leaves; clear with winds ~30 mi/h, slowly decreasing throughout evening to 18–20 mi/h; insect activity low; ~4 owl-like targets.
16 MY	Observatory	1900–2330 (9)	1900–2330 (9)	1900–2330 (9)	Clear with winds ~20 mi/h; insect activity very low; ~4 owl-like targets.
17 MY	Observatory	1900–2300 (8)	1900–2300 (8)	1900–2300 (8)	Clear with light–moderate winds; insect activity low–moderate; ~3 owl-like targets.
18 MY	Observatory	1900–2300 (8)	1900–2300 (8)	1900–2300 (8)	Light partial overcast with light winds; insect activity moderate; 1–2 owl-like targets.
19 MY	–	– (0)	– (0)	– (0)	Disassemble and pack radar; ship off-island.
20 MY	–	– (0)	– (0)	– (0)	R. Burgess and A. Gall depart.

- light condition (6 categories)—daylight with or without precipitation, crepuscular (i.e., civil twilight) with or without precipitation, darkness (i.e., the period between the end of civil twilight in the evening and the beginning of civil twilight in the morning) with or without precipitation;
- precipitation (6 categories)—none, fog, drizzle, light rain, heavy rain, scattered showers; and
- moon phase (16 categories)—moon up or not up and phase as New Moon, waxing crescent, First Quarter, waxing gibbous, Full Moon, waning gibbous, Third Quarter, waning crescent.

These standardized weather and environmental data are collected during all of our radar studies. All information on lunar phases, sunrise and sunset times, and moonrise and moonset times was taken for Pukalani, Hawaii, from the website http://www.sunrisesunset.com.

DATA COLLECTION

RADAR SAMPLING

Radar data-collection protocols were identical to previous studies conducted in this area and followed standardized sampling protocols (e.g., Cooper and Day 1995, 2003; Day and Cooper 1995, 1999, 2002, 2003a, 2003b, 2003c; Day et al. 2003b) for the surveillance sampling. (This was the first time vertical radar has been used in the Hawaiian Islands.) The Furuno FR-1510 surveillance radar was an X-band radar transmitting at 9.410 GHz with a peak power output of 12 kW. The range of this radar was set at 1.50 km, the pulse length was set at 0.07 µsec, and the plotting function was set to "continuous." The XN-3 antenna for this radar has a beam width of 25°; that is, it sends out a beam 25° high, centered on a horizontal plane oriented perpendicular to the antenna face. A similar radar unit is described in Cooper et al. (1991).

The radar scanned a 360° arc around the mobile radar laboratory and was used to obtain information on movement rates, flight paths, and ground speeds of birds. At the short pulse length used in this study, echo definition was high and provided precise information on target location. (An echo is a picture of a target on the radar display screen; a target is one or more birds displayed as a single echo on the radar display screen.) This radar has a digital color display with several scientifically useful features, including on-screen plotting of a sequence of echoes (to depict flight paths) and True North correction for the display screen (to determine flight directions easily). Because this radar plots the location of a target at fixed time intervals, ground speed is directly proportional to the distance between consecutive echoes and can be measured with a hand-held scale.

Whenever energy is reflected from the ground, surrounding vegetation, and other objects that surround the radar unit, a "ground-clutter" echo appears on the display screen. Because ground-clutter echoes can obscure bird echoes when sampling in surveillance mode, we attempted to minimize this ground clutter by elevating the forward edge of the antenna (described in Cooper et al. 1991) and, in some cases, positioning the radar so that nearby hills acted as a radar fence (see Eastwood 1967).

We used this radar in two modes of operation: surveillance and vertical (Figs. 2–4). In surveillance mode, we scanned the entire area around the radar laboratory with a horizontal range (radius) of 1.50 km (Fig. 3). In vertical mode, we reset the radar mount so that the radar beam was shooting upward into the air-column (Fig. 4); the range was set at 1.50 km. During both surveillance and vertical sampling, we traced flight tracklines (i.e., a series of echoes generated by one bird that was plotted on the screen) of petrel targets onto clear acetates that were laid upon the screen. Each trackline was uniquely numbered so that it could be cross-referenced to individual lines of data.

We recorded the following data for each surveillance trackline seen on the radar display screen:

- time;
- flight direction (to the nearest 1°);
- flight behavior (3 categories)—straight-line directional, erratic, circling;
- cardinal transect crossed (4 categories)—north, east, south, west (the four primary

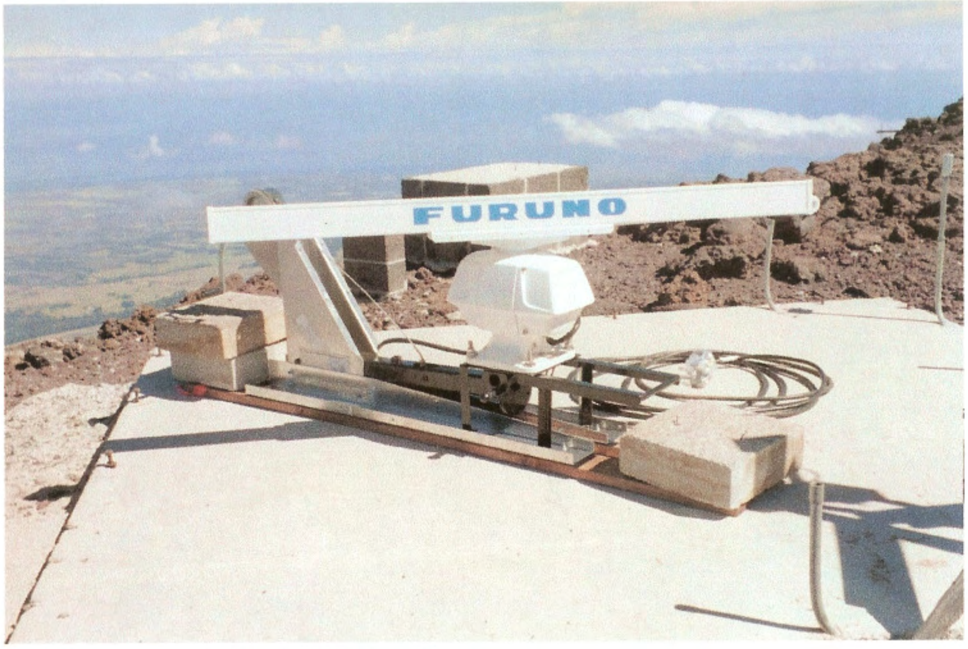

Figure 2. Vertical radar mount in folded position.

Figure 3. Vertical radar mount extended and in surveillance sampling position.

Figure 4. Vertical radar mount extended and in vertical sampling position.

compass bearings that are used to tell in which general direction from the laboratory the radar target occurred);

- minimal distance from the radar laboratory (used to reconstruct flight tracklines of birds, if needed); and
- flight velocity (to the nearest 5 mi/h [8 km/h]).

We recorded the following data for each vertical trackline seen on the radar display screen:

- time;
- cardinal transect crossed (3 categories)—north, east, west (the southern transect would be in the ground when the antenna was oriented in this way);
- minimal flight altitude (meters) above a horizontal plane passing through the radar sampling site (calculated with GIS software—see later);
- minimal flight altitude (meters) above ground level (calculated with GIS software—see later);
- minimal horizontal distance from the radar sampling site of the minimal flight altitude above a horizontal plane passing through the sampling site (calculated with GIS software—see later); and
- minimal horizontal distance from the radar sampling site of the minimal flight altitude above ground level (calculated with GIS software—see later); and
- flight velocity (to the nearest 5 mi/h [8 km/h]).

For both sampling modes, we collected data only on targets flying ≥30 mi/h (≥48 km/h) (following Day and Cooper 1995). We also included any targets flying <30 mi/h (<48 km/h) that we identified visually as being of Hawaiian Petrels and excluded any targets flying the appropriate speed but of another species; altogether, we detected 23 targets that we believe were of Hawaiian Petrels flying <30 mi/h (primarily subadults that were displaying over Haleakala Crater) and excluded no targets of other species that were flying otherwise-appropriate speed during this study.

VISUAL SAMPLING

Visual data-collection protocols were identical to previous studies conducted in the area and followed standardized sampling protocols (e.g., Cooper and Day 1995, 2003; Day and Cooper 1995, 1999, 2002, 2003a, 2003b, 2003c; Day et al. 2003b). Prior to darkness, we used 8X or 10X binoculars to scan the sky for Hawaiian Petrels. After darkness, we scanned the sky with a night-vision scope fitted with a 5X eyepiece (fall 2004; Model # Noctron-V; Generation 2; Varo Systems, Garland, TX) or with night-vision goggles fitted with a 1X eyepiece (summer 2005; Model # PVS-7B/D; Generation 3; NiViSys Industries LLC, Tempe, AZ). We were able to see farther with this equipment by using a Mag-lite 2D flashlight equipped with a dark red filter, to minimize disturbance of these birds.

We recorded the following data for each bird recorded visually:

- time;
- number of birds;
- general flight direction (10 categories)—north, northeast, east, southeast, south, southwest, west, northwest, circling, erratic;
- flight behavior (3 categories)—straight-line, circling, erratic; and
- flight altitude (m above ground level [agl]; estimated to the nearest 1 m up to 25 m; to the nearest 5 m between 25 and 50 m; to the nearest 10 m between 50 and 100 m; to the nearest 25 m between 100 and 200 m; and to the nearest 50 above 200 m).

DATA ANALYSIS

We used Excel and SPSS 13.0 software for data summaries. In all statistical tests, the level of significance (α) was 0.05.

RADAR SAMPLING

Surveillance radar

We tabulated counts of numbers of targets recorded during each surveillance sampling session, then converted these counts to estimates of movement rates of birds (radar targets/h), based on the number of minutes sampled. Because rain showers sometimes obscured significant portions of the radar display screen (Tables 1 and 2), we subtracted that time during which we could not sample from the length of time allotted to the sampling session and used the resulting adjusted time in the calculation of movement rates for each session. We then the estimated movement rate for each sampling session (e.g., 1900–1929, 1930–1959) at a site to calculate the mean $\pm$ 1 standard error (SE) movement rate by date. We also used nightly estimates of mean movement rates to calculate the movement rate by season. In addition, we standardized movement rates by time of each sampling session within a season and calculated mean $\pm$ 1 SE movement rates by time of the night among all sites combined for each season.

For each observation of a surveillance-radar target that we believed was that of a petrel and had traced the flight trackline that plotted on the screen, we digitized the tracklines into a GIS system (ArcGIS 9). We then overlaid these digitized tracklines onto a "hillshade" map of the summit of the mountain, created from a Digital Elevation Model, and calculated mean flight-direction vectors with the ArcGIS routine "linear directional means."

We used the flight-direction data to calculate the mean flight direction $\pm$ 1 circular standard deviation and vector length (r) of flight direction by ridge section and by geographic stratum for the entire multi-night sample within a season. The ridge strata were used to evaluate flight directions of targets across the ridge and consisted of a series of alternating topographic high points (pu'us) and low points (saddles; Fig.1). The geographic strata were broad areas and included the northwestern slope, the southeastern slope, and the crater area (Fig. 1). For all flight-direction calculations, we converted flight directions to radians and calculated the mean direction and circular standard deviation (S') following Zar (1984).

We summarized the data on flight behavior by calculating the total number of targets exhibiting each behavior during each season. We tested for a difference between seasons in proportions of each flight behavior with a Chi-square test for row-by-column independence (Zar 1984). The null hypothesis was that proportions of flight behaviors being exhibited by birds did not differ between seasons.

Vertical radar

For each observation of a vertical-radar target that we believed was that of a petrel and had traced the flight trackline that plotted on the screen, we digitized the tracklines in GIS. We then overlaid these digitized tracklines onto a "hillshade" map of the summit of the mountain, created from a Digital Elevation Model, and used those elevations under each trackline to determine flight altitude; we also used ArcGIS to calculate horizontal distance of tracklines from the radar sampling site.

We calculated flight altitudes with respect to the actual height of the ground. We used the GIS to calculate the minimal flight altitude above actual ground level in the Digital Elevation Model by sampling every 10 m along the trackline to determine the minimal altitude. We then summarized these flight-altitude data by season.

We examined the effects of four weather variables (wind speed, cloud cover, ceiling height, and precipitation), plus the factor season (fall 2004, summer 2005), on flight altitude with general linear models, using model-selection techniques developed by Burnham and Anderson (2002). We classified wind speed as low (0–10 mi/h) or high (>10 mi/h). We classified cloud cover as low (0–50%) or high (>50%), classified ceiling height as low (0–500 m) or high (>501 m), and classified precipitation as present or absent. We constructed a global model that included all four weather variables as main effects. Season was included as a covariate in all models to account for differences in flight behavior between the chick-rearing stage (fall 2004) and the incubation stage (summer 2005). We evaluated a model set of the global model, plus all possible one-, two-, and three-factor combinations of the main effects by using Akaike's Information Criterion corrected for small sample sizes (AIC_c) to select the model best supported by the data (Burnham and Anderson 2002). We included a null model in the model set to assess the fit of the global model to the data. Models within two AIC_c units of the top-ranked model were considered supported by the data for drawing inferences (Burnham and Anderson 2002). We used model-averaged parameter estimates, which account for account for model-selection uncertainty, from the candidate model set to draw inferences about factors affecting variation in flight altitude.

We classified the flight-altitude data into geographic strata with GIS, then summarized the data by geographic stratum. The three strata included the Northwestern Slope, the Southeastern Slope, and the Crater area (Fig. 1). These geographic strata were identical to those used for flight-direction analyses. Unfortunately, sample sizes in two of the strata were too small to make statistical comparisons of differences in mean flight altitudes among strata.

We classified flight altitudes measured on the vertical radar into 100-m categories (e.g., 1–100 m agl, 101–200 m agl) and plotted the data by altitude category and season. We then tested for a difference in the two statistical distributions with a Kolmogorov–Smirnov test (Zar 1984). The null hypothesis was that the distribution of petrels in the airspace (100-m categories) did not differ between seasons. We also classified flight altitudes measured on the vertical radar in both seasons combined and flight altitudes of Hawaiian Petrels recorded visually on Kaua'i Island into 100-m categories and plotted the data by altitude category and location. We then tested for a difference in the two statistical distributions with a Kolmogorov–Smirnov test (Zar 1984). The null hypothesis was that the distribution of petrels in the airspace (100-m categories) did not differ between locations.

VISUAL SAMPLING

We summarized the flight-altitude data by season by calculating the mean ± 1 standard error (SE) flight altitude. We also compiled frequencies of each flight behavior of birds observed visually and compared them with frequencies of behaviors of birds recorded on radar at the Visitor's Center, where all visual observations occurred; because all visual data were recorded during the summer, we used just that subset of radar data for this comparison. We tested for a difference between the two sampling techniques in proportions of each flight behavior with a Chi-square test for row-by-column independence (Zar 1984). The null hypothesis was that proportions of flight behaviors being exhibited by birds did not differ between sampling techniques.

RESULTS

In fall 2004, sunset occurred between 1824 and 1838, and it became completely dark (i.e., the point at which the lux level reached 0) between 1846 and 1901. The Full Moon occurred the night of 29–30 August, the Last Quarter occurred the night of 5–6 September, the New Moon occurred the night of 14–15 September, and the First Quarter occurred the night of 20–21 September. In summer 2005, sunset occurred between 1850 and 1856, with complete darkness occurring between 1913 and 1920. The Third Quarter occurred the night of 30 April–1 May, the New Moon occurred the night of 7–8 May, the First Quarter occurred the night of 15–16 May, and the Full Moon occurred the night of 23–24 May. Hence, during both seasons, this sampling occurred during both waxing and waning moons.

We recorded 518 targets on surveillance radar over 16 nights of sampling in fall 2004 and 355 targets over 16 nights of sampling in summer 2005. We recorded 72 targets on vertical radar over 14 nights of sampling in fall 2004 and 47 targets over 16 nights of sampling in summer 2005. We recorded 0 Hawaiian Petrels during visual sampling over 14 nights of sampling in fall 2004 and 107 Hawaiian Petrels over 15 nights of sampling in summer 2005. Overall weather was good, but we lost some sampling time to inclement weather. In both seasons, we lost some surveillance-radar, vertical-radar, and/or visual sampling time because of rain clutter on the radar screen, battery failure, problems with access to sampling sites, and/or fog. The amounts of time lost were not extensive, however, and this loss of time did not affect our results because samples were collected by sampling sessions. Sampling sessions for radar movement rates (calculated as targets/h) were standardized by the length of time during which we collected data.

MOVEMENT RATES

Movement rates varied between seasons, among sites, and among nights (Fig. 5, Tables 3–4). The overall mean movement rate was 13.6 ± SE 3.5 targets/h in fall 2004 and 10.5 ± 3.2 targets/h in summer 2005. In fall 2004, the mean movement rate was highest at the FAA Saddle (26.8 ± 15.2 targets/h), followed in decreasing order by the Visitor's Center (21.0 ± 7.4), the MSSC Gate/Observatory (7.5 ± 4.4), and the MSSC (6.2 ± 2.8). (Because of their proximity, the MSSC Gate site and the Observatory site are considered to be synonymous in all analyses.) In summer 2005, the mean movement rate was

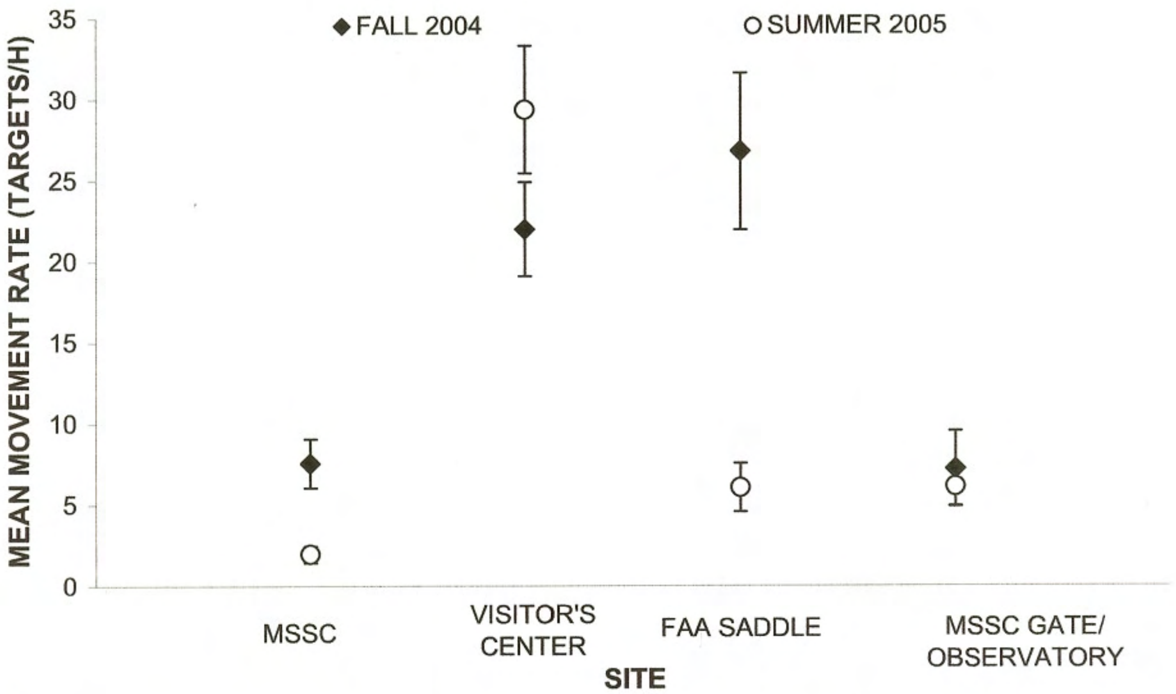

Figure 5. Mean movement rate (targets/h) of Hawaiian Petrel radar targets near four sites near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by site and season. Data are plotted as mean ± 1 SE. The MSSC Gate and Observatory sites were located nearby and were considered to be the same in analyses.

Table 3. Movement rates (targets/h) of radar targets sampled near the summit of Haleakala, Maui Island, fall 2004. For individual dates, *n* is the number of sampling sessions; for totals, *n* is the number of nights of sampling.

		Movement rate (targets/h)		
Site	Date	Mean ± SE	Range	*n*
MSSC	4 SE	0 ± 0	0	5
	5 SE	2.4 ± 2.4	0–9.6	4
	6 SE	7.2 ± 1.1	4.8–9.6	5
	7 SE	0 ± 0	0	9
	8 SE	4.0 ± 1.8	0–8.0	5
	9 SE	8.1 ± 1.2	4.0–12.0	10
	10 SE	21.6 ± 4.5	0–44.0	10
	Total	6.2 ± 2.8	0–44.0	7
Visitor's Center	11 SE	20.8 ± 5.9	0–52.0	10
	12 SE	5.2 ± 1.5	0–12.0	10
	13 SE	5.4 ± 2.8	0–20.0	7
	14 SE	43.7 ± 6.0	0–64.6	10
	15 SE	30.0 ± 3.9	4.0–48.0	10
	Total	21.0 ± 7.4	0–64.6	5
FAA Saddle	16 SE	42.0 ± 6.3	0–68.0	10
	17 SE	11.6 ± 2.9	0–28.0	10
	Total	26.8 ± 15.2	0–68.0	2
MSSC Gate/Observatory	18 SE	11.8 ± 4.2	0–32.0	8
	19 SE	3.1 ± 1.5	0–12.0	9
	Total	7.5 ± 4.4	0–32.0	2
Total		13.6 ± 3.5	0–68.0	16

highest at the Visitor's Center (28.0 ± 6.8 targets/h), followed in decreasing order by the FAA Saddle (6.2 ± 2.4), the MSSC Gate/Observatory (5.9 ± 2.4), and the MSSC (1.9 ± 0.5). Hence, in both seasons, the highest or second-highest mean movement rate was at the Visitor's Center and the lowest mean movement rate was at the MSSC.

Movement rates at individual sites generally were similar between fall 2004 and summer 2005 (Fig. 5, Tables 3–4). Mean movement rates were consistently low at the MSSC and the Gate/Observatory in both seasons and were consistently high at the Visitor's Center in both seasons, reflecting the importance of this last area to nesting birds (Fig 5). In contrast, mean movement rates at the FAA Saddle varied dramatically between seasons, being four times higher in fall 2004 than in summer 2005 (Fig. 5, Tables 3–4). Movement rates at the Visitor's Center in summer 2005 were the highest of all sites across all seasons, reflecting the heavy use of that area by displaying birds in the summer.

Movement rates showed great among-night variation in both seasons (Tables 3–4). In fall 2004, mean nightly movement rates varied between 0 and 21.6 targets/h at the MSSC, between 5.2 and 43.7 targets/h at the Visitor's Center, between 11.6 and 42.0 targets/h at the FAA Saddle, and between 3.1

Table 4. Movement rates (targets/h) of radar targets sampled near the summit of Haleakala, Maui Island, summer 2005. For individual dates, *n* is the number of sampling sessions; for totals, *n* is the number of nights of sampling.

		Movement rate (targets/h)		
Site	Date	Mean ± SE	Range	*n*
MSSC	3 MY	0.3 ± 0.3	0–2.4	8
	4 MY	2.3 ± 1.5	0–8.0	7
	5 MY	2.2 ± 1.0	0–8.0	9
	6 MY	2.8 ± 1.0	0–8.0	10
	Total	1.9 ± 0.5	0–8.0	4
Visitor's Center	7 MY	27.1 ± 4.5	0–44.0	9
	8 MY	15.3 ± 5.5	0–32.0	6
	9 MY	47.1 ± 8.7	0–96.0	9
	10 MY	22.5 ± 7.3	0–52.0	8
	Total	28.0 ± 6.8	0–96.0	4
FAA Saddle	11 MY	9.8 ± 3.8	0–32.0	9
	12 MY	1.8 ± 1.0	0–8.0	9
	13 MY	2.2 ± 1.0	0–8.0	9
	14 MY	11.0 ± 4.1	0–32.0	8
	Total	6.2 ± 2.4	0–32.0	4
MSSC Gate/Observatory	15 MY	10.2 ± 2.3	0–24.0	9
	16 MY	9.8 ± 2.4	0–24.0	9
	17 MY	2.5 ± 1.5	0–12.0	8
	18 MY	1.0 ± 1.0	0–8.0	8
	Total	5.9 ± 2.4	0–24.0	4
Total		10.5 ± 3.2	0–96.0	16

and 11.8 targets/h at the MSSC Gate/Observatory. In summer 2005, mean nightly movement rates varied between 0 and 2.8 targets/h at the MSSC, between 15.3 and 47.1 targets/h at the Visitor's Center, between 1.8 and 11.0 targets/h at the FAA Saddle, and between 1.0 and 10.2 targets/h at the MSSC Gate/Observatory.

Activity patterns of petrel movements around the summit of Haleakala varied within nights and between seasons (Fig. 6). During both fall 2004 and summer 2005, movement rates increased dramatically immediately after it became completely dark, resulting in a sharp increase in the number of targets detected within the first hour of complete darkness. In fall 2004, movement rates remained high during the entire evening's sampling period (to about midnight), once birds arrived at the mountain summit. The abrupt decline in the last sampling session had a sample size of only one, so the apparent size of this decline is questionable. In contrast, in summer 2005, movement rates were high for the first two hours after darkness, then decreased steadily until the end of the evening's sampling period (about midnight).

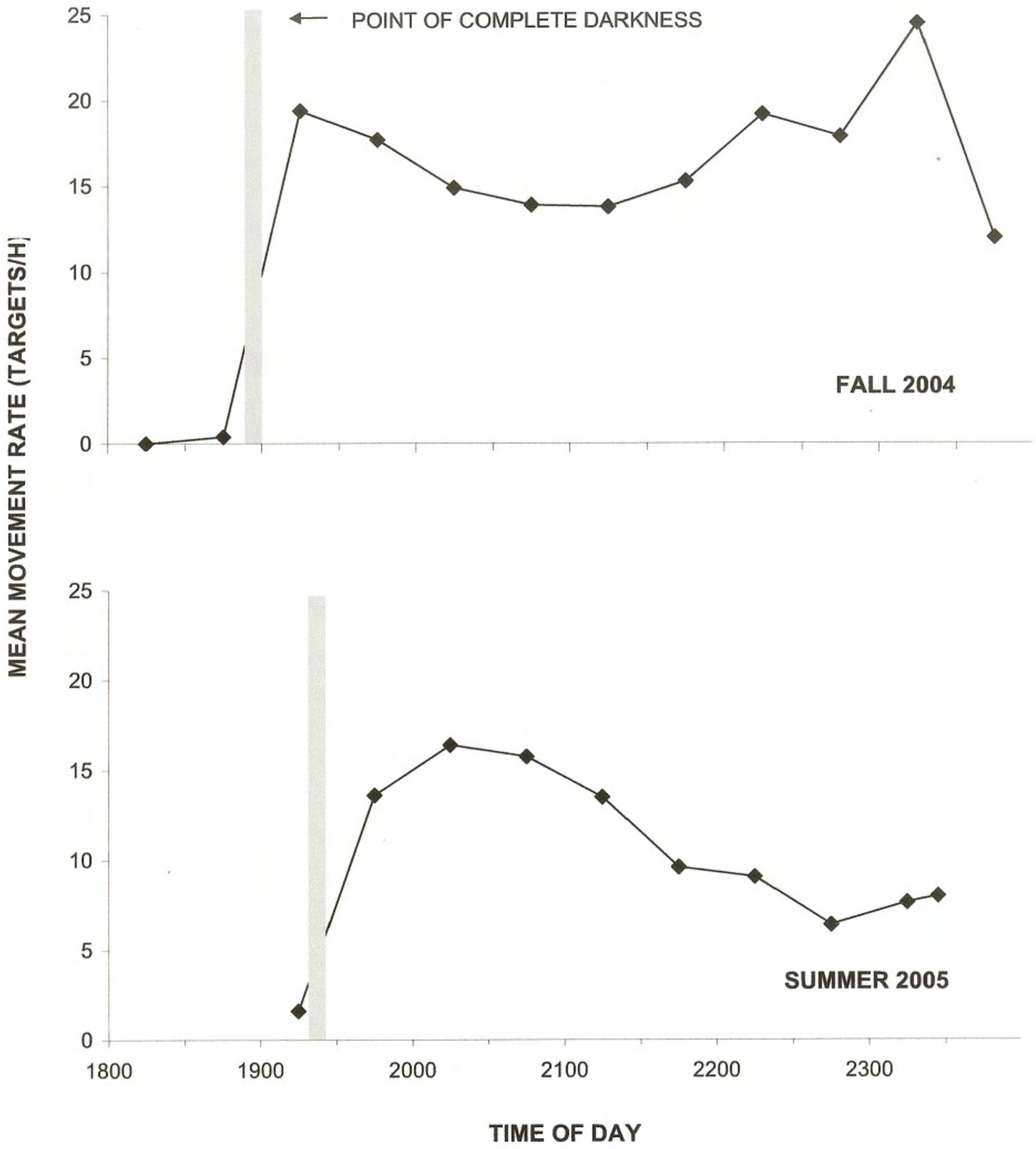

Figure 6. Mean movement rate (targets/h) of Hawaiian Petrel radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by time of the day. Data are plotted as the mean and are for all sites combined; for reference, the point of complete darkness (that period when twilight ends and complete darkness begins) is presented.

SPATIAL MOVEMENTS AND FLIGHT DIRECTIONS

We recorded 518 targets on surveillance radar in fall 2004 (Fig. 7). At the MSSC site, we recorded Hawaiian Petrels flying in scattered locations around the pu'u called Kolekole, where the observatories and the MSSC site were located; surprisingly, we recorded the most birds flying along the southern edge of the ridge on which the MSSC was located and saw few flying over the large slope to the north of the ridgeline (the Northwestern Slope; Fig. 1). At the Visitor's Center, we saw some birds flying along the inside of the crater rim, but most appeared to be crossing the road while flying to and from the Northwestern Slope; indeed, workers at the MSSC told us that they occasionally see Hawaiian Petrels sitting in the middle of the road in this area. At the FAA Saddle, we saw many birds clearly flying along the southern side of the ridge, with some crossing the ridge by passing through the FAA Saddle itself and some crossing the ridge south of there. At the MSSC Gate, we saw few targets in general; all were flying on either side of the ridge and parallel to it.

We recorded 355 targets on surveillance radar in summer 2005 (Fig. 8). At the MSSC site, we recorded few targets, most of which were flying over the Southeastern Slope; qualitatively, the spatial pattern was similar to that seen in fall 2004, although there simply were many fewer targets in summer 2005 than fall 2004. At the Visitor's Center, most birds were seen flying along the inner edge of the crater; perhaps one-third of all targets recorded at this location were seen flying to/from the Northwestern Slope, in contrast to the emphasis on this route seen in fall 2004. At the FAA Saddle, we recorded few targets; most were flying over the Southeastern Slope near the ridge itself, similar to the pattern seen in fall 2004. At the Observatory Site (essentially identical to the MSSC Gate Site used in fall 2004), we saw targets flying over the Northwestern Slope, along the southern side of the ridge, and near the crater. Only this final pattern had not been seen in fall 2004.

Flight directions suggested distinct patterns of movement in the three broad geographic strata near the summit of Haleakala (Fig. 9, Table 5). Patterns were nearly identical between seasons, so we pooled the data for overall estimates across both seasons (Table 5). The mean flight direction was 245° on the Northwestern Slope, 247° on the Southeastern Slope, and 243° in the Crater. Although the vector lengths (r) for the Northwestern and Southeastern slopes were high (0.82 and 0.89, respectively), indicating strong consistency in flight directions of individual targets, the vector length for the Crater was much lower, indicating much less consistency in flight directions.

Flight directions also suggested distinct patterns of movement in across seven ridge sections near the summit of Haleakala (Fig. 9, Table 5). Patterns were nearly identical between seasons, so we pooled the data for overall estimates across both seasons (Table 5). The mean flight direction was 282–298° across Saddle 1 (the low point of the ridge, southwest of the FAA site), Pu'u 1 (the pu'u on which the FAA site sits), and Saddle 2 (the FAA saddle); 235–252° across Pu'u 2 (the pu'u on which the MSSC and observatories sit) and Saddle 3 (the saddle between the MSSC Gate and Red Hill); 214° across Pu'u 3 (Red Hill); and 262° across Saddle 4 (the saddle between Red Hill and Paka'oa'o). Flight directions, however, were strongly directional (as indicated by a large vector length r) only over Saddle 1 and Pu'u 1, whereas they were only moderately directional over the other sections. This directional pattern is reinforced in the analysis of overall consistency of flight directions (Table 6), where 90–97% of all targets crossing Saddle 1 and Pu'u 1 were flying with the mean flight direction. In contrast, 71–79% of all targets were flying with the mean direction across all other segments except one. In the final segment (Pu'u 3), only 40% of the targets were flying with the mean flight direction, and 60% were flying perpendicular to the mean direction. In general, the percentage of targets flying either away from the mean flight direction or perpendicular to it increased with increasing proximity to the Crater.

FLIGHT VELOCITY

The mean flight velocity of Hawaiian Petrels as measured on surveillance radar was 37.7 ± SE 0.3 mi/h (n = 871; range = 25–70; Fig. 10, Table 7). Almost 77% of the radar targets flew 30–44 mi/h,

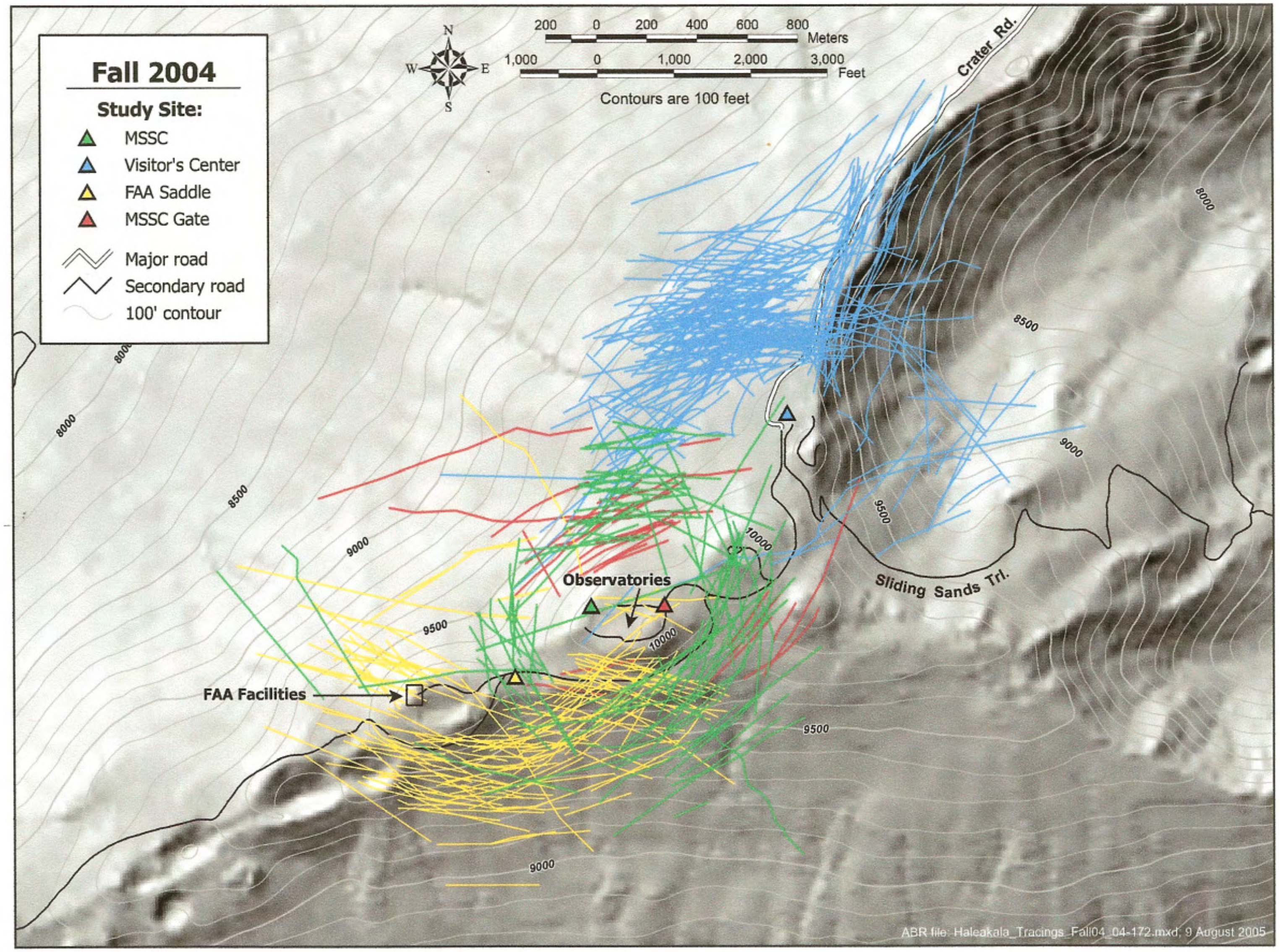

Figure 7. Flight tracklines of Hawaiian Petrels flying near the summit of Haleakala, Maui Island, fall 2004. Tracklines are colored to match the site (colored triangles) at which they were recorded.

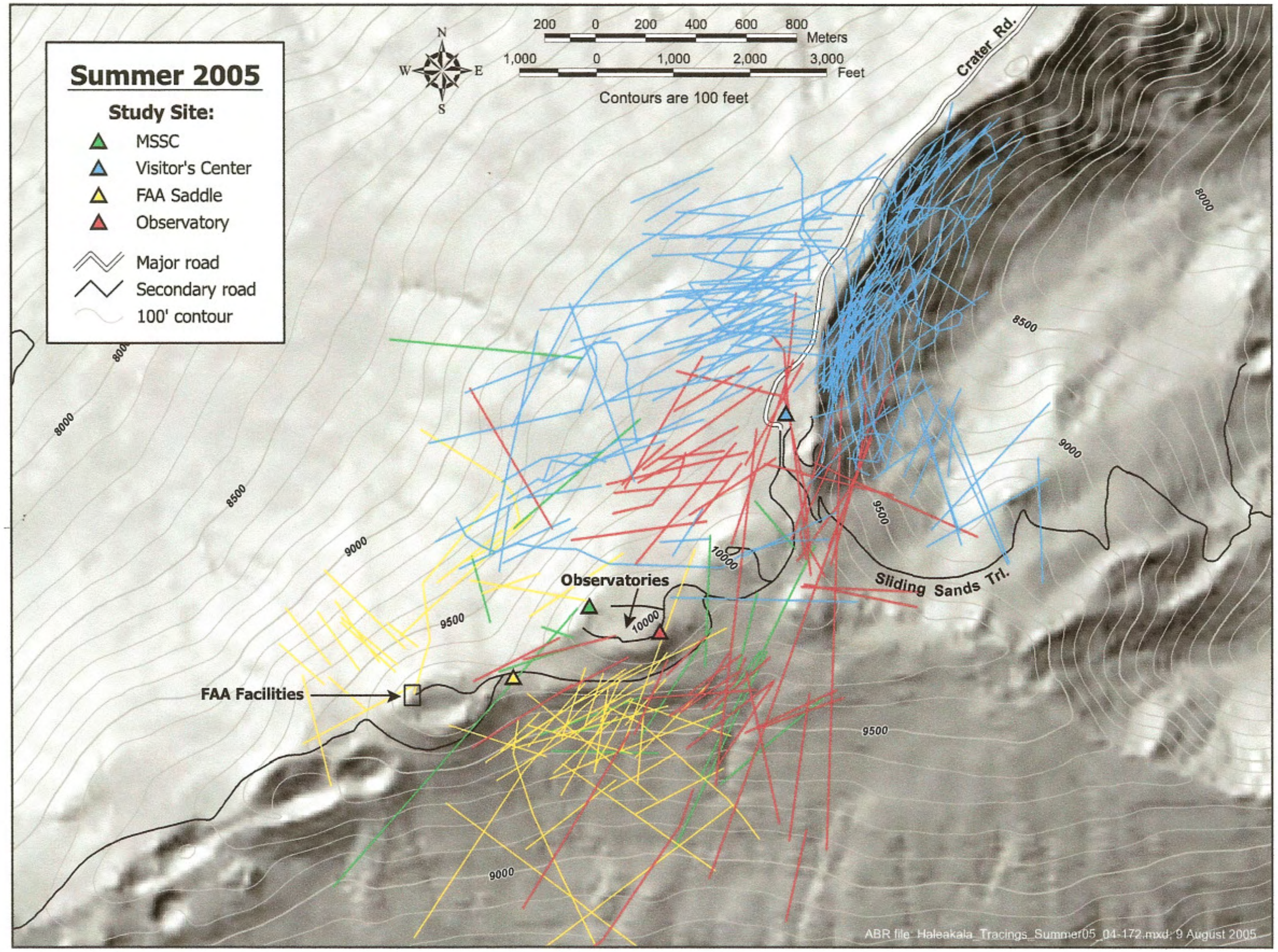

Figure 8. Flight tracklines of Hawaiian Petrels flying near the summit of Haleakala, Maui Island, summer 2005. Tracklines are colored to match the site (colored triangles) at which they were recorded.

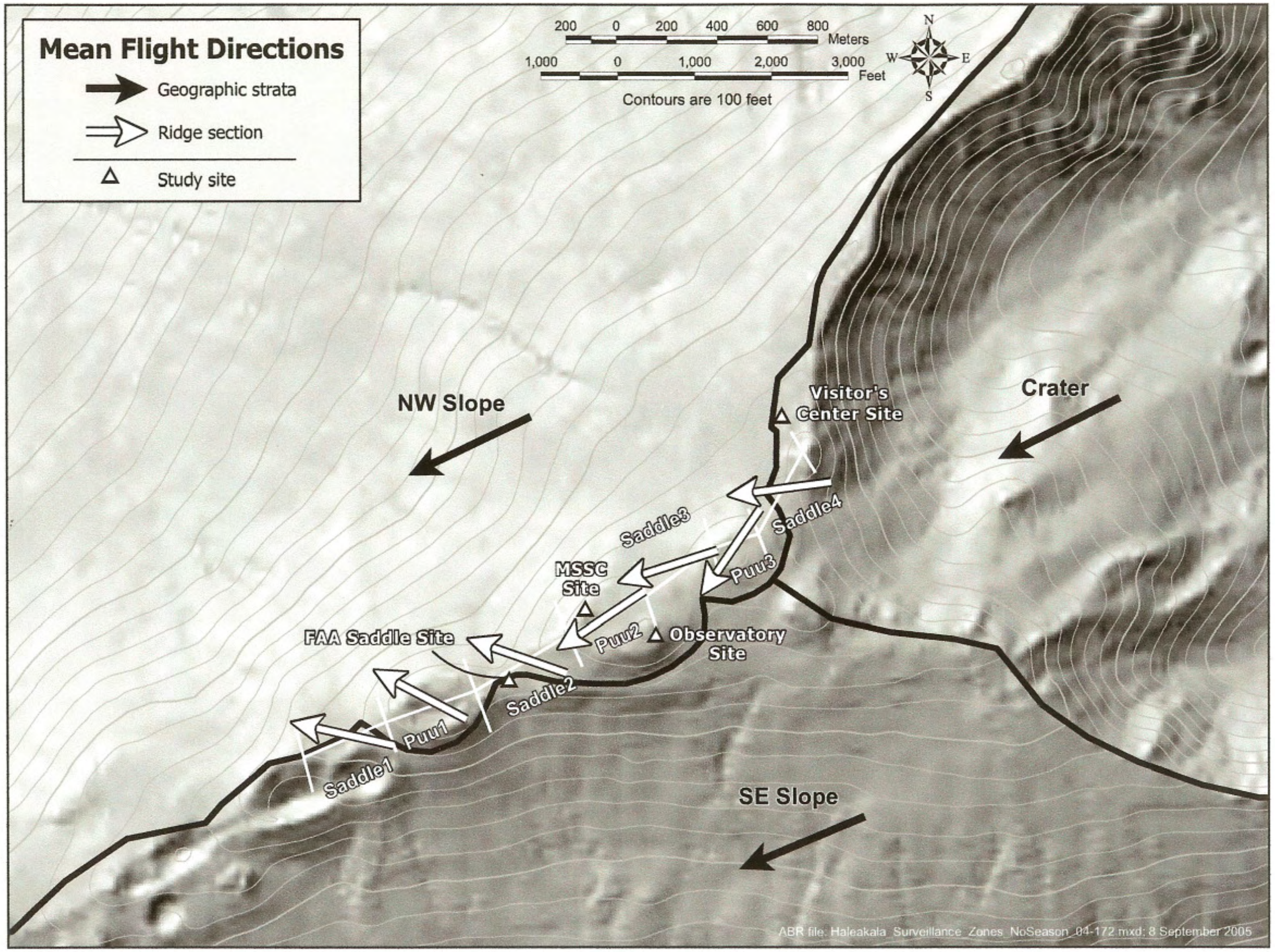

Figure 9. Flight directions of Hawaiian Petrel radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005 combined. Arrows show mean flight directions for the three geographic strata and the seven ridge sections.

Table 5. Flight directions of radar targets sampled near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by geographic stratum and ridge section (Fig. 1). Data are presented as mean (° True), circular SD (*S'*), directional vector (*r*), and sample size (*n* targets).

Stratum/section	Mean	*S'*	*r*	*n*
STRATUM				
NW Slope	245	28	0.88504	303
SE Slope	247	36	0.82086	116
Crater	243	66	0.51355	186
SECTION				
Saddle 1	282	38	0.80270	32
Pu'u 1	298	23	0.92308	30
Saddle 2	289	53	0.65440	46
Pu'u 2	235	61	0.56424	17
Saddle 3	252	75	0.42843	14
Pu'u 3	214	62	0.56066	14
Saddle 4	262	55	0.63026	33

Table 6. Overall directions of travel of radar targets sampled near the summit of Haleakala, fall 2004 and summer 2005, by ridge section (Fig. 1). Data are presented as proportions of the total number of targets in each section whose flight path was traveling with (≤ ± 62° of the mean), traveling away from (≤ ±62° of [the mean – 180]), and traveling perpendicular to (≤ ± 22° of [the mean ≤ ± 90°]) the mean flight direction.

Section	Mean direction (°)	Proportion traveling with mean direction	Proportion traveling away from mean direction	Proportion traveling perpendicular to mean direction
Saddle 1	282	90.3	6.5	3.2
Pu'u 1	298	96.7	0.0	3.3
Saddle 2	289	77.8	8.9	13.3
Pu'u 2	235	70.6	5.9	23.5
Saddle 3	252	40.0	0.0	60.0
Pu'u 3	214	78.6	14.3	7.1
Saddle 4	262	71.9	12.5	15.6

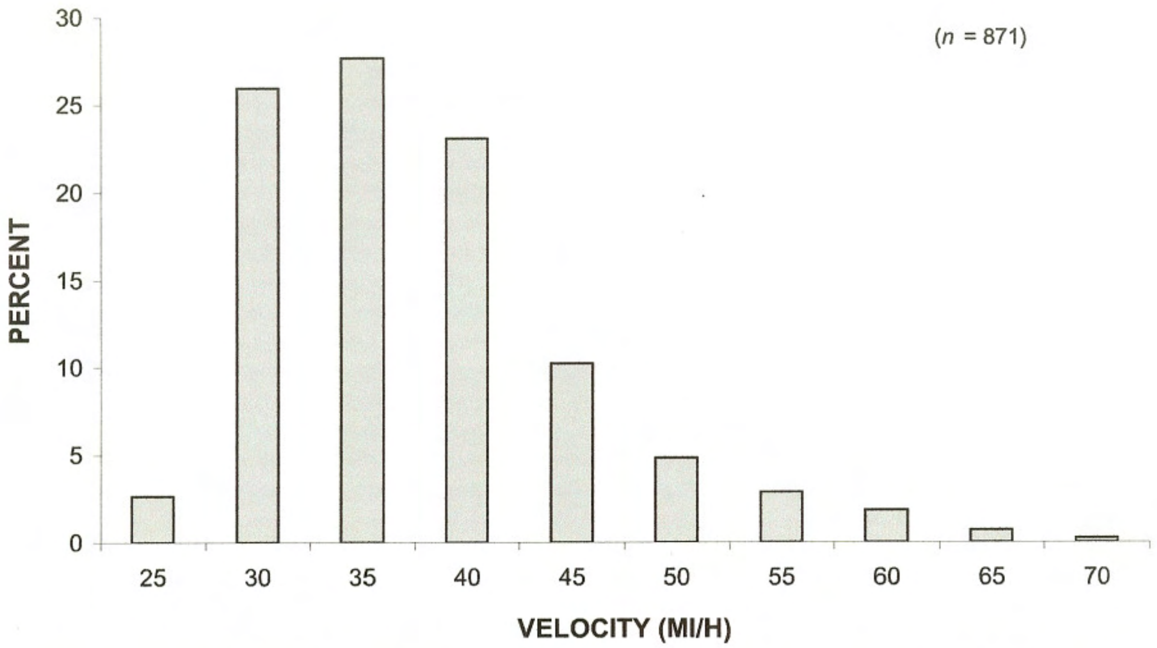

Figure 10. Velocity (mi/h) of Hawaiian Petrel radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005 combined. Data are presented as the percentage of all targets in each velocity category.

Table 7. Velocity (mi/h) of radar targets of Hawaiian Petrels and Newell's Shearwaters sampled on the Hawaiian Islands, 1992–2005.

Island	Years	Mean ± SE	Range	*n*
Kaua'i	1992–2002	36.6 ± <0.1	25–70	18,206
Maui (excluding Haleakala)	1999–2004	42.9 ± 0.1	30–60	1,312
Maui (Haleakala)	2004–2005	37.7 ± 0.3	25–70	871
Hawai'i	1994–2003	38.4 ± 0.1	30–65	4,104

and ~87% flew 30–49 mi/h; in contrast, <3% of all targets that we were certain Hawaiian Petrels flew <30 mi/h. Mean velocities recorded near the summit of Haleakala in this study were similar to, and within the range of, mean velocities recorded on Maui in previous years and to those recorded on other Hawaiian Islands (Table 7). In fact, excluding the high mean values for Maui in previous years (mean 42.9 mi/h), all mean velocities differed by <2 mi/h, with the Haleakala data in 2004–2005 falling between estimates for Kaua'i and Hawai'i.

FLIGHT BEHAVIOR

Flight behaviors differed substantially in frequency between seasons. In fall 2004, straight-line, directional flight occurred just under 100% of the time, with erratic flight occurring 0.2% of the time and circling behavior not recorded at all (Fig. 11). In contrast, in summer 2005, straight-line flight occurred only ~74% of the time, whereas erratic flight occurred ~23% of the time and circling behavior occurred ~2% of the time. These proportions differed significantly between seasons ($\chi^2 = 144.613$; df = 2; $P < 0.001$), indicating a significant seasonal difference in overall behavior. Erratic flight behavior showed the greatest seasonal change by increasing in frequency in summer 2005 and contributed a χ^2 value of 117.7 to the total value. Chi-square contributions for the other two behaviors indicated a significant increase in the frequency of erratic behavior and circling behavior ($\chi^2 = 11.673$) and a significant concomitant decrease in the frequency of straight-line flight ($\chi^2 = 15.239$) from fall 2004 to summer 2005.

FLIGHT ALTITUDES

The mean minimal flight altitude of all targets recorded on vertical radar was 175 ± SE 14 m agl (range = 2–856; n = 116). The mean altitude, however, was significantly higher in fall 2004 (239 ± 19 m agl; range = 2–856; n = 70) than in summer 2005 (79 ± 13 m agl; range = 3–436; n = 46; Table 8), indicating that we could not pool data between seasons in our analysis of factors affecting flight altitude (see below). Eight models were within two AIC_c units of the top-ranked model, indicating that all potentially could be plausible models to explain the data; however, the top three models had similar model weights and included season, wind speed, and/or ceiling height, suggesting that these factors most strongly helped to explain variation in flight altitude (Table 9). The sum of Akaike Weights (Σw_i) provided only moderate support for the importance of wind speed ($\Sigma w_i = 0.550$) and ceiling height ($\Sigma w_i = 0.520$), whereas the Σw_i for cloud cover and precipitation were only 0.334 and 0.328, respectively, indicating low importance (Table 10). Of the five factors examined (season as a covariate and the four weather factors), model-weighted parameter estimates and confidence intervals indicated that only season and wind speed significantly affected flight altitude (Table 10). Flight altitudes averaged 158 m higher (95% confidence interval = 102 to 214 m) in fall than in summer and averaged 60 m higher (95% confidence interval = 0 to 120 m) when wind speeds were >10 mi/h than when they were ≤10 mi/h. Parameter estimates provided little support for an effect of ceiling height and no support for effects of cloud cover and precipitation on flight altitudes.

In both fall 2004 and summer 2005, most detections on vertical radar occurred in the Northwestern Slope stratum (Table 8). In fall 2004, 64% (44 of 69) of the detections occurred above the Northwestern Slope, 33% (23 of 69) occurred above the Crater, and only 3% (2 of 69) occurred above the Southeastern Slope. In summer 2005, 83% (34 of 41) detections occurred above the Northwestern Slope, 10% (4 of 41) occurred above the Crater, and 7% (3 of 41) occurred above the Southeastern Slope. We were unable to test for differences in flight altitudes between strata because sample sizes in all strata except the Northwestern Slope were too small for statistical validity. We did, however, calculate mean flight altitudes over the Northwestern Slope: 261 ± SE 26 m agl (n = 44) for fall 2004, 71 ± 13 m agl (n = 34) for summer 2005, and 178 ± 19 m agl (n = 78) overall.

Seasonal differences in the distribution of flight altitudes within the air column followed the same pattern as mean flight altitudes in each season, with flight altitudes in fall 2004 being significantly higher than altitudes in summer 2005 ($D_{max} = 0.670$, $Z = 4.738$, $P < 0.001$). In fall 2004 (summer 2005), 13.0% (80.5%) of all targets flew 1–100 m agl, 47.8% (90.2%) flew 1–200 m agl,

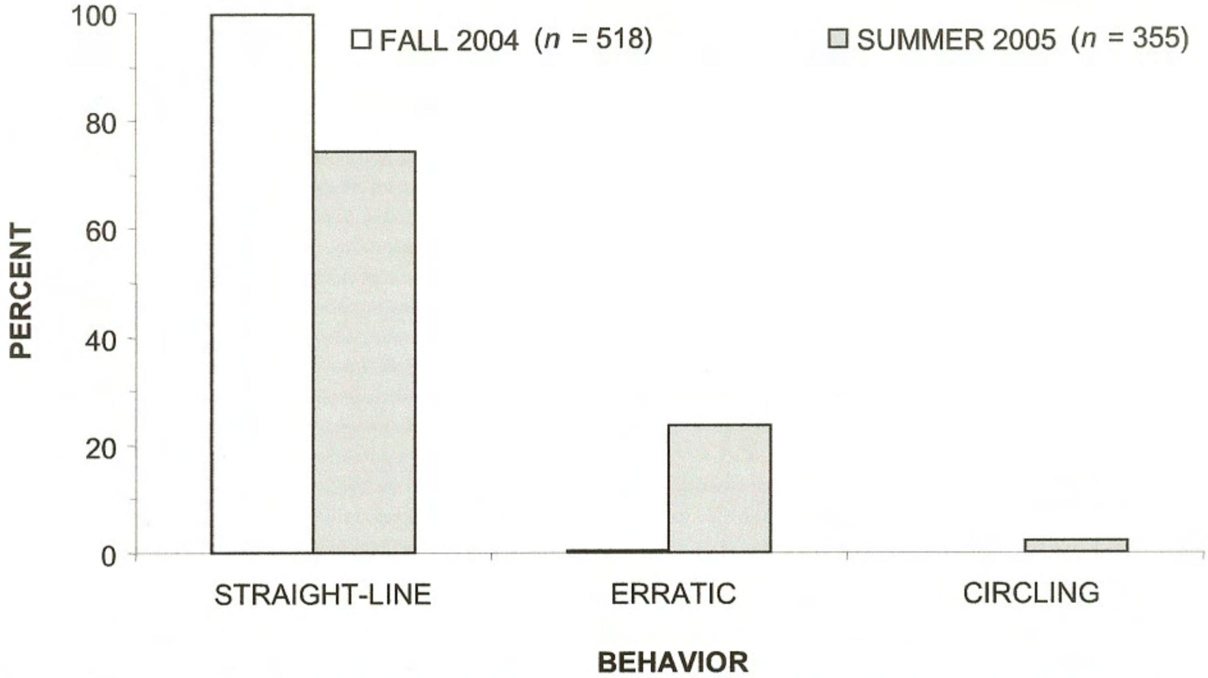

Figure 11. Behavior of Hawaiian Petrel radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by season.

Table 8. Flight altitude (m agl) of radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by season and geographic stratum.

		Flight altitude (m agl)		
Season	Stratum	Mean ± SE	Range	*n*
Fall 2004	Northwestern slope	261 ± 26	2–856	44
	Southeastern slope	184 ± 50	134–233	2
	Crater	203 ± 28	34–727	24
	Total	239 ± 19	2–856	70
Summer 2005	Northwestern slope	67 ± 11	3–367	38
	Southeastern slope	78 ± 6	69–93	4
	Crater	192 ± 84	51–436	4
	Total	83 ± 14	3–436	46

Table 9. Model-selection results for factors affecting flight altitudes (m agl), of Hawaiian Petrels flying near the summit of Haleakala, Maui Island, fall 2004 and summer 2005. Models examined the effects of the factors precipitation, wind strength, ceiling height, and cloud cover on the response variable. These models have a ΔAICc of ≤2.

Model	RSS[a]	*n*[b]	K[c]	AICc[d]	ΔAICc[e]	w_i[f]
Season, wind speed	1,984,282	116	4	738.88	0.00	0.154
Season, ceiling height	1,992,929	116	4	739.10	0.22	0.138
Season, wind speed, ceiling height	1,911,632	116	5	739.19	0.31	0.132
Season, precipitation	2,034,159	116	4	740.13	1.25	0.082
Season, cloud cover	2,034,844	116	4	740.15	1.27	0.082
Season, wind speed, cloud cover	1,962,868	116	5	740.52	1.64	0.068
Season, wind speed, precipitation	1,973,984	116	5	740.81	1.93	0.059

[a] Residual Sum of Squares.
[b] Sample size.
[c] Number of estimatable parameters in the approximating model.
[d] Akaike's Information Criterion corrected for small sample size.
[e] Difference in value between AICc of the current model and that of the best approximating model ($AICc_{min}$).
[f] Akaike Weight—probability that the current model (*i*) is the best approximating model among those considered.

Table 10. Model-weighted parameter estimates and sum of Akaike weights (Σw_i) for the parameters in candidate models for flight altitude of Hawaiian Petrels near the summit of Haleakala, Maui Island, fall 2004 and summer 2005. The sum of Akaike Weights for both the intercept and season was 1.000 because those parameters were included in all models.

Model parameter	Σw_i	Estimate	SE	*P*
Intercept	1.000	110.14	52.37	0.035
Season	1.000	158.06	28.34	<0.001
Wind speed	0.550	–59.90	30.70	0.051
Ceiling height	0.520	–68.13	39.17	0.082
Cloud cover	0.334	7.20	63.54	0.910
Precipitation	0.328	–4.81	52.41	0.927

76.8% (95.1%) flew 1–300 m agl, 88.4% (97.6%) flew 1–400 m agl, and 94.2% (100.0%) flew 1–500 m agl (Fig. 12). Hence, the greatest seasonal difference in the distribution of targets within the air column occurred in the lowest 200 m (and especially the lowest 100 m) of the air column, with a much higher percentage of birds flying at low altitudes in summer than in fall.

As a check on the radar-based estimates of flight altitude, we calculated the mean flight altitude of all Hawaiian Petrels seen flying inland or seaward on Kauai in 1992–2002 (Day and Cooper, unpubl. data) and compared them with our pooled Maui vertical radar data from 2004–2005 (Fig 13). Those birds on Kauai flew at a mean altitude of 236.8 ± SE 8.5 m agl (n = 556; range = 10–1,000 m), or ~30% higher than what we recorded in this study. On Maui (Kauai), 38.2% (36.7%) flew 1–100 m agl, 63.7% (56.7%) flew 1–200 m agl, 83.7% (74.2%) flew 1–300 m agl, 91.9% (85.3%) flew 1–400 m agl, and 96.4% (90.8%) flew 1–500 m agl. As might be expected from a visual examination of the data (Fig. 13), these two distributions were not significantly different (D_{max} = 0.090, Z = 0.636, P = 0.813). In addition, patterns for both locations suggest that the number of Hawaiian Petrels in the air column decreases logarithmically with increasing height above ground; both patterns show extremely high R^2 values (Maui R^2 = 0.943, Kauai R^2 = 0.961), indicating an excellent fit to an exponential-decay model. Both of these results suggest that, although there are seasonal differences in the dispersion of Hawaiian Petrels in the air column near the summit of Haleakala, overall patterns of dispersion of birds in the air column across all seasons are similar between the two locations.

VISUAL SAMPLING

We conducted visual sampling concurrently with radar sampling at all sites in both fall 2004 and summer 2005. We detected no Hawaiian Petrels visually in fall 2004. In summer 2005, we detected 107 Hawaiian Petrels. The timing of movements detected visually was similar to that for movements detected with radar at this site, in that we saw none until after the point of complete darkness. Further, we visually detected slowly-flying petrels circling and gliding at the Visitor's Center, suggesting that those radar targets traveling 25–30 mi/h and flying in circular or erratic patterns near the nesting colony were Hawaiian Petrels. Hawaiian Petrels occasionally were heard calling and seen flying 4–8 m above the parking lot of the Visitor's Center, usually beginning within 10 min of complete darkness. Birds also were heard calling elsewhere while flying, and some were heard calling from nesting crevices on the ground. At least three individuals crossed the parking lot and landed on the rocky slope of Paka'oa'o (also called White Hill; south of the parking lot) during the first hour of complete darkness. High levels of activity continued for 2^+ h after complete darkness, with birds seen circling the summit of Paka'oa'o in groups of 1–4 birds. We also saw birds flying inside the crater, both along the crater wall and across the center of the crater; we assume that these were subadults displaying off the nesting area. This flight often consisted of circling or erratic behavior and typically involved little flapping. Both visual and auditory detections decreased ~3 h after complete darkness, suggesting a reduction in displaying activity.

The mean minimal flight altitude of Hawaiian Petrels seen flying near the Visitor's Center was 12.4 ± 1.6 m agl (n = 107; range = 2–100 m agl). Over three-fourths (~79%) of the petrels flew ≤15 m agl, suggesting that many of the birds in this location were flying at altitudes so low that they would not have been detected by the radar. In the first hour after complete darkness, petrels flew directly to the rocks and dropped onto the surface of the colony. As the night progressed, we saw petrels circling and calling above the summit of Paka'oa'o, rather than landing in the colony. We also saw petrels circling and gliding over the rim of the crater. Flight altitudes relative to ground level were higher for birds over the crater than for birds flying over Paka'oa'o because the crater walls drop steeply from the rim.

Because we recorded all petrels visually at the Visitor's Center in summer 2005, we used the summer subset of the radar data at the same site for a comparison of flight behavior (Fig. 14). The radar data for the Visitor's Center area indicated that ~82% of the radar targets were flying with straight-line behavior, ~16% flew erratically, and ~2% flew by circling. In contrast, the visual data indicated that ~13% of the birds (essentially equal

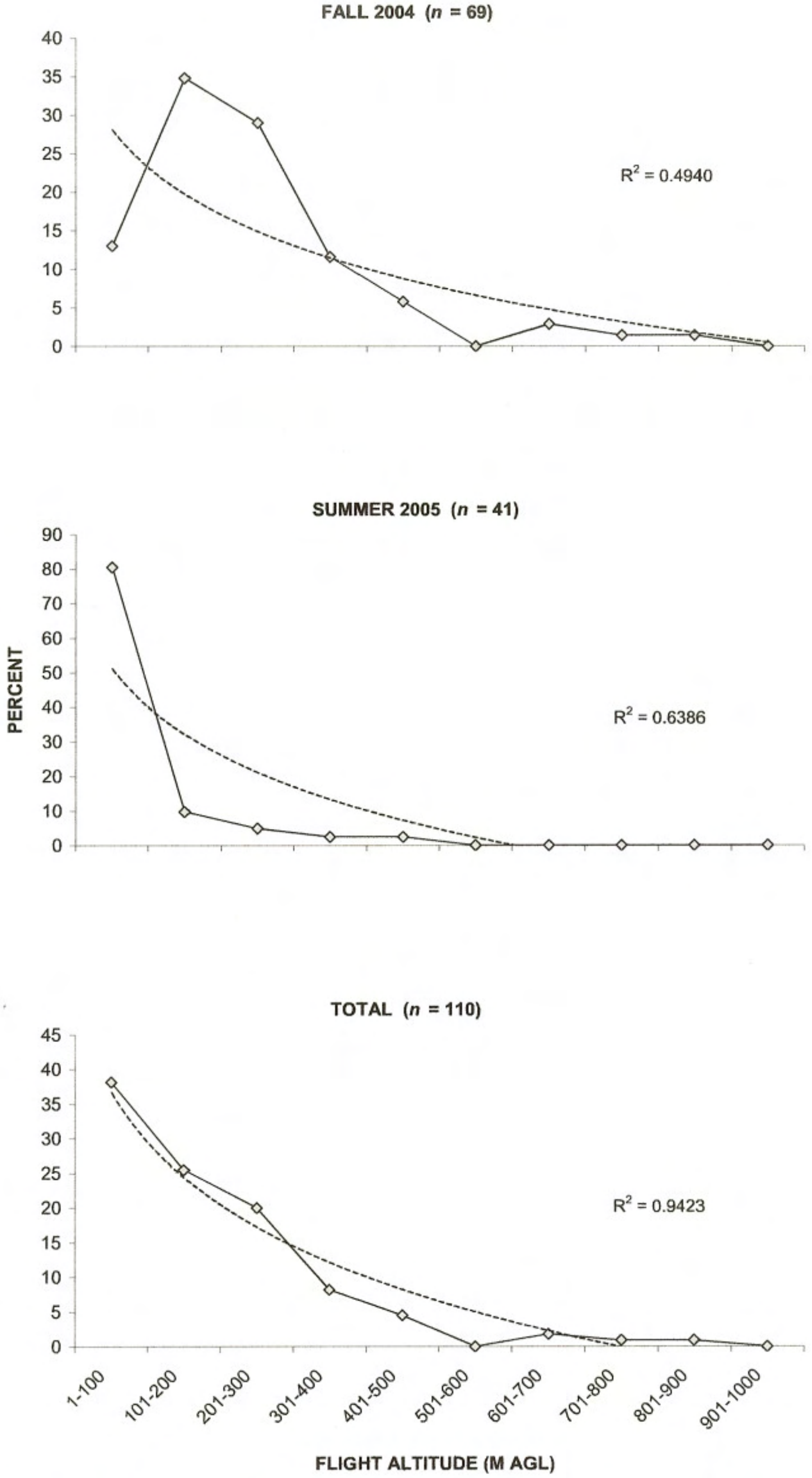

Figure 12. Minimal flight altitudes (meters agl) of Hawaiian Petrel radar targets measured on the vertical radar near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by season and combined. Data are plotted as the percentage of all targets flying that minimal altitude in each altitude category. A fitted logarithmic curve also is included; the Coefficient of Determination (R^2) is listed for this curve fitted to the categorical data.

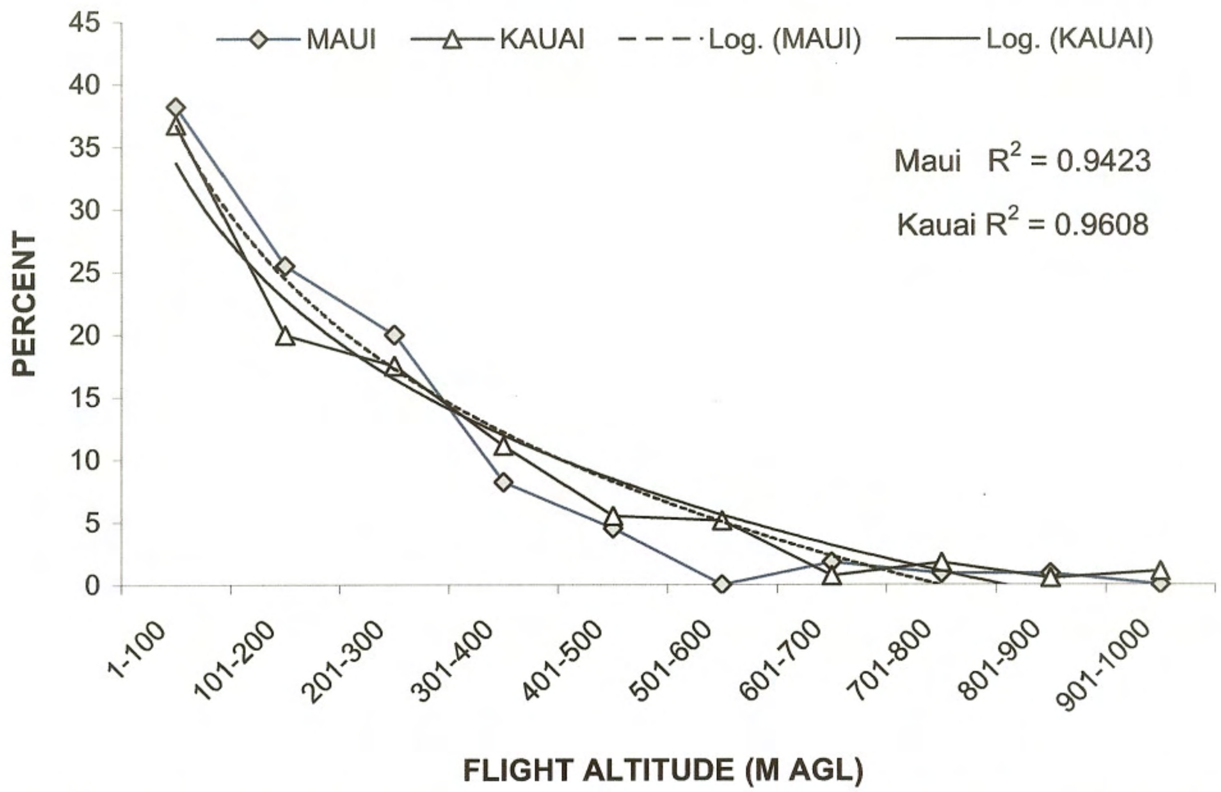

Figure 13. Minimal flight altitudes (meters agl) of Hawaiian Petrel targets measured on the vertical radar near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, and flight altitudes estimated visually for flying birds observed at Kaua'i Island, 1992–2002. Data are plotted as the percentage of all targets flying that minimal altitude in each altitude category. A fitted logarithmic curve also is included; the Coefficient of Determination (R^2) is listed for this curve fitted to the categorical data. Sample sizes (n) are 110 for Maui and 566 for Kaua'i.

to radar targets, because the mean number of Hawaiian Petrels/flock = 1.02 ± SE 0.01; n = 585 flocks; Day and Cooper, unpubl. data) flew with straight-line behavior, ~2% flew erratically, and ~85% flew by circling. There was a highly significant difference in these proportions (χ^2 = 237.565; df = 2; P <0.001), indicating a great difference in behavior between what petrels were doing in the area as a whole and what the subset that we were able to detect visually near the ground was doing. All three behaviors contributed significant Chi-square values to this overall value, although the contribution from differences in proportions of circling behavior contributed the most (straight-line = 37.875; erratic = 32.046; circling = 167.736).

