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VOLUME II of III

SUPPLEMENTAL DRAFT ENVIRONMENTAL IMPACT STATEMENT

SURVEYS AND ASSESSMENTS

Advanced Technology Solar Telescope
Haleakalā, Maui, Hawai‘i

May 2009

VOLUME II

SURVEY AND ASSESSMENT REPORTS

Volume II contains survey and assessment reports that were conducted in the surrounding environment at and near HO, which provide detailed and/or focused information relative to key environmental impacts and topics addressed in Volume I and other relevant documentation used in producing this EIS.

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APPENDIX A

ARCHAEOLOGICAL FIELD INSPECTION

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)

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2 January2006

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

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[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).

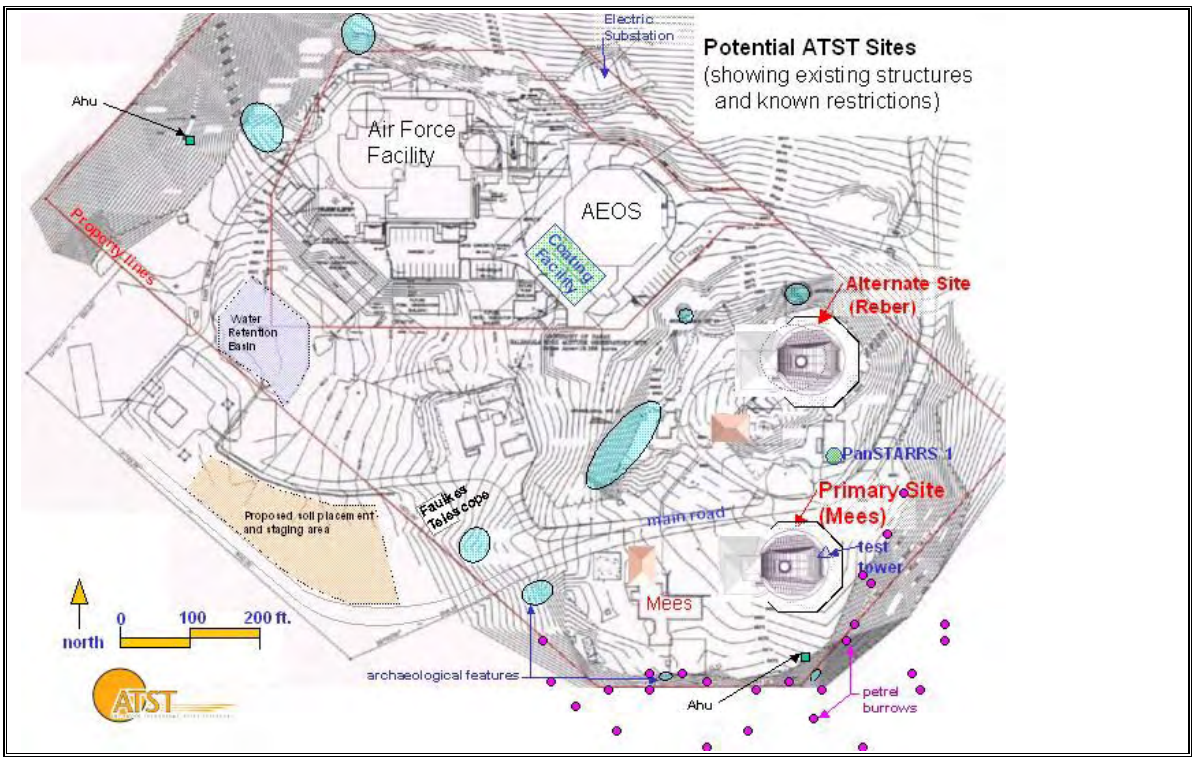
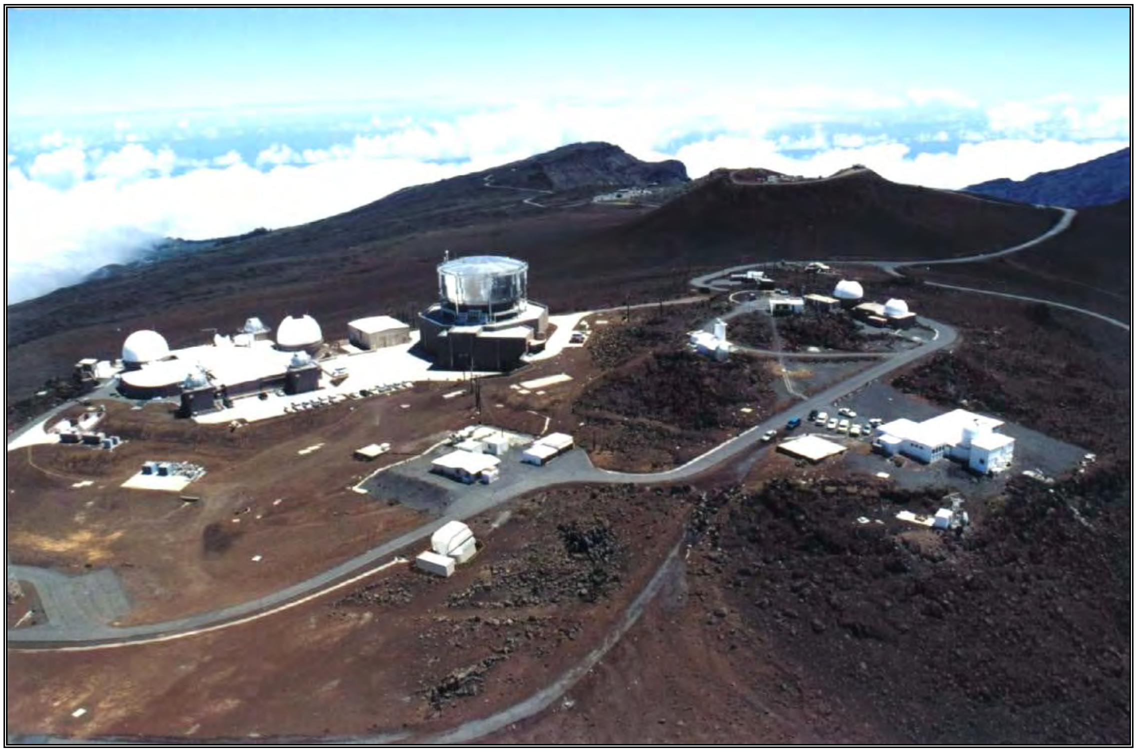


Figure 2: Potential ATST site location map, including primary Mees and alternate Reber Circle sites.

[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.

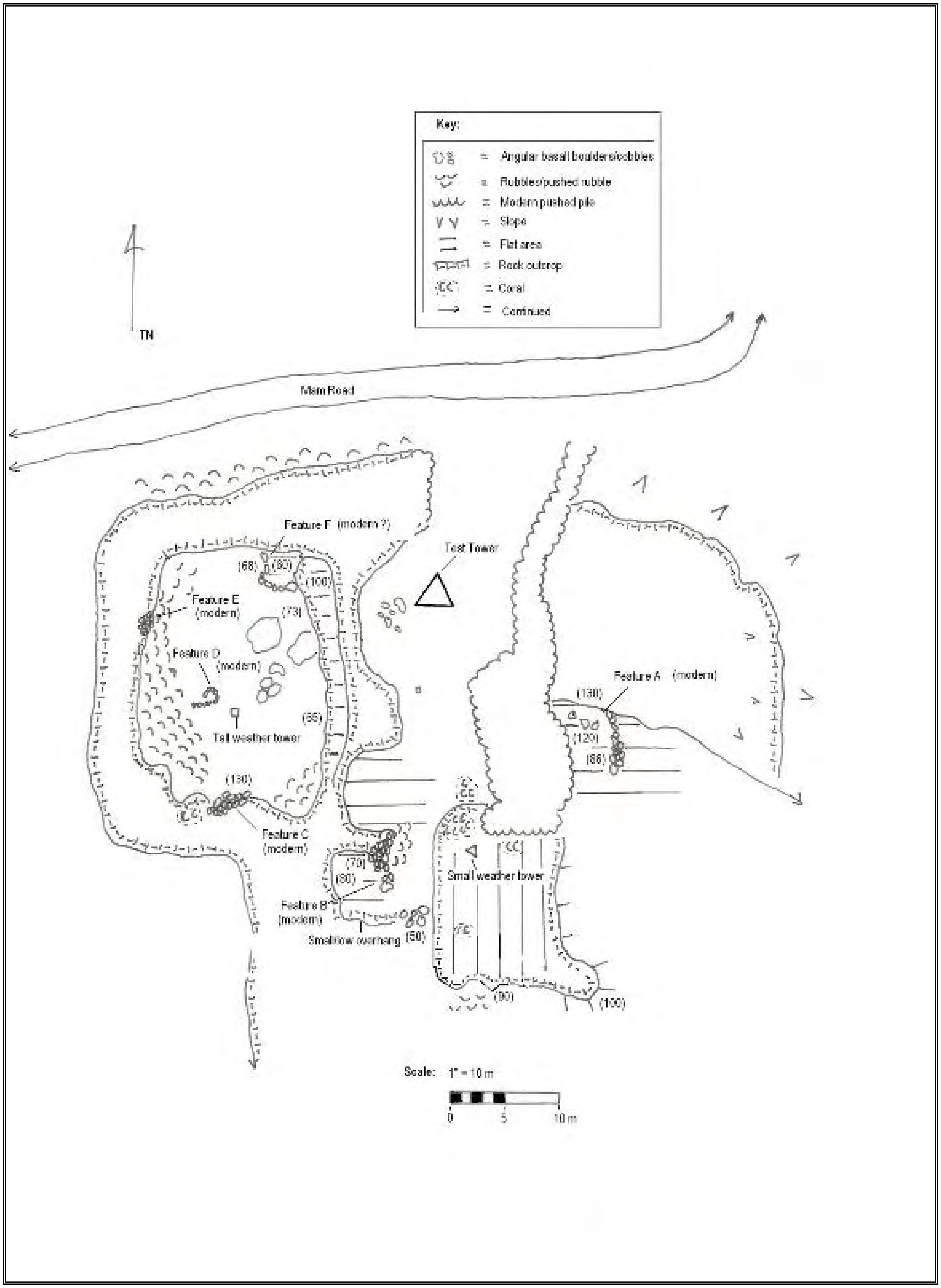
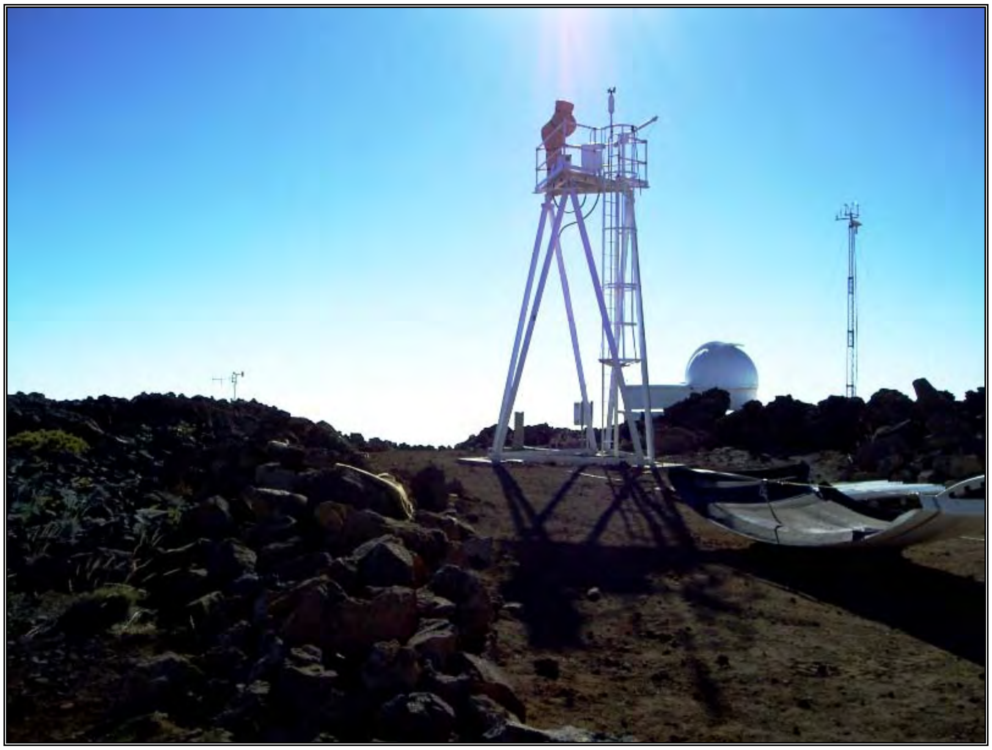


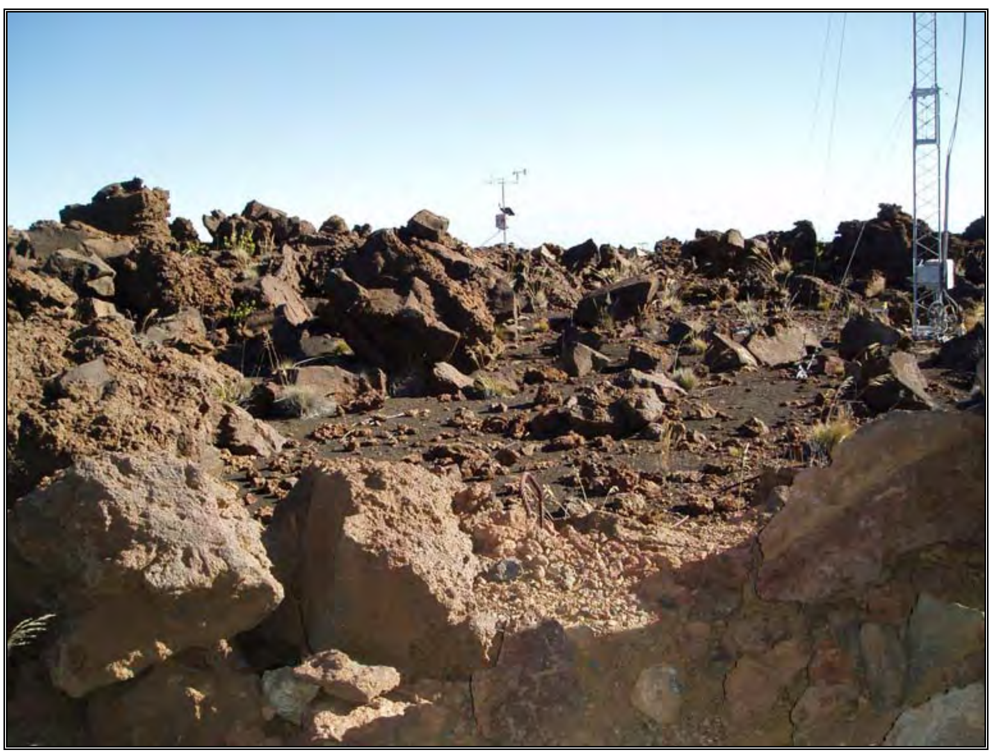
Figure 3: Plan view of the Primary Mees location for the ATST, Haleakala.

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).

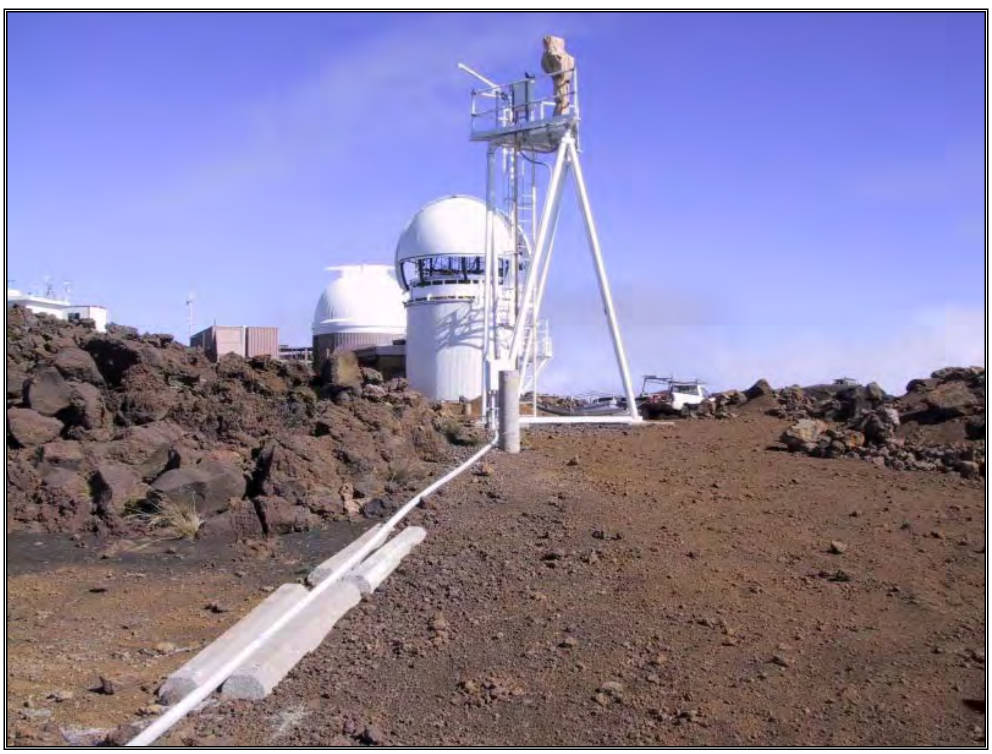


Photograph 4: View to the southwest of the data tower and weather tower (right), note push pile at left and construction materials at right; Mees Observatory is in the background.



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 4; 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 4). 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*.

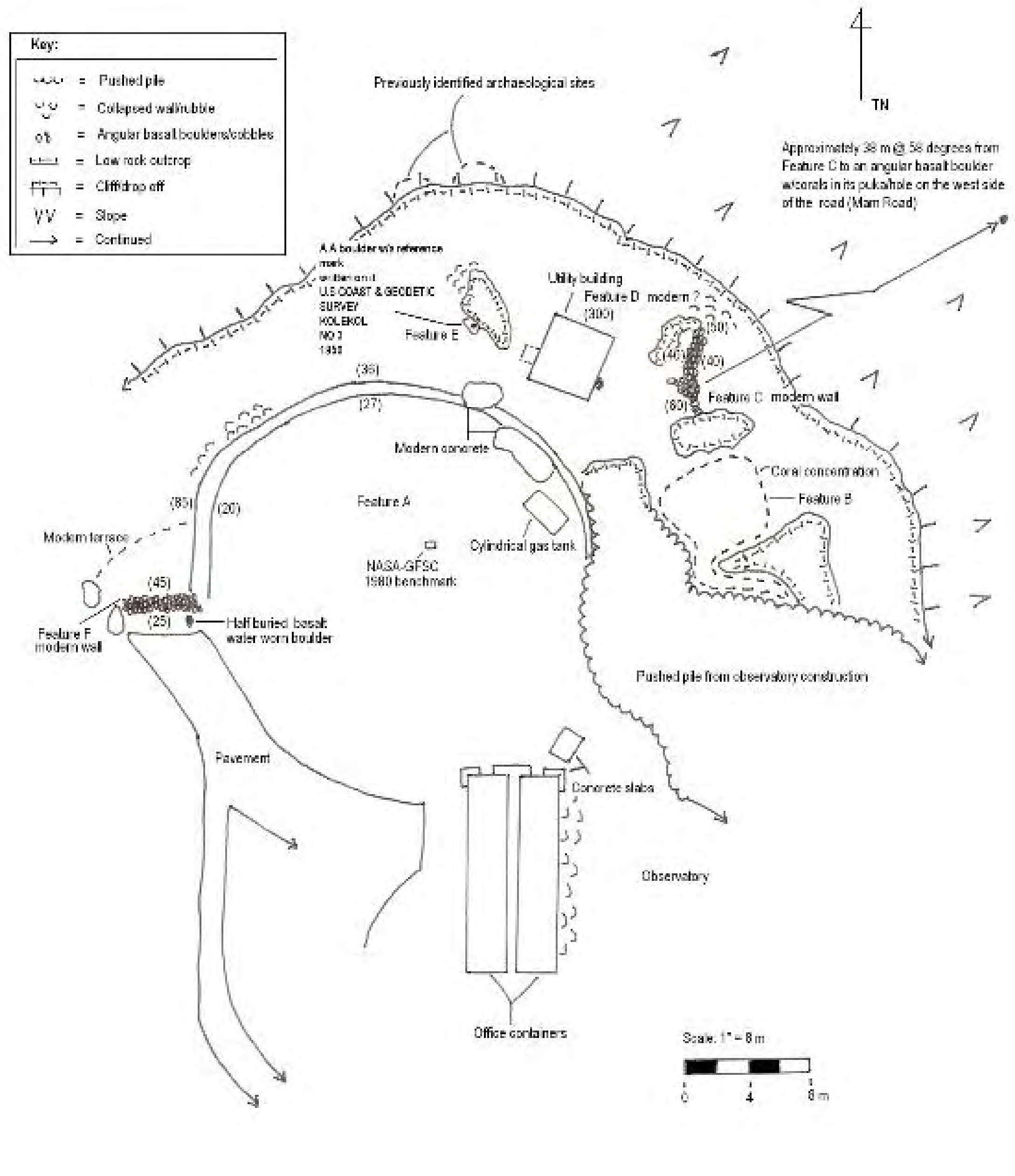


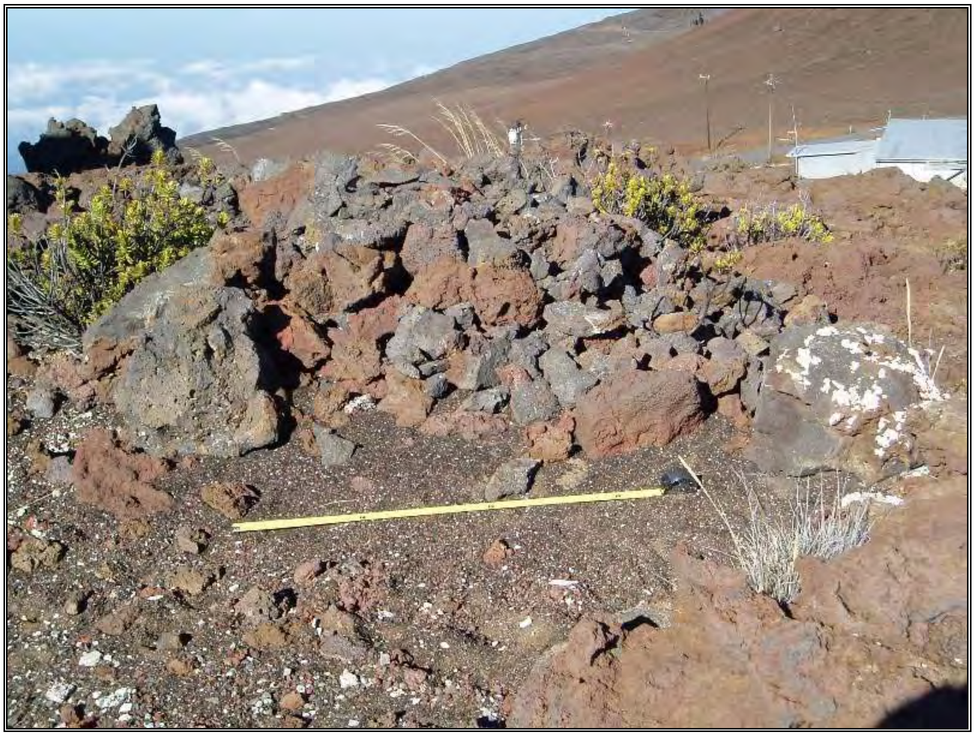
Figure 4: Plan view of Pu`u Kolekole with Reber Circle (Site 5443) and other features. Updated map prepared by Jonas Madeus in December 2005.