DISCUSSION

Movements of Hawaiian Petrels near their breeding colonies are influenced by the stage of the breeding cycle. Petrels observed at the colony during the summer include nesting adults and non-breeding birds that are prospecting for burrows and/or mates. Attendance patterns in the summer showed a sharp increase within 30 min of complete darkness, followed by a steady decline in activity throughout the rest of the evening. Petrels that arrived in straight-line flight within an hour of complete darkness probably were breeding adults returning to burrows (Simons 1985, Hodges 1994). Later arrivals tended to circle and call over the colony and probably were non-breeding birds (subadults and possibly some adults) engaging in

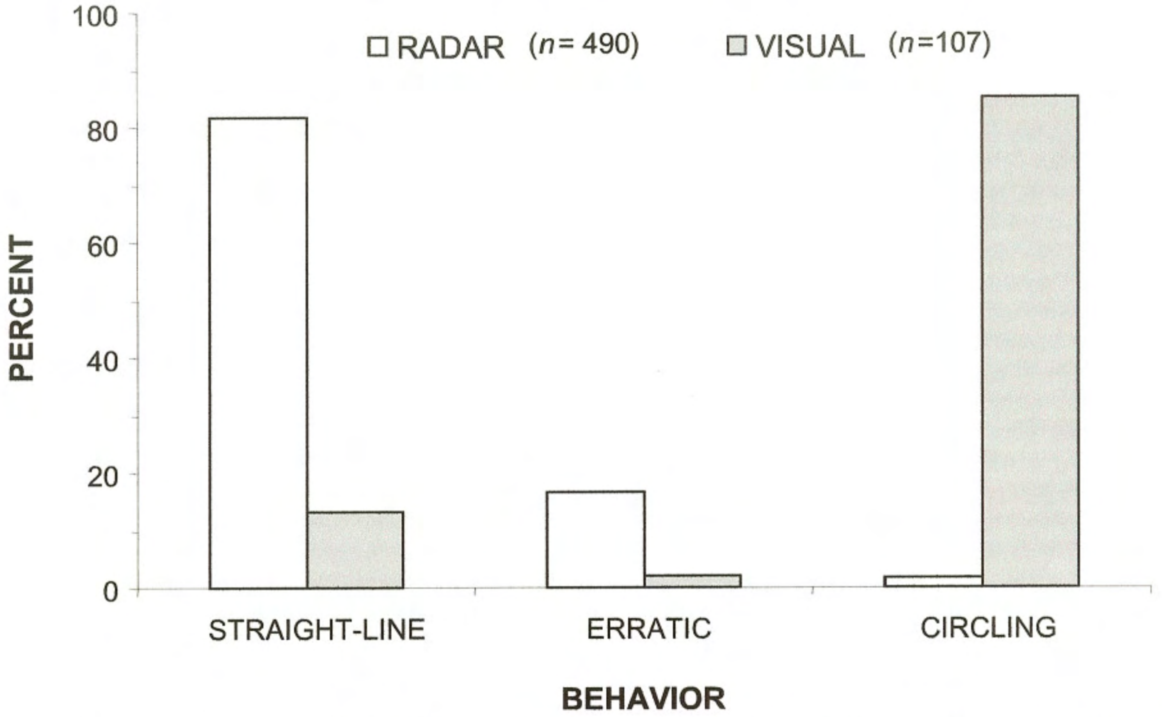

Figure 14. Behavior of Hawaiian Petrel radar targets and behavior of visually-observed birds at the Visitor's Center Site near the summit of Haleakala, Maui Island, in summer 2005.

courtship displays. Waring (1996) reported circling activity over Paka'oa'o during pre-laying, similar to what we saw for displaying birds during incubation.

Most non-breeders abandon the colony in late July, so fall sampling coincided with late chick-rearing, when essentially only breeders are present (Simons 1985). Movement patterns in the fall averaged greater than 10 targets/h for the entire sampling period, indicating sustained activity to/from the colony by adults feeding chicks. During fall sampling, breeding petrels may be visiting the colony frequently to feed chicks.

MOVEMENTS

Movement rates differed among sites, with consistently the lowest rates seen near MSSC (both at the MSSC Site and at the MSSC Gate/Observatory Site) and consistently the highest rates seen near the Crater (at the Visitor's Center Site). Only the FAA Saddle Site showed a seasonally-variable pattern, being high in fall 2004 but very low in summer 2005. Although it is possible that some of these differences in mean movement rates may be attributable to variable radar shadows among sites, we believe that they primarily reflect differential use of this area by nesting adults and displaying non-breeders (subadults and non-breeding adults). Clearly, the Crater is where most breeding and nesting activity occurs, both based on the radar data and on visual and auditory data, in that displaying birds vocalize while displaying over specific areas. We heard no birds displaying, saw no birds visually, and saw many fewer birds on radar over that part of the colony located on the ridge to the southwest of the Crater than we did over the Crater itself. This spatial pattern matches information of the Petrel Biologist at the National Park, who estimates that only ~2% of burrows in the vicinity of the ridge are occupied, whereas essentially all available nesting habitat in the Crater itself is being occupied (C. Bailey, Haleakala National Park, Makawao, HI, pers. comm.). Perhaps most striking to us was the lack of calling birds displaying over this southwestern part of the colony, suggesting either essentially no productivity for many years (i.e., no young have been produced to come back and attempt to enter the breeding population) or a shift in the location of most breeding birds toward the Crater. The cause(s) for this decline in this part of the colony are unknown but may reflect predation (that part of the colony in the Crater is protected by extensive trapping of predators; Hodges 1994) and/or disturbance by grazing animals or human activities.

Seasonal patterns of mean movement rates differed at two sites, with fall being higher than summer at MSSC and the FAA Saddle, and both seasons being similar at the Visitor's Center and the MSSC Gate/Observatory. Two of these results (MSSC and FAA Saddle) differ from the seasonal pattern identified by Day and Cooper (1995), who found that mean movement rates at most sites on Kauai declined from summer to fall. These two studies may differ in part because this study was conducted at breeding colonies, whereas Day and Cooper's work was conducted near the ocean, as birds headed inland or seaward. These studies also may differ because displaying birds in the summer tend to fly at very low altitudes—probably many of which are below the ability of the radar to sample (see below)—resulting in an underestimation of summer abundance at the colony.

Hawaiian Petrels fly inland from coastal sites primarily within 15 min before the point of complete darkness (Day and Cooper 1995, unpubl. data; Cooper and Day 2003). We observed petrels arriving on the colony within 30 min after complete darkness, indicating that these birds can gain 3,000 m in elevation while traveling 6–15 km horizontal distance in less than 1 h. The peak of movement rates was ~1 h after complete darkness, suggesting that most petrels make the trip from the sea to the colony in 1–1.5 h.

The flight-direction analyses and the maps of target locations suggested a discernible pattern of movement of Hawaiian Petrels near the summit of Haleakala. Petrels flying upslope from the southeastern side of the island generally flew toward the southwest as they approached the summit of the mountain, skirting along the southern edge of the southwestern ridge; some birds leaving the Crater's southern part also may do the same. They crossed the ridge between the Southeastern and Northwestern slopes in many locations, with a slightly higher rate (mean 55.2 targets/section) for saddles than for pu'us (mean 48.7 targets/section). Flight was highly directional at the western part of the ridge but became less so as birds approached the Crater. Birds on the Northwestern Slope also flew strongly toward the southwest, with many of those birds coming out of the Crater. We suspect, however, that the apparent similarity of mean flight directions between the Crater and those for the other geographic strata simply may be a statistical artifact, in that many erratically-flying and circling birds had no flight directions (they were considered to be non-directional in many cases) and, therefore, were excluded from this analysis. Of those birds whose directions we were able to measure, most were flying toward the southwest from the Crater, but many birds circling and flying erratically at the Crater were not flying toward the southwest.

This spatial movement pattern is different from what we expected, although nobody had ever studied movements near a nesting colony before. We expected to see movement in both directions over the ridge and along the northwestern slope, with birds flying to and from the Crater. In contrast, the overall direction in nearly all locations measured with radar was toward the southwest, with birds crossing over the ridge and birds on both of the large slopes flying toward the southwest. This overall movement pattern was consistent between seasons and suggests a net movement of birds toward the southwest, which would have them leaving the island toward the southwestern part of East Maui (i.e., near Makena Bay). Cooper and Day (2003) saw little movement of birds in that area, however, so perhaps the petrels change course over the lower part of the Northwestern Slope and head back toward the Crater below the sampling ability of the surveillance radar (literally "below the radar"). Alternatively, some of the targets may have been misidentified large moths, which occasionally are seen at these altitudes (Cooper and David 1995), form large targets that resemble those of petrels, and would be expected to travel toward the southwest (i.e., with the wind); however, we do not believe that contamination of the data set by these specific moths could be so great that it could significantly affect the results. Hence, although this pattern of movement was pronounced, we cannot explain with confidence at this time why it was the way it was and why it differed from our expectation.

FLIGHT VELOCITY

Flight velocities averaged ~37 mi/h, which is nearly identical to velocities of these birds measured on Maui in different years and measured elsewhere in the Hawaiian Islands. Therefore, it appears that these birds fly at the same speed both at low elevations, as they fly to/from nesting colonies, and at high elevations, as they fly over the colonies. This consistency of flight velocities implies that there is an optimal flight speed of these birds, presumably based on wing-loading and wing-shape characteristics, that rarely is changed dramatically.

FLIGHT BEHAVIOR

Flight behaviors differed significantly between seasons, with birds in summer exhibiting primarily erratic and circling behaviors and birds in fall exhibiting primarily straight-line, directional behaviors. This seasonal difference parallels what we know about attendance of birds of different breeding status at nesting colonies. In the summer, non-directional behaviors dominated because they were conducted by displaying subadults and non-breeding adults (also see Waring 1996). In contrast, most of the straight-line behaviors probably were exhibited by breeding adults, which tend to fly straight to burrows. In the fall, straight-line flight dominated because non-breeders were absent from the colony, leaving breeding adults, who were feeding chicks, to fly straight to burrows.

FLIGHT ALTITUDE

Minimal flight altitudes differed significantly between seasons, being higher in the fall than in the summer; they also were significantly affected by wind speed, in that they flew at higher altitudes when winds were >10 mi/h than when they were ≤10 mi/h. In contrast, cloud cover and precipitation had little effect on flight altitudes; ceiling height also had a small effect, but it was not significant. Effects of weather on flight altitudes of this species have not been studied previously. Our results suggest that season and wind speed (and possibly ceiling height) may influence flight altitudes. Further studies can increase the power to determine what effects weather may have on flight altitudes and improve our estimates of these effects.

Visual sampling by Hodges (1992) at a site along the ridge southwest of the FAA facilities in June 1992 suggested that a substantial number of birds there were flying ≤10 m agl, consistent with the low altitudes (mostly of displaying non-breeders) we recorded during the summer. Most of her birds, however, were heard, rather than seen, and few high-flying birds and no non-calling birds could be detected with her methods, precluding a quantitative assessment of the distribution of birds in the airspace. Our data indicate that a substantial proportion of petrels probably is flying high enough to be detected by radar, although an indeterminate number of petrels is flying too low for the radar to detect them at all times.

Minimal flight altitudes of Hawaiian Petrels as measured by vertical radar over the nesting colonies on Maui during both seasons combined showed a pattern similar to that for petrels studied visually on Kaua'i Island (Day and Cooper 1995, unpubl. data). In fact, both data sets indicated that the number of Hawaiian Petrels in the air column generally decreases exponentially with increasing altitude and in a pattern that was virtually identical between the two locations.

VISUAL SAMPLING

Activity as detected by the visual sampling matched what we saw with the radar sampling. Birds generally arrived on the breeding colonies shortly after the point of complete darkness but became more common over the next 1–1.5 h. Displaying birds circled and flew erratically over the nesting colonies while calling; some birds also called from nesting sites on the ground, indicating that they were pre-breeding subadults that had been able to secure a potential nest and were calling to advertise for a mate. Activity generally decreased toward midnight, similar to what we saw on radar. The Petrel Biologist for the National Park also believes that petrel activity on the colonies decreases somewhere around midnight (Bailey, pers. comm.).

We saw as many as 49 individuals in one night of sampling at the Visitor's Center Site in summer 2005. We suspect that movement rates of petrels detected visually may not be comparable to movement rates detected by radar. The range of visual detections was limited by (1) the strength of the beam from the spotlight, and (2) the low power of the night-vision goggles. Many of the petrels seen at the Visitor's Center were circling just over the summit of Paka'oa'o and often would disappear behind the summit of the hill. It is possible that we were seeing the same several birds repeatedly, rather than seeing many different individuals.

During visual sampling in summer 2005, behavior was dominated by erratic and circling flight, a pattern significantly different from that recorded by the radar overall at the same location (dominance of straight-line flight). This difference indicates that there was a great difference in behavior between what petrels were doing over the entire sampling area (range = 1.5 km) and the behavior of those petrels we could detect visually near the ground (range ≤~100 m). We suspect that much of this difference occurred because displaying birds over the colonies flew at low altitudes and would have been lost in the ground clutter on the radar screen.

Minimal flight altitudes estimated from birds detected visually were low, much lower than those measured with the radar. Almost 80% of the petrels flew ≤15 m agl, suggesting that many of the birds in this location were flying at altitudes so low that they would not have been detected by the radar. To some extent, this apparent bias is exacerbated by the fact that the low-flying birds were displaying birds that were not breeding anyway. The analysis of flight altitudes (above) suggests that, on an annual basis, the most petrels will be flying at very low altitudes. It is clear that the radar cannot detect all birds flying over the landscape at all times, resulting in an underestimation of movement rates.

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APPENDIX I

Stormwater Management Plan for HO, March 2006

Stormwater Management Plan
For Haleakalā High Altitude Observatory

Prepared for

University of Hawai‘i
Institute for Astronomy

Prepared by

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March 2006

1.0 Introduction

Purpose

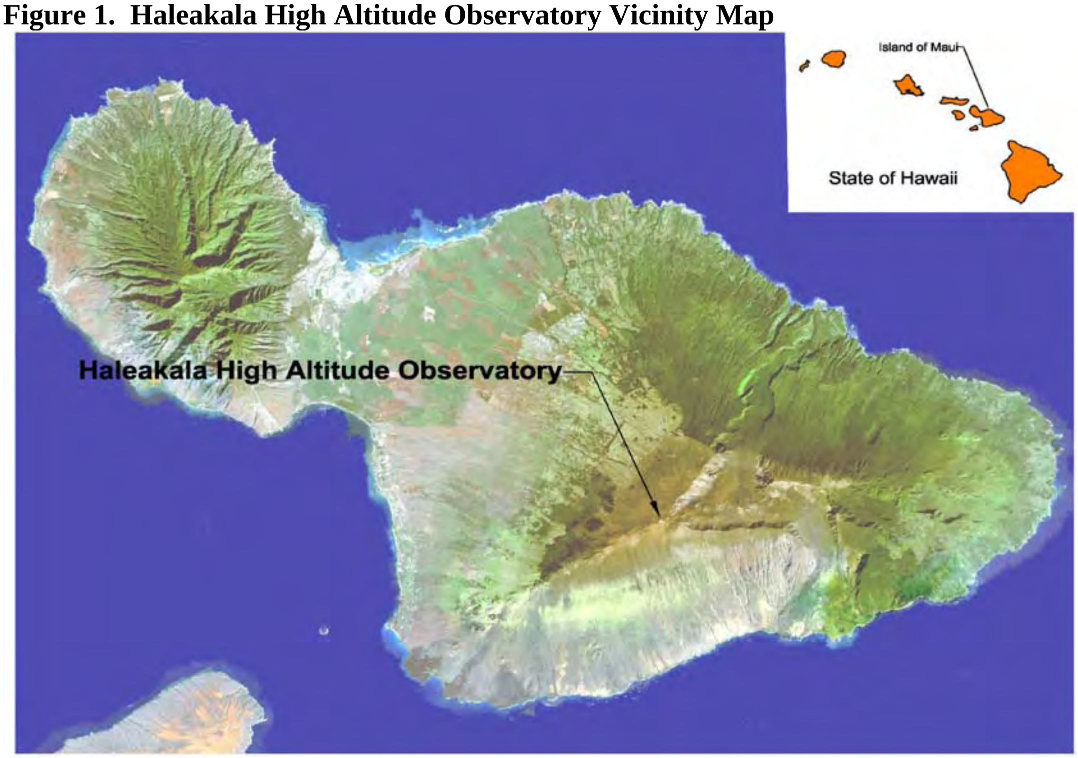
The observatories at the summit of Haleakalā have been an important and valuable asset to astronomers for over 50 years. The Haleakalā area also contains both culturally and environmentally significant assets. In the interest of balancing the need of the astronomy community with the needs to protect cultural and natural resources of the area, the University of Hawai‘i Institute for Astronomy (IfA), provides for the control of stormwater runoff from its facilities on Haleakalā, Maui.

IfA contracted with Tetra Tech, Inc. (Tetra Tech) to develop a stormwater management plan (SWMP) for the Haleakalā High Altitude Observatory site (HO). This SWMP details existing stormwater conditions within the HO site, necessary stormwater improvements associated with existing and future site expansion, best management practices (BMP), and recommendations on maintenance practices.

Site Background

The 18.166 acres of land associated with the HO was given to the University of Hawai‘i in 1961 for scientific purposes, by Executive Order from Hawai‘i's Governor. The HO is located on the extinct Kolekole volcanic cinder cone in eastern Maui (Figure 1). The central area of Kolekole crater is a naturally flattened bowl of ponded ankaramite lava, spatter, and pyroclastic ejecta. There are believed to be two volcanic vents within the HO site. The primary vent is located approximately under the new Pan-STARRS facility, located on the southeast quarter of the cone (Figure 2). The second vent is likely within the wide depression near the western border of the property.

Figure 1. Haleakala High Altitude Observatory Vicinity Map



Ten major structures house the facilities at the HO site (Figure 2). There are also many smaller support structures such as utility buildings, generators, and cisterns located throughout the site. The U.S. Air Force (USAF) operates facilities on the northern side of the site, collectively known as the Maui Space Surveillance Complex. On separately owned land in the western portion of Kolekole, the Federal Aviation Administration (FAA) and Department of Energy (DOE) maintain two buildings. The remaining structures within the site are maintained by the IfA.

Figure 2. Haleakala High Altitude Observatory Site Photograph

For the purposes of this Plan, we have included the evaluation of stormwater conditions on both FAA and DOE lands, because stormwater flow paths on Kolekole and natural drainage include those areas (Figure 3), although UH IfA has no direct responsibility for stormwater management of those areas.

The isolated location of the facility requires potable water to be trucked in. Non-potable water collected in cisterns throughout the facility is used for non-drinking purposes, such as flushing toilets. Wastewater generated at the site is treated using a septic system discharging to a leach field. A stormwater collection system has been constructed within the HO site. Stormwater runoff is collected off impervious surfaces and conveyed to an on-site infiltration basin located near the western end of the HO property. There are a few locations around the site where stormwater runoff flows from impervious surfaces associated with HO observatories and discharges onto the slopes of Haleakalā.

2.0 Analysis of Existing Stormwater Conditions

Stormwater within the HO site is generated from the impervious surfaces associated with the facility. These surfaces include buildings, roads, and parking areas. The native soils within the site generally have the capacity to infiltrate all but the most extreme storm events, whereas the impervious surfaces have no infiltration capacity.

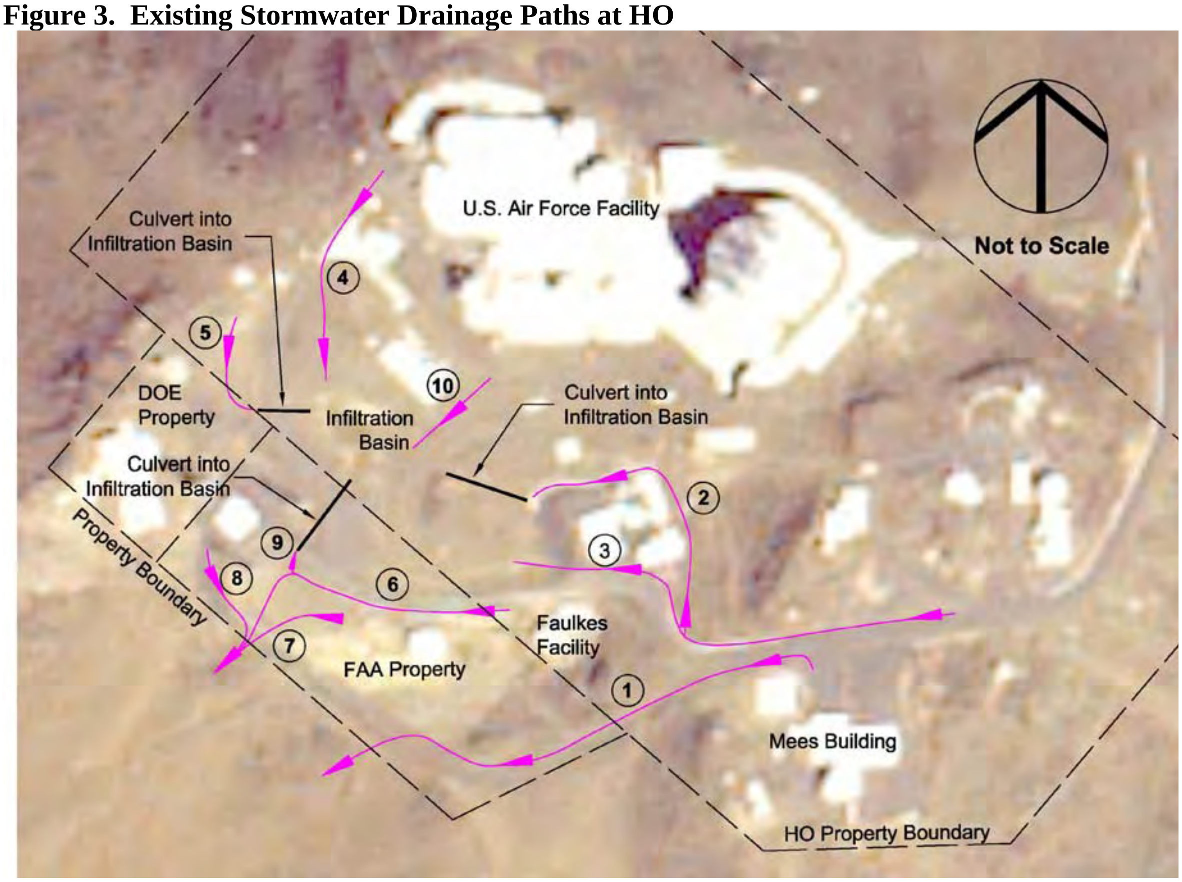
The following sections detail the investigation of the hydrologic characteristics of the HO site. The investigation consisted of identifying runoff flow paths at the facility and assessing infiltration rates at four locations across the facility. Based on the information determined in the field, a hydrologic model of the stormwater system was developed and calibrated. The model allows for the analysis of existing site conditions at the HO as well as the ability to analyze the impacts to the stormwater system that future expansion at the site may cause.

2.1 Stormwater Flow Paths

Stormwater generated within the HO site is controlled and conveyed via natural drainage paths due to site topography, as well as a small collection of stormwater conveyance systems consisting of concrete channels and culverts. The stormwater collection system was originally designed to maintain stormwater runoff on paved surfaces and consists of gutters and channels intended to prevent stormwater from discharging onto native soils adjacent to paved surfaces. Erosion and lack of maintenance has adversely impacted much of the constructed stormwater system. During field work for the SWMP, it was noted that concrete channels designed to convey stormwater to the infiltration basin were blocked with sediment, and fine sediment has accumulated in the infiltration basin, adversely impacting the infiltration capacity of the native soils.

Ten main stormwater flow paths have been identified at the HO site. Figure 3 illustrates the existing runoff patterns associated with the facility. A brief description of each flow path is provided below.

Figure 3. Existing Stormwater Drainage Paths at HO



Flow Path 1- Stormwater runoff from the parking lot associated with the Mees facility leaves the paved surface and flows down an abandoned road. The runoff then flows across a flat area before discharging along the southern slopes of the volcanic cone. A concrete channel constructed to force the runoff to stay on the paved surface and discharge into the infiltration pond failed to mitigate the issue.

Flow Path 2- Runoff from the upper portion of the site drains onto the road and flows into a paved gutter. As designed, the runoff was to enter a concrete channel constructed behind the gathering of buildings and then be conveyed through a culvert into the infiltration basin. Sediment has completely blocked the concrete channel, which has forced the runoff to flow along Flow Path 3.

Flow Path 3- Due to the sediment blockage of the original concrete channel, concentrated runoff flow was redirected along the paved areas associated with the cluster of buildings. An asphalt berm was constructed to direct the runoff away from the buildings and toward the infiltration basin. Once the runoff discharges onto the native material, the flow dissipates into multiple undefined channels leading toward the infiltration basin.

Flow Path 4- Stormwater runoff from a small portion of the Air Force complex, along with runoff from the access road and concrete storage areas, flows along the edge of the road leading toward the infiltration basin.

Flow Path 5- The native soil in this DOE controlled area appears to have been impacted from past activities such as parking and storage. Runoff from this area is conveyed to the infiltration basin through a culvert under the access road.

Flow Path 6- This concrete channel is designed to convey runoff from the road and from the Faulkes facility. The channel leads to two culverts under the access roads. The lower portion of the channel is a deposition location for sediment prior to where it enters the first culvert. The sediment has virtually plugged the channel, forcing runoff to leave the channel and flow toward the south.

Flow Path 7- The native soil in this portion of the HO and FAA site has been impacted by construction activities. The area shows signs of compaction and is currently being used to store construction materials. The compaction of the soil lessens the soil's infiltration rate, resulting in runoff that flows toward the south instead of into the infiltration basin.

Flow Path 8- A portion of the runoff from the FAA facility flows toward the south and discharges over the slopes of the volcanic cone.

Flow Path 9- Runoff within the concrete channel was designed to flow into the infiltration basin through a series of two culverts that were placed under access roads. Sediment deposition has adversely impacted the flow capacity of the two culverts.

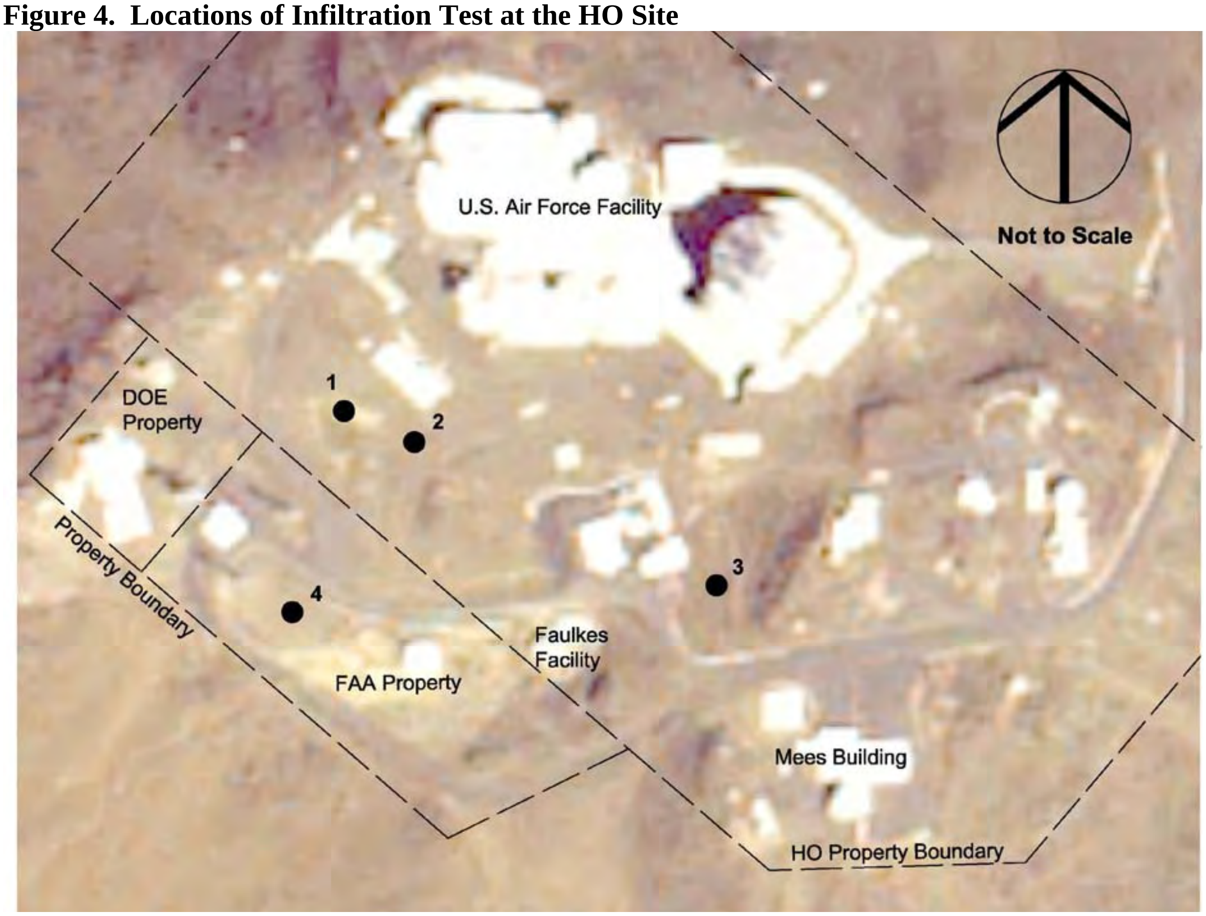
Flow Path 10- A large portion of the Air Force facility generates stormwater runoff that flows into the infiltration basin. The paved surfaces associated with the facility have curbs, which keep the runoff on paved surfaces until it enters the pipe network that discharges into the infiltration basin.

2.2 Assessment of Infiltration Rates

The majority of the stormwater runoff from the HO, FAA, and DOE sites is conveyed to an infiltration basin located in the western portion of the site. The infiltration basin appears to be a natural sink associated with an historic volcanic vent. The rate at which stormwater in the infiltration basin infiltrates into the underlying soils controls the basin's ability to store runoff. If the infiltration rate of the underlying soil is high, stormwater runoff entering the basin infiltrates as it enters and the basin never ponds or fills. If the underlying soil infiltration rate is low, then runoff may enter the pond at a rate higher than it can be infiltrated. The excess flow is then stored in the basin until in can infiltrate. During extended periods of stormwater storage in the infiltration basin, the underlying soils will become saturated, resulting in lower infiltration rates and longer draw-down periods for the infiltration basin.

To better understand the infiltration rate of the basin and the surrounding native soils, infiltration tests were conducted at the HO site. A total of four (4) infiltration tests were conducted within the HO site on October 11, 2005. Figure 4 shows the locations of the tests throughout the site.

Figure 4. Locations of Infiltration Test at the HO Site



The infiltration tests were conducted using infiltration rings. The two-ring method consists of driving two open cylinders, one inside the other, into the ground, partially filling the rings with water and then maintaining the liquid at a constant level. The volume of liquid added to the inner ring during the test is equal to the volume of water infiltrated into the soil. The volume infiltrated during timed intervals is converted to an incremental infiltration velocity expressed in inches per hour.

Site 1— Infiltration Basin, fine sediment. Currently, fine sediment transported into the basin during storm events has been deposited. The fine sediment covers approximately 20% of the infiltration basin area. Where the sediments are deposited, the infiltration rate of the native soils has been adversely impacted, causing infiltration into the underlying soil to be limited. The fine sediments appear to have been deposited into the lower elevation of the pond.

Site 2— Infiltration Basin. The areas of the infiltration basin not impacted by fine sediments are composed of more native materials. There areas are located along the higher elevations within the basin.

Site 3— Undisturbed native soil. This test location was chosen to represent the pervious areas throughout the site. If the resulting infiltration rates are high enough, the undisturbed areas at the HO can be eliminated from the hydrologic model, as they will not produce runoff.

Site 4— Staging Area. This area, located south of the infiltration basin on FAA property, appears to be impacted by continued use as a staging area for historic and current construction projects at the site. Soil in the area has a more compacted look, and it appears that runoff may drain off-site at the scour hole, which historically caused erosion impacts to the lower access road.

The values shown in Table 1 represent estimated infiltration rates. The site conditions during the infiltration testing and the duration of the test may result in infiltration rates higher than might be experienced during a large storm event. The antecedent moisture level in the soils at the start of the tests was low. During a long storm event, the soil may become saturated, which may reduce the infiltration capacity of the soil.

Table 1. Estimated Infiltration Rates within the HO Facility

	Infiltration Test Location			
	Site 1	**Site 2**	**Site 3**	**Site 4**
Infiltration Rate, in/hr	0.25	9.0	>20	3.0

Based on the values shown in Table 1 the infiltration rate for Site 3, the undisturbed native soils, indicates that most precipitation events at the HO site will be infiltrated directly into undisturbed soils. Site evidence suggests this to be true. There are little, if any, signs of erosion or surface drainage in areas not impacted by impervious surfaces at the HO facility. The Site 3 result allows for not including these areas in the hydrologic model as contributor of stormwater runoff. The Site 4 infiltration rate is low enough during dry conditions to assume that it produces stormwater runoff and so the area is included in the hydrologic model.

The infiltration tests conducted within the infiltration basin, sites 1 and 2, indicate that recurring inundation of the native soils during storm events and deposition of fine sediment may have impacted the infiltration capacity of the soils.

2.3 Cisterns

Stormwater runoff is collected for non-potable reuse in 2 known cisterns within the HO site. One cistern, located next to Mees facility collects runoff from the roof of the structure. The second cistern is located adjacent to the Neutron Monitor Station. This cistern collects runoff from the concrete channel associated with Flow Path 2.

Overflow from the Mees cistern discharges along Flow Path 1. When the other cistern reaches storage capacity, runoff with the concrete channel flows to the infiltration basin instead of the cistern. The storage capacity of the cisterns within the HO site is small compared to the volume of runoff generated by the modeled storm events so they were not considered in the modeling effort. This decision will provide for a more conservative evaluation of the infiltration basin because no runoff volume is being removed from the system due to the cisterns.

2.4 Hydrologic Modeling

Development of a hydrologic model for the HO site provides a tool for investigating the relationship between precipitation and stormwater runoff. Using this modeling tool, estimations can be made for the peak stormwater runoff flow rate as well as total stormwater runoff flow volumes. The hydrologic modeling was conducted in four phases; model development, model calibration, hydrologic analysis, and conclusions.

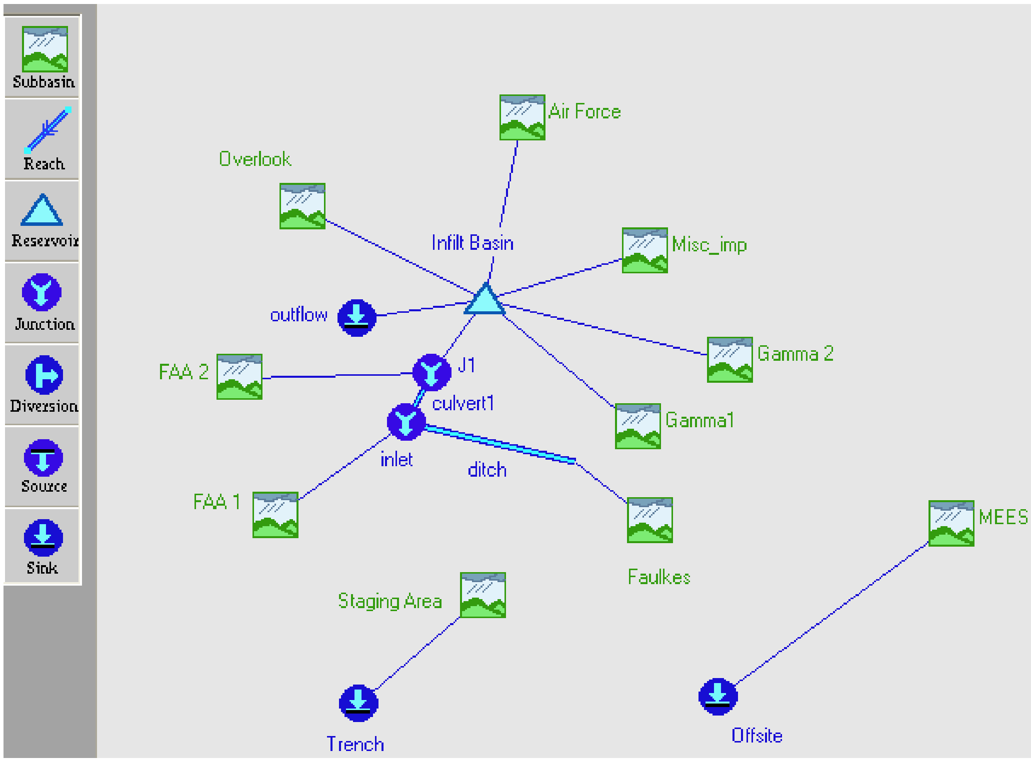
In order to estimate the volume and peak flow rate of stormwater at the HO site, a hydrologic model of the site was developed. The U.S. Army Corps of Engineers' Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) was used to perform the hydrologic analysis of the HO facility. HEC-HMS is used to simulate event-based or continuous precipitation runoff processes of a watershed. The model can be used to simulate a range of study areas, from large natural basins to small urban watersheds.

2.4.1 Model Development

The model uses the watershed characteristics such as basin area, time of concentration, conveyance system geometry, and land cover to estimate the study area's reaction to rainfall events. The HEC-HMS model of the HO site used site records of precipitation and water levels in the infiltration basin to calibrate the hydrologic model.

Sub-basins. The information gathered during the site investigation for the storm conveyance system was used to develop the boundaries for the HO sub-basins. The sub-basins are individual areas that provide direct runoff to the infiltration basin or off site. Generally the sub-basins only comprise impervious (paved) area. Site conditions show evidence that most of the native lands do not generate stormwater runoff, so these areas are not included in the model. There are three exceptions to this: the staging area, the parking area on FAA property, and the area west of the Air Force access road. All of these areas have been impacted by parking and construction activities. Figure 5 illustrates the delineations of the individual sub-basin areas included in the HEC-HMS model. A short description of the individual sub-basins is provided to better understand the properties of the areas.

Figure 5. Existing conditions HEC-HMS Model Schematic



***MEES*—**This refers to the Mees Building and parking lot. The drainage area only includes the existing paved parking area generates stormwater runoff. Runoff from the roof of the Mees structure is collected and conveyed to a nearby cistern. Under existing conditions, the runoff generated from the MEES sub-basin is modeled as leaving the site without flowing to the infiltration basin. Under future conditions modeling it is assumed the Mees facility drains to the infiltration basin.

***Faulkes*—**This sub-basin represents the impervious area associated with the Faulkes Telescope structure. This includes a roof and associated pavement surrounding the building. All runoff is collected in channels and conveyed to the concrete channel along the access road where it eventually enters the infiltration basin. A portion of the access road also is included in this drainage area.

***Air Force*—**The Air Force sub-basin reflects the portion of the Air Force facilities that drain to the infiltration basin. The sub-basin includes the roofs and paved parking area in the site. The final delineation was determined using site maps and site inspections that detailed the stormwater system and grading of the area.

***Gamma 1*—**The Gamma Ray building complex drains to two locations. The Gamma 1 drainage area includes a large portion of the access road from the Mees Building to the Gamma Ray area. An asphalt berm has been constructed that forces runoff to discharge onto native material near the southern edge of the area and flow through random channel into the infiltration basin.

Gamma 2—This sub-basin represents the northern portion of the Gamma Ray facility. Runoff from this area discharges onto native material in multiple areas where it eventually flows to the infiltration basin.

FAA1—The southern portion of the FAA site drains toward the culvert inlet at the upstream side of the access road the FAA facility. Runoff is combined with runoff from the Faulkes facility and conveyed into the infiltration basin.

FAA2—The northern portion of the FAA facility drains to short the open concrete channel near the paved parking area. The flow is combined with all the runoff entering the upstream culvert and then conveyed into the infiltration basin.

Staging Area—The pervious area south of the access road has been impacted by numerous activities. The native soils have been compacted by using the area for construction storage and driving vehicle across it. The topography of the site as well as localized erosion patterns suggest this area does not currently drain to the infiltration basin but instead discharges to the south on to the slopes of the Kolekole cinder cone. Under future conditions the hydrologic model includes the staging area as contributing runoff to the infiltration basin.

Overlook—The Overlook area is location to the west of the access road to the Air Force site. This area too has been impacted by storage and/or vehicle traffic. The sub-basin drains to a culvert under the access road and discharges into the infiltration basin. The Overlook sub-basin also includes a small portion of paved area associated with the Department of Energy facility.

Misc Imperv—There are multiple impervious areas at the HO site that drain directly into the infiltration. These include the access road to the Air Force site and the concrete pad adjacent to the infiltration area. These areas were all combined into one sub-basin since the hydrologic characteristics of the sites are similar.
Future Mirror Coating Facility—Expansion plans associated with the existing Air Force facility include a new structure and parking locations. Based on the proposed locations of the expansion facilities, they will all drain into the infiltration basin.

Time of Concentration (Tc). Tc is the duration of time for runoff to travel from the hydraulically most distant point of the sub-basin to a point of interest within the sub-basin. Due to the small sub-basin area and paved nature of the site, Tc was set at 5 minutes for each sub-basin. Five minutes is generally considered the minimum Tc for hydrologic modeling. Using a shorter Tc will provide for higher peak flows, resulting in conservative (higher) peak flow estimations.

Curve Number (CN). CN is a numeric representation of the hydrologic characteristic of the surface within an area. The major factors impacting the determination of a CN are hydrologic soil group (HSG), cover type, and land use. The HSG is based on the infiltration rate of a soil. The HSG system uses A, B, C, or D to indicate the soil infiltration capacity, ranging from high (HSG=A) to low (HSG=D). The infiltration rate of the soil impacts what portion of the precipitation enters the soil and what portion becomes runoff. Cover type is used to indicate the impacts of vegetation and interception. If an area is heavily vegetated, the vegetation will intercept precipitation before it can be either infiltrated or become runoff. Land use is considered to show the impact of whether an area is lawn, field, pasture, cropland, etc. Based on the combination of the three parameters, a CN is assigned to the area. CN values can range from 30 (low runoff potential) to 100 (all rainfall is turned into runoff).

For the HO, the only areas modeled are impervious areas except for the three exceptions of impacted soil area described above. The CN value for impervious surfaces such as street/road is 98. For the impacted pervious sites, a CN of 87 was assigned. Table 2 shows the parameter values used in the HO HEC-HMS model.

Table 2. HEC-HMS Parameters for the HO Facility

Drainage Basin Name	Basin Area (ft^2)		Time of Concentration, Tc, min	SCS Curve Number
	Impervious	Pervious		
Mees Bldg	4,855		5	98
Faulkes	5,812		5	98
Air Force	65,025		5	98
Gamma 1	13,573		5	98
Gamma 2	8,396		5	98
FAA 1	3,574		5	98
FAA 2	11191	5267	5	98 and 87
Staging Area	0	26,070	5	98 and 87
Overlook	1005	9049	5	98 and 87
Misc Imperv	18,105		5	98
Future Mirror Coating Facility	12642		5	98

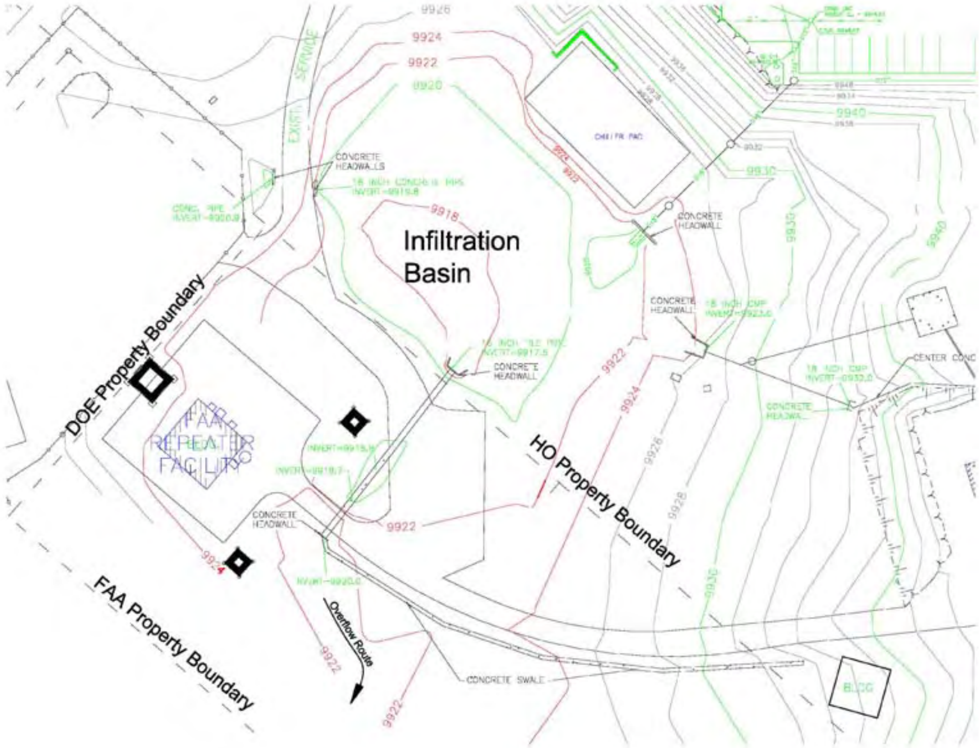
Both UH and the Air Force plan to expand their facilities at the HO site in the future. The Air Force plans to construct a Mirror Coating Facility and associated parking. The Air Force expansions will discharge to the infiltration basin. The UH is planning to construct the proposed Advanced Technology Solar Telescope (ATST) facility near the Mees building. This facility will include a structure and replacement of current paved parking. The stormwater runoff from the ATST structure will be collected and transferred to an existing cistern. Improvements to the existing Mees building parking will redirect runoff from flowing offsite to draining to the infiltration basin. These two site changes are reflected in HEC-HMS model representing future expansion at the HO site. The future model is intended to demonstrate impacts to the stormwater system due to the increase in impervious area at the HO site.

Infiltration Basin. The existing infiltration basin has been included in the HEC-HMS model of the HO site. The infiltration basin is modeled as a reservoir, with the infiltration rate being modeled as the outflow from the basin. To effectively model the basin, HEC-HMS considers the surface area of the stored water in the basin associated with varying depths, along with the outflow from the basin associated with water level. As the water level in the basin increases, the surface area associated with the water surface also increases. As the surface area of the water increases, the rate of infiltration also increases because water covers more land.

Using the available topography of the infiltration basin (Figure 6) along with the recorded infiltration rates within the basin, the relationship between basin depth and surface area was developed, as was the relationship between surface area and the infiltration rate (outflow) of the basin.

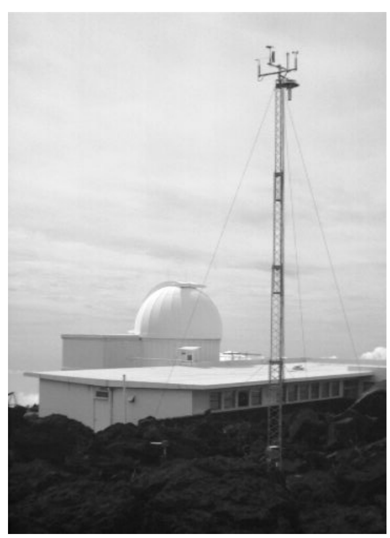
The total storage volume of the infiltration basin is estimated to be 1.5 ac-ft. The estimation assumes the maximum storage occurs at elevation 9922 ft. The topography survey reveals that a water level higher than 9920 feet within the infiltration basin will cause runoff to back up through the culvert at the south end of the basin. As the water level increases above the elevation of 9920 ft, runoff will start to be stored in the staging area along the south of the site. Based on the site topography, any water surface elevation above 9922 feet will likely discharge uncontrolled toward the south, onto the volcanic cone.

Figure 6. Topographic Map of the Infiltration Basin at the HO Site



2.4.2 Hydrologic Model Calibration

Model calibration is conducted in an attempt to verify that the parameters used in the modeling effort reproduce recorded events at the site. In order to calibrate the HO model, one or more storm events must result in recorded rainfall amounts along with coinciding water level measurements in the infiltration basin. There are multiple weather stations in place around the HO facility recording precipitation. A water level gage was installed in the infiltration basin at the onset of the SWMP project. Both sets of recorded data were used during the calibration efforts of the HEC-HMS model.



Rainfall Gage

The rain gage instrument is mounted on a 10-meter tower, 30 meters east of the Mees building. The rain gage is a Climatronics 100508 6-inch tipping bucket (.01-inch resolution). Precipitation is recorded every 10 minutes. This project required the precipitation record for the same time period as the water level recording in the infiltration basin.

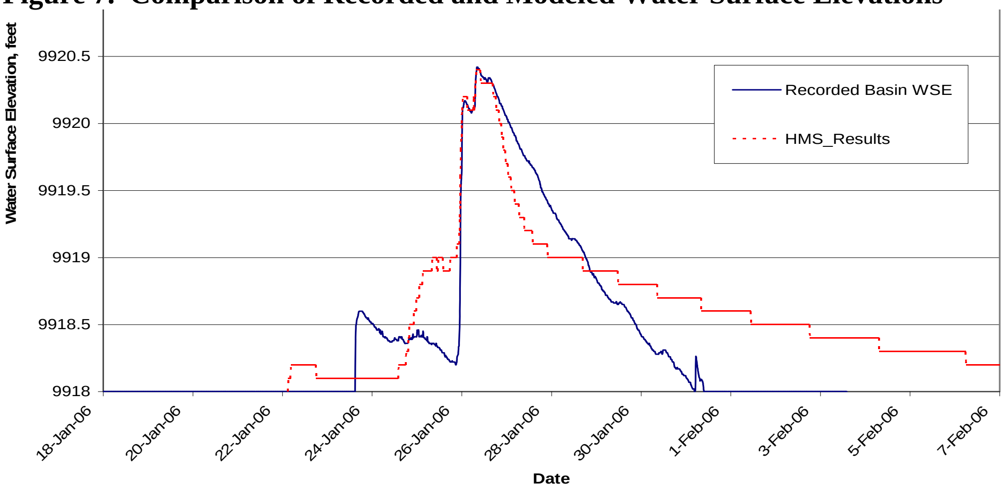
Infiltration Basin Water Level Gage

As part of this SWMP, a water level gage was installed at the infiltration basin. The gage recorded the depth of water in the basin at 15-minute intervals from October 11, 2005, to February 3, 2006. The infiltration basin is dry the majority of the time, with inflows into the basin's intermittent ponds only occurring after rainfall events at the summit of Haleakala.

Calibration Results

Using the recorded precipitation record along with the water levels recorded in the infiltration basin, the hydrologic model of the HO was calibrated to reproduce the recorded rainfall events' impacts on the infiltration basin at the HO site. Figure 7 shows the recorded infiltration basin water surface elevations compared to the HEC-HMS model results for the same rainfall event.

Figure 7. Comparison of Recorded and Modeled Water Surface Elevations



Based on the water surface elevation (WSE) recorded in the infiltration basin, there was a storm event at the HO site near January 24, 2006. Review of the precipitation recorded noted missing recorded data for the entire day of January 24, 2006. In the calibration modeling effort, the missing rainfall data was replaced with 0.00 readings to provide continuity to the HEC-HMS model.

Based on the modeling results shown on Figure 7, the HEC-HMS hydrologic model output provides a reasonable simulation of the water surface elevations in the infiltration basin at the HO site. The model reacts well to the water levels rising and peaking, but the model results in faster initial drainage of the pond and then a much longer final drying out of the basin. The changing dynamics of the site's soil infiltration rates cannot be adequately replicated with the HEC-HMS model. However, the HEC-HMS model does adequately replicate the peaks, and this is the more significant output of the model because it reflects whether the basin provides the required storage volume to mitigate the impervious surfaces associated with the HO facility.

2.4.3 Hydrologic Analysis

The calibrated HEC-HMS model was used to simulate the infiltration basin's response to rainfall events for various return frequencies. A Type I SCS, 24-hour unit hydrograph was used to model the impacts of the 1-year through 100-year storm events on the infiltration basin. Table 3 contains the total precipitation for the various 24-hour storm events. The storm precipitation totals were estimated using the isopluvial maps presented in Technical Paper No. 43, Rainfall-Frequency Atlas of the Hawaiian Islands (U.S. Department of Commerce, 1962).

Table 3. 24-Hour Rainfall Totals Associated with HO

24 Hour Storm Event Precipitation Total (inches)						
1-Year	**2-Year**	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**
4.0	5.0	8.0	9.0	10.0	13.0	15.0

Technical Paper No. 43 provides total rainfall totals associated with multiple storm durations including, 30-minute, 1-hour, 2-hour, 6-hour, and 12-hour storms. The 24-hour storm event was selected for modeling purposes because this duration of storm will provide the largest volume of rainfall, resulting in the largest volume of stormwater runoff.

Using the calibrated HEC-HMS model, the multiple 24-hour storm events were modeled to estimate the peak runoff flow rate and the peak WSE in the infiltration basin. Table 4 contains the results for the existing conditions model. The peak WSE shown in the table assumes that when the WSE in the infiltration basin exceeds 9922.0 feet, the basin will overtop, and runoff will discharge off site toward the south. Because the runoff can flow unrestricted out of the basin at elevations above 9922.0 feet, flow out of the basin would equal flow into the basin. The result would be that the basin WSE would not increase much above the 9922.0 feet elevation.

Table 4. Existing Conditions HEC-HMS Modeling Results for the Infiltration Basin

Drainage Basin	Peak Stormwater Runoff Rates, cfs						
	1-Year	**2-Year**	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**
Peak Inflow, cfs	8.7	11.0	17.7	19.9	22.2	28.9	33.4
Maximum WSE	9920.3	9920.6	9921.5	9921.8	9922.0	9922 (+)	9922 (+)

The future conditions scenario model was then used to estimate the peak runoff rates and WSE in the infiltration basin. The future conditions model assumes the Mees parking lot, and future Air Force expansion will all be conveyed into the infiltration basin. From the current architectural plans for ATST, It is assumed that the entire runoff volume from the proposed ATST facility will be captured for use and not play a role in this scenario. The results are shown in Table 5.

Table 5. Site Expansion Conditions HEC-HMS Modeling Results for the Infiltration Basin

Drainage Basin	Stormwater Runoff Volumes, cubic feet						
	1-Year	**2-Year**	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**
Peak Inflow, cfs	11.1	14.1	22.9	25.9	28.8	37.6	43.5
Maximum WSE	9920.6	9921.0	9922 (+)	9922 (+)	9922 (+)	9922 (+)	9922 (+)

As described earlier, the peak WSEs shown in the Table 5 assumes the uncontrolled outflow from the basin with WSE elevation above 9922.0 feet. A more detailed topographic survey of the open area south of the infiltration basin would determine the elevation at which the pond would start to overtop.

2.4.4 Conclusions

Based on the results of the hydrologic modeling efforts, under existing drainage conditions the infiltration basin appears to adequately contain the stormwater runoff for all but the most extreme storm events (50-year and above). Under proposed conditions, including facility expansion and containment of currently flowing off-site runoff, the infiltration basin is estimated to overtop at storm events larger than the 5-year recurrence interval. Generally, containment of larger storm events is considered to be for flood control only. When water quality is the concern of the site, then controlling the smaller, more commonly occurring events is important. Since neither of these concerns applies to HO, we consider the containment for stormwater runoff to be adequate.

Additional stormwater best management practices are desired at the HO site to contain all stormwater runoff generated within the HO facility. The remaining sections of this SWMP contain best management practices (BMP) to be considered during design and construction of the future HO site expansion. Also included are maintenance practices that are intended to improve the effectiveness of the existing and future stormwater management systems.

3.0 Construction Best Management Practices

The County of Maui has developed BMPs required during construction for the control of erosion from stormwater. The following text is taken verbatim from the county code and edited to contain only sections applicable to the HO site.

3.1 County of Maui Code, Section 20.08.035, Minimum BMPs

Regardless of whether a permit is required pursuant to this chapter, all grading, grubbing and stockpiling activities shall provide bmps to the maximum extent practicable to prevent damage by sedimentation to streams, watercourses, natural areas and the property of others. It shall be the permittee's and the property owner's responsibility to ensure that the bmps are satisfactorily implemented.

> ***Drainage.*** *On-site drainage shall be handled in such a way to as to control erosion, prevent damage to downstream properties and to return waters to the natural drainage course in a manner which minimizes sedimentation or other pollution to the maximum extent practicable.*
>
> ***Dust Control.*** *All areas disturbed by construction activities shall control dust emissions to the maximum extent practicable through the application of bmps, that may include watering with trucks or sprinklers, erection of dust fences, and limiting the area of disturbance.*
>
> ***Vegetation.*** *Whenever feasible, natural vegetation, especially grasses, should be retained. If it is necessary to be removed, trees, timber, plants, shrubbery and other woody vegetation, after being uprooted, displaced or dislodged from the ground by excavation, clearing or grubbing, shall not be stored in or deposited along the banks of any stream, river or natural watercourse. The director may require the removal and disposal of such vegetation from the site within a reasonable time but not to exceed three months.*
>
> ***Erosion Controls.*** *All disturbed areas shall be stabilized with erosion control measures that may include: staging construction: clearing only areas essential for construction; locating potential nonpoint pollutant sources away from steep slopes, water bodies, and critical areas; routing construction traffic to avoid existing or newly planted vegetation; protecting*

natural vegetation with fencing, tree armoring, and retaining walls or tree wells; stockpiling topsoil, covering the stockpile to prevent dust, and reapplying the topsoil; covering or stabilizing all soil stockpiles; using wind erosion control; intercepting runoff above disturbed slopes and conveying it to a permanent channel or storm drain; constructing benches, terraces, or ditches at regular intervals to intercept runoff on long or steep disturbed or man-made slopes; providing linings or other method to prevent erosion of storm water conveyance channels; using check dams where needed to slow flow velocities; using seeding and fertilizing, mulching, sodding, matting, blankets, bonded fiber matrices, or other effective soil erosion control technique; and providing vehicle wheel wash facilities for vehicles before they leave the site.

Sediment Control. *In addition to the erosion control measures of this section, providing practices to capture sediment that is transported in runoff to minimize the sediment from leaving the site. Filtration and detention (gravitational settling) are the main processes used to remove sediment from construction site runoff. Sediment control measures include sediment basins; sediment traps; filter fabric silt fences; straw bale, sand bag, or gravel bag barriers; inlet protection; stabilized construction entrances, and other measures to minimize off site tracking of sediment by construction vehicles; and vegetated filter strips.*

Material and Waste Management. *Measures to insure the proper storage of toxic material and prevent the discharge of pollutants associated with construction materials and wastes shall be implemented.*

Erosion Control Plan.

The erosion control plan shall employ best management practices to the maximum extent practicable to prevent or reduce pollutants from water bodies, including sediment and other contaminants, in discharges from a construction site. The erosion control plan shall include drawings with notes and details on the bmps to be implemented for the project, pursuant to section 20.08.035, Minimum bmps. The erosion control plan shall address the following to the extent applicable:

a. Stabilization of denuded areas,
b. Protection/stabilization of soil stockpiles,
c. Permanent soil stabilization,
d. Establishment and maintenance of permanent vegetation,
e. Protection of adjacent properties and water bodies,
f. Sediment trapping measures,
g. Sediment basins,
h. Cut and fill slopes (terracing),
i. Stormwater management,
j. Sequence of construction operations, including phased and successive development projects,
k. Stabilization of waterways and outlets,
l. Storm sewer inlet protection,
m. Control of access and vehicular movement,
n. Vehicular control on residential lots during construction,
o. Working in or crossing watercourses,
p. Underground utility construction,
q. Timely installation of permanent erosion and sediment control,
r. Maintenance of erosion control facilities,
s. Protection of existing vegetation, and
t. Dust control.

Drainage Plan and Report.
The drainage plan and report shall provide hydrologic and hydraulic calculations and information in accordance with title 15, "rules for the design of storm drainage facilities in the County of Maui," and revisions thereof, and other standards approved by the department of public works and waste management. The potential effects of the water runoff from the entire area covered by the permit on lower lying housing, business and other developments and on water bodies shall be included in the drainage plan and report.

Engineer's Soils Report.
In the event a proposed cut or fill is greater than fifteen feet in height, or in the event any fill is in the water, including wetlands and streams or in the event the fill material will be a highly plastic clay, submit an engineer's soils report, to include data regarding the nature, distribution and engineering characteristics of existing soils, the subsurface conditions at the site or the presence of ground water when detected, and recommending the limits for the proposed grading, the fill material to be used and the manner of placing it, including the height and slopes of cut and fill sections. Terminology for describing soils in the engineer's soils report, insofar as practical, shall be based on the soil survey of islands of Kaui, Oahu, Maui, Molokai and Lanai, State of Hawaii, or its revisions, issued by the soil conservation service in connection with the university of Hawaii agriculture experiment station.

Responsibility.
The permittee and the property owner shall be responsible for construction, installation, and maintenance of structural and nonstructural bmps at construction sites in accordance with the approved erosion control and drainage plans. The adequacy of bmps employed, the implementation of correction action if needed and the cost thereof shall be the responsibility of the permittee and the property owner. (Ord. 2684 § 8, 1998: Ord. 816 § 1 (part), 1975: prior code § 24-2.2(b).

3.2 Stormwater Best Management Practices

Four BMPs are recommended to address existing and potential future stormwater management issues at the HO facility.

Rainwater Harvesting/Cisterns
Cisterns are currently being used at the Mees Observatory to store roof runoff for reuse as non-potable water associated with flushing the toilets at the facility. This practice should be used where appropriate throughout the facility. In addition, new technologies can be used to store and treat the collected runoff from rooftops for potable water reuse.

Infiltration Trenches/Dry Wells
Infiltration-related stormwater BMPs are designed to remove stormwater runoff from the collection system. The runoff is contained on site and infiltrated into the existing soils. For the HO site, the existing soil conditions are ideal for this type of stormwater runoff control. The high infiltration rates associated with the undeveloped, porous soils allows for quick removal of stormwater from the collection system. The use of onsite infiltration practices also limits the need for the construction of a conveyance system, such as channels or pipes. The infiltration-based BMPs can be used to manage runoff from any impervious surface such as rooftops or paved parking areas.

Covered Collection Systems
An existing stormwater conveyance issue at the HO is the amount of sediment accumulating in the open channels used to transport runoff into the infiltration basin. Many of the channels are constructed across the slope, which allows sediment from the upslope of the channel to be transported by gravity into the channel. In locations where the gradient of the channel is low, the stormwater runoff does not provide enough energy to transport the sediment; instead, the sediment is deposited and it just accumulates. Eventually the sediment blocks the channel, and stormwater is forced out of the channel and onto unprotected native material where erosion can occur. Future stormwater channels should be constructed as enclosed systems, either pipes or covered channels, to prevent sediment accumulation in the future.

Roadside Berms and Curbs
Asphalt curbs and/or berms should be constructed to keep stormwater runoff on paved surfaces. Currently, stormwater runoff generated on much of the existing road surfaces at the HO site is allowed to flow onto unpaved areas. At the access road below the Faulkes facility, the runoff leaves the road surface, flows across unpaved areas, and then enters into a concrete channel where it is conveyed to the infiltration basin. The concern is that when the runoff flows across the unpaved areas, it starts to erode the supporting edge of the road, which undermines the paved section and causes cracks to appear. The runoff also transports sediment from the unpaved areas into the concrete channel, where the sediment is either transported into the infiltration basin or deposited in the concrete channel, adversely impacting the conveyance capacity of the channel. This also occurs along the access road to the Air Force facility.

3.3 Operation and Maintenance Plan

The existing stormwater conveyance system within the HO facility was designed to convey runoff generated from rainfall events. The system limits the erosion capability of runoff by keeping the flow on hardened surfaces or within channels. When the runoff has the opportunity to flow over native, unprotected soil, the stormwater runoff causes adverse erosion impacts. This Operation and Maintenance Plan section of the SWMP provides techniques required to maintain the existing and future collection system associated with the HO facility.

Sediment Control
In accordance with the IfA Long Range Development Plan, all sediment or rock displaced during maintenance or construction must remain on site, in observance of cultural protocols. The material removed from ditches can be spread around the site or used to repair berms, potholes, etc.

Infiltration Basin
The infiltration basin is a key element for the control of stormwater at the HO facility. Maintaining the basin will ensure the HO site can continue to effectively control stormwater runoff while not adversely impacting the natural conditions of the HO site and adjacent area.

Sediment that has been deposited into the basin should be removed to another location on site. The deposition of sediment in the basin adversely impacts the facility in two ways: (1) The sediment deposited in the basin diminishes the storage capacity for stormwater runoff, (2) fine material clogs the open areas I the soil reducing the soil's ability to infiltrate stormwater. As impervious surfaces increase at the HO facility due to expansion at the site, the volume of the stormwater generated and conveyed into the infiltration basin will increase, so maintaining the basin's storage and infiltration capacity is very important.

The removal and placement of sediment from the infiltration basin must comply with the criteria set forth in the LRDP for the site. All sediment removed from the basin must remain on Haleakala. The sediment can be spread out over the HO site or it can be transported from the HO site to other locations on the mountain. If the removed sediment remains at the HO site, the control of dust during the removal and placement phases is very important.

Channels

The concrete channels should be inspected routinely after every wet season. During the inspection, all accumulated sediment should be removed from the channel and distributed within the site. If the channel is constructed across a slope, the removed sediment should be placed in a location on the down gradient side of the channel. Placing the removed sediment below the channel will ensure the material is not re-transported back into the channel.

Not only should material within the channel be removed, but if accumulated sediment is noticed near the channel, it too should be moved or redistributed to eliminate the chance of the material being transported into the channel.

Mees Facility

The un-maintained concrete channel designed to convey runoff from the parking area to the road needs to be redesigned and reconstructed. The current channel was poorly formed and did not have adequately stable base material. As a result, the channel cracked and runoff was allowed to flow under the channel, causing additional erosion. The proposed design should take into account the causes of the current channel failures and also provide protection from vehicular damage due to its proximity to the existing Mees building parking lot.

APPENDIX J

Botanical Surveys, December 2005 and July 2009

BOTANICAL SURVEY

For

THE ADVANCED TECHNOLOGY SOLAR TELESCOPE (ATST) "SCIENCE CITY", ISLAND OF MAUI, HAWAI'I

prepared by

Forest Starr & Kim Starr (Starr Environmental)

December 2005

BOTANICAL SURVEY
THE ADVANCED TECHNOLOGY SOLAR TELESCOPE (ATST)
"SCIENCE CITY", ISLAND OF MAUI, HAWAIʻI

Forest Starr & Kim Starr (Starr Environmental)

December 2005

INTRODUCTION

The National Science Foundation has applied to develop the Advanced Technology Solar Telescope (ATST) within the 18.166-acre University of Hawaiʻi Institute for Astronomy Haleakalā High Altitude Observatories (HO) site at the summit of Haleakalā, county of Maui, Hawaiʻi. The project site is located on TMK 2-2-2-007-008, located on the top of Puʻu Kolekole cinder cone. It is proposed to construct the ATST project on approximately 0.60 acres (25,800 sq ft) of undeveloped land east of the existing Mees Solar Observatory facility, or at the alternative site within HO at Reber Circle. These are the results of a botanical survey of the proposed sites.

OBJECTIVES – SCOPE

1. Provide general description of the vegetation type.
2. Inventory terrestrial vascular flora.
3. Identify any vegetation that has federal status, and indicate locations on a map.
4. Provide recommendations to minimize negative impacts on botanical resources.

SURVEY METHODS

Prior to undertaking the field work, previous surveys done by the U.S. Air Force (Air Force, 1991), Belt Collins and Associates (Belt Collins, 1992), Char and Associates (Char, 2000), the Maui Space Surveillance Complex (MSSC, 2002), and Forest Starr and Kim Starr (Starr and Starr, 2002) were reviewed and maps of the site were acquired. The survey work was performed by two botanists, Forest Starr and Kim Starr on December 2, 2005. Access to the site was by vehicle. Once at the site, a walk-through survey method was used to record plant species. Species identification was made primarily in the field. Plants which could not be positively identified in the field were collected for later determination. Images were taken of all plant species to help with creation of a non-technical guide. All plants with federal status were noted, and their locations marked on a map of the site. Plant names in the following report generally follow Wagner *et al.* (1999) as well as other sources including Palmer (2003) and Neal (1965).

DESCRIPTION OF THE VEGETATION

The vegetation type on Puu Kolekole is an *Argyroxiphium* / *Dubautia* alpine dry shrubland. Dry alpine shrublands are typically open communities, occurring at 3,000-3,400 m (9,842-11,155 ft) elevation, predominantly on barren cinders, with very sparse vegetation cover (Wagner *et al.*, 1999). The site is located near the summit of Haleakalā, at 2,999-3,052 m (9,840-10,012 ft) elevation. Average annual rainfall is 112 cm (44 in), occurring primarily during the winter months (County of Maui, 1998). Temperatures occasionally dip below freezing, with average annual temperature at the summit of Haleakalā ranging from 42.6 - 50 degrees F (5.9 - 10 degrees C) (County of Maui, 1998), and once every few years it will snow. The substrate is a mixture of ash, cinders, pumice, and lava (MSSC, 2002). The vegetation is sparse, from a near barren <1% cover to about 10% cover. The vegetation is also low, no more than one meter (3 ft) tall anywhere on the site. During our survey, a total of 25 plant species were observed. Of which, 11 (44%) were native and 14 (56%) were non-native.

Both the preferred and the alternate sites contain two general types of areas, undisturbed areas and areas where construction has occurred. Undisturbed areas generally retain the original landscape of the mountain, and are comprised of predominantly native plants including shrubs, such as naenae (*Dubautia menziesii*), pukiawe (*Styphelia tameiameiae*) and ohelo (*Vaccinium reticulatum*), herbs, such as tetramolopium (*Tetramolopium humile*), and grasses, including bentgrass (*Agrostis sandwicensis*), hairgrass (*Deschampsia nubigena*), and mountain pili (*Trisetum glomeratum*). Three species of native ferns, ‘iwa ‘iwa (*Asplenium adiantum-nigrum*), ‘oali‘i (*Asplenium trichomanes* subsp. *densum*), and kalamoho (*Pellaea ternifolia*) are found tucked into rock crevices and overhangs.

Areas of both sites where construction has occurred generally show signs of disturbance by heavy machinery, support fewer native species, and contain more weeds. Weeds found in these disturbed areas include non-native herbs, such as thyme-leaved sandwort (*Arenaria serpyllifolia*), storksbill (*Erodium cicutarium*), hairy cat's ear (*Hypochoeris radicata*), sweet allysum (*Lobularia maritima*), black medick (*Medicago lupulina*), evening primrose (*Oenothera* *stricta* subsp. *stricta*), common plantain (*Plantago lanceolata*), and common vetch (*Vicia sativa* subsp. *nigra*). These areas also harbor a selection of non-native grasses, including rescue grass (*Bromus willdenowii*), Yorkshire fog (*Holcus lanatus*), and Kentucky bluegrass (*Poa pratensis*). The only "trees" known from the sites are two unidentified pine trees (*Pinus* sp.) that were located between a weather station and the Mees Solar Observatory offices (Starr and Starr, 2002), and one Japanese sugi pine (*Cryptomeria japonica*) located near the former LURE facility. The pines were about 20 cm tall and looked more like a small multi-branched shrub than a tree. This was the first record of pines on the summit of Haleakalā. It was not known if the trees were planted, arrived as contaminants in soil, or blew in on the wind. Though small, they appeared to be many years old. At the recommendation of the Friends of Haleakalā National Park, the trees were removed.

MEES SITE

The "Mees" site is located just east of the existing Mees Solar Observatory. The site is mostly undisturbed, with the original mountain profile remaining intact, except in the center of the property near the test tower where the ground was scraped flat by heavy machinery, and large piles of rubble, soil, and rocks were placed on the margins of the flattened area.

There were 10 native and 9 non-native plants found on the Mees site. The most heavily disturbed portions of the site, such as the scraped portions near the test tower, contained virtually no plants, native or non-native. Areas covered in asphalt with no cracks also contained no plants.

Portions of the site that were moderately disturbed, especially areas near buildings and roads contained the most weeds and fewest natives. Non-native plants found on the Mees site include thyme-leaved sandwort (*Arenaria serpyllifolia*), storksbill (*Erodium cicutarium*), hairy cat's ear (*Hypochoeris radicata*), black medick (*Medicago lupulina*), evening primrose (*Oenothera stricta* subsp. *stricta*), pine (*Pinus* sp.), English plantain (*Plantago lanceolata*), Kentucky bluegrass (*Poa pratensis*), and common or spring vetch (*Vicia sativa* subsp. *nigra*).

Portions of the site that were the least disturbed contain the most native plants and the least weeds. Native plants found on the Mees site include Hawaiian bentgrass (*Agrostis* *sandwicensis*), ‘iwa ‘iwa (*Asplenium adiantum-nigrum*), ‘oali‘i (*Asplenium trichomanes* subsp. *densum*), hairgrass (*Deschampsia nubigena*), kupaoa (*Dubautia menziesii*), kalamoho (*Pellaea ternifolia*), pukiawe (*Styphelia tameiameiae*), tetramolopium (*Tetramolopium humile*), mountain pili (*Trisetum glomeratum*), and ohelo (*Vaccinium reticulatum*).

The most undisturbed areas of HO hold remnant pockets of native plants indicative of relatively pristine conditions. Two native shrubs, ohelo and pukiawe, appear to be sensitive to disturbance/urbanization on Pu‘u Kolekole, and were found on the Mees site, but not on the Reber Circle site, suggesting a lower level of overall disturbance has occurred on the Mees site compared to the Reber site.

REBER CIRCLE SITE

The Reber Circle ("Reber") site is located near the MAGNUM and Atmospheric Airglow facilities. The bulk of the Reber site was previously a radio telescope in the early 1950's. Most of the site is disturbed, with the original profile of the mountain evident only on the margins of the site, often where the land is steep. There were large piles of soil and a pile of coral rubble placed between Reber and MAGNUM. The center of the site was the foundation of the radio telescope, and is currently a gravel parking lot.

There were 9 native and 7 non-native plants found on the Reber site. The most heavily disturbed portions of the site, such as the roads, parking lots, and existing buildings, contained virtually no plants, native or non-native.

Portions of the site that were moderately disturbed, especially those areas near buildings and roads, contained the most weeds and fewest natives. Non-native plants found on the Reber site include Japanese sugi pine (*Cryptomeria japonica*), storksbill (*Erodium cicutarium*), Yorkshire fog (*Holcus lanatus*), hairy cat's ear (*Hypochoeris radicata*), lythrum (*Lythrum maritimum*), evening primrose (*Oenothera stricta* subsp. *stricta*), and Kentucky bluegrass (*Poa pratensis*).

Portions of the site that were the least disturbed contained the most native plants and the least weeds. Native plants found on the Reber site include Hawaiian bentgrass (*Agrostis sandwicensis*), ‘ahinahina (*Argyroxiphium sandwicense* subsp. *macrocephalum*),‘iwa ‘iwa

(*Asplenium adiantum-nigrum*), ‘oali‘i (*Asplenium trichomanes* subsp. *densum*), hairgrass (*Deschampsia nubigena*), kupaoa (*Dubautia menziesii*), kalamoho (*Pellaea ternifolia*), tetramolopium (*Tetramolopium humile*), and mountain pili (*Trisetum glomeratum*).

The same patterns of nativity in relation to disturbance that occur on the Mees site also seem to occur on the Reber site. In other words, native plants dominate undisturbed areas and non-natives dominate disturbed sites. Additionally, it appears some natives drop out completely in the most disturbed sites. As was stated earlier, the Reber site does not contain the native shrubs pukiawe and ohelo, suggesting a higher level of disturbance than some of the other areas at HO, such as the Mees site which contains both pukiawe and ohelo. One dead silversword was found east of the Reber circle, near the existing small building.

SOIL PLACEMENT / STAGING AREA

Located just west of HO, between the Faulkes Telescope North and the Department of Energy site. The site is bare dirt that is basically devoid of vegetation, has been heavily disturbed, and appears to be actively used. No plants, native or non-native, were found on the site.

ENDANGERED, THREATENED, LISTED, OR PROPOSED PLANT SPECIES

Haleakalā silverswords (*Argyroxiphium sandwicense* subsp. *macrocephalum*) are federally listed as "threatened" species, meaning they may become endangered throughout all or a significant portion of their range if no protection measures are taken. In 2002, nine live silverswords and three dead silversword flower stalks were located on the UH property. All of the live plants were on the MSSC site. Despite being quite large, up to 50 cm (20 in) in diameter, these nine live silverswords apparently were all less than five years old and have come up since construction of the facility (Steve Shimko pers. comm.). The live silverswords were located in landscaped areas, alongside retaining walls, on a steep slope just below the parking area, and in the MSSC leach field. There were also three dead silversword flower stalks on the UH property. Two stalks were placed near the MSSC leach field by National Park Service personnel. The other dead silversword flower stalk was located near the Lure observatory and was alive in 1991 (Air Force, 1991).

It is this last silversword which was found again during this recent survey. The lone silversword is located near the Reber site, east of the Reber Circle, near an existing small building. The silversword appeared to have been dead for many years, and to have gone to flower before dying. The dead silversword flowering stalk skeleton was not observed, and it is not known where it went. The area around the silversword plant was searched for seeds, but none were found.

DISCUSSION & RECOMMENDATIONS

SILVERSWORDS

As has been stated in previous botanical surveys of HO (Belt Collins, 1992; Char, 2000; Starr and Starr, 2002) if there was to be construction in areas of the property where silverswords now occur, the silverswords could likely be relocated to another area without adverse effects. New silverswords could also likely be planted if transplanting of live silverswords was unsuccessful. Those performing relocations should consult with Haleakalā National Park and United States Fish and Wildlife personnel before construction to determine where and how best to relocate the plants. We understand that no ATST construction is planned for areas where silverswords now occur.

NON-NATIVES

There are an inordinate number of non-native plants on the HO site compared to similar adjacent "pristine" areas of Haleakalā National Park, Kahikinui Forest Reserve, and Kula Forest Reserve. There appear to be many reasons for this.

To some extent, development at this site seems to promote plant growth, both native and non-native. Given the disturbance to the soil from construction, additional water sources from discharge pipes and gutters, and protection from the elements by objects such as building foundations and sidewalks, both native and non-native plants are able to find refuge in otherwise inhospitable locations.

Intentional plantings are one way non-native plants have been introduced to the site. Steve Shimko of Boeing LTS mentioned that UH did some experimental plantings of non-native grasses on the site in the 1970s. Aerial photographs from 1975 confirm rows of plants, presumably grasses, being cultivated near the center of the site (Starr and Starr, 2002). The large number of alien grasses at the UH site compared to similar areas nearby may be attributable in part to these experimental plantings. In addition to the non-native grass plantings, the only "trees" found on the site appear to have been planted, though it is not definitively known if the trees were planted, arrived as contaminants in soil, or blew in on the wind.

Unintentional introduction seems to be the main way non-native plants have gotten to the site. Presumably as a direct result of HO being developed and operated, there are many more non-native plants at HO, than on nearby similar land. Most of the non-natives at HO are found in disturbed areas that are frequented, especially near buildings and roads. Existing non-native plants at HO now create a foci from which invasion into un-infested portions of the HO site and nearby pristine areas is now possible.

Given all this, it seems that weed prevention and control efforts on the HO site should be increased, to minimize the impacts to the native botanical resources. For example, the MSSC does a good job of controlling weedy species on their site, while letting the native species flourish. Similar efforts on the rest of the HO would go a long way towards protecting the summit flora, and minimizing negative effects on the botanical resources. We estimate that one person one day a month would be able to keep the non-native plants in check at HO. Volunteer groups, such as the Friends of Haleakalā National Park could also be enlisted to help. In addition to weed control, future plantings of non-natives at HO should be avoided. Lastly, better weed prevention measures during facility operation should be implemented.

NATIVES

Construction on either the Mees or Reber sites will destroy hundreds of native plants. Some will perhaps be able to re-colonize undeveloped portions of the sites, but most will be displaced and unable to recover. That said, unless the entire HO property was covered in concrete, it seems likely that coupled with prevention measures outlined below, and weed control efforts like those currently employed at the MSSC, the development of the ATST on the Mees or Reber site would not have a significant negative impact on the native Hawaiian botanical resources.

CONSTRUCTION MEASURES

Accidentally introducing non-native species to the summit area during construction can disrupt the native ecosystem and have significant adverse effects to the native biota (Char, 2000; Belt Collins, 1992). As potential mitigation measures and to reduce potential for unwanted introductions, the construction contractor should utilize the following measures as outlined in the IfA Long Range Development Plan (LRDP, Section 9.3.1).

Haleakalā National Park has experienced the introduction of destructive non-native species that compete with and have in some cases displaced native plants and insects. These introductions threaten the ecological balance at the site, and in cooperation with Haleakalā National Park, IfA requires any contractor to take the following measures at HO to prevent construction or repair activities from introducing new species:

- Any equipment, supplies, and containers with construction materials that originate from elsewhere, i.e., the other islands or the mainland, must be checked for infestation by unwanted species by a qualified biologist or agricultural inspector prior to being transported from Kahului. Specimens of non-native species found in these inspections are to be offered to the state for curation, and those not wanted are to be destroyed. All construction vehicles must be steam cleaned before they are transported through the National Park. The contractor shall provide certification attesting to compliance with this paragraph for inspection and steam cleaning. Contractors shall also notify IfA a week prior to their initial entry into Haleakalā National Park, so that arrangements can be made with the Park Service or other provider of inspection services. After the initial entry, coordination shall be directly between the inspectors and the contractor.

- Importation of fill material to the site is prohibited, unless such fill (e.g., sand) is sterilized to remove seeds, larvae, insects, and other biota that could survive at the site and propagate. All material obtained from excavation is to remain on Haleakalā. Surplus excavated cinders, soil, etc., is to be offered to other agencies located at the summit or the NPS.

- Contractors are required to participate in IfA pre-construction briefings to inform workers of the damage that can be done by unwanted introductions. Satisfactory fulfillment of this requirement would be evidenced by a signed declaration from each worker who drives a construction vehicle into the site.

- Parking of heavy equipment and storage of construction materials outside the immediate confines of HO property is prohibited.

- Contractors are required to remove construction trash frequently, particularly materials that could serve as a food source that would increase the population of mice and rats that prey on native species.

OPERATING MEASURES

Recent surveys have found that non-native plant species are able to establish well after construction has taken place, during normal operations of facilities at HO. Workers transporting themselves, their vehicles, and their gear up and down the mountain provide the opportunity for weedy non-native plants to be introduced to the site. Some of these plant species have the ability to negatively impact the native botanical resources of HO and adjacent lands. To reduce potential for unwanted introductions and spread during facility operations, the operating contractor should take the following measures.

- Have contractor be familiar with native and non-native plants at the site. A non-technical color guide has been created during this survey to help with this.

- Assure all gear, clothing, boots, and vehicles are weed free before proceeding to the summit.

- Prohibit plantings of non-native plants on site.

- Arrange for regular weed control on the site, by folks familiar with the vegetation of Haleakalā, with the ultimate goal of no non-native plants on the site.

ANNOTATED CHECKLIST

Below is a narrative on each of the vascular plant species found at the proposed sites (Mees and Reber). Information from the water retention basin (Basin) is also included. The scientific name, common name, family, and nativity status is given. Following that are comments on the species in general, and then more specific information, including locations and numbers of individuals observed, at each of the proposed sites. The numbers of individuals are often approximate and are generally more indicative of relative abundance than exact counts.

***Agrostis sandwicensis* -- Hawaiian bentgrass (Poaceae)**

Endemic. Slender native bunch grass. The least common of the three native grasses found in the alpine area of Haleakalā. Scattered about both sites.

Mees: Occasional. A dozen or so plants scattered amongst the rocks.

Reber: Occasional. A bit more common than at the Mees site, with 33 plants observed.

***Arenaria serpyllifolia* -- Thyme-leaved sandwort (Caryophyllaceae)**

Non-native. Ephemeral herb that seems to come and go with the rains. Most common near Mees Solar Observatory.

Mees: A few plants in rocks in relatively undisturbed portion of site. Many more plants along the north wall of Mees Solar Observatory.

Reber: None.

***Argyroxiphium sandwicense* subsp. *macrocephalum* -- Haleakalā silversword, ʻahinahina (Asteraceae)**

Endemic. Distinctive silver rosette plant found only on East Maui. The silverswords at HO are some of the only known silverswords in the wild beyond the Haleakalā National Park boundary. One dead plant was found near the Reber site.

Mees: None.

Reber: One dead plant observed near the site. The area around the silversword plant was searched for seeds, but none were found

***Asplenium adiantum-nigrum* – ‘Iwa ‘iwa (Aspleniaceae)**

Indigenous. Leathery fern with black stipe found scattered about both sites, especially in rock crevices.

Mees: Occasional. A half dozen clumps found in rock crevices.

Reber: Occasional. Eight clumps found in rock crevices.

***Asplenium trichomanes* subsp. *densum* – ‘Oali‘i (Aspleniaceae)**

Indigenous. Diminutive fern with small leaves found tucked in rock crevices.

Mees: Occasional to rare. Three clumps found tucked in rock crevices, in northwest portion of site.

Reber: Rare. One clump found.

***Bromus willdenowii* -- Rescue grass (Poaceae)**

Non-native. Hardy grass with large seed heads. Scattered individuals found around HO, but most common and vigorous in the water retention basin.

Mees: None.

Reber: None.

Basin: A few dozen vigorous plants found in the retention basin, especially on the northwest side.

***Cryptomeria japonica* -- Japanese sugi pine (Taxodiaceae)**

Non-native. One lone tree. This is a new addition to plants known from HO, and the only live "tree" found during a prior survey.

Mees: None.

Reber: Rare. One tree near former LURE facility. It was about a meter tall, was alive, but not exceptionally vigorous. It appeared to be planted. In following with the Friends of Haleakalā request it was removed (LRDP, 2005). See also *Pinus* sp.

***Deschampsia nubigena* -- Hairgrass (Poaceae)**

Endemic. Feathery bunch grass. The most common of the three native alpine grasses.

Mees: Common. This is the most common grass on the site. It covers most of the site, especially tucked under rocks; 470 clumps were found scattered here and there.

Reber: Common. This is the most common grass on the site; 213 clumps were observed scattered about.

***Dubautia menziesii* -- Kupaoa,** na‘ena‘e **(Asteraceae)**

Endemic. A relative of the silversword, and known only from East Maui, this hardy native shrub can be found over most of HO, even in the most urbanized sections. The wind dispersed seeds of this shrub presumably help it re-colonize disturbed areas. In many cases this plant was observed growing through cracks in asphalt, and on the margins of concrete.

Mees: Common. The most common shrub on the site;160 plants were observed.

Reber: Common. The most common shrub on the site;209 plants were observed.

***Erodium cicutarium* -- Storksbill (Geraniaceae)**

Non-native. Ephemeral herb that is established near structures.

Mees: Occasional. 22 plants and many more small seedlings were found near the existing Mees Solar Observatory building and parking lots.

Reber: Occasional. One plant and numerous seedlings at base of walls of Atmospheric Airglow Facility.

***Holcus lanatus* -- Yorkshire fog (Poaceae)**

Non-native. Invasive grass that is established at HO, but is currently only known from a couple lone plants and one localized patch. This is one of the non-native species that would be good to remove before it becomes further established at HO and begins to spread to adjacent parklands.

Mees: None.

Reber: Occasional to rare. One patch of dozens of plants found half way up hill with small asphalt foot path. A couple small plants were found scattered on the same hill.

***Hypochoeris radicata* -- Hairy cat's ear (Asteraceae)**

Non-native. Cosmopolitan tap-rooted herb that is found virtually everywhere in small numbers.

Mees: Occasional to rare. Three small patches observed.

Reber: Occasional. 17 plants observed.

***Lobularia maritima* -- Sweet alyssum (Brassicaceae)**

Non-native. One of the more aggressive species on Puu Kolekole right now. It has spread in distribution since we last surveyed the site, especially near the water retention basin and behind the building near the Department of Energy site. This is another invasive plant species that would be good to keep in check in order to minimize negative impacts on the native botanical resources of HO and nearby areas.

Mees: None.

Reber: None.

Basin: Occasional. A few plants scattered about the southwest rim of the basin.

***Lythrum maritimum* -- Lythrum (Lythraceae)**

Questionably indigenous. A slender shrub of questionable nativity. A new addition to the plants known from "Science City". Prefers moist sites.

Mees: None.

Reber: Rare. One plant found along small path that leads up the rock hill to the Atmospheric Airglow facility.

***Medicago lupulina* -- Black medick (Fabaceae)**

Non-native. Mat forming herb with trifoliate leaves and yellow flowers.

Mees: Occasional to common. Well established near existing buildings and parking lot at Mees Solar Observatory. Large patches were forming mats in the gravel parking lot, cracks in the paved parking lot, and near the building.

Reber: None.

***Oenothera stricta* subsp. *stricta* -- Evening primrose (Onagraceae)**

Non-native. Colorful yellow flowered plant that can be quite invasive.

Mees: Occasional to common. Found near roads and buildings. A patch of 100+ seedlings and small plants was found near the existing cistern near the Mess Solar Observatory.

Reber: Occasional. A half-dozen or so plants scattered over site.

***Pellaea ternifolia* -- Cliff brake, kalamoho (Sinopteridaceae)**

Indigenous. Three leaved fern found in small numbers in rock cracks.

Mees: Rare. One patch seen.

Reber: Occasional to rare. Three patches observed on a small south-facing cliff on the southern part of the property.

***Pinus* sp. -- Pine (Pinaceae)**

Non-native. Two pines were previously known from the Mees site. They have since been removed at the request of the Friends of Haleakalā National Park (KC Environmental, 2005). The skeleton of one of those pines was found.

Mees: One dead individual found stuffed in rocks.

Reber: None.

***Plantago lanceolata* -- English plantain (Plantaginaceae)**

Non-native. A cosmopolitan weed that is currently a target for control by the Friends of Haleakalā National Park near Kapalaoa Cabin.

Mees: Occasional. 15 plants observed, mostly near the cistern.

Reber: None.

***Poa pratensis* -- Kentucky bluegrass (Poaceae)**

Non-native. Hardy grass that forms small patches by root suckering. The blades of this grass are often very short in the open, and much longer in the protected areas near buildings.

Mees: Occasional. A half-dozen patches found, especially near the Mees Solar Observatory and cistern.

Reber: Occasional. A dozen patches found, especially near the base of walls at the Atmospheric Airglow Facility.

***Styphelia [syn. Leptecophylla] tameiameiae* -- Pukiawe (Epacridaceae)**

Indigenous. Hardy native shrub that appears to not do as well in heavily disturbed areas. A fair amount at the Mees site, but none found at the Reber site.

Mees: Occasional. 38 plants found scattered across site, mostly in undisturbed portions.

Reber: None. The lack of pukiawe is likely a result of the disturbed condition of the site.

***Tetramolopium humile* -- Tetramolopium (Asteraceae)**

Endemic. Succulent native herb that prefers cracks in rocks, and can seemingly cope with limited levels of disturbance.

Mees: Occasional. A dozen plants scattered across site. Some growing in cracks in asphalt parking lot.

Reber: Occasional. 15 plants observed.

***Trisetum glomeratum* -- Mountain pili, pili uka (Poaceae)**

Endemic. Tussock forming grass. The 2nd most common native grass of the alpine area.

Mees: Occasional. 119 plants observed on site.

Reber: Occasional. 56 plants observed on site.

***Vaccinium reticulatum* --Ohelo (Ericaceae)**

Endemic. Fruit bearing native shrub that appears to be confined to areas that have not seen heavy disturbance in the past.

Mees: Occasional. A half dozen plants were observed on the site, in relatively undisturbed areas.

Reber: None. The lack of ohelo at this site likely attests to the disturbed condition of the site.

***Vicia sativa* subsp. *nigra* -- Common or spring vetch (Fabaceae)**

Non-native. Twining vine with purple flowers and twisted pods. This is a new addition to plants known from "Science City". This species is currently found in very limited distribution.

Mees: Rare. A few plants found near north facing wall of Mees Solar Observatory, presumably it's point of introduction. The plants were pulled and bagged, but it had already gone to seed, so follow up will likely be necessary.

Reber: None.

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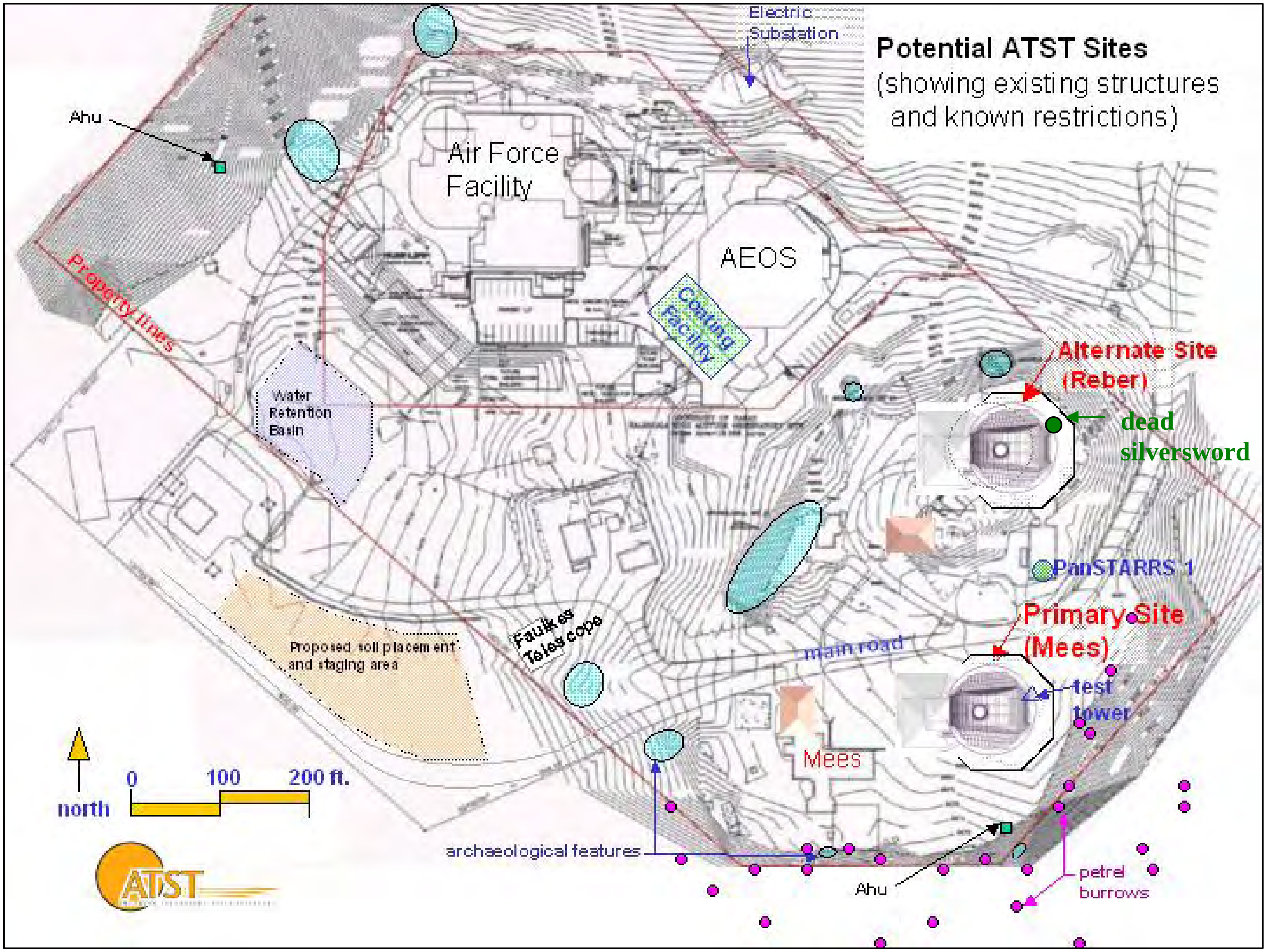
PLANT CHECKLIST

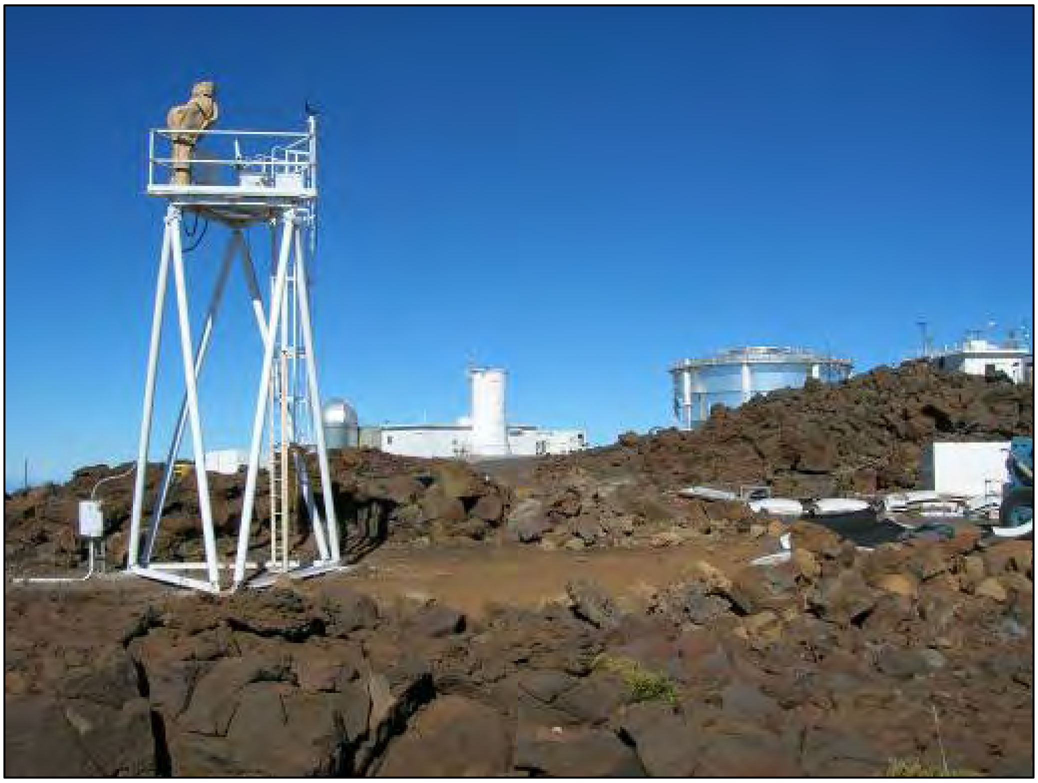
Scientific name	Common name	Mees	Reber	Retention	Staging
Agrostis sandwicensis	Hawaiian bentgrass	O	O	--	--
Arenaria serpyllifolia *	Thyme-leaved sandwort	O	--	--	--
Argyroxiphium sandwicense subsp. *macrocephalum*	Haleakalā silversword, ‘ahinahina	--	R	--	--
Asplenium adiantum-nigrum	‘Iwa‘ iwa	O	O	--	--
Asplenium trichomanes subsp. *densum*	‘oali‘i	O/R	R	--	--
Bromus willdenowii *	Rescue grass	--	--	O	--
Cryptomeria japonica *	Japanese sugi pine	--	R	--	--
Deschampsia nubigena	Hairgrass	C	C	O	--
Dubautia menziesii	Kupaoa, na‘ena‘e	C	C	O	--
Erodium cicutarium *	Storksbill	O	R	--	--
Holcus lanatus *	Yorkshire fog	--	O	--	--
Hypochoeris radicata *	Hairy cat's ear	O/R	O	--	--
Lobularia maritima *	Sweet alyssum	--	--	O	--
Lythrum maritimum *	Lythrum	--	R	--	--
Medicago lupulina *	Black medick	C/O	--	--	--
Oenothera stricta subsp. *stricta* *	Evening primrose	C/O	O	--	--
Pellaea ternifolia	Cliff brake, kalamoho	O/R	R	--	--
Pinus sp. *	Pine	R	--	--	--
Plantago lanceolata *	English plantain	O	--	--	--
Poa pratensis *	Kentucky bluegrass	O	O	O	--
Styphelia tameiameiae	Pukiawe	C	--	--	--
Tetramolopium humile	Tetramolopium	O	O	R	--
Trisetum glomeratum	Mountain pili, pili uka	O	O	--	--
Vaccinium reticulatum	‘Ohelo	O	--	--	--
Vicia sativa subsp. *nigra* *	Common or spring vetch	R	--	--	--

* = Non-native   R = Rare   O = Occasional   C = Common   -- = Not present

Location of dead silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*) found near the Reber Circle site.



SITE PHOTOS –PROPOSED ATST



West of Mees site

Reber Circle site

Soil placement / staging area

PICTORIAL PLANT GUIDE:
ADVANCED TECHNOLOGY SOLAR TELESCOPE (ATST)

It is hoped this pictorial plant guide will provide a non-technical resource for those wishing to learn more about the vegetation on the proposed ATST sites and the other areas of HO. Native and non-native (indicated by an *) plants are included. All images were taken by Forest Starr and Kim Starr. The following includes images of all the vascular plant species found on the proposed ATST building sites; however, not all the images were taken at the proposed ATST sites, but ATST- and HO-specific images were used whenever possible. Additional images of these species can be found at www.hear.org/starr.

Agrostis sandwicensis

Hawaiian bentgrass (Poaceae)

*Arenaria serpyllifolia** -- Thyme-leaved sandwort (Caryophyllaceae)

Argyroxiphium sandwicense subsp. *macrocephalum* -- Haleakalā silversword, ‘ahinahina (Asteraceae)

Asplenium adiantum-nigrum
‘Iwa ‘iwa (Aspleniaceae)

Asplenium trichomanes subsp. *densum* – ‘Oali‘i (Aspleniaceae)

*Bromus willdenowii**
Rescue grass (Poaceae)

*Cryptomeria japonica**
Japanese sugi pine (Taxodiaceae)

Deschampsia nubigena
Hairgrass (Poaceae)

Dubautia menziesii
Kupaoa, naenae (Asteraceae)

*Erodium cicutarium**
Storksbill (Geraniaceae)

*Holcus lanatus**
Yorkshire fog (Poaceae)

*Hypochoeris radicata**
Hairy cat's ear (Asteraceae)

*Lobularia maritima**
Sweet alyssum (Brassicaceae)

*Lythrum maritimum**
Lythrum (Lythraceae)

*Medicago lupulina**
Black medick (Fabaceae)

Oenothera stricta subsp. *stricta** Evening primrose (Onagraceae)

Pellaea ternifolia -- Cliff brake, kalamoho (Sinopteridaceae)

*Plantago lanceolata**
English plantain (Plantaginaceae)

*Poa pratensis**
Kentucky bluegrass (Poaceae)

Styphelia tameiameiae
Pukiawe (Epacridaceae)

Tetramolopium humile
Tetramolopium (Asteraceae)

Trisetum glomeratum
Mountain pili, pili uka (Poaceae)

Vaccinium reticulatum
Ohelo (Ericaceae)

Vicia sativa subsp. *nigra** Common or spring vetch (Fabaceae)

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BOTANICAL SURVEY
HALEAKALA OBSERVATORIES
ISLAND OF MAUI, HAWAII

Forest Starr & Kim Starr (Starr Environmental)

July 2009

INTRODUCTION

The University of Hawaii (UH) is gathering resource information for their property, the Institute for Astronomy (IfA) Haleakala High Altitude Observatories (HO), near the summit of Haleakala as part of a Long Range Development Plan (LRDP).

In broad terms, this LRDP describes the general environmental, cultural, and historical conditions along with site characteristics that will guide future development. It also describes the principles that define the scientific programs that UH strive to maintain and develop at HO, and the potential new facility developments that will keep UH in the forefront of astronomy into the next decade. In order to describe and to protect this resource while accommodating the growing need for public scrutiny and partnering in astronomical planning, the IfA planning process for long-range development takes into consideration the environmental, cultural, and historic importance of Haleakala. Described here are the botanical resources.

The project site is TMK 222007008, IfA HO, which is also known as the bulk of "Science City" to local residents. The 18.166-acre parcel is located largely within the Kolekole cinder cone, and the property is roughly rectangular in shape. It is mostly surrounded by State Conservation District lands, with a small adjoining Federal property on the southwest boundary.

OBJECTIVES - SCOPE

1. Provide general description of the vegetation.
2. Note any changes in vegetation over time.
3. Inventory terrestrial vascular flora.
4. Identify any vegetation that has federal status, and indicate locations on a map.
5. Provide recommendations to minimize negative impacts on botanical resources.

SURVEY METHODS

Previous botanical surveys conducted at HO were reviewed prior to conducting the fieldwork, including the following: U.S. Air Force (1991), Belt Collins & Associates (1994), Char & Associates (2000), Rocketdyne Technical Services (2002), Starr & Starr (2002), and Starr & Starr (2005). Only the Starr and Starr 2002 survey covered the entire HO property, the others were for discrete projects within HO. We also reviewed Bishop Museum's online herbarium for collections previously made at HO (Bishop Museum 2009). Additional HO information was provided by Mike Mayberry and Charlie Fein.

Two botanists, Forest Starr and Kim Starr, conducted a botanical survey of HO on May 4, 2009 and June 28 - June 30, 2009. Access to the Air Force site is restricted and we were escorted by Charles Hardy (Boeing) and Patrick Easterling (Air Force) during the initial survey. They also provided additional notes and maps they had for the silverswords (*Argyroxiphium sandwicense* subsp. *macrocephalum*) located on Maui Space Surveillance Complex (MSSC). During the second site visit to the Air Force site on June 30, 2009 we were escorted by Charles Hardy (Boeing), Patrick Easterling (Air Force), Michael Dale (Boeing), and Tom McCall (Boeing). Care was taken during surveys to avoid disturbing the active petrel burrows and archeological sites. We were limited on the MSSC site to taking pictures looking down; no shots of plants in relation to buildings were allowed.

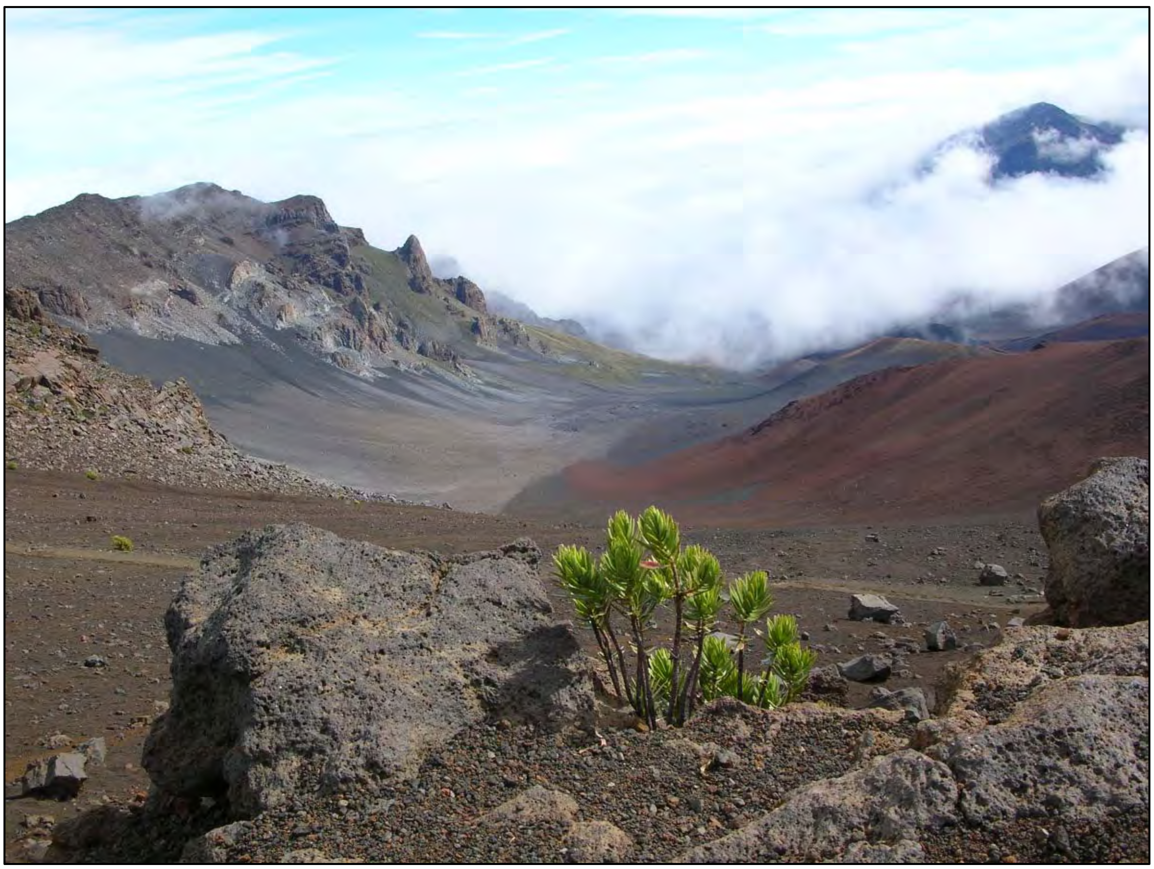
During our initial survey in May, a walk-through survey method was used to record plant species that were present. During our second survey in June, we gathered more detailed location information for each species by taking a GPS (global positioning system) point for each plant noting the species. Where plants were continuous we took a point about every 1-3 m (3-9 ft). The information gathered is displayed in the maps provided in the annotated checklist portion of this report.

During this survey we also provided plant identification training and orientation to personnel that will be taking on non-native species removal efforts.

Species identification was made primarily in the field. Plants that could not be positively identified in the field were photographed or collected for later determination. Collections will be accessioned at Bishop Museum, Honolulu, Hawaii. All plants were noted and their locations recorded using a Garmin eTrex LegendH and Garmin eTrex global positioning systems. Plant names in the following report generally follow Wagner et al. (1999) and Palmer (2003).

DESCRIPTION OF THE VEGETATION

The vegetation type on Puu Kolekole is an *Argyroxiphium* / *Dubautia* alpine dry shrubland. Dry alpine shrublands are typically open communities, occurring at 3,000-3,400 m (9,842-11,155 ft) elevation, predominantly on barren cinders, with very sparse vegetation cover (Wagner *et al.*, 1999). HO is located near the summit of Haleakala, at 2,999-3,052 m (9,840-10,012 ft) elevation. Average annual rainfall is 112 cm (44 in), occurring primarily during the winter months (County of Maui, 1998). Temperatures occasionally dip below freezing, with average annual temperature at the summit of Haleakala ranging from 42.6 - 50 degrees F (5.9 - 10 degrees C) (County of Maui 1998), and once every few years it will snow. The substrate is a mixture of ash, cinders, pumice, and lava (RTS 2002). The vegetation is sparse, from a near barren <1% cover to about 10% cover. The vegetation is also low, no more than one meter (3 ft) tall anywhere on the site. During our survey, a total of 44 plant species were observed. Of which 14 (32%) were native and 30 (68%) were non-native.



Example of *Argyroxiphium* / *Dubautia* alpine dry shrubland found within nearby Haleakala National Park, along Sliding Sands Trail (Keoneheehee). Oct. 3, 2005.

GROUND DISTURBANCE

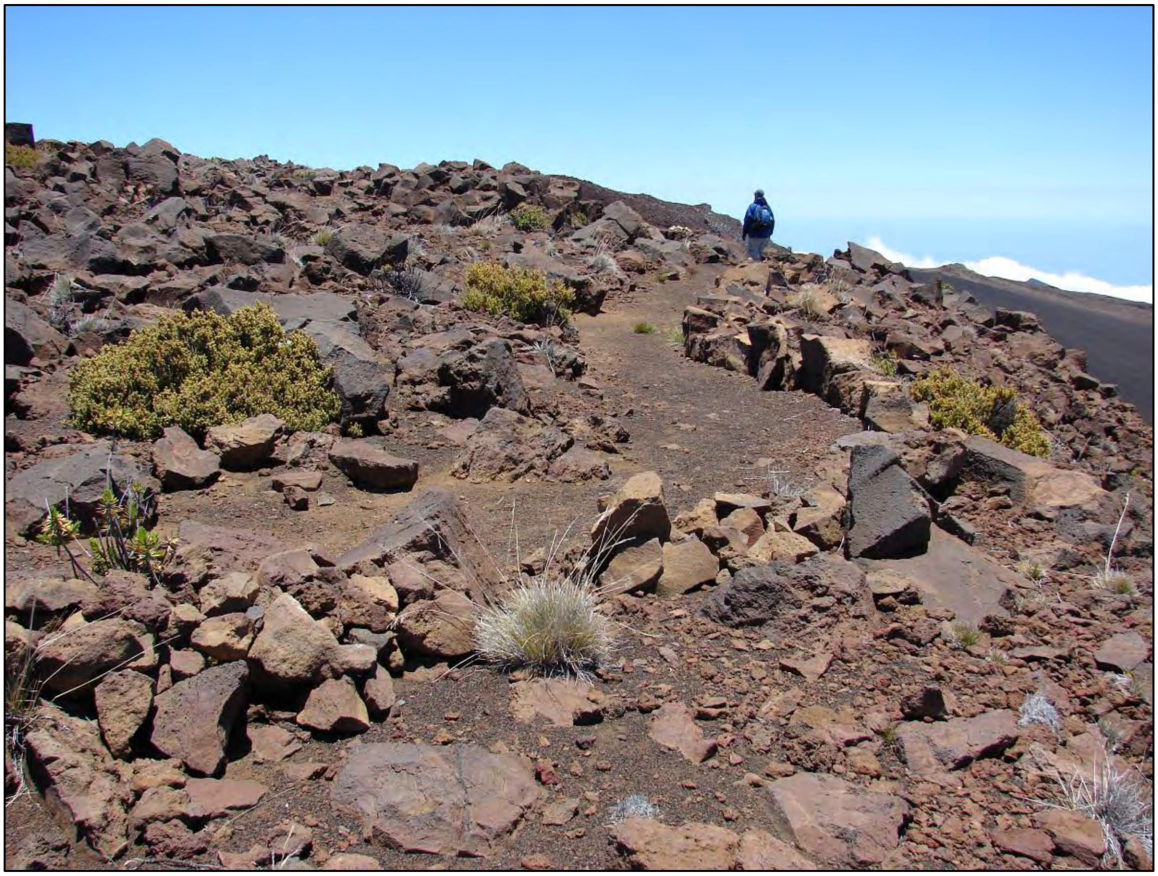
The relative ground disturbance of an area is generally a good indicator of what sort of vegetation can be expected in that area. The most significant disturbance at HO is where a structure or road now exists, followed by areas where large machinery has graded the original land form. The least disturbed areas appear to have the original land form and are generally steep and rocky. Technically, those portions of HO that have been reshaped, graded, or where sediment has been removed are here considered "disturbed" in relation to the vegetation. However, much of this work is considered effective erosion control.

We and other workers have found the least disturbed portions of HO hold the most native plants, and the most disturbed portions of HO hold the most non-native plants. One notable exception is the Haleakala silversword, which currently occurs at HO almost exclusively in areas heavily modified by construction.

Even with all the activity HO has had in its history, there are still some relatively undisturbed areas of HO that appear to have the original landform and flora. Protecting these least disturbed areas, and focusing future construction and activities on areas that have already had the most disturbance and subsequent change of flora would seemingly decrease the negative impact on the botanical resources at HO.

Screen capture from 1964 video showing the MSSS site being leveled by a bulldozer before construction.

LESS DISTURBED AREAS



The southern end of HO is relatively undisturbed compared to the rest of the site, as evidenced by the mostly native plants, including the native pukiawe shrub (*Leptecophylla tameiameiae*) which seems to not return to disturbed areas as quickly as other native plants. May 4, 2009.

Undisturbed areas are comprised of predominantly native plants including shrubs, such as kupaoa (*Dubautia menziesii*), pukiawe (*Leptecophylla tameiameiae*) and ohelo (*Vaccinium reticulatum*), herbs, such as tetramolopium (*Tetramolopium humile* subsp. *haleakalae*) and catchfly (*Silene struthioloides*), and the three native alpine grasses, bentgrass (*Agrostis sandwicensis*), hairgrass (*Deschampsia nubigena*), and mountain pili (*Trisetum glomeratum*). Five species of native ferns, iwa iwa (*Asplenium adiantum-nigrum*), oalii (*Asplenium trichomanes* subsp. *densum*), laukahi (*Dryopteris wallichiana*), kalamoho (*Pellaea ternifolia*), and bracken fern (*Pteridium aquilinum* subsp. *decompositum*) are found tucked into rock crevices and overhangs.

MORE DISTURBED AREAS

Heavily disturbed areas, such as the Reber Circle, one of the first structures to be built at HO, generally have more weeds and less native plants than nearby less disturbed areas. Dec. 2, 2005.

Areas of HO where construction has occurred generally support fewer native species and contain more weeds. Weeds found in these disturbed areas include the non-native herbs thyme-leaved sandwort (*Arenaria serpyllifolia*), storksbill (*Erodium cicutarium*), hairy cat's ear (*Hypochoeris radicata*), sweet allysum (*Lobularia maritima*), common mallow (*Malva neglecta*), black medick (*Medicago lupulina*), evening primrose (*Oenothera stricta* subsp. *stricta*), common plantain (*Plantago lanceolata*), sheep sorrel (*Rumex acetosella*), and common dandelion (*Taraxicum officinale*). These areas also harbor a selection of non-native grasses, including rescue grass (*Bromus catharticus*), Bermuda grass (*Cynodon dactylon*), red fescue (*Festuca rubra*), Yorkshire fog (*Holcus lanatus*), annual bluegrass (*Poa annua*), Kentucky bluegrass (*Poa pratensis*), brome fescue (*Vulpia bromoides*), and rat tail fescue (*Vulpia myuros*). Interestingly, in these disturbed areas on HO can also be found the endemic silversword or ahinahina (*Argyroxiphium sandwicense* subsp. *macrocephalum*) which, though it used to be found in undisturbed areas, is currently found exclusively on areas in HO where heavy disturbance has occurred.

BUILDINGS AND ROADS

Haleakala silversword thriving in an MSSC "planter" next to a vegetation-free concrete slab. May 4, 2009.

There are large areas of HO covered by buildings, concrete, and asphalt. As could likely be surmised, no plants grow there. The exception is the cracks in concrete and asphalt, where some plants are able to get a foothold. Several non-native species, some previously not recorded before this survey, were found in road and concrete cracks, including Maui pamakani (*Ageratina adenophora*), hairy horseweed (*Conyza bonariensis*), Kikuyu grass (*Pennisetum clandestinum*), and pine (*Pinus* sp.). Also of note are the cinder "planters" in the Maui Space Surveillance Complex (MSSC) where the Haleakala silversword has thrived, increasing from three cultivated silverswords in 1991 to 159 silverswords found in 2009, most of which appeared since 2002.

CHANGES IN VEGETATION OVER TIME

In general the number of species has increased over time, and it appears the distribution and abundance of both native and non-native plants has increased. GPS work conducted during this study will allow for greater resolution detail of future vegetation changes.

The number of native and non-native plant species at HO has increased. In 2002 there was a total of 32 plant species, 11 were native and 21 were non-native. In 2009 there was a total of 44 plant species, 12 more than previously, 3 new natives and 9 new non-natives, for a total of 14 native species and 30 non-native species currently known from HO.

Species previously reported from HO that were not observed in 2009 include *Anthoxanthum odoratum* and *Senecio sylvaticus*. These species may have disappeared, may have been overlooked, or may persist as seed in the soil.

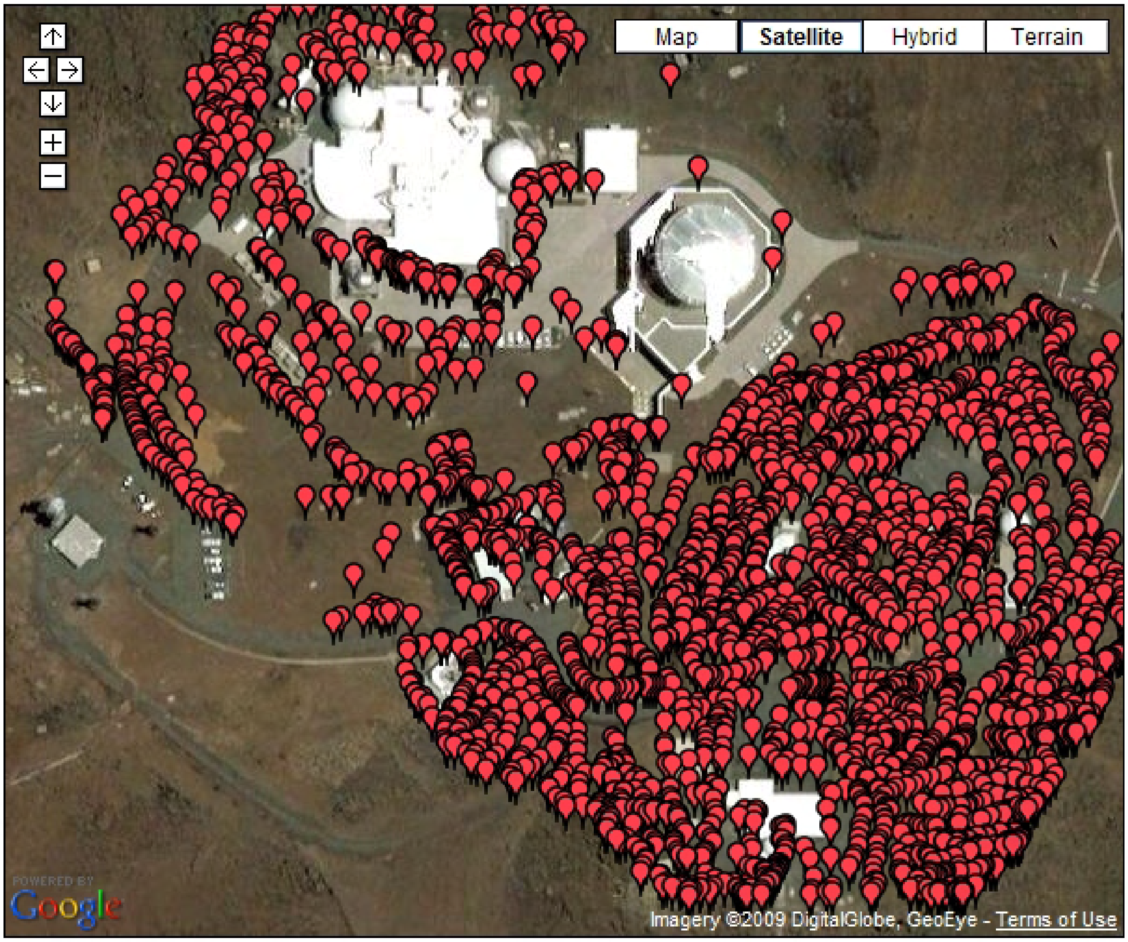
There were 9 new non-native species recorded in 2009 (*Ageratina adenophora, Bromus diandrus, Conyza bonariensis, Dactylis glomerata, Festuca rubra, Pennisetum clandestinum, Trifolium repens*, Unknown sp., and *Vulpia myuros*). These species may be new arrivals, they may have been overlooked in previous studies, or perhaps they were persisting as seeds in the soil and have recently germinated.

There were 3 new native species recorded in 2009 (*Dryopteris wallichiana, Pteridium aquilinum* var. *decompositum, Silene struthioloides*). These could be new arrivals, but these inconspicuous natives could have just as easily been overlooked in previous surveys. There are individual write-ups for each species in the annotated checklist.

Silene struthioloides, a new addition to the native plants known from HO. May 4, 2009.

DISTRIBUTION OF NATIVES

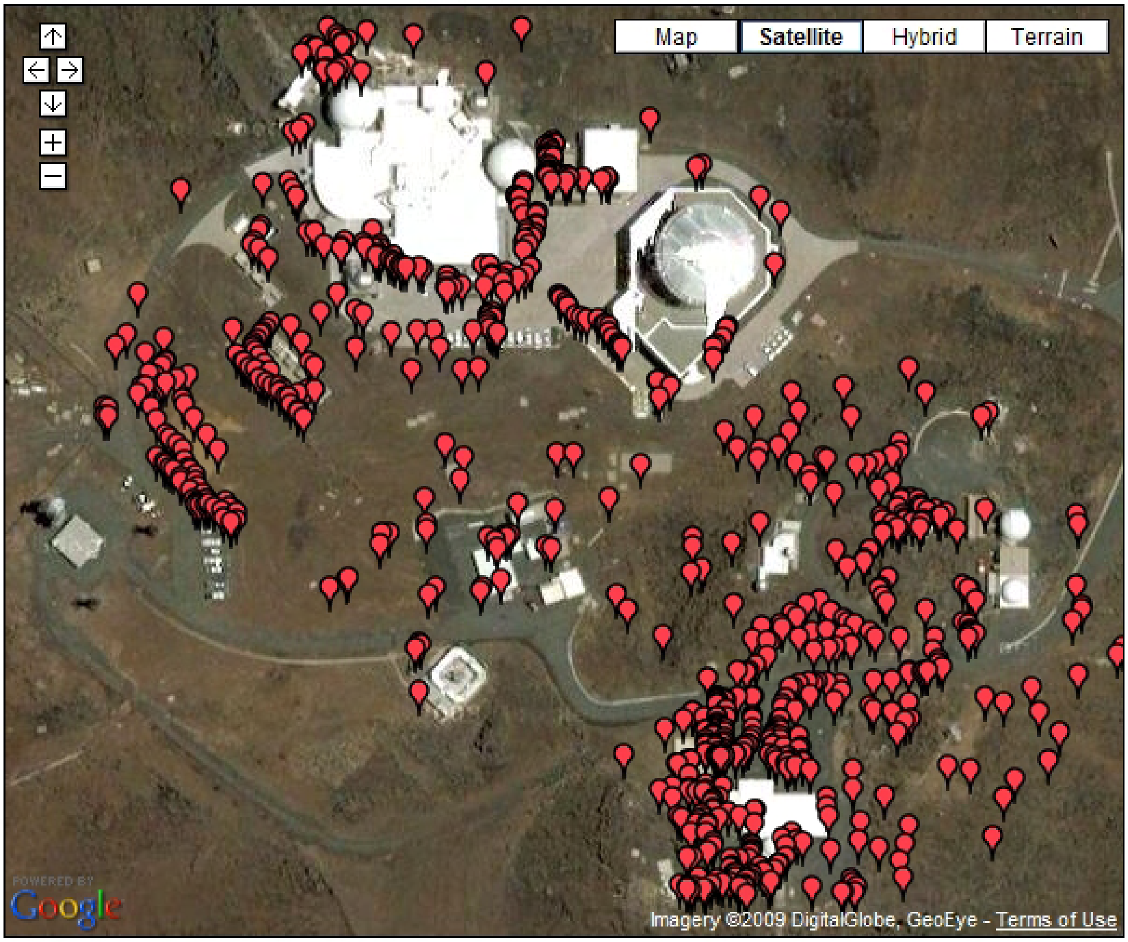
Native - June 2009



Despite the sparse looking nature of HO, native plants cover most of the site, except for recently disturbed ground or permanently surfaced areas. Of the 3754 plant points collected during this survey, 2949 were for native plants. Most of these points were for the native bunch grass *Deschampsia nubigena* and the native shrub *Dubautia menziesii*. There are individual maps for each species in the annotated checklist.

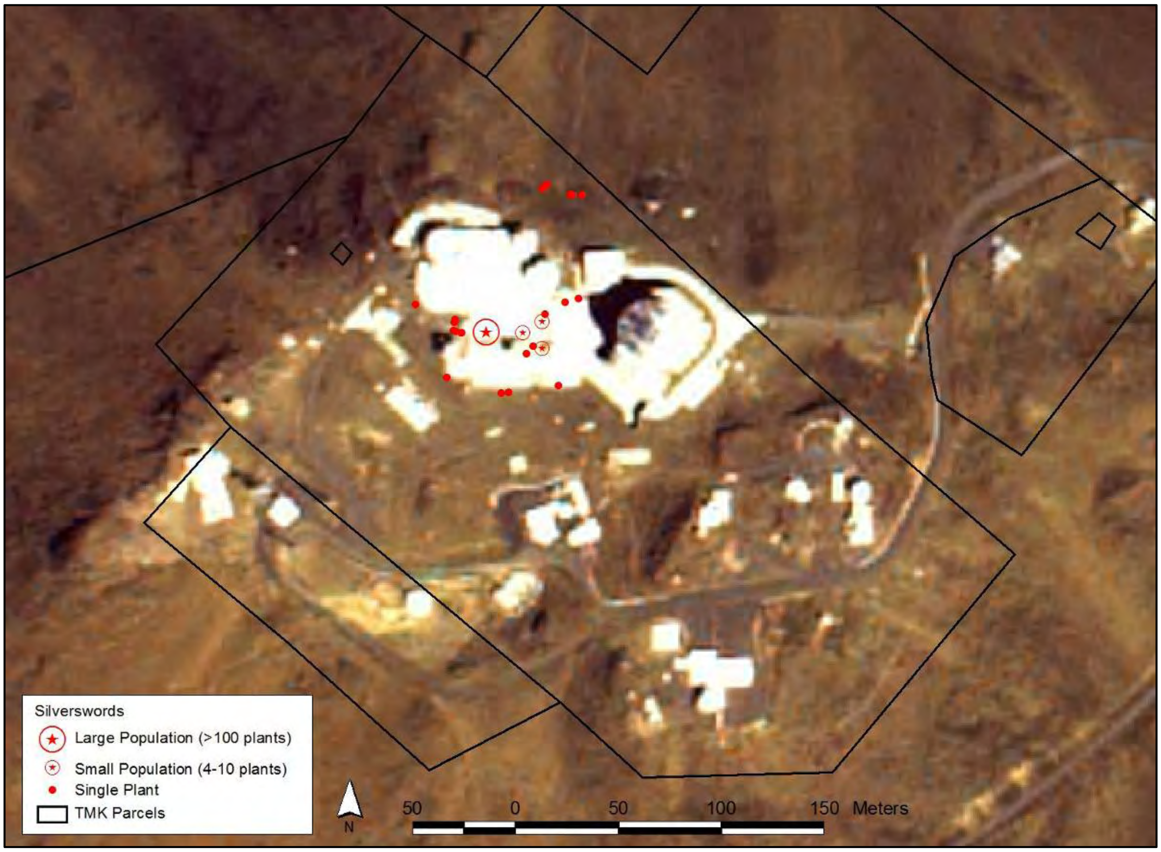
DISTRIBUTION OF NON-NATIVES

Non-Native - June 2009



Non-native plants are abundant at HO, but are generally restricted to areas of previous disturbance. Of the 3754 plant points collected during this survey, 805 were for non-native plants. The area around the Mees Solar Observatory seems to be the weediest portion of HO. *Lobularia maritima* is an emerging weed. There are individual maps for each species in the annotated checklist.

ENDANGERED, THREATENED, LISTED, OR PROPOSED PLANT SPECIES



Map of 159 Haleakala silversword plants currently found at HO during recent (2009) survey.

Haleakala silverswords (*Argyroxiphium sandwicense* subsp. *macrocephalum*) are the only plant with federal status on the HO property. Haleakala silverswords are federally listed as "threatened" species, meaning they may become endangered throughout all or a significant portion of their range if no protection measures are taken. 159 live silverswords were located at HO. All live plants are located on or near MSSC on land that has undergone heavy construction activities.

As has been stated in previous botanical surveys (Belt Collins & Associates 1994; Char & Associates 2000; Starr & Starr 2002), and given what has been witnessed to date, it appears that if there was to be construction in areas of the property where silverswords now occur, the silverswords could likely be relocated to another area without adverse effects. Those performing relocations should consult with Haleakala National Park and United States Fish and Wildlife personnel before construction to determine where and how best to relocate the plants.

It should be noted the workers at HO, in particular the MSSC, are very proud of the silverswords on site and do a great job tracking the plants and making sure they are not impacted during operations. It is nice to see this iconic plant able to find a home at HO. There is a detailed write up about the HO silverswords in the annotated checklist.

WEED CONTROL

Non-native plants such as this *Erodium cicutarium* appeared more common at HO in 2009 than in 2005. May 4, 2009.

IfA is known to be a stellar performer when taking into consideration the environmental, cultural, and historic importance of Haleakala.

With that in mind, it appears there has not been much weed control at HO since our last botanical survey in 2005. In 2002, when IfA was gathering botanical information for a Long Range Development Plan, we had high praise for part of HO and wrote "The MSSC does a good job of controlling weedy species while letting the native species flourish on their site." We added "Similar efforts on the rest of the UH property would go a long way towards protecting the summit flora, and minimizing negative effects on the botanical resources." We reiterated the same in 2005 for the ATST project.

For a number of reasons, an increased emphasis in weed control was not able to be implemented. However, IfA is now making an effort to address the spread of weeds at HO, and we are hopeful the weed situation will soon be brought under control.

We suggest regular weed control be done on the entire HO property, with the ultimate goal of no non-native plants.

NON-NATIVE PLANTINGS

A Japanese tsugi pine (*Cryptomeria japonica*) planted at HO. This is one of three non-native conifers removed from HO at the request of the Friends of Haleakala National Park. Dec. 2, 2005.

There have been examples of folks intentionally planting non-native plants at HO in the past. However, there was no evidence of plantings of non-native plants since the last survey. This is likely due to IfA's training and orientation for workers at HO.

In 1972 UH did some experimental non-native grass plantings at HO. Belt Collins (1994) reports "many of the weedy species on the site are recently introduced and occupy, or have spread from an experimental plot of grasses ... that was planted in 1972." We recall seeing an aerial image of the HO site from that period that showed the strips of grass, which could potentially be the original source for some of the non-native grasses found at HO today.

More recently two unidentified pine species (*Pinus* sp.) and a Japanese tsugi pine (*Cryptomeria japonica*) were found at HO. These non-native conifers were removed at the request of the Friends of Haleakala National park. There are additional write-ups for these species in the annotated checklist.

PLANT OFFERINGS

Ahu on Northwest side of HO with offerings of ti leaf (*Cordyline fruticosa*). May 4, 2009.

Rock ahu have recently been constructed of on either side of HO. On top of these ahu are regularly placed offerings of various items, including plants.

From a botanical perspective, these offerings appear to currently have little effect on the vegetation, as they are mostly sterile ti leaves (*Cordyline fruticosa*). However, we feel obligated to mention that offerings containing seeds of plants could have the potential to introduce species to the site.

It would also be prudent to mention fruits or other items could potentially attract predators, such as mongooses, that could put nearby Hawaiian Petrels at risk. Additionally, some plant items could attract small mammals, such as mice, that could then prey on native insects and arthropods. Having the folks doing the offerings be aware of this should help protect the environmental resources at HO.

WEED PREVENTION DURING CONSTRUCTION

As mentioned in previous surveys, accidentally introducing non-native species to the summit area during construction can disrupt the native ecosystem and have significant adverse effects to the native biota.

To reduce potential for unwanted introductions, the construction contractor should take the following measures outlined in Belt Collins (1994).

- Arrange for a qualified biologist or agricultural inspector to check shipments of new equipment, supplies, and containers holding construction materials before departure from the Mainland and prior to unloading at Kahului Harbor or Airport. Specimens of non-native species that are found by these inspections would be collected and offered to the Bishop Museum for curation; those not wanted by the Museum would be destroyed. Containers that are too heavily infested to permit complete cleaning would be returned undelivered.

- Prohibit the construction contractor from bringing fill material into the National Park. Instead, fill would be limited to material obtained from excavation within the Science City area, and the contractor would be prohibited from returning excavated material to the site once it has been taken to lower elevations. The contractor would also be required to make surplus material available to the University of Hawai'i for use elsewhere within Science City or to the National Park Service for reutilization within Haleakala National Park.

- Require the contractor to wash all equipment (to insure removal of all organic matter and insects) before entering the National Park. Qualified personnel would inspect the equipment while it is at lower elevations to assure that the cleaning is thorough. National Park Service personnel would make spot checks of the equipment at the Park entrance to further insure the adequacy of the cleaning. Equipment failing the inspections would not be allowed to enter the Park.

- Require the contractor to cooperate with the National Park Service in developing and implementing a construction worker education program that informs workers of the damage that can be done by unwanted introductions. Satisfactory fulfillment of this requirement would be evidenced by successful completion of a test approved by the National Park Service and administered by the contractor under the Air Force's supervision. All workers bringing vehicles into Science City would be required to pass the test before beginning work on the site, as would all drivers of construction vehicles entering the National Park.

- Prohibit parking of heavy equipment and storage of construction materials on adjacent cinder areas that would not otherwise be affected by the proposed action, thus limiting the disturbance to the natural ground surface and minimizing the potential for the contamination of natural areas.

- Require the frequent removal of construction trash, particularly materials that could serve as a food source for small alien mammals (such as mice) that prey on native insects and arthropods.

WEED PREVENTION DURING OPERATION

Protection of the botanical resources shouldn't end after completion of a structure. The following guidelines should help minimize negative impacts to the botanical resources during operation of facilities.

- Regular weed control should be done on the entire HO property, with the ultimate goal of no non-native plants.

- Future plantings of non-native species should be avoided.

- Workers should be aware the summit area contains valuable botanical resources, and they should help minimize negative impacts on those resources.

- Workers should clean / brush off their shoes before entering the site, especially if they are noticeably soiled. This will help prevent seeds and other organisms from hitching a ride.

- The same general cleanliness should apply to vehicles and equipment; visibly soiled items should be cleaned before entering HO.

PLANT CHECKLIST

Below are all the plant species known from HO, based on previous and current botanical surveys. Only Starr 2002 and Starr 2009 survey the full site.

Native	Scientific name	Starr 2009	Starr 2005	Starr 2002	RTS 2002	Char 2000	BC 1994	AF 1991
	Ageratina adenophora	R						
*	*Agrostis sandwicensis*	O	X	O			X	X
	Anthoxanthum odoratum			R				
	Arenaria serpyllifolia	O	X	R				
*	*Argyroxiphium sandwicense* subsp. *macrocephalum*	C	X	R	X		X	X
*	*Asplenium adiantum-nigrum*	O	X	R				
*	*Asplenium trichomanes* subsp. *densum*	R/O	X	R				
	Axonopus sp.	R						
	Bromus catharticus	O	X	R				
	Bromus diandrus	R						
	Conyza bonariensis	R						
	Cynodon dactylon	R		R				
	Cryptomeria japonica		X					
	Dactylis glomerata	R						
*	*Deschampsia nubigena*	C	X	C	X	X	X	X
*	*Dubautia menziesii*	C	X	C	X	X	X	X
*	*Dryopteris wallichiana*	R						
	Erodium cicutarium	C	X	O				
	Festuca rubra	O						
*	*Geranium cuneatum* subsp. *tridens*						X	
	Holcus lanatus	O	X	O				
	Hypochoeris radicata	C	X	O	X	X	X	X
*	*Leptecophylla tameiameiae*	O	X	O		X	X	
	Lobularia maritima	C	X	O				
*	*Lythrum maritimum*		X					
	Malva neglecta	R		R				
	Medicago lupulina	C	X	O				
	Oenothera stricta subsp. *stricta*	O/C	X	R				
*	*Pellaea ternifolia*	R/O	X	R				
	Pennisetum clandestinum	R						
	Pinus sp.	R	X	R				
	Plantago lanceolata	O/C	X	O				
	Poa annua	R		R				
	Poa pratensis	C	X	O				
	Polycarpon tetraphyllum	R		R				
*	*Pteridium aquilinum* var. *decompositum*	R						
	Rumex acetosella	R		O				
	Senecio sylvaticus			R				
	Senecio vulgaris				X		X	X
*	*Silene struthioloides*	R						
	Sonchus oleraceus	R		R				

Native	Scientific name	Starr 2009	Starr 2005	Starr 2002	RTS 2002	Char 2000	BC 1994	AF 1991
	Taraxacum officinale	O/C		O	X		X	X
*	*Tetramolopium humile* subsp. *haleakalae*	C	X	C	X	X	X	X
	Trifolium repens	R						
*	*Trisetum glomeratum*	C	X	C	X	X	X	X
	Unknown sp.	R						
*	*Vaccinium reticulatum*	R/O	X	R			X	
	Vicia sativa	R	X					
	Vulpia bromoides	O		O				
	Vulpia myuros	O						
Total		45	25	33	8	6	12	9

* = Native, X = Present, R = Rare, O = Occasional, C = Common

Starr 2009 - Survey of HO
Starr 2005 - Survey of proposed ATST sites
Starr 2002 - Survey of HO
Rocketdyne Technical Services (RTS) 2002 - Survey of MSSC (Maui Space Surveillance Complex
Char 2000 - Survey of Faulkes site (1.5 acre)
Belt Collins & Associates 1994 - Survey of MSSS
Air Force (AF) 1991 - Suvey of Maui Space Surveillance Site (MSSS)

ANNOTATED CHECKLIST

The following annotated checklist is designed to capture the history of every plants species ever recorded from HO, and to provide an identification guide to assist with management of the botanical resources.