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 4 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 B

ARCHAEOLOGICAL RECOVERY PLANS

(1) Archaeological Data Recovery Plan for Site 50-50-11-5443 (Reber Circle), December 2005.

a. State of Hawaiʻi, Department of Land and Natural Resources (DLNR) approval letter sent to Erik Fredericksen, Xamanek Researches, regarding Data Recovery Plan for SIHP 50-50-11-5443 from Peter Young, Chair, State Historic Preservation Officer, dated June 14, 2006.

b. Archaeological Data Recovery Plan for Site 50-50-11-5443 18.1-acre parcel known as "Science City", Haleakalā Crater, Papaʻanui *Ahupuaʻa*, Makawao District, Maui Island (TMK: 2-2-07: portion of 8), December 2005.

(2) "Science City" Preservation Plan, March 2006.

a. State of Hawaiʻi, Department of Land and Natural Resources (DLNR) approval letter sent to Erik Fredericksen, Xamanek Researches, regarding Preservation Plan for Eleven Sites at Science City, from Peter Young, Chair, State Historic Preservation Officer, dated July 10, 2006.

b. Archaeological Preservation Plan for an 18-1-acre parcel known as "Science City", Haleakalā Crater, Papaʻanui *Ahupuaʻa*, Makawao District, Maui Island (TMK: 2-2-07: por. of 8).

APPENDIX B(1)

a. State of Hawai‘i, Department of Land and Natural Resources (DLNR) approval letter sent to Erik Fredericksen, Xamanek Researches, regarding Data Recovery Plan for SIHP 50-50-11-5443 from Peter Young, Chair, State Historic Preservation Officer, dated June 14, 2006.

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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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

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

APPENDIX B (1)

b. Archaeological Data Recovery Plan for Site 50-50-11-5443, 18.1-acre parcel known as “Science City”, Haleakalā Crater, Papa‘anui *Ahupua‘a*, Makawao District, Maui Island (TMK: 2-2-07: portion of 8), December 2005.

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

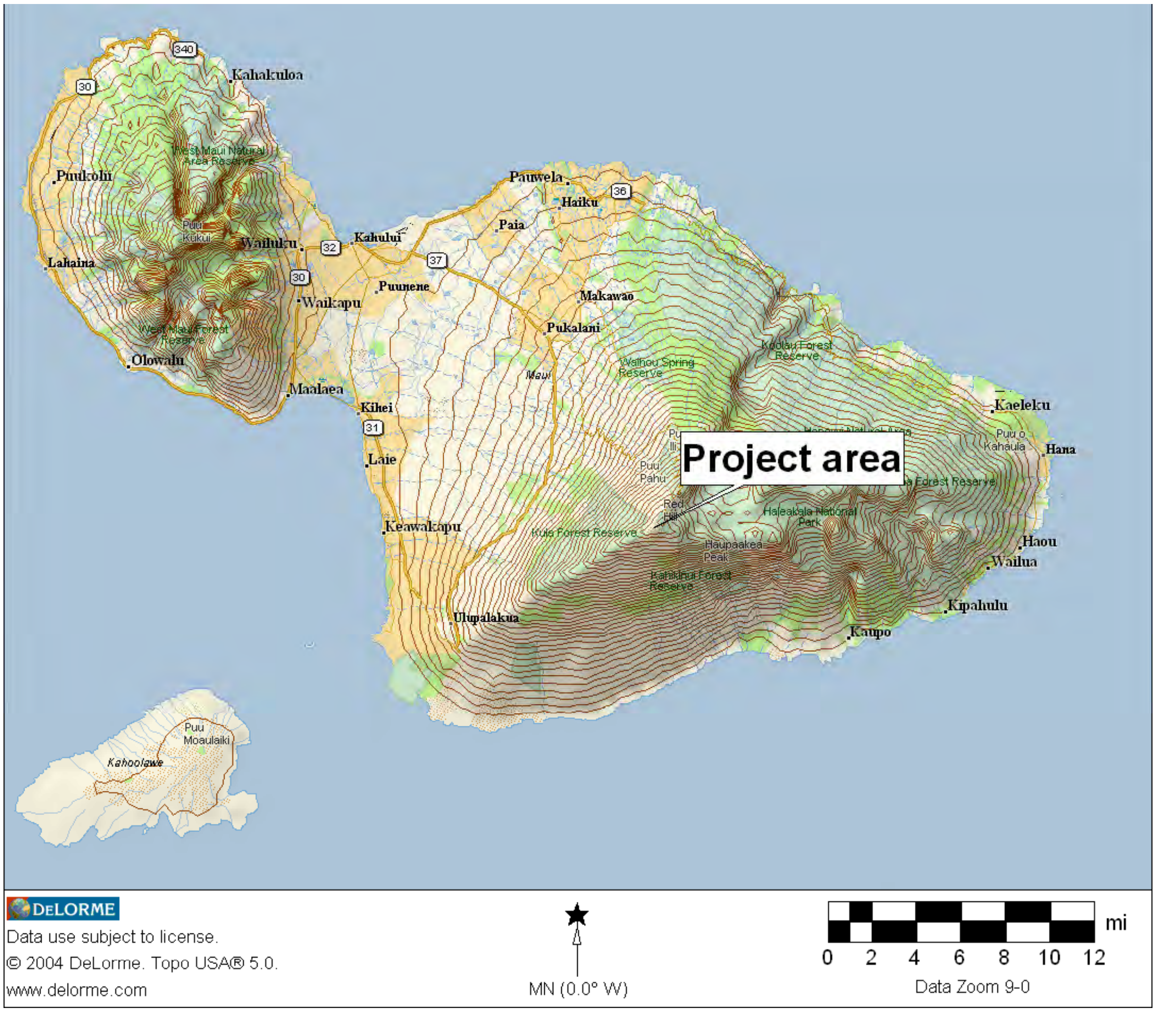


Figure 1: Location of the project area, Haleakala, Maui.

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.

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

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.

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]

---

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

[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.

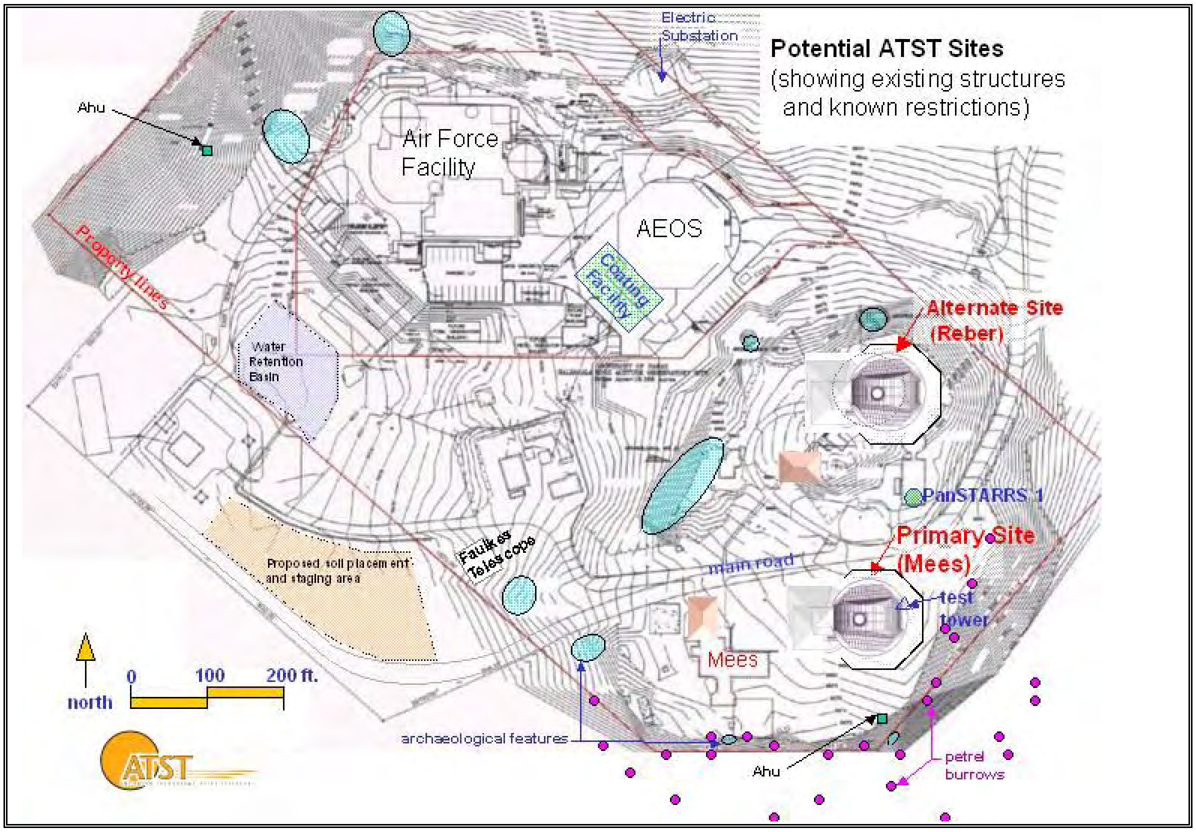
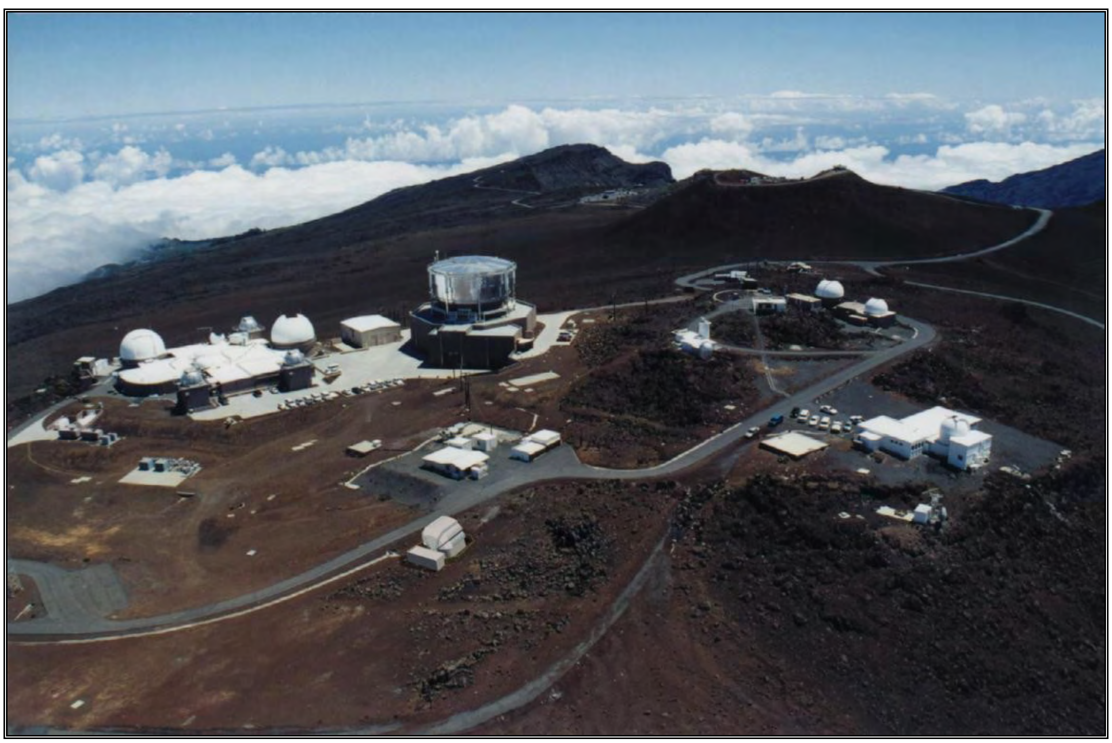


Figure 2: Potential ATST site location map, including alternate Reber Circle site.



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 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.

[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).

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).

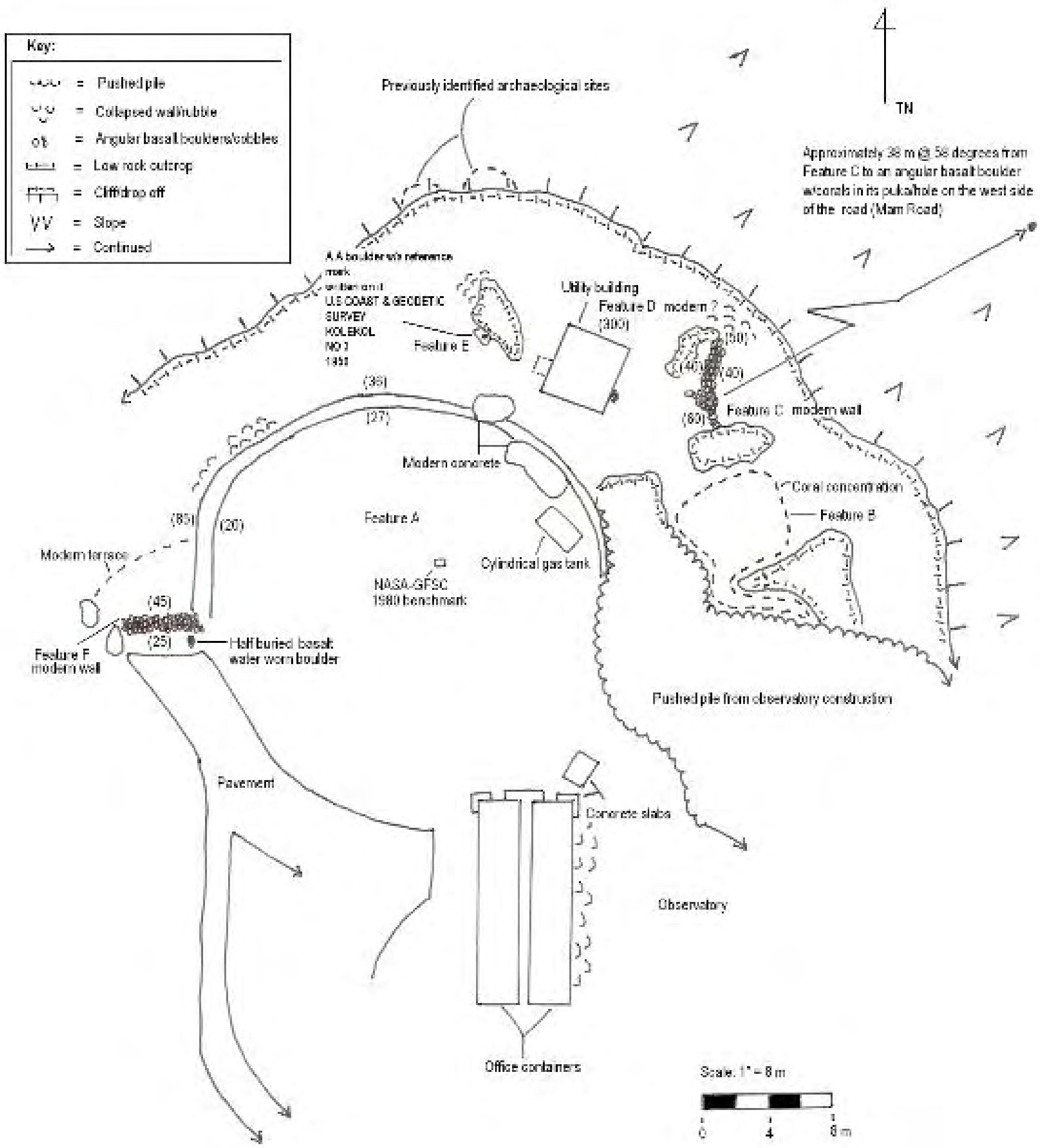


Figure 3: Plan view of Pu`u Kolekole with Reber Circle (Site 5443) and other features.
Updated map prepared by Jonas Madeus in December 2005.

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.

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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[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.

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APPENDIX B (2)

ARCHAEOLOGICAL RECOVERY PLANS

a. State of Hawaiʻi, Department of Land and Natural Resources (DLNR) approval letter sent to Erik Fredericksen, Xamanek Researches, regarding Preservation Plan for Eleven Sites at Science City, from Peter Young, Chair, State Historic Preservation Officer, dated July 10, 2006.

LINDA LINGLE
GOVERNOR OF HAWAII

PETER T. YOUNG
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

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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

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

APPENDIX B (2)

b. Archaeological Preservation Plan for an 18-1-acre parcel known as "Science City", Haleakalā Crater, Papa‘anui *Ahupua‘a*, Makawao District, Maui Island (TMK: 2-2-07: por. of 8).

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.

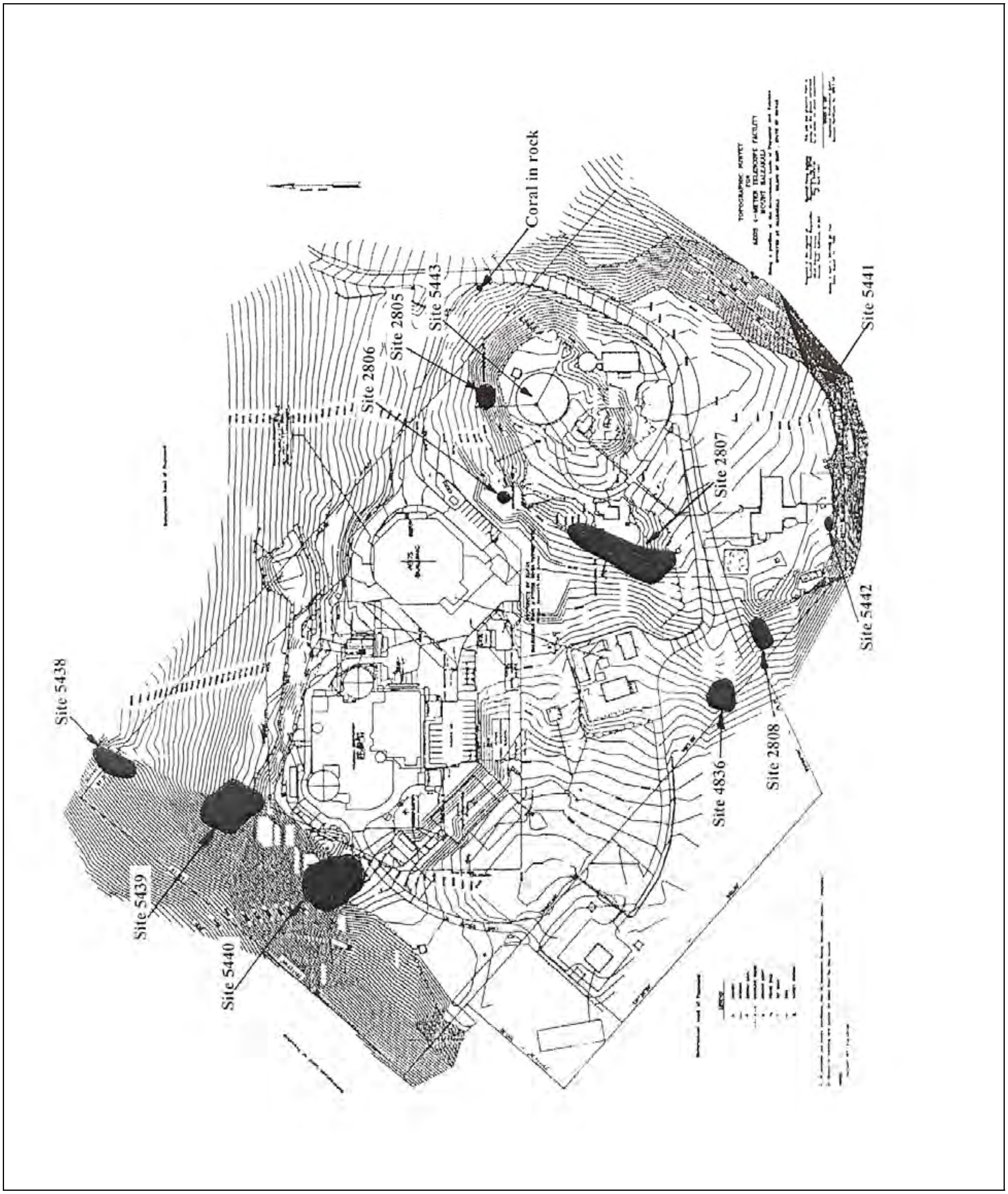

Figure 1: Plan view of the Science City project area with site locations.

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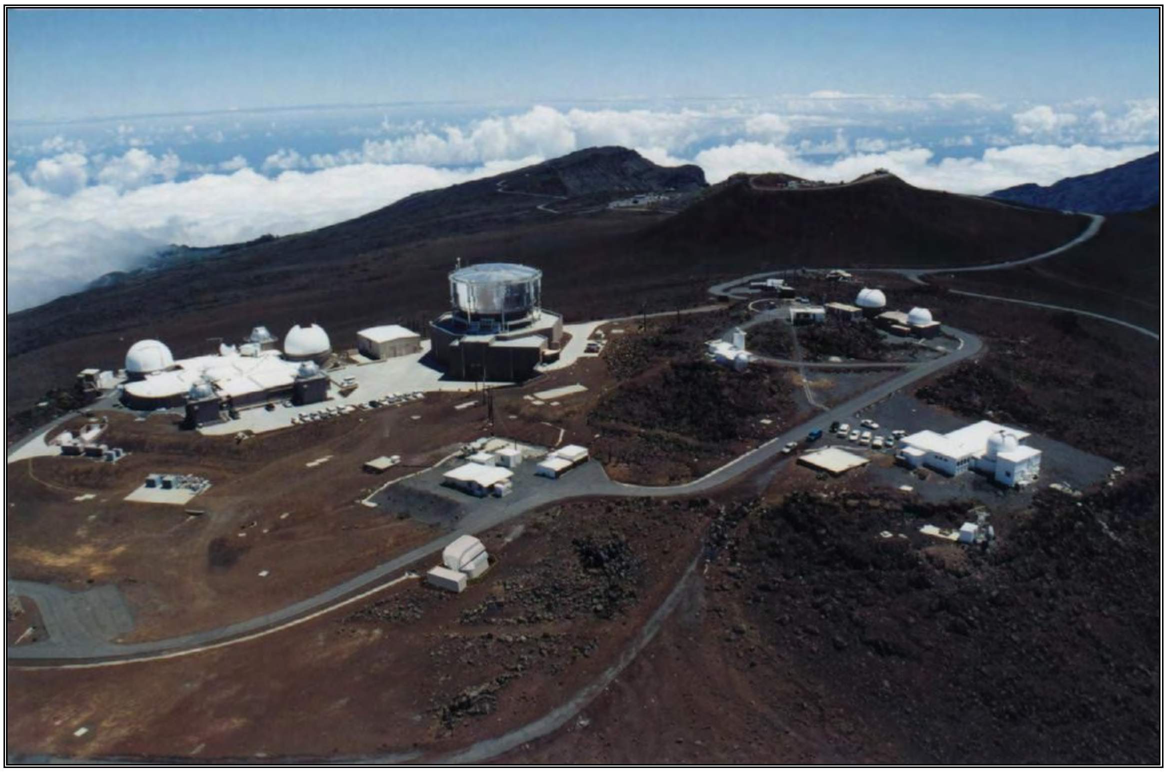
[6] SIHP = **S**tate **I**nventory of **H**istoric **P**roperties

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.