Each plant has the scientific name, common name, plant family, nativity status, an image (images not always from HO), a history of the plant from previous botanical surveys, the current status of the species at HO, and a map of GPS locations for species observed during this botanical survey.

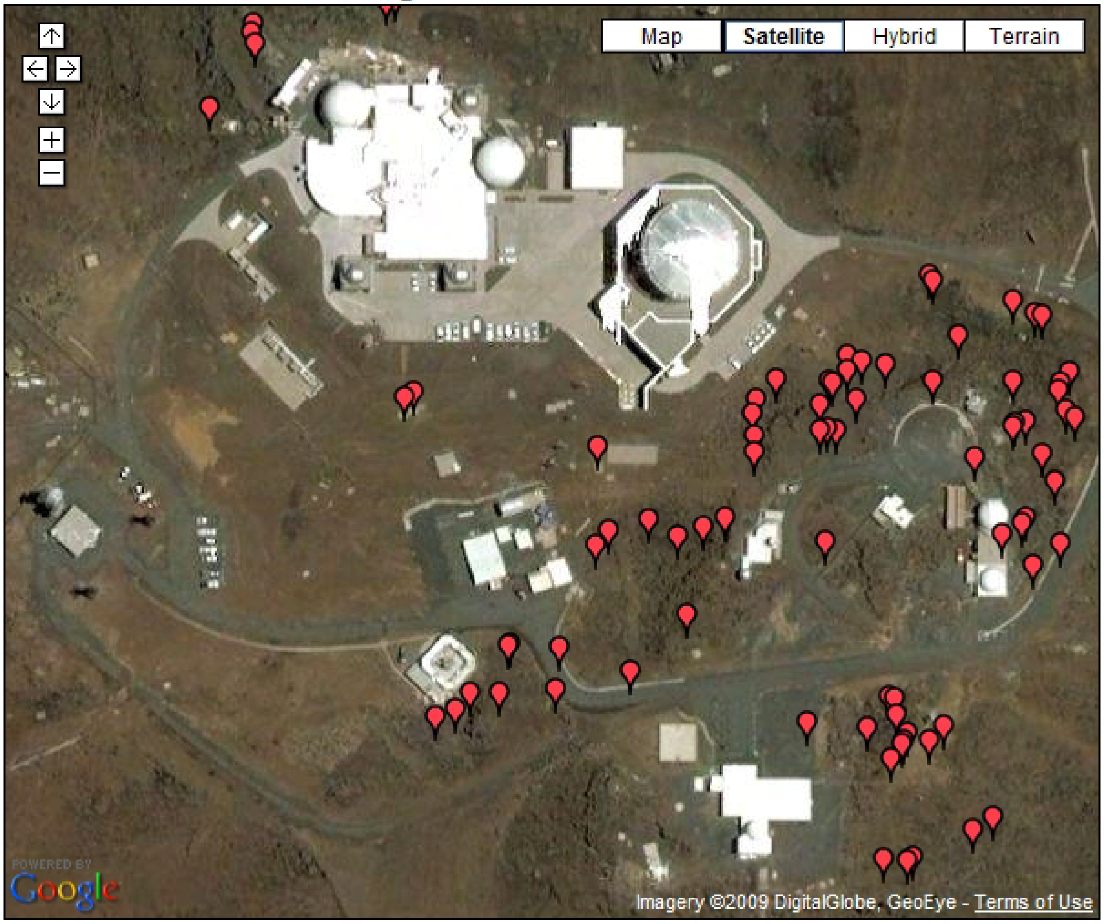
Some of the species included here were not observed in 2009.

Ageratina adenophora - June 2009

Ageratina adenophora - Maui pamakani - Asteraceae - (Non-native)

This aromatic herb was recorded from HO for the first time during this survey. We found one small sterile plant in a crack between the asphalt and concrete near MSSS. It was pulled.

Agrostis sandwicensis - 2009



Agrostis sandwicensis **- Bentgrass - Poaceae - (Native: Endemic)**

The U.S. Air Force (1991) noted this species as a characteristic component of the vegetation type, alpine dry shrubland. Belt Collins & Associates (1994) noted this species as being found within the study site. Starr & Starr (2002) reported this species as occasional and typically found within areas that were not disturbed by construction, such as sites identified as having archeological significance around the LURE observatory and on the steep slopes on the southeast part of the property near the Mees Observatory. Starr & Starr (2005) reported "Endemic. Slender native bunch grass. The least common of the three native grasses found in the alpine area of Haleakala. Scattered about both sites. Mees: Occasional. A dozen or so plants scattered amongst the rocks. Reber: Occasional. A bit more common than at the Mees site, with 33 plants observed." In 2009 this bunch grass was occasional to common, scattered over the least disturbed areas of HO.

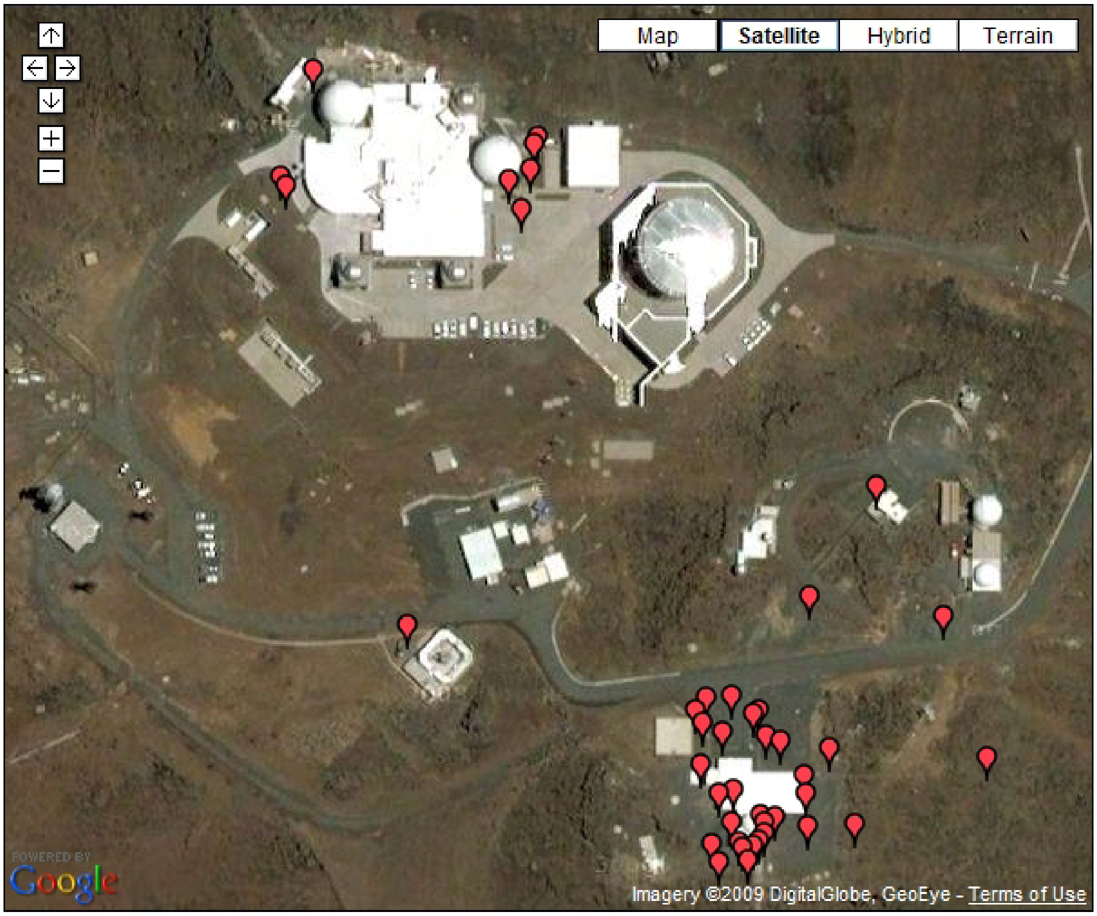
Anthoxanthum odoratum - June 2009

Not observed in 2009

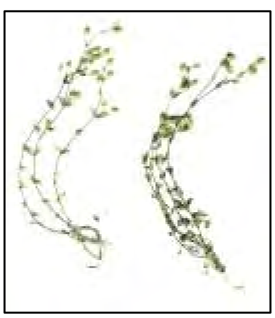
***Anthoxanthum odoratum* - Sweet vernal grass - Poaceae - (Non-native)**

Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. This slender bunch grass was not observed in 2009. The species could be gone, overlooked, or exist in the soil as seed.

Arenaria serpyllifolia - June 2009

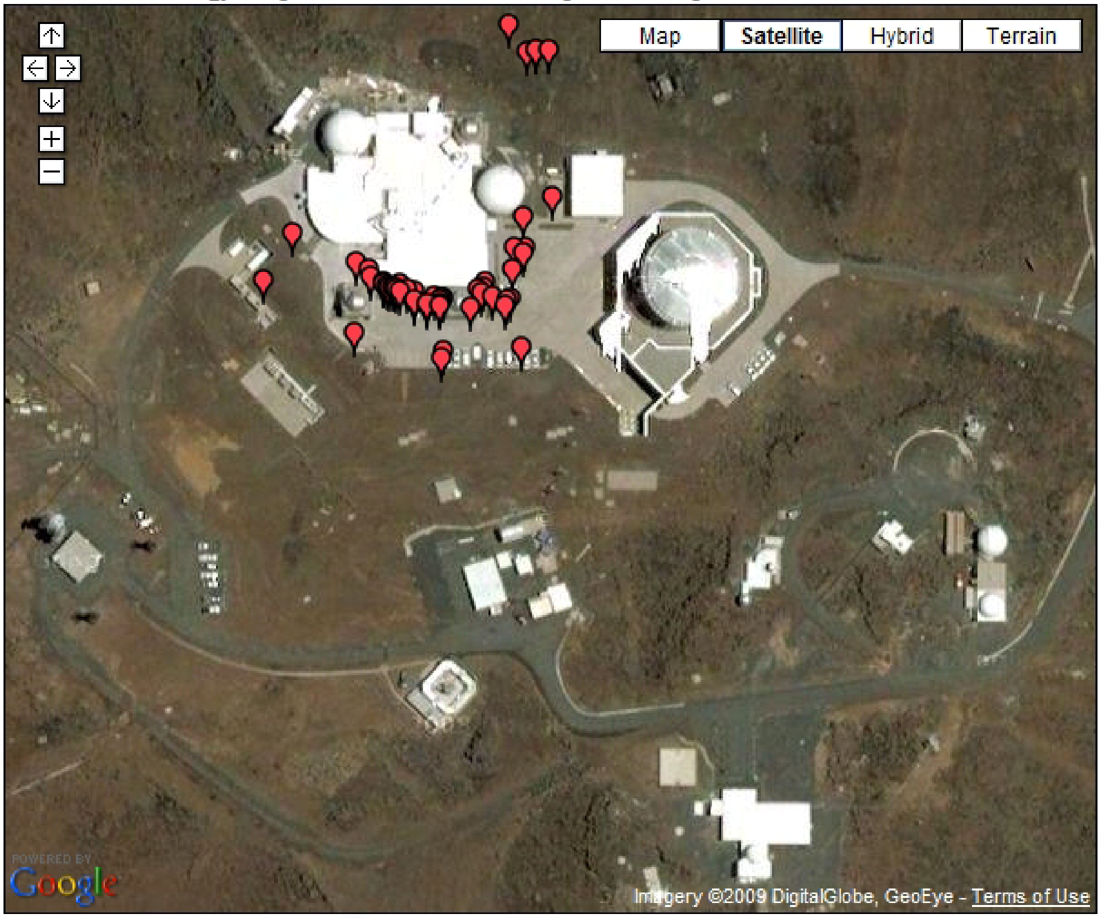


Arenaria serpyllifolia **- Thyme-leaved sandwort - Caryophyllaceae - (Non-native)**



Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. Ephemeral herb that seems to come and go with the rains. Most common near Mees Solar Observatory. Mees: A few plants in rocks in relatively undisturbed portion of site. Many more plants along the north wall of Mees Solar Observatory. Reber: None." In 2009 this delicate herb was found to be occasional in disturbed areas, especially near buildings.

Argyroxiphium sandwicense subsp. macrocephalum - June 2009



Argyroxiphium sandwicense subsp. _macrocephalum_ - Ahinahina, silversword - Asteraceae - (Native: Endemic)

The iconic Haleakala silversword is the only plant species at HO that has any Federal status, it is currently listed as Threatened by the United States Fish and Wildlife Service.

The U.S. Air Force (1991) noted this species as a characteristic component of the vegetation type, alpine dry shrubland. In their survey, they did not recognize this plant to subspecies level and noted that, "*A. sandwicense* is found only on Haleakala on Maui and on Mauna Kea on the island of Hawaii growing in elevations between 2125 and 3750 m (7000 and 12,300 ft). It favors the rocks in dry, porous soil or volcanic cinders (Wagner et al. 1990)". In addition, they note the following. "Three native but cultivated Ahinahina have been successfully transplanted near the facilities. A fourth ahinahina is growing between the LURE facility and Kolekole Hill."

Belt Collins & Associates (1994) reported "Three ahinahina have been successfully transplanted to locations within the MSSS complex, and a fourth ahinahina is growing near the LURE facility. The oldest ahinahina within the MSSS complex flourished until it bloomed, then died, a natural part of its life cycle. The remaining plants continue to do well."

Char & Associates (2000) reported "Plants of the endangered silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*) were found in the earlier studies for the Maui Space Surveillance Site expansion (U.S. Air Force 1991) and the AEOS Telescope site (Belt Collins & Associates 1994). No silversword plants were found on the proposed Faulkes Telescope site during this study."

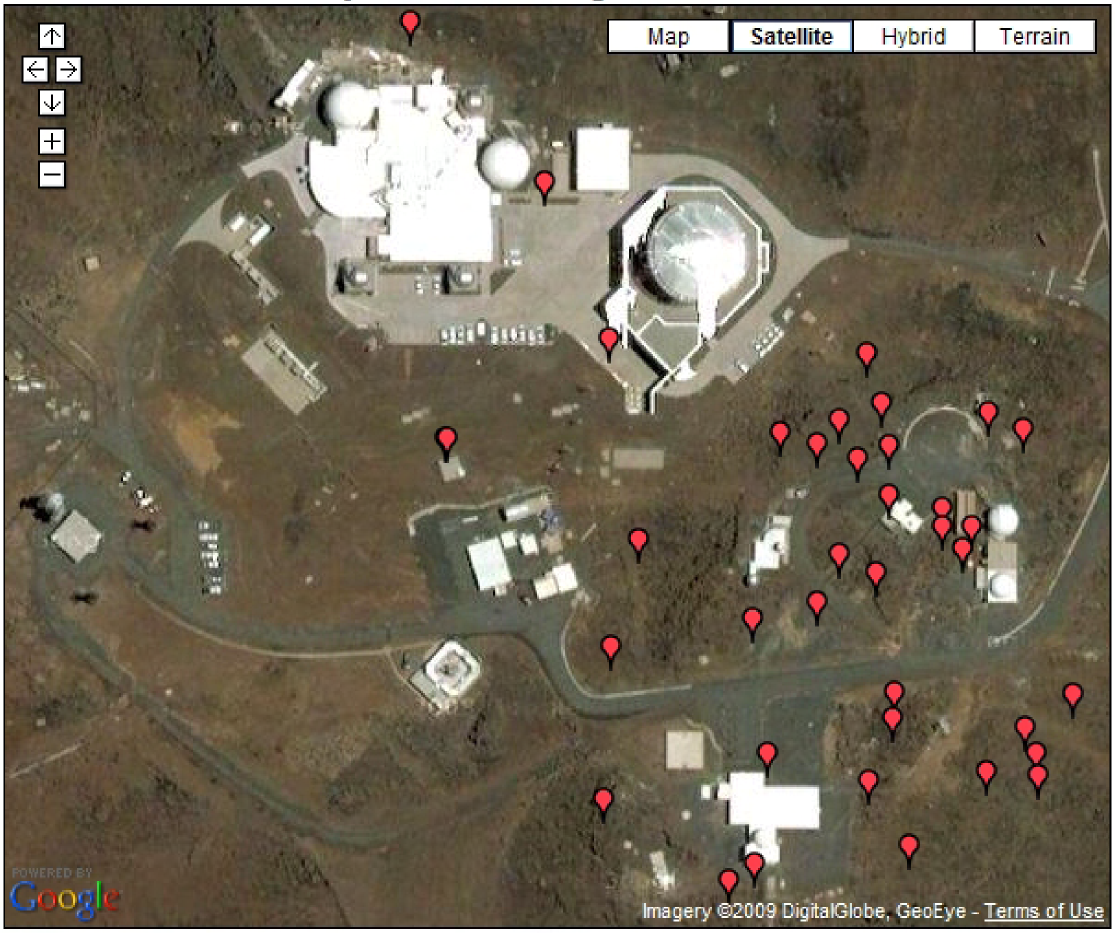
RTS (2002) noted "The native (or endemic) silversword, which is listed as a threatened species, is found on land adjacent to the MSSC (Maui Space Surveillance Complex) and has been known to occur on the site in the past. Currently, several juvenile silverswords grow within the site boundaries."

Starr & Starr (2002) found the silversword to be rare at HO, and reported "Areas of the UH property where construction has occurred generally support fewer native species and contain more weeds. One notable exception is the endemic silversword or ahinahina which is found exclusively on areas where construction has occurred." They add further, "Nine live silverswords and three dead silversword flower stalks were located on the UH property. All of the live plants are on the MSSC. Despite being quite large, up to 50 cm (20 in) in diameter, these nine live silverswords apparently are all less than five years old and have grown since construction of the Advanced Electro-Optical System (AEOS) facility (Steve Shimko pers. comm.). They are located in landscaped areas, alongside retaining walls, on a steep slope just below the parking area, and in the MSSC leach field. There are also three dead silversword flowers stalks on the UH property. National Park Service personnel placed two of the stalks near the MSSC leach field. The other dead silversword flower stalk is located near the LURE Observatory and was alive in 1991 (Department of Air Force 1991)."

Starr & Starr (2005) reported "Endemic. Distinctive silver rosette plant found only on East Maui. The silverswords at HO are some of the only known silverswords in the wild beyond the Haleakala National Park boundary. One dead plant was found near the Reber site. Mees: None. Reber: One dead plant observed near the site. The area around the silversword plant was searched for seeds, but none were found." They add, "The lone silversword is located on the Reber site, east of the Reber Circle, near an existing small building. The silversword appeared to have been dead for many years, and to have gone to flower before dying. The dead silversword flowering stalk skeleton was not observed, and it is not known where it went. The area around the silversword plant was searched for seeds, but none was found."

In 2009 we were pleasantly surprised to find silverswords were now locally common within the Air Force site at HO, with 159 silverswords counted. The silverswords were generally in the same places as in 2002, but in much greater abundance. At first we were gathering a GPS point for each silversword plant encountered until we came to the large patch of silverswords between the two GEODSS domes. There were so many in this small area (118) that we switched to taking single GPS points for a discrete area and counting silverswords in that area. Most of the silversword plants were less than 20 cm, but there were some 40+ cm plants. It appears the silverswords growing in this heavily modified situation grow much quicker than in natural environments. For example, one of the largest plants (40+ cm) is apparently only five years old. We have never witnessed a silversword grow that fast in the wild. This same accelerated growth also occurs within Haleakala National Park planters. This rapid growth and subsequent shortened life span of cultivated silverswords has been attributed to added moisture and runoff near buildings, a disturbed substrate, and protection from harsh climatic conditions (e.g. wind). Apparently there was a Propylene Glycol spill in February 2008 that entered the areas where the silverswords are. Folks familiar with the spill said the silverswords were unaffected, others jested that perhaps the Propylene Glycol made the silversword do so well at MSSC. Sarah Loney is currently maintaining a detailed history of individual silverswords on the MSSC site. This MSSC Silversword Log goes back to 1998 and chronicles the rapid increase and occasional odd demise of silverswords over the past ten years.

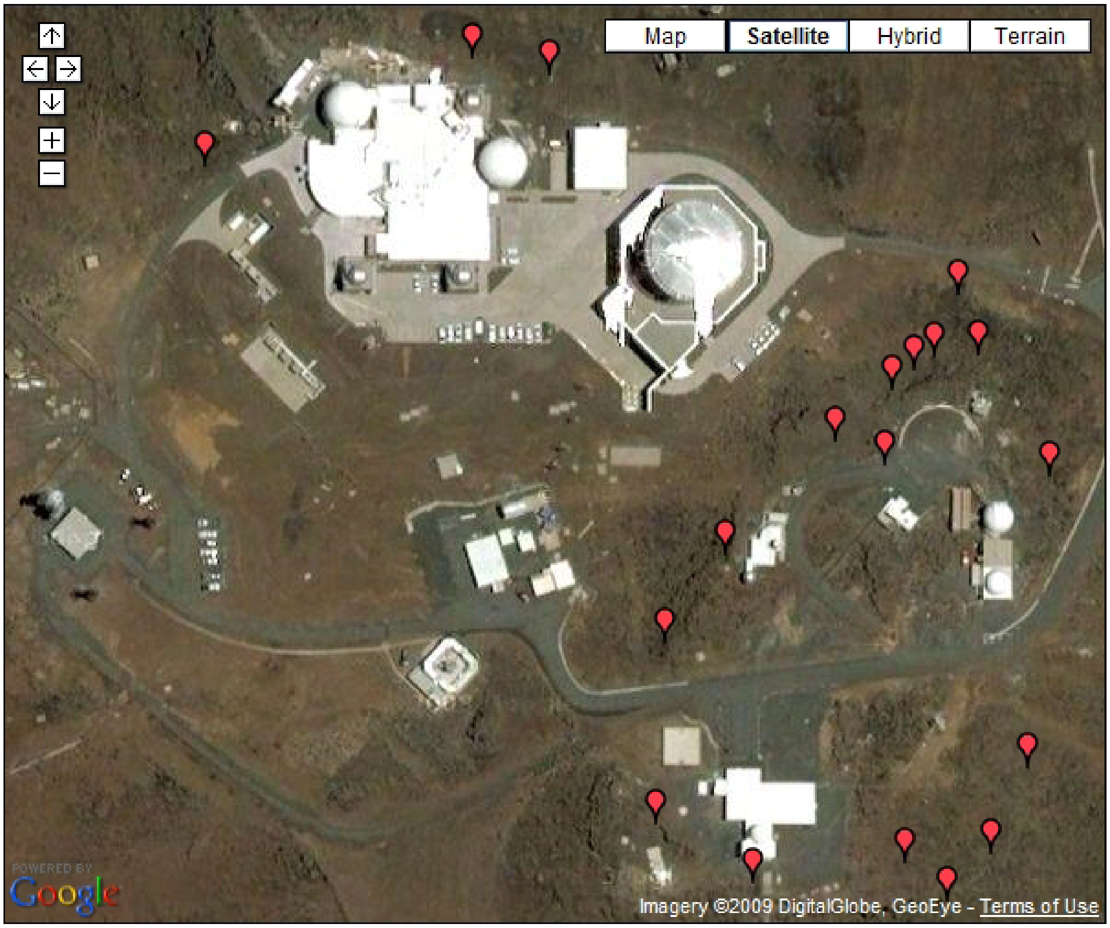
Asplenium adiantum-nigrum - June 2009



***Asplenium adiantum-nigrum* - Iwaiwa - Aspleniaceae - (Native: Indigenous)**

Starr & Starr (2002) reported this species as rare and typically found within areas that were not disturbed by construction and found tucked into rock crevices and overhangs. Starr & Starr (2005) reported "Indigenous. Leathery fern with black stipe found scattered about both sites, especially in rock crevices. Mees: Occasional. A half dozen clumps found in rock crevices. Reber: Occasional. Eight clumps found in rock crevices." In 2009 found to be occasional to common, tucked into rock crevices, especially near steep undisturbed areas.

Asplenium trichomanes subsp. densum - June 2009



Asplenium trichomanes **subsp.** ***densum*** **- Maidenhair spleenwort - Aspleniaceae - (Native: Endemic)**

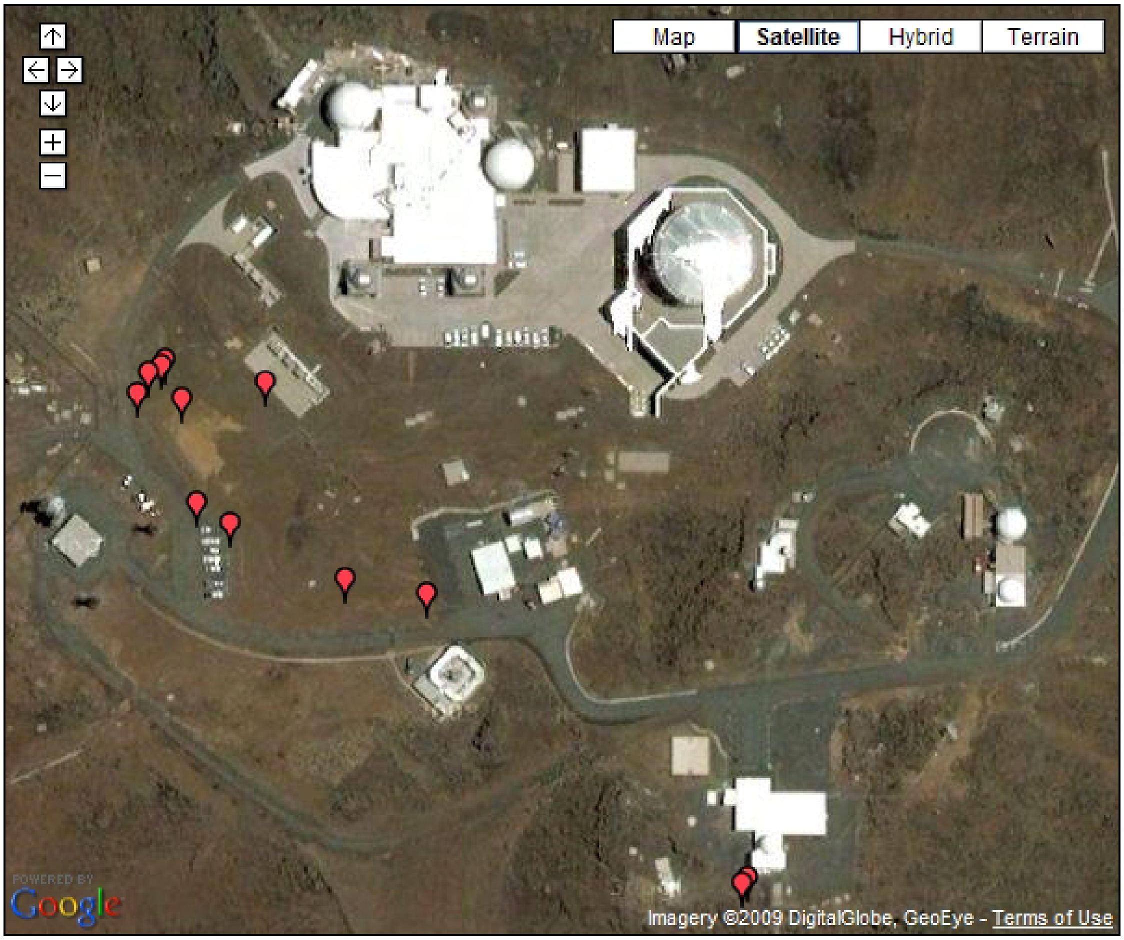
Starr & Starr (2002) reported this species as rare and typically found within areas that were not disturbed by construction and found tucked into rock crevices and overhangs. Starr & Starr (2005) reported "Indigenous. Diminutive fern with small leaves found tucked in rock crevices. Mees: Occasional to rare. Three clumps found tucked in rock crevices, in northwest portion of site. Reber: Rare. One clump found." In 2009 found to be occasional, tucked into rocks in areas with minimal disturbance.

Axonopus sp. - June 2009

***Axonopus* sp. - Carpet grass - Poaceae - (Non-native)**

First found in 2009 as rare. One small sterile patch of what appeared to be this grass was found in a road crack in the Mees parking lot area. This would be the first record of this species at HO. Fertile material would help provide a more definitive ID.

Bromus catharticus - June 2009



***Bromus catharticus* - Rescue grass - Poaceae - (Non-native)**

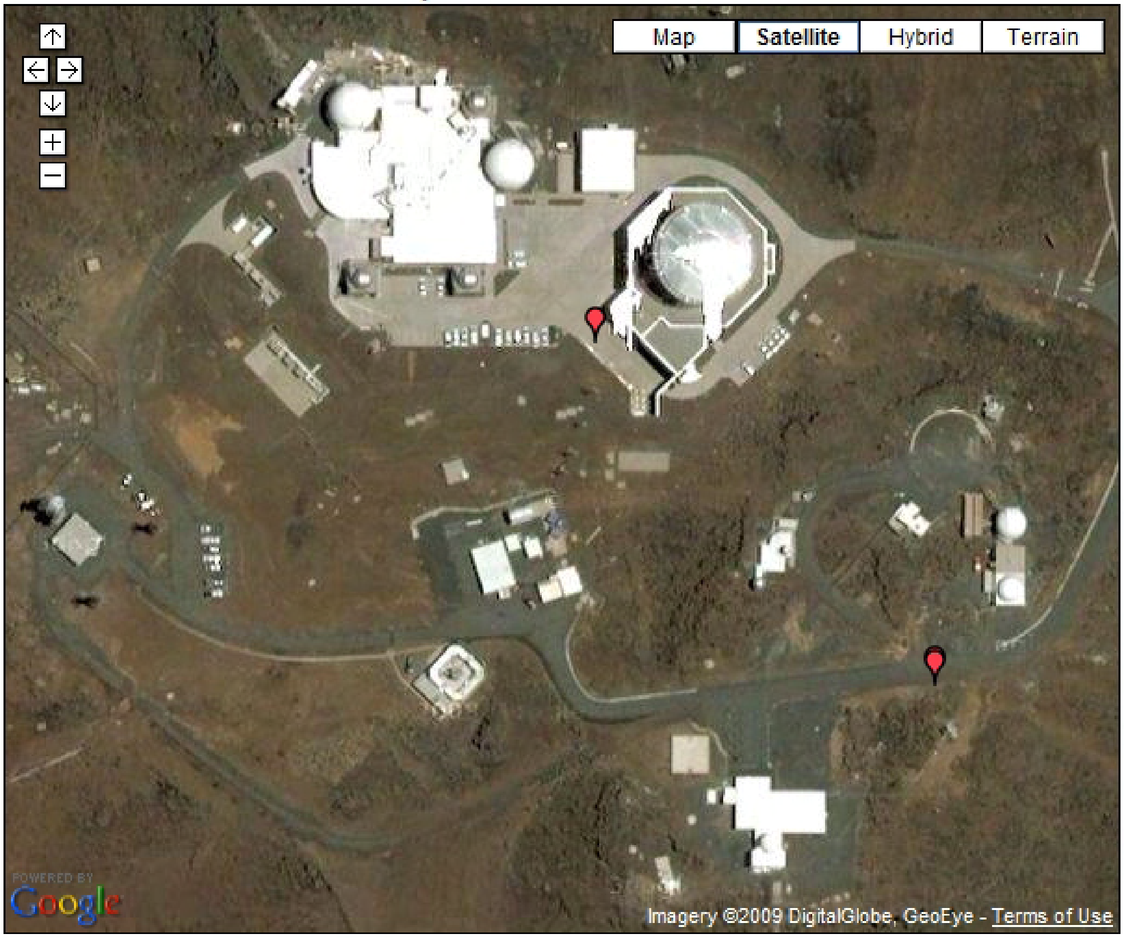
Collected from Science City in 1982 by K.M. Nagata (*#2580, BISH 453791*). Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. Hardy grass with large seed heads. Scattered individuals found around HO, but most common and vigorous in the water retention basin. Mees: None. Reber: None. Basin: A few dozen vigorous plants found in the retention basin, especially on the northwest side." In 2009 found to be rare to occasional, near buildings and in the water retention area.

Bromus diandrus - June 2009

***Bromus diandrus* - Ripgut grass - Poaceae - (Non-native)**

One small patch of about 12 seeding plants was found among the rocks and cinder just west of the Pan Star buildings on the south side of a rock wall surrounding a weather station. The plants were pulled and bagged but were fertile and will likely produce seedlings. Collected to confirm the identity and document a high elevation record (*Starr & Starr 090628-02).*

Conyza bonariensis - June 2009



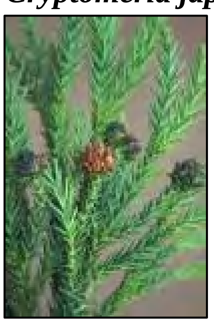
Conyza bonariensis **- Hairy horseweed - Asteraceae - (Non-native)**

First found at HO in 2009 as rare. A few sterile plants were observed growing in a road crack near the LURE complex. One plant was also observed near the AEOS mirror coating facility.

Cryptomeria japonica - June 2009

Not observed in 2009

***Cryptomeria japonica* - Japanese tsugi pine - Taxodiaceae - (Non-native)**



Starr & Starr (2005) reported "Non-native. One lone tree. This is a new addition to plants known from Haleakala Observatories, and the only live "tree" found during a prior survey. Mees: None. Reber: Rare. One tree near former LURE facility. It was about a meter tall, was alive, but not exceptionally vigorous. It appeared to be planted. In following with the Friends of Haleakala request it was removed." Tsugi pine was not observed at HO in 2009.

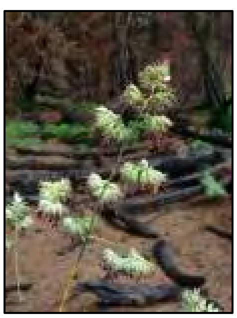
Cynodon dactylon - June 2009

***Cynodon dactylon* - Bermuda grass - Poaceae - (Non-native)**

Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. In 2009 found to still be rare, with one small patch near the Mees Solar Observatory building. It is not known how this grass got to the summit area, but there is a chance it could be a remnant of the 1972 experimental grass plantings.

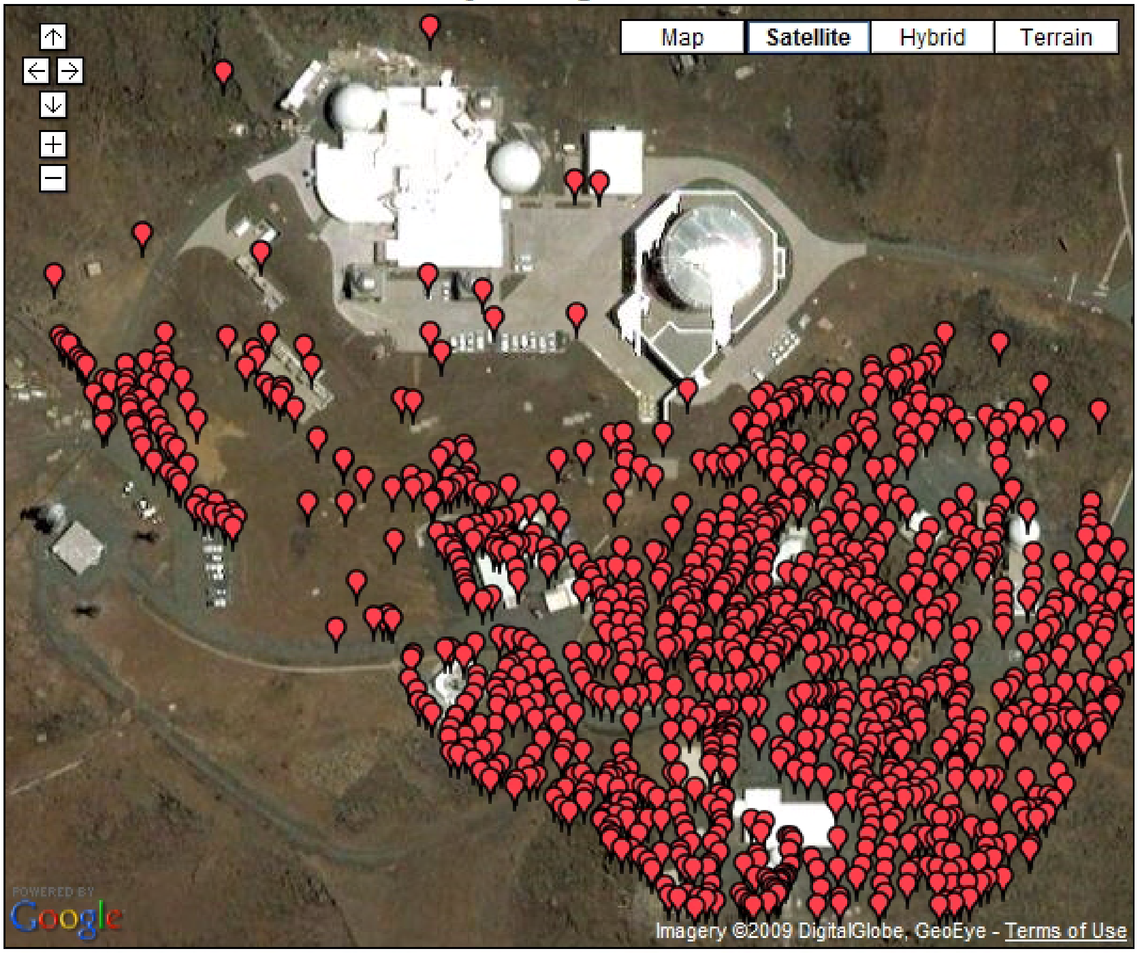
Dactylis glomerata - June 2009

Dactylis glomerata **- Cocksfoot - Poaceae - (Non-native)**



First found at HO in 2009 as rare. One small seeding plant was observed on the west side of the Mees Solar Observatory, between the building and a trailer. Collected do document a high elevation record for the species in Hawaii (*Starr & Starr 090628-01)*.

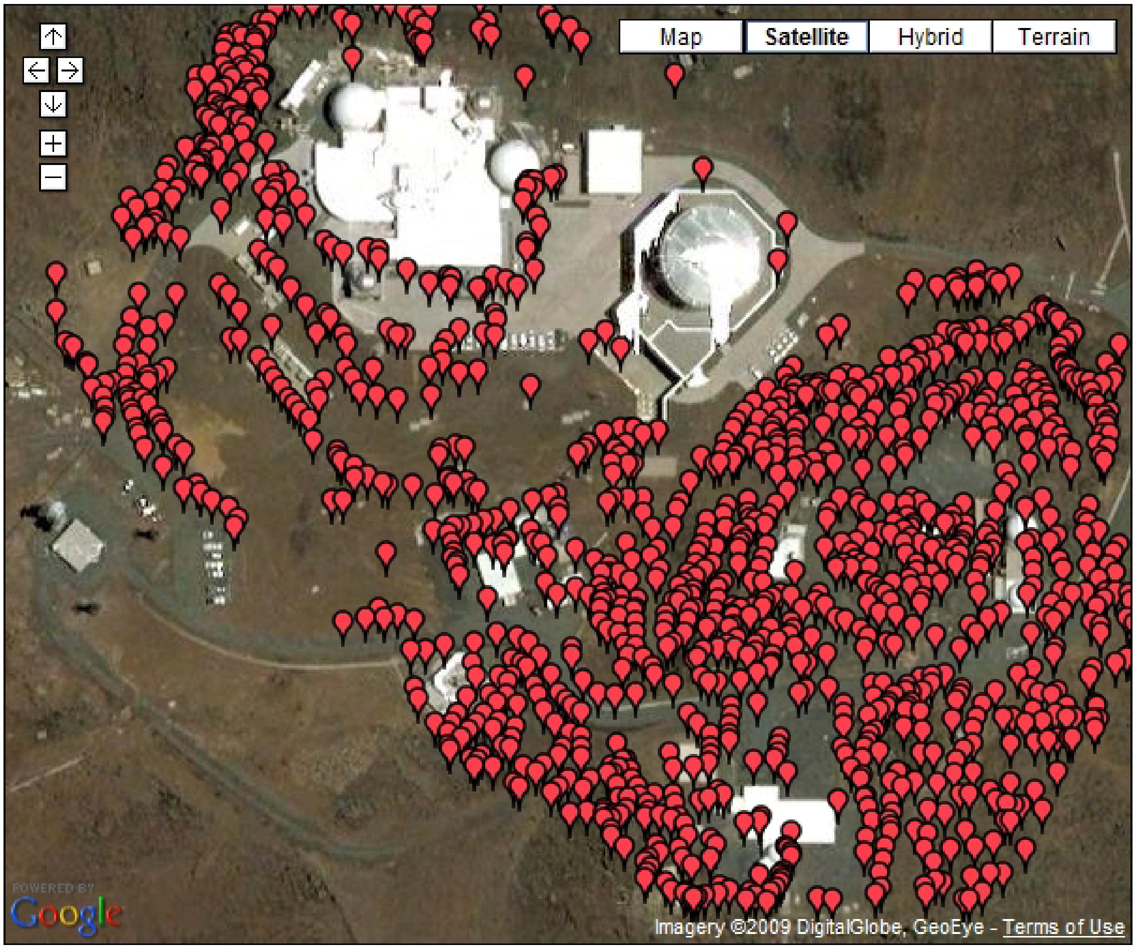
Deschampsia nubigena - June 2009



***Deschampsia nubigena* - Hairgrass - Poaceae - (Native: Endemic)**

Noted as one of the native species found within the MSSS complex by the U.S. Air Force (1991). Belt Collins & Associates (1994) noted this species as being found within the study site. Char & Associates (2000) noted that scattered clumps of hairgrass were one of the primary species making up the sparse plant cover on the Faulkes site. Char & Associates (2000) adds further, "Deschampsia, an endemic, perennial grass which forms rounded tufts, 6 to 12 inches tall with flowering stalks 1 to 2 feet tall. It is the most commonly encountered grass species at this elevation." RTS (2002) noted that hairgrass was one of the sparse representative native grass species present within the MSSC. Starr & Starr (2002) reported this species as common and typically found within areas that were not disturbed by construction. Starr & Starr (2005) reported "Endemic. Feathery bunch grass. The most common of the three native alpine grasses. Mees: Common. This is the most common grass on the site. It covers most of the site, especially tucked under rocks; 470 clumps were found scattered here and there. Reber: Common. This is the most common grass on the site; 213 clumps were observed scattered about." In 2009 found to be the most common grass at HO, with clumps found over most of the property, even in disturbed areas.

Dubautia menziesii - June 2009



***Dubautia menziesii* - Kupaoa - Asteraceae - (Native: Endemic)**

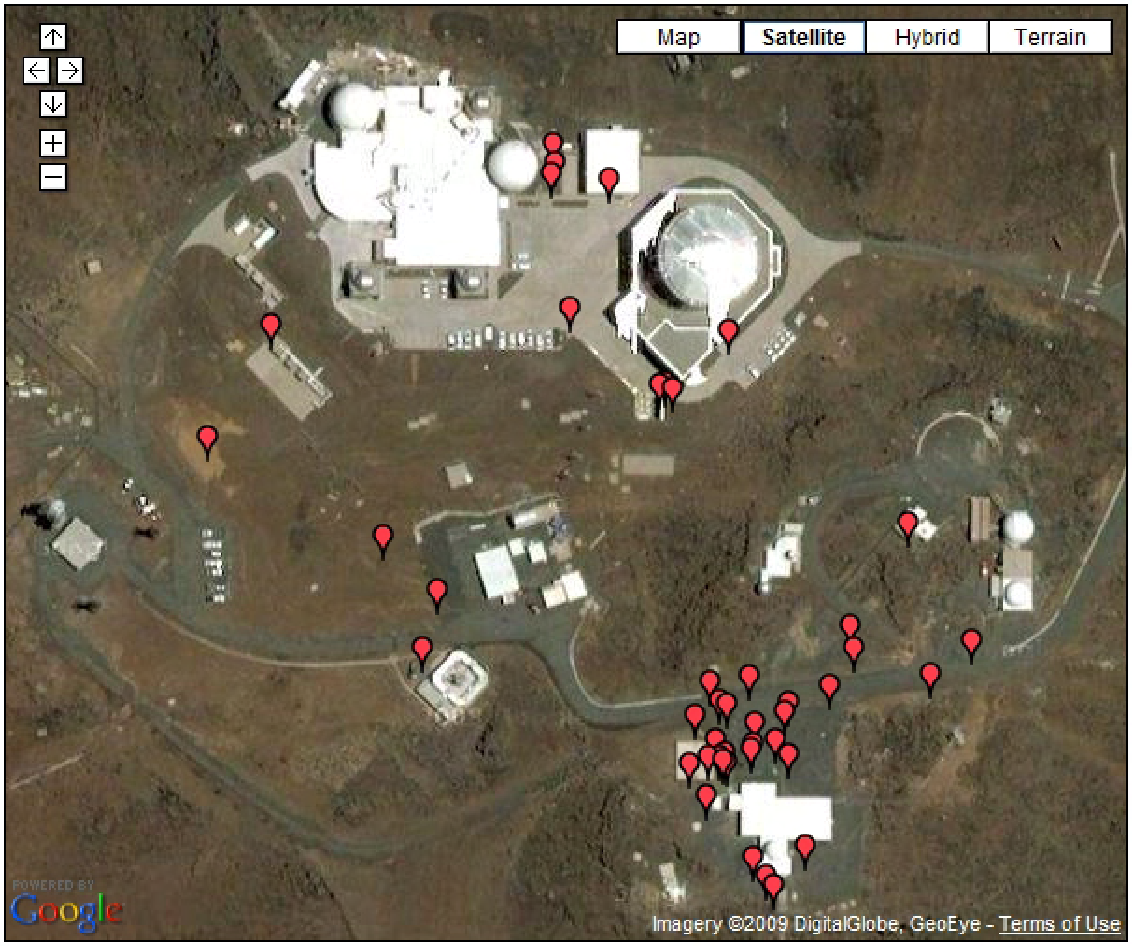
The U.S. Air Force (1991) noted this species as a characteristic component of the vegetation type, alpine dry shrubland. Belt Collins & Associates (1994) noted this species as being found within the study site. Char & Associates (2000) noted this species as one of the primary low shrubs, 1 to 3 feet tall, making up the sparse plant cover on the site. Char & Associates (2000) adds further, "The kupaoa, an endemic member of the daisy family (Asteraceae), has stiff, upright, branches and stiff leaves arranged in whorls around the branches; yellowish orange, daisy-like flowers are arranged in compact clusters. The kupaoa is a common species on the upper slopes of Haleakala and within the crater (Wagner et al. 1990)." Kupaoa was noted being more numerous on the small pu'u located nearby which offered a few protected pockets and overhangs. RTS (2002) noted that kupaoa was one of the sparse representative native species present within the MSSC. Starr & Starr (2002) reported this species as common and typically found within areas that were not disturbed by construction. Starr & Starr (2005) reported "Endemic. A relative of the silversword, and known only from East Maui, this hardy native shrub can be found over most of HO, even in the most urbanized sections. The wind dispersed seeds of this shrub presumably help it re-colonize disturbed areas. In many cases this plant was observed growing through cracks in asphalt, and on the margins of concrete. Mees: Common. The most common shrub on the site; 160 plants were observed. Reber: Common. The most common shrub on the site; 209 plants were observed." In 2009 this shrub was the most common shrub at HO, found over much of the site, including disturbed areas.

Dryopteris wallichiana - June 2009

Dryopteris wallichiana **- Laukahi - Dryopteridaceae- (Native: Indigenous)**

Found for the first time at HO during this survey. It was rare, with one small plant found on the northeast side of the Mees Solar Observatory among large lava boulders.

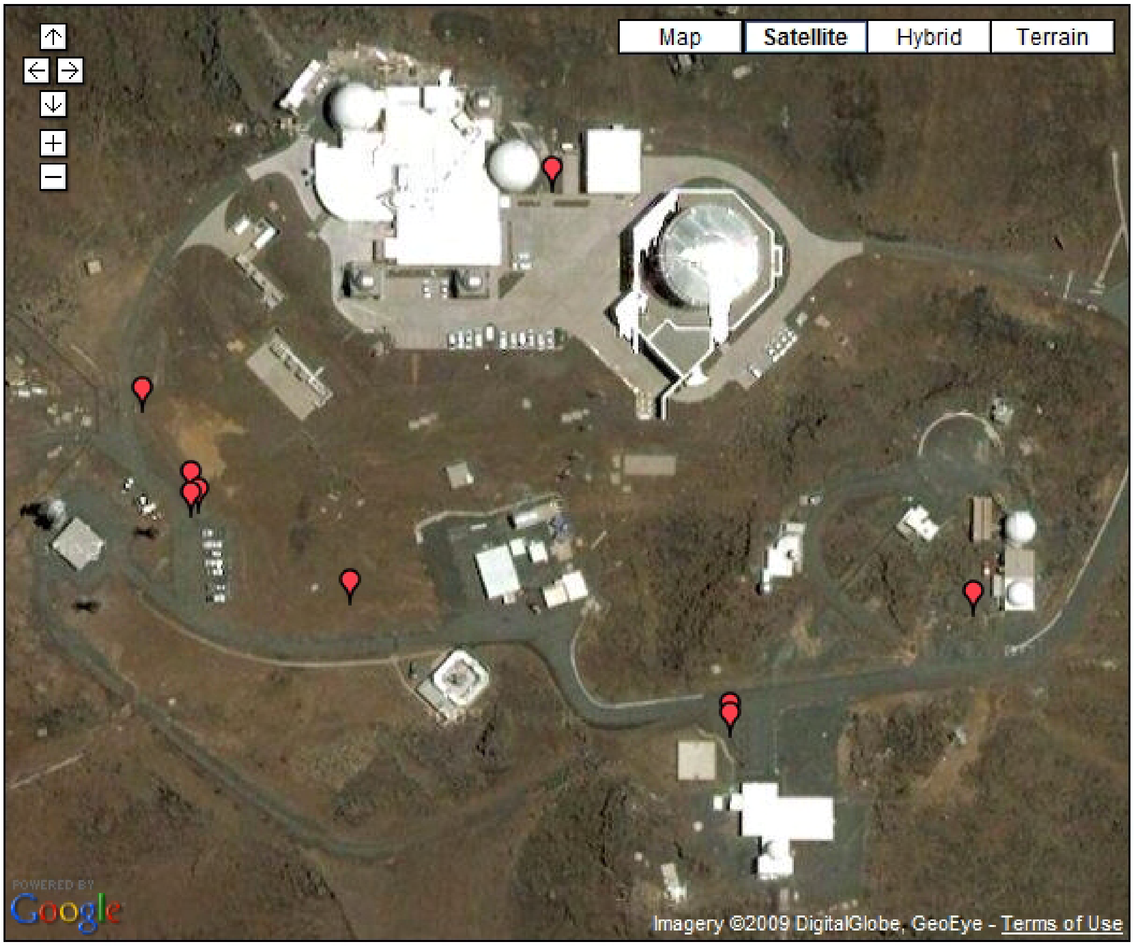
Erodium cicutarium - June 2009



Erodium cicutarium **- Alfilaria, pin clover, storksbill - Geraniaceae - (Non-native)**

Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. Ephemeral herb that is established near structures. Mees: Occasional. 22 plants and many more small seedlings were found near the existing Mees Solar Observatory building and parking lots. Reber: Occasional. One plant and numerous seedlings at base of walls of Atmospheric Airglow Facility." In 2009 this colorful herb was common, found in patches near buildings. This species seems to have spread since the last survey.

Festuca rubra - June 2009



***Festuca rubra* - Red fescue - Poaceae - (Non-native)**

Recorded for the first time during this survey, where it was found to be occasional, scattered over the site. This non-native bunch grass is often sterile and we were lucky enough to find some fertile material to help us with the ID. Since this is the first record of this non-native species on the site, one may think it was recently introduced. However, given the similar vegetative growth form to the native *Deschampsia* grass, the often sterile state, and the pattern of distribution on the site, it is perhaps more likely this species was overlooked in previous surveys. A collection was made to confirm the identity, to document the presence of this species at HO, and to document a new elevation record for this species (*Starr 090504-01 BISH*).

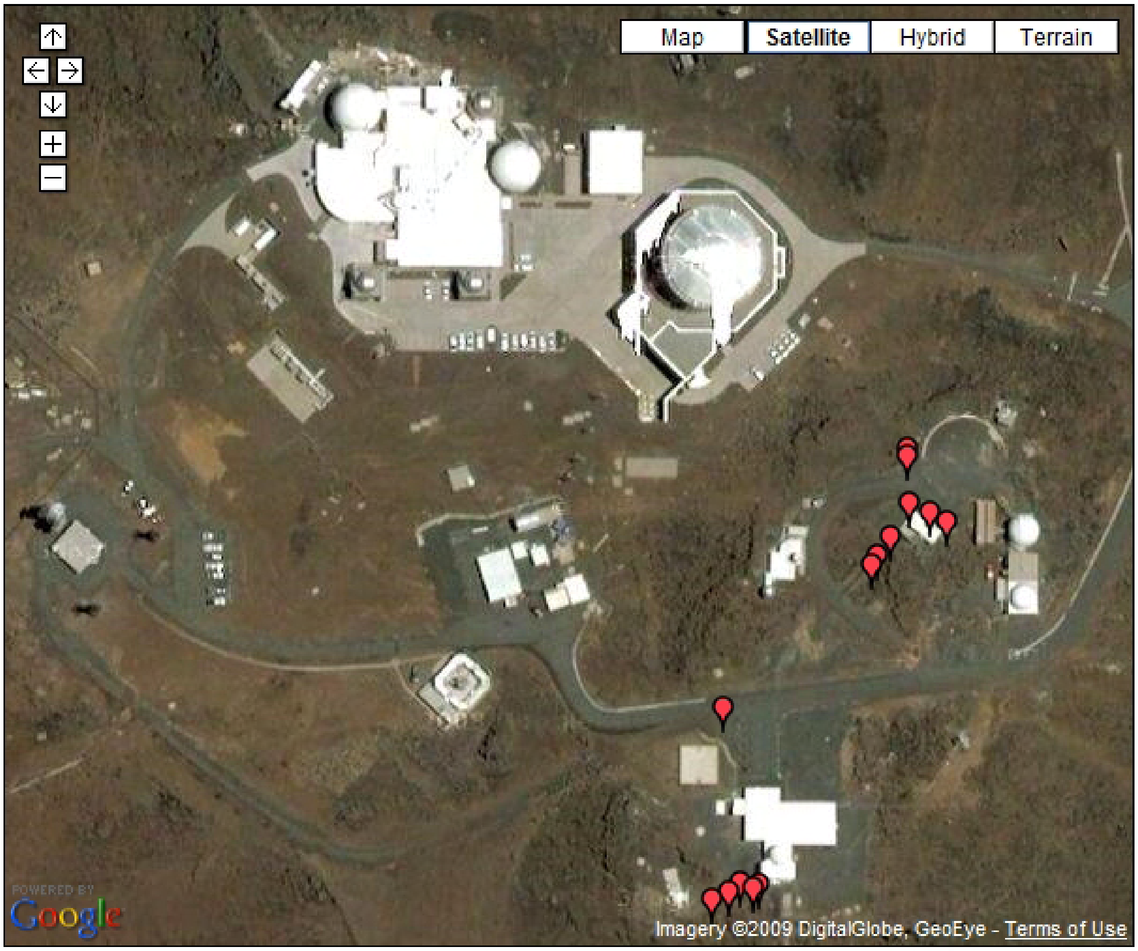
Geranium cuneatum subsp. tridens - June 2009

Not observed in 2009

Geranium cuneatum subsp. _tridens_ - Hinahina - Geraniaceae - (Native: Endemic)

Belt Collins & Associates (1994) noted this charismatic species as being found within the study site. Not observed in any survey since, though in 2002 we did see an individual further down the west slope, off HO property. It is not known if this individual on the western slope is the one mentioned in 1994, if the plant used to exist at HO and no longer does, or if it is hidden somewhere in the jumble of boulders.

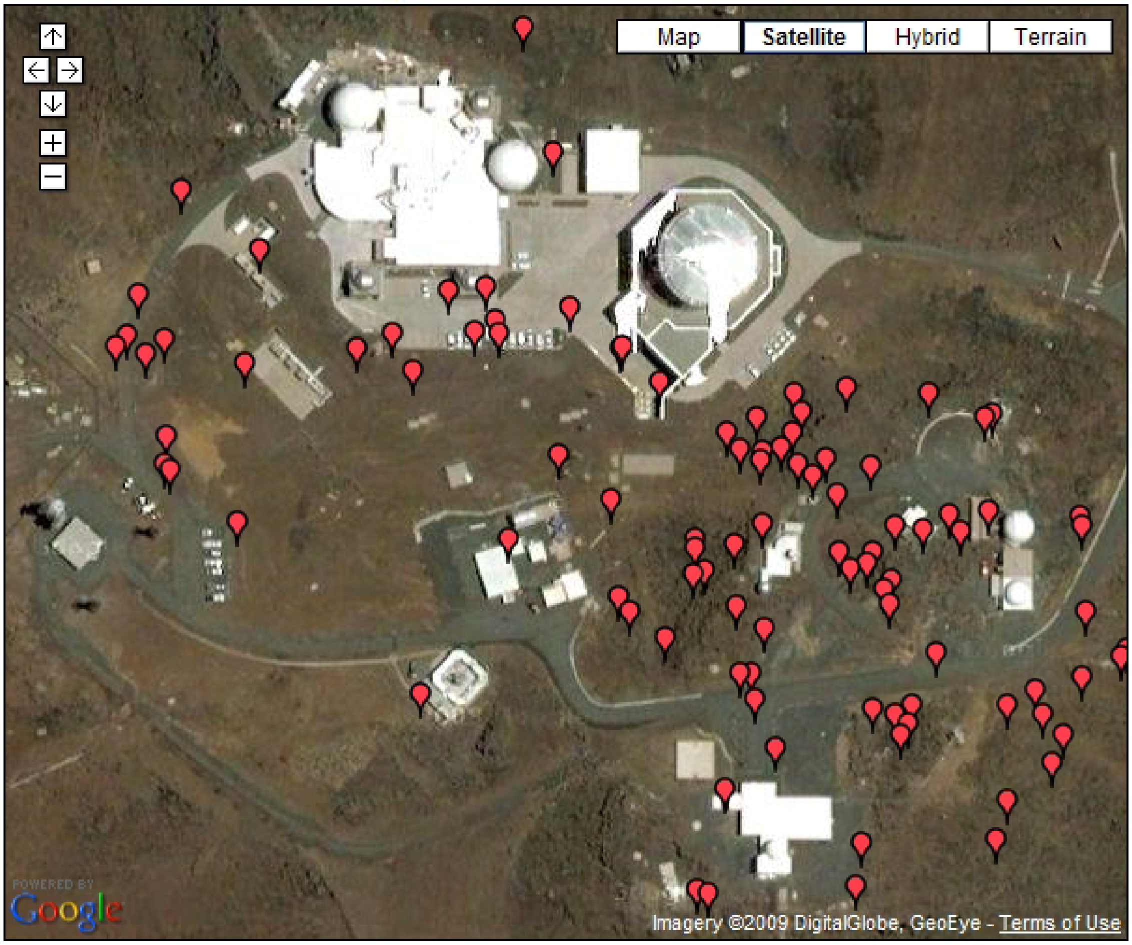
Holcus lanatus - June 2009



***Holcus lanatus* - Yorkshire fog - Poaceae - (Non-native)**

Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. Invasive grass that is established at HO, but is currently only known from a couple lone plants and one localized patch. This is one of the non-native species that would be good to remove before it becomes further established at HO and begins to spread to adjacent parklands. Mees: None. Reber: Occasional to rare. One patch of dozens of plants found half way up hill with small asphalt foot path. A couple small plants were found scattered on the same hill." In 2009 this invasive grass was still found to be occasional, with a few localized patches on the same hill between the Zodiacal Observatory and the Airglow Facility and some patches around the Mees Solar Observatory. It would be good to remove the existing clumps of this invasive grass before it spreads to other areas of the site and nearby lands.

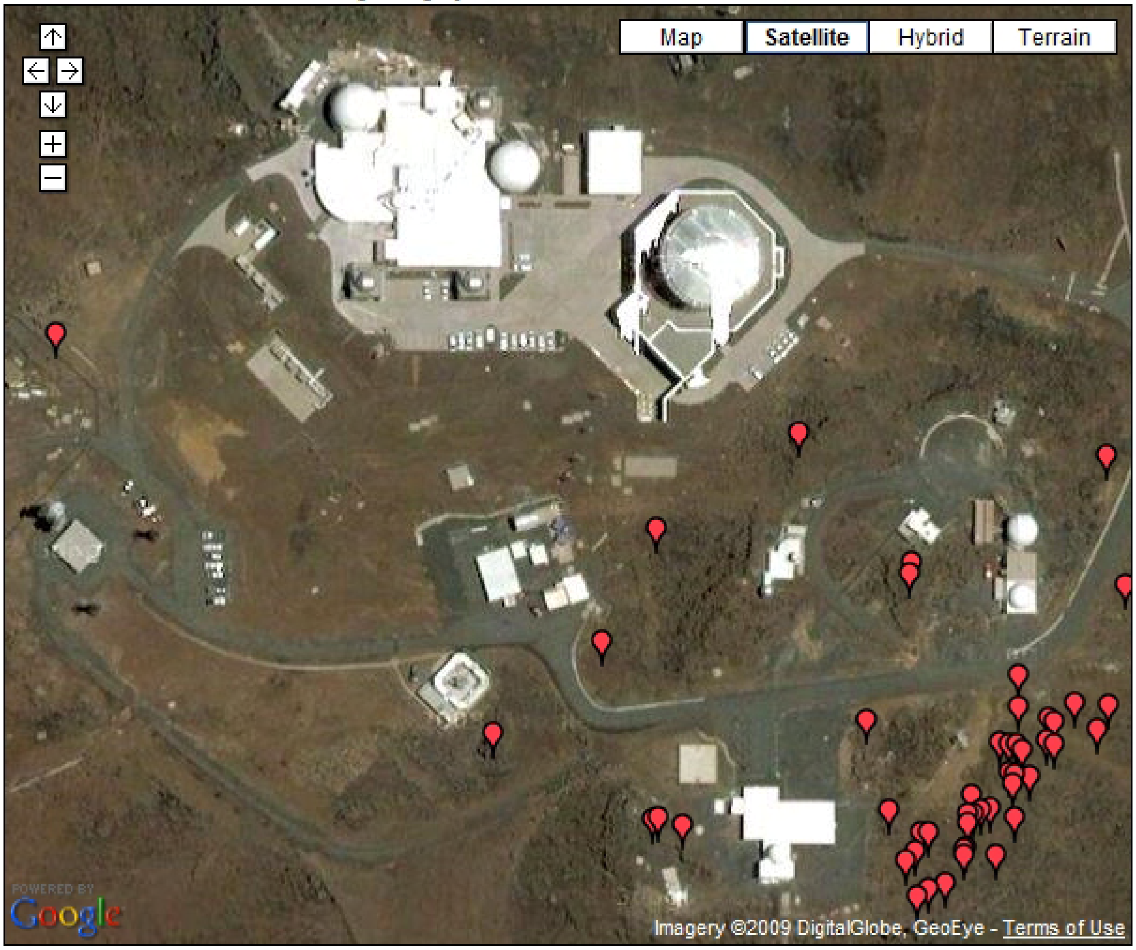
Hypochoeris radicata - June 2009



***Hypochoeris radicata* - Hairy cat's ear - Poaceae - (Non-native)**

Noted by the U.S. Air Force (1991) as one of the naturalized exotic species occurring in locations that receive moisture from runoff or from anthropogenic sources (e.g., at the discharge pipes from MSSS humidifiers) and have some protection from the harsh physical environment (e.g., near building foundations and the parking lot). Belt Collins & Associates (1994) noted this species as being found in disturbed areas (e.g. near buildings) within their study site. Char & Associates (2000) reported that other plants were found on the flat area occurring in smaller numbers, with a few hairy cat's ear, a weedy herb native to Eurasia, found scattered here and there. Char & Associates (2000) noted that hairy cat's ear was also found on a small pu'u located nearby that offered a few protected pockets and overhangs where plants were more numerous. RTS (2002) noted this species as one of the non-native species found within the MSSC, mostly around and near buildings where they receive more moisture and greater protection from the harsh environment. Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. Cosmopolitan tap-rooted herb that is found virtually everywhere in small numbers. Mees: Occasional to rare. Three small patches observed. Reber: Occasional. 17 plants observed." In 2009 this cosmopolitan herb was common over much of HO.

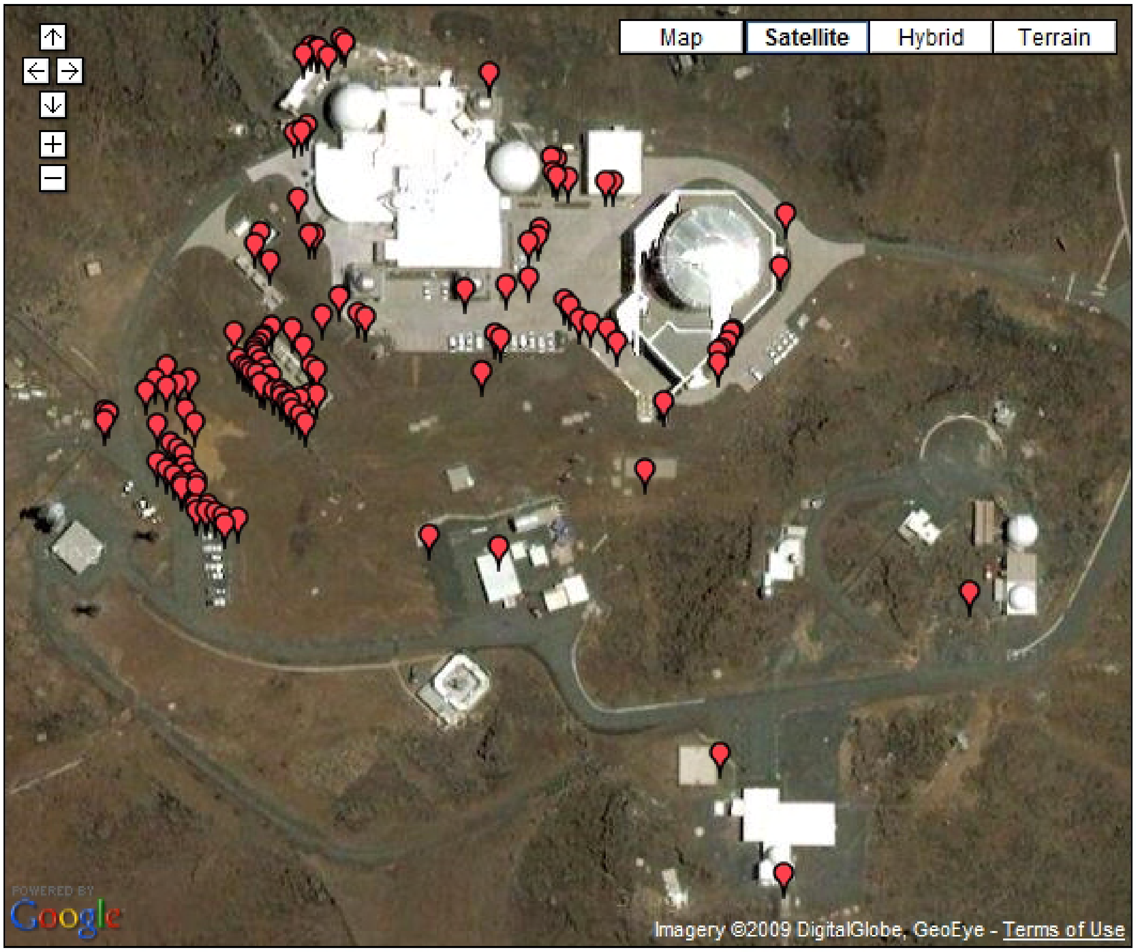
Leptecophylla tameiameiae - June 2009



***Leptecophylla tameiameiae* - Pukiawe - Ericaceae - (Native: Indigenous)**

Not noted in the U.S. Air Force 1991 survey. Belt Collins & Associates (1994) noted this species as being found within the study site. Char & Associates (2000) noted one small bush of pukiawe, about a foot tall, found among some boulders on the flat, cinder covered area. It was also noted by Char & Associates (2000) as more common on a small pu'u nearby that offered a few protected pockets and overhangs. Starr & Starr (2002) reported this species as occasional and typically found within areas that were not disturbed by construction. Starr & Starr (2005) reported "Indigenous. Hardy native shrub that appears to not do as well in heavily disturbed areas. A fair amount at the Mees site, but none found at the Reber site. Mees: Occasional. 38 plants found scattered across site, mostly in undisturbed portions. Reber: None. The lack of pukiawe is likely a result of the disturbed condition of the site." In 2009 this native shrub was still found to be occasional, continuing to be more common on the southeast part of the site and in areas with the least amount of disturbance.

Lobularia maritima - June 2009



Lobularia maritima **- Sweet alyssum - Brassicaceae - (Non-native)**

Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. One of the more aggressive species on Puu Kolekole right now. It has spread in distribution since we last surveyed the site, especially near the water retention basin and behind the building near the Department of Energy site. This is another invasive plant species that would be good to keep in check in order to minimize negative impacts on the native botanical resources of HO and nearby areas. Mees: None. Reber: None. Basin: Occasional. A few plants scattered about the southwest rim of the basin." In 2009 this spindly herb was now common over most of site. It appeared little to no control work had been done on the species and this prolific herb continued to spread.

Lythrum maritimum - June 2009

Not observed in 2009

Lythrum maritimum - Lythrum - Lythraceae - (Native: Questionably Indigenous)

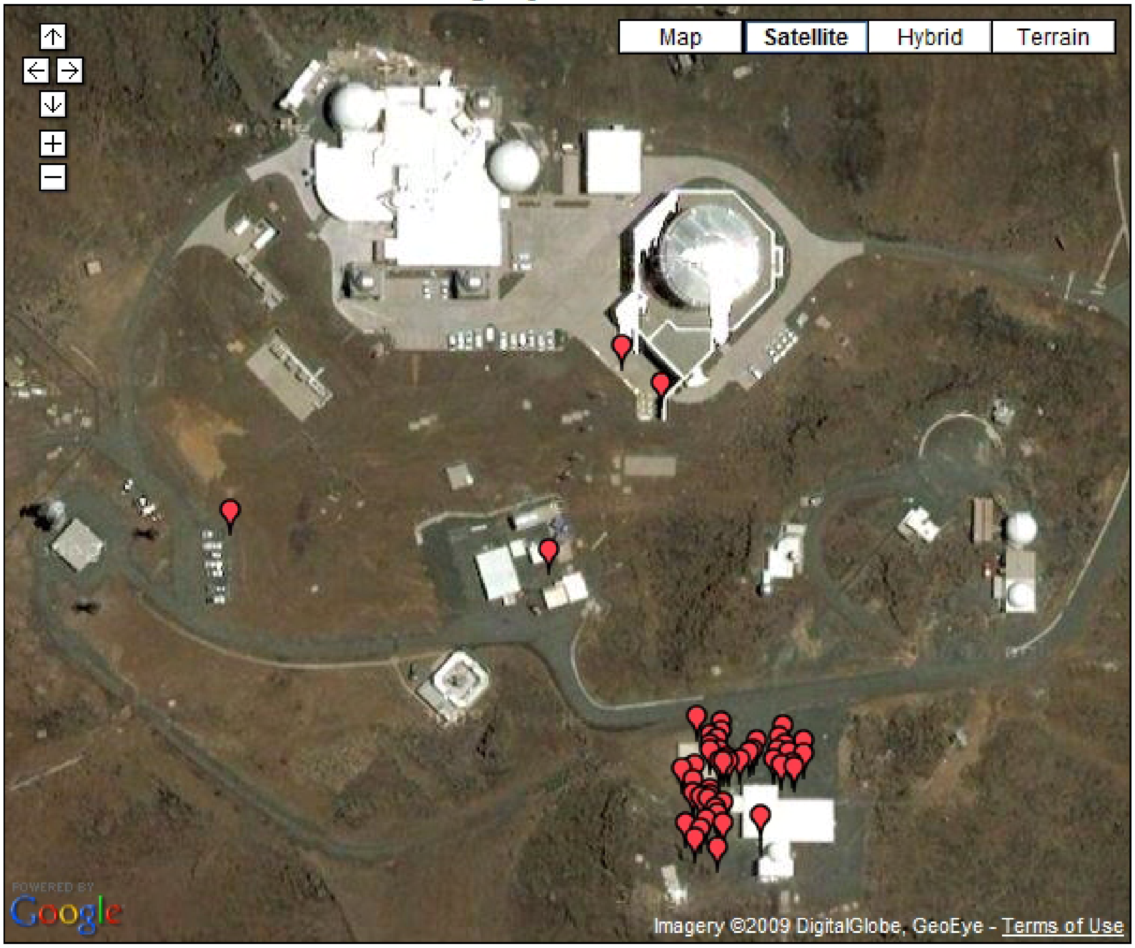
Starr & Starr (2005) recorded this plant on HO for the first time and reported "Questionably indigenous. A slender shrub of questionable nativity. A new addition to the plants known from "Science City". Prefers moist sites. Mees: None. Reber: Rare. One plant found along small path that leads up the rock hill to the Atmospheric Airglow facility." Not observed in 2009. The single plant may be gone or may have been overlooked.

Malva neglecta - June 2009

Malva neglecta - Common mallow - Malvaceae - (Non-native)

Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. In 2009 this incipient herb was found to be rare with one patch observed by the Airglow Facility. This plant is known from very few places on Maui. A specimen was collected to confirm the identity, to document the presence of this species at HO, and to document a high elevation record for this species (*Starr 090504-07 BISH*).

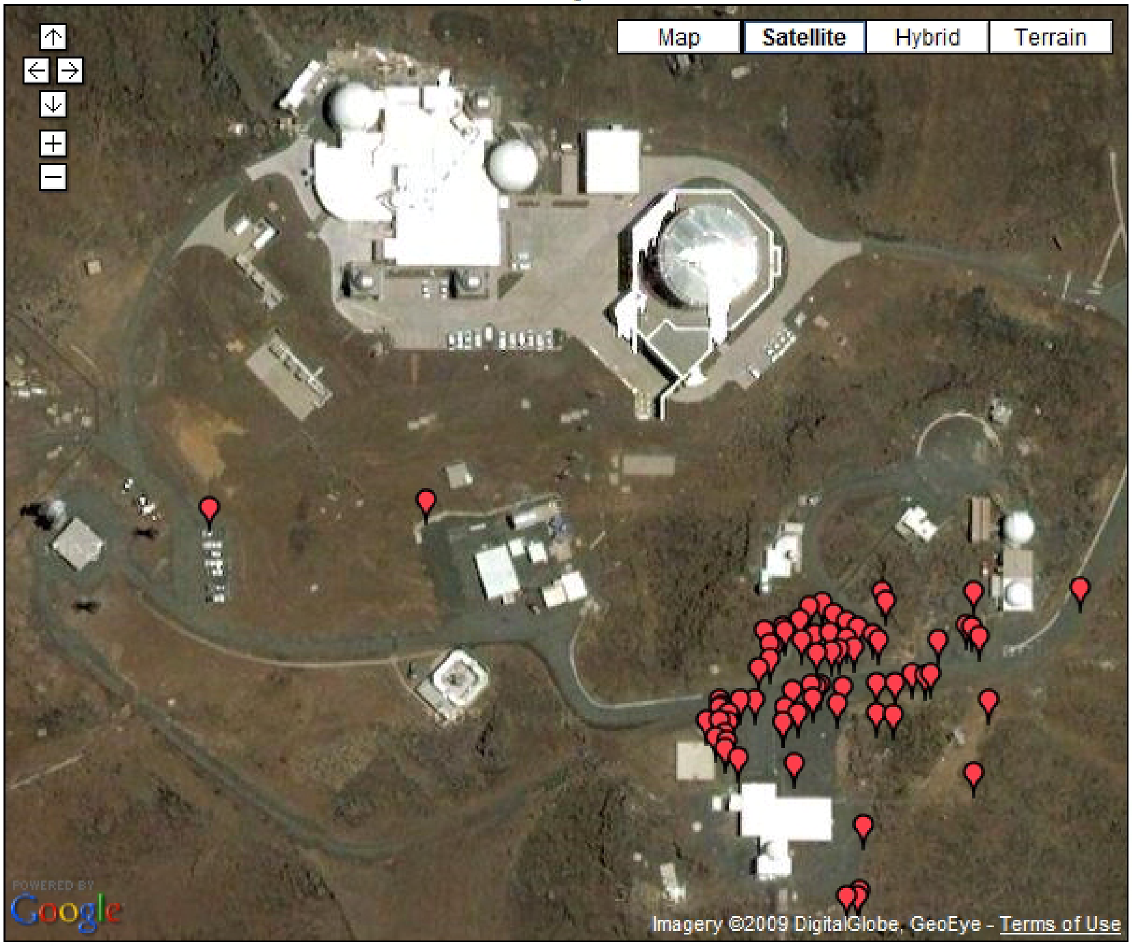
Medicago lupulina - June 2009



***Medicago lupulina* - Black medic - Fabaceae - (Non-native)**

Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. Mat forming herb with trifoliate leaves and yellow flowers. Mees: Occasional to common. Well established near existing buildings and parking lot at Mees Solar Observatory. Large patches were forming mats in the gravel parking lot, cracks in the paved parking lot, and near the building. Reber: None." In 2009 this prostrate legume was still common, with a few large patches on site, especially near the Mees Solar Observatory.

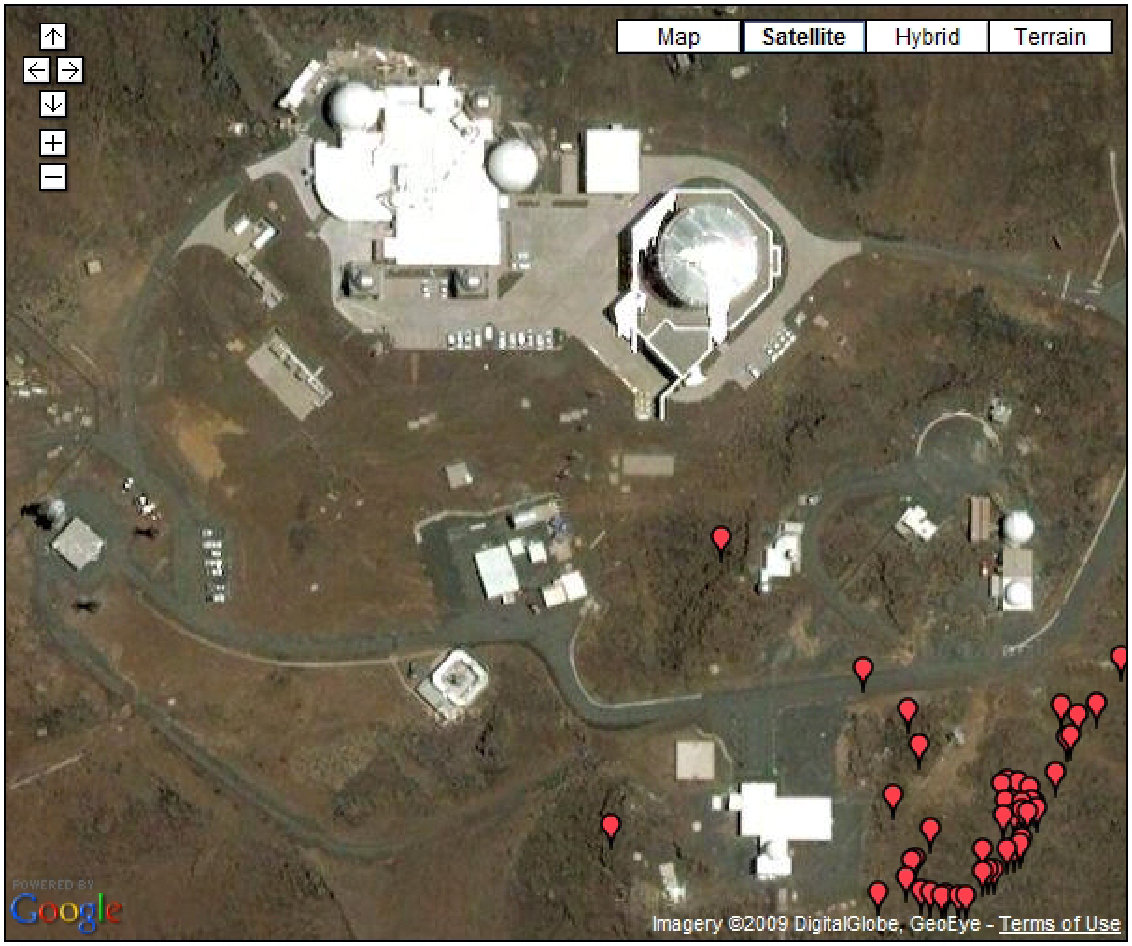
Oenothera stricta subsp. stricta - June 2009



Oenothera stricta subsp. _stricta_ - Evening primrose - Onagraceae - (Non-native)

Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. Colorful yellow flowered plant that can be quite invasive. Mees: Occasional to common. Found near roads and buildings. A patch of 100+ seedlings and small plants was found near the existing cistern near the Mess Solar Observatory. Reber: Occasional. A half-dozen or so plants scattered over site." In 2009 this colorful plant was found to be occasional to common over much of the southern portion of the site, especially between the Mees Solar Observatory and the Lure Complex. This colorful plant has the ability to cover much of the disturbed ground at HO.

Pellaea ternifolia - June 2009



Pellaea ternifolia - Kalamoho - Pteridaceae - (Native: Indigenous)

Starr & Starr (2002) reported this species as rare and typically found within areas that were not disturbed by construction and found tucked into rock crevices and overhangs. Starr & Starr (2005) reported "Indigenous. Three leaved fern found in small numbers in rock cracks. Mees: Rare. One patch seen. Reber: Occasional to rare. Three patches observed on a small south-facing cliff on the southern part of the property." In 2009 this diminutive fern was rare to occasional, tucked under rocks near steep areas on southeast edge of HO.

Pennisetum clandestinum - June 2009

Pennisetum clandestinum **- Kikuyu grass - Poaceae - (Non-native)**

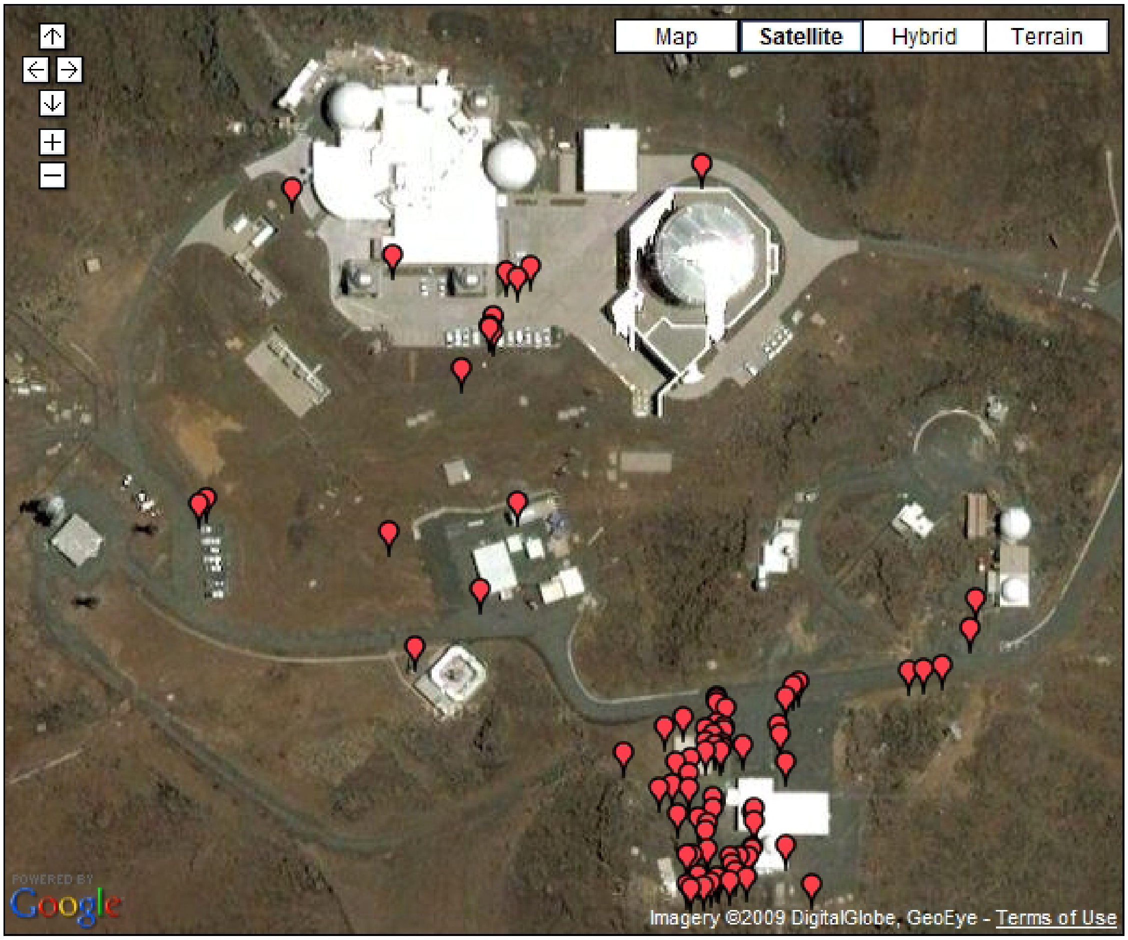
First recorded at HO during this survey, where it was found to be rare. A single small plant was found in a crack in the road at the Mees Solar Observatory parking area. The plant was sterile. This grass could have recently arrived at the site or could have been overlooked in previous surveys.

Pinus sp. - June 2009

Pinus sp. - Pine - Pinaceae - (Non-native)

Reported in Starr & Starr (2002) as rare. The only trees found at the site, two pine trees were located between a weather station tower and the Mees Observatory. They were about 20 cm tall and looked more like a small multi-branched shrub than a tree. They report, "This is the first record of pines on the summit area of Haleakala. It is not known if the trees were planted, arrived as contaminants in soil, or blew in on the wind. Though small, they appeared to be many years old." Starr & Starr (2005) reported "Non-native. Two pines were previously known from the Mees site. They have since been removed at the request of the Friends of Haleakala National Park (KC Environmental 2005). The skeleton of one of those pines was found. Mees: One dead individual found stuffed in rocks. Reber: None." In 2009 a small seedling was found in a road crack just west of the retention basin. The leaves were in bundles of three and it had a piney smell, though we were unable to determine exactly which species it was. This plant was most likely not planted in the middle of the road, and appeared to be a new arrival as it was relatively young (only a few inches tall). It likely either blew in on the wind from nearby wild pine trees or arrived as a contaminant.

Plantago lanceolata - June 2009



Plantago lanceolata **- Narrow-leaved plantain - Plantaginaceae - (Non-native)**

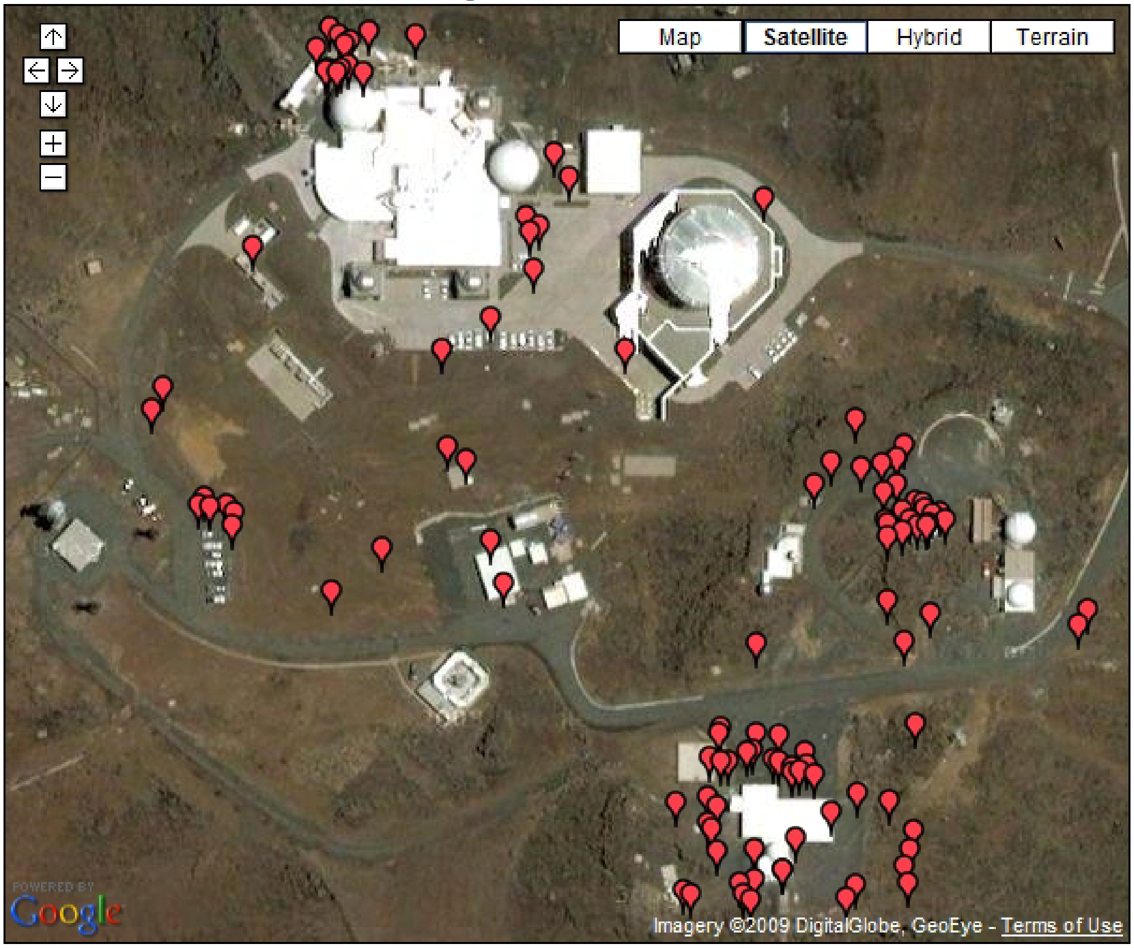
Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. A cosmopolitan weed that is currently a target for control by the Friends of Haleakala National Park near Kapalaoa Cabin. Mees: Occasional. 15 plants observed, mostly near the cistern. Reber: None." In 2009 this cosmopolitan herb was found to be occasional to common, scattered over much of disturbed areas of the site, especially near the Mees Solar Observatory.

Poa annua - June 2009

***Poa annua* - Annual bluegrass - Poaceae - (Non-native)**

Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. In 2009 this diminutive grass was rare, with a few clumps observed in the developed areas of the site, though only one clump was relocated during the GPS portion of the survey. A collection was made to confirm the identity, to document the presence of this species at HO, and to document the high elevation record for this species (*Starr 090504-03 BISH*).

Poa pratensis - June 2009

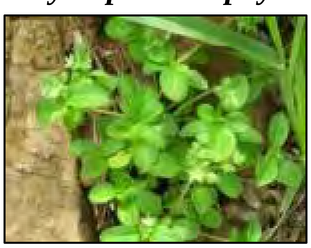


Poa pratensis **- Kentucky bluegrass - Poaceae - (Non-native)**

Collected from Science City in 1982 by K.M. Nagata (*#2579, BISH 453792*). Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. Starr & Starr (2005) reported "Non-native. Hardy grass that forms small patches by root suckering. The blades of this grass are often very short in the open, and much longer in the protected areas near buildings. Mees: Occasional. A half-dozen patches found, especially near the Mees Solar Observatory and cistern. Reber: Occasional. A dozen patches found, especially near the base of walls at the Atmospheric Airglow Facility." In 2009 this stoloniferous grass was common at HO with many patches found over the site. A collection was made to confirm the identity, to document the presence of this species at HO, and to document the high elevation record for this species (*Starr 090504-02 BISH*).

Polycarpon tetraphyllum - June 2009

***Polycarpon tetraphyllum* - Polycarpon - Caryophyllaceae - (Non-native)**



Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. In 2009 this diminutive herb was still found to be rare, mostly occurring near MSSS, within the cinder filled concrete landscaped areas.

Pteridium aquilinum var. decompositum - June 2009

***Pteridium aquilinum* var. *decompositum* - Bracken fern - Hypolepidaceae- (Native: Endemic)**

First recorded at HO during this survey and found to be rare. One small plant found on the west side of the Faulkes telescope building at the edge of the concrete. This seasonal fern could have recently arrived at the site, or could have been dormant or overlooked in previous surveys. Large stands of this fern exist on the cinder slopes south of HO.

Rumex acetosella - June 2009

Rumex acetosella - Sheep sorrel - Polygonaceae - (Non-native)

Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. In 2009 this tangy herb was found to be rare, with only a few patches observed, by Mees Solar Observatory and MSSS.

Senecio sylvaticus - June 2009

Not observed in 2009

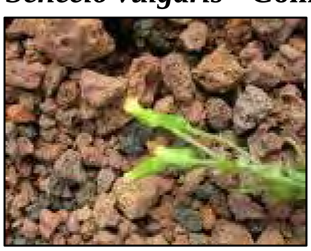
Senecio sylvaticus - Common groundsel - Asteraceae - (Non-native)

Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. Not observed during the 2009 survey. These weedy Asteraceae tend to come and go. The species could be gone, overlooked, or present as seed in the soil.

Senecio vulgaris - June 2009

Not observed in 2009

Senecio vulgaris - Common groundsel - Asteraceae - (Non-native)



Noted by the U.S. Air Force (1991) as one of the naturalized exotic species occurring in locations that receive moisture from runoff or from anthropogenic sources (e.g., at the discharge pipes from MSSS humidifiers) and have some protection from the harsh physical environment (e.g., near building foundations and the parking lot). Belt Collins & Associates (1994) noted this species as being found in disturbed areas (e.g. near buildings) within the study site. They add further, "All are recently introduced weedy species. Many of these plants occupy, or have spread from an experimental plot of grasses located approximately 20 meters (65 feet) southeast of the MSSS complex that was planted in 1972." RTS (2002) noted this species as one of the non-native species found within the MSSC, mostly around and near buildings where they receive more moisture and greater protection from the harsh environment. Not observed during the 2009 survey. This species is similar to *S. sylvaticus* in its ephemeral nature.

Silene struthioloides - June 2009

Silene struthioloides **- Catchfly - Caryophyllaceae - (Native: Endemic)**

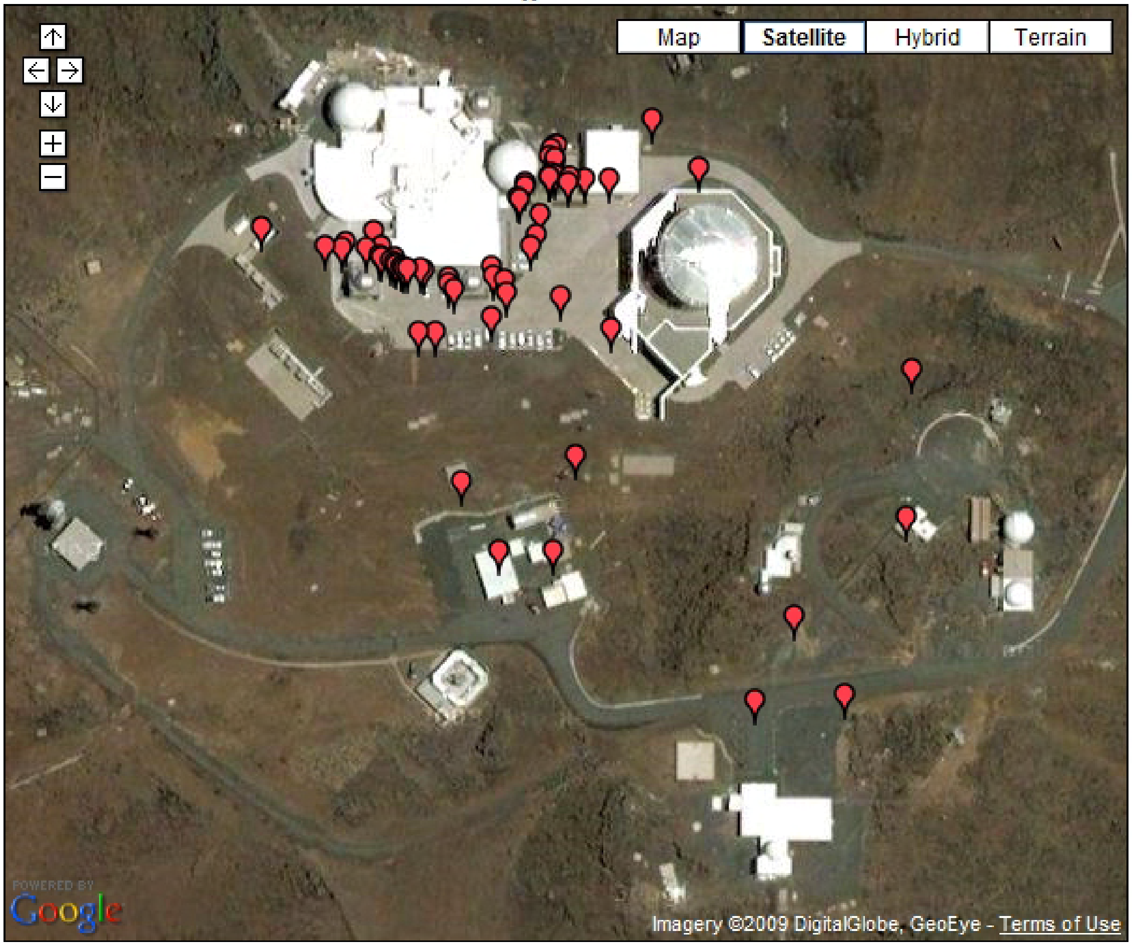
First recorded at HO during this survey, where it was found to be rare, with one plant observed by the Mees Solar Observatory. Though this native plant could have recently arrived on site, the inconspicuous shrub looks somewhat old and was likely overlooked in previous surveys.

Sonchus oleraceus - June 2009

***Sonchus oleraceus* - Sow thistle - Asteraceae - (Non-native)**

Reported in Starr & Starr (2002) as rare and typically found in disturbed areas where construction has occurred. At the time it was sterile and was called *Sonchus* sp. In 2009, a couple small plants were observed, one east of Mees, and another near the AEOS Mirror Coating Facility.

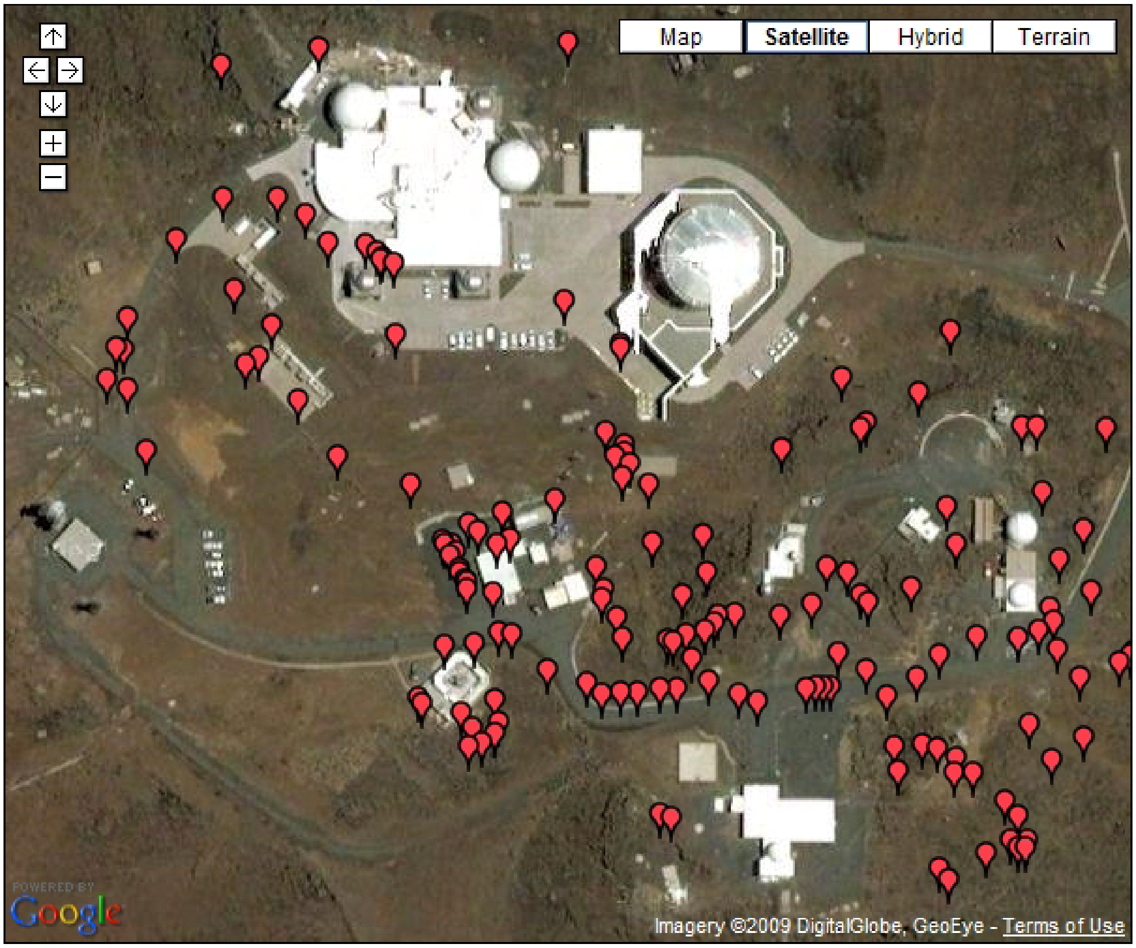
Taraxacum officinale - June 2009



Taraxacum officinale **- Common dandelion - Asteraceae - (Non-native)**

Noted by the U.S. Air Force (1991) as one of the naturalized exotic species occurring in locations that receive moisture from runoff or from anthropogenic sources (e.g., at the discharge pipes from MSSS humidifiers) and have some protection from the harsh physical environment (e.g., near building foundations and the parking lot). Belt Collins & Associates (1994) noted this species as being found in disturbed areas (e.g. near buildings) within the study site. They add further, "All are recently introduced weedy species. Many of these plants occupy, or have spread from an experimental plot of grasses located approximately 20 meters (65 feet) southeast of the MSSS complex that was planted in 1972." RTS (2002) noted this species as one of the non-native species found within the MSSC, mostly around and near buildings where they receive more moisture and greater protection from the harsh environment. Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. In 2009 this cosmopolitan herb was found to be occasional to common over most of the site, especially disturbed areas and around MSSS. In previous surveys someone on the Air Force property use to control the dandelions that would pop up, scarcely a leaf could be found on that part of HO. However, that person must have left as MSSC now holds the bulk of the dandelions on HO, with the highest concentration in the silversword planters.

Tetramolopium humile subsp. haleakalae - June 2009



***Tetramolopium humile* subsp. *haleakalae* - Tetramolopium - Asteraceae - (Native: Endemic)**

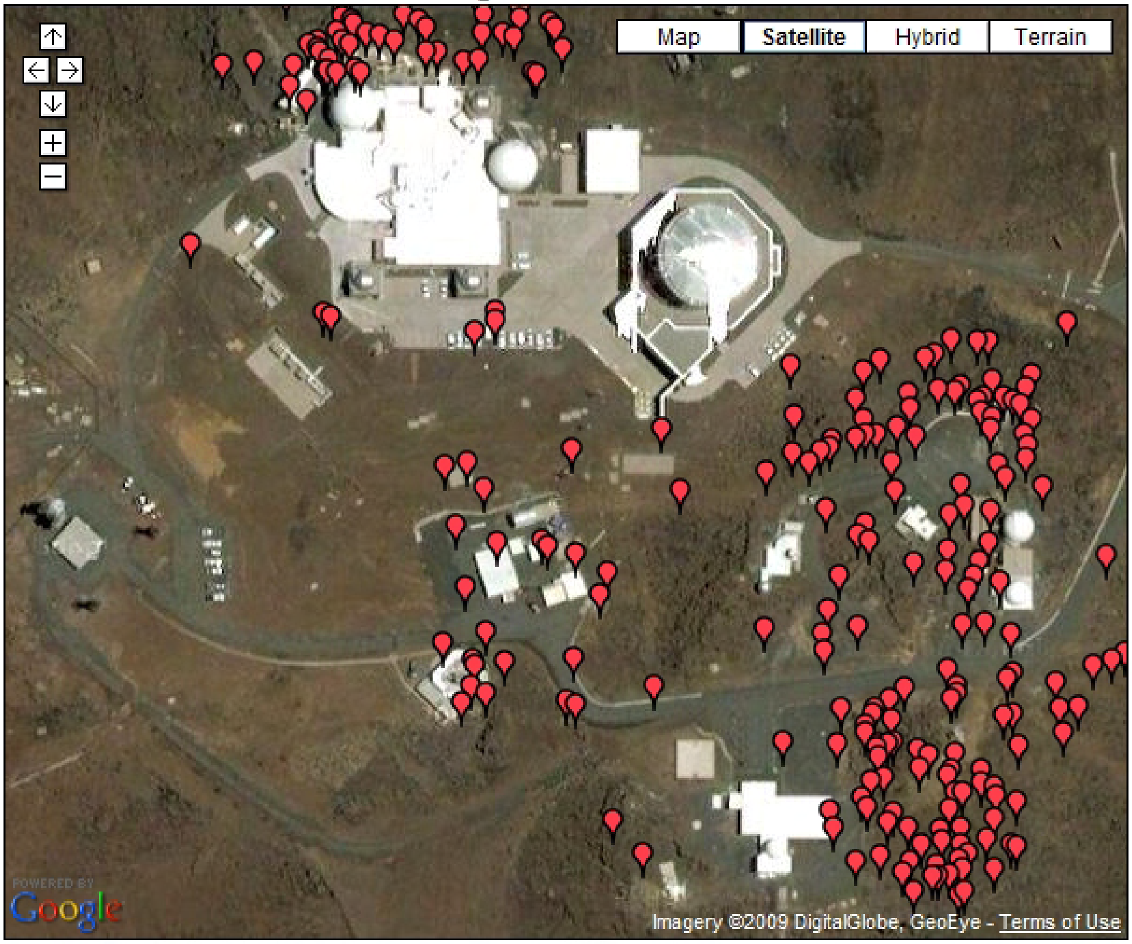
Noted as one of the native species found within the MSSS complex by the U.S. Air Force (1991). Belt Collins & Associates (1994) noted this species as being found within the study site. Char & Associates (2000) noted a few small tussocks of Tetramolopium were found near the access road. Char & Associates (2000) adds further, "Tetramolopium, an endemic member of the daisy family...is a rounded, dwarf shrub, 3 to 10 inches tall, with leaves covered with white hairs and clusters of white flowers." Char & Associates (2000) noted that Tetramolopium was also found on a small pu'u located nearby that offered a few protected pockets and overhangs where plants were more numerous. RTS (2002) noted that Tetramolopium was one of the common native herbs present within the MSSC. Starr & Starr (2002) reported this species as common and typically found within areas that were not disturbed by construction. Starr & Starr (2005) reported "Endemic. Succulent native herb that prefers cracks in rocks, and can seemingly cope with limited levels of disturbance. Mees: Occasional. A dozen plants scattered across site. Some growing in cracks in asphalt parking lot. Reber: Occasional. 15 plants observed." In 2009 this endemic daisy was found to be common, and continued to eek out an existence at HO, tucking under rocks and even asphalt cracks.

Trifolium repens - June 2009

Trifolium repens **- White clover - Fabaceae - (Non-native)**

Recorded from HO for the first time in 2009, where this cosmopolitan legume was found to be rare, with only a couple small patches by the Mees Solar Observatory. It is not known if the species was overlooked in previous surveys, as the similar leaved Medicago is abundant nearby. Perhaps if the clover was not in flower it would have been easily missed. Alternatively, it could be a new introduction. There is virtually no weed control currently occurring at HO, so any plant that did hitchhike on a worker or their gear would be able to grow at HO unchecked.

Trisetum glomeratum - June 2009



***Trisetum glomeratum* - Pili uka - Poaceae - (Native: Endemic)**

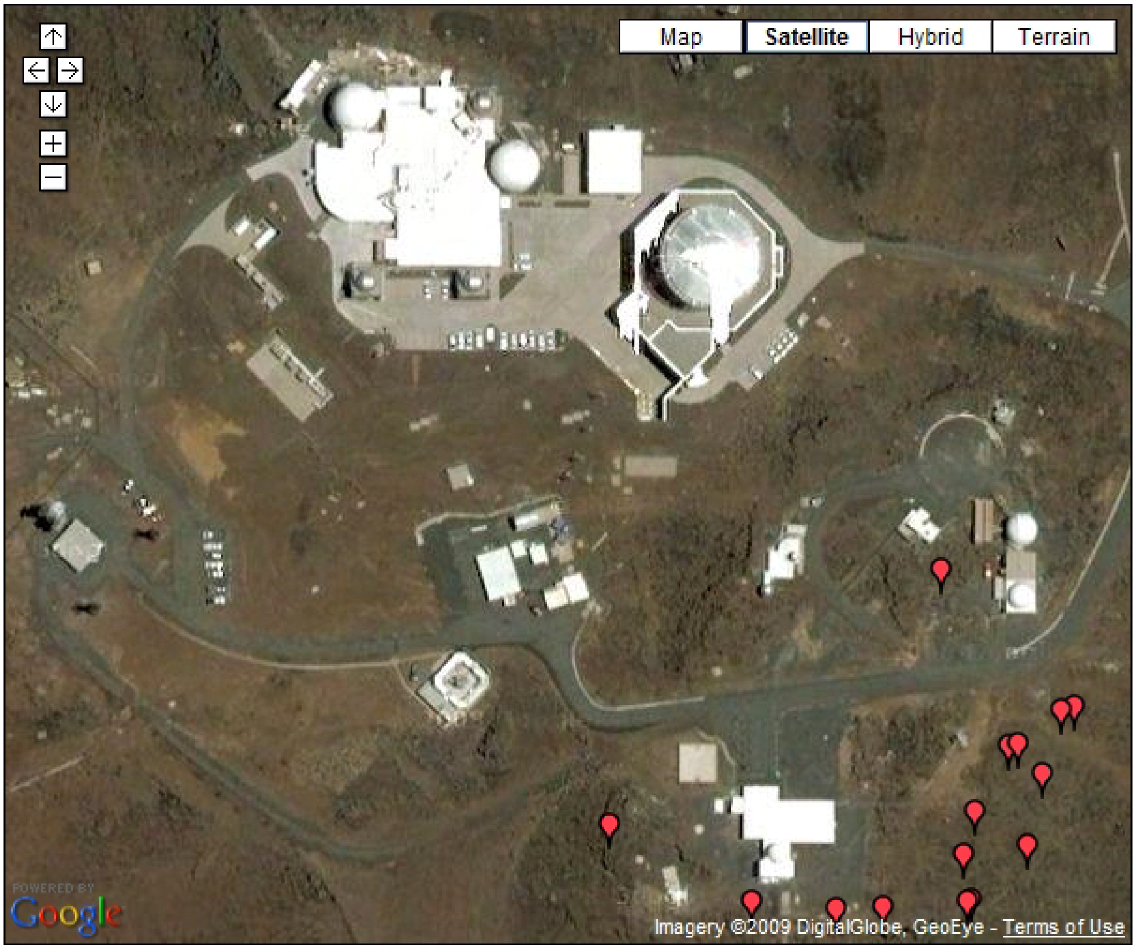
Found within the MSSS complex by the Air Force in the 1991 survey. Belt Collins & Associates (1994) noted this species as being found within the study site. A few clumps of pili uka were noted by Char & Associates (2000) near the base of a small pu'u. Char & Associates (2000) added further, "An endemic, perennial grass; the robust tufts are 6 to 12 inches tall with spike-like flowering stalks." Pili uka was noted as more numerous by Char & Associates (2000) on the small pu'u which offered a few protected pockets and overhangs. RTS (2002) noted that pili uka was one of the sparse representative native grass species present within the MSSC. Starr & Starr (2002) reported this species as common and typically found within areas that were not disturbed by construction. Starr & Starr (2005) reported "Endemic. Tussock forming grass. The 2nd most common native grass of the alpine area. Mees: Occasional. 119 plants observed on site. Reber: Occasional. 56 plants observed on site." In 2009 this endemic bunch grass was found to be common, with many clumps scattered across HO, especially on the east and north margins.

Unknown sp. - June 2009

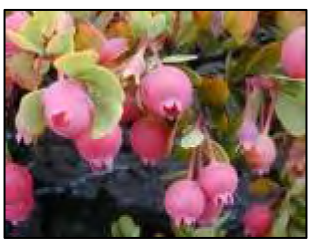
Unknown sp. - Unknown plant - Unknown - (Non-native?)

A single sterile plant that doesn't match any other species previously record from HO was found in 2009 in the gravel area near the Lure Complex. We could not identify the sterile plant. Returning when there is fertile material will help determine the identity of this lone plant.

Vaccinium reticulatum - June 2009



Vaccinium reticulatum **- Ohelo - Ericaceae - (Native: Endemic)**



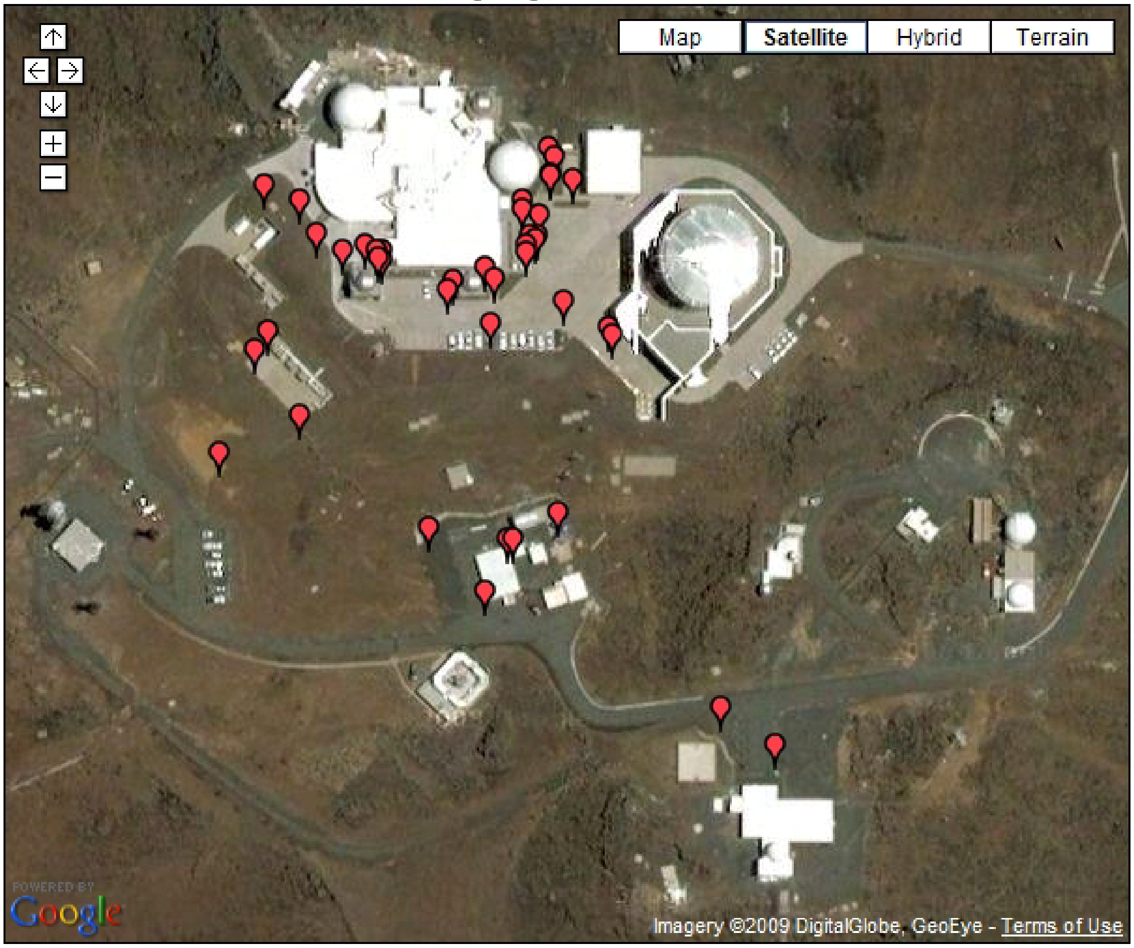
Belt Collins & Associates (1994) noted this species as being found within the study site. Starr & Starr (2002) reported this species as rare and typically found within areas that were not disturbed by construction. Starr & Starr (2005) reported "Endemic. Fruit bearing native shrub that appears to be confined to areas that have not seen heavy disturbance in the past. Mees: Occasional. A half dozen plants were observed on the site, in relatively undisturbed areas. Reber: None. The lack of ohelo at this site likely attests to the disturbed condition of the site." In 2009 this tasty native shrub was found to be rare to occasional, with a few clumps of shrubs found on HO, mostly restricted to the southeast side of the site in areas that had not been as heavily disturbed.

Vicia sativa - June 2009

Vicia sativa - Vetch - Fabaceae - (Non-native)

Starr & Starr (2005) reported "Non-native. Twining vine with purple flowers and twisted pods. This is a new addition to plants known from "Science City". This species is currently found in very limited distribution. *Mees*: Rare. A few plants found near north facing wall of Mees Solar Observatory, presumably it's point of introduction. The plants were pulled and bagged, but it had already gone to seed, so follow up will likely be necessary. *Reber*: None." In 2009 this purple flowered vine was once again found to be rare, with one small plant by the Mees Solar Observatory. The lone plant, which was pulled, had flowered but not yet set seed. This species likely persists in the soil as seed. A collection was made to remove the only known plant, to confirm the identity, to document the presence of this species at HO, and to document a new high elevation record for this species (*Starr 090504-06 BISH*).

Vulpia sp. - June 2009



Vulpia bromoides **- Brome fescue - Poaceae - (Non-native)**

Reported in Starr & Starr (2002) as occasional and typically found in disturbed areas where construction has occurred. In 2009 this wispy grass was found to be occasional, in scattered patches over the disturbed sections of HO. A collection was made to confirm the identity, to document the presence of this species at HO, and to document the high elevation record for this species (*Starr 090504-05 BISH*).

Vulpia myuros **- Rat tail fescue - Poaceae - (Non-native)**

Recorded at HO for the first time during this survey, where it was found to be occasional, occurring in scattered patches on disturbed ground. This wispy grass could be a new introduction, or could have just as likely been overlooked in previous surveys due to its ephemeral, often sterile nature, and the fact that it looks virtually identical to *V. bromoides*. It was microscope work confirming IDs during this survey that helped determine both *V. bromoides* and *V. myuros* currently occur at HO. A collection was made to confirm the identity, to document the presence of this species at HO, and to document a new high elevation record for this species (*Starr 090504-04 BISH*).

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APPENDIX K

University of Hawai‘i Institute for Astronomy
Haleakalā High Altitude Observatory Site
Management Plan
June 8, 2010

University of Hawai‘i
Institute for Astronomy

Haleakalā High Altitude Observatory Site
Haleakalā, Maui, Hawai‘i

Management Plan

June 8, 2010

Prepared by

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EXECUTIVE SUMMARY

This Management Plan (MP) for the University of Hawai‘i (UH) Institute for Astronomy (IfA) Haleakalā High Altitude Observatory Site (HO) is in accordance with Hawai‘i Administrative Rules (HAR) Chapter 13: Department of Land and Natural Resources (DLNR), Subtitle 1: Administration, Chapter 5: Conservation District, where this document is implemented to regulate land use in the Conservation District for the purpose of conserving, protecting, and preserving the important natural resources of the State through appropriate management and use to promote their long term sustainability and the public health, safety, and welfare. This MP was also prepared according to Exhibit 3 in HAR 13-5. “Management plan”, as defined in HAR 13-5-2, means a comprehensive plan for carrying out multiple land uses (HAR §13-5-2).

HO is not a multiple land use property. HO is a single land use parcel that is not open to the general public. This MP replaces the management planning policies and practices in the University of Hawai‘i Institute for Astronomy Haleakalā High Altitude Observatory Site Long Range Development Plan (LRDP). While the long range planning aspect of the LRDP is current, the management plans for HO that were included in the LRDP are superseded by the more comprehensive management plans in this MP.

The MP describes the proposed land use for HO and how it is consistent with the purpose of the Conservation District and General Subzone. The MP provides a tax map key, a map showing the HO site and adjacent properties, and an aerial photo annotated with the existing facilities within HO.

The ownership of the property is explained with respect to the Executive Order (EO) 1987 that established HO in 1961. EO 1987 has no expiration date. Details are provided on the natural resources at the site, including plants, wildlife, endangered species, cultural, historic, and archeological resources, and visual resources; as well as the constraints for access to the site. The existing land uses are described, including the history of the facilities at HO and a description of the currently active facilities. A list of existing Conservation District Use Permits (CDUPs) for HO is also provided.

The proposed land use is within the 18.166-acre HO site, where facilities observe the Sun, provide a world-class telescope for education and research outreach to students all over the world, use lasers to measure the distance to satellites, track and catalogue man-made objects, track asteroids and other natural potential space threats to Earth, and obtain detailed images of spacecraft. It is a principal site for optical and infrared surveillance, inventory and tracking of space debris, and active laser illumination of objects launched into Earth orbit, activities that are all crucial to the nation’s space program. Under this MP, this land use would continue with current operations, new scientific experiments and research, and new facilities would be developed as appropriate. The Site Plan would be unchanged from the 18.166 acres currently designated for “…Haleakalā High Altitude Observatory Site purposes only” under EO 1987. Further justification is presented for the above land use within the subzone and its relationship to the existing land use.

Monitoring strategies are presented to ensure the protection of cultural, historic, and archeological resources through policies, practices, and procedures developed in consultation with Native Hawaiian practitioners, agencies, interested individuals, and the Maui community, to ensure that historic preservation concerns are met. Monitoring strategies are also presented to prevent introduction of alien invasive species (AIS), to protect endangered species, and to educate all workers and contractors as to the potential impacts of construction and operations on the cultural and biological resources. Monitoring for construction practices to protect all resources at the site is described. Finally, the MP imposes certain design criteria on new facilities to minimize inappropriate design elements within the natural environment at the summit.

The effective time duration for this MP shall be for an initial term of one decade, beginning December 1, 2010, and ending on November 30, 2020, and may be extended if appropriate. An annual reporting schedule is established, along with annual reporting requirements.

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1.0 GENERAL DESCRIPTION

MANAGEMENT PLAN

This Management Plan (MP) for the University of Hawaiʻi (UH) Institute for Astronomy (IfA) Haleakalā High Altitude Observatory Site (HO) is prepared in accordance with Hawaiʻi Administrative Rules (HAR) Chapter 13: Department of Land and Natural Resources (DLNR), Subtitle 1: Administration, Chapter 5: Conservation District, where this document is implemented to regulate land use in the Conservation District for the purpose of conserving, protecting, and preserving the important natural resources of the State through appropriate management and use to promote their long term sustainability and the public health, safety, and welfare. This MP was prepared according to Exhibit 3 in HAR 13-5.

"Management Plan" as defined in HAR 13-5-2 means a comprehensive plan for carrying out multiple land uses (HAR §13-5-2). HO is not a multiple land use property. HO is a single land use parcel and is not open to the general public.

The Chapters and Sections of this MP are outlined in accordance with HAR 13-5, Exhibit 3: Management Plan Requirements, September 6, 1994.

HALEAKALĀ HIGH ALTITUDE OBSERVATORY SITE

In 1961, Executive Order (EO) 1987 issued by Hawaii's Governor Quinn to UH set aside 18.166 acres of land on the summit of Haleakalā to establish the HO site. EO 1987 has no expiration date. This area of the Conservation District was set aside for "…Haleakalā High Altitude Observatory Site purposes only" (EO 1987). Since then, consistent land uses for HO include the numerous facilities conducting astronomical research and advanced space surveillance that exist within the property boundaries. Other agencies established facilities adjacent to HO through EO during the same period.

The UH IfA is the steward of the 18.166 acres of land designated as HO and is responsible for managing and developing the property. HO is a preeminent state, national, and international resource for astronomical and related studies. In order to continue in the forefront of astronomy, UH must provide high-quality research and training facilities, and place special emphasis on programs that have distinctive attributes, while maximizing both the educational and scientific benefits for UH and the State of Hawaiʻi. It is important that these goals be achieved while preserving, protecting, integrating, and balancing significant and unique cultural and natural resources and educational and research values on Haleakalā.

Presently, facilities located within HO observe the Sun, provide a world-class telescope for education and research outreach to students all over the world, use lasers to measure the distance to satellites, track and catalogue man-made objects, track asteroids and other natural potential space threats to Earth, and obtain detailed images of spacecraft. It is a principal site for optical and infrared surveillance, inventory and tracking of space debris, and active laser illumination of objects launched into Earth orbit, activities that are all crucial to the nation's space program.

HO LONG RANGE DEVELOPMENT PLAN - http://www.ifa.hawaii.edu/haleakala/LRDP/

The IfA Long Range Development Plan (LRDP) for the HO site is a publicly vetted document. In broad terms, the LRDP describes the general environmental, cultural, and historic conditions, and the site characteristics that guide future development. It also describes the principles that define the scientific programs that the UH strives to maintain and develop at HO and the potential new facility developments that will keep the UH in the forefront of astronomy into the next decade. In order to describe and to protect this resource, while accommodating the growing need for public scrutiny and partnering in its astronomical planning, the IfA planning process for long-range development takes into consideration the environmental, cultural, and historic importance of Haleakalā. The LRDP also includes discussion of possible locations for future development within the HO property.

Following the review process used for environmental documents, the LRDP was distributed to State of Hawaiʻi and County of Maui entities, the National Park Service (NPS), the U.S. Air Force, community associations, individuals, and Maui public libraries. Notice of release of the draft LRDP was also published in the local newspaper, the *Maui News*. The draft LRDP had an extended, nine-month, public comment period. Therefore, one intention for the LRDP had been to provide a vehicle for consulting with the greater Maui community, Upcountry organizations, and individuals concerned about development, as well as Native Hawaiian interests.

While the long range planning aspect of the LRDP is current, the management plans for HO that were included in the LRDP are superseded by the comprehensive management plans in this MP.

1.1 Proposed Land Use In General Terms

In 1961, the State Land Use Law (Act 187), codified as HRS, Chapter 205, established the State Land Use Commission (LUC) and granted the LUC the power to zone State lands into one of three districts: Agriculture, Conservation, and Urban. Act 187 vested the DLNR with jurisdiction over the Conservation District.

The objectives of the State Conservation District is to conserve, protect, and preserve the important natural resources of the State through appropriate management and use to promote their long-term sustainability and the public health, safety, and welfare. This area of the Conservation District has been set aside for astronomical research, and many facilities conducting astronomy and advanced space surveillance already exist within the HO area.

The DLNR formulated subzones within the Conservation District and regulates land uses and activities therein. Figure 1-1 is a subzone map from the Office of Conservation and Coastal Lands (OCCL) website. Conservation District Subzone designations regulated by the DLNR are Protective, Limited, Resource, General, and Special. Since 1964, the Board of Land and Natural Resources (BLNR) has adopted and administered land use regulations for the Conservation District.

"Subzone" means a zone established within the Conservation District, which is identified by boundaries and resource characteristics (HAR 13-5-2). The objectives of the General Subzone are to designate open space where specific conservation uses may not be defined, but where urban uses would be premature.

In 1961, an EO by Hawaii's Governor Quinn set aside 18.166 acres of land on the summit of Haleakalā in a place known as Kolekole to be under the control and management of the Board of Regents of the University of Hawaiʻi. The site is known as HO and UH is the owner of the parcel. The IfA is responsible for managing and developing the land. The EO has no expiration date.

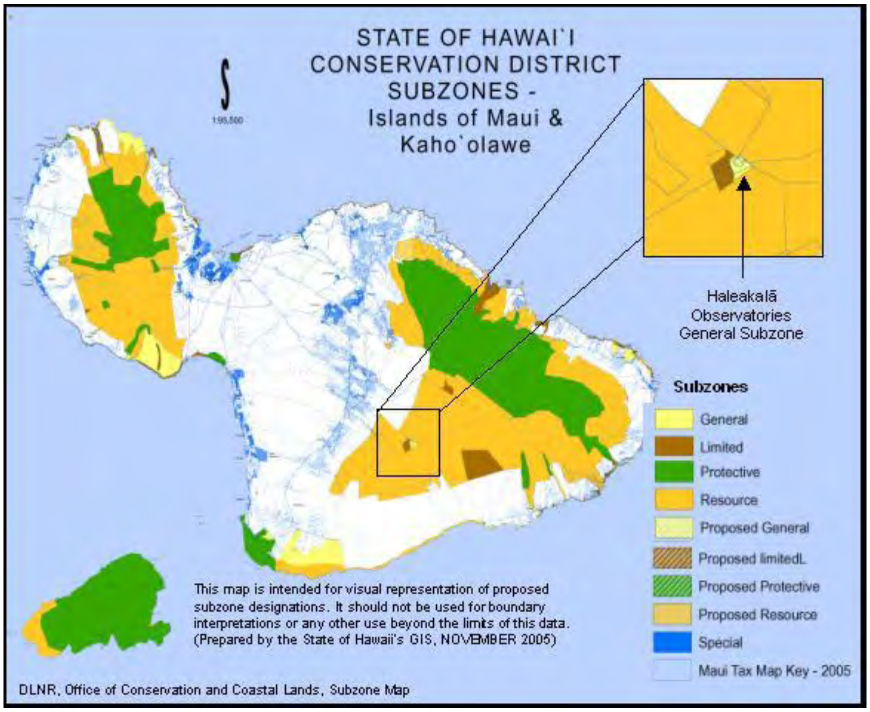


Figure 1-1. Island of Maui Conservation District Subzones Showing HO in General Subzone.

1.2 Land Use Consistent with the Purpose of the Conservation District and the Property's Subzone

HO is located within a General Subzone of the State of Hawai'i Conservation District that has been set aside for astronomical research (Fig. 1-1). The objectives of the General Subzone (HAR Chapter 13-5-14) are to designate open space where specific conservation uses may not be defined, but where urban uses would be premature. Identified applicable land uses in the General Subzone include R-3 Astronomy Facilities, (D-1) Astronomy facilities under an approved management plan (HAR 13-5-25).

1.3 Location Map

The land designated and assigned to UH in 1961 for scientific purposes via EO 1987 is located on State of Hawai'i land within the Conservation District and General Subzone, on Pu'u Kolekole, near the summit of Haleakalā, about 0.3 miles from the highest point, Pu'u Ula'ula (Red Hill) Overlook, which is in Haleakalā National Park (HALE). Figure 1-2 shows the Tax Map Key (2) 2-2-07-008. At an elevation of 10,023 feet above sea level (ASL), Haleakalā is one of the prime sites in the world for astronomical and space surveillance activities. The Kolekole cinder cone lies near the apex of the Southwest rift zone of the mountain. The rift zone forms a spine separating the Kula Forest Reserve from the Kahikinui Forest Reserve, both of which are pristine lands along the rift zone.

Other agencies established adjacent facilities through EO during the same period. Figure 1-3 shows the HO site and the adjacent properties. Figure 1-4 shows an annotated aerial view of HO.

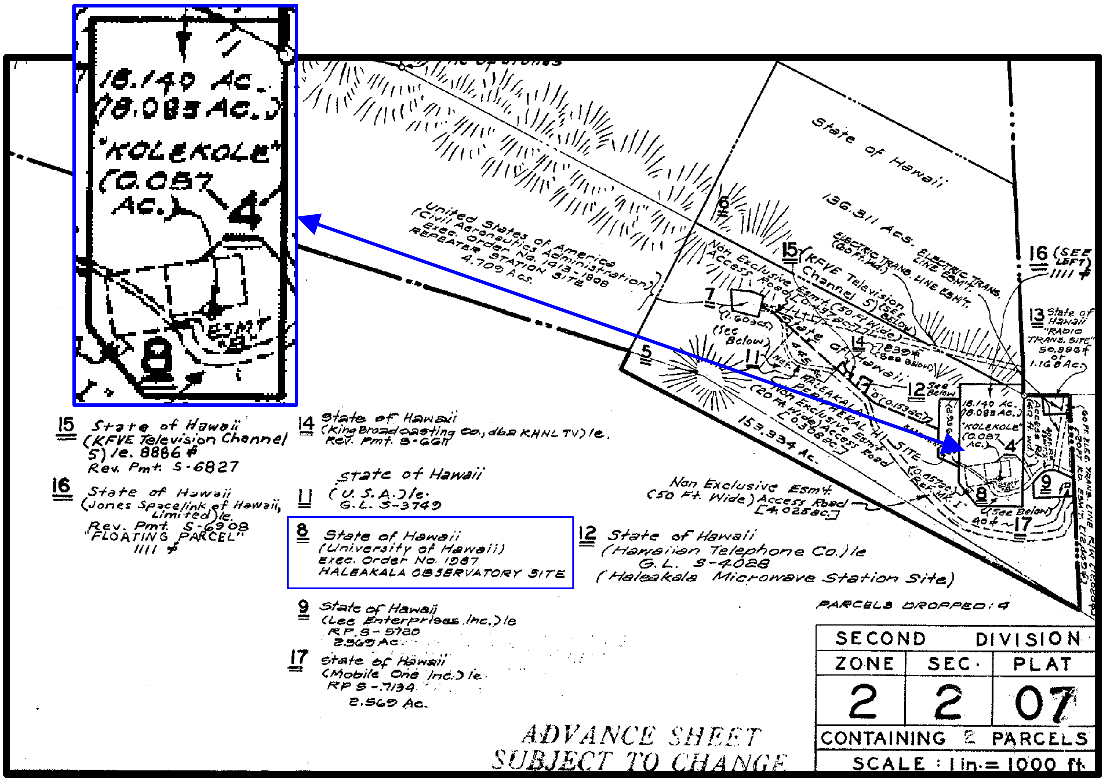
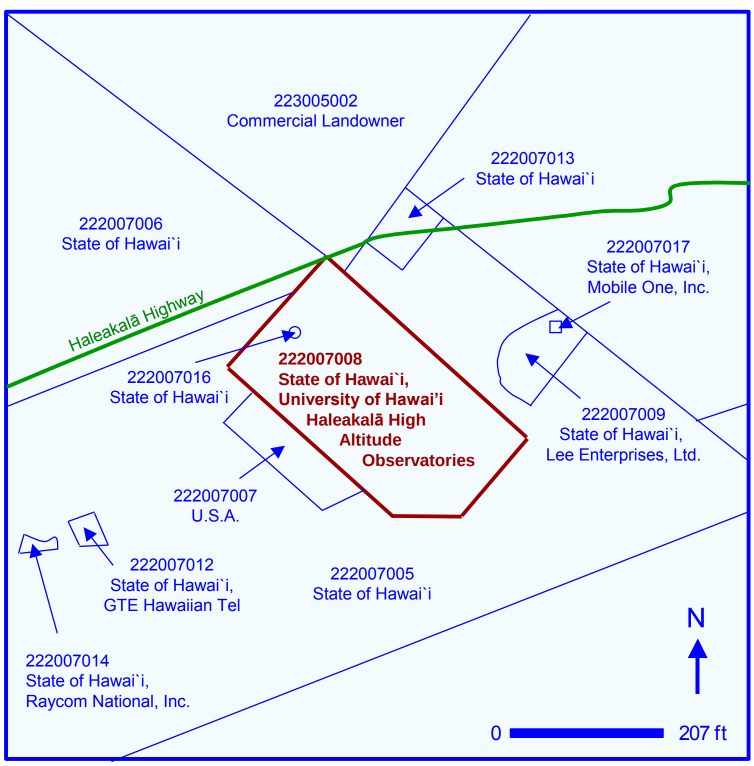


Figure 1-2. Tax Map Key Showing HO.



Internet website: http://kivanetext.co.maui.hi.us/kivanet/2/permit/index.cfm

Figure 1-3. HO Site and Adjacent Properties.

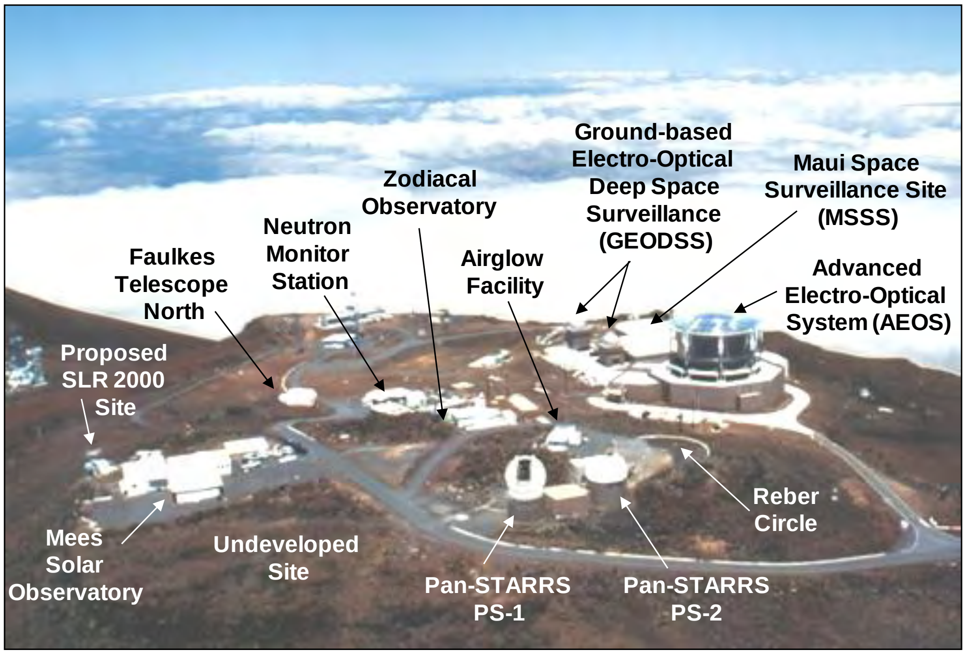


Figure 1-4. Aerial View of HO.

2.0 EXISTING CONDITIONS ON PARCEL

2.1 Ownership

In 1961, an EO by Governor Quinn set aside 18.166 acres of land on the summit of Haleakalā in a place known as Kolekole. The site is known as HO. UH is the owner of the parcel, under the control and management of the UH Board of Regents for observatory site purposes only. The EO has no expiration date.

HO is located in the area of the State of Hawai‘i Conservation District that has been set aside for astronomical research (HAR 13-5-25: Identified land uses in the General Subzone, R-3 Astronomy Facilities, (D-1) Astronomy facilities under an approved management plan); and many facilities conducting astronomy and advanced space surveillance already exist within HO.

2.2 Resources

The following sections describe the natural resources currently found at HO. “Natural resource” means resources such as plants, aquatic life and wildlife, cultural, historic and archeological sites and minerals (HAR 13-5-2, Definitions).

2.2.1 Cultural and Historic Resources

According to o‘mana‘o (remembrances, recollections) of many Native Hawaiians interviewed for the recent cultural impact assessments, for the ancient Native Hawaiians, Haleakalā — which includes the Kolekole area on which HO resides — is considered a piko (the navel, or center of Maui Nui a Kama (Greater Maui). It is a Pu‘u Honua (sacred refuge, or place of peace), which Hawaiian ancestors believed was a Wao Akua, or place where gods and spirits walk. The cultural resources of Kolekole date back more than a thousand years and are an integral part of the Hawaiian culture, both past and present. In ancient times, commoners could not even walk on the summit because it belonged to the gods. The sacred class of na poāo kāhuna (priest) used the summit area as a learning center. It was a place where the kāhuna could absorb the tones of ancient prayer and balance within the vortex of energy, for spiritual manifestations, the art of healing, and the study the heavens for navigation purposes. Kolekole itself was a very special religious place used by the kāhuna po'o (head priest) as a training site in the arts. There are numerous gods and goddesses said to reside on the summit, in the crater, and all around the mountain. (CKM 2006).

Planning and management for scientific development at HO must be conducted with an understanding of, and a respect for, the connection and delicate balance between the Native Hawaiians, the āina (land), and the ocean from which it was born.

A Cultural Resource Survey (CKM 2003), a Traditional Practices Assessment (CKM 2002), and an archeological inventory (Fredericksen 2003), were completed in 2003 to address historic and cultural issues for long-range development planning at HO. A subsequent cultural resources study, Cultural and Historical Compilation of Resources Evaluation and Traditional Practices Assessment was conducted in 2006 (CKM 2006) as part of the environmental compliance process for the proposed Advanced Technology Solar Telescope (ATST) Project.

In 2007, Cultural Surveys Hawai'i, Inc. (CSH) was commissioned to conduct a Supplemental Cultural Impact Assessment (SCIA). The SCIA was performed in accordance with the guidelines for assessing cultural impacts, as set forth by the Office of Environmental Quality Control (OEQC 1997) and was intended to supplement the initial Cultural Resource Evaluation (CKM 2006) for the proposed ATST Project. The primary purposes of the SCIA were to widen community outreach and to gather additional information on the Traditional Cultural Property (TCP) of Haleakalā as an additional means to assess the potential effects of that particular proposed undertaking on Native Hawaiian traditional cultural practices and beliefs. Although the SCIA was conducted for a specific project, the preparers of the SCIA made an additional effort to gather supplementary information, community input, and knowledge of the summit area, and therefore, the information is relevant to the management of HO. The SCIA contains considerable additional historical perspective on Haleakalā. It discusses in great detail the symbology of the mountain, its role in the history of Maui as a living entity, as well as the archeological record. The information provided is intended to educate the reader about the spiritual sacredness and cultural relationship of Native Hawaiians to Haleakalā as a whole and to the summit area in particular.

This section briefly describes the results of those surveys and the numerous previous studies with respect to resources of cultural value and their significance, ancient traditional practices, and archeological sites in and around what is now HO.