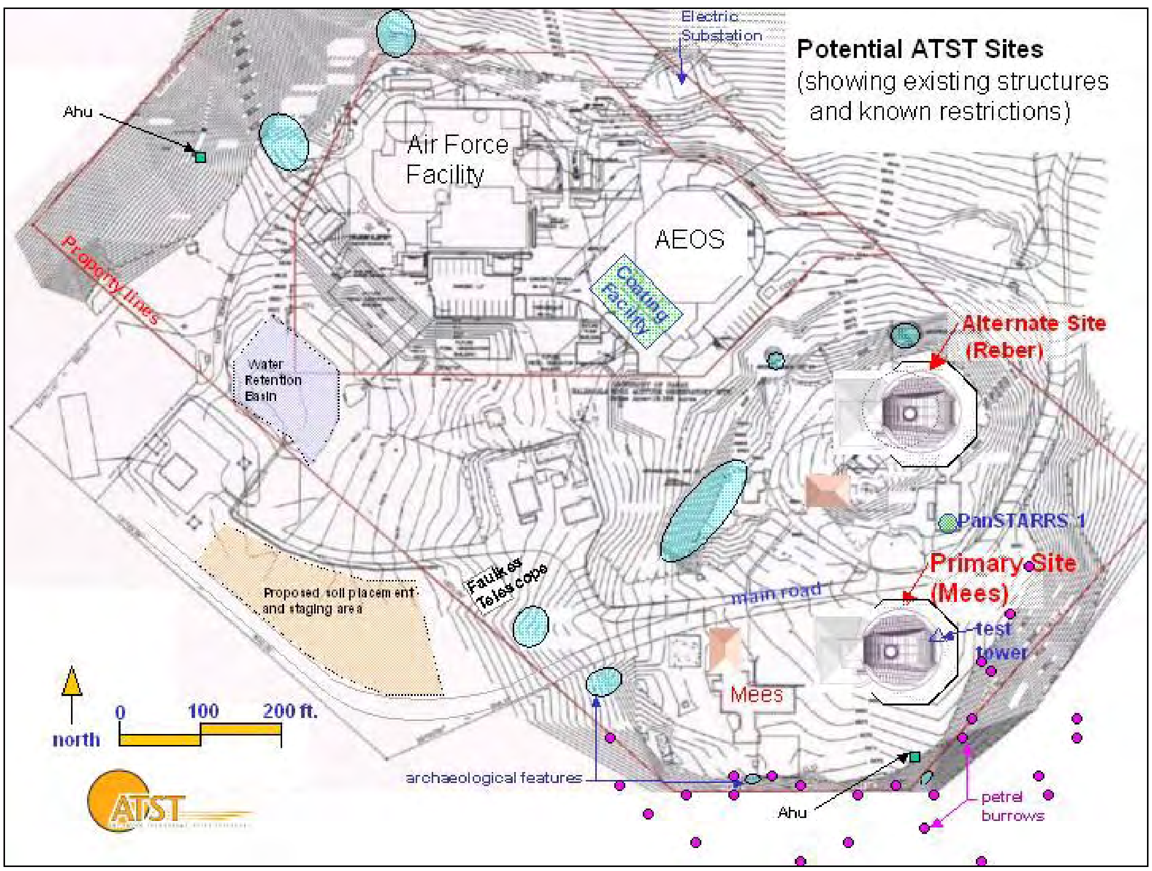


Figure 2: Potential ATST site location map, including approximate locations of identified cultural resources.

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.

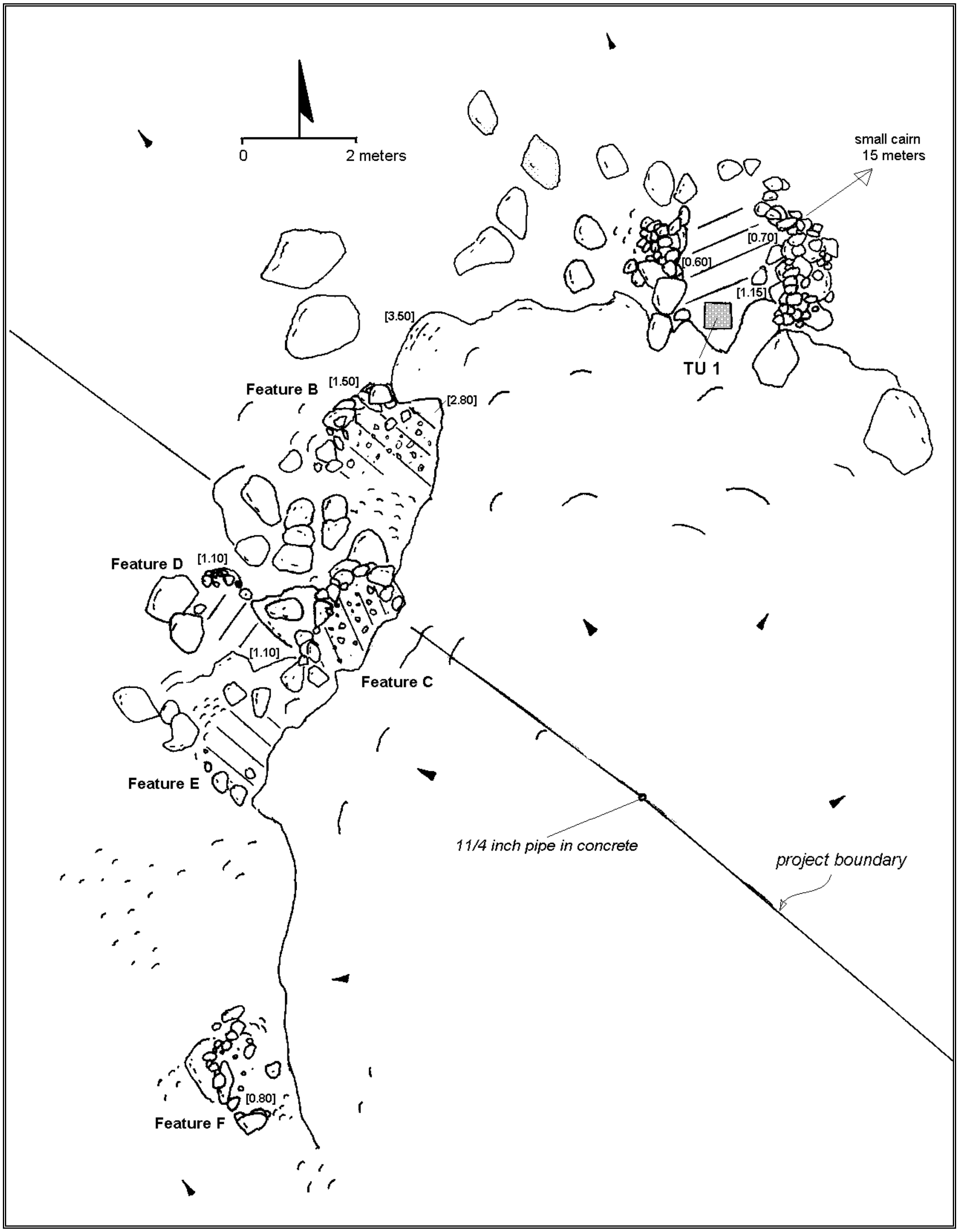


Figure 3 – Plan view of Site 5438.

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.

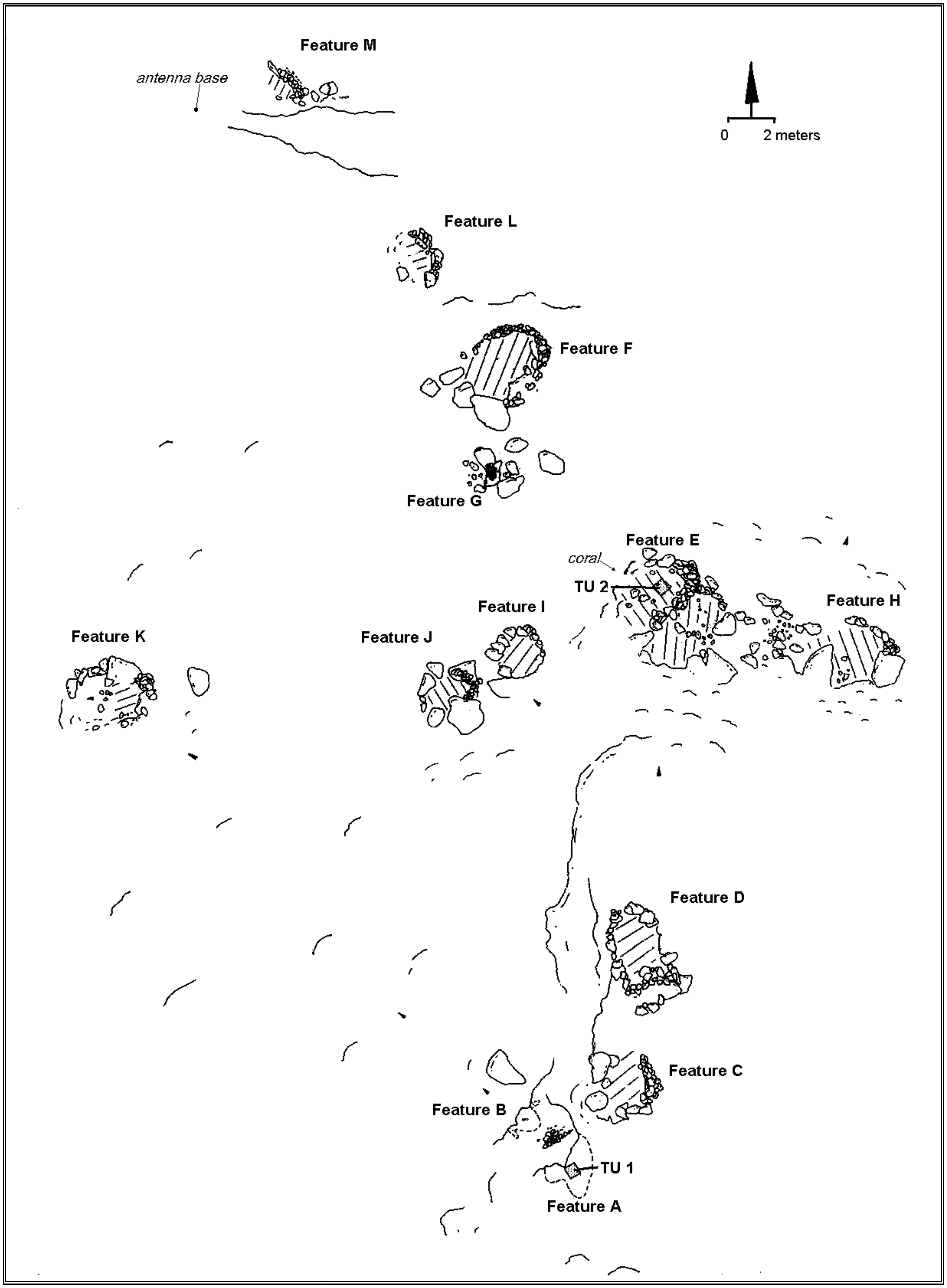


Figure 4 - Plan view of Site 5439.

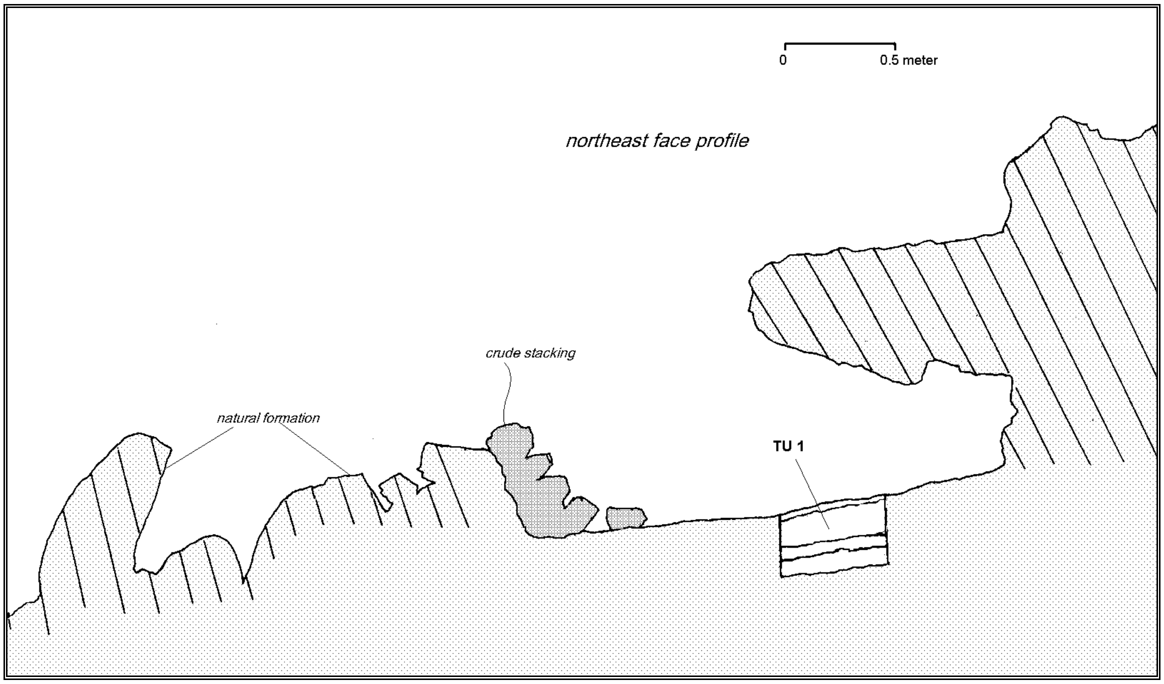


Figure 5 – Northeast face profile of Feature A, Site 5439—showing TU 1.

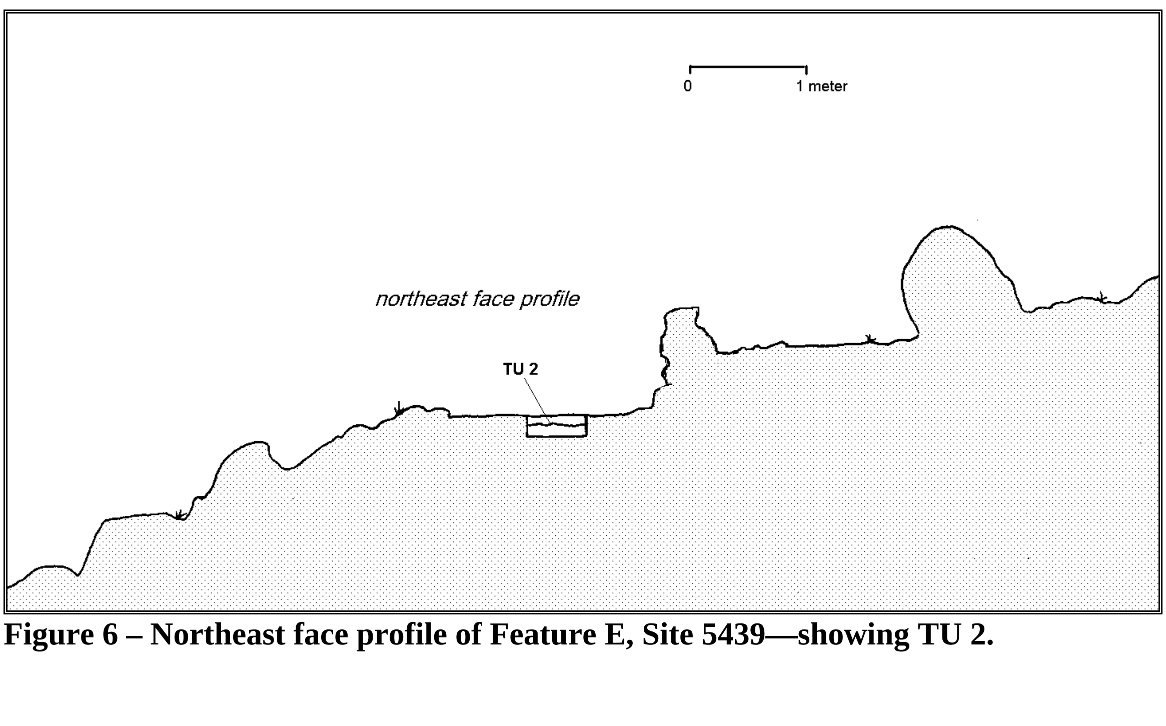


Figure 6 – Northeast face profile of Feature E, Site 5439—showing TU 2.

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.

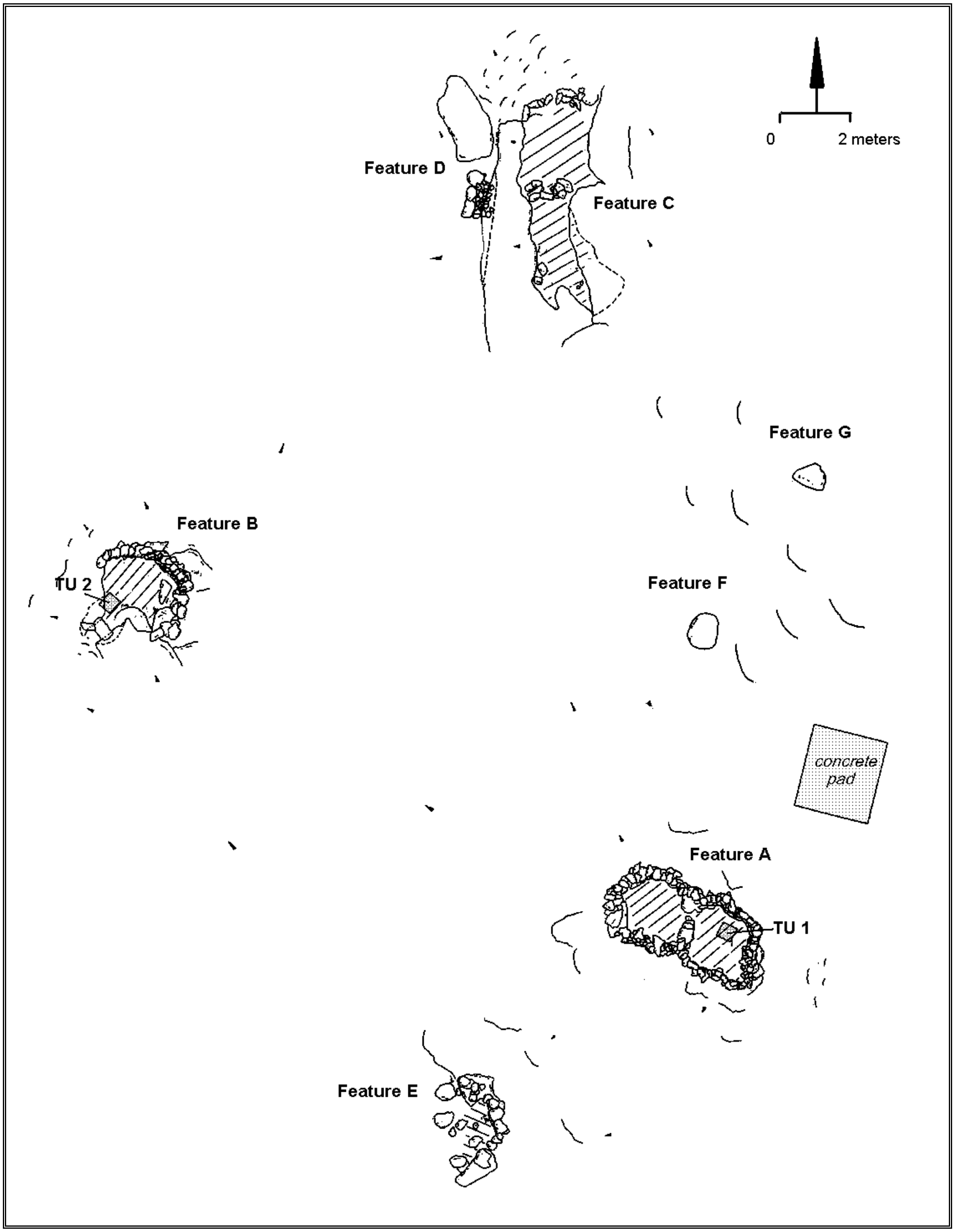


Figure 7 – Plan view of Site 5440.

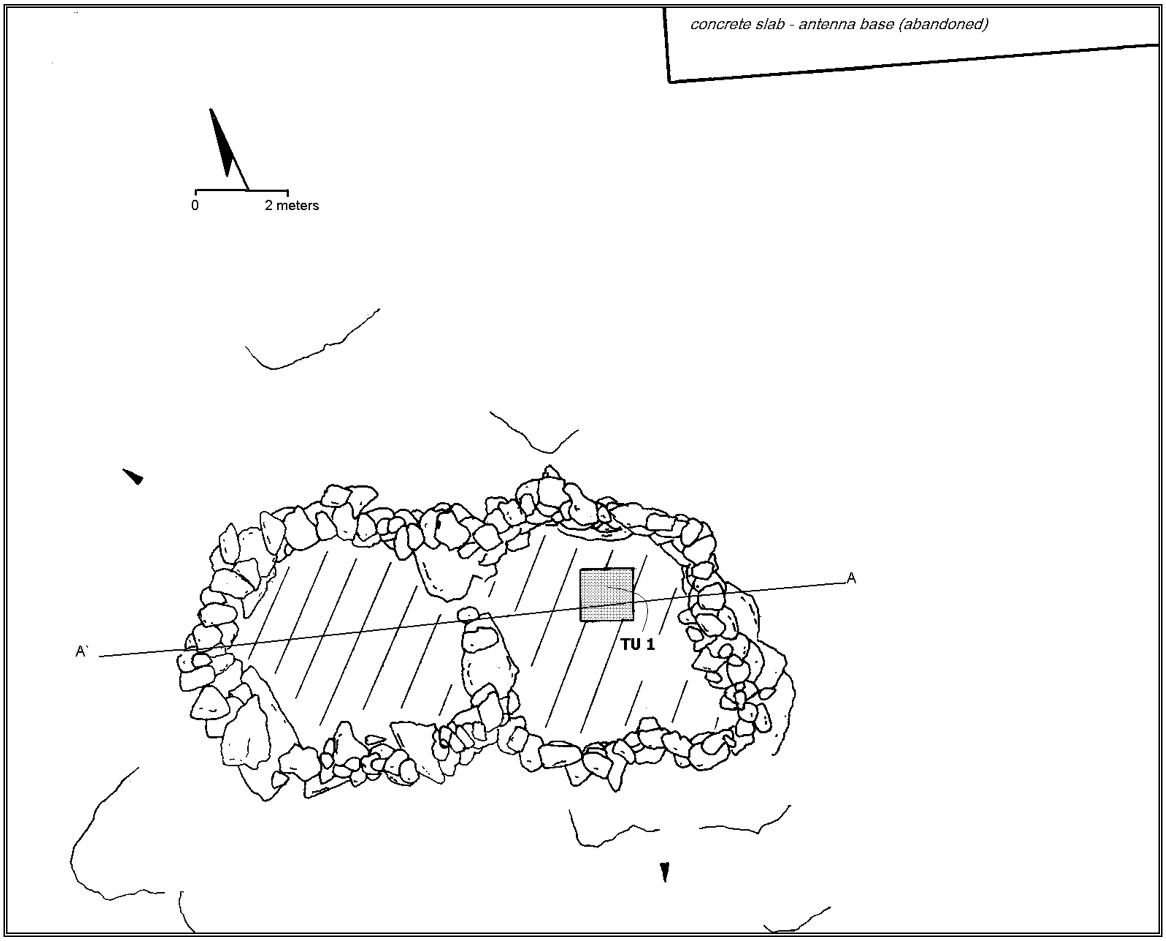


Figure 8 – Plan view of Feature A, Site 5440.