Cultural Resources

Pele (goddess of fire), Poli'ahu (goddess of snow), Māui (the demi-god), and others inhabited the area. In Hawaiian lore, it is said that Māui stood with one foot on Kolekole and the other on Hanakauhi Peak when he lassoed the Sun.

Haleakalā Crater was used as a trans-Maui thoroughfare and source for basalt stones. There are specific teachings related by the kupuna (elder) that guided commoners who were permitted access for gathering stones and to bury the dead. Numerous archeological sites have been recorded on the crest and in the crater, including, in order of frequency, temporary shelters, cairns, platforms with presumed religious purposes, adze quarries and workshops, caves, and trails (Rosendahl 1978). These are all remnants of the very elaborate spiritual and cultural life that the Native Hawaiians focused around the summit area.

Within Kolekole, cultural resources of importance are: temporary habitation or wind shelters, two petroglyph images, one site interpreted as a possible burial, and two ceremonial sites (CKM 2003). The sites are important in that they have yielded information on prehistory. Native Hawaiians know that this area, as a remnant of a Native Hawaiian landscape, provides significant cultural value because of its ceremonial and traditional importance.

Traditional Cultural Practices

During preparation of the Traditional Practices Assessment (CMK 2002), it was understood that due to the construction of former and existing buildings over the past 70+ years, much of the physical evidence of ancient Hawaiian traditional and cultural practices in the area was destroyed. The SCIA also provides information about Haleakalā as an important place where traditional cultural practices take place and several types of traditional cultural practices continue to take place, as listed and described below:

1. Gathering of plants
2. Traditional hunting practices
3. Collecting for basalt and tools
4. Pōhaku Pālaha – The Piko of East Maui
5. Traditional Birth and Burial Practices
6. Haleakalā as a Sacred Mountain
7. Ceremonial Practices, e.g., honoring the solstice or equinox
8. Astronomy
9. Travel

<u>Gathering of Plants</u>

Several plants have had and continue to have particular cultural importance. The SCIA reported that traditional gathering of plant resources continues to take place today within the upper elevations surrounding the summit (SCIA p. 102).

In the past, ʻōhelo berries (*Vaccinum sp.*) were traditionally offered to Pele by those who frequented the upper elevations of the mountainous regions (SCIA, p. 102). Today, upland hikers and those in transit often pick ʻōhelo berries as a food resource when found ripe. Another example of plant gathering is the collection of pūkiawe (*Syphelia tameiameiae*) and *lehua* blossoms used for lei making (SCIA, p. 102). The SCIA also reported that pūkiawe, lehua, māmane and other plants and flowers are used for this same purpose (SCIA, p. 102). The trunks and branches of the ʻaʻaliʻi (*Dodonaea viscosa*) and māmane (*Sophora chrysophylla*) were traditionally harvested and used for hale, or house, posts. Present day efforts have revived the construction of traditional structures, however, it is unknown at this time whether these plants are actively harvested (SCIA, p. 102). Māmane timber has also been traditionally used for weaponry, particularly spears; however, it is unknown whether modern craftsmen of traditional weaponry harvest this timber today (SCIA, p. 102). Pōpolo (*Solanum americanum*) leaves, which are also found along the upper elevations and summit of Haleakalā were traditionally used (and appear to continue to be used) in laʻau lapaʻau, or Hawaiian medicinal practices. Specifically, they have been used for alleviating sore tendons, muscles, and joints (SCIA, p. 102).

<u>Hunting Practices</u>

Traditional hunting of birds for food and feathers was documented at least 100 years ago (SCIA, p. 103). The ʻuaʻu (Hawaiian petrel, *Pterodroma phaeopygia sandwichensis*) was particularly sought after; they were considered to be very tasty, especially the nestlings, which were reserved for the exclusive enjoyment of the chief (SCIA, p. 103 and NPS 2008 Ethnographic Study, p. 36). In addition to the ʻuʻau and nēnē (*Nesochen sandvicensis*), the extinct flightless birds *Platochen pau* and *Branta hylobadisies* were hunted. Hunting practices today include the hunting and taking of "deer, goats, pigs, pheasant, chukar partridges, francolin and other game birds has become a culturally- supported subsistence practice" (SCIA, p. 104). Feathers from some of the game birds "are highly prized for their use in hatbands (SCIA, p. 104).

Basalt Collection

One of the reasons people came to the mountain was to collect basalt for use in tool-making. Physical evidence from several archeological sites on the mountain seems to indicate that there were areas used for collection, reduction, and transport of basalt to lower elevations (NPS 2008 Ethnographic Study, p. 36). Evidence exists of areas where basalt was quarried that were used for "lithic workshops", which "are surface scatters of basalt debitage, with very few finished tools. This suggests that the scatters are related to reduction activities rather than sites where tools were used" (NPS 2008 Ethnographic Study, p. 36). Many of the lithic workshops are associated with cave shelters, structures, or natural rock formations (such as cliff faces) that would have afforded protection from inclement weather (NPS 2008 Ethnographic Study, p. 36).

Pōhaku Pālaha – The Piko of East Maui

Traditionally, Maui Island was separated into 12 moku, or districts during the time of the Aliʻi Kakaalaneo and under the direction of the Kahuna Kalaihaʻohiʻa (SCIA ref. Beckwith 1940:383). The western portion Maui Island, dominated by Mauna Eke, the range commonly referred to as the West Maui Mountains, was subdivided into three moku: Lāhaina, Kaʻanapali, and Wailuku. The eastern portion of Maui Island, dominated by Mauna Haleakalā, was subdivided into the remaining nine moku: Hāmākua Poko, Hāmākua Loa, Koʻolau, Hāna, Kīpahulu, Kaupō, Kahikinui, Honuaʻula, and Kula. There is a naturally circular stone plateau, referred to as Pālaha (SCIA ref. Sterling 1998:3), along the summit of Haleakalā where one ahupuaʻa from each moku, with the exception of Hāmākua Poko, originate. Pōhaku Pālaha (SCIA Fig ref), as it is commonly known today, is located on the northeast edge of Haleakalā Crater, at Lauʻulu Paliku and is considered as the piko (navel or umbilical cord [Pukui and Elbert 1986]) of east Maui (Mr. Timothy Bailey, personal communication (References omitted).

The term, *Pōhaku Pāloha*, is used to describe a place in the northeast corner of the crater. The origin of the term is complex, perhaps interpreted as smooth and flat, or flat rock, but essentially referring to a convergence point where eight of the nine districts of Maui meet, which is a unique spatial organization of the islands (NPS 2008 Ethnographic Study, p. 24). There are more prominent points on the mountain, e.g., Haleakalā Peak, which is the high point on the south rim of the crater, but the cultural significance of this location originates with the concept of a piko, or mouth, which has been described as that of an octopus (SCIA, p. 106) from which eight tentacles spread out over a rock, making it difficult to pry loose, in essence, they are stuck flat to the rock. The symbolic significance of the piko to Native Hawaiians as the center, or source life, would apply to this locus of interlocking districts, or moku (SCIA, p. 107).

Birth and Burial Practices

Native Hawaiians frequently buried their dead in the crater. In addition, the umbilical cords of newborns, or piko, were left in the crater as well. Burial sites have been identified in the crater and one possible burial feature has been described at HO (Fredericksen 2003). Haleakalā is vital to the birth and death life cycle for Native Hawaiians who were and continue to be maʻa (familiar or accustomed) to this place (SCIA, p. 103).

Haleakalā as a Sacred Mountain

There is much historical research, testimonies, and other views that Haleakalā is a sacred place. As such, those who view Haleakalā as sacred consider development of the summit area to be desecration. Different individuals explain this viewpoint in various terms, or as expressed by one Maui kupuna (elder), "[w]hen a culture depends on these natural wonders of their environment for survival and reverence communications to a higher power than themselves, all care must be given to this practice" (SCIA, p. 105).

The summit area is referred to as Wao Akua and is considered to be the realm of the gods, and, as such, is a place to be revered. It is an area that is described to have been kapu, or restricted to all but the highest ranking of Native Hawaiians, such as their kāhuna, or priests. Even today, visitors "…must go in a sense of humbleness and in a sense of asking and in a sense of not disturbing unduly…" (SCIA, p. 106)

There is a protective instinct among Hawaiian people to properly care for Haleakalā, not just for themselves but for future generations. That care is expressed as a strong feeling for responsibility to prevent development on Haleakalā, rather than propose or agree to mitigation for the adverse cultural effects that may result from construction at the summit (SCIA, p. 106).

<u>Ceremonial Practices</u>
Most of the cultural rituals and ceremonies that may be practiced on Haleakalā are not known to the general public because they are kept secret for personal reasons or to maintain the integrity of particular rituals from generation to generation (SCIA, p. 107). This is not uncommon in the Hawaiian culture, and during consultations with Native Hawaiians only a few specifics of these practices have been shared (SCIA, p. 107). The best-known ritual to non-Native Hawaiians is the calling of the Sun, or "e ala e", which is a chant used to greet ancestors, kupuna, and [also] greet the Sun as it rises (SCIA, p. 107). Some consulted parties have shared other rituals that include such practices as annual pilgrimages to honor certain trees, conducting solstice ceremonies, visiting special sites at certain times of the year for offerings, and going to the summit for chanting. Certain times of the day, month, or year are considered important because at these times the Sun is at zenith. The zenith has particular significance in that there would be the greatest amount of hā, or spiritual breath that comes from above. For example, ceremonies at Leleiwi, about two miles from HO, have been described that involve the time when one's shadow is completely absent. These are described as being a time of hālāwai, or meeting, where everything in the world meets (Leleiwi is famous for "Specter of the Brocken", an unusual effect in which one can see his/her own shadow in the clouds surrounded by a rainbow, if the clouds are low and the Sun is behind the viewer. The hālāwai can also provide an opportunity to simply sit, with a sense of being with one's ancestors, doing what they did for generations (SCIA, p. 109).

Another example of the importance of Haleakalā for ritual practices is the ability to honor the Sun during the solstices and equinoxes in ways that are not possible at sea level. With visibility to the horizon over long distances, it is possible to see, for example, the Sun track across the sky and touch particular points around the summit, e.g., Pu'ukukui. These practices essentially use Haleakalā as a calendar (SCIA, pp. 107-108).

<u>Astronomy</u>
As described in oli (chants) and the mo'olelo (stories) about the summit of Haleakalā, the area around Kolekole was used for a training ground in the arts of reading the stars and being one with the celestial entities above and was considered sacred because of its height and closeness to the heavens.

Astronomy has a very large role in the cultural importance of Haleakalā:

> Astronomical matters, both practical and ceremonial, may have been the basis for the most important activities at Haleakalā. All of the possible traditional names for the mountain are associated with tales of the demi-god Māui and his efforts to catch and slow the Sun. These tales involve two aspects, one is the perception of Haleakalā reaching to the sky, and the other is

> Haleakalā as a place where the observation of solar movement (that is, the marking of seasons) took place.

The recognition of Haleakalā as a place to study the Sun, astronomy, astrology, and the constellations continues into modern times (NPS 2008 Ethnographic Study, p. 31).

Travel

Haleakalā has long been recognized as a traditional traveling route through East Maui. Travel from one side of Maui Island to the other side often resulted in experiencing Haleakalā. The Kaupō and Ko'olau Gaps provided an excellent route to connect these two districts, and it traversed through the crater (NPS 2008 Ethnographic Study, p. 33). A trail once led from Nu'u (in Kaupō) directly up the steep southern flank of the mountain to the south rim of the summit of Haleakalā (NPS 2008 Ethnographic Study, p. 33).

In 2005, in recognition of the cultural importance of Haleakalā and in the spirit of ho'oponopono (to "make right"), UH contracted Native Hawaiian stonemasons to erect a west-facing ahu (altar or shrine) (Fig. 2-1) within the HO set aside "Area A" for the sole reverent use of Native Hawaiians for religious and cultural purposes with the understanding that such use will not interfere with other uses and activities within HO (Fig. 2-2). A ho'omahanahana (dedication or "warming" offering) was held, at which time the ahu was named Hinala'anui.

In 2006, in the spirit of makana aloha (gift of friendship) for a proposed project, UH contracted the same Native Hawaiian stonemasons to erect an east-facing ahu near the UH Mees Solar Observatory (MSO) site (Fig. 2-1), not within the HO set aside "Area A". Upon its completion, a ho'omahanahana was held and the ahu was named Pā'ele Kū Ai I Ka Moku. Native Hawaiians are welcome to utilize these sites for reverent, religious and cultural purposes, on a non-interference basis with site activities.

As shown in oli (chants) and the mo'olelo (stories) about the summit of Haleakalā, the area around Kolekole was used for a training ground in the arts of reading the stars and being one with the celestial entities above, by the Kahuna Po'o (High Priest). This site was sacred to them because of its height and closeness to the heavens.

Evidence of sacred use found within HO includes ko'a (ceremonial rock formations) and temporary habitation shelters. These may have been used for ceremonies by the priesthood during Makahiki festivals. In ancient times, the mo'olelo tells of kāhuna and their haumāna (students) living at Haleakalā and conducting initiation rites and practices. Traditional accounts also exist of the use of Haleakalā in rites of passage such as birth and death. Haleakalā's connection to a symbolic rebirth is reflected in the traditional Hawaiian practice of piko storing. A pit at Haleakalā named Na Piko Haua was still being used by Kaupo residents in the 1920s to store their offspring's umbilical cords (Krauss 1988).

Haleakalā has long been recognized as a traditional traveling route thru East Maui. In the sixteenth century, Kihapi'ilani, Ali'i nui (high chief) of a united Maui constructed a trail around the island and over Haleakalā, uniting the politically important districts of Hana and Kaupo with West Maui. Peoples of Honua'lua buried their dead in Haleakalā Crater (Handy and Handy 1972). Several references specify burials of both chiefs and commoners in Haleakalā Crater (SCIA ref. Ka'ai'e, Kamakau; in Sterling, 1998:264-265), and one possible burial is recorded on the northwest boundary of HO property (Fredericksen 2003).

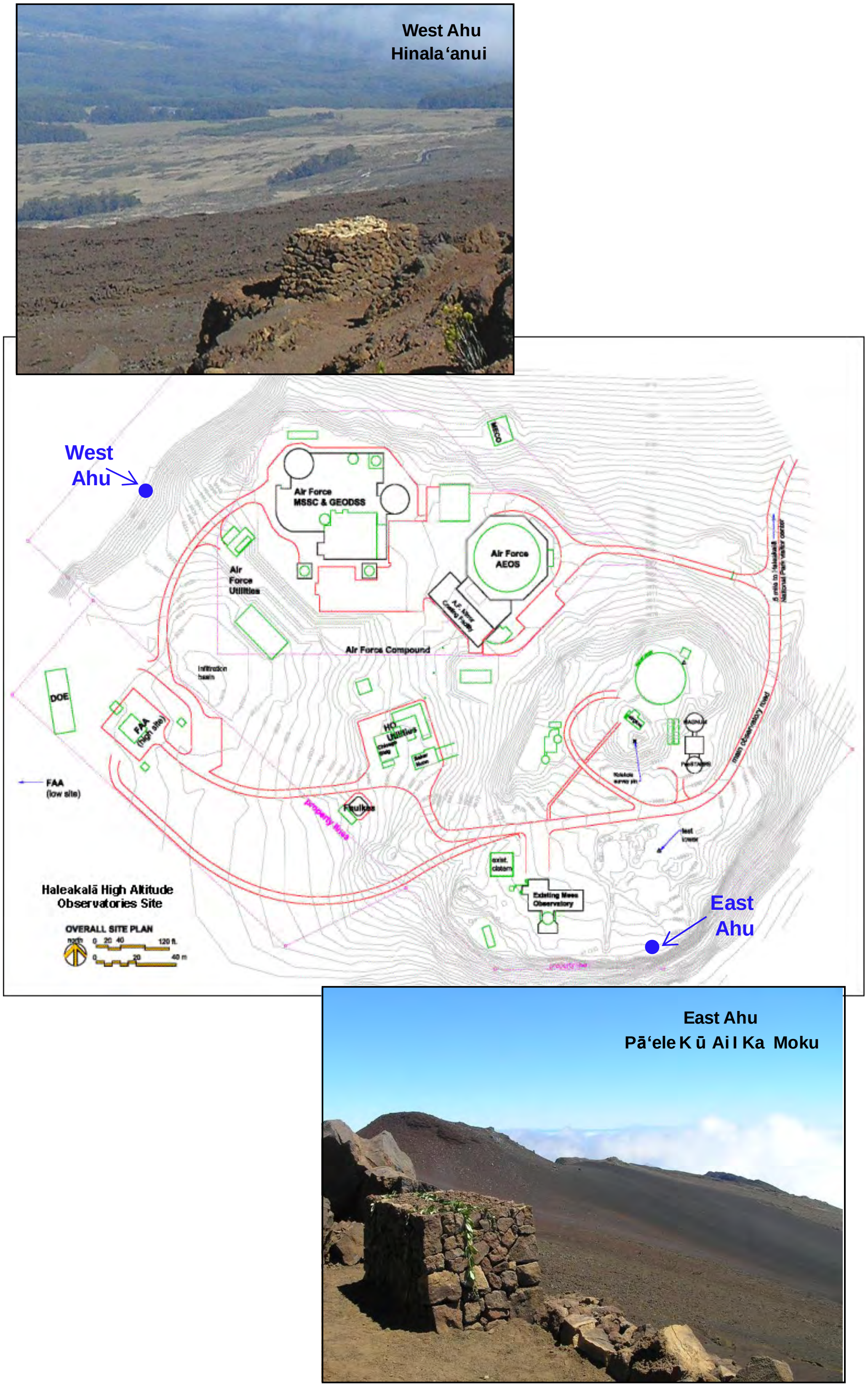


Figure 2-1. East- and West-facing Ahu Locations at HO.

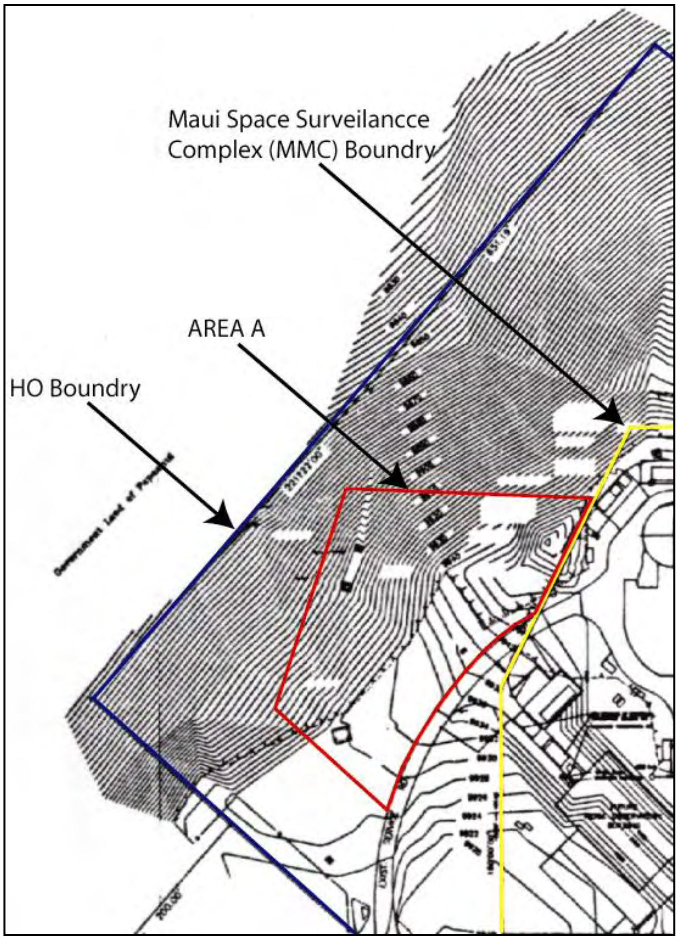


Figure 2-2. Set Aside "Area A" Location at HO.

Early post-contact travel to Haleakalā by haole (foreigner) was mostly limited to expeditions and sightseeing until the late 1800s. There is evidence that the Hawaiians continued to ascend Haleakalā throughout the 1800s not only for its popularity as a traveling route, but also for its ceremonial significance. Cattle ranching occurred on the slopes in the late 1800s, and in 1916 the U.S. Congress allotted 21,000 acres at the summit of Haleakalā as part of the Hawaiʻi National Park. The Park opened in 1921 and operated peacefully for 20 years until the U.S. Army began seeking sites for "unspecified defense installations" (Jackson 1972:130). By 1945, the Army had installations on both Red Hill and Kolekole Peak, just outside National Park boundaries. These installations were utilized until the end of World War II and intermittently thereafter, including during the Korean War. Grote Reber built a radio telescope on Kolekole in 1952, and between 1955 and 1958, the UH and the U.S. Air Force shared use of the Red Hill facilities. By 1960 to 1961, the UH was operating its observatory at the Kolekole location (Jackson 1972:131).

Today, spiritual practices continue in and around Kolekole. Flora and fauna are still collected for hula adornment by Kumu Hula, and native Hawaiians frequent the site for sunrise or sunset practices. The mana (spirit) of the area is wholly dependent on the vistas that can be viewed and the connection with earth and sky. For example, Native Hawaiians know that the spiritual essence is not something tangible at the summit area, but that one can feel the presence of the gods (CKM 2003, oral history).

Haleakalā Summit

The summit of Haleakalā is considered a significant cultural resource in and of itself. It is eligible for listing on the National Register of Historic Places (NRHP) as a TCP through consultation with the State Historic Preservation Division (SHPD) under Criterion "A" for its association with the cultural landscape of Maui and this is reflected in the number of known uses, oral history, mele (song) and legends surrounding Haleakalā. The term "Traditional Cultural Property" is used in the NRHP to identify a property "that is eligible for inclusion in the NRHP because of its association with cultural practices or beliefs of a living community that, (a) are rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community" (DOI 1994). The summit is also eligible under NRHP Criterion "C" because it is an example of a resource type, a natural summit, and a source for both traditional materials and sacred uses. The value ascribed to Haleakalā as a TCP can be expressed in five distinct attributes, solidifying the role of the summit as a place of value.

1. Haleakalā summit is considered by Native Hawaiians, as well as more recent arrivals to Hawai'i, as a place exhibiting spiritual power.
2. The summit of Haleakalā is significant as a traditional cultural place because of traditional cultural practices conducted there. For both Hawaiians and non-Hawaiians who live and visit here, the summit is a place of reflection and rejuvenation.
3. The mo'olelo and oli surrounding the summit present a collection of stories suggesting the significance of Haleakalā as a TCP.
4. Some believe that the summit possesses therapeutic qualities.
5. The summit provides an "experience of place" that is remarkable.

Historic Resources

One historic site is present at HO. It is identified as the Reber Circle site, which is a remnant of early 1950s astronomy construction that lies at the peak of Pu'u Kolekole. It is designated by the State Inventory of Historic Places (SIHP) as Site 5443 (UH IfA 2005) and is eligible for listing on the NRHP under Criterion "A" because of its association with mid-20th century scientific studies at Haleakalā, and under Criterion "D" for its information content. This site remnant consists of a concrete and rock foundation that was part of the former radio telescope facility that was constructed in 1952 by Grote Reber, an early pioneer of radio astronomy. The bulk of this structure was dismantled about 18 months after the facility was completed. This site is composed of a concrete and rock foundation that is approximately 25 meters (82 feet) in diameter, the outer rim of which is up to 1 meter (3.28 feet) in width and approximately 80 centimeters (2.62 feet) in height.

2.2.2 Archeological Resources

There were two archeological surveys conducted in portions of HO during the 1990s. The first of these was in 1990 and consisted of a reconnaissance survey by Pacific Northwest Laboratory on behalf of the US Air Force for the Advanced Electro-optical System (AEOS) Environmental Assessment (EA) (Chatters 1991). Cultural Surveys Hawai'i, Inc., conducted the second study, an archeological inventory, in 1998. During the course of this study, a walkover, four archeological sites were identified, primarily along the western side of Kolekole. These sites included 23 temporary shelters and a short low wall. These wind shelters were typically constructed against the existing rock outcrop of the hill. The sites were designated Site 50-50-11-2805 through 50-50-11-2808. One sling stone was found on the floor of Feature J at Site 50-50-11-2807. In addition, one 'opihi (limpet) (*Cellana* spp.) shell, was noted on the surface of the Feature B floor of Site 50-50-11-2808. There was no subsurface investigation carried out, and only Site 50-50-11-2805 was mapped (additional inventory work was done at these sites in 2005).

Cultural Surveys Hawai‘i, Inc. conducted another study in 2000 (FTF EA 2001), in conjunction with the planned construction of the FTF. They located two previously unidentified sites (50-50-11-4835 and 50-50-11-4836) to the west of the MSO facility. Both of these sites were constructed against an exposed rock outcrop. Site 50-50-11-4835 consists of two features—both historic rock enclosures filled with burned remnants of modern refuse—obviously historic trash burning pits. The researchers speculated that the U.S. Army might have initially used these during the war and later UH workers used them (FTF EA). Site 50-50-11-4836 consists of three terraces, a rock enclosure, two leveled areas and a rock wall, all constructed against an exposed rock outcrop. Five of the features are interpreted as temporary shelters, while the two leveled areas were of indeterminate usage. Although one test unit did not reveal any pre-Contact cultural materials, their construction is consistent with pre-Contact structures used for temporary shelters in other areas of Haleakalā Crater (Bushnell and Hammatt). The IfA has preserved both sites.

A comprehensive archeological inventory survey of HO was completed in fall 2002 (UH IfA 2005) and the inventory survey report was approved by SHPD. An archeological preservation plan for “Science City” (Xamanek Researches, 2006) was prepared in 2006 and approved by SHPD in a July 10, 2006, review letter (DLNR 2006). Whereas surveys had previously been conducted for specific construction projects within HO and a number of archeological features had been identified, the 2002 survey of the entire 18.166 acres for the LRDP (UH IfA 2005) was exhaustive and included location and description of six previously unidentified sites. These sites were assigned State of Hawai‘i designations, and further documentation was obtained for four previously identified sites that were listed with the SHPD. In total, 29 new features were identified and five excavation units were used to sample selected features that were located in some of the previously undocumented sites. These sites consist of wind shelters, two petroglyph images, a possible burial feature, and an historic foundation known as Reber Circle. Supplemental information was obtained from Sites 50-50-11-2805 to 50-50-11-2808 per discussions with Dr. Melissa Kirkendall of the SHPD Maui office. In addition, a trail segment was recorded at Site 50-50-11-4836 and designated as Feature F. Several isolated pieces of coral were noted in the southeastern portion of the 18.166-acre study area, but not assigned a formal site number because the coral pieces were not weathered. A possible site consisting of several pieces of coral in a boulder was plotted on the project map, but was determined to lie off the project area. The results of the inventory survey were submitted to SHPD for preservation review, although there was no triggering action requiring submittal of the survey, as described in HRS Section §6E-8. The significance assessments were accepted (DLNR 2003).

Most of the newly identified features are temporary habitation areas or wind shelters. Two features at one site are petroglyph images and, as indicated above, one new site is interpreted as a possible burial. Two small platforms thought to have ceremonial functions were also identified, as was a possible trail segment. All of the newly identified sites and previously designated ones retain their significance rating under at least Criterion “D” for their information content under NRHP and State historic preservation guidelines. All of the previously identified sites mentioned in this report qualify for significance because of their information content under Criterion “D” of State and NRHP historic preservation guidelines. In addition, the possible burial (Feature D) and the 2 petroglyph images (Features F and G) of Site 50-50-11-5440, as well as Site 50-50-11-5441 and the Site 50-50-11-4836 trail segment (Feature F) also qualify for their cultural significance under state Criterion “E”. Finally, it is important to note that the various sites located in HO are a remnant of a Native Hawaiian cultural landscape. Because Haleakalā is noted for its ceremonial and traditional importance to the Native Hawaiians, the entire HO complex of sites may well qualify for importance under significance NRHP Criterion “A” and state criterion “E”.

The general lack of material culture remains suggests that the HO area was used for short-term shelter purposes, rather than extended periods of temporary habitation. While there was no charcoal located during testing in the project area, the newly identified sites are nevertheless tentatively interpreted as indigenous cultural resources, some of which may have been modified or used in modern times. A map of the archeological features at HO, including Historic Site 5443 Reber Circle, is presented in Figure 2-3.

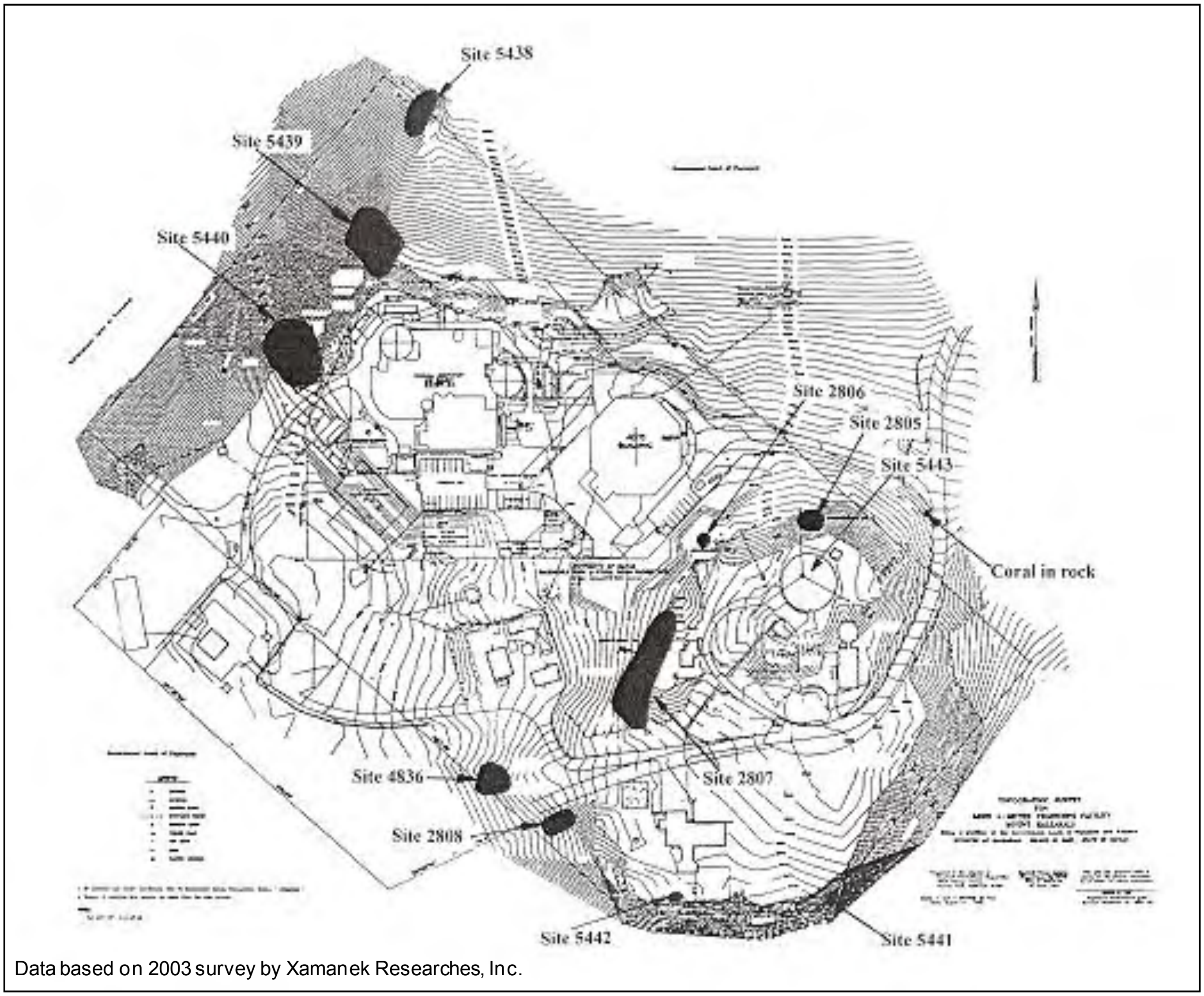


Figure 2-3. Archeological Sites at HO.

Table 2-1 Summary of HO Archeological Sites.

Site numbers are prefaced by 50-50-11: 50=State of Hawai‘i, 50=Maui, 11=Kilohana quadrangle.

SIHP Site #	Description (Number of Features)	Age	NRHP Significance Criterion
2805	Wind shelter (1)	Pre-contact - post-contact	D
2806	Wind shelter (1)	Pre-contact	D
2807	Wind shelter (13), Wind shelter, C-shape (2), Wind shelter/terrace (1)	Pre-contact - post-contact	D
2808	Wind Shelter (3)	Pre-contact - post-contact	D
4835	Trash pit (2)	Possible WWII era, modern trash observed	D
4836	Wind shelter (5), Trail (1)	Pre-contact-post-contact	D
5438	Wind shelter (1), Terrace/Wind shelter (1), Terrace-like Wind shelter (3), Rock pile (1)	Pre-contact - post-contact	D
5439	Rock Shelter (2), Wind shelter (4), Wind shelter, C-shape (6), Rock pile (1)	Pre-contact - post-contact	D
5440	Wind shelter, enclosure (1), Wind shelter, C-shape(2), Wind shelter natural terrace (1), Platform (1), Petroglyph (2)	Pre-contact - post-contact	D
5441	Terrace (2)	Pre-contact - post-contact	D
5442	Rock wall partial enclosure (1)	Pre-contact - post-contact	D

2.2.3 Topography Geology, and Soils

Haleakalā Observatories is wholly contained within Pu‘u Kolekole. The Kolekole volcanic center is located in East Maui on the southwest rift of Haleakalā, adjacent to the deeply eroded and spectacular summit depression. Alkalic lava flows in this area belong to both the post-shield stage Kula series as well as to the initial phase of the rejuvenated stage Hana series. The observatories are largely built on ankaramitic picro-basalts and some basanites (Bhattacharji 2002). Geological field studies describe the HO property as an asymmetric volcanic cone whose slopes are steeper at the western and northwestern sides, while the eastern and southern slopes are gentler. Much of the northern slope — most of which is occupied by the Air Force Maui Space Surveillance Complex (MSSC) — is flattened and had been disturbed. The central crater of Kolekole is described as a flattened bowl of ponded ankaramite lava, spatter and pyroclastic ejecta. More than one eruptive vent was present on Kolekole. The primary vent was likely in the approximate position of the present day Panoramic-Survey Telescope and Rapid Response System (Pan-STARRS) PS1 telescope (LURE Observatory South Dome), and one prominent likely secondary event is within the wide depression near the western border of the property (Bhattacharji 2002, Fig. 5).

The significance of Pu‘u Kolekole appears to be a result of its geographical position near the apex of the southwest rift zone of Haleakalā, which resulted in a somewhat unusual volcanic history. Kolekole exhibits both post-shield (Kula) volcanism and the initial stage of rejuvenated (Hana) alkaline volcanism in proximity to each other on or near the surface. Samples from different eruptive centers on the site that were collected and analyzed demonstrate that the transition between eruptive cycles was taking place at

Puʻu Kolekole. Age dating of lavas from the site and micro-chemical barometry confirm this unusual confluence of what are two distinct volcanic regimes elsewhere on Maui.

Topography

The Island of Maui, nicknamed "The Valley Isle" and the second largest of the Hawaiian Islands, is a volcanic doublet: an island formed from two volcanic mountains that abuts one another to form the isthmus between them (Fig. 2-4). Mauna Kahalawai, also known as the West Maui Mountain, is the much older volcano and has been eroded considerably. Haleakalā, the larger volcano on the eastern side of Maui, rises above at 10,023 feet ASL. The last eruption occurred sometime between 1650 and 1790, and the lava flow can been seen between Āhihi Bay and La Perouse Bay on the southwest shore of East Maui. Both volcanoes are shield volcanoes and the low viscosity of the Hawaiian lava makes the likelihood of the large explosive eruptions negligible.

The summit area of Haleakalā is rugged and barren, consisting of lava and pyroclastic materials. Within a 4-mile radius of HO, the elevation drops to approximately 3,600 feet ASL, with an average slope greater than 30 percent.

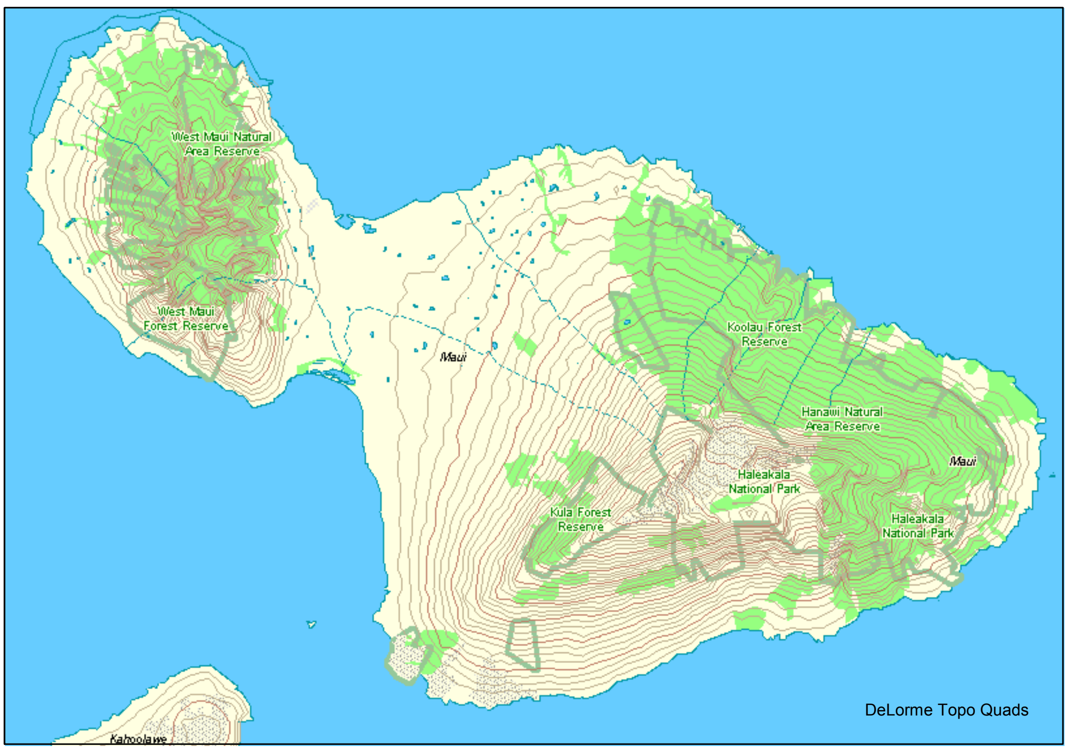


Figure 2-4. Topography for Island of Maui, Hawaiʻi.

Geology

Over the course of Haleakalā's formation, three distinct phases of eruption have taken place. The first, called the Honomanu Volcanic Series, is responsible for the formation of Haleakalā's primitive shield and most likely its three prominent rift zones. Honomanu lavas are exposed over less than 1 percent of Haleakalā, but are believed to form the foundation of the entire mountain to an unknown depth below sea level. The second series, or Kula Volcanic Series, overlaid the previous Honomanu Series with its lava flows. Eruptions of this series were considerably more explosive than its predecessor, leading to the formation of most of the cinder cones along the three rift zones.

A period of inactivity followed the Kula Series, during which time erosion began to predominate the formation of Haleakalā Crater by forming great valleys leading to the coast. After this long period of erosion, the final volcanic eruptions, called the Hana Volcanic Series, partially filled the deep valleys. Several cinder cones and ash deposits lined the East and Southwest Rift Zones ranging from a few feet high to large cones more than a mile across at the base and 600 feet high. Lava flows within the Haleakalā Southwest Rift Zone range from 200 to 20,000 years old. Six flows have erupted in this area within the last 1,000 years. During the latest eruption, sometime between 1650 and 1790, lava emerged from two vents and flowed into La Perouse Bay, where a small peninsula was constructed. Recent studies have indicated that Haleakalā volcano may still be active, in light of the numerous eruptions during the last 8,000 years (Bergmanis, et al, 2000).

Soils

The summit area is covered with volcanic ejecta consisting of lava, cinder, and ash of the Kula and Hana Volcanic Series. There is no soil development in the immediate vicinity of HO. Soil development occurs with increased distance (greater than 1.5 miles) from the summit. Most of the area is situated on Cinder Land (rCl), which is thought to be of the Kula period of volcanism (U.S. Soil Conservation Service, 1972). A foundation investigation conducted in 1991, in the northern area of HO revealed that cinder in this area is underlain by 5 feet of volcanic clinker and 16 feet of volcanic cinder.

2.2.4 Biological Resources

2.2.4.1 Botanical Resources

The vegetation type at HO is an *Argyroxiphium*/*Dubautia* alpine dry shrubland. Dry alpine shrublands are typically open communities, occurring at 3,000 to 3,400 meters (9,842 to 11,155 feet) elevation, predominantly on barren cinders, with very sparse vegetation cover (Wagner et al. 1999). The substrate is a mixture of ash, cinders, pumice, and lava (MSSC 2002). The vegetation is sparse, from a near barren <1 percent cover to about 10 percent cover. The vegetation is low, no more than one meter (3 feet) tall anywhere on the site. During the most recent survey (Starr 2002), a total of 32 plant species were observed. Of these, 11 (34 percent) were native and 21 (66 percent) were non-native.

Within the site there are two general types of land area: undisturbed and those where construction has occurred. Undisturbed areas are comprised of predominantly native plants including shrubs, such as na‘ena‘e (*Dubautia menziesii*), pukiawe (*Styphelia tameiameiae*) and ‘ohelo (*Vaccinium reticulatum*), herbs, such as tetramolopium (*Tetramolopium humile*), and grasses, including bentgrass (*Agrostis sandwicensis*), hairgrass (*Deschampsia nubigena*), and mountain pili (*Trisetum glomeratum*). Three species of native ferns, ‘iwa ‘iwa (*Asplenium adiantum-nigrum*), ‘oali‘i (*Asplenium trichomanes* subsp. *densum*), and kalamoho (*Pellaea ternifolia*) are found tucked into rock crevices and overhangs around the Lunar Ranging Experiment (LURE) Observatory and on the steep slopes on the southeast part of the property near the MSO facility.

Areas of HO property where construction has occurred generally support fewer native species and contain more weeds. One notable exception is the endemic silversword or ‘ahinahina (*Argyroxiphium sandwicense* subsp. *macrocephalum*) which is found exclusively on areas where construction has occurred. Weeds found in these disturbed areas include non-native herbs, such as thyme-leaved sandwort (*Arenaria serpyllifolia*), storksbill (*Erodium cicutarium*), hairy cat's ear (*Hypochoeris radicata*), sweet alyssum (*Lobularia maritima*), common mallow (*Malva neglecta*), black medick (*Medicago lupulina*), evening primrose (*Oenothera stricta* subsp. *stricta*), common plantain (*Plantago lanceolata*), polycarpon (*Polycarpon tetraphyllum*), sheep sorrel (*Rumex acetosella*), wood groundsel (*Senecio sylvaticus*), sow thistle (*Sonchus* sp.), and common dandelion (*Taraxicum officinale*). These areas also harbor a selection of non-native grasses, including sweet vernal grass (*Anthoxanthum odoratum*), rescue grass (*Bromus* *willdenowii*), Bermuda grass (*Cynodon dactylon*), Yorkshire fog (*Holcus lanatus*), annual bluegrass (*Poa annua*), Kentucky bluegrass (*Poa pratensis*), and brome fescue (*Vulpia bromoides*).

ʻahinahina (Haleakalā silversword)
The ʻahinahina or Haleakalā silversword are Federally-listed as a "threatened" species, meaning they may become endangered throughout all or a significant portion of their range if no protective measures are taken. In 2002, nine live ʻahinahina and three dead ʻahinahina flower stalks were located within the HO property. All of the live plants are on the MSSC site. During the June 2009 botanical survey (Starr 2009), the same botanists who conducted the 2002 survey "...were pleasantly surprised to find silverswords were now locally common within the Air Force site at HO, with 159 silverswords counted. The silverswords were generally in the same places as in 2002, but in much greater abundance."

2.2.4.2 Avifaunal Resources

ʻUaʻu (Hawaiian Petrel)
The ʻuaʻu, or Hawaiian Petrel *(Pterodroma sandwichensis)*, a Federal- and State-listed endangered bird species, is present in the summit area (UH IfA 2005). Haleakalā National Park (HALE) biologists have been conducting regular monitoring and searches of ʻuaʻu nests since 1988. Approximately 85 percent of the world's known ʻuaʻu population nests on Haleakalā (Fig. 2-5), near the summit (HALE 2003). Most of the population is within HALE boundaries. About 55 burrows are within 1/4 mile (400 meters) of the Haleakalā Observatories, but outside HALE boundaries (HALE unpublished data). These are considered part of the "Haleakalā population." Approximately 30 known burrows are along the southeastern perimeter of HO and several burrows are northwest of HO, with a large number of burrows in and around HO (Fig. 2-6). This was derived from data obtained during the 2006 and 2007 surveys by the NPS and KC Environmental, Inc.

The ʻuaʻu can be found nesting at Haleakalā from February to November. The birds make their nests in burrows and return to the same burrow every year. The species distribution during their non-breeding season is poorly known, but they are suspected to disperse north and west of Hawaiʻi, with very little movement to the south or east. The ʻuaʻu typically leave their nests just before sunrise to feed on ocean fish near the surface of the water and just before sunset transit from the ocean back to Haleakalā. These birds have limited vision and their high speed and erratic nocturnal flight patterns may increase the possibility of collisions with fences, utility lines, and utility poles (Simons and Hodges 1998).

ʻUaʻu are believed to navigate by stars, so man-made lights may confuse in-flight ʻuaʻu. Evidence suggests these birds will fall to the ground in exhaustion after flying around lights, where they are susceptible to being hit by cars or attacked by predators (Simons and Hodges 1998); however, this has not been observed at HO. In addition to these hazards, confirmed causes of ʻuaʻu mortality include nest collapse by wild goats, predation by native owls and introduced predators, road-kills, collision with such objects as buildings, utility poles, fences, lights, and vehicles, and disturbance from road resurfacing activity (Natividad Hodges and Nagata 2001).

During fall 2004, ABR, Inc. conducted a study for the MSSC (ABR 2005). Using ornithological radar and visual sampling techniques, this study's objective was to determine movement patterns of ʻuaʻu near the summit of Haleakalā, including spatial movement patterns, temporal movement patterns, and flight altitudes. Many of the patterns observed in this study matched what is known about the biology of ʻuaʻu. Breeding adults, non-breeding sub-adults, and adults are active in the summer when the displaying non-breeders are active and fly erratically and circle the colonies at low altitudes. In contrast, only adults visit the colonies during the fall, when they simply fly in and land at burrows to feed young. It is suspected that fewer birds were seen on the radar in the vicinity of the MSSC than near the crater because the crater is much more active for breeding and displaying birds than is that part of the colony along the southwestern ridge (i.e., the ridge on which the observatories and the Federal Aviation Administration (FAA) site are located).

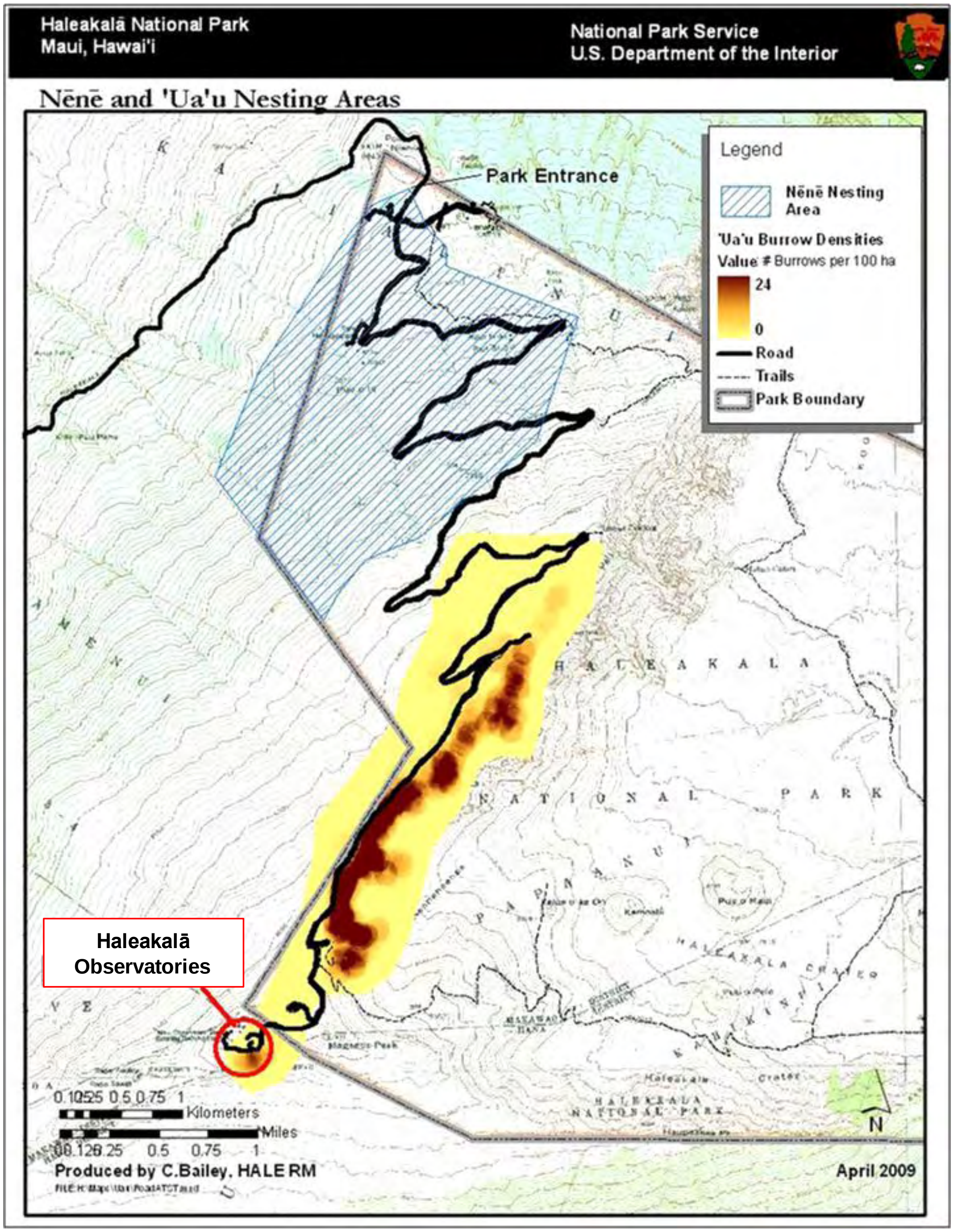


Figure 2-5. Petrel Burrows Near Summit of Haleakalā.

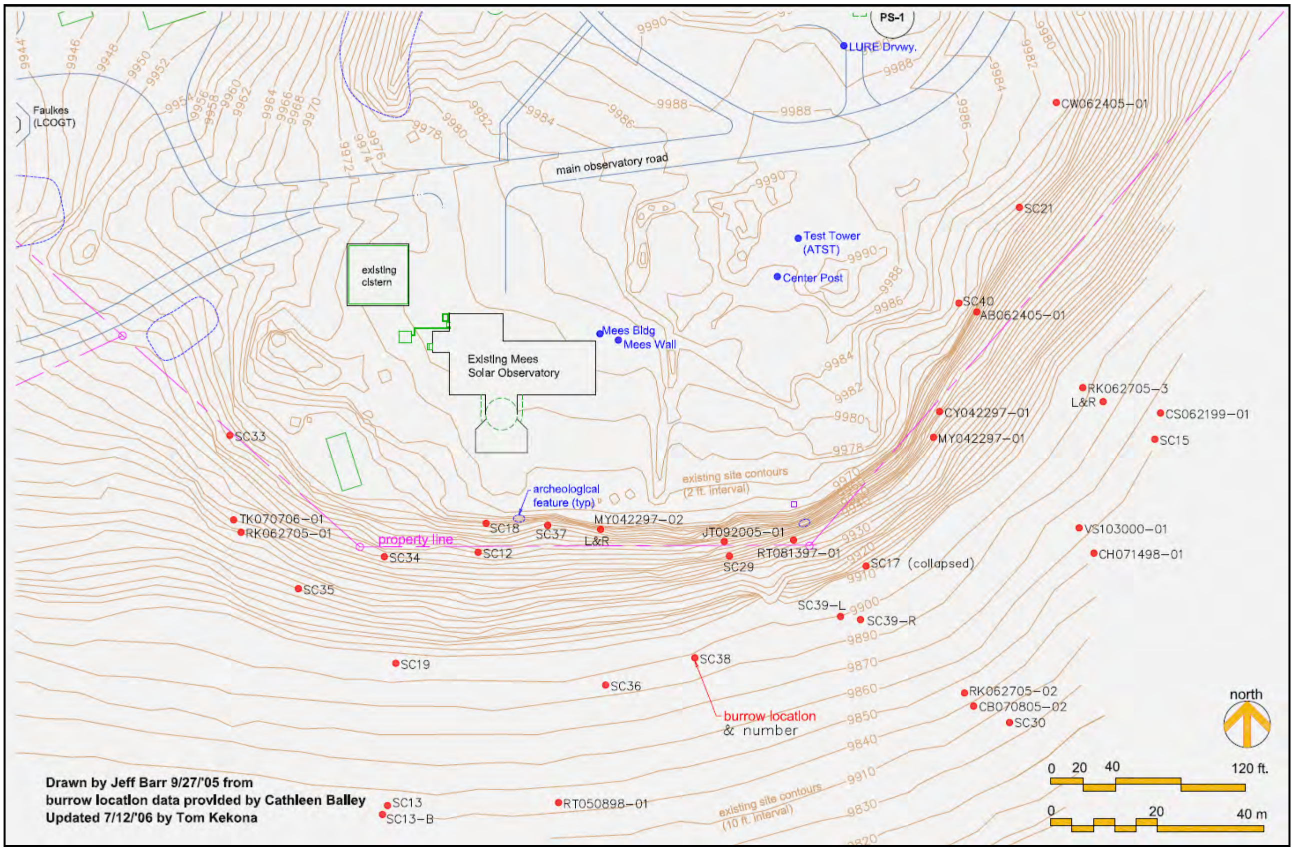


Figure 2-6. Petrel Burrows In and Around HO.

Nene (Hawaiian Goose)

The nēnē, or Hawaiian goose *(Branta sandvicensis* also known as *Nesochen sandvicensis),* is a Federal- and State-listed endangered species on Haleakalā and is the only extant species of goose not occurring naturally in continental areas. The nēnē formerly bred on most of the Hawaiian Islands, but currently is restricted to the islands of Hawai‘i, Kaua‘i and Maui. Nēnē seem to be adaptable and are found at elevations ranging from sea level to almost 8,200 feet (Fig. 2-7) in a variety of habitats, including non-native grasslands, sparsely vegetated, high elevation lava flows, cinder deserts, native alpine grasslands and shrublands, open native and non-native alpine shrubland-woodland community interfaces, mid-elevation (approximately 2,300 to 3,900 feet) native and non-native shrubland, and early successional cinder fall. Critical habitat has not been designated for the nēnē. The nēnē population on Maui is thought to consist of approximately 330 individuals. While the nēnē has been known to fly over HO, the summit area is outside the known feeding range of the bird.

These non-migrating, terrestrial goose nesting periods occur from October to March. Preferred nest sites include sparsely to densely vegetated beach strands, shrublands, grasslands and woodlands on well-drained soil, volcanic ash, cinder, and lava rock substrates. Nēnē are ground nesters and their nests are usually well hidden in the dense shade of a shrub or other native vegetation, but on Kaua‘i nēnē have built nests under alien species. Nēnē are browsing grazers, eating over 50 species of native and introduced plants.

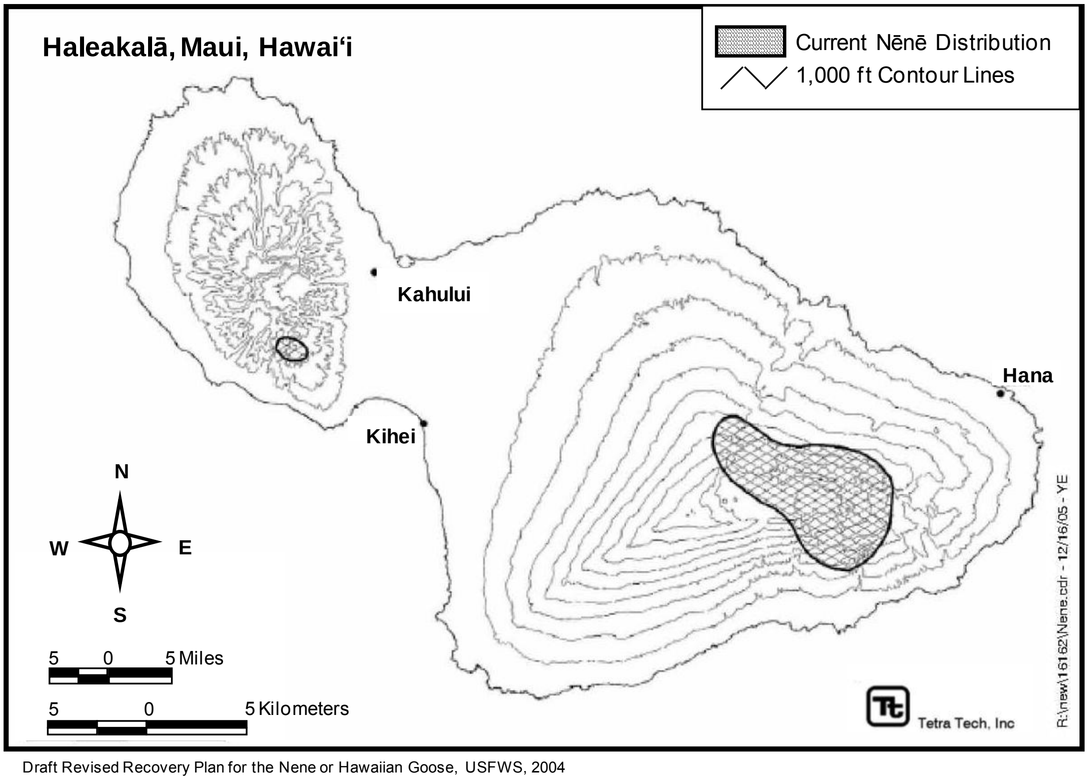


Figure 2-7. Current Distribution of Nēnē on Maui.

Once abundant, the nēnē population has declined. The primary causes of this decline were habitat loss, hunting during the nēnē breeding season (fall and winter), and the impacts of alien mammals introduced during both Polynesian and western colonization.

Current threats to the nēnē population include predation, nutritional deficiency due to habitat degradation, a lack of lowland habitat, human-caused disturbance, road-kills, behavioral problems, and inbreeding depression. Dogs *(Canis familiaris)*, cats *(Felis cattus)*, mongoose *(Herpestes auropunctatus)*, rats *(Rattus* spp.*)*, and pigs *(Sus scrofa)* prey on nēnē, while feral cattle *(Bos taurus)*, goats *(Capra hircus)*, pigs, and sheep *(Ovis aries)* have been known to alter and degrade nēnē habitat through their foraging.

Potential threats to the nēnē are identified below and follow U. S. Fish & Wildlife Service (USFWS) classification of factors that may negatively affect a species, leading to its decline, as identified in Section 4(a) of the Endangered Species Act (ESA). These include:

1. The present or threatened destruction, modification, or curtailment of its habitat or range;
2. Over-utilization for commercial, recreational, scientific, or educational purposes;
3. Disease or predation;
4. The inadequacy of existing regulatory mechanisms; and,
5. Other natural or manmade factors affecting its continued existence.

The "Draft Revised Recovery Plan for Nēnē or Hawaiian Goose" (USFWS 2004) indicates there is a high degree of threat to this species. USFWS also believe that this species has a high recovery potential because it is a taxonomically, or genetically "pure" species and as such does not interbreed with domestic geese and is generally not in conflict with regular human activities.

'Ope'ape'a (Hawaiian Hoary Bat)

The 'ope'ape'a, or Hawaiian hoary bat *(Lasiurus cinereus semotus),* is a Federal-listed endangered species that resides on the lower slopes of Haleakalā. A recovery plan was assigned to the 'ope'ape'a, which indicates it is a subspecies with moderate degree of threat and a high potential for recovery. The 'ope'ape'a is found on Hawai'i Island, Maui, O'ahu, Kaua'i and Moloka'i. On the island of Hawai'i, most observations have been from between sea level and 7,500 feet ASL, although individuals have been recorded at elevations as high as 13,000 feet. On Maui, the bat resides in the lowlands of the Haleakalā slopes. Even though several sightings have been reported near HO, it is unlikely that the bat is a resident of the area, due to the relatively cold summit temperatures and the lack of flying insects in the area, which is the preferred food source (AFRL 2005).

The nocturnal 'ope'ape'a is the only native terrestrial mammal known to occur in the Hawaiian archipelago, although other bat species have been found in sub-fossil remains. According to the USFWS, relatively little research has been conducted on this endemic Hawaiian bat and data regarding its habitat and population status are very limited. It is believed that bats typically depart the roost shortly before sunset and return before midnight, although this is based on a small number of observations (USFWS 1998). Bats are most often observed foraging in open areas, near the edges of native and non-native forests, or over both marine and fresh open water, and over lava flows. Roosting bats have been recorded from a variety of species including hala *(Pandanus tectorius),* kukui *(Aleurites moluccana),* pukiawe *(Styphelia tameiameaiae),* java plum *(Syzygium cumini),* ohia lehua *(Metrosideros polymorpha),* and *Eucalyptus* sp. Bats have been observed feeding from 3 to 492 feet above ground and water. Most of the available data suggests that this elusive bat roosts solitarily in the foliage among trees in forested areas.

Habitat requirements may vary seasonally and with reproductive condition, but this is not clear. Breeding probably occurs mostly between September and December, with young being born in May or June. Hawaiian hoary bats do not migrate off island, although seasonal elevation movements and island-wide migrations may occur. The availability of roosting sites is believed to be a major limitation in many bat species, but other threats to this subspecies include direct and indirect effects of pesticides, predation, alteration of prey availability (introduced insects), and roost disturbance (USFWS 1998). The recovery plan for the Hawaiian hoary bat (USFWS 1998) suggests the subspecies is experiencing a moderate degree of threat and has a high potential for recovery. Critical habitat has not been designated for this species.

2.2.4.3 Other Introduced Fauna

Introduced fauna that could be observed within the summit area include the chukar (*Alectoris chukar*), the feral goat (*Capra hircus*), the Polynesian rat (*Rattus exulans),* and the roof rat (*Rattus rattus*) (AFRL 2005). The Indian mongoose (*Herpestes auropunctatus*) is occasionally observed on the summit. These species are not included on Federal or State threatened or endangered lists.

2.2.4.4 Invertebrate Resources

The highest elevations of Haleakalā were once considered lifeless, but biologists have discovered a diverse fauna of resident insects and spiders. These arthropods inhabit unique natural habitats on the bare lava flows and cinder cones. Because they feed primarily on windblown organic materials, they form an aeolian ecosystem.

In Hawai'i, aeolian ecosystems are used to describe those that exist on non-weathered lava substrates mostly, but not exclusively, found at high elevations (Medeiros and Loope 1994). On Haleakalā an aeolian ecosystem extends up the summit from about the 7,550 feet elevation. It is characterized by relatively low precipitation, porous lava substrates that retain relatively little moisture, little plant cover, and high solar radiation. The dark, heat-absorbing cinder provides only slight protection from the extreme temperatures, and thermal regulation and moisture conservation are critical adaptations of arthropods occurring in this unusual habitat.

Due to the harsh environment, fewer insects are present at upper elevations on Haleakalā than are found in the warm, moist lowlands. However, an exceptional assemblage of insects and spiders make their home on the mountain's upper slopes. A survey and inventory of arthropod fauna was conducted for the 18.166 acres of HO in 2003 for the LRDP (Pacific Analytics 2003). In the 2003 study, several species were added to the previous inventory site records.

An additional survey including arthropod collection and analysis was conducted in 2005 at the Mees and Reber Circle sites for the proposed ATST Project (Pacific Analytics 2005). The arthropod species that were collected in this study were typical of what had been found during previous studies. Although the study was conducted during the winter months, no species were found that are locally unique to the site, nor were there any species found whose habitat is threatened by normal observatory operations.

In March 2007, another arthropod inventory was conducted for arthropod sampling at the sites considered in the proposed ATST Project (Pacific Analytics 2007). The goal was to detect additional species that may have been missed during previous samplings. This additional survey, including night sampling, covers a seasonal component not included in the two previous studies. This survey was conducted during the winter months. The results of the 2007 arthropod survey indicate there are no species of concern or legal constraints related to invertebrate resources in that project area. No invertebrate species listed as endangered, threatened, or that are currently proposed for listing under either Federal or State of Hawai'i endangered species statutes were found.

A June 2009 arthropod survey was conducted and extended to larger portions of the HO property (Pacific Analytics 2009). There were a number of additional species collected, including one endemic carabid beetle (*Mecyclothorax*), and two species of long horn beetles of the genus *Plagithmysus*. Carabid beetle populations appear to be impacted when alien predators are introduced to their habitats and their conservation is considered important. The two species of long-horn beetles are considered rare and are infrequently collected.

The diversity of the arthropod fauna at HO is somewhat less than what has been reported in adjacent, undisturbed habitat. This is expected, in that buildings, roads, parking areas, and walkways occupy 40 percent of the site. However, the undisturbed habitat on the site that was sampled has an arthropod fauna generally similar to what could be expected from other sites on the volcano with similar undisturbed habitat. Most of the arthropods collected during the 2003 study were largely associated with vegetation at the site. Observatory construction and operations have increased the suitability of some habitats for plants and increased vegetation has probably caused an increase in the populations of some native arthropod species.

2.2.4.5 Presence of Threatened or Endangered Species

The following is a summary of species listed as either threatened or endangered under the ESA, which have been observed in or near the boundaries of HO and described in the sections above.

1. 'ahinahina or Haleakalā silversword *(Argyroxiphium sandwicense* ssp. *macrocephalum),*

2. ‘ua‘u or Hawaiian Petrel *(Pterodoma phaeopygia sandwichnesis)*,
3. nēnē or Hawaiian goose *(Branta sandvicensis)*; and,
4. ‘ope‘ape‘a or Hawaiian hoary bat *(Lasiurus cinereus semotus)*.

2.2.5 Visual Resources

Approximately 1.7 million visitors annually (HALE 2006) are attracted to Haleakalā’s various lookouts and vantage points for its spectacular vistas. Looking down the slopes to the northwest, a majestic view of Maui’s isthmus and West Maui Mountains is afforded, while to the east are the richly colored scenes of the crater and, on minimal cloud-cover days, the slopes of Maunakea, Maunaloa and Hualālai.

On a cloudless night, Haleakalā also serves as an outstanding platform from which to view the heavens, facilitated by its position above the cloud inversion layer, the clean atmosphere, and the lack of degrading light sources. As indicated on the HALE signage on Pu‘u Ula‘ula, “Observatories were built near the highest point on Maui because the air offers the fourth best viewing conditions on the planet. Here above the clouds, the atmosphere is clear and dry, with minimal air and light pollution.” Because Haleakalā is blanketed with dark-hued cinders and ash and lacks vegetation, its appearance contrasts sharply with the lush tropical forests found at lower elevations.

Visibility of the HO facilities within HALE varies depending upon one’s vantage point within HALE. Several HO facilities are highly visible from Pu‘u Ula‘ula (Fig. 2-8). Some HO facilities are partially visible from the Park entrance station to about the first mile of the Park road, the Park Headquarters Visitor Center, portions of the Park road corridor (particularly the last one-third of the Park road closest to the summit), and near the summit from the Haleakalā Visitor Center (Pa Ka‘oao or White Hill).

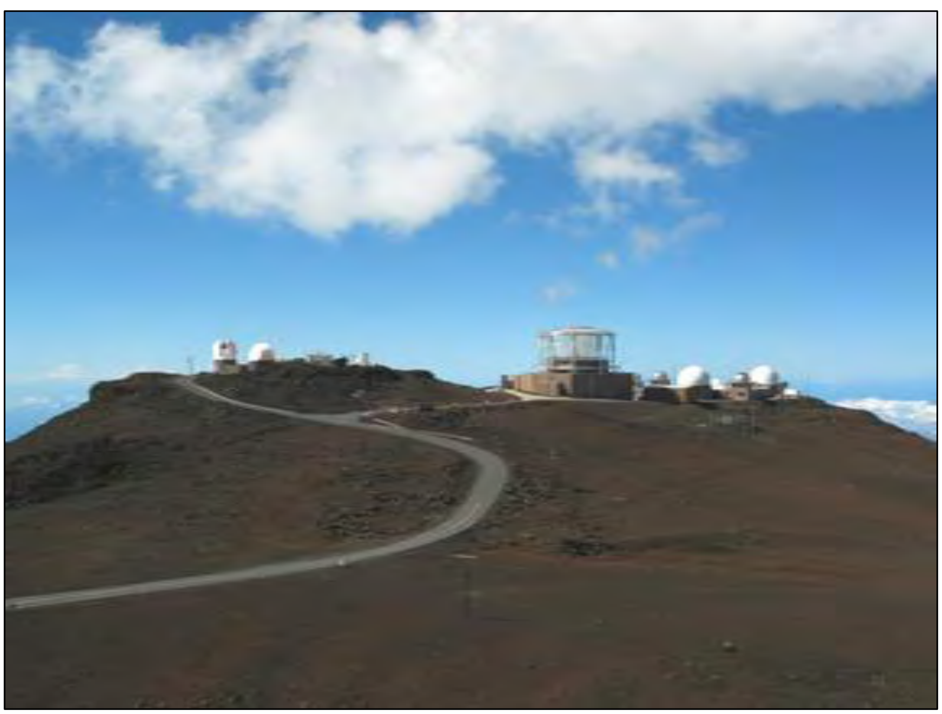


Figure 2-8. Current View of HO from Pu‘u Ula‘ula.

Overall, visibility of the HO facilities is highly variable depending on a combination of factors. These include locations from where one views them on the island, atmospheric conditions (e.g., dust content, humidity), time of day, cloud cover, and human activity (e.g., cane burning). For example, on a clear, low-humidity day, some of the facilities would be distinguishable as very small man-made objects from as far away as Maʻalaea Bay, which is a distance of approximately 17 linear miles. However, in humid and/or dusty conditions, they may not be visible at all from Maʻalaea Bay or even from locations in Upcountry Maui at half that distance.