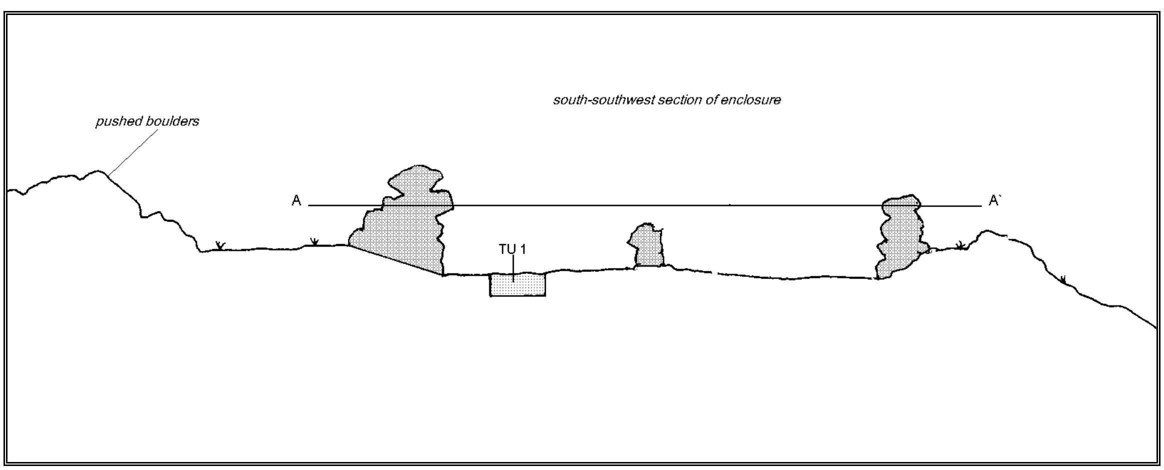


Figure 9 – South-southwest profile of Feature A, Site 5440.

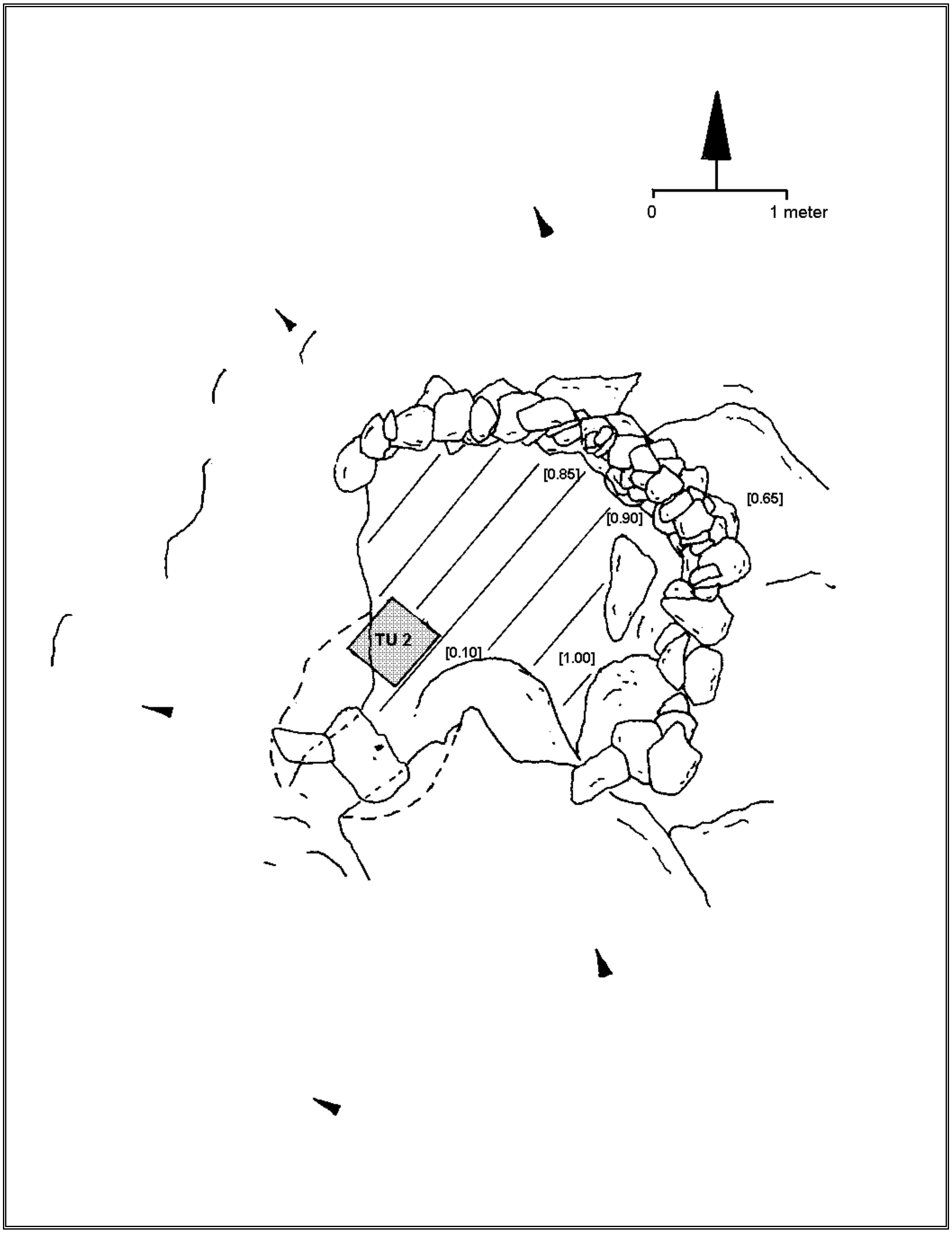


Figure 10 – Plan view of Feature B, Site 5440.

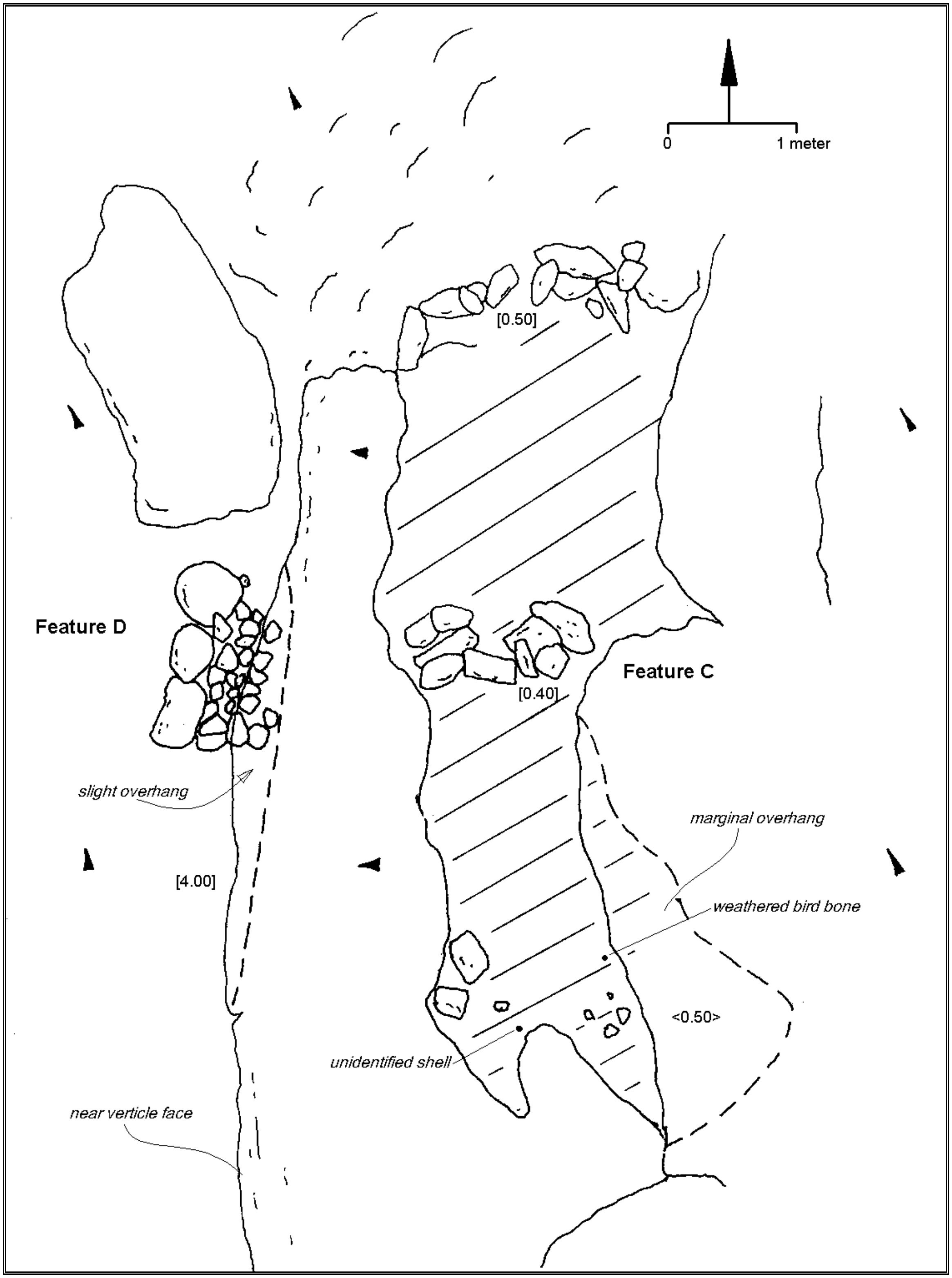


Figure 11 – Plan view of Features C and D, Site 5440.

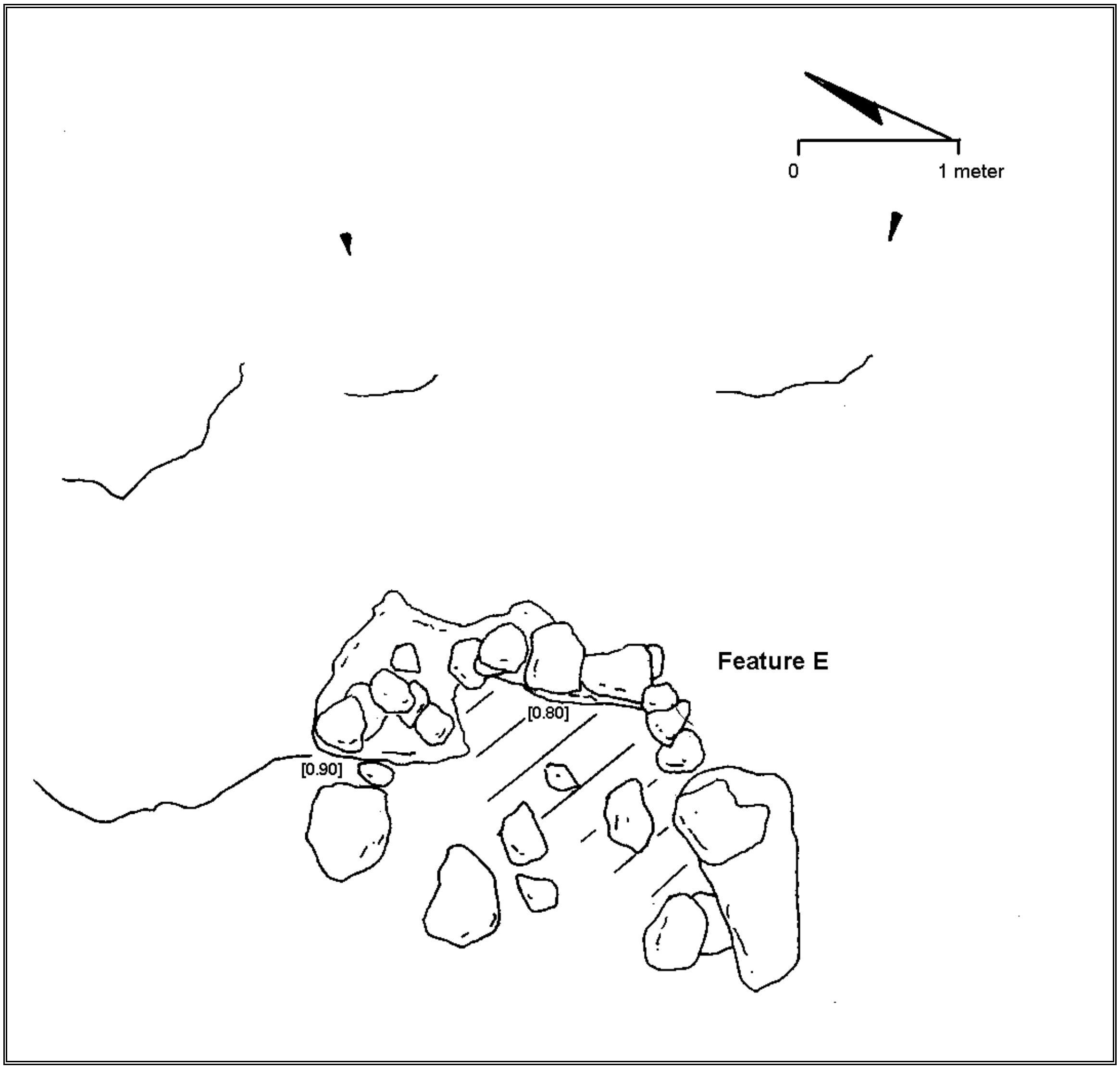


Figure 12 - Plan view of Feature E, Site 5440.

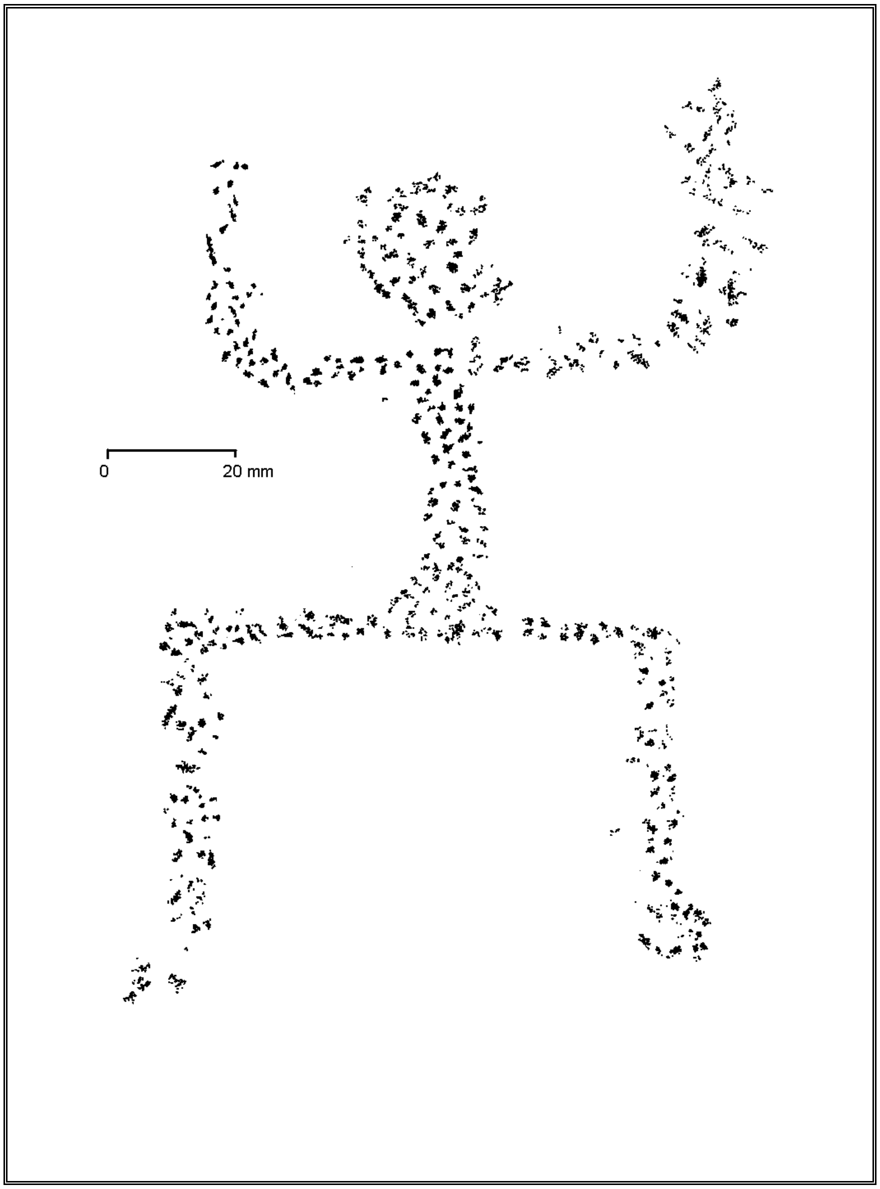


Figure 13 - Drawing of Feature F petroglyph, Site 5440.

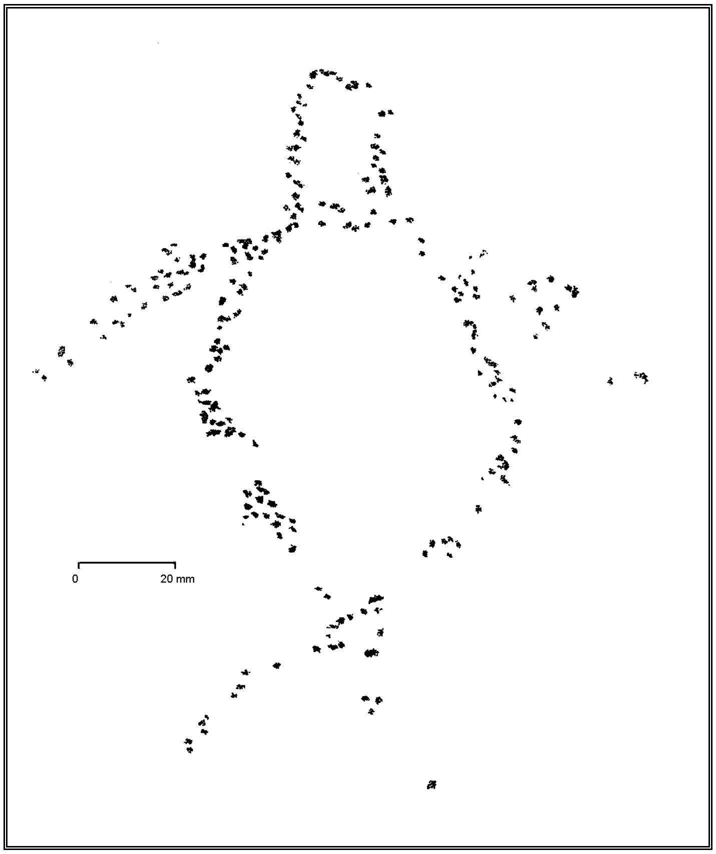


Figure 14 – Drawing of Feature G petroglyph, Site 5440.

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.

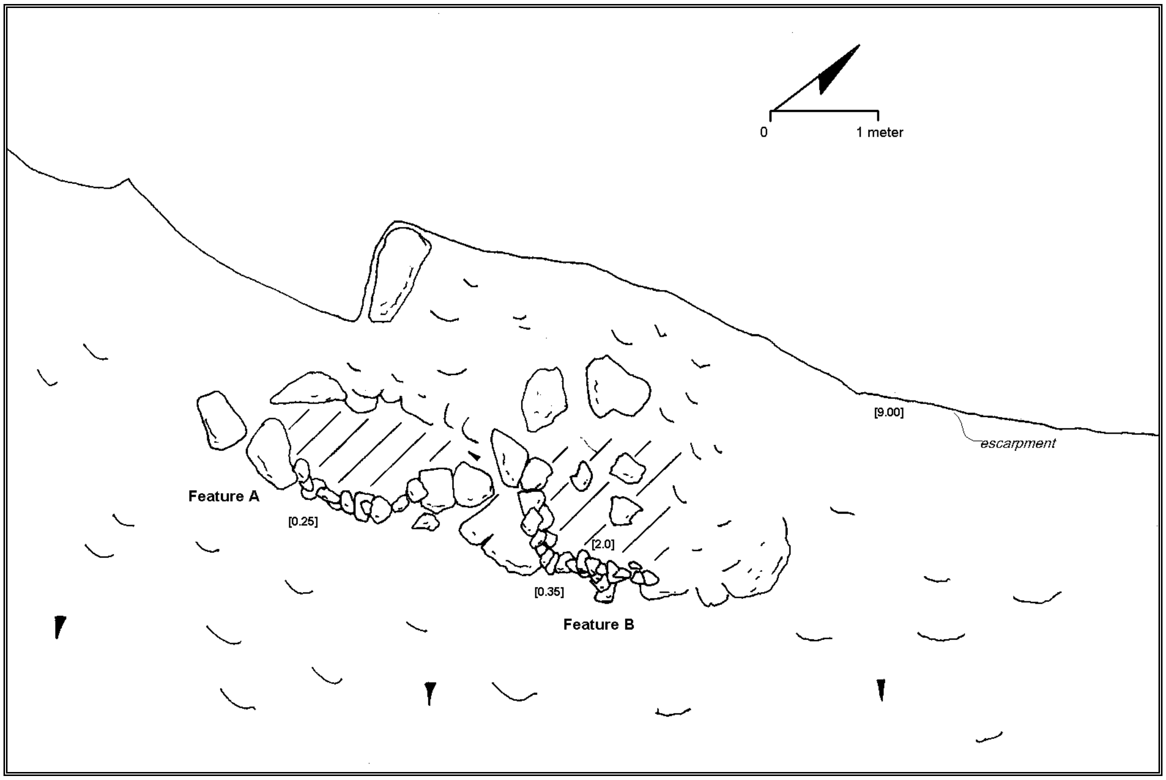


Figure 15 – Plan view of Site 5441.

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.

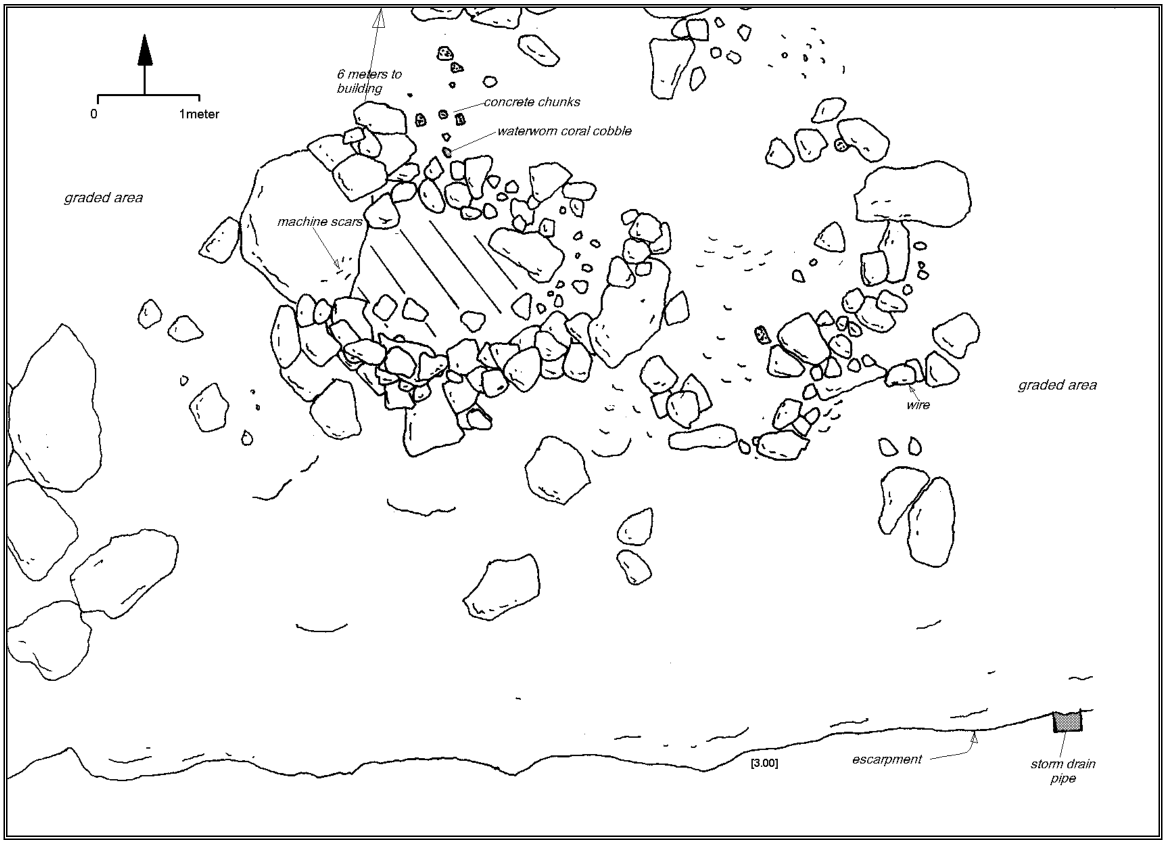


Figure 16 – Plan view of Site 5442.

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.

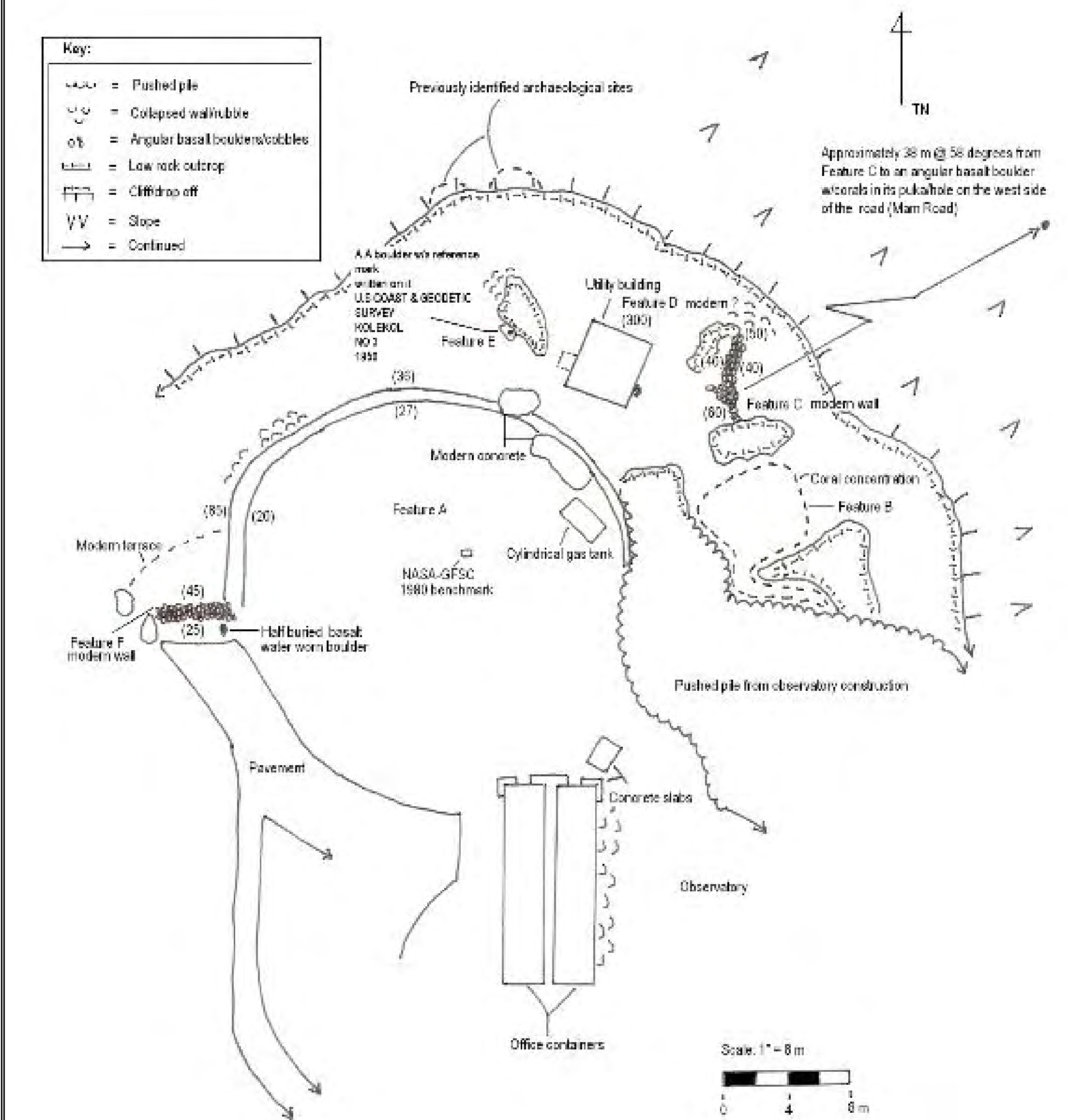


Figure 17 - Plan view of Site 5443.

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.

[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.

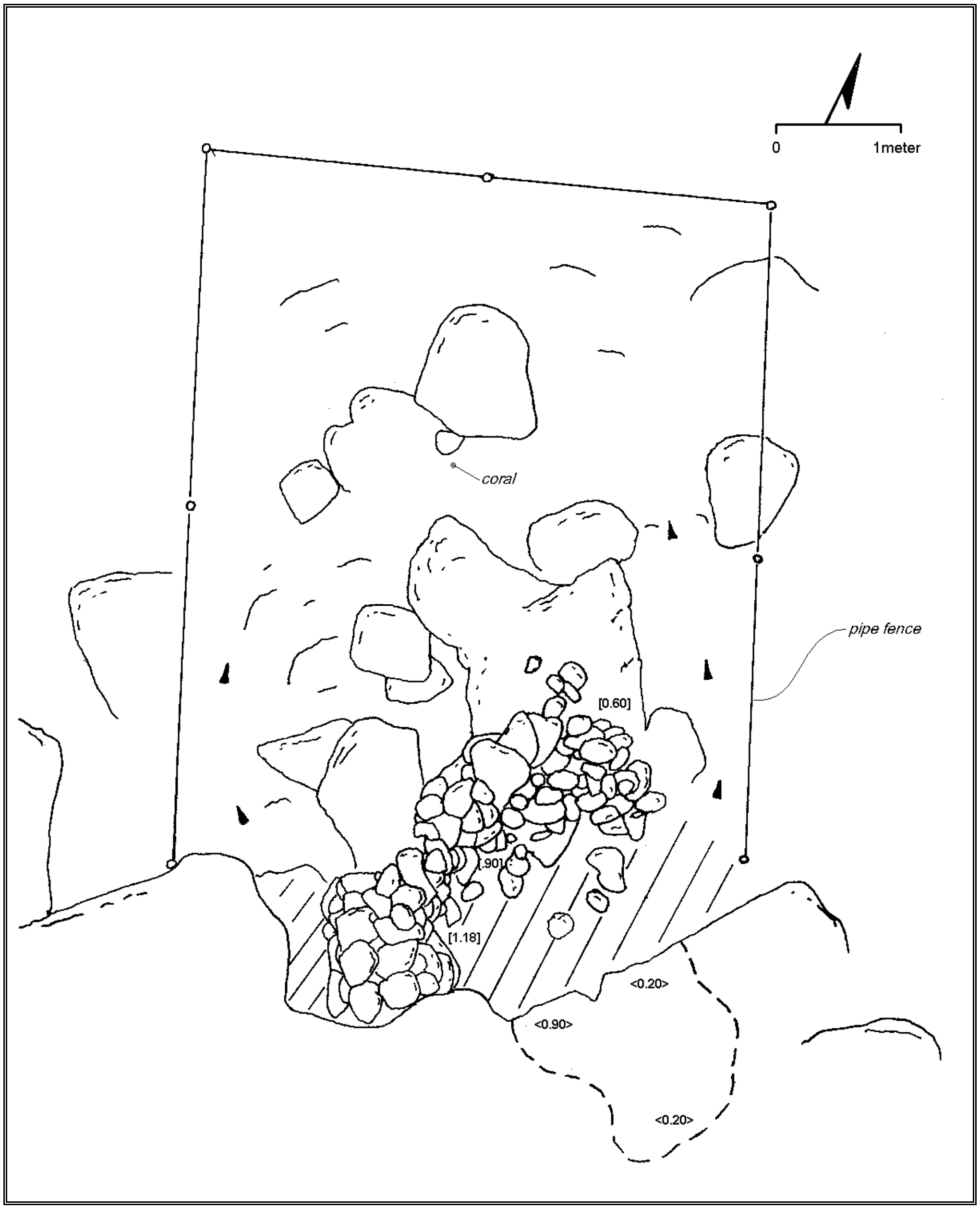


Figure 18 – Plan view of Site 2805.

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.

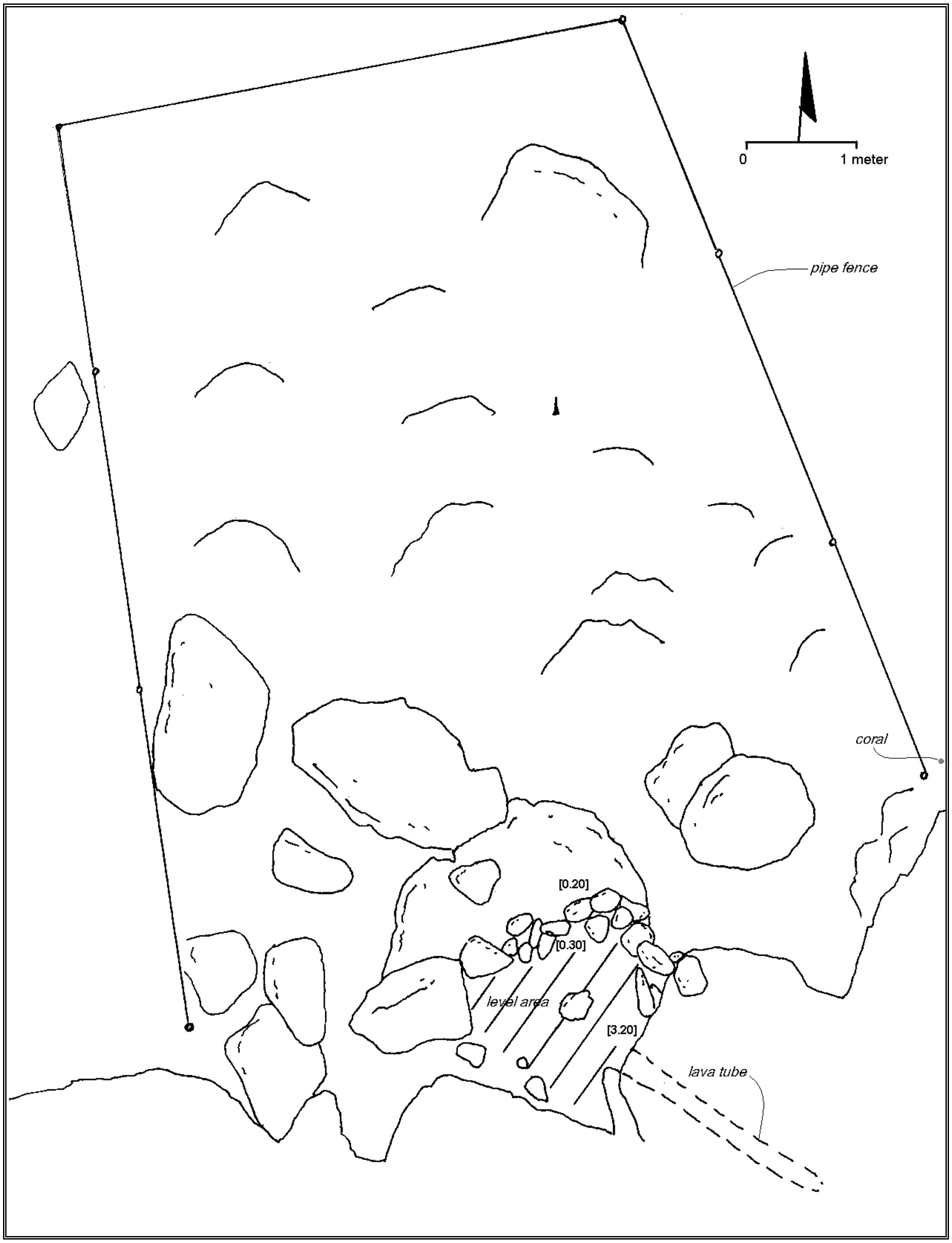


Figure 19 – Plan view of Site 2806.

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.

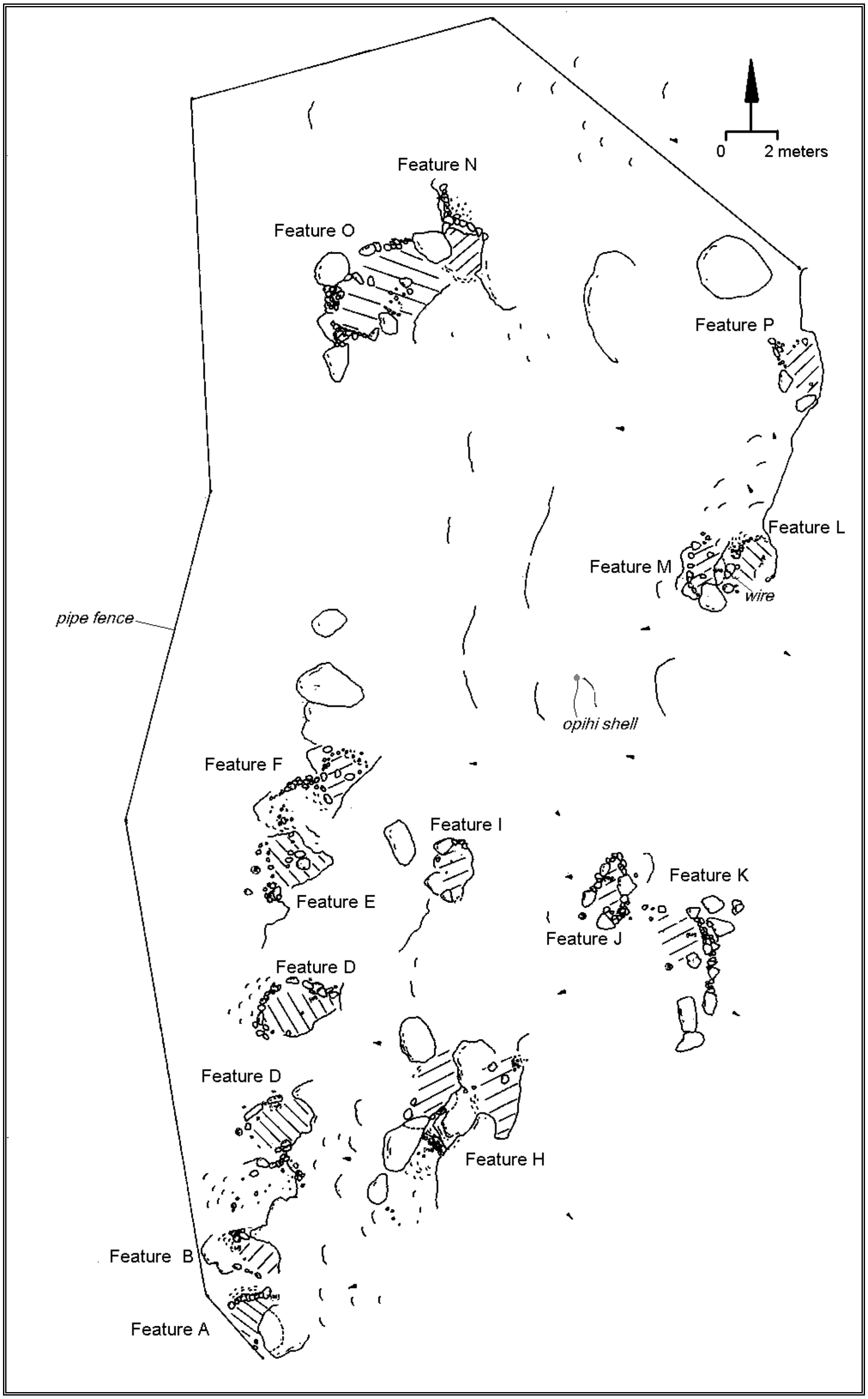


Figure 20 - Plan view of Site 2807.

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.

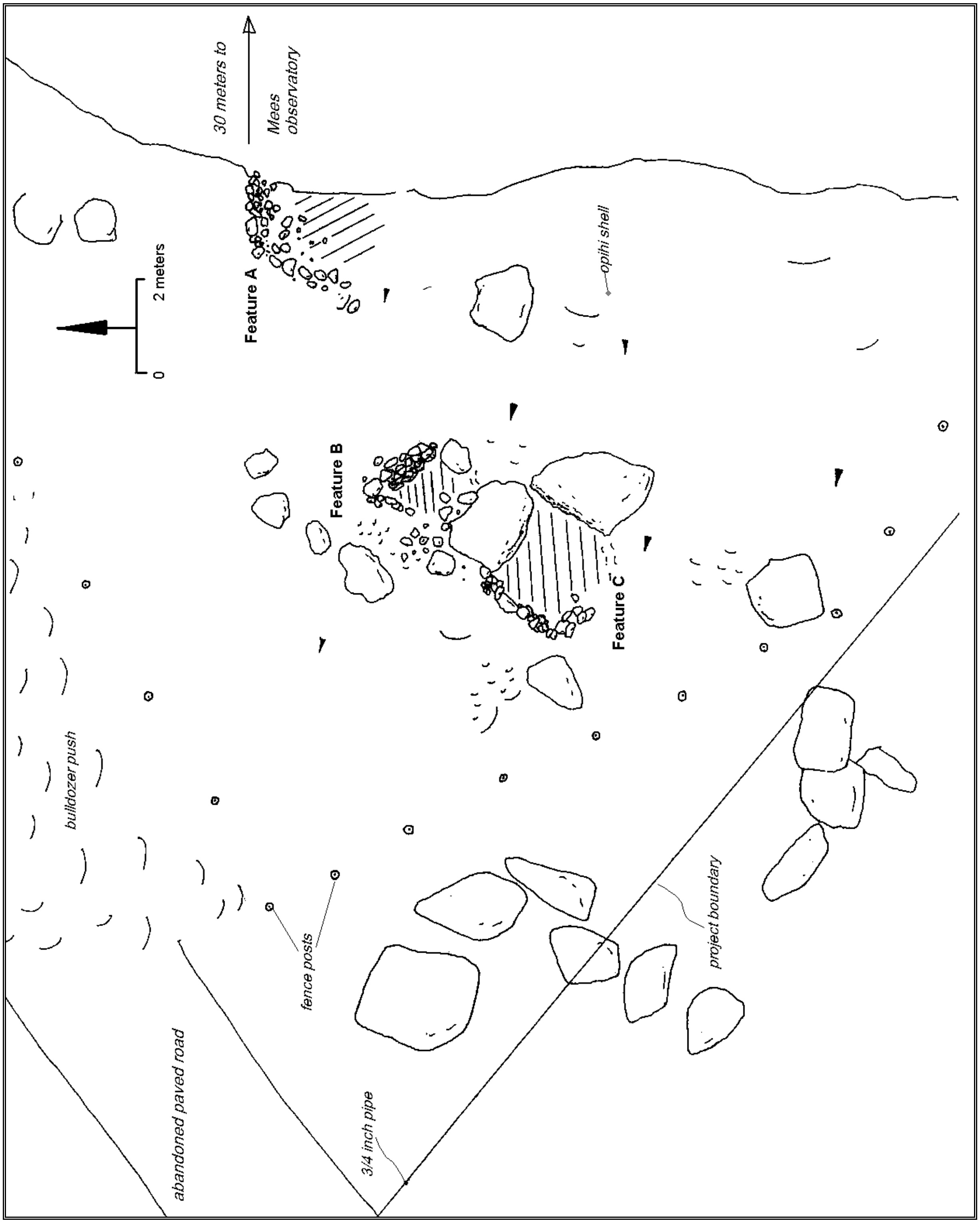


Figure 21 – Plan view of Site 2808.

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.

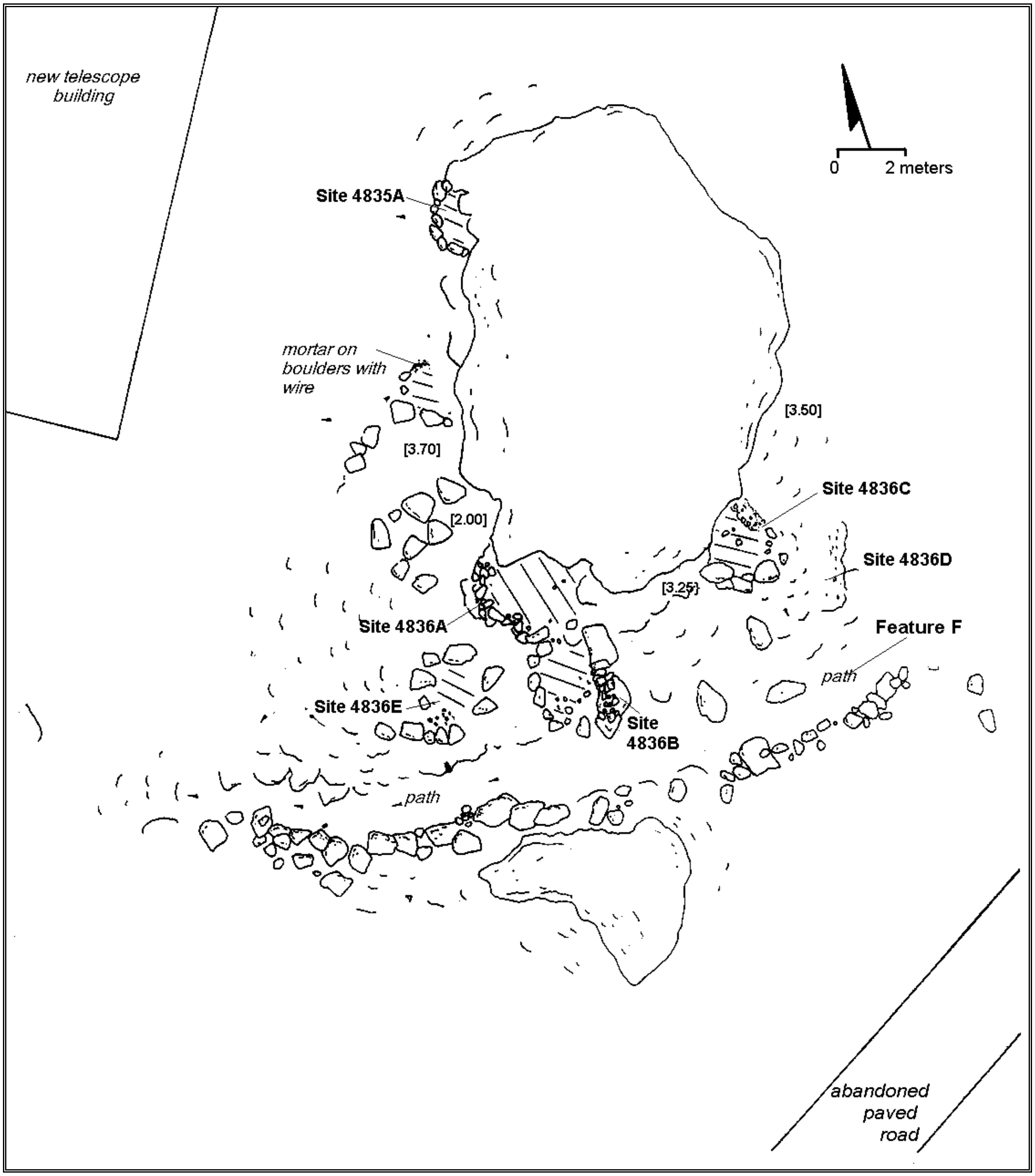

Figure 22 – Plan view of Sites 4835 and 4836 (including Feature F path of Site 4836).

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 recommended 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.

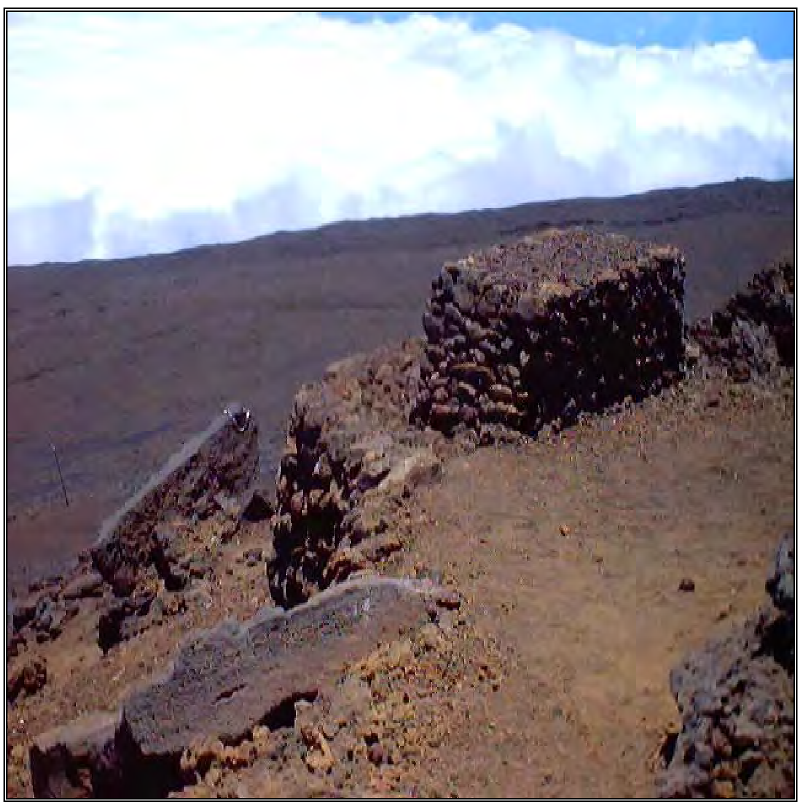
Signage

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).

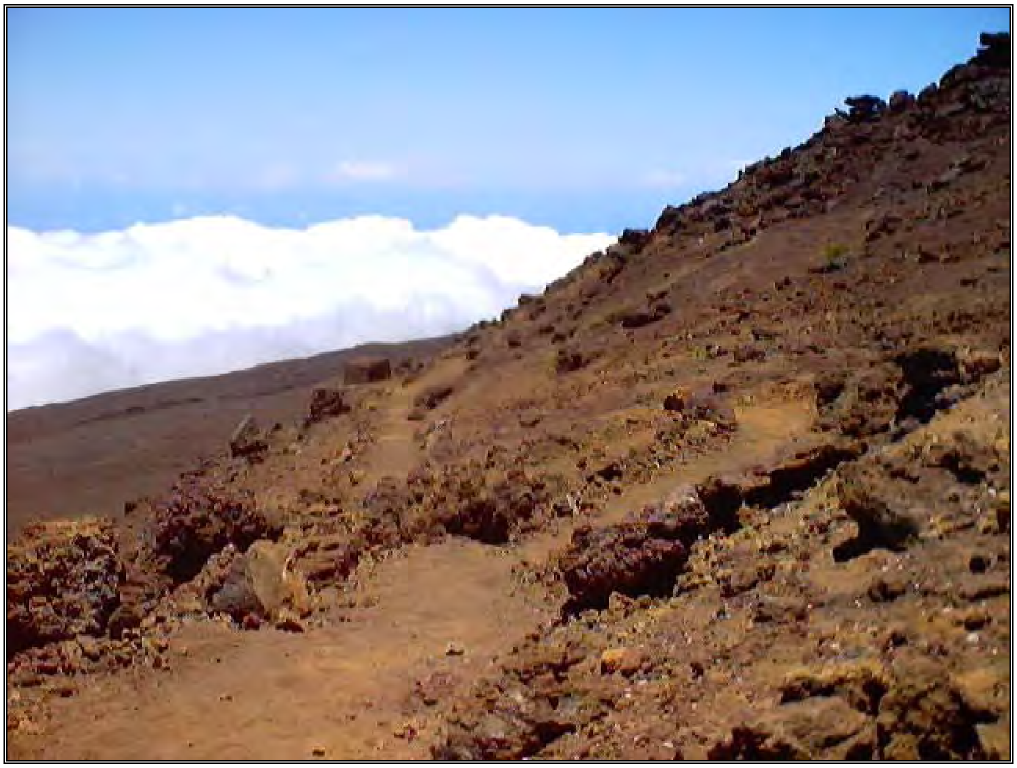
Placement of two *Ahu*

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 C

(1) UPDATED ARTHROPOD INVENTORY AND ASSESSMENT, DECEMBER 2005

(2) SUPPLEMENTAL ARTHROPOD SAMPLING, MARCH 2007

(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

Prepared for

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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.

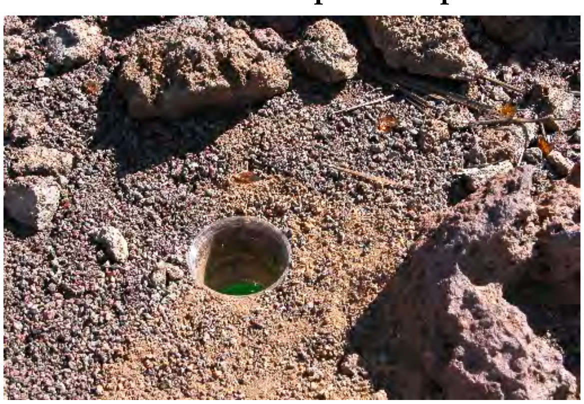
Setting an Ethylene Glycol Pitfall Trap

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

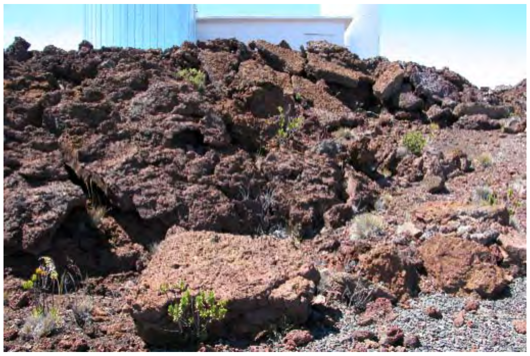


Step 5
Pour in 15 ml of Ethylene glycol

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.



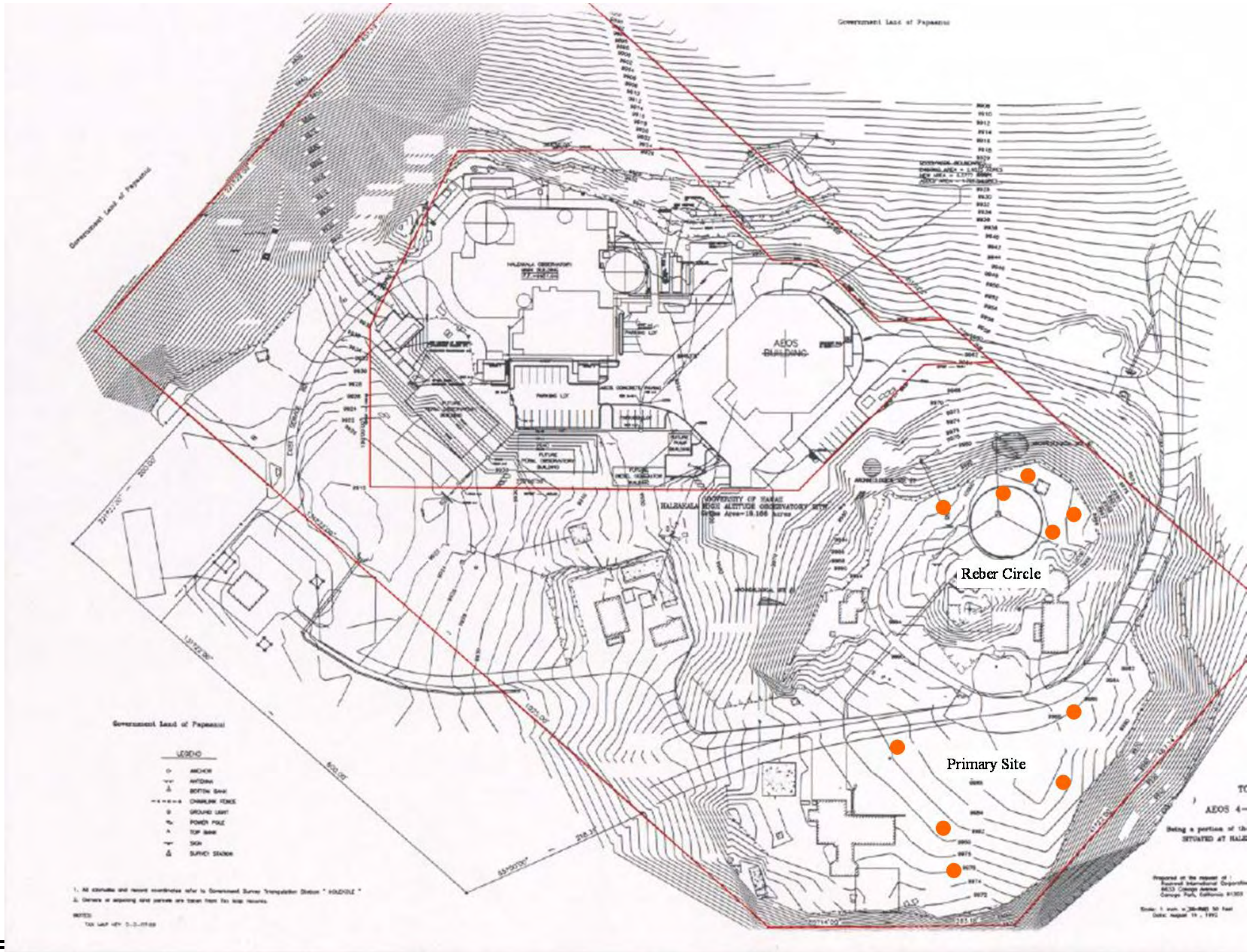
Aa flow near Reber Circle forms a rocky cliff face.

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.



METHODS

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.

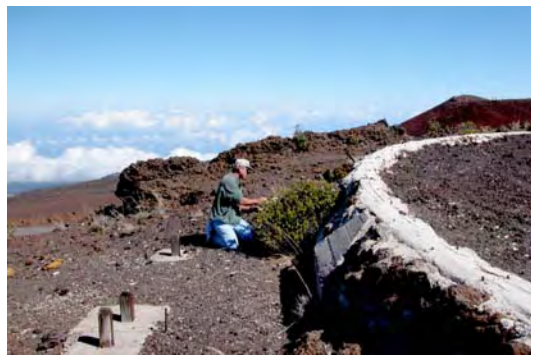
Sensitive Nesting Sites

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 Hawaiʻi, 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 Hawaiʻi, 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 Hawaiʻi. There are 1,983 species of beetles reported in Hawaiʻi (Nishida 1997), 544 on Maui (B.P. Bishop Museum 2002).

Five species of beetles were found during this study, one endemic to Hawaiʻi. 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).

Carabidae – Ground Beetles

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 Hawaiʻi , 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 Hawaiʻi, 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 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 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 Hawai'i, 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 Hawai'i.

Bees and wasps are common in Hawai'i. There are 1,270 species that occur in Hawai'i. Of these species, 652 are endemic to Hawai'i 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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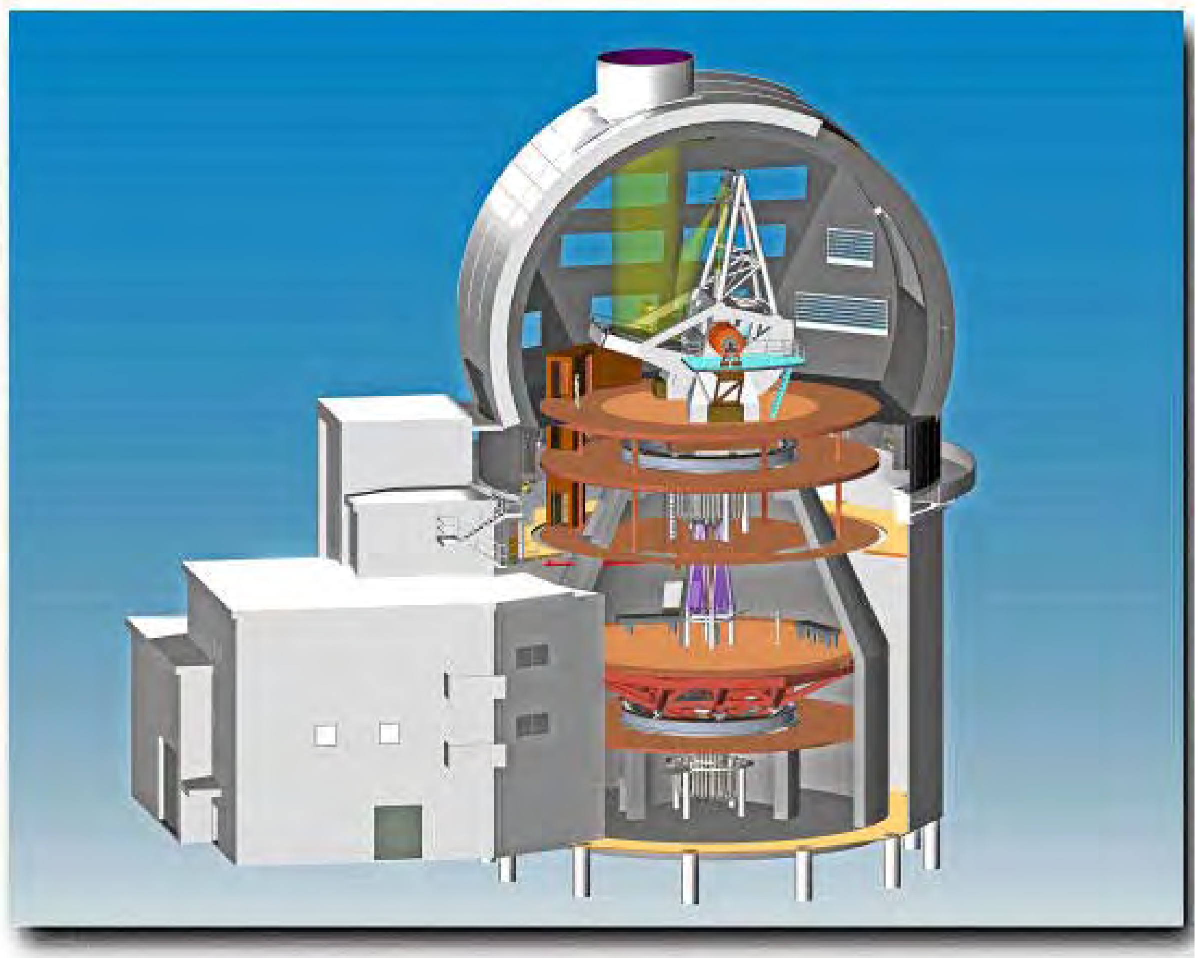
APPENDIX D

ATST HAZARDOUS MATERIAL AND HAZARDOUS WASTE MANAGEMENT PROGRAM

Project Documentation
SPEC-0035
Revision A

ATST Hazardous Material and Hazardous Waste Management Program



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APPENDIX D:
ATST HAZARDOUS MATERIAL AND
HAZARDOUS WASTE MANAGEMENT PROGRAM

REVISION SUMMARY:

1. Date: 13 April 2006
   Revision: A
   Changes: Initial Release

Table of Contents

1. INTRODUCTION

Personnel working at the ATST facility on Haleakalā are expected to be environmentally responsible. This will include sensitivity to the special nature of the mountain to Native Hawaiians, and also adherence to applicable regulations for the handling and disposal of all potentially hazardous materials. In regard to statutory requirements, it is AURA's intention to maintain the U.S. Environmental Protection Agency (EPA) status of a "Conditionally Exempt Small Quantity Generator" (CESQG) throughout the construction and operation of the Advanced Technology Solar Telescope (ATST) The EPA does not mandate that a CESQG facility have a written Hazardous Material and Hazardous Waste Management Program or the requisite recordkeeping that accompanies such a program. This document is considered necessary, however, to ensure protection of the uniquely sensitive environment on Haleakalā. Though it is primarily intended to be an operational policy manual, this document also provides information that may be useful for evaluating the potential environmental impact of the ATST facility.

This program outlines AURA's requirements for the management of hazardous materials, the disposal of hazardous waste, and other wastes at ATST facilities on Haleakalā. These requirements are based on Federal, State and County regulations. Failure to comply with these requirements may subject AURA and/or individuals to fines and civil or criminal prosecution. Additionally, proper management of hazardous materials and other waste reduces disposal costs.

2. RESPONSIBLE PERSONNEL

2.1 REQUIREMENTS FOR ALL ATST PERSONNEL:

- Become familiar with the hazardous materials in their area and the requirements of this hazardous material and hazardous waste management program.
- Use the *ATST PROCUREMENT AND USE AUTHORIZATION OF HAZARDOUS MATERIALS* form (Attachment 1) to obtain approval for the purchase and use of a hazardous material.
- Provide a monthly inventory of hazardous wastes (Attachment 2) to the ATST Site Manager.
- Store and label hazardous materials and waste properly.
- Contact the ATST Site Manager or the AURA Risk Management Specialist to clarify requirements of this program or about how to properly dispose of waste.

2.2 DESIGNATED PROGRAM COORDINATOR

The ATST Site Manager is responsible for overall coordination of Hazardous Materials, Hazardous Waste Management and other wastes as detailed in this Program. The ATST Site Manager may designate other personnel to manage certain requirements as detailed in this program.

3. HAZARDOUS MATERIAL MANAGEMENT

3.1 TRAINING

The ATST Site Manager shall attend an initial Resource Conservation and Recovery Act (RCRA) training class and thereafter an RCRA annual refresher. (Note: RCRA training is not required for CESQG's locations, however it is a requirement established by AURA to ensure that the ATST Site Manager understands the requirements of hazardous waste management and regulations.)

ATST personnel shall attend Hazardous Material and Hazardous Waste Management awareness training with emphasis on the requirements of this program. Those that work with hazardous materials shall have OSHA - Right to Know training.

3.2 Authorization to Purchase Chemicals and/or Hazardous Materials

Approval by the ATST Site Manager is required for the purchase and use of all chemicals and/or hazardous materials. The *ATST PROCUREMENT AND USE AUTHORIZATION OF HAZARDOUS MATERIALS* form (Attachment 1) shall be completed and submitted to ATST Site Manager at least two weeks before a purchase order for the hazardous material(s) is initiated. If approved, a copy of the form will be provided to the requestor for attachment to the purchase order or requisition. The purpose of the approval is to ensure the safe storage, handling, and eventual disposal of the material.

4. INVENTORY CONTROL PROCEDURES

4.1 Hazardous Waste Storage Area Inspection

The ATST Site Manager shall conduct a weekly inspection of the area where hazardous wastes are stored, to ensure that containers are in good condition, properly labeled and there is no leakage.

4.2 Monthly Inventory of Hazardous Wastes

The ATST Site Manager is required to complete the *ATST MONTHLY HAZARDOUS WASTE INVENTORY FORM* (Attachment 2). The waste inventory is designed to monitor usage, prevent unnecessary accumulation and to help ensure that hazardous waste does not exceed accumulation limits, thus subjecting ATST to more stringent RCRA regulations.

4.3 Inventory of Special Wastes

While certain wastes are not hazardous, they also cannot be disposed of in a sanitary landfill or down the drain, and may necessitate special disposal procedures. These non-hazardous wastes should be included in Waste Inventory Form for proper disposal.

4.4 Auditing

The AURA Risk Management Specialist or a designate will conduct periodic audits of the site to review the current operations with respect to all applicable safety, health and environmental policies and regulations. The following issues will be reviewed: hazardous material storage, hazardous waste accumulation, Material Safety Data Sheet availability, hazardous waste accumulation areas, and emergency plans. A report indicating any corrective actions that are necessary and suggesting any improvements will be provided at the end of the audit.

4.5 Storage of Material Safety Data Sheets (MSDS)

All chemical manufacturers and suppliers of hazardous chemicals must furnish an MSDS with each initial shipment and furnish new MSDS information upon request. The MSDS generally contain information such as the following:

- Chemical composition
- Physical characteristics and chemical properties
- Fire, explosion, and reactivity hazards
- Health hazard information and symptoms of overexposure
- Protective equipment recommendations

- Handling and storage precautions
- Cleanup and disposal procedures
- Emergency first aid procedures

Federal and state law requires that written MSDSs must be kept in proximity to the area where products are stored and must be readily available to all employees at any time. MSDSs must also be available for emergency personnel or any state or federal agency that requests them. It is the responsibility of the supervisor in each work area to ensure that all MSDSs are kept in an accessible storage area and are updated. If an MSDS is missing or incomplete, it is likely that you can obtain a copy from the Internet or from the manufacturer. Requests for missing MSDSs should be made in writing and sent by fax, and a copy of the request should be kept in your file.

5. CRITERIA FOR DETERMINING HAZARDOUS WASTE

Note: This is a comprehensive guideline; not all of following classifications are expected to be utilized at ATST.