Visibility of the summit area would be more likely in the early morning before the daytime cloud inversion layer builds up, and in the late afternoon after the inversion layer dissipates. When mid- and upper-level cloud cover is absent, a few of the existing structures at HO are, depending on one's vantage point, visible from miles away. Some of the facilities can also be seen from public viewpoints and highways that climb the slopes of the mountain (UH IfA 2005). The current facilities at HO that are closest to the northern boundary of the property are visible in various locations on Maui. The tallest of these, the metallic 117-foot tall U. S. Air Force Advanced Electro-optical System (AEOS) completed in 1994, is easily seen with the unaided eye from most areas within the Central Valley as well as from some windward and leeward communities, especially in morning and late afternoon hours. However, the two white 60-foot tall domes of the Maui Space Surveillance Site (MSSS), completed in 1965, are also visible in many of those same areas when the summit area is free of clouds. The colors of the domes of the HO facilities, which are either white or aluminized, make them more or less visible depending on Sun angle, cloud cover, and position of the viewer.

2.2.6 Water Resources

Haleakalā Observatories is within the Waiakoa and the Manawainui Gulch watersheds. As shown on Figure 2-9, the groundwater boundaries are the Kamaole and Makawao Aquifer Systems of the Central Aquifer Sector and the Lualailua and Nakula Aquifer Systems of the Kahikinui Aquifer Sector (AFRL 2005). The watersheds and aquifer systems make up the Region of Influence (ROI). A sector is a large region with hydro-geological similarities that primarily reflects broad hydrogeological features, and secondarily, geography. A system is an area within a sector showing hydro-geological continuity.

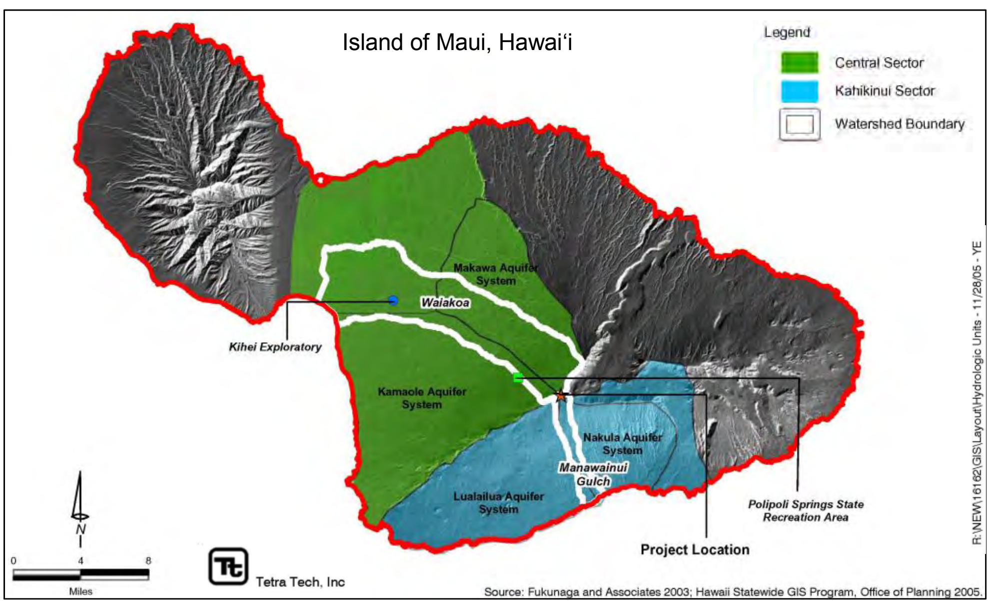


Figure 2-9. Hydrologic Features.

There is no source or supply of water at the summit area of Haleakalā. At various times during the year — particularly the winter months — rainwater is collected from building roofs, etc., and stored in water-catchment systems. To supplement this source, water is trucked to each user in certified tanks where it is stored on-site. Users maintain their own collection systems and storage tanks for potable and/or non-potable water, as well as their individual pumping and distribution systems.

Surface Water

The primary hydrologic unit for describing stream flow is the drainage basin, whereas the principal division for groundwater is the aquifer system. The boundaries of drainage basins and aquifer systems do not necessarily coincide because groundwater flow is governed by subsurface geological continuity rather than by topographic controls (Yuen and Associates 1990). Drainage basin boundaries for the Proposed Action are the Waiakoa and Manawainui Gulch watersheds, two of the 112 Maui Watershed Units totaling 466,437 acres.

Most streams on Haleakalā are intermittent because of the steep, permeable lava terrain. The nearest intermittent streams are approximately 1.9 miles down slope of the MSO facility. Perennial streams at low elevations originate from groundwater springs. An area of lower elevation within HO acts as a ponding and infiltration area for stormwater at Kolekole cinder cone (AFRL 2005).

There are no water bodies at the HO site. The Polipoli Springs water system is within the project aquifer system. The Polipoli Springs State Recreation Area water system is in the Kahikinui Forest Reserve, 9.7 miles upland from Kula on Waipoli Road. The water system is owned and operated by the State of Hawai‘i and managed by the Hawai‘i DLNR State Parks. The water system serves a park cabin and campground area. The non-potable source for the water system is an unnamed spring whose water flows through a 1.5-inch pipe to the campground area. The estimated water demand is 2,000 gallons daily (Fukunaga and Associates 2003).

Drainage Features

On the native slopes of Haleakalā, virtually all precipitation infiltrates the soil profile. Once in the soil, gravity continues to force the water down into the soil. When the water hits a less permeable layer, such as basalt, it flows in the path of least resistance. This means subsurface water flows, driven by gravity, down gradient along the surface of the basalt layer. The flow continues along the interface between the highly pervious cinder material and the basalt layer until it either resurfaces as a spring or stream or flows into a fissure in basalt, contributing to groundwater storage (UH IfA 2005a).

In March 2005, soil borings were taken at HO (Island Geotechnical). The results of the exploratory borings revealed that the soil profile generally consists of sands and gravels on top of a basalt layer. This means water can easily infiltrate the upper soils and then becoming significantly slowed when it reaches the basalt layer, which ranges from 5 to 21 feet (UH IfA 2005a).

All precipitation falling near the summit is infiltrated and flows subsurface toward the natural drainage courses, such as Manawainui Gulch. Loss of rainfall would be caused by evaporation in the soil column (UH IfA 2005a). Due to site topography, as well as a small collection of stormwater conveyance systems consisting of concrete channels and culverts, runoff generated within the HO site is controlled and conveyed via natural drainage paths to an infiltration basin at the western extremity of HO property. The runoff collection system was originally designed to maintain stormwater runoff on paved surfaces and consists of gutters and channels intended to prevent stormwater from discharging onto native soils adjacent to paved surfaces. Ten main stormwater flow paths have been identified at the HO site. Figure 2-10 illustrates the existing runoff patterns associated with HO.

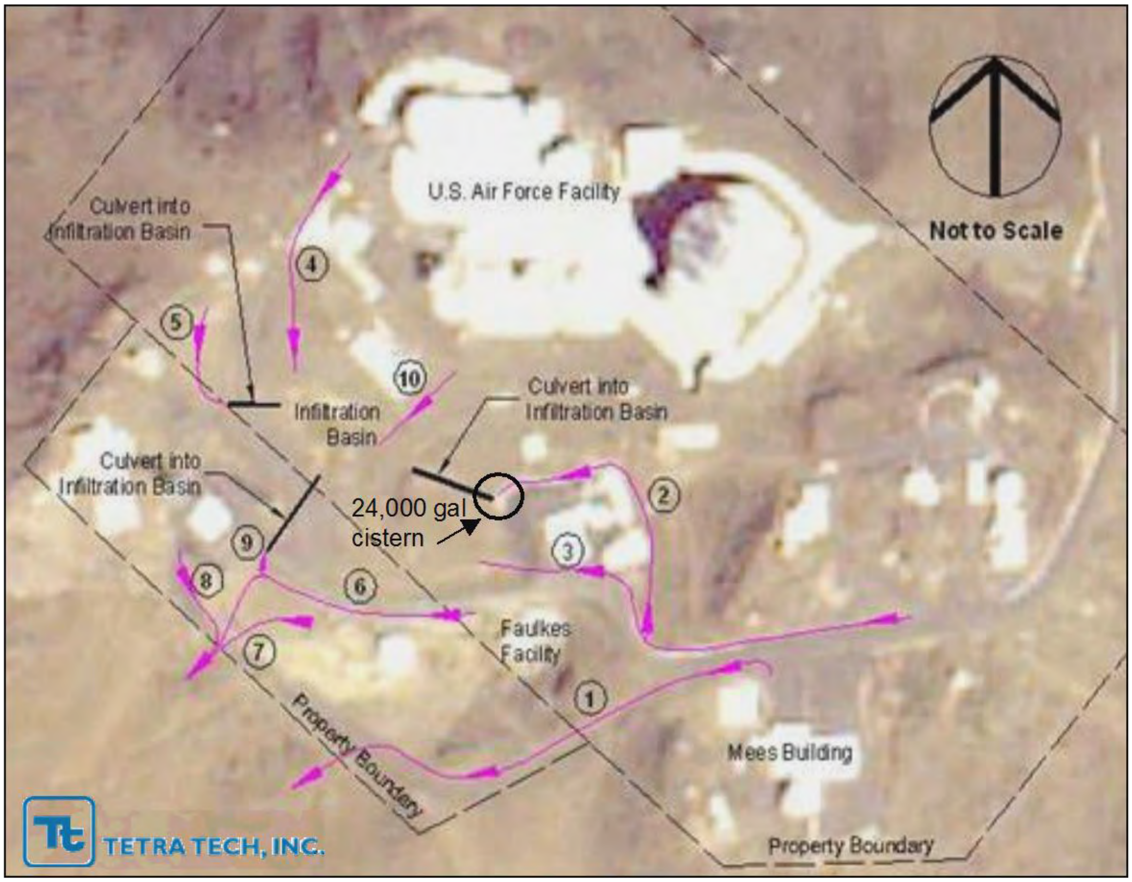


Figure 2-10. Existing Stormwater Runoff Patterns at HO.

The following is a brief description of each flow path in the HO drainage system:

Flow Path 1: Runoff from the parking lot associated with the MSO facility leaves the paved surface and flows down an abandoned road. The runoff then flows across a flat area before discharging along the southern slopes of the volcanic cone.

Flow Path 2: Runoff from the upper portion of the site drains onto the road and flows into a paved gutter. As designed, the runoff was to enter a concrete channel constructed behind the gathering of buildings and then be conveyed through a culvert into the infiltration basin.

Flow Path 3: Due to temporary blockage of Flow Path 2, concentrated runoff flow was redirected along the paved areas associated with the cluster of buildings. An asphalt berm was constructed to direct the runoff away from the buildings and toward the infiltration basin. Once the runoff discharges onto the native material, the flow dissipates into multiple undefined channels leading toward the infiltration basin.

Flow Path 4: Stormwater runoff from a small portion of the Air Force complex, along with runoff from the access road and concrete storage areas, flows along the edge of the road leading toward the infiltration basin.

Flow Path 5: The native soil in this Department of Energy (DOE)-controlled area appears to have been impacted from past activities such as parking and storage. Runoff from this area is conveyed to the infiltration basin through a culvert under the access road.

Flow Path 6: This concrete channel is designed to convey runoff from the road and from the Faulkes facility. The channel leads to two culverts under the access roads. The lower portion of the channel is a deposition location for sediment prior to where it enters the first culvert.

Flow Path 7: Runoff flows toward the south.

Flow Path 8: A portion of the runoff from the FAA facility flows toward the south and discharges over the slopes of the volcanic cone.

Flow Path 9: Runoff within the concrete channel was designed to flow into the infiltration basin through a series of two culverts that were placed under access roads

Flow Path 10: A large portion of the Air Force facility generates stormwater runoff that flows into the infiltration basin. The paved surfaces associated with the facility have curbs, which keep the runoff on paved surfaces until it enters the pipe network which discharges into the infiltration basin.

Runoff harvesting is also part of the drainage features at HO. Runoff from the MSO facility building is captured and stored in the adjacent 64,100 gallon cistern and is used for domestic water; and a 24,000 gallon cistern is associated with the Neutron Monitoring Station below the MSO facility. Some of the runoff from the UH facilities is captured by these cisterns before it reaches the infiltration basin.

Groundwater

As previously mentioned, the groundwater resources below HO are characterized as part of the Kamaole and Makawao systems of the Central sector and the Lualailua and Nakula systems of the Kahikinui sector. The characteristics of the groundwater of the Kamaole, Makawao, Lualailua, and Nakula systems are the same as those of the nearby systems and sectors. Two high-level, unconfined, perched aquifers exist, one on top of the other in dike compartments. Groundwater in both the upper and lower aquifers was identified as freshwater (containing less than 250 milligrams per liter of chloride) that has the potential for future use as drinking water, but it was not being used when the aquifer was classified. The upper aquifer is classified as being replaceable and highly vulnerable to contamination, while the lower dike aquifers are classified as being irreplaceable and moderately vulnerable to contamination. There are no drinking water wells within 11 miles of the summit (AFRL 2005).

The current MSO facility at HO uses a cesspool for handling wastewater and septic waste. This could affect subsurface water quality, but plans are in place to remove the cesspool, to remediate the site, and to construct a wastewater treatment facility in accordance with appropriate permits and procedures of Maui County and the State Department of Health. Generally speaking, cesspools do not treat wastewater, but rather remove solids and provide for anaerobic digestion of solids. The cesspool effluent is then filtered through the surrounding soil and groundwater providing for the general "treatment" of the (non-solids) wastewater. Pathogens and nutrients in potentially high concentrations (particularly nitrogen and phosphorous) are typically released from such systems, possibly degrading subsurface water quality and resulting in minor, adverse, and long-term impacts on groundwater within a discrete distance of the cesspool. Given the distance of approximately 11 miles to the nearest drinking water well, it is unlikely that continued operation of the cesspool would have an adverse affect on drinking water. If cesspool contaminants reach perched groundwater several thousand feet below HO, which then flows to surface water, then some adverse affects from cesspool operation could occur to human or ecological exposures to the surface water. Any dissolved recalcitrant contaminants (e.g. metals) discharged to the cesspool would be expected to migrate further from the cesspool, and/or remain present longer than less recalcitrant contaminants. Organic and inorganic solids would continue to accumulate in the cesspool, requiring ongoing periodic removal and off-site disposal.

2.3 Constraints (e.g., Flood plain, tsunami, volcanic, topography)

The location of HO is at an elevation of 10,023 feet ASL. Constraints known to occur at higher elevations in Hawaiʻi and other constraints in and around HO are addressed in the following sections.

2.3.1 Unauthorized Entry

Existing access to HO is via HALE (Fig. 2-11) and then through the entrance to the HO complex just past Puʻu ʻUla ʻUla. There is no general public access to HO and authorized entry only is posted on the sign (Fig. 2-12) located at the entrance to the facilities. Native Hawaiians are welcome to enter for cultural and traditional practices as indicated on the sign.

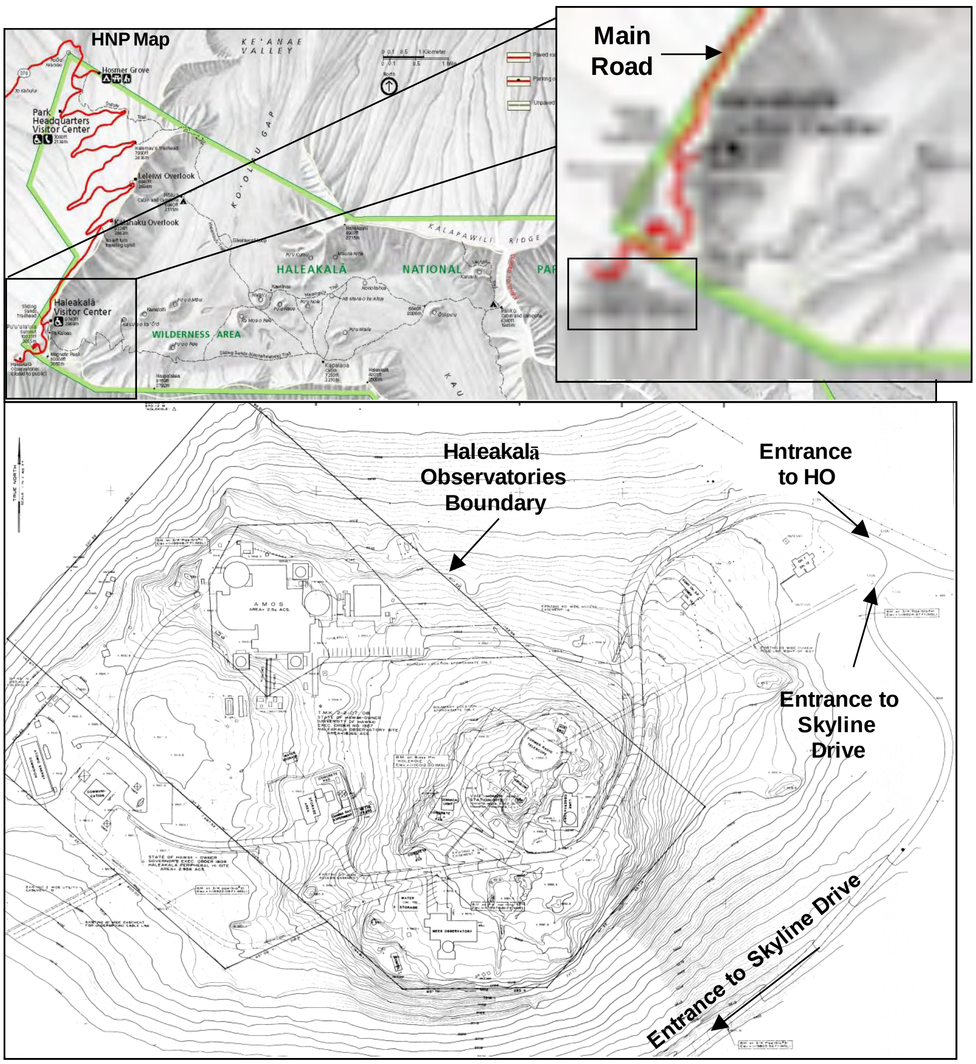


Figure 2-11. Existing Access to HO.

Figure 2-12. Sign at Entrance to HO.

2.3.2 Coastal Zone Management Area

To determine whether HO falls in the Coastal Zone Management area, reference was made to the County of Maui Planning Department map entitled *Island of Maui Showing Special Management Area* provided by the County of Maui GIS Program Office of the Managing Director, dated July 2002, and located in the Zoning and Administration Enforcement Division of the Planning Department, Wailuku, Maui. The map clearly indicates that the HO complex is not in the Coastal Zone Management area. The Kilohana Map M-11, State Land Use Designation Map (Conservation District topography map) located in the same County office verifies that the subject parcel is not within the Special Management Area (June 1995, State of Hawaiʻi Land Use Commission). In addition, prior projects at HO requiring Conservation District Use Permits were submitted for zoning evaluation by the County Department of Planning. No special zoning was identified for HO.

2.3.3 Existing Covenants, Easements, and Restrictions

Other than the use restrictions described in the Governor's EO 1987 "…Haleakala High Altitude Observatory Site purposes only". EO 1987 has no expiration date and there are no other existing covenants, easements, and restrictions, which would constrain the use of HO.

2.4 Existing Land Use

In 1961, the State Land Use Law, Act 187, which has been codified as HRS, Chapter 205, established the State LUC and granted the LUC the power to zone all lands in the State into three districts: Agriculture, Conservation, and Urban (the Rural District was added in 1963). Act 187 vested the DLNR with jurisdiction over the Conservation District, who then divided the Conservation District to subzones in order to better regulate land uses and activities therein. Since 1964, the BLNR has adopted and administered land use regulations for the Conservation District and made major changes to the regulations in 1978 and 1994.

The objective of the Conservation District is to conserve, protect, and preserve the important natural resources of the State through appropriate management and use in order to promote their long-term sustainability and the public health, safety, and welfare. The use of the HO property has been and will continue to be consistent with the purposes under which the HO area was set aside to UH by Governor's EO 1987. The HO area wholly within the Conservation District has been set aside for "…Haleakalā High Altitude Observatory Site "…Haleakalā High Altitude Observatory Site purposes only" (EO 1987). Many facilities conducting astronomical research and advanced space surveillance already exist within HO (see Fig. 1-4). In accordance with HAR 13-5, uses on HO property are consistent with Conservation District land use requirements, which require a Conservation District Use Application (CDUA) be filed with the DLNR and approved by the BLNR prior to the initiation of such uses.

The Conservation District has five subzones: Protective, Limited, Resource, General and Special. Omitting the Special Subzone, the four subzones are arranged in a hierarchy of environmental sensitivity, ranging from the most environmentally sensitive (Protective) to the least sensitive (General); the Special Subzone is applied in special cases specifically to allow a unique land use on a specific site.

These subzones define a set of "identified land uses" that may be allowed by discretionary permit. The OCCL can accept a permit application only for an identified land use listed under the particular subzone covering the subject property. Most of the identified land uses require a discretionary permit or some sort of approval from the DLNR or BLNR. Major permits are required for land uses that have the greatest potential impact. Major permits also require an EA or an Environmental Impact Statement (EIS), possibly a public hearing, and decision making by the BLNR. Minor permits are required for land uses that may have fewer impacts. Minor permits may be approved by the BLNR chairperson (and may not require a public hearing) or by the OCCL administrator (for certain minor uses within the Conservation District).

2.4.1 HO Facilities

This area of the Conservation District is set aside for "…Haleakalā High Altitude Observatory Site purposes only" (EO 1987). Presently, facilities located within HO (see Fig. 1-4) observe the Sun, provide a world-class telescope for education and research outreach to students all over the world, use lasers to measure the distance to satellites, track and catalogue man-made objects, track asteroids and other natural potential space threats to Earth, and obtain detailed images of spacecraft. It is a principal site for optical and infrared surveillance, inventory and tracking of space debris, and active laser illumination of objects launched into earth orbit, activities that are all crucial to the nation's space program.

Historical Uses

Over the past 45 years, HO has experienced managed growth of scientific research within its boundaries (UH IfA 2005). Table 2-2 lists a facility history for scientific events that occurred beginning in the spring of 1951 when Grote Reber conducted radio astronomy experiments at Haleakalā.

Table 2-2. Facility History at Haleakalā High Altitude Observatory Site.

Facility	Date	Event
"Reber Circle"	1951	Grote Reber, one of the pioneers of radio astronomy, experimented with radio interferometry using a large steel and wood truss antenna. Site abandoned approximately one year later.
none	1955	Dr. Walter R. Steiger of the UH Department of Physics conducted a site survey study near the summit of Haleakalā to determine the suitability of the location for a solar observatory.
none	1961	EO 1987 from Hawaii's Governor Quinn to UH set aside 18+ acres of land on the summit of Haleakalā to establish the HO site. UH responsible for managing and developing land.
Mees Solar Observatory (MSO)	1957 to 1976	In preparation for the International Geophysical Year, the UH was approached by Dr. C. Kenneth Mees of Eastman Kodak to locate and operate a Baker-Nunn satellite-tracking facility on Haleakalā. In 1964, the MSO facility was named for Dr. C. Kenneth Mees.
	1964 to Present	NSF initially funded, and in later years the National Aeronautics and Space Administration (NASA) funded, the C. E. Kenneth Mees Solar Observatory, which began astronomical studies of the solar corona and chromosphere.
Airglow and Zodiacal Light Programs	1962	Airglow and Zodiacal Light program initiated in the old blockhouse in which Grote Reber had once housed his equipment.
University of Hawai'i Institute for Astronomy (IfA)	1967	The University of Hawaiʻi founded the Institute for Astronomy. The IfA's primary research activities include the study of galaxies, cosmology, stars, planets, and the Sun. At this point in time, the IfA's assets included the Waiakoa Laboratory in Kula, the Mees Solar Observatory, and the newly constructed Zodiacal Light observatory at the summit.
Airglow Facility	1972	Airglow program equipment moved to new facility.
Lunar Ranging Experiment Observatory (LURE)	1974 to 2004	LURE, which was operated by IfA under contract to the NASA Goddard Space Flight Center, supported the NASA Space Geodesy and Altimetry Projects, has provided NASA with highly accurate measurements of the distance between LURE and satellites in orbit about the Earth, and which was involved in the NASA Crustal Dynamics Project. This project was replaced by the Pan-STARRS test-bed (PS1) in 2006.
Cosmic Ray Neutron Monitor Station	1991 To 2007	Cosmic Ray Neutron Monitor Station, the only such station in the world, operated in association with the University of Chicago Enrico Fermi Institute and the Faulkes Telescope Facility.
Multi-color Active Galactic Nuclei Monitor Project (MAGNUM)	1998 to 2008	The University of Tokyo, the National Astronomical Observatory of Japan, and the Australian National University have installed a 2-meter telescope in the 9-meter North dome of the LURE complex to support the MAGNUM Project.
Faulkes Telescope Facility (FTF)	2004	The Faulkes Telescope Facility at HO houses the largest educational outreach optical telescope in the world in support of astronomy research and education for grades K-college in Hawaiʻi and the United Kingdom. The FTF on Maui is known as the FTF North and its twin in Australia is known as FTF South.

Table 2-2. Facility History at Haleakalā High Altitude Observatory Site (cont.).

<table>
<tr><th>Facility</th><th>Date</th><th colspan="2">Event</th></tr>
<tr><td rowspan="8">Presently known as the Maui Space Surveillance Complex (MSSC)</td><td>1963</td><td colspan="2">Construction begins on the Advanced Research Projects Agency (ARPA) Maui Optical Station (AMOS), designated in 1977 as Maui Space Surveillance System (MSSS).</td></tr>
<tr><td>1965</td><td colspan="2">AMOS satellite tracking facility achieves first light.</td></tr>
<tr><td>1967</td><td colspan="2">ARPA designated MSSS site for Western Test Range midcourse observations, with the University of Michigan (UM) conducting operations and maintenance at the site. About 40 scientists, engineers and technicians worked for UM, about half traveling to the summit on any given day.</td></tr>
<tr><td>1969</td><td colspan="2">Routine missile tracking operations began under new contractors AVCO Everett Research Laboratory (AVCO) and Lockheed Missiles and Space Company. AVCO adds about 40 additional personnel for research and development, about half at the summit at any given time.</td></tr>
<tr><td>1977</td><td colspan="2">The twin 1.2-meter telescope at AMOS is dedicated to the Maui Optical Tracking and Identification Facility, known now as the MSSC, for daily routine satellite tracking operations. No new personnel were required.</td></tr>
<tr><td>1980</td><td colspan="2">Construction begins at MSSS on Ground-Based Electro-Optical Deep Space Surveillance System (GEODSS). Three new domes are built and approximately 10,000 square feet of office and laboratory space on the south side of MSSS.</td></tr>
<tr><td>1982</td><td colspan="2">The GEODSS, with three 1-meter telescopes becomes one of four operational sites in the world performing ground-based optical tracking of space objects. It employs about 15 operations and maintenance personnel.</td></tr>
<tr><td>1995 to Present</td><td colspan="2">One part of the MSSC is the MSSS, a facility combining operational satellite tracking facilities with a research and development facility. This also includes the Dept. of Defense's (DoD) largest telescope, the Advanced Electro-Optical System (AEOS). Over the years the Air Force operation has grown to include a total of approximately 125 civilian and military personnel housed at the Kihei Research and Technology Park and approximately 115 more based at MSSS.</td></tr>
<tr><td rowspan="2">Panoramic-Survey Telescope and Rapid Response System (Pan-STARRS) (LURE)</td><td>2006</td><td>PS1 South Dome</td><td rowspan="2">These facilities house a 1.8-meter wide-field optical imaging system equipped with a 1.44-billion pixel charge-coupled device camera. This unique combination of sensitivity and field-of-view will address a wide range of time-domain astronomy and astrophysical problems in the Solar System, Galaxy, and Universe.</td></tr>
<tr><td>2010</td><td>PS2 North Dome</td></tr>
</table>

Exiting Uses

Table 2-3 lists existing astronomical research facilities for advanced studies of astronomy, space surveillance, and atmospheric sciences at HO.

Table 2-3. Existing Facility Uses at Haleakalā High Altitude Observatory Site.

<table>
<tr><th>Facility</th><th colspan="2">Primary Function</th></tr>
<tr><td>U.S. Air Force Maui Space Surveillance Complex</td><td colspan="2">Presently, of the 18.166 acres, 4.5 acres are leased to the United States Army Corps of Engineers for the MSSC. MSSC conducts space surveillance and research activities for the DoD.</td></tr>
<tr><td>Ground-Based Electro-Optical Deep Space Surveillance System</td><td colspan="2">Another major part of the MSSC, which is one of four operational sites in the world performing ground-based optical tracking of space objects.</td></tr>
<tr><td>C. E. Kenneth Mees Solar Observatory</td><td colspan="2">Emphasizes studies of the solar corona and chromosphere.</td></tr>
<tr><td>Zodiacal Observatory</td><td colspan="2">Houses the test-bed Scatter-free Observatory for Limb Active Regions and Coronae (SOLAR-C) Telescope Facility, both supported by UH IfA.</td></tr>
<tr><td rowspan="2">Panoramic-Survey Telescope and Rapid Response System</td><td>PS1 South</td><td rowspan="2">These facilities house a 1.8-meter wide-field optical imaging system equipped with a 1.44-billion pixel charge-coupled device camera. This unique combination of sensitivity and field-of-view will address a wide range of time-domain astronomy and astrophysical problems in the Solar System, the Galaxy, and the Universe.</td></tr>
<tr><td>PS2 North</td></tr>
<tr><td>Faulkes Telescope Facility</td><td colspan="2">Faulkes houses the largest educational outreach optical telescope in the world in support of astronomy research and education for grades Kindergarten through college in Hawai‘i and the United Kingdom.</td></tr>
<tr><td>Haleakalā Amateur Astronomers</td><td colspan="2">The IfA dedicated a small building for the Haleakalā Amateur Astronomers to organize and host programs for professors and students at UH Maui College (UH MC), K-12, Boy Scout groups, Akamai students, community members and others to conduct astronomy observations at HO.</td></tr>
</table>

The first major UH facility at HO was the MSO facility. UH has operated the MSO facility since 1964. The scientific programs at the MSO facility emphasize studies of the solar corona and chromosphere. The LURE Observatory was operated by IfA under contract to NASA Goddard Space Flight Center from 1972 until 1993 conducting highly accurate measurements of the distance between LURE and the Moon, as well as measurements of the distance between LURE and satellites in orbit about the Earth. From 1993 to 2004 LURE was operated for the NASA Space Geodesy and Altimetry Projects, and provided NASA with highly accurate range measurements between LURE and satellites, and was involved in the NASA Crustal Dynamics Project.

The Pan-STARRS (PS1) telescope was dedicated on June 30, 2006, and is within the footprint of the former LURE Observatory South Dome. The testing of extremely high resolution camera imagery will lead to development and deployment of a small, economical, four-telescope system for observing the entire available sky several times each month to discover and characterize Earth-approaching objects, both “killer asteroids” and comets, that might pose a danger to our planet.

The Faulkes Telescope Facility (FTF) was originally built by the Dill Faulkes Educational Trust and became operational in 2004. Ownership of the FTF and the lease of the FTF site were assumed by the Las Cumbres Observatory Global Telescope Network, Inc. (LCOGT) in 2005 and continues to be a joint effort with IfA. The goal of this facility is to give students and teachers in Hawai‘i and the United Kingdom (UK) access to a research grade telescope. With its 2-meter diameter primary mirror, this telescope (along with its twin in Australia) is the largest telescope designated solely for educational use in the world. This 2-meter (6.6-foot) telescope is operated remotely over the Internet, without need for permanent on-site operational staff.

The IfA also leases 4.5 acres at HO for the Maui Space Surveillance Complex (MSSC), which supports optical and infrared experiments and observations carried out by the United States Air Force (USAF). The Air Force Research Laboratory (AFRL) is the host command with responsibility for the MSSC. One part of the MSSC is the Maui Space Surveillance System (MSSS), a state-of-the-art electro-optical facility combining operational satellite tracking facilities with a research and development facility. The MSSS houses the largest telescope in the Department of Defense (DoD) inventory, the 3.67-meter (12-foot) Advanced Electro-Optical System (AEOS), as well as several other telescopes ranging from 0.4 to 1.6 meters (1.3 to 5.2 feet).

Another major part of the MSSC is the Ground-Based Electro-Optical Deep Space Surveillance System (GEODSS), which is operated for the Air Force Space Command. The GEODSS at HO is one of four operational sites in the world performing ground-based optical tracking of space objects. The main telescope has a 102-centimeter (3.3-foot) aperture and a 2-degree field-of-view and is used primarily to search the deep sky for faint (+16 magnitude), slow-moving objects. The auxiliary telescope has a 38-centimeter (15-inch) aperture and 6-degree field-of-view, and does wide area searches of lower altitudes where objects travel at higher relative speeds. The telescopes are able to "see" objects 10,000 times dimmer than the human eye can detect.

The IfA has dedicated a small building for the Haleakalā Amateur Astronomers to organize and host programs for professors and students at UH MC, K-12, Boy Scout groups, Akamai students, community members and others to conduct astronomy observations at HO.

2.5 Existing Conservation District Use Permits

Table 2-4 lists Conservation District Use Permits (CDUPs) for HO that has been authorized by the DLNR.

Table 2-4. Conservation District Use Permits for HO.

CDUP No.	Date	Project
MA-386	1973	Lunar Ranging Experiment
MA-386	1998	Site Plan Approval LURE Accessory Trailers
98-164	1999	Accessory Structure Zodiacal Light Observatory/Exempt class
MA-3201	11/04/04	Pan-STARRS (PS1)
MA-3032B	04/29/04	Faulkes Telescope Facility
MA-0516	02/11/05	Site Plan Approval for ATST Geotechnical Soil Coring
MA2705	07/31/06	Advanced Electro-optical System
MA-3308	08/07/06	Transportable Laser Ranging System (TLRS)
MA-3032	11/12/08	Site Plan Approval for Faulkes Telescope Facility Site Improvements
MA-3308	08/06/09	Accessory Trailer TLRS/Exempt class

2.6 Access

Existing access to HO is via HALE (see Fig. 2-11) and then through the entrance to the HO complex just past Puʻu ʻUla ʻUla. There is no general public access to HO and authorized entry only is posted on the sign (see Fig. 2-12) located at the entrance to the facilities. Native Hawaiians are welcome to enter for cultural and traditional practices as indicated on the sign. An unimproved, access road known as Skyline Drive (see Fig. 2-11) originates 0.5 miles away from HO at the Saddle Area. It traverses the Southwest Rift Zone, ultimately leading to Polipoli State Park, which is located at 6,200 feet ASL in the Kula Forest Reserve (DLNR, Hawaiʻi State Parks). Its entire length is located on State land within the Forest Reserve. A locked gate near the Saddle Area restricts vehicle access to the road from the Haleakalā summit to only those holding DLNR permits. Hikers, hunters, and HALE personnel primarily use the unpaved road.

3.0 PROPOSED LAND USES ON PARCEL

3.1 Description of Proposed Land Use

The proposed land use would be located within the 18.166-acre HO site at the summit of Haleakalā, County of Maui, Hawaiʻi. Presently, facilities located within HO observe the Sun, provide a world-class telescope for education and research outreach to students all over the world, use lasers to measure the distance to satellites, track and catalogue man-made objects, track asteroids and other natural potential space threats to Earth, and obtain detailed images of spacecraft. It is a principal site for optical and infrared surveillance, inventory and tracking of space debris, and active laser illumination of objects launched into earth orbit, activities that are all crucial to the nation's space program. Table 2-3, above, lists existing astronomical research facilities for advanced studies of astronomy, space surveillance, and atmospheric sciences at HO.

Because observatory sites require clear fields-of-view and shielding from warm ventilated air from other facilities, which negatively impact atmospheric "seeing", there are only a limited number of viable sites within HO for observatories. Those are:

1. the areas where existing facilities reside (see Table 2-3), which would be eligible for replacement, renovation, or upgrades, and;

2. two other undeveloped sites that the surveys and studies suggest would not contribute significant impact to the existing facilities. As previously shown in Figure 1-4, these are:

   a. Reber Circle, which is suitable for 2- to 4-meter class telescopes. It is listed in the archaeology inventory as a former radio telescope site that qualifies by its age (1952) for recovery of data, but need not be preserved; and,

   b. The approximately 1.5-acre undeveloped site just to the northeast of the Mees Solar Observatory, which is suitable for 2- to 4-meter class telescopes.

Should the proposed ATST be constructed at the undeveloped site northeast of the Mees Solar Observatory, as selected in the ATST Record of Decision, the Reber Circle site would be the only undeveloped site eligible for new construction. In December of 2006, the United States Air Force published an Environmental Impact Statement Preparation Notice (EISPN) for the University of Hawaii's Pan-STARRS project. The EISPN identified the Reber Circle site as a potential alternative site for proposed Pan-STARRS PS4.

All these areas, including the undeveloped sites, were graded at least once (during the 1950-60 era). They are not host to endangered faunal or botanical species or archaeological, historic, or cultural resources, and they are positioned within HO to provide favorable telescope fields-of-view and atmospheric "seeing".

There is additional undeveloped acreage at HO, but it is not suitable for development for various reasons. Some locations would infringe on the fields-of-view for other observatories, or be disadvantageously positioned with respect to horizon obstruction or wind regime. Importantly, based on available surveys and maps, some of the HO areas probably should not be developed because they are unsuitably close to endangered species habitat or archaeological or cultural resources (see Figs. 2-3 and 2-6).

3.2 Site Plan

The HO site and adjacent properties are shown in Figure 1-3. The boundaries of HO shown in Figure 3-1 are on State Conservation Land, and other lands directly adjacent to HO occupied by the FAA and DOE are also under an EO. Existing facilities located within HO are shown on Figure 1-4.

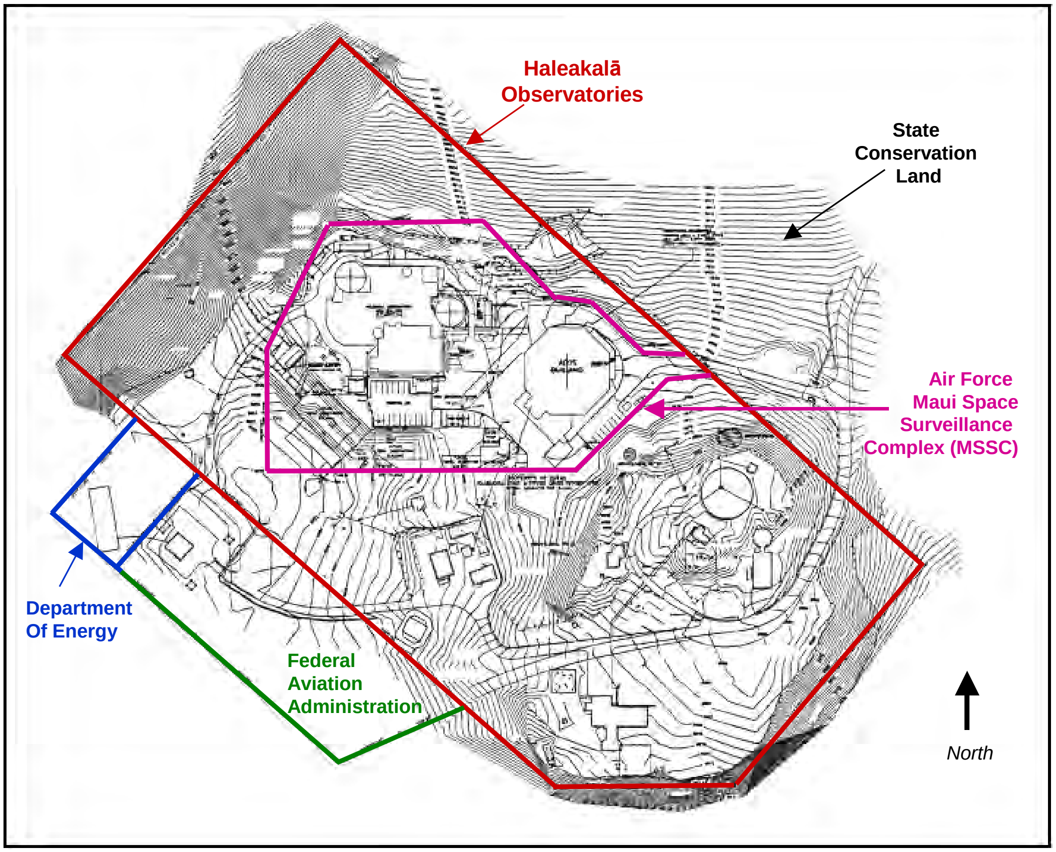


Figure 3-1. HO, Federal Aviation Administration, and Dept. of Energy Properties.

3.2.1 Site Plan Details

Over the past 45 years, HO has experienced managed growth of scientific research within its boundaries The first major UH facility at HO was the MSO facility. UH has operated the MSO facility since 1964. The scientific programs at the MSO facility emphasize studies of the solar corona and chromosphere. The LURE Observatory was operated by IfA under contract to the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center from 1972 until 1993, to conduct highly accurate measurements of the distance between LURE and the Moon as well as measurements of the distance between LURE and satellites in orbit about the Earth. From 1993 to 2004 LURE was operated for the NASA Space Geodesy and Altimetry Projects, providing NASA with highly accurate range measurements between LURE and satellites, and the facility was also involved in the NASA Crustal Dynamics Project.

The Pan-STARRS (PS1) telescope was dedicated on June 30, 2006, and is within the footprint of the former LURE Observatory South Dome. The testing of extremely high resolution camera imagery will lead to development and deployment of a small, economical, four-telescope system for observing the entire available sky several times each month to discover and characterize Earth-approaching objects, both “killer asteroids” and comets, that might pose a danger to our planet.

The Faulkes Telescope Facility was originally built by the Dill Faulkes Educational Trust and became operational in 2004. Ownership of the FTF and the lease of the FTF site were assumed by the LCOGT in 2005 and continues to be a joint effort with IfA. The goal of this facility is to give students and teachers in Hawaiʻi and the UK access to a research grade telescope. With its 2-meter diameter primary mirror, this telescope (along with its twin in Australia) is the largest telescope designated solely for educational use in the world. This 2-meter (6.6-foot) telescope is operated remotely over the Internet, without need for permanent on-site operational staff.

The IfA also leases a site for MSSC, which supports optical and infrared experiments and observations carried out by the United States Air Force (USAF). The Air Force Research Laboratory (AFRL) is the host command with responsibility for the MSSC. One part of the MSSC is the Maui Space Surveillance System (MSSS), a state-of-the-art electro-optical facility combining operational satellite tracking facilities with a research and development facility. The MSSS houses the largest telescope in the Department of Defense (DoD) inventory, the 3.67-meter (12-foot) Advanced Electro-Optical System (AEOS), as well as several other telescopes ranging from 0.4 to 1.6 meters (1.3 to 5.2 feet).

Another major part of the MSSC is the Ground-Based Electro-Optical Deep Space Surveillance System (GEODSS), which is operated for the Air Force Space Command. The GEODSS at HO is one of four operational sites in the world performing ground-based optical tracking of space objects. The main telescope has a 102-centimeter (3.3-foot) aperture and a 2-degree field-of-view and is used primarily to search the deep sky for faint (+16 magnitude), slow-moving objects. The auxiliary telescope has a 38-centimeter (15-inch) aperture and 6-degree field-of-view, and does wide area searches of lower altitudes where objects travel at higher relative speeds. The telescopes are able to “see” objects 10,000 times dimmer than the human eye can detect.

The IfA has dedicated a small building for the Haleakalā Amateur Astronomers to organize and host programs for professors and students at MCC, K-12, Boy Scout groups, Akamai students, community members and others to conduct astronomy observations at HO.

3.3 Justification of Identified Land Use

The proposed land use for HO qualifies as an identified use in the General Subzone and is consistent with the objectives of the General Subzone of the land (see Fig. 1-1). The objectives of the General Subzone (HAR 13-5-14) are to designate open space where specific conservation uses may not be defined, but where urban uses would be premature.

The proposed land use is to continue using HO for astronomical research facilities for advanced studies of astronomy and atmospheric sciences. HO is located within a General Subzone of the State of Hawaiʻi Conservation District that has been set aside for astronomical research (see Fig. 1-1). The objectives of the General Subzone (HAR Chapter 13-5-14) are to designate open space where specific conservation uses may not be defined, but where urban uses would be premature. Identified applicable land uses in the General Subzone, include R-3 Astronomy Facilities, (D-1) Astronomy facilities under an approved management plan (HAR 13-5-25).

3.4 Expected Timing

Ongoing research actions are expected to continue at HO. The scientific programs that UH will develop at HO and potential new facility developments that will keep UH in the forefront of astronomy can have long lead times to be defined, designed, proposed, and implemented. Therefore, the timing of proposed land use for future actions can be defined herein as those that would occur in the reasonably foreseeable future, which for the purposes of the MP are those that would occur during the next decade.

This MP is intended to serve the planning processes for programs and facility developments for an initial term of 10 years, subject to extension. However, the monitoring strategies and steps to ensure that historic preservation concerns are met were both prepared with considerable input from the greater Maui community, Native Hawaiian interests, the Haleakalā neighbors, such as the National Park Service, the U.S. Air Force, and other interested agencies and individuals. One intention for this document is to provide a vehicle for continuing consultations as HO evolves, such that the MP continues to provide the most effective management planning for the site.

3.5 Monitoring Strategies

This section of the MP provides comprehensive monitoring strategies for the proposed land uses at HO. The strategies are based on and expanded from the IfA LRDP.

3.5.1 History of Monitoring Strategies at HO

Beginning about 1980, numerous studies of environmental, cultural, historic, and economic resources, as well as potential impacts to those resources, have been undertaken at HO for various purposes. Construction of the Air Force GEODSS facility was preceded by an EA in 1980, an EA was completed for the AEOS telescope in 1994, another filed with the State of Hawaiʻi prior to construction of the Faulkes Telescope Facility in 2001, and a Federal EA was filed for the construction of the Mirror Coating Facility at AEOS in 2005. Other assessments have also been completed for environmental compliance management. While the resource descriptions in these assessments frequently encompassed the entire 18.166 acres of HO, many studies were focused on specific project areas within HO. Some of these assessments addressed cumulative impacts on the site that may have been incurred by new construction of those facilities since 1980.

For the LRDP, comprehensive, site-wide environmental, cultural, historic, and conceptual planning studies, surveys and inventories were completed during 2002 to 2003. The survey work was coordinated with the appropriate State agencies where required, and although much prior work was already available as reference resources, all of the qualified experts involved conducted their own field and laboratory work at the HO site to collect samples, examine in-situ materials, take measurements, etc. The surveys and studies established a baseline for conditions in support of the guidelines for the future physical and management planning that was described in the LRDP. Subsequent to publication of the LRDP, numerous additional studies and surveys were conducted. Some of these were for the proposed ATST Project, and others were conducted under IfA auspices to provide better information needed to effectively manage HO resources.

The surveys and studies include geological history, structure, and geochemistry, soils, distribution and inventory of botanical resources, avifaunal distribution and population analysis, description and inventory of invertebrate species, identification and significance of historic and cultural resources, assessment of traditional practices, inventory and analysis of archeological resources, analysis of visual resources, traffic volume, stormwater flows and effects, ground vibration, and analyses of potential economic impacts and benefits. In total, the many surveys, studies, inventories, and reports constitute a comprehensive picture of the conditions at HO. In addition, those elements of the dynamic environment at HO, such as invertebrate and botanical species and distribution, stormwater flows and effects, and economic conditions have been re-evaluated to represent the most recent conditions at HO.

During the nine-month public vetting period for the LRDP, IfA conducted consultations with Haleakalā neighbors about various aspects of future planning and conducted initial consultations with the Native Hawaiian community, and individuals in the Upcountry and broader Maui communities. Subsequently, those consultations have been much more extensive, as described below.

The evaluation of resources by specialists and consultations with interested agencies and individuals culminated in the management planning measures implemented through the LRDP published in January 2005. Subsequent consultations for projects such as the Air Force Mirror Coating Facility, Pan-STARRS PS1, and the proposed ATST Project have been useful in further developing the management policies, practices, and procedures implemented in this MP.

3.5.2 MP Monitoring Strategies

The MP is the governing document used for existing and future development at HO. It specifies the design and environmental criteria that would be followed when implementing development, and presents strategies for managing, monitoring, and protecting the various natural and cultural resources and uses of UH-controlled areas.

Management planning addresses:

1. specific requirements and guidelines for future astronomical facilities,
2. guidelines for U. S. Air Force facilities and other scientific activities at the site,
3. terms and conditions that will be applied to leases; and,
4. future planning for IfA in support of HO.

In preparing the general plans for managing HO, IfA has taken into account the data and recommendations from the experts who provided surveys and studies, such as archeological and cultural resources, traditional cultural practices at the summit and other areas, botanical and faunal resources, traffic, and others. Since the LRDP was completed, additional consultations for the Mirror Coating Facility and PS1 provided input to the general plans. In addition, the National Environmental Policy Act (NEPA) and National Historic Preservation Act (NHPA) processes for the proposed ATST Project provided the Maui community and its organizations, State and Federal agencies, and Native Hawaiian interests with opportunities to provide further input for more effective management of HO as a whole. The MP has incorporated many of these recommendations and the intent of the IfA is to continue to provide opportunities for the public to participate with comments and recommendations on these plans from all who wish to provide input.

The overall objective for management of astronomical facilities is to create a structure for sustainable, focused management of the resources and operations of HO, in order to protect historic/cultural resources (e.g. archaeology sites and traditional cultural practices) to protect natural resources, to protect and enhance education and research, and to provide the opportunity, where appropriate, for future expansion of the scope of activities at HO.

3.5.2.1 Cultural and Historic Preservation Management

Workers at HO need to be culturally sensitive to the fact that they are in a place considered sacred by Native Hawaiians. As the responsible agency, IfA is committed to preserving the cultural resources at the site and has sought advice from the Native Hawaiian community on Maui concerning the best methods to achieve that objective. One outcome of those consultations and the cultural resource evaluations of HO is that the IfA has implemented policies and practices for the long-term preservation of archeological and cultural resources within HO, based on recommendations in the Cultural Resources Assessment, the SCIA, and by interested agencies and the Maui community.

Compliance with the IfA policy for the preservation of cultural resources is defined as follows:

1. The sign at the entrance to HO states that Native Hawaiians are welcome to practice traditional cultural practices within the HO property.
2. All contractors and personnel working within HO must receive IfA-approved environmental and cultural training before beginning work. Training programs explain and amplify the requirements applicable to all construction projects within HO boundaries. For environmental protection and preservation of cultural and historic resources, the requirements to protect these resources are as follows:
    a. Any construction within HO requiring a permit from DLNR requires the consultation and monitoring of a Cultural Specialist. This person will be engaged at the earliest stages of the planning process, will monitor the construction process, and will consult with and advise the onsite project manager about any cultural or spiritual concerns. For the purposes of this section, a Cultural Specialist must be a Native Hawaiian, preferably a kupuna (elder) and a Kahu (clergyman, caretaker), and one who has personal knowledge of the spiritual and cultural significance and protocol of Haleakalā.
    b. All cultural and archeological sites and features identified in the Archeological Inventory Surveys should be protected and preserved in accordance with HAR, Title 13, Subtitle 13, Chapter 277, "Rules Governing Requirements for Archeological Site Preservation Development." Protection should include the establishment of clearly marked buffer zones and periodic monitoring by both the project archeologist and cultural specialist throughout any construction.
    c. All construction crewmembers shall attend IfA-approved "Sense of Place" training before working at projects within HO.
    d. All permanent employees working at HO shall attend IfA-approved "Sense of Place" training before working at HO facilities.

The requirements specified above apply to and must be included in all land use-related memoranda, facility use agreements, operating and site development agreements and leases.

Additionally, the area consisting of approximately 24,000 square feet (0.55 acre) and located southwest of the MSSC, as further identified and more particularly described as "Area A" (see Fig. 2-2), will be set aside in perpetuity for the sole reverent use of the Native Hawaiians for religious and cultural purposes, with the understanding that such use will not interfere with other uses and activities within HO.

A preservation plan for archeological sites contained within HO was submitted to IfA with the 2006 archeological inventory survey (Xamanek Researches 2006) to ensure protection of the archeological resources at the site. The preservation plan had been coordinated with and approved by the SHPD, in accordance with HAR 13 Subtitle 6, Chapter 148 (DLNR 2006). This preservation plan has been adopted by the IfA to protect those resources. In summary, a total of 11 sites are involved in the preservation plan. The majority of sites and features are wind shelters, along with two petroglyph images, a possible burial, and two possible ceremonial platforms. Passive as-is preservation has been adopted for these sites, except for the remnants of Reber Circle. There is no signage proposed for any of these sites, in order to prevent unwanted attention and potential adverse impacts.

3.5.3 Environmental Protection of Site Resources

During the course of more than 40 years of IfA management of the 18.166 acres of HO land near the summit, there has been a significant increase in awareness of the importance of effective, long-term stewardship of the land by the public and U.S. Government. On Maui, the Native Hawaiians who lived and cared for the land and its resources did so for many hundreds of years before the public or government became concerned about conservation, preservation, and restoration during the last century. Centuries before inception of any National or State environmental regulations or policies, the Native Hawaiian Aliʻi imposed strict constraints on use and preservation of resources.

IfA has listened to the recommendations by Native Hawaiians and experts working with IfA at the site; and, in the spirit of the ancient Hawaiians who closely protected the summit and in compliance with the regulatory requirements of the State of Hawaiʻi, IfA has developed principles and practices to which everyone must adhere when working at HO. These principles and practices were developed in cooperation with the DLNR, HALE, the U.S. Air Force, Boeing LTS, Maui Economic Development Board, and other Haleakalā neighbors and summit users.

3.5.3.1 IfA-Implemented Practices

The IfA has implemented a number of measures, as described in the MP. From year-to-year, these are subject to State funding availability, and include, but are not limited to:

1. Weeding of the HO property. (The entire 18.166 acres was weeded in July 2009 to remove weeds and to document likely areas of re-growth.)
2. Vector control for rodents.
3. Soil and erosion control, in accordance with the Storm Water Management Plan (SWMP) (UH IfA 2006), to maintain habitat ecosystem
4. Nighttime lighting restrictions to prevent misdirecting ʻuaʻu.
5. Frequent removal of trash to prevent predators from obtaining food sources.

3.5.3.2 Construction Practices

All subcontractor personnel working at HO must receive IfA-approved environmental training, prior to beginning work. This training program explains and amplifies the requirements imposed on all construction projects within HO boundaries. For environmental protection, the IfA requires the following to protect vital environmental resources:

1. HALE has experienced the introduction of destructive non-native species that compete with and have in some cases displaced native plants and insects. These introductions threaten the ecological balance at the summit area, and in cooperation with HALE, IfA requires any contractor to take the following measures at HO to prevent construction or repair activities from introducing new species:

a. Any equipment, supplies, and containers with construction materials that originate from elsewhere, i.e., the other islands or the mainland, must be checked for infestation by unwanted species by a qualified biologist or agricultural inspector prior to being transported to the summit. Specimens of non-native species found in these inspections are to be offered to the state for curation, and those not wanted are to be destroyed. All construction vehicles that will be used off paved surfaces must be steam cleaned/pressure washed before they travel or are transported through HALE. It shall be the sole responsibility of the contractor to coordinate inspections with the HALE Business and Revenue Program Specialist.

b. Importation of fill material to the site is prohibited, unless such fill (e.g., sand) is sterilized to remove seeds, larvae, insects, and other biota that could survive at HO and propagate. All material obtained from excavation is to remain on Haleakalā. Surplus excavated cinders, soil, etc., is to be offered to other agencies located at the summit or HALE.

c. Contractors are required to participate in IfA-approved pre-construction briefings to inform workers of the damage that can be done by unwanted introductions. Satisfactory fulfillment of this requirement can be evidenced by a signed certification from the contractor.

d. Parking of heavy equipment and storage of construction materials outside the immediate confines of HO property is prohibited.

e. Contractors are required to remove construction trash frequently, particularly materials that could serve as a food source that would increase the population of mice and rats that prey on native species.

2. The endangered ‘ua‘u, or Hawaiian Petrel, occupies burrows on the upper slopes of Haleakalā from February to October. The burrows are located in cinder and are active year after year, since the birds return to the site of their birth. Petrels are night flying birds, leaving their burrows to search for food during nesting and fledgling seasons. The burrows are located on the south slopes below the MSO facility and on the north slopes below the MSSC. The following requirements are in place to ensure that the ‘ua‘u habitat will be protected during any construction activities.

a. During the months when ‘ua‘u are present on Haleakalā, care must be exercised to ensure that ‘ua‘u will not be disturbed. Therefore, vibration and noise from heavy construction equipment or activities must not impact the normal life-cycle of resident birds. If heavy construction equipment will be necessary at the HO site, consultation with the USFWS, the Division of Forestry and Wildlife (DOFAW), and avifaunal experts will be required to determine feasibility and any applicable mitigation requirements.

Furthermore, it would be necessary to determine whether human receptors in areas outside of the HO would be affected by construction noise. There are areas within HO close enough to HALE visitors, such that they would be able to detect noise from construction of and traffic at the proposed facilities. These sounds could affect Native Hawaiian cultural practitioners and those engaged in recreation at nearby locations. The analyses provided by the contractor would be used to help develop methods to avoid, minimize, or mitigate such noise where it would or may affect endangered species, sensitive cultural practices, or the experience of visitors to the summit area outside of HO.

Such methods could include:

i. Workers at the site must be informed of vibration, noise, and lighting hazards to endangered species, that their activities are to be confined to the construction site to minimize risk to birds in adjacent areas, and that noise sources should be shielded where possible.

ii. Conducting all noise-emitting activities within strict day and time constraints, with work prohibited during sensitive nighttime periods.

iii. Reducing or substituting power operations/processes through use of proportionally sized and powered equipment necessary only for tasks at hand.

iv. Maintaining all powered mechanical equipment and machinery in good operating condition with proper intake and exhaust mufflers.

v. Turning off or shutting down equipment and machinery between active operations.

b. Contractors will be given current maps of locations of ‘ua‘u burrows to assist with ‘ua‘u conservation. HALE biologists are continuously finding and mapping new ‘ua‘u burrows and these maps are made available to IfA for planning purposes.

c. HO personnel will notify USFWS of any ‘ua‘u mortalities. Contractor personnel will report mortalities to IfA immediately.

d. Construction of fences will be avoided, to prevent ‘ua‘u mortality from collisions.

e. Lighting for construction hazards or night work must be approved by IfA prior to installation. All lighting must be shielded from above, so that night flying birds will not be disoriented by upward projecting lights that are mistaken for natural sources of navigable lighting.

f. To avoid attracting ‘ua‘u, contractors will make every effort not to use safety/security lighting the same color as stars. Other colors, such as red, blue, or orange or similar colors, should be considered.

3. HO is located in a cinder cone in a State Conservation District. Construction at the site requires special care to maintain the unpolluted environment.

a. No hazardous materials are to be released at the site. Substances such as surplus or used paint, oil, solvents, cleaning chemicals, etc., must be removed from the area and disposed of properly.

b. Accidental spills of any hazardous material during the execution of a contractor’s project at the site must be reported immediately to the IfA. Spill containment will be supervised by UH personnel at the site.

c. Spill remediation methods must be approved by the University of Hawaii’s Environmental Health and Safety Office (EHSO) prior to clean-up, and all costs incurred for clean-up will be paid by the contractor. In the event of a release, the contractor will be liable for any Federal- or State-imposed response action, costs, or penalties.

d. Washing and curing water used for aggregate processing, concrete curing, clean up, etc., cannot be released into the soil at the site. A recovery process is required by the contractor to capture wastewaters.

4. It is of particular importance to maintain a dust-free environment at HO. Telescope mirrors, lenses, and sensors can be quickly damaged by wind born dust. HO is located at 10,000 feet, and is often exposed to winds in excess of 30 miles per hour (mph). Before, during, and after winter storms,

winds can exceed 50 mph. The natural substrate at the site is a mixture of fine volcanic sand and cinders. Fugitive dust from the finer material can be released when the substrate is disturbed. Therefore:

a. Contractors must establish a written dust control plan that must be observed by all contractor personnel during the project. Contractors will adhere strictly to the requirement that dust be controlled at all times, including non-working hours, weekends, and holidays.

b. Dust control must be accomplished by equipment that the Contractor keeps on site and sprinkling or similar methods will be required to keep disturbed finer material from becoming airborne and must result in less than 10 pounds of fugitive dust released into the atmosphere per 24-hour period, as measured by standard collection methods.

c. No oil or chemical treating shall ever be used at the site for dust control.

d. Dust resulting from surface preparation of surfaces to be painted by sanding, power tools, or scraping and brushing shall be controlled by the Contractor by use of catchments and filtering systems/devices to prevent damage to the telescope mirrors, lenses and sensors.

e. Where practical, erect a designated on-site facility with wash racks to clean equipment and machinery before they are removed from construction zones.

f. Reduce vehicle emissions from construction projects and operations at HO by establishing worker carpools and shuttles to and from the job site, and mitigate construction equipment/machinery emissions by using proper emission-control technologies and standard exhaust filtration devices.

5. Construction or refurbishing of existing facilities will result in quantities of solid waste, and remnants of food and packaging that construction crews may bring for consumption at the site. Therefore:

a. Only materials that are not hazardous wastes can be managed as solid waste at the site.

b. Solid waste cannot be stockpiled or dumped at the site or on the slope below the HO facilities. Construction contractors must remove construction trash frequently, particularly food sources that could increase the population of mice and rats that prey on native species. Most construction waste should be removed in roll-off trash receptacles that are covered before transport.

c. Construction and demolition solid waste and debris must be secured such that strong winds cannot disperse materials. This is particularly important during weekends, holidays, and other non-working hours.

d. Construction and demolition solid waste and debris should be transported to the Maui Demolition and Construction Landfill in Maʻalaea.

e. No food is to be left on the ground or in HO solid waste storage areas. This is to prevent attraction of rats and other pests.

f. Non-hazardous trash and solid waste will be transported in covered refuse containers and disposed of off-site at Maui's licensed landfill.

3.5.4 Facility Design Criteria

The IfA requires that facilities designed for construction at HO follow certain guidelines. The IfA has learned from observatories constructed elsewhere and from its own long experience at HO how to incorporate design elements that minimize the impact of new facilities on others on or off the site, as well as how to minimize any environmental and cultural impacts. The intention is to be as appropriate as possible on a mountain summit that has rich natural, cultural, and spiritual resources. The design criteria are in keeping with that intention, as outlined in the LRDP:

1. Existing observatories require a clear line-of-sight in so far as is possible given the terrain. New facilities will not be permitted to obscure the observation function of existing facilities.

2. New facilities will not be permitted to impact the ʻuaʻu habitat. Facilities will not be fenced, in order to protect ʻuaʻu flyways, and they will not have unshielded lights or other attractants. (See Section 3.5.3.2-Construction Practices, Items 2e and f above regarding lighting.)

   During the nesting season (February to November) when birds are present on Haleakalā, care must be exercised to ensure that the birds will not be disturbed. Vibration and noise from heavy construction equipment or activities must not impact the normal life cycle of resident birds. If heavy construction equipment will be necessary at the site, consultation with IfA and avifaunal experts will be required to determine feasibility and any applicable mitigation requirements.

3. New facilities will not impact known archeological resources. The resources at HO have been mapped and those sites nearest to facilities have been delineated with single post and railing buffers. No construction will be permitted within 50 feet of any archeological site or feature.

4. Presently, all HO facilities are painted with a formula that was computer-matched to the most common color of the cinders and lava within HO boundaries. Whenever possible, new buildings will be painted to blend with their surroundings; however, solar observatories that operate during daylight hours will be allowed to be painted white, as it would otherwise be virtually impossible to keep the enclosure and building surfaces cool enough to prevent degradation of seeing conditions.

5. Construction design will consider sight planes to population centers of Maui. Where buildings can be oriented to limit visibility or be built partly underground, they will be. Where they cannot, every effort will be made not to use materials that draw attention from a distance, i.e., reflective surfaces, unusual shapes, incompatible colors.

6. Wherever possible, natural materials from the construction site will be used for building facings, walls, walkways, entryways, etc.

7. IfA will seek early and broad public comments and input concerning any new proposed construction at HO.

8. The summit area poses certain risks to people and structures from natural hazards, and since these are well understood, new projects will be required to be designed such that they would minimize such potential adverse impacts, including structural damage to facilities from wind, storm flooding, earth movement, ice and other natural events, vehicular accidents, and personnel requiring medical treatment for illness.

As HO is located in the Conservation District and not in an area defined in the Maui County General Plan as the Urban Region, Maui County Code 16.26.101.3 exempts HO from County regulation and restrictions.

3.6 Management and Monitoring Strategies Summary

The MP offers a physical plan and management structure that seeks to preserve a balance within HO, in which astronomy can continue to evolve as a premier ground-based viewing location bringing with it the associated economic benefits, while protecting cultural and environmental resources and values. Additionally, the MP provides resource protection and guidelines for future development that are intended to prevent desecration or over-development of the small HO property, as the IfA continues to lead the international scientific community toward a deeper understanding of the Universe in which we live.

3.7 Environmental Assessment

A Draft Environmental Assessment (DEA) for HO has been prepared in accordance with the State of Hawai‘i HRS Chapter 343 to ensure compliance with the policies and goals defined in this statute. The DEA evaluates the potential impacts on HO and relevant neighboring lands that may be incurred by implementation of this MP.

4.0 REPORTING SCHEDULE

4.1 Time Duration of Management Plan

The effective time duration for this MP shall be for an initial term of ten years, beginning December 1, 2010 and ending on November 30, 2020, and may be extended if appropriate.

4.2 Annual Reporting Schedule

The annual reporting schedule shall be June 30th of each year, or the end of each fiscal year for the State of Hawai‘i.

4.3 Annual Reporting Requirements

An annual report to the DLNR will be prepared that will include the status of compliance of permit conditions subsequent to approval of this MP, and the implementation of land uses pursuant to the approved management plan schedule.

5.0 REFERENCES

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6.0 ACRONYMS, ABBREVIATIONS, AND TERMINOLOGY

‘ahinahina	Haleakalā silversword
AEOS	Advanced Electro-optical System
AFRL	Air Force Research Laboratory
ahu	altar or shrine
ahupua‘a	land division, usually extending from the uplands to the sea
āina	land
AIS	alien invasive species
Ali‘i	Chief
Ali‘i nui	high chief
AMOS	ARPA Maui Optical Station
ARPA	Advanced Research Projects Agency
ASL	above sea level
ASTM	American Society for Testing and Materials
ATST	Advanced Technology Solar Telescope
AVCO	AVCO Everett Research Laboratory
BLNR	Board of Land and Natural Resources
CDUA	Conservation District Use Application
CDUP	Conservation District Use Permit
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CSH	Cultural Surveys Hawai‘i, Inc.
DEA	Draft Environmental Assessment
DEIS	Draft Environmental Impact Statement
DLNR	Dept. of Land and Natural Resources
DOD	Dept. of Defense
DOE	Dept. of Energy
DOFAW	Division of Forestry and Wildlife
DOI	U. S. Department of the Interior
e ala e	a chant used to greet ancestors, kupuna, and also greet the Sun as it rises
EA	Environmental Assessment
EHSO	Environmental Health and Safety Office
EIS	Environmental Impact Statement
EISPN	Environmental Impact Statement Preparation Notice
EO	Executive Order
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESA	Environmental Site Assessment
FAA	Federal Aviation Administration
FTF	Faulkes Telescope Facility
GEODSS	Ground-Based Electro-Optical Deep Space Surveillance System
hā	spiritual breath that comes from above
hālāwai	meeting

HALE	Haleakalā National Park
haole	foreigner
HAR	Hawai'i Administrative Rules
haumāna	students
Hinala'anui	name of the West-face ahu
ho'omahanahana	dedication or "warming" offering
ho'oponopono	to "make right
HO	Haleakalā High Altitude Observatory
HRS	Hawai'i Revised Statutes
IfA	Institute for Astronomy
Kahu	clergyman, caretaker
Kāhuna	Priest
Kāhuna Po'o	head priest
kapu	restricted to all but the highest ranking of Native Hawaiians
ko'a	ceremonial rock formations
kumu hula	hula teacher
kupuna	elder
LCOGT	Las Cumbres Observatory Global Telescope Network
LRDP	Long Range Development Plan
LUC	Land Use Commission
LURE	Lunar Ranging Experiment
ma'a	familiar or accustomed
MAGNUM	Multi-color Active Galactic Nuclei Monitor Project
Makahiki	Ancient festival beginning about the middle of October and lasting about four months, with sports and religious festivities and taboo on war
makana aloha	gift of friendship
mana	spirit
Māui	demi-god
Maui Nui a Kama	the greater Maui
Mele	song
mo'olelo	stories
Moku	districts
MP	Management Plan
mph	miles per hour
MSO	Mees Solar Observatory
MSSC	Maui Space Surveillance Complex
MSSS	Maui Space Surveillance Site
na poāo kāhuna	priest
NASA	National Aeronautics and Space Administration
nēnē	Hawaiian goose
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOI	Notice of Intent
NPS	National Park Service
NRHP	National Register of Historic Places

‘ope‘ape‘a	Hawaiian hoary bat
‘opihi	limpet
o‘mana‘o	remembrances or recollections
OCCL	Office of Conservation and Coastal Lands
OEQC	Office of Environmental Quality Control
oli	chants
OSDA	Operating and Site Development Agreement
Pā‘ele Kū Ai I Ka Moku	name of the East-facing ahu
Pa Ka‘oao	White Hill
Pan-STARRS	Panoramic-Survey Telescope and Rapid Response System
Pele	goddess of fire
piko	navel or umbilical cord
Poli‘ahu	the goddess of snow
Pu‘u Honua	sacred refuge or place of peace
RAP	remedial action plan
rCL	Cinder Land
ROI	Region of Influence
SAP	Sampling and Analysis Plan
SCIA	Supplemental Cultural Impact Assessment
SHPD	State Historic Preservation Division
SIHP	State Inventory of Historic Places
SWMP	Stormwater Management Plan
TCP	Traditional Cultural Property
TLRS	Transportable Laser Ranging System
‘u‘au	Hawaiian petrel
UH	University of Hawai‘i
UH MC	University of Hawai‘i Maui College
UK	United Kingdom
USAF	U.S. Air Force
USFWS	U.S. Fish & Wildlife Service
Wao Akua	place where gods and spirits walk

APPENDIX L

Draft Environmental Assessment Comment and Response Letters

PHONE (808) 594-1888

FAX (808) 594-1865

STATE OF HAWAI'I
OFFICE OF HAWAIIAN AFFAIRS
711 KAPI'OLANI BOULEVARD, SUITE 500
HONOLULU, HAWAI'I 96813

May 12, 2010

HRD10/4890

Charlie Fein, Ph.D
KC Environmental, Inc.
P.O. Box 1208
Makawao, HI 96768

Re: Draft Environmental Assessment for the Management Plan for the Haleakalā High Altitude Observatory Site; Maui, Waiakoa, Papa'anui, Makawao; TMK (2) 2-2-07-008

Aloha e Charlie Fein, Ph.D:

The Office of Hawaiian Affairs (OHA) is in receipt of your March 15, 2010 submission concerning the Draft Environmental Assessment (DEA) prepared pursuant to Chapter 343, HRS and Chapter 11-200, HAR. The DEA evaluates the Management Plan (MP) for activities proposed by the University of Hawai'i, Institute for Astronomy (IfA) at the Haleakalā High Altitude Observatory Site (HO). The instant proposal is defined as the implementation of the MP and does not involve any specific construction or undertaking. The purpose of the DEA is to provide information of likely environmental consequences of ongoing and future actions at HO in support of astronomical research. OHA apologizes for the delayed response and offers the following comments.