5.1 DEFINITION OF HAZARDOUS WASTE

Generally, hazardous materials are not waste until they leave the process or they are no longer needed for use. As defined by RCRA, a waste is a useless by-product of an operation, a material which is to be disposed, any material which can no longer be used, or a manufacturing or process by-product.

5.2 HAZARDOUS WASTE IDENTIFICATION AND CLASSIFICATION

As defined by the EPA, a hazardous waste is a chemical composition or has other properties that make it capable of causing illness, death, or some other harm to humans and the environment when mismanaged or released into the environment. MSDSs may provide information, which will assist in making a proper hazardous waste determination. EPA 40 Code of Federal Regulations (CFR) 262.11 requires that generators must determine if their waste is hazardous. All wastes must be identified and then classified as hazardous or non-hazardous according to specific federal and state definitions, a procedure is detailed below.

5.3 PROCEDURE FOR MAKING HAZARDOUS WASTE DETERMINATIONS

The EPA has determined that the following meet the definition of a hazardous waste:

> a) A waste which is listed as hazardous in the regulations (40 CFR 261); or b) A mixture that includes a listed hazardous waste; or a waste which exhibits any of the four following characteristics; ignitability, corrosivity, reactivity, or toxicity.

The following procedure must be used to determine if a waste is hazardous. If it is, the procedures will identify the appropriate EPA hazardous waste number for each waste, which will in turn determine disposal requirements:

- Determine the proper name of the waste and its specific source.

- Check the EPA's hazardous waste lists (see www.epa.gov/epaoswer/osw/) in the following order:

    - "U" list of toxic wastes (40 CFR 261.33f). See Attachment 6 at pp. 38-45.

- “P” List of acutely hazardous waste (40 CFR 261.33e). See Attachment 6 at pp. 35-38.
- “K” List of hazardous wastes from specific sources (40 CFR 261.32). See Attachment 6 at pp. 30-33.
- “F” List (40 CFR 261.31) for a non-specific source of waste. See Attachment 6 at pp. 25-27.

- If the waste is not one the “U” List, the “P” List, the “K” List, or the “F” List, you must determine whether the waste exhibits any of following four characteristics:
  - Ignitability: A waste that exhibits the characteristic of ignitability has the EPA hazardous waste number of D001. See 40 CFR §261.20, Attachment 6, for instructions on how to determine whether a waste exhibits the characteristic of ignitability. Generally, a liquid with a flashpoint below 140 degrees F, not a liquid but capable of starting a fire under standard temperature and pressure, an ignitable compressed gas, or a DOT oxidizer.
  - Corrosivity: A waste that exhibits the characteristic of corrosivity has the EPA hazardous waste number of D002. See 40 CFR §261.22, Attachment 6, for instructions on how to determine whether a waste exhibits the characteristic of corrosivity. Generally, aqueous with pH less than 2 and greater than 12.5.
  - Reactivity: A waste that exhibits the characteristic of reactivity has the EPA hazardous waste number of D003. See 40 CFR §261.23, Attachment 6, for instructions on how to determine whether a waste exhibits the characteristic of reactivity. Generally a material that undergoes rapid or violent chemical reactions with water or other materials.
  - Toxicity: A waste that exhibits the characteristic of reactivity will have and the EPA hazardous waste number of D004 through D043. See 40 CFR §261.24, Attachment 6, for instructions on how to determine whether a waste exhibits the characteristic of reactivity. Generally, leachates that contain high concentrations of toxic metals or specific organics.

5.4 MIXED WASTE RULE

This EPA rule is intended to ensure that hazardous waste is not diluted to prevent the waste from being hazardous.

For EPA listed wastes, a mixture made up of any amount of non-hazardous waste and a listed waste is a hazardous waste.

For Characteristic Wastes, a mixture involving characteristics wastes is hazardous only if the mixture exhibits a characteristic such as ignitability, corrosivity, reactivity, or toxicity.

5.5 DERIVED – FROM RULE

Any material derived from an EPA listed waste is also a listed waste.

A material derived from a characteristic hazardous waste is only hazardous if the resultant material has the characteristic of a hazardous waste.

6. ACCUMULATION OF WASTES FOR CONDITIONALLY EXEMPT SMALL QUANTITY GENERATORS (CESQG)

6.1 LIMITS ON WASTE GENERATION AND ACCUMULATION

To maintain the status of Conditionally Exempt Small Quantity Generator:

> The facility may not <u>generate</u> more than 100 kilograms (approximately one-half of a 55-gallon drum, 27 gallons, or 220 pounds) of hazardous waste. The facility may not generate more than 1 kilogram (2.2 pounds) of acute hazardous waste in one month.
>
> The facility may not <u>have</u> more than 1000 kilograms (approximately five 55-gallon drums, or 275 gallons, or 2200 pounds) of total accumulated hazardous waste and no more than 1 kilogram (2.2 pounds) of accumulated acute hazardous waste at any time.

6.2 EPISODIC GENERATION OF HAZARDOUS WASTE

Generators must comply with the requirements of their status, in this case CESQG, even if the status changes from month to month. Generation of hazardous waste cannot be averaged over the year; it must be counted in the month it is generated. Therefore, it is important to plan activities not to exceed the limits of waste generation and limits of accumulation.

6.3 RECORDKEEPING AND REPORTING (40 CFR 262, SUBPART D) FOR CESQG

Training records are to be kept for the duration of employment plus three years.

Records involving environmental investigation or litigations shall be kept for three years.

CESQG are not required to submit information regarding the generation, accumulation, treatment, storage, or disposal of hazardous waste unless disposal of hazardous waste is "on-site" or 1000 kg of hazardous waste or 1 kg of acute hazardous waste is accumulated.

7. STORAGE OF HAZARDOUS WASTE

7.1 DESIGNATION OF WASTE MANAGEMENT AREA

The ATST Site Manager shall establish a safe area near the point of generation for the temporary storage of that waste before disposal by a licensed contractor. The ATST Site Manager shall periodically hire a licensed hazardous waste contractor to transport the waste to an EPA permitted hazardous waste treatment, storage, and disposal facility.

7.2 WASTE CONTAINER LABELING

All hazardous waste containers must be labeled with the words "Waste _____." (Example: Waste Solvent, Waste Acid, etc) and dated with the accumulation start date (the date declared waste). The container label shall have an accurate description of the contents of the container. The manufacturer's label or a label giving the chemical name and specific hazards (e.g., flammable, corrosive, or poison) is acceptable. Ensure that all the chemical name(s) (e.g., "waste methyl alcohol") are noted. Generic names can be used if a separate list is maintained to indicate the each chemical name and the approximate amounts of the solution, like an MSDS.

7.3 CLOSED CONTAINERS

All hazardous waste containers must remain closed except when waste is being added to them.

7.4 CONTAINERS IN GOOD CONDITION

Containers used for wastes must be in good condition (i.e. no rusting, cracks, or structural defects). If a container is broken or begins to leak, the material must be transferred to a container in good condition. The material composition must be compatible with the material to be stored and incompatible materials must not be stored in proximity to one another. Package materials in sturdy cardboard boxes or plastic waste containers. Cushion the material in the containers to prevent breakage. If cardboard boxes are used which originally held other chemicals, the name of the chemical must be covered over or defaced. Failure to do so constitutes improper marking as to contents and is an EPA and OSHA regulation violation.

7.5 CONTAINMENT

Secondary containment is not mandatory for containers of liquid hazardous waste that is less than 55 gallons. However, a plan for handling spills must be in place.

7.6 SEPARATE INCOMPATIBLE MATERIALS/WASTE

Incompatible materials shall be segregated in separate boxes for quantity greater than 1/4 lb/100 grams for solids and 4-ounces/100 ml for liquids. Examples of incompatible materials are acids/bases, organics/oxidizers, and flammable liquids/oxidizers. Unknowns and high hazard materials such as water reactives shall be packaged separately regardless of quantity.

7.7 HAZARDOUS WASTE DISPOSAL

The disposal of hazardous wastes requires that a licensed hazardous waste contractor be hired to transport and dispose of the waste. The contractor must have Department of Transportation (DOT) hazardous materials endorsement on their driver's license and other DOT credentials. Prior to transport, the ATST Site Manager shall prepare the materials per:

- 40 CFR 262.30 package per DOT 49 CFR 173, 178, and 179
- 40 CFR 262.31 label per DOT 49 CFR 172
- 40 CFR 262.32 mark each package in accordance with DOT 49 CFR 172 and 172.304 (Hazard Waste: Federal Law Prohibits Improper Disposal……)
- and 40 CFR 262.33 Placard or offer Placard to initial transporter in accordance with DOT requirements (front, back and sides) or offer DOT placards to initial transporter.

7.8 DRAIN DISPOSAL PROHIBITED

No hazardous materials/waste may be disposed of directly to the infiltration well or to the environment at ATST or any other Haleakalā site.

8. PREPAREDNESS AND PREVENTION (40 CFR 264/265 SUBPART C)

The ATST Site Manager shall ensure that he/she and the staff understands the design and operational aspects of the facility and ensures that the following provisions are met:

- Internal and external communications are functional
- Fire extinguisher and other emergency equipment are tested and inspected
- Spill control and decontamination procedures are written and known by the staff

- Testing and inspection of equipment is adequate
- Access to communications and alarms systems are not blocked or hindered
- Hallways and aisle spaces are not blocked or congested
- Arrangements with local emergency response agencies have been made.

9. EMERGENCY SPILL PROCEDURES

9.1 EMERGENCY PROCEDURES

The ATST Site Manager shall ensure that there are specific spill emergency plans and provide information and training to individuals working in the areas where hazardous materials that may be used. Emergency procedures and emergency telephone numbers shall be posted in the work area. Personnel working with hazardous chemicals should be able to answer the question: "What would I do if this material spilled?"

9.2 SPILL KITS

The ATST Site Manager shall ensure that a spill kit(s) with instructions, absorbents, reactants, and protective equipment is available for clean up of minor spills. It is recommended that at least a 90-gallon universal spill kit should be at the site.

9.3 SPILL CLEAN UP

A minor spill is one that does not spread rapidly, does not endanger people or property except by direct contact, does not endanger the environment, and the workers in the area are capable of handling safely without the assistance of safety and emergency personnel. All other chemical spills are considered major. If the spill is major, contact the Fire Department (911), other local authorities, and the AURA Risk Management Specialist for advisement.

In the event of a spill, attend to anyone who may have been contaminated or hurt, if it can be done without endangering yourself. Open windows where this can be done without endangering yourself. If flammable materials are spilled, de-energize electrical devices if it can be done without endangering yourself. The following are general procedures for the handling spills:

Ready the spill kit, move to a safe proximity of the spill

Ensure protective apparel is resistant to the spilled material.
Neutralize acids and bases, if possible using neutralizing agents such as sodium carbonate or sodium bisulfate.

Control the spread of liquids by containing the spill. Absorb liquids by adding appropriate absorbent materials, such as vermiculite or absorbent material, from the spill's outer edges toward the center. Paper towels and sponges may also be used as absorbent material, but this should be done cautiously considering the character of the spilled material.

Collect and contain the cleanup residue and any materials used to clean up the spill by scooping them into a plastic bucket or other appropriate container and prepare the container for properly disposing of the waste as hazardous waste.

Decontaminate the area and affected equipment. Ventilating the spill area may be necessary.

Document what happened, why, what was done, and what was learned. Such documentation can be used to avoid similar instances in the future. Major incidents are usually preceded by numerous near misses.

9.4 REPORTING REQUIREMENTS

After the initial spill response, contact the AURA Risk Management Specialist to determine whether there are any federal or state reporting requirements. Some reporting obligations are immediate, and must be made within 24 hours.

10. SPECIFIC INFORMATION ON THE DISPOSAL OF VARIOUS MATERIALS/WASTE

10.1 RESPONSIBILITY

The individual possessing or generating the material/waste retains the primary responsibility for the material/waste. The ATST Site Manager shall provide information on the requirements and assistance in handling the materials. Specific information on various types of materials is given below.

10.2 RCRA EMPTY CONTAINERS OF HAZARDOUS WASTES

Containers or inner liners removed from a container that held non-acutely hazardous waste (P List) is empty if:

- All waste has been removed that can be removed by normal means and
    - No more that 2.5 cm (1 inch) heel remains or
        - No more than 3% (wt) if less than 110 gallon container or
        - No more than 0.3% (wt) if greater than 110 gallons remains

10.3 BATTERIES

Lithium, nickel/cadmium or mercury batteries shall be stored at the hazardous waste accumulation site for contract disposal. Vehicle batteries are recyclable and arrangements with local vendors shall be made.

10.4 COMPRESSED GASES

Compressed gas cylinders should be returned to the vendor. A return agreement with the vendor should be included in the contract. Without such an agreement, the return or disposal of the cylinders is difficult and very costly.

10.5 HAZARDOUS CHEMICALS AND HAZARDOUS WASTE ALTERNATE USE

The ATST Site Manager shall periodically (on an as needed bases) hire a licensed contractor to transport and dispose of hazardous wastes. Efforts should be made to determine if others could use excess hazardous chemicals in other department or facilities prior to submitting for contract disposal. Chemicals considered non-hazardous waste (see "Non-hazardous Waste" below) could be disposed of in the municipal sanitary landfill or sanitary sewer.

10.6 MERCURY

Discarded items containing functional mercury (e.g. light switches, barometers, and thermometers) shall be stored at the hazardous waste accumulation site for contract disposal.

11. NON-HAZARDOUS WASTE

11.1 LAB CHEMICALS

Listed below are typical laboratory chemicals that are not considered hazardous wastes by the U.S. Environmental Protection Agency. Chemicals with an LD50 (oral rat) greater than 500 mg/kg are considered non-hazardous unless they are suspect carcinogens, mutagens, or teratogens (the LD50 can be found in the MSDS). Non-hazardous waste can be disposed of in the municipal sanitary landfill if solid. Some examples include:

- Organic chemicals, salts: Na, K, Mg, Ca, NH4
- Inorganic Chemicals, Sulfates: Na, K, Mg, Ca, Sr, NH4
- Phosphates: Na, K, Mg, Ca, Sr, NH4
- Carbonates: Na, K, Mg, Ca, Sr, NH4
- Oxides: B, Mg, Sr, Al, Si, Ti, Mn, Fe, Co, Cu, Zn
- Chlorides: Na, K, Mg
- Fluorides: Ca
- Borates: Na, K, Mg, Ca
- Alum, Alumina and Silica gel.

Always refer to the “Procedure for Making Hazardous Waste Determinations” section of this program and the products MSDS for more detail.

11.2 ALKALINE BATTERIES

Attempts should be made to recycle alkaline batteries.

11.3 OILS (AND OTHER MATERIALS WITH SIMILAR HANDLING AND DISPOSAL REQUIREMENTS):

11.3.1 Hydrostatic Oil, Diesel Fuel, Transformer Fluid and Propylene Glycol

The ATST Site Manager will assist with disposal of these materials. Used motor oil is recyclable through local vendors. The following requirements apply to used oil:

- Used oil may only be stored in containers that are in good condition and not leaking.
- Containers, aboveground storage tanks, and fill pipes must be labeled or marked clearly with the words “Used Oil.”
- Upon detection of a release of used oil, stop the release, contain the used oil, clean up and manage properly the used oil and other materials, and if necessary, repair or replace any leaking used oil storage containers.
- If a release of used oil occurs, Contact the AURA Risk Management Specialist for information regarding cleanup and special regulatory reporting requirements that may apply.

11.4 PAINT WASTE

Excess paint or waste paint containing cadmium, chromium, lead, or mercury will not be recycled but will be disposed of as hazardous waste. Other paint waste generated will be stored in a marked container labeled, “Paint Waste for Recycling”.

11.5 Fluorescent Light Tubes

The ATST Site Manager shall designate a storage area for burned out fluorescent light tubes. Tubes shall not be crushed and shall be transferred to a recycler or a licensed disposal contractor.

11.6 Mirror Stripping

Chemicals used for aluminum stripping process are not EPA listed chemicals. They are, however, considered characteristically hazardous before and during use. The waste stream generated should result in no hazardous waste, as the final by-product will have a pH greater than 2 and less than 12.5, and will contain only salts of the metals aluminum, copper, calcium, and potassium. The process-completion wash effluent shall be sent to special process completion holding tank(s).

It is expected that process-completion effluent will have a pH between 2 and 12.5, and the mixture would be considered non-hazardous. The process completion effluent shall be checked with litmus strips and a calibrated pH meter at the end of the process. Treating industrial waste on-site will not be done without proper licensing permits.

The ATST Site Manager shall have a certified lab analysis done of the process completion effluent to determine actual pH and consult with local authorities about the accepted mode of disposal of the effluent.

Wipes for each process shall be containerized and disposed of properly.

The solution of soap and water used during the prewashing of the mirror with soap may be released to the infiltration well.

11.7 Dome and Structure Cooling Fluid

Propylene Glycol is not an EPA listed or a characteristically hazardous chemical. It is however being treated as a foreign material due to the environmental sensitivity of Haleakalā. In the event of a spill, follow the spill procedure for oil.

12. HAZARDOUS WASTE MINIMIZATION

12.1 Buying Chemicals in Smaller Amounts

The "large economy size" may cost less to buy, but disposal costs, in most cases, are several times the initial cost of the material. Many of the bottles of excess or waste chemicals sent for disposal are full or 3/4 full. Everyone needs to try to accurately estimate the amount of a chemical they expect to use.

12.2 Recycling and Redistribution

Efforts should be made to find other departments who can use the hazardous material before it is submitted to the ATST Site Manager as waste for contract disposal.

12.3 Use of Less Hazardous or Non-hazardous Materials

Employees are encouraged to investigate the use of use of less hazardous or non-hazardous materials.

(Attachment 1)
ATST PROCUREMENT AND USE AUTHORIZATION OF HAZARDOUS MATERIALS

An approved (signed) copy of this form must accompany any request, purchase order, or requisition for the procurement and use of all hazardous materials.

NAME: ______________________________ (requestor)

DEPARTMENT: ____________________ PHONE NO., EXT.: ____________________

LOCATION: ____________________ PURCHASE ORDER NO.: ________________

Chemical Name	***Solid/Liquid/ Gas***	***Amount (gallon, lbs)***	***Usage Plan***	***Estimated Usage Period***

REQUESTOR: ______________________________ (signature)

DATE: ______________________________

PLEASE SEND THE COMPLETED FORM TO: ATST Site Manager

APPROVAL FOR PROCUREMENT AND USE:

______________________________ DATE: ____________________

ATST SITE MANAGER (signature) APPROVAL NO.: ____________________

(Attachment 2)
ATST MONTHLY HAZARDOUS WASTE INVENTORY FORM

This form is designed to assists ATST with proper management of our hazardous waste. If you have any hazardous or non-hazardous waste being stored for disposal, please provide the information requested. If additional space is needed, you may use an attached sheet using the same format. If at a later date you generate wastes not previously listed, please submit an amended form.

Chemical Name	***Solid/Liquid/ Solution***	***Amount (gallon, lbs)***

_______________________________________ _______________________________________

ATST SITE MANAGER (Printed Name) (Signature)

DATE: ______________________________

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APPENDIX E

BOTANICAL SURVEY

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

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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, ʻiwa ʻiwa (*Asplenium adiantum-nigrum*), ʻoaliʻi (*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*), ʻiwa ʻiwa (*Asplenium adiantum-nigrum*), ʻoaliʻi (*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 Puʻu 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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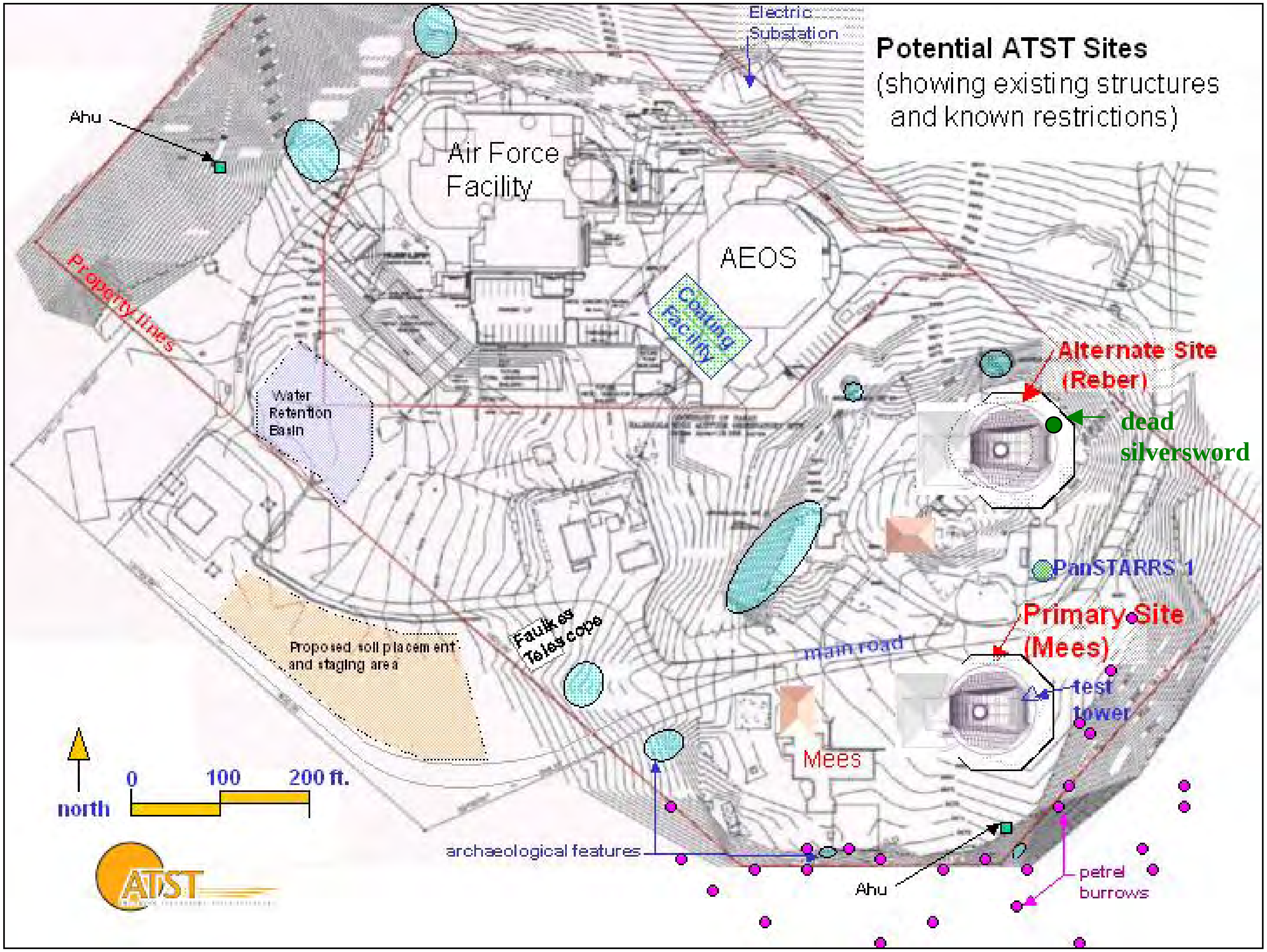
PLANT CHECKLIST

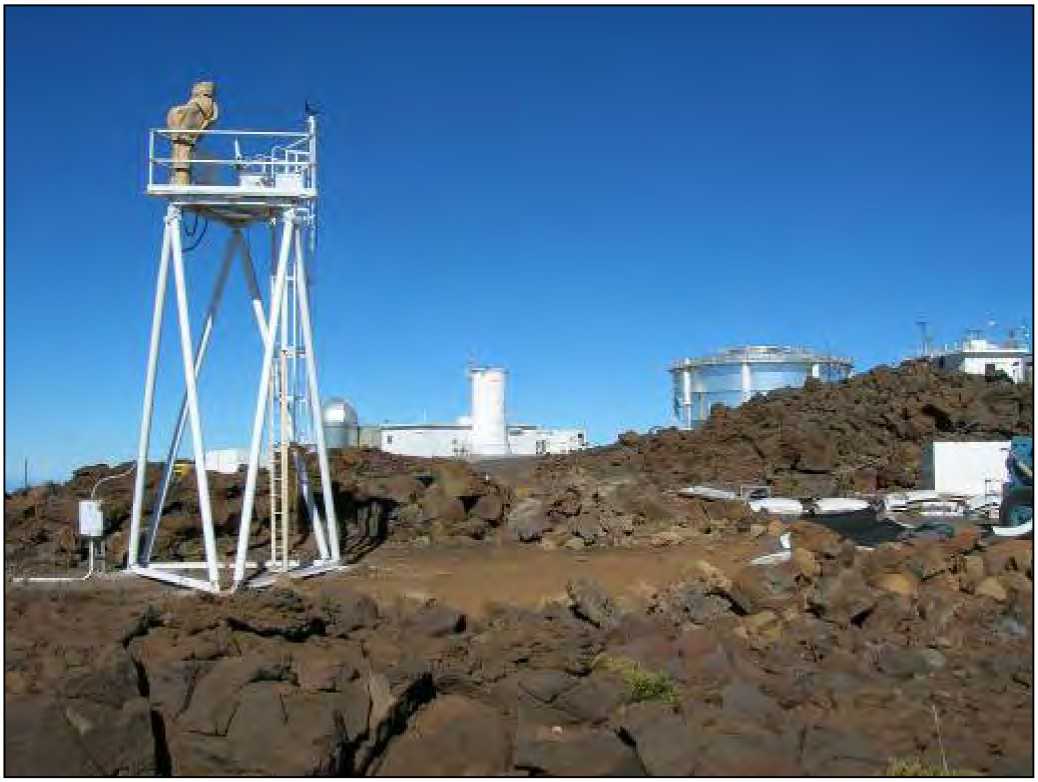
Scientific name	Common name	Mees	Reber	Retention	Staging
Agrostis sandwicensis	Hawaiian bentgrass	O	O	--	--
Arenaria serpyllifolia *	Thyme-leaved sandwort	O	--	--	--
Argyroxiphium sandwicense subsp. *macrocephalum*	Haleakalā silversword, ‘ahinahina	--	R	--	--
Asplenium adiantum-nigrum	‘Iwa‘ iwa	O	O	--	--
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, ʻahinahina
(Asteraceae)

Asplenium adiantum-nigrum
ʻIwa ʻiwa (Aspleniaceae)

Asplenium trichomanes* subsp. *Densum
ʻOaliʻi (Aspleniaceae)

Bromus willdenowii*
Rescue grass (Poaceae)

*Cryptomeria japonica**
Japanese sugi pine (Taxodiaceae)

Deschampsia nubigena
Hairgrass (Poaceae)

Dubautia menziesii
Storksbill (Geraniaceae)

*Erodium cicutarium**
Kupaoa, naenae (Asteraceae)

Holcus lanatus*
Hairy cat's ear (Asteraceae)

Hypochoeris radicata*
Yorkshire fog (Poaceae)

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)

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Kentucky bluegrass (Poaceae)

Styphelia tameiameiae
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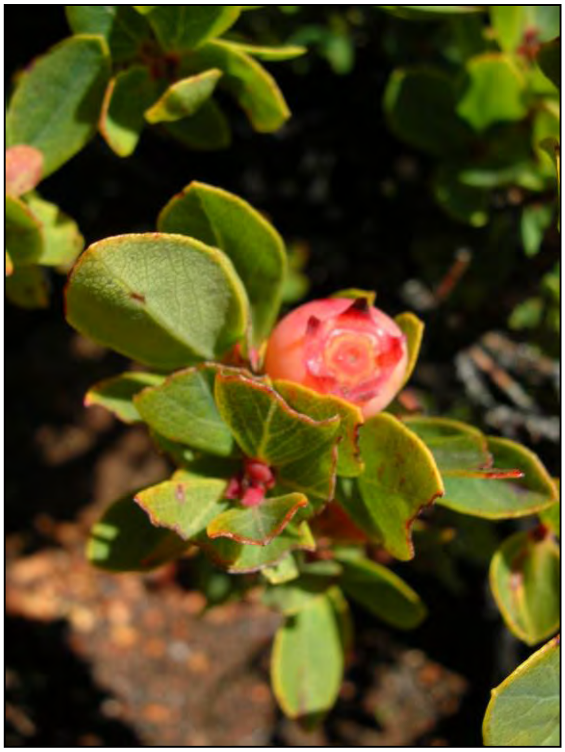
Tetramolopium humile
Tetramolopium (Asteraceae)

Trisetum glomeratum
Mountain pili, pili uka (Poaceae)

Vaccinium reticulatum
Ohelo (Ericaceae)



Vicia sativa* subsp. *nigra*
Common or spring vetch (Fabaceae)

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APPENDIX F

(1) CULTURAL AND HISTORICAL COMPILATION OF RESOURCES EVALUATION AND TRADITIONAL PRACTICES ASSESSMENT, JANUARY 2006

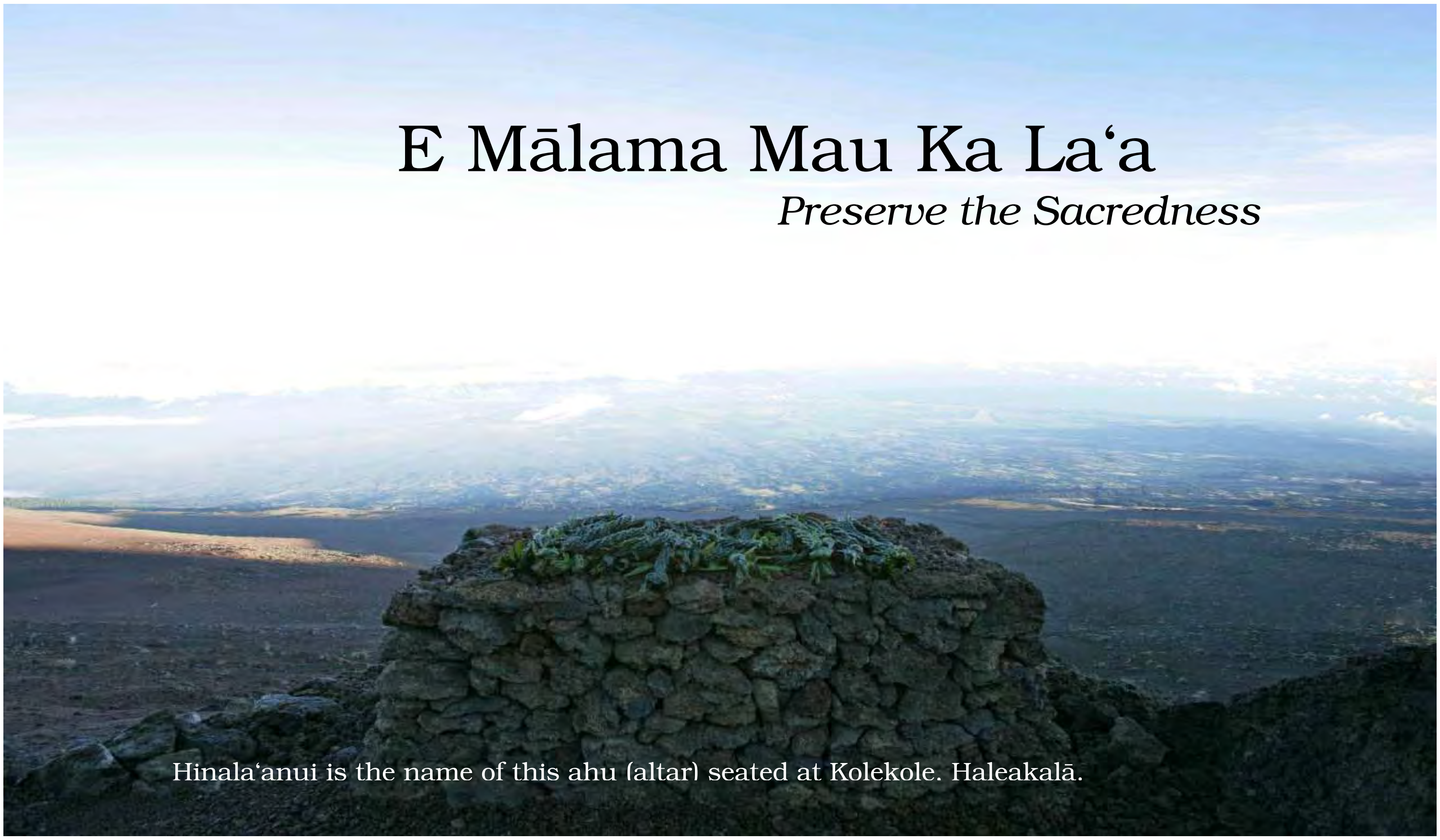
(2) SUPPLEMENTAL CULTURAL IMPACT ASSESSMENT, MAY 2007

APPENDIX F(1)

CULTURAL RESOURCE EVALUATION AND TRADITIONAL PRACTICES OF THE PROPOSED ADVANCED TECHNLOGY SOLAR TELESCOPE (ATST) AT HALEAKALĀ HIGH ALTITUDE OBSERVATORIES

E Mālama Mau Ka Laʻa

Preserve the Sacredness



Hinalaʻanui is the name of this ahu (altar) seated at Kolekole. Haleakalā.

Photo taken by: Mike Mabery

A Cultural and Historical Compilation of Resources Evaluation and Traditional Practices Assessment

FINAL REPORT

January 2006

Cultural Resource Evaluation and Traditional Practices
Of the Proposed Advanced Technology Solar Telescope
(ATST) at Haleakalā High Altitude Observatories

Prepared for:
KC Environmental, Inc.
P.O. Box 1208, Makawao, HI 96768

Prepared By:
CKM Cultural Resources L.L.C.
157 Ale'a Place, Pukalani, HI 96768

Kahu Charles Kauluwehi Maxwell, Sr.
Principal Researcher
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E Mālama Mau Ka La'a

Preserve the Sacredness

Cultural Resource Evaluation and Traditional Practices Assessment of the Proposed Advanced Technology Solar Telescope (ATST) at Haleakalā[1] High Altitude Observatories

Title Page

F I N A L R E P O R T

MITIGATING MEASURES
Full time cultural and spiritual monitoring as stated in IfA Long Range Development Plan Appendix F & G. Full time Monitoring of Archaeological sites and 'Ua'u (Petrel) Burrows at Kolekole, Haleakalā, Maui Hawai'i

Kolekole Haleakalā High Altitude Observatories
Tax Map Key 2-2-7-08 18.3 Acre Site

Prepared for:
KC Environmental, Inc.
P.O. Box 1208, Makawao, HI 96768

Prepared By:
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157Ale'a Place, Pukalani, HI 96768

[1] **Haleakalā: Kaupō District. 10,023 feet in height. North(+)Latitude:20° 42 17 West (-) Longitude: 156° 10 36. This data was extracted from the United States Geological Survey GNIS Database (November 2000)**

E Mālama Mau Ka La‘a

Preserve the Sacredness

Table of Contents

E Mālama Mau Ka La'a

Preserve the Sacredness

ABSTRACT

This study is in accordance with the Office of Environmental Quality Control, which describes resources having Hawaiian Cultural Value. It will describe potential impacts from further development, along with measures that could possibly be employed to mitigate those impacts. The study will evaluate the cultural significance of historic and prehistoric resources identified during an archaeological survey, and assist in the development of a general preservation plan for those resources. It will also address the requirements of the Office of Hawaiian Affairs, in regards to cultural impacts. Specifically, the document will address potential effects on the Hawaiian Cultural and Traditional Customary Rights, as described in the legislation known as Act 50, Sessions Laws of Hawaii, 2002, and meet the requirements of the HRS Chapter 343, which also requires an environmental assessment of cultural resources, in determining the significance of a proposed project. In addition, Articles IX and XII of the State Constitution, other state laws, and the courts of the state, require government agencies to promote and preserve cultural beliefs, practices, and resources of Native Hawaiians and other ethnic groups.

A Hawaiian cultural resource evaluation revealed that Haleakalā, home of the sun, is considered one of the most sacred sites on Maui to *Kanaka Maoli*,[2], or Hawaiian native person, for many reasons but mainly that it is *Wao akua*[3], or "where the gods live".

In ancient times, the Kanaka Maoli depended on the rising and setting of the sun. They believed that going into the crater at night was disrespectful to the gods that dwelled there and disturbing to the sun. There are many stories about Haleakalā. One famous story is about the demigod Maui, lassoing the sun to slow it down so his mother could dry her tapa cloth. We learned from early childhood, that Pele, the volcano goddess, created the crater here on Maui. In her travels throughout the Pacific islands, she created land and finally found her home on the island of Hawai'i at Kilauea Caldera.[4]

New gods and different Christianity philosophies were brought to Hawai'i to instill the Kanaka Maoli. They could not understand how their ancient gods, who helped them live on these islands for more than a thousand years, did not come to their rescue and punish the people who ignored their spiritual laws. The Hawaiian people lost faith in their

[2] Kanaka Maoli, full blooded Hawaiian person, today used to refer to Hawaiian Native person

[3] Wao Akua where the gods reside

[4] Kilauea Caldera located on the Island of Hawai'i at Kilauea Crater

ancient gods, and were "forced" to embrace the Christian gods by their Queen Ka'ahumanu, who converted into the Christian faith.

As new people moved into Hawai'i, the Kanaka Maoli lifestyle, culture, religion, respect for the 'āina, or land, and the association to the gods, were bypassed and eventually forgotten.

As Hawai'i's population grew and the Kanaka Maoli became minorities in their own land, a resurgence of the Hawaiian culture occurred in the late 60's and early 70's. Kanaka Maoli started to realize the importance of perpetuation of their culture and that in essence was the most important factor to restore their self-esteem and that of their children. The language, land issues, and identity became very important to the Kanaka Maoli of today, and what was permissible to be built years ago on sacred grounds, was protested by the natives for the importance of sacredness to the culture.

For numerous years, many have fought to stop structures from being built at Kolekole, and have found that it was almost impossible to do. Congress dictates what happens here because Hawai'i is part of the United States of America.

For the last several years the author of this report has insisted that cultural protocol be used at Haleakalā, (refer to http://www.ifa.hawaii.edu/haleakala/LRDP/). It establishes Hawaiian Cultural protocol when activity occurs at Kolekole. These protocols have been on-going in the destruction and replacement of the structures on the site or any ground altering activities over the last year.

Through the efforts of Mr. Mike Mabery of the IfA, we constructed two *Ahu*, or shrine, one facing the West and the other facing the East. William Field, a Kanaka Maoli tradition stonemason, constructed them in the traditional way of "free stacking" stonework. Kanaka Maoli will use these shrines for prayer and offering to the gods. Access to these shrines is strictly for Hawaiian religious ceremonies until there is better security at Kolekole. Only Kanaka Maoli are informed of the Ahu at this time and no publicity was made. There is a sign at the entrance to "Science City" at Kolekole, which restricts access to anyone, except for: *I na 'ōiwi Hawai'i aloha 'āina, or* "To the native caretakers of the land, please enter."

Proposed sites: The proposed ATST site at Mees is one of two places that is being studied. The alternate site is at Reber Circle. From the Mees site, ATST is partially obscured by the AEOS telescope. From the Reber Circle alternate site ATST is fully visible, towering over the AEOS Telescope.

Reber Circle is over 50 years old and has a historical site number, 50-50-11, 5443 State of Hawaii. According to Melanie Chinen, Director of the Historic Preservation of the Department of Land and Natural Resources of Hawai'i, a process to request a change of Reber Circle to the department could be made to restore the *pu'u*, or hill, to its original form.

Mitigation measures: From the perspective of a Kanaka Maoli, less building on Kolekole is a wise choice because it would not disrupt the spiritual flow of being in an area of the wao akua, or realm of the gods. If Kolekole had been treated as a sacred area in the 1930's, 40's and 50's, it would be easier to control construction on it today.

The best way to manage mitigation measures are to insure that whatever is built on Kolekole, or anywhere on Haleakalā for that matter, be researched on the purpose to have it built, and a complete cultural assessment including the mitigation measures that would be undertaken before any development occurs.

Due to the sacredness of Haleakalā, here and throughout the Polynesian Triangle, it is most important that this cultural treasure be preserved for the future.

E Mālama Mau Ka La‘a

Preserve the Sacredness

Outline

I. Introduction
   A. Scope
   B. Specific area of research
      a. Kolekole[1], Mākena/Kilohana (“Science City”)
         1. Clarification of district area: There seems to be (in the context of the research) discrepancies as to what ahupua‘a the area of focus resides.
   C. Tangent areas of research
      a. Mākena (In its entirety)
      b. Pu‘u O Kali
      c. Kilohana
      d. Nāhiku
      e. Kaupō
      f. Luala‘i Lua

II. In the beginning…
   A. Beginning of the islands
   B. Traditional ties to ‘āina[2]
   C. Its care today

III. Native Vegetation and Habitat
   A. Native Plant growth at the summit
   B. Wildlife

IV. Haleakalā: The Historical and The Cultural Context
   A. Māui: Slowing of the Sun.
   B. Pele’s relation to Haleakalā / Hi‘iakaikapoliopele
   C. Burial Pit
   D. Ala Hea Ka Lā

---

[1] Land section in Kilohana and Mākena. There are two versions of what Kolekole means: (1) One account explicates that Kolekole was named after the fist Kole, for its similarity in the abundance of the rusty hue. (2) The second account stated that Kolekole means to “talk story”. Some believe it was an area where Kahuna Po’o or High Priests would come to delve over tough issues.

[2] n. Land, earth. Cf. *‘ai*, to eat; ‘aina, kama’āina. Kō nā ‘āina like ‘ole, belonging to foreign lands, foreign, international. ‘Āina ho’oilina, inherited property or estate. Ua mau ke ea o ka ‘āina i ka pono (motto of Hawai’i), the life of the land is preserved in righteousness.

E. Ke Koʻi (The Adzes)
F. Historical References
    a. Depth of Haleakalā's meaning through a *kanikau*
    b. Palikū Order
G. Current References
    a. Current Cultural Structures
    b. Poetical References

E Mālama Mau Ka Laʻa

Preserve the Sacredness

Introduction – Eia ka lā hiki

The Scope:

The scope of this report will be to compile various historical, cultural, traditional practices and topographical accounts of Haleakalā and its surrounding areas. It will consist of two phases, the first being Traditional Practices and the second being the Spiritual and Cultural Association to Haleakalā and to the rest of the Pae ʻĀina O Hawaiʻl, or islands of Hawaiʻi.

Specific Area of Research:

The area being researched is referred to as Haleakalā. The name *Haleakalā*[3], speaks of one specific mountain and not the entire perceived area. However, what needs to be determined is the specification of the area in question. According to the University of Hawaiʻi's Institute for Astronomy (UH-IFA) website, it explicates the following:

In 1961, an executive order by Governor Quinn, set aside land on the summit of Haleakalā in a place known as Kolekole, to be under the control and management of the University of Hawaiʻi which established the "Haleakalā High Altitude Observatory Site," sometimes referred to as "Science City.[4]"

In its own admittance, the UH-IFA clearly understands the importance of the specific name of the area. Therefore, this report's focus area shall be Kolekole.

Kolekole had conflicting results when in the process of researching the *ahupua*ʻa, or land divisions. According to Mary Kawena Pūkuʻi's Place Names of Hawaiʻi[5], Kolekole is located in the Mākena ahupuaʻa of Maui. However, according to a November 2000 United States Geological Survey GNIS Database, it places

[3] Haleakalā: Kaupō District. 10,023 feet tall. North (+) Latitude: 20° 42 17. West (-) Longitude: 156° 10 36. This data was extracted from the United States Geological Survey GNIS Database (November 2000).

[4] http://www.ifa.hawaii.edu/haleakala. However, for the greater portion of this report, the upper mountains of the Kilohana *ahupuaʻa* will be referred to as Haleakalā.

[5] Pūkuʻi, Mary Kawena, et al. Place Names of Hawaiʻi. University of Hawaiʻi Press, Honolulu, 1974.

Kolekole[6] in the Kilohana ahupuaʻa. According to several maps, the ahupuaʻa of Mākena and Kilohana meet. Therefore, it is assumed that Kolekole is in the vicinity where both ahupuaʻa convene.

[6] Maui: Kolekole – Kilohana District: 10,012 feet tall. North (+) Latitude: 20º 42 38, West (-) Longitude 156º 15 33. This data was extracted from the United States Geological Survey GNIS Database (November 2000).

Geographical Information

Tangent Areas of Research:

The study of Kolekole is difficult to conduct unless the tangent areas are congruently studied. Therefore, the tangent areas will also be accounted in this specific section of the report.

Mākena
Mākena is located on the southeastern portion of Maui. The area, however, does not reflect the same landscape as that of the upper summits of Kilohana and various other ahupuaʻa in the upper portions of Maui.

Puʻu O Kali
Puʻu O Kali is an ahupua'a which sits above Mākena ahupuaʻa and next to Kilohana ahupuaʻa.

Kilohana
Kilohana encompasses the majority of the region of what many people today consider to be Haleakalā. The area includes a partial district of Kolekole.

Nāhiku:
Nāhiku resides directly next to Kilohana and Hāna. Nāhiku, the Hawaiian name for the "Big Dipper," or Ursa Major, was important in the study of celestial navigation.

Kaupō
Kaupō was a major living area in *ka wā kahiko*[7]. Kaupō is also known as the area behind Kilohana and Haleakalā.

Lualaʻi Lua
Lualaʻi Lua, meaning "twofold tranquility," is in the specific area that tranquility would be obtained for traveling to the summit.

This is just a few ahupuaʻa that borders the area of Kilohana and will become imperative to the research of Kolekole.

---

[7] n. Ancient times, antiquity.

In the beginning…

There are many beliefs of how the Hawaiian Islands were formed. Several people believed that Hawaiʻi was pulled out of Oceania's vast holding, and others thought that the islands were born of Papahānaumōkū and Wākea. Moreover, there were others who also believed that these islands were produced through the lineage of the *Kumulipo*[8]. Through the passages of Papa and Wākea, or the line of *Mānaiakalani*[9], or the verbs of the *Kumulipo*, the islands come alive with its rich and vibrant history.

Without taking a side of any version of Hawaiʻi's beginnings, *ka poʻe o ka wā kahiko*[10] recognized: "*Akāka wale o Haleakalā*[11]." It is known that Haleakalā stands in full view. From time immemorial, Hawaiians have revered the sanctity of the slopes of Haleakalā and the summits of Kilohana.

Some say the beginning