OHA appreciates each and every consulting opportunity that broadens understandings among stakeholders with respect to Hawai'i's vibrant culture, landscape, needs and traditions. As with an astronomer's quest to elucidate the properties of space, Native Hawaiians and practitioners in particular undergo similar processes of discovery on multiple levels. For many it begins with their genealogy and heritage, but for the more versed it spans the depths of ka 'āina, ke kai and ka Lani as the evolution of customary and traditional practices and spirituality becomes more widely understood. For instance, representatives of today's kilokilo po'epo'e—stargazers, seers, navigators—readily acknowledge the fruits of contemporary astronomy; however, an overwhelming segment of the Native Hawaiian community have expressed support for "No Action" when concerning any such business proposed for sacred Haleakalā.[1]

[1] The opinions expressed earlier by a majority of the Native Hawaiian community members during the Section 106 public review process indicates that such projects have very little possibility to properly mitigate negative impacts to cultural resources on Haleakalā. Therefore, OHA recommended "No Action" during the Section 106 consultation process for the proposed Advanced

While this dichotomy scantily lends to perceptions about an inability of Native Hawaiians to come to agreement, we interpret it more as a need for project supporters to better justify the necessity for such undertakings. OHA recognizes the great investment this DEA and all the appended supporting studies and reports required, and we appreciate the lengths to which the MP goes acknowledging Haleakalā's preeminence with the culturally-sensitive mitigative protocol proposed; however, nowhere does your submission explain how the MP can assist with OHA's mandate in advancing the interests of its beneficiaries.

We reference Article XII, Section 7, of the Constitution of the State of Hawai'i, which states:

> TRADITIONAL AND CUSTOMARY RIGHTS, Section 7. The State reaffirms and shall protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by ahupua'a tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778, subject to the right of the State to regulate such rights. [Add Const Con 1978 and election Nov 7, 1978.][2]

OHA has substantive obligations to protect the cultural and natural resources of Hawai'i for its beneficiaries, the people of this land, and for the public good. Hawai'i law mandates that OHA "[s]erve as the principal public agency in the State of Hawaii responsible for the performance, development, and coordination of programs and activities relating to native Hawaiians and Hawaiians; . . . and [t]o assess the policies and practices of other agencies impacting on native Hawaiians and Hawaiians, and conducting advocacy efforts for native Hawaiians and Hawaiians."[3]

Such guidance is taken neither lightly nor for granted. Of equal importance, indeed, is the role of companion agencies such as IfA:

> It shall be the duty and responsibility of all state departments and instrumentalities of state government providing services and programs which affect native Hawaiians and Hawaiians to actively work toward the goals of this chapter and to cooperate with and assist wherever possible the office of Hawaiian affairs. [L 1979, c 196, pt of Section 2][4]

By direction of such authority, OHA engages divergent strategies in protecting of the traditional cultural landscapes of Hawai'i. This includes, among other things, the preservation of

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Technology Solar Telescope, Haleakalā, Maui; TMK: 2-2-007:008. See Correspondence dated July 26, 2007, from Clyde W. Nāmu'o, OHA Administrator, to Charlie Fein, KC Environmental.

[2] This key provision, along with a body of pivotal caselaw (Kalipi and its progeny) beginning with the 1970's Native Hawaiian Renaissance, has reestablished and fine-tuned the utility of Hawaiian rights and practices into everyday business and life in modern times Hawai'i.

[3] HRS § 10-3.

[4] HRS § 10-1(b).

archeological and historic properties, the perpetuation of customary and traditional practices, and the enhancement of our beneficiaries' health and well-being.

As noted, OHA maintains fiduciary duties for a diverse constituency and must in turn hold accountable entities impacting the public trust *corpus*—ceded lands—and serving secular interests with astronomical research amidst Wao Akua—Haleakalā. There stands the pervasive instinct among Hawaiian people to mālama Wao Akua, the realm of the gods, and to guard against hana'ino or mistreatment of wahi pana by trespassers to these legendary places. Therefore, we strongly recommend HO/MP supporters to craft alternatives more suitable under the circumstances and to continue good faith consultations for reconciliation with OHA beneficiaries. Please continue to consult with OHA pursuant to Chapter 343, HRS, Chapter 11-200, HAR, and all applicable sections under constitution and law.

In closing, if during any phase significant cultural deposits or any human skeletal remains are encountered, we request that all work cease in the immediate vicinity and the State Historic Preservation Division (SHPD) and proper authorities be contacted pursuant to applicable law. OHA would also like to be advised of any substantive finds.

Thank you for the opportunity to comment. Should you have any questions, please contact Jerome Yasuhara at 594-0129 or by email at jeromey@oha.org.

'O wau iho nō, me ka ha'aha'a,

Clyde W. Nāmu'o
Chief Executive Officer

c: OHA Board of Trustees
OHA CRC (Maui)

KC Environmental, Inc.

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charlie@kcenv.com

October 25, 2010

Mr. Clyde W. Nāmuʻo
Chief Executive Officer
Office of Hawaiian Affairs
711 Kapiʻolani Boulevard, Suite 500
Honolulu, HI 96813

Subject: Draft Environmental Assessment for the Haleakalā High Altitude Observatory Site Maui, Hawaiʻi Management Plan
Tax Map Kay (2) 2-2-07-008
Waiakoa, Papaʻanui, Makawao, Maui, Hawaiʻi

Dear Mr. Nāmuʻo:

Thank you for your comment letter of May 12, 2010, regarding the Draft Environmental Assessment (EA) for the Haleakalā High Altitude Observatory Site Maui (HO), Hawaiʻi Management Plan (MP). The following responses are provided to your comments in the order they were presented in your letter.

1. *. . . [A]n overwhelming segment of the Native Hawaiian community have expressed support for "No Action" when concerning any such business proposed for sacred Haleakalā.*

Thank you for your comment, the Native Hawaiian community's support for "no action" is noted. This Environmental Assessment concerns the Management Plan and does not permit any construction. Any future construction will be subject to the requirements of state and federal law.

2. *OHA recognizes the great investment this DEA and all the appended supporting studies and reports required, and we appreciate the lengths to which the MP goes acknowledging Haleakalā's preeminence with the culturally-sensitive mitigative protocol proposed; however, nowhere does your submission explain how the MP can assist with OHA's mandate in advancing the interests of its beneficiaries.*

Thank you for your recognition of the investment and extent of the Draft EA. The MP is consistent with OHA's mandate to advance the interests of its beneficiaries by advancing those interests within HO. It describes management policy and procedures for a set aside designated exclusively for protection and encouragement of rights possessed by Native Hawaiians. Executive Order 1987, attached to the Final EA, established the boundaries of the HO and designated its use for astronomy. The MP sets aside approximately 24,000 square feet (0.55 acre) within the HO in perpetuity for the sole reverent use of the Native Hawaiians for religious and cultural purposes.

3. *We reference Article XII, Section 7, of the Constitution of the State of Hawaiʻi, which states:*

> *TRADITIONAL AND CUSTOMARY RIGHTS, Section 7. The State reaffirms and shall protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by ahupuaʻa tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778, subject to the right of the State to regulate such rights [citations and footnote omitted].*

OHA has substantive obligations to protect the cultural and natural resources of Hawai'i for its beneficiaries, the people of this land, and for the public good. Hawai'i law mandates that OHA "[s]erve as the principal public agency in the State of Hawaii responsible for the performance, development, and coordination of programs and activities relating to native Hawaiians and Hawaiians; . . . and [t]o assess the policies and practices of other agencies impacting on native Hawaiians and Hawaiians, and conducting advocacy efforts for native Hawaiians and Hawaiians."

In recognition of the cultural importance of Haleakalā and in the spirit of hoʻoponopono (to "make right"), UH contracted Native Hawaiian stonemasons in 2005 to erect a west-facing ahu (altar or shrine) within the HO set aside for the sole reverent use of Native Hawaiians for religious and cultural purposes A ho ʻomahanahana (dedication or "warming" offering) was held, at which time the ahu was named Hinala anui. In 2006, in the spirit of makana aloha (gift of friendship) for a proposed project, UH contracted the same Native Hawaiian stonemasons to erect an east-facing ahu near the UH Mees Solar Observatory (MSO) site. Upon its completion, a ho'omahanahana was held and the ahu was named Pāʻele Kū Ai I Ka Moku. These gifts were not required by State law, but are considered a reaffirmation of UH's responsibility to protect the interests of Native Hawaiians with respect to traditional rights.

4. *Of equal importance, indeed, is the role of companion agencies such as IfA:*

> *It shall be the duty and responsibility of all state departments and instrumentalities of state government providing services and programs which affect native Hawaiians and Hawaiians to actively work toward the goals of this chapter and to cooperate with and assist wherever possible the office of Hawaiian Affairs [citations and footnote omitted.*

The University acknowledges its obligations imposed by state law.

5. *As noted, OHA maintains fiduciary duties for a diverse consitutency and must in turn hold accountable entities impacting the public trust corpus – ceded lands – and serving secular interests with astronomical research amidst Wao Akua – Haleakalā. There stands the pervasive instinct among Hawaiian people to mālama Wao Akua, the realm of the gods, and to guard against hanaʻino or mistreatment of wahi pana by trespassers to these legendary places.*

Therefore we strongly recommend HO/MP supporters to craft alternatives more suitable under the circumstances and to continue good faith consultations for reconciliation with OHA beneficiaries.

The alternative to the MP required to be considered was No Action, which would mean not implementing the MP. This alternative was discussed in Section 1.3.1 of the Draft EA. IfA will continue consultations with OHA beneficiaries as required by law.

6. Please continue to consult with OHA pursuant to Chapter 343, HRS, Chapter 11-200 HAR, and all applicable sections under constitution and law.

Consultations with OHA will continue as required by law.

7. [I]f during any phase significant cultural deposits or any human skeletal remains are encountered, we request that all work cease in the immediate vicinity and the State Historic Preservation Division (SHPD) and proper authorities be contacted pursuant to applicable law. OHA would also like to be advised of any substantive finds.

IfA will comply with applicable law in the event that any significant cultural deposits or any human skeletal remains are encountered, and will advise OHA of any of any substantive finds.

Once again, thank you for providing comments on this matter. Should you have any further questions or comments, please contact me at (808) 573-1903.

Respectfully,

Dr. Charlie Fein
Vice President

LINDA LINGLE
GOVERNOR OF HAWAII

LAURA H. THIELEN
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

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AQUATIC RESOURCES
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COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

April 21, 2010

Charlie Fein, Ph.D
KC Environmental Inc
P.O. Box 1208
Makawao, HI 96768

LOG NO: 2010.1667
DOC NO: 1004NM48

Dear Dr. Fein:

Subject: **Chapter 6E-8 Historic Preservation Review – Draft EA for Haleakala High Altitude Observatory, Hawaii Management Plan and Appendices**
Pu'u Kolekole, Waiakoa District
Papaanui Ahupua'a, Makawao District, Island of Maui
TMK: (2) 2-2-007:008

Thank you for your submittal of the Draft Environmental Assessment for the Haleakala High Altitude Observatory Site Maui (HO), Hawaii Management Plan (MP) requesting our review.

Your Draft EA for HO MP addresses 11 historic properties; SIHP 50-50-11-5438-5443 with 30 component features, SIHP 50-50-11-2805-2808 with 21 features, and SIHP 50-50-11-4835 and 4836 with eight (8) features. The sites and component features consist of temporary habitations, wind shelters (C-shapes), two (2) small terrace features, petroglyphs and a remnant of a 1952 radio telescope facility foundation, and Feature D at SIHP 5440 is interpreted as a possible burial. In addition, Crater Historic District (SIHP 50-50-11/12-1739) which is listed on State Inventory of Historic Places, and also listed on the National Register of Historic Places]; Haleakala Crater Road, which is significant under Criterion "A" and Criterion "C" (development circa 1930s) for its historic bridges, box culverts and original culverts with mortared stone headwalls; and Haleakala summit area, which is eligible for listing on the National Register as a Traditional Cultural Property, should be included in your management plan/DEA.

As stated in the approved preservation plan dated July 10, 2006 (LOG NO: 2287/DOC NO 0606MK44), for 11 of the 14 historic properties, short-term and interim preservation measures include the removal of non-native plants (flush cutting) and erection of orange plastic construction fencing around these historic properties as a protection measure during any construction activities. All operating facilities within the Science City project area should maintain copies of the overall project map that clearly depict site locations.

Long term preservation will be accomplished via passive "as is" protection. No access trails are planned to the sites. Limited access provisions are provided, although no formal access is recommended. Buffers for each site and feature are depicted in the preservation plan and are acceptable. No landscaping is detailed, with the exception of the aforementioned removal of non-native plants. No signage is recommended. Two (2) *ahu* or ceremonial markers have been constructed with adjacent well-marked trails to the *ahu* for cultural practices.

If you have any questions regarding this review please call Nancy McMahon or Phyllis Cayan at 692-8015.

Sincerely,

Nancy A. McMahon

Nancy McMahon
Archaeology and Historic Preservation Manager

Cc: Mike Maberry, Assistant Director, UH Institute for Astronomy, 34 Ohi'a Ku Street, Pukalani, HI 96768
Sam Lemmo, OCCL, DLNR

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October 25, 2010

Nancy McMahon
Archaeology and Historic Preservation Manager
State of Hawaiʽi Dept. of Land and Natural Resources
State Historic Preservation Division
Post Office Box 621
Honolulu, HI 96809

Subject: Draft Environmental Assessment for the Haleakalā High Altitude Observatory Site
Maui, Hawaiʻi Management Plan
Tax Map Kay (2) 2-2-07-008
Waiakoa, Papaʻanui, Makawao, Maui, Hawaiʻi

Dear Ms. McMahon:

Thank you for your comment letter of April 21, 2010 regarding the Draft Environmental Assessment (EA) for the Haleakalā High Altitude Observatory Site Maui (HO), Hawaiʻi Management Plan (MP). The following response is provided to your comments.

1. *Your Draft EA for HO MP addresses II historic properties; SIHP 50-50-11-5438-5443 with 30 component features, SIHP 50-50-11-2805-2808 with 21 features, and SIHP 50-50-11-4835 and 4836 with eight (8) features. The sites and component features consist of temporary habitations, wind shelters (Cshapes), two (2) small terrace features, petroglyphs and a remnant of a 1952 radio telescope facility foundation, and Feature D at SIHP 5440 is interpreted as a possible burial. In addition, Crater Historic District (SIHP 50-50-11112-1739) which is listed on State Inventory of Historic Places, and also listed on the National Register of Historic Places]; Haleakala Crater Road, which is significant under Criterion "A" and Criterion "C" (development circa 1930s) for its historic bridges, box culverts and original culverts with mortared stone headwalls; and Haleakala summit area, which is eligible for listing on the National Register as a Traditional Cultural Property, should be included in your management plan/DEA.*

In response to your comment that Crater Historic District, Haleakala Crater Road and Haleakala summit area should be included in the Draft EA for the Management Plan, these areas are described in section 2.2.1 of the Draft EA.

2. *As stated in the approved preservation plan dated July 10,2006 (LOG NO: 2287IDOC NO 0606MK44), for II of the 14 historic properties, short-term and interim preservation measures include the removal of non-native plants (flush cutting) and erection of orange plastic construction fencing around these historic properties as a protection measure during any construction activities. All operating facilities within the Science City project area should maintain copies of the overall project map that clearly depict site locations.*

   Long term preservation will be accomplished via passive "as is" protection. No access trails are planned to the sites. Limited access provisions are provided, although no formal access is recommended. Buffers for each site and feature are depicted in the preservation plan and are acceptable. No landscaping is detailed, with the exception of the aforementioned removal of non-native plants. No signage is recommended. Two (2) ahu or ceremonial markers have been constructed with adjacent well-marked trails to the ahu for cultural practices.

The University of Hawaii Institute for Astronomy (IfA) will comply with both short and long-term preservation plans for the historic properties within HO. These measures were approved by DLNR in the July 10, 2006 (LOG NO: 2287/DOC NO 0606MK44) response to the Preservation Plan submitted by IfA for those historic features. LOG NO: 2287/DOC NO 0606MK44 is attached to this letter for reference.

Once again, thank you for providing comments on this matter. Should you have any further questions or comments, please contact me at (808) 573-1903.

Respectfully,

Dr. Charlie Fein
Vice President

Encl.

LINDA LINGLE
GOVERNOR OF HAWAII

PETER T. YOUNG
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

ROBERT K. MASUDA
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LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

July 10, 2006

Mr. Erik Fredericksen
Xamanek Researches
P.O. Box 880131
Pukalani, Hawai'i 96788

LOG NO: 2006.2287
DOC NO: 0606MK44
Archaeology

Dear Mr. Fredericksen:

SUBJECT: National Historic Preservation Act (NHPA) Section 106 Review – Preservation Plan for Eleven Sites at Science City, Haleakala Papaanui Ahupua'a, Makawao District, Island of Maui TMK: (2) 2-2-007: por. 008

Thank you for the opportunity to review and comment on this preservation plan received by our staff April 6, 2006 (Fredericksen 2006, *An Archaeological Preservation Plan for an 18.1 Acre Parcel Known as Science City, Haleakala Crater, Papaanui Ahupua'a, Makawao District, Maui Island [TMK 2-2-007: por 008])*...Xamanek Researches, LLC, ms. An archaeological inventory survey was conducted on the subject parcel in 2002, and was reviewed and accepted by our office (DOC NO: 0307MK03). We agreed that the distribution of these features and sites across the cultural landscape of Haleakala has the potential to yield additional information, and should be passively preserved. In addition, SHPD concurred with precautionary monitoring as mitigation during any construction that might occur in the subject area.

The preservation plan provides details for 11 historic properties; SIHP 50-50-11-5438-5443 with 30 component features, SIHP 50-50-11-2805-2808 with 21 features, and SIHP 50-50-11-4835 and 4836 with eight (8) features. The sites and component features consist of temporary habitations, wind shelters (C-shapes), two (2) small terrace features, petroglyphs and a remnant of a 1952 radio telescope facility foundation, and Feature D at SIHP 5440 is interpreted as a possible burial.

Short-term and interim preservation measures include the removal of non-native plants (flush cutting) and erection of orange plastic construction fencing as a protection measure during construction activities. All operating facilities within the Science City project area should maintain copies of the overall project map that clearly depict site locations.

Long term preservation will be accomplished via passive "as is" protection. No access trails are planned to the sites. Limited access provisions are provided, although no formal access is recommended. Buffers for each site and feature are depicted in the preservation plan and are acceptable. No landscaping is detailed, with the exception of the aforementioned removal of non-native plants. No signage is recommended. Two (2) *ahu* or ceremonial markers have been constructed under the direction of Mr. Charles Kauluwehi Maxwell, with adjacent well-marked trails to the *ahu*.

Mr. Erik Fredericksen
Page 2

The Preservation Plan is acceptable. The State Historic Preservation Division (SHPD) will await the submittal of a Burial Treatment/Preservation Plan for Feature D at SIHP 50-50-11-5440. If you have any questions, please contact Dr. Melissa Kirkendall of SHPD, Maui Section, at (808) 243-5169.

Aloha,

for Peter Young, Chair
State Historic Preservation Officer

MK:kf

c: Bert Ratte, DPWEM, County of Maui, FAX 270-7972
Michael Foley, Director, Dept. of Planning, FAX 270-7634
Maui Cultural Resources Commission, Dept. of Planning, 250 S. High Street, Wailuku, HI 96793

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April 21, 2010

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Laura Thielen
Board of Land and Natural Resources
P.O. Box 621
Honolulu HI 96809-0621

Dear officials,

RE: <u>DEA for Management Plan for the Haleakala High Altitude Observatory Site</u>

Thank you for the opportunity to comment on the Draft Environmental Assessment of the Management Plan for the Haleakala High Altitude Observatory Site. These comments are submitted on behalf of Kilakila `O Haleakalā. Kilakila `O Haleakalā requests a hard copy of the Final Environmental Assessment or the Environmental Impact Statement Preparation Notice as well as a CD version when it is completed.

Kilakila `O Haleakalā has three overarching concerns with the DEA, namely the assessment's: (1) lack of specificity both as to the proposed action as well as the proposed mitigation measures; (2) erroneous conclusion that an EIS is not required; and (3) misleading statements regarding similar applications combined with a failure to address related projects and their impacts on the area.

THE PROPOSED ACTION

The DEA does a poor job of explaining what is being proposed. In fact, the entire description of the action that is being proposed to be approved is one sentence:

Services made possible with major funding from the Office of Hawaiian Affairs.

> The Proposed Action includes monitoring and management strategies for implementing astronomical experiments, replacing HO facilities in support of long-term science investigations and as guidance for design and construction of new facilities.

No one reading this DEA can determine what is being approved – and therefore no one can determine what the impacts could be from this action. What specifically is being proposed that is not currently being done and that is over and above the no action alternative? What specifically is being proposed that will allow IFA to "effectively and efficiently manage HO for scientific purposes"?

Some details are buried at the very end of the very last appendix to this document. On page 40 of Appendix K, it states that the management plan

> specifies the design and environmental criteria that would be followed when implementing development, and presents strategies for managing, monitoring, and protecting the various natural and cultural resources and uses of UH-controlled areas.

Yet, nowhere in the plan are these specifics spelled out. Without appropriate detail, this document does not constitute a management plan; it is a plan full of sound and fury, signifying nothing.

The plan fails to specify how the natural and cultural resources of the area will be protected:

Monitoring. How often is monitoring supposed to take place? Who is going to do it? What will the monitoring consist of? What will be monitored?

Management. No substantive information regarding the management measures proposed on page 42 of Appendix K is provided. How often will weeding, vector control and trash removal take place? Who will be doing it? If the commitment is subject to funding, what kind of commitment is that?

Protection. The so-called management plan fails to address the protection of resources that need protection.

Construction fifty feet from an archaeological structure may protect its physical integrity, but a looming structure within fifty feet of a significant archaeological site does not protect its archaeological integrity. Protecting the context of an archaeological feature is critical to the protection of the site.

Why is there no discussion in the management plan about protecting traditional cultural practices?

Why is it that the plan states in absolute terms that "New facilities will not be permitted to obscure the observation function of existing facilities," but uses far less categorical language when it comes to obscuring scenic views:

> Whenever possible, new buildings will be painted to blend with their surroundings; however, solar observatories that operate during daylight hours will be allowed to be painted white, as it would otherwise be virtually impossible to keep the enclosure and building surfaces cool enough to prevent degradation of seeing conditions.
> 5. Construction design will consider sight planes to population centers of Maui. Where buildings can be oriented to limit visibility or be built partly underground, they will be. Where they cannot, every effort will be made not to use materials that draw attention from a distance, i.e., reflective surfaces, unusual shapes, incompatible colors.

When will the IFA take measures to protect subsurface water quality (p. 2-34)?

> The current MSO facility at HO uses a cesspool for handling wastewater and septic waste. This could affect subsurface water quality, but plans are in place to remove the cesspool, to remediate the site, and to construct a wastewater treatment facility in accordance with appropriate permits and procedures of Maui County and the State Department of Health.

Given the importance of protecting sub-surface water quality ("The upper aquifer is classified as being replaceable and highly vulnerable to contamination" p 2-34), why does the management plan not call for centralized and better management of wastewater (p. 2-35)?

Why does the plan not include any effort to protect the natural quiet of the area?

Without such details, the DEA cannot provide an accurate assessment of the management plan and the projects that fall under this plan.

<u>EIS REQUIRED</u>

Because the IFA is simultaneously seeking a Conservation District Use Application (CDUA) for the Advanced Technology Solar Telescope (ATST), this DEA <u>must</u> consider the impacts of this related action. *See*, HAR § 11-200-7 and 11-200-2 ("cumulative impact"). There is no doubt that this management plan is inextricably linked to IFA's plans to build the ATST facility on Haleakala. For example:

- the DEA refers to the ATST on page 46 of appendix K ("solar observatories that operate during daylight hours will be allowed to be painted white, as it would otherwise be virtually impossible to keep the enclosure and building surfaces cool enough to prevent degradation of seeing conditions");

- the DEA refers to its purpose in getting the ATST approved on page 2-3 ("HAR 13-5-25 identifies land uses for HO as General Subzone, which is applicable for astronomy facilities (HAR 13-5-25, R-3) under an approved management plan (HAR 13-5-25, D-1");
- the DEA refers to the ATST plans "to remove the cesspool, to remediate the site, and to construct a wastewater treatment facility in accordance with appropriate permits and procedures of Maui County and the State Department of Health." (p. 2-34) This plan is specifically discussed on page 4-115 of the ATST FEIS.
- the DEA refers to the ATST by name on pages 3-18, 4-2, 4-3 and 4-7.

The discussion of cumulative impacts sometimes includes the ATST, but frequently fails to mention it. The DEA strangely observes:

> While a separate analysis of land use resources for the proposed ATST Project describes specific impacts, it can be stated that this proposed project would be an incremental addition of approximately 4 percent to the use of Conservation District lands within HO and only a fraction of a percent of the total resource subzone. In consideration of these factors, if construction is approved, the proposed ATST Project is anticipated to result in less than significant cumulative impacts on land use.

How can the IFA state this with any credibility when its own CDUA for the ATST includes the FEIS, which itself concludes: "Construction and operation of the proposed ATST Project . . . would result in major, adverse, short- and long-term direct impacts on traditional and cultural resources within the ROI.. . . Mitigation measures would . . . not reduce the impact intensity: impacts would remain major, adverse, long-term and direct." (p. ES-36). Or, when it states, "[I]n views from within two miles of the proposed ATST project site . . .[the project] would result in moderate, adverse and long-term impacts to visual resources. No mitigation would adequately reduce this impact." (p ES-39). The FEIS for the ATST concedes that the project will have significant impacts – including major adverse long-term impacts.

Because the activities described in the DEA are inextricably linked to the ATST and because the cumulative impacts of the projects are significant, there can be no doubt that an EIS is required.

OTHER ISSUES

The DEA's citation to other CDUA's for rejected projects is misleading. For example, page 2-2 –2-3 states: "During the past few years, the DLNR's Office of Conservation and Coastal Lands (OCCL) has administered Conservation District Use Applications (CDUAs) for: open ocean aquaculture projects, telescopes on top of Haleakalā and Mauna Kea, major powerline projects on scenic ridges, telecommunication facility projects, single family residences, Parks; and

Commercial Forest projects." The DEA uses the vague term "administered." Yes, OCCL has received applications for various projects. But the Board of Land and Natural Resources, in fact, rejected the application (the only application) for a major powerline project on a scenic ridge. It rejected the koa logging project proposed on Hawai`i Island. And the court overturned the BLNR's approval of a CDUP for a telescope on Mauna Kea. The DEA, therefore, misleads by suggesting that, because these applications have been "administered", there is nothing unusual about the proposed use.

Is this management plan being submitted to the Board of Land of Natural Resources for approval?

On page 2-3, the DEA puts two facts together to create a misleading impression. It may in fact be true that the parcel of land at issue was set aside for astronomical research. It is true that the Haleakala High Altitude Observatories are in the conservation district. It is not accurate, however, to imply that (1) the purpose of the conservation district, or this part of the conservation district, is for astronomy or (2) this area has been designated for astronomical research pursuant to Act 187 or the conservation district rules. The executive order setting land aside has nothing to do with the regulatory restrictions on uses in the conservation district.

The DEA states: "Since the rules were issued in 1994, all new facilities within HO that involve conservation land use (excluding interior renovation and reuse of lands) have required a CDUP." What is the basis for the assumption that "reuse of lands" does not require a CDUP? Does the IFA believe that by obtaining approval of this plan, the "reuse" of an observatory facility will not require a new CDUP?

The applicant failed to discuss other EAs and EISes for projects in the area. These documents can demonstrate whether: (a) the IFA and other users of the area accurately predicted impacts; (b) the IFA and other users of the area followed through on prior promises; and (c) proposed mitigation was effective. This analysis is necessary to perform a credible analysis of the effectiveness of the management plan.

In 1994, the IFA stated:

> The proposed facility, approximately 120 feet above grade, would be the largest structure on the upper portions of Haleakala. However, it would be generally consistent with the existing structures, and it would not greatly alter the general appearance of the complex as seen from a distance. The proposed facilities would be clearly visible from the Pakaoao Visitor Center and Red Hill Overlook, where the height and mass of the proposed telescope dome enclosure would make it a strong visual element under certain conditions. The visual impact of the telescope dome would be mitigated by its reflective surface. This type of surface tends to take on the color of the sky, and does not stand out strongly. In addition, its proximity to the existing observatory structures that are readily recognizable as telescope housings would indicate the scientific purpose of the entire complex.

Despite IFA's assurances, the Air Force's large AECOS facility (a) is not consistent with the existing structures; (b) greatly altered the appearance of the complex; (c) was not mitigated by its reflective surface; and (d) stands out strongly. Why is there no discussion in the management plan to correct past errors to reduce the visual blight of the facilities on Haleakalā?

What authority would the "cultural specialist" have? Will s/he merely be able to provide advice that does not have to be followed?

CONCLUSION

The DEA is flawed in its conclusion that no EIS is required when (1) the Management Plan lacks the necessary details to provide an accurate assessment of the impacts, and (2) the FEIS for the ATST concedes that the project will have significant impacts. The concerns outlined above must be addressed and an EIS must be prepared.

Sincerely,

David Kimo Frankel
Camille K. Kalama
Staff Attorneys

KC Environmental, Inc.

P.O. Box 1208
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October 25, 2010

Mr. David Kimo Frankel
Ms. Camille K. Kalama
Staff Attorneys
Native Hawaiian Legal Corporation
1164 Bishop Street, Suite 1205
Honolulu, HI 96813

Subject: Draft Environmental Assessment for the Haleakalā High Altitude Observatory Site
Maui, Hawai'i Management Plan
Tax Map Kay (2) 2-2-07-008
Waiakoa, Papa'anui, Makawao, Maui, Hawai'i

Dear Mr. Frankel and Ms. Kalama:

Thank you for your comment letter of April 21, 2010 regarding the Draft Environmental Assessment (EA) for the Haleakalā High Altitude Observatory Site Maui (HO), Hawai'i Management Plan (MP). The following responses are provided to your comments in the order they were presented in your letter.

1. *The DEA does a poor job of explaining what is being proposed. In fact, the entire description of the action that is being proposed to be approved is one sentence:*

> *The Proposed Action includes monitoring and management strategies for implementing astronomical experiments, replacing HO facilities in support of long-term science investigations and as guidance for design and construction of new facilities.*

No one reading this DEA can determine what is being approved - and therefore no one can determine what the impacts could be from this action. What specifically is being proposed that is not currently being done and that is over and above the no action alternative? What specifically is being proposed that will allow IFA to "effectively and efficiently manage HO for scientific purposes"?

The Draft EA describes in detail what is being proposed. A copy of the Management Plan itself is attached to the Draft EA as Appendix K, so there is no ambiguity about what is being proposed. The proposed action is further described in the first paragraph of the Executive Summary which provides:

> This Draft Environmental Assessment (DEA) evaluates a Management Plan (MP) for appropriate and reasonable activities that would be undertaken by the University of Hawaiʻi Institute for Astronomy (IfA) at the Haleakalā High Altitude Observatory Site (HO) in support of ongoing and future astronomical research activities, including those that would require a Conservation District Use Permit (CDUP), in accordance with Hawaiʻi Administrative Rules (HAR) 13-5-39. For this EA, the Proposed Action is defined as the implementation of a MP, which would regulate land use in the Conservation District for the purpose of conserving, protecting, and preserving the important natural resources of the State through appropriate management and use to promote their long term sustainability and the public health, safety, and welfare.

2. *Some details are buried at the very end of the very last appendix to this document. On page 40 of Appendix K, it states that the management plan*

> *specifies the design and environmental criteria that would be followed when implementing development, and presents strategies for managing, monitoring, and protecting the various natural and cultural resources and uses of UH-controlled areas.*

Yet, nowhere in the plan are these specifics spelled out. Without appropriate detail, this document does not constitute a management plan; it is a plan full of sound and fury, signifying nothing.

Monitoring strategies are described in the Section 3.5.2 of the Management Plan which is attached as Appendix K to the Draft EA. Section 3.5.2-MP Monitoring Strategies provides that the specifics for "…design and environmental criteria that would be followed when implementing development, and presents strategies for managing, monitoring, and protecting the various natural and cultural resources and uses . . . " can be found in the following sections:

3.5.2.1-Cultural and Historic Preservation Management
3.5.3-Environmental Protection of Site Resources
3.5.3.1-IfA-Implemented Practices
3.5.3.2-Construction Practices
3.5.4-Facility Design Criteria

3. The plan fails to specify how the natural and cultural resources o f the area will be protected:

Monitoring. *How often is monitoring supposed to take place? Who is going to do it? What will the monitoring consist of? What will be monitored?*

The monitoring strategies for natural and cultural resources are described in section 3.5.2 of the Management Plan. That section provides,

> In preparing the general plans for managing HO, IfA has taken into account the data and recommendations from the experts who provided surveys and studies, such as archeological and cultural resources, traditional cultural practices at the summit and other areas, botanical and faunal resources, traffic, and others.

New projects at HO are required by the MP to protect natural and cultural resources through monitoring protocols. For example, the ATST Project is required to monitor natural and cultural resources at HO using qualified expertise to protect archaeological, cultural, botanical, faunal and other environmental resources. The specifics of the monitoring programs are described in the ATST FEIS, the Habitat Conservation Plan for Construction of the Advanced Technology Solar Telescope at the Haleakalā High Altitude Observatory Site, Maui, Hawaiʻi , and the Incidental Take License and Proposed Conservation Measures Associated with the Advanced Technology Solar Telescope.

4. ***Management.*** *No substantive information regarding the management measures proposed on page 42 of Appendix K is provided.*

Page 42 of Appendix K (The Management Plan) is a detailed description of the compliance requirements for preservation of cultural practices within the HO property. Specific and substantial policies and practices for both permanent employees and outside contractors are described to ensure the long-term preservation of archeological and cultural resources. These policies and practices were developed in consultation with the Native Hawaiian community, the National Park Service, the State Historic Preservation Division of DLNR, and other agencies, and, through recommendations from two Cultural Resource Assessments.

5. *How often will weeding, vector control and trash removal take place? Who will be doing it? If the commitment is subject to funding, what kind of commitment is that?*

Regarding the frequency of weeding, vector control and trash removal, funding from the state legislature is subject to change, and therefore IfA has only some level of control over the level of practices implemented through state funding. However, major users are required to contribute to weeding, vector control, and trash removal as it pertains to their leased property. For example, both the Air Force and the ATST Project provide supplemental funding and personnel to weed, control rodents, and remove trash from the site.

In fact, semi-annual weeding at HO to this point has resulted in a weed/invasive species population that is significantly lower than on the adjacent Park lands, according to U.S.G.S. staff biologist Art Medeiros, who has been responsible for weeding the HO property since 2009 (pers. comm., 2010).

6. ***Protection.*** *The so-called management plan fails to address the protection of resources that need protection.*

   Construction fifty feet from an archaeological structure may protect its physical integrity, but a looming structure within fifty feet of a significant archaeological site does not protect its archaeological integrity. Protecting the context of an archaeological feature is critical to the protection of the site.

   Why is there no discussion in the management plan about protecting traditional cultural practices?

Section 3.5.2.1 of the Management Plan describes practices and policies for traditional and cultural practices protected through the permitting process. Traditional cultural practices will be protected under the FEIS, CDUP and Programmatic Agreement prepared for ATST. The MP is not inconsistent with protections afforded in other documents.

7. *Why is it that the plan states in absolute terms that "New facilities will not be permitted to obscure the observation function of existing facilities," but uses far less categorical language when it comes to obscuring scenic views:*

> *Whenever possible, new buildings will be painted to blend with their surroundings; however, solar observatories that operate during daylight hours will be allowed to be painted white, as it would otherwise be virtually impossible to keep the enclosure and building surfaces cool enough to prevent degradation of seeing conditions.*
> *5. Construction design will consider sight planes to population centers of Maui. Where buildings can be oriented to limit visibility or be built partly underground, they will be. Where they cannot, every effort will be made not to use materials that draw attention from a distance, i.e., reflective surfaces, unusual shapes, incompatible colors.*

The EA considers impacts to view planes as discussed in section 3.5. The analysis includes addressing policies and practices intended to manage visual resources. With the exception of the proposed ATST Project on a previously undeveloped site east of the Mees Solar Observatory, the lack of new sites for construction means that existing facilities and structures would be replaced with facilities and structures of similar size, scale, dimension, and appearance.

8. When will the IFA take measures to protect subsurface water quality (p. 2-34)?

> *The current MSO facility at HO uses a cesspool for handling wastewater and septic waste. This could affect subsurface water quality, but plans are in place to remove the cesspool, to remediate the site, and to construct a wastewater treatment facility in accordance with appropriate permits and procedures of Maui County and the State Department of Health.*
>
> *Given the importance of protecting sub-surface water quality ("The upper aquifer is classified as being replaceable and highly vulnerable to contamination" p 2-34), why does the management plan not call for centralized and better management of wastewater (p. 2-35)?*

IfA has already taken measures to protect subsurface water quality. A Storm Water Management Plan was prepared for HO and is available online at: http://atst.nso.edu/FEIS, Appendix L, Stormwater Management Plan for Haleakalā High Altitude Observatories, March 2006. In addition, future construction at the site for ATST will be utilizing a waste treatment plant as described in ATST FEIS, Vol. I, Section 2.4.4.

Regarding protection of sub-surface waters, all facilities will be constructed and operated in compliance with DOH wastewater regulations which are designed to protect sub-surface waters.

9. Why does the plan not include any effort to protect the natural quiet of the area?

Tens of thousands of cars, buses, trucks and other vehicles enter Haleakalā National Park every year (average of nearly 189,000/year from 2004-2008; Federal Highway Administration, 2009). To the extent that noise requirements are applicable, either through Conservation District Rules or Noise and Radiation Branch Rules at the Department of Health, IfA will comply.

10. Because the IFA is simultaneously seeking a Conservation District Use Application (CDUA) for the Advanced Technology Solar Telescope (ATST), this DEA must consider the impacts of this related action. See, HAR § 11-200-7 and 11-200-2 ("cumulative impact"). There is no doubt that this management plan is inextricably linked to IFA's plans to build the ATST facility on Haleakala. For example:

• the DEA refers to the ATST on page 46 of appendix K ("solar observatories that operate during daylight hours will be allowed to be painted white, as it would otherwise be virtually impossible to keep the enclosure and building surfaces cool enough to prevent degradation of seeing conditions");

• the DEA refers to its purpose in getting the ATST approved on page 2-3 ("HAR 13-525 identifies land uses for HO as General Subzone, which is applicable for astronomy facilities (HAR 13-5-25, R-3) under an approved management plan (HAR 13-5-25, D-1");

• the DEA refers to the ATST plans "to remove the cesspool, to remediate the site, and to construct a wastewater treatment facility in accordance with appropriate permits and procedures of Maui County and the State Department of Health." (p. 2-34) This plan is specifically discussed on page 4-115 of the ATST FEIS.

• the DEA refers to the ATST by name on pages 3-18, 4-2, 4-3 and 4-7.

The discussion of cumulative impacts sometimes includes the ATST, but frequently fails to mention it. The DEA strangely observes:

> *While a separate analysis of land use resources for the proposed ATST Project describes specific impacts, it can be stated that this proposed project would be an incremental addition of approximately 4 percent to the use of Conservation District lands within HO and only a fraction of a percent of the total resource subzone. In consideration of these factors, if construction is approved, the proposed ATST Project is anticipated to result in less than significant cumulative impacts on land use.*

> *How can the IFA state this with any credibility when its own CDUA for the ATST includes the FEIS, which itself concludes: "Construction and operation of the proposed ATST Project ... would result in major, adverse, short- and long-term direct impacts on traditional and cultural resources within the ROI.. . . Mitigation measures would . . . not reduce the impact intensity: impacts would remain major, adverse, long-term and direct." (p. ES-36). Or, when it states, "[I]n views from within two miles of the proposed ATST project site ...[the project] would result in moderate, adverse and long-term impacts to visual resources. No mitigation would adequately reduce this impact." (p ES-39). The FEIS for the ATST concedes that the project will have significant impacts - including major adverse long-term impacts.*
>
> *Because the activities described in the DEA are inextricably linked to the ATST and because the cumulative impacts of the projects are significant, there can be no doubt that an EIS is required.*

IfA has identified ATST as a reasonably foreseeable future action and has looked at the impacts of the MP combined with the implementation of ATST in the cumulative impacts analysis which looks at past, present and reasonably foreseeable future action. Please see section 3.10 of the DEA which refers to cumulative impacts.

11. The DEA's citation to other CDUA's for rejected projects is misleading. For example, page 2-2-2-3 states: "During the past few years, the DLNR's Office of Conservation and Coastal Lands (OCCL) has administered Conservation District Use Applications (CDUAs) for: open ocean aquaculture projects, telescopes on top of Haleakala and Mauna Kea, major powerline projects on scenic ridges, telecommunication facility projects, single family residences, Parks; and Commercial Forest projects." The DEA uses the vague term "administered." Yes, OCCL has received applications for various projects. But the Board of Land and Natural Resources, in fact, rejected the application (the only application) for a major powerline project on a scenic ridge. It rejected the koa logging project proposed on Hawai'i Island. And the court overturned the BLNR's approval of a CDUP for a telescope on Mauna Kea. The DEA, therefore, misleads by suggesting that, because these applications have been "administered", there is nothing unusual about the proposed use.

Your reference to the DLNR OCCL citation was taken from the DLNR OCCL website: http://hawaii.gov/dlnr/occl/conservation. The website reference has been added to the text in the document.

12. Is this management plan being submitted to the Board of Land of Natural Resources for approval?

Yes, the Management Plan was submitted to BLNR on June 8, 2010.

13. *On page 2-3, the DEA puts two facts together to create a misleading impression. It may in fact be true that the parcel of land at issue was set aside for astronomical research. It is true that the Haleakala High Altitude Observatories are in the conservation district. It is not accurate, however, to imply that (1) the purpose of the conservation district, or this part of the conservation district, is for astronomy or (2) this area has been designated for astronomical research pursuant to Act 187 or the conservation district rules. The executive order setting land aside has nothing to do with the regulatory restrictions on uses in the conservation district.*

In Section 2.2.1-Resources Overview, the first paragraph refers to HO as being "... in the State of Hawaiʻi Conservation District with an identified use in the General Subzone and is consistent with the objectives of the General Subzone of the land." The second paragraph refers to HO as, "This area of the Conservation District has been set aside for "…Haleakalā High Altitude Observatory Site purposes only" under EO 1987 (will be attached to FEA as an Appendix). HAR 13-5-25 identifies land uses for HO as General Subzone, which is applicable for astronomy facilities (HAR 13-5-25, R-3) under an approved management plan (HAR 13-5-25, D-1)."

14. *The DEA states: "Since the rules were issued in 1994, all new facilities within HO that involve conservation land use (excluding interior renovation and reuse of lands) have required a CDUP." What is the basis for the assumption that "reuse of lands" does not require a CDUP? Does the IFA believe that by obtaining approval of this plan, the "reuse" of an observatory facility will not require a new CDUP?*

The portion of the sentence referring to reuse of land has been deleted.

15. *The applicant failed to discuss other EAs and EISes for projects in the area. These documents can demonstrate whether: (a) the IFA and other users of the area accurately predicted impacts; (b) the IFA and other users of the area followed through on prior promises; and (c) proposed mitigation was effective. This analysis is necessary to perform a credible analysis of the effectiveness of the management plan.*

Cumulative impacts associated with the Management Plan were evaluated in Section 4 of the EA. The section evaluated past, present and reasonably foreseeable future actions for impacts to environmental and cultural/historic resources at HO.

16. *. . . Despite IFA's assurances, the Air Force's large AECOS facility (a) is not consistent with the existing structures; (b) greatly altered the appearance of the complex; (c) was not mitigated by its reflective surface; and (d) stands out strongly. Why is there no discussion in the management plan to correct past errors to reduce the visual blight of the facilities on Haleakalā?*

The AEOS facility was constructed pursuant to a CDUP issued by BLNR where these very issues were considered. It is not within the scope of the MP to change existing permits.

17. What authority would the "cultural specialist" have? Will s/he merely be able to provide advice that does not have to be followed?

As stated in the MP, Section 3.5.2.1, any construction within HO requiring a permit from DLNR requires the consultation and monitoring of a Cultural Specialist. This person will consult with and advise the on-site project manager about any cultural or spiritual concerns.

18. The DEA is flawed in its conclusion that no EIS is required when (1) the Management Plan lacks the necessary details to provide an accurate assessment of the impacts, and (2) the FEIS for the ATST concedes that the project will have significant impacts. The concerns outlined above must be addressed and an EIS must be prepared.

For the reasons set forth above, we believe that the Management Plan includes adequate detail to allow impacts to be assessed, and we respectfully disagree with your conclusion that an EIS must be prepared.

Once again, thank you for providing comments on this matter. Should you have any further questions or comments, please contact me at (808) 573-1903.

Respectfully,

Dr. Charlie Fein
Vice President

CHARMAINE TAVARES
Mayor

JEFFREY S. HUNT
Director

KATHLEEN ROSS AOKI
Deputy Director

COUNTY OF MAUI
DEPARTMENT OF PLANNING

April 22, 2010

Mr. Mike Maberry, Assistant Director
University of Hawaii, Institute for Astronomy
34 Ohi'a Ku Street
Pukalani, Hawaii 96768

Charlie Fein, Ph.D.
KC Environmental, Inc.
P.O. Box 1208
Makawao, Hawaii 96768

Dear Mr. Maberry and Mr. Fein:

SUBJECT: COMMENTS ON DRAFT ENVIRONMENTAL ASSESSMENT (EA) FOR THE PROPOSED MANAGEMENT PLAN FOR THE HALEAKALA HIGH ALTITUDE OBSERVATORY SITE, AT WAIAKOA, PAPA'ANUI, MAKAWAO, ISLAND OF MAUI, HAWAII; (EAC 2010/0005)

The Department of Planning (Department) is in receipt of the above-referenced request for Draft EA comments for the proposed Master Plan for the Haleakala High Altitude Observatory Site. The Department understands the proposed action includes the following:

1. The Draft EA evaluates a Management Plan (MP) for appropriate and reasonable activities to be undertaken by the University of Hawaii, Institute for Astronomy at the Haleakala High Altitude Observatory Site (HO);

2. The implementation of the MP is intended to comply with Exhibit 3 of Hawaii Administrative Rules (HAR) 13-5 and is not intended to assess impacts from construction or operation of any new project at HO or to authorize construction of any proposed action; and

3. The purpose of the Draft EA is to inform the relevant state agencies and the public of the likely environmental consequences of the MP on ongoing and future actions at HO in support of astronomical research.

Based on the foregoing, the Department provides the following comments on the Draft EA:

1. According to the Makawao-Pukalani-Kula Community Plan of the County of Maui, the following policies may affect the proposed project and necessitate discussion in the Final EA:

    a. Environment, Policy 4: Encourage Federal, State, and County cooperation in the preparation of a comprehensive Haleakala

250 SOUTH HIGH STREET, WAILUKU, MAUI, HAWAII 96793
MAIN LINE (808) 270-7735; FACSIMILE (808) 270-7634
CURRENT DIVISION (808) 270-8205; LONG RANGE DIVISION (808) 270-7214; ZONING DIVISION (808) 270-7253

summit MP to promote orderly and sensitive development which is compatible with the natural and native Hawaiian cultural environment of Haleakala National Park; and

b. <u>Government, Planning Standards, Design</u>: Limit building height throughout the region to two (2) stories, not to exceed 35 feet above grade. Exceptions to this standard may be considered for Public and Quasi-Public facilities such as gymnasiums, medical facilities, and fire stations.

2. It is assumed the Project site is located on State Conservation land. However, if the Project site is located on State Agricultural land, a Land Use Commission Special Use Permit or a District Boundary Amendment/Change in Zoning may be required;

3. On Page 2-21, the Draft EA refers to 'Ua'u burrows in Figures 2-6 and 2-7. This appears to be a mistake as it should actually refer to Figures 2-4 and 2-5. Please make the correction in the Final EA;

4. Similarly on Page 2-23, the Draft EA refers to Nene habitat in Figure 2-8. This should refer to Figure 2-6. Please make the correction in the Final EA; and

5. Also on Page 2-27, the Draft EA refers to Maui's topography in Figure 2-9. This should refer to Figure 2-7. It might be worth checking Figure numbers to their matching references throughout the Draft EA.

6. The MP has correctly defined the project area as a Traditional Cultural Property or "TCP" that is eligible for listing in the National Register of Historical Places (NRHP) and we concur with that finding (Appendix K: p, 13).

7. "Traditional Cultural Property" (16 U.S.C. 470h-2) is also defined in NPS Bulletin #38 as a property "that is eligible for inclusion in the National Register because of its association with cultural practices or beliefs of a living community that (a) are rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community."

8. The study includes relevant archaeological and cultural data (Appendices A-C), the latter of which support the classification of the site as a "TCP." Please provide a more detailed explanation of how the project comports with the TCP determination.

9. In addition, it remains problematic that although the MP states that Native Hawaiians or Kānaka Maoli are "welcome to practice traditional cultural practices within the HO property" (Appendix K: p. 41) that this may occur "so long as it does not interfere...with operations..."

10. The American Indian Religious Freedom Act or "AIRFA" (42 U.S.C. § 1996) states that "it shall be the policy of the United States to protect and preserve for American Indians their inherent right of freedom to believe, express, and exercise the traditional religions of the American Indian, Eskimo, Aleut, and Native Hawaiians, including but not limited to access to sites...and the freedom to worship through ceremonials and traditional rites." The act does not indicate that an outside entity should dictate terms for the practice of such ceremonials and traditional rites.

11. Please identify specific measures to mitigate the potential impact and "adverse effect" that the construction of the telescope will have on the TCP as a sacred site for native Kānaka Maoli.

12. We recommend that this issue be addressed by the following actions:

    a. That the site shall be nominated to the NRHP as a "TCP" and that further consultation with the Kānaka Maoli community shall be conducted to produce a mitigation plan where the population receives some direct benefit in increased accessibility, in the creation of jobs, and in education of Kānaka Maoli students;

    b. That further development shall not exceed the boundaries proposed in the MP for a period of twenty years; and,

    c. If future needs require additional development, that the instrumentation contained within the existing facilities shall be up upgraded or replaced before the construction of new buildings can be considered or proposed.

Thank you for the opportunity to comment. Should you require further clarification, please contact Staff Planner Joseph Prutch at joseph.prutch@mauicounty.gov or at 270-7512.

Sincerely,

JEFFREY S. HUNT, AICP
Planning Director

xc: Clayton I. Yoshida, AICP, Planning Program Administrator
Joseph M. Prutch, Staff Planner
Department of Health, Office of Environmental Quality Control
2010 EAC File
General File

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KC Environmental, Inc.

P.O. Box 1208
Makawao, HI 96768

(808) 573-1903
fax: (808) 573-7837
charlie@kcenv.com

October 25, 2010

Mr. Jeffery Hunt, AICP
Planning Director
County of Maui, Dept. of Planning
250 South High Street
Wailuku, Maui, HI 96793

Subject: Draft Environmental Assessment for the Haleakalā High Altitude Observatory Site Maui, Hawaiʻi Management Plan
Tax Map Kay (2) 2-2-07-008
Waiakoa, Papaʻanui, Makawao, Maui, Hawaiʻi

Dear Mr. Hunt:

Thank you for your comment letter of April 22, 2010, regarding the Draft Environmental Assessment (EA) for the Haleakalā High Altitude Observatory Site Maui (HO), Hawaiʻi Management Plan (MP). The following responses are provided to your comments in the order they were presented in your letter.

1. *According to the Makawao-Pukalani-Kula Community Plan of the County of Maui, the following policies may affect the proposed project and necessitate discussion in the Final EA:*

   a. <u>Environment, Policy 4</u>: Encourage Federal, State, and County cooperation in the preparation of a comprehensive Haleakala summit MP to promote orderly and sensitive development which is compatible with the natural and native Hawaiian cultural environment of Haleakala National Park; and

   b. <u>Government Planning Standards, Design</u>: Limit building height throughout the region to two (2) stories, not to exceed 35 feet above grade. Exceptions to this standard may be considered for Public and Quasi-Public facilities such as gymnasiums, medical facilities, and fire stations.

Makawao-Pukalani-Kula Community Plan of the County of Maui ("Community Plan"), Environment, Policy 4. The text of the Community Plan provides,

> 4. Encourage Federal, State and County cooperation in the preparation of a comprehensive Haleakala summit *<u>master plan</u>* to promote orderly and sensitive development which is compatible with the natural and native Hawaiian cultural environment of Haleakala National Park.

(emphasis added). The Community Plan provision refers to a master plan, not a management plan. The document which is the subject of this EA is a management plan. When and if a master plan is proposed, the University of Hawaiʻi Institute for Astronomy (IfA) will certainly take this comment into consideration.

Government, Planning Standards, Design. The document which is the subject of this EA is a management plan, which is a management planning document that does not set or allow height restrictions. Any future facilities that would be built would not only have to comply with this MP, but will comply with any applicable laws and regulations.

2. *It is assumed the Project site is located on State Conservation land. However, if the Project site is located on State Agricultural land, a Land Use Commission Special Use Permit or a District Boundary Amendment/Change in Zoning may be required;*

The Management Plan which is the subject of this EA only covers property in the conservation district, not on state agricultural land The Management Plan, Section 1.2 - Land Use Consistent with the Purpose of the Conservation District and the Property's Subzone, provides,

> HO is located within a General Subzone of the State of Hawaiʻi Conservation District that has been set aside for astronomical research. The objectives of the General Subzone (HAR Chapter 13-5-14) are to designate open space where specific conservation uses may not be defined, but where urban uses would be premature. Identified applicable land uses in the General Subzone include R-3 Astronomy Facilities, (D-1) Astronomy facilities under an approved management plan (HAR 13-5-25).

3. *3. On Page 2-21, the Draft EA refers to 'Ua'u burrows in Figures 2-6 and 2-7. This appears to be a mistake as it should actually refer to Figures 2-4 and 2-5. Please make the correction in the Final EA;*

4. *Similarly on Page 2-23, the Draft EA refers to Nene habitat in Figure 2-8. This should refer to Figure 2-6. Please make the correction in the Final EA; and*

5. *Also on Page 2-27, the Draft EA refers to Maui's topography in Figure 2-9. This should refer to Figure 2-7. It might be worth checking Figure numbers to their matching references throughout the Draft EA.*

The labeling of figures has been corrected, thank you.

6. *The MP has correctly defined the project area as a Traditional Cultural Property or "TCP" that is eligible for listing in the National Register of Historical Places (NRHP) and we concur with that finding (Appendix K: p, 13).*

Thank you for your comment acknowledging that the EA has correctly identified the project area as eligible for listing on the National Register of Historical Places.

7. *"Traditional Cultural Property" (16 U.S.C. 470h-2) is also defined in NPS Bulletin #38 as a property "that is eligible for inclusion in the National Register because of its association with cultural practices or beliefs of a living community that (a) are rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community."*

Thank you for providing the definition of a traditional cultural property from NPS Bulletin #38. Your comment is acknowledged, thank you.

8. *The study includes relevant archaeological and cultural data (Appendices A-C), the latter of which support the classification of the site as a "TCP." Please provide a more detailed explanation of how the project comports with the TCP determination.*

As the Maui County Planning Department acknowledges in comment 6, the property is eligible, but has not been listed, as a Traditional Cultural Property. *See* Management Plan, p. 13, paragraph labeled Haleakalā Summit; s*ee* EA, p. 2-12, Haleakalā Summit as a Traditional Cultural Property. When and if TCP requirements are applicable to this property, IfA will comply with all laws and regulations associated with Traditional Cultural Properties.

9. *In addition, it remains problematic that although the MP states that Native Hawaiians or Kanaka Maoli are "welcome to practice traditional cultural practices within the HO property" Appendix K: p. 41) that this may occur "so long as it does not interfere... with operations... "*

Safety at HO is a primary goal of working in and around the HO site. While Native Hawaiians are welcome to enter to participate in traditional cultural practices, their safety at HO is paramount.

10. *The American Indian Religious Freedom Act or "AIRFA" (42 U.S.C. § 1996) states that "it shall be the policy of the United States to protect and preserve for American Indians their inherent right of freedom to believe, express, and exercise the traditional religions of the American Indian, Eskimo, Aleut, and Native Hawaiians, including but not limited to access to sites ... and the freedom to worship through ceremonials and traditional rites." The act does not indicate that an outside entity should dictate terms for the practice of such ceremonials and traditional rites.*

Your comment regarding obligations under the American Indian Religious Freedom Act is acknowledged. The Management Plan does not dictate terms for the practice of such ceremonials and traditional rites, and while Native Hawaiians are welcome to enter to participate in traditional cultural practices, their safety at HO is paramount and must be protected.

11. *Please identify specific measures to mitigate the potential impact and "adverse effect" that the construction of the telescope will have on the TCP as a sacred site for native Kānaka Maoli.*

This Environmental Assessment concerns the Management Plan. The proposed action does not involve construction of a telescope. Any future construction will be subject to the requirement of state and federal law with regard to traditional and cultural properties.

12. *We recommend that this issue be addressed by the following actions:*

a. That the site shall be nominated to the NRHP as a "TCP" and that further consultation with the Kanaka Maoli community shall be conducted to produce a mitigation plan where the population receives some direct benefit in increased accessibility, in the creation of jobs, and in education of Kanaka Maoli students;

IfA will take this suggestion regarding nomination and consultation under advisement.

b. That further development shall not exceed the boundaries proposed in the MP for a period of twenty years; and,

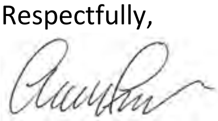
The Management Plan that is the subject of this EA has boundaries defined by Executive Order 1987. A copy of Executive Order 1987 is attached to Final EA (Appendix M). The proposed action does not involve further development. Any further development will be subject to the requirements of state and federal law.

c. If future needs require additional development, that the instrumentation contained within the existing facilities shall be . . . upgraded or replaced before the construction of new buildings can be considered or proposed.

Instrumentation of individual facilities is outside the scope of the MP.

Once again, thank you for providing comments on this matter. Should you have any further questions or comments, please contact me at (808) 573-1903.

Respectfully,



Dr. Charlie Fein
Vice President

CHARMAINE TAVARES
Mayor

CHERYL K. OKUMA, Esq.
Director

GREGG KRESGE
Deputy Director

TRACY TAKAMINE, P.E.
Solid Waste Division

DAVID TAYLOR, P.E.
Wastewater Reclamation
Division

COUNTY OF MAUI
DEPARTMENT OF
ENVIRONMENTAL MANAGEMENT
2200 MAIN STREET, SUITE 100
WAILUKU, MAUI, HAWAII 96793

May 21, 2010

Mr. Mike Maberry, Assistant Director
University of Hawaii Institute for Astronomy
34 Ohi'a Ku Street
Pukalani, Hawaii 96768

Dear Mr. Maberry:

SUBJECT: **HALEAKALA HIGH ALTITUDE OBSERVATORY SITE**
DRAFT ENVIRONMENTAL ASSESSMENT
TMK (2) 2-2-007:008, KULA

We reviewed the subject project as a pre-application consultation and have the following comments:

1. Solid Waste Division comments:

   a. None.

2. Wastewater Reclamation Division (WWRD) comments:

   a. None.

If you have any questions regarding this memorandum, please contact Gregg Kresge at 270-8230.

Sincerely,

Cheryl K. Okuma

Cheryl K. Okuma, Director

xc: Charlie Fein

APPENDIX M

Executive Order No. 1987

1987

Executive Order No. ______

Setting Aside Land for Public Purposes

By this Executive Order, I, the undersigned, Governor of the ~~Territory~~ STATE of Hawaii, by virtue of the authority in me vested by paragraph q of Section 73 of the Hawaiian Organic Act, and every other authority me hereunto enabling, do hereby order that the public land hereinafter described be, and the same is, hereby set aside for the following public purposes:

FOR University of Hawaii Haleakala High Altitude Observatory Site, to be under the control and management of the Board of Regents of the University of Hawaii.

UNIVERSITY OF HAWAII

HALEAKALA HIGH ALTITUDE OBSERVATORY SITE

Waiakoa, Papaanui, Makawao (Honuaula), Maui, Hawaii

Being portions of the Government Lands of Papaanui and Waiakoa

Beginning at the north corner of this parcel of land and on the boundary between the lands of Waiakoa and Kealahou 3 and 4 (L.C.Aw. 8452, Apana 21 to A. Keohokalole, the coordinates of said point of beginning referred to Government Survey Triangulation Station "KOLEKOLE" being 300.45 feet North and 570.12 feet West, thence running by azimuths measured clockwise from True South:-

1. 307° 41' 92.21 feet along the lands of Kealahou 3 and 4 (L.C.Aw. 8452, Apana 21 to A. Keohokalole), to concrete monument 25;
2. 311° 22' 1142.90 feet along remainder of the Government Lands of Papaanui;
3. 41° 22' 467.14 feet along remainder of the Government Land of Papaanui;
4. 89° 14' 283.18 feet along remainder of the Government Lands of Papaanui;
5. 131° 22' 1025.00 feet along remainder of the Government Lands of Papaanui, along Haleakala Peripheral Hi Site (Governor's Executive Order 1808), and again along remainder of the Government Lands of Papaanui to a 3/4-inch pipe;

APPENDIX M:
EXECUTIVE ORDER NO. 1987

6. 221° 22' 651.19 feet along remainder of the Government Lands of Papaanui and Waiakoa, to the point of beginning and containing a GROSS AREA OF 18.166 ACRES and a NET AREA OF 18.052 ACRES, after excluding therefrom the Sites for Government Survey Triangulation Station "KOLEKOLE" and Reference Mark 1, together with rights of ingress and egress to and from said Sites, and subject to certain sight clearance conditions from said station "KOLEKOLE"; said Site and sight clearance conditions being described as follows:

<u>Site for Government Survey Triangulation Station "KOLEKOLE"</u>

Beginning at the northeast corner of this site, the true azimuth and distance from Government Survey Triangulation Station "KOLEKOLE" being 225° 00' 35.36 feet, thence running by azimuths measured clockwise from True South:-

1. 360° 00' 50.00 feet;
2. 90° 00' 50.00 feet;
3. 180° 00' 50.00 feet;
4. 270° 00' 50.00 feet to the point of beginning and containing an AREA OF 0.057 ACRE.

<u>Sight Clearance Conditions</u>

So long as Government Survey Triangulation Station "KOLEKOLE" remains in use for a Triangulation Station, there shall not be erected, maintained or allowed to grow on the land of the above-described University of Hawaii, Haleakala High Altitude Observatory Site, any structure or object of natural growth exceeding in height to obstruct or to block the lines of sight observed with an engineer's instrument from said Station "KOLEKOLE" to Government Survey Triangulation Stations "PUU PANE", " PUU NANIAU", "HALEAKALA 2", "KA LAE O KA ILIO", "SHORE D", "KANAHAU", "KAHOOLAWE" and also to REFERENCE MARKS

1, 2 and 3, the directions of these lines of sight are delineated on Government Survey Map C.S.F. No. 13,564, a print of which is attached hereto and made a part hereof.

Site for Reference Mark 1

Beginning at the northeast corner of this parcel of land, the true azimuth and distance from Government Survey Reference Mark 1, marked by a standard disk set in rock outcrop, being 212° 00' 47.17 feet, and the true azimuth and distance from Government Survey Triangulation Station "KOLE-KOLE", to said Reference Mark 1 being 17° 19' 24.2" 353.64 feet, thence running by azimuths measured clockwise from True South:-

1. 360° 00' 50.00 feet;
2. 90° 00' 50.00 feet;
3. 180° 00' 50.00 feet;
4. 270° 00' 50.00 feet to the point of beginning and containing an AREA OF 0.57 ACRE.

The above-described Haleakala High Altitude Observatory Site is subject, however, to portion of Easement A (40.00 feet wide) and Easements B and C (20.00 feet wide), covered by Governor's Executive Order 1808, as shown on plan attached hereto and made a part hereof and more particularly described as follows:-

PORTION OF EASEMENT A: Access Road for Haleakala Peripheral Hi Site (Governor's Executive Order 1808)

Being a strip of land forty (40.00) feet wide, extending twenty (20.00) feet on each side of the following described centerline:-

Beginning at the east end of this centerline and on the northeast boundary of the hereinabove described Haleakala High Altitude Observatory Site, the coordinates of said point of beginning referred to Government Survey Triangulation Station "KOLEKOLE" being 112.25 feet North and 220.37 feet East, thence running by azimuths measured clockwise from True South:-

1. On a curve to the right having a radius of 257.38 feet, the chord azimuth and distance being: 19° 54' 49" 96.04 feet;

2. 30° 40' 103.00 feet;

3. Thence on a curve to the right having a radius of 111.92 feet, the chord azimuth and distance being: 75° 56' 30" 159.04 feet, the true azimuth and distance from the end of this course to Government Survey Triangulation Station "KOLEKOLE" being 190° 19' 107.00 feet, containing an AREA OF 0.346 ACRE.

EASEMENTS B AND C: Access Road to Haleakala Peripheral Hi Site (Governor's Executive Order 1808)

Being a strip of land twenty (20.00) feet wide, extending ten (10.00) feet on each side of the following described centerline:-

Beginning at the east end of this centerline, the true azimuth and distance from the west end of the centerline of the above described Easement A being: 31° 13' 20.00 feet, thence running by azimuths measured clockwise from True South:-

1. 79° 41' 95.32 feet;

2. Thence on a curve to the left having a radius of 991.13 feet, the chord azimuth and distance being: 72° 20' 30" 253.30 feet;

3. 65° 00' 26.10 feet to the northeast boundary of Haleakala Peripheral Hi Site (Governor's Executive Order 1808) and containing an AREA OF 0.174 ACRE. All these lands are shown on CSF No. 13,564, prepared by the Survey Division of the Department of Accounting and General Services.

THIS EXECUTIVE ORDER is subject to the following conditions:

1. That the lands herein set aside shall be used for the Haleakala High Altitude Observatory Site purposes only;

2. Should the lands herein described be abandoned for a period of one year or used for purposes other than those permitted herein, this Executive Order shall automatically terminate and the lands herein described shall forthwith be forfeited and revert to the State, resuming the status of public lands.

In Witness Whereof, I have hereunto set my hand and caused the Great Seal of the ~~Territory~~ State of Hawaii to be affixed. Done at the Capitol at Honolulu this 12th day of December, Nineteen Hundred and Sixty one

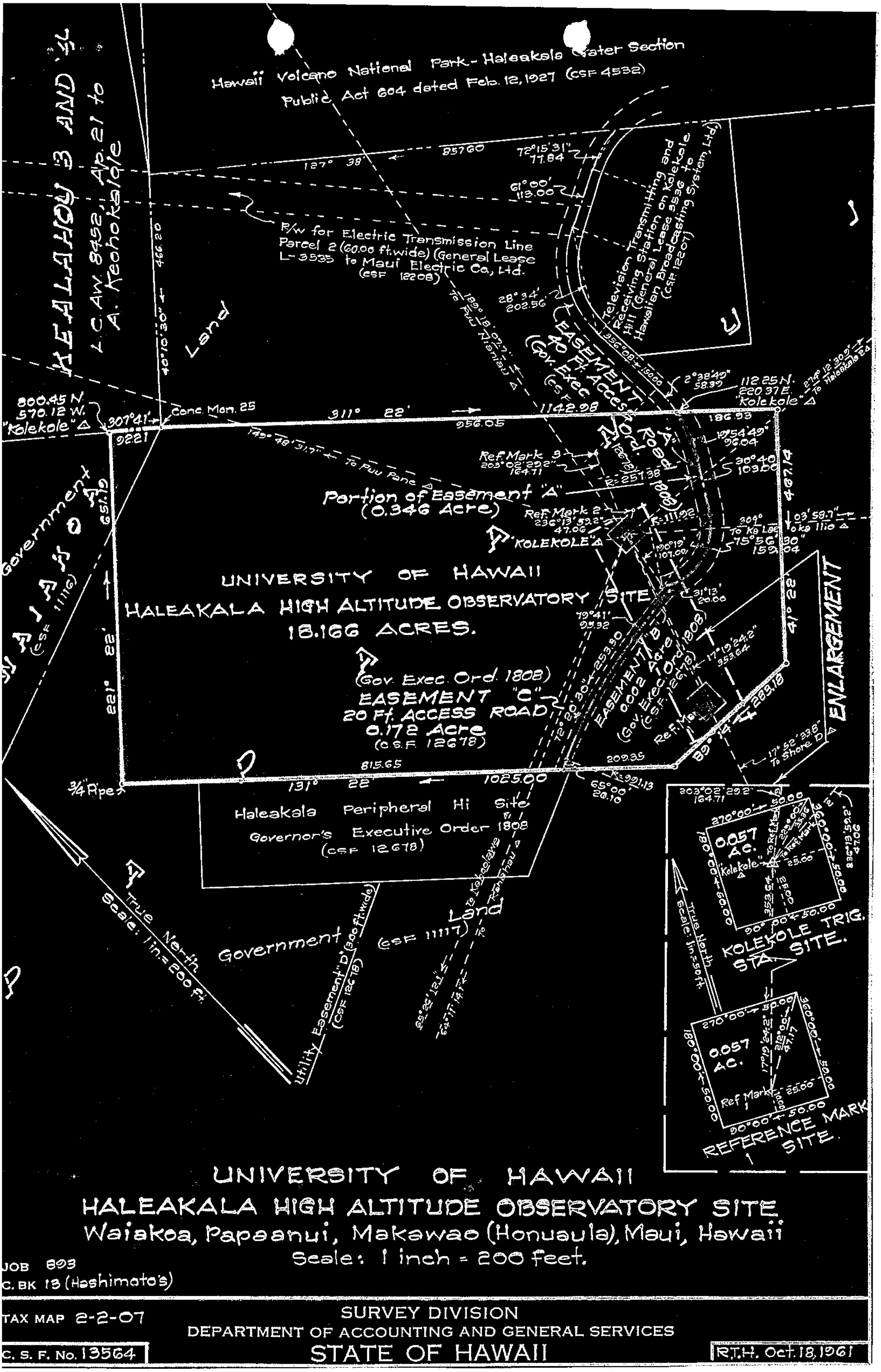
William F. Quinn
Governor of the ~~Territory~~ State of Hawaii

Approved as to form:

Shiro Kashiwa
Attorney General

by: L.S.
Checked by: mm

APPENDIX M:
EXECUTIVE ORDER NO. 1987



APPENDIX M:
EXECUTIVE ORDER NO. 1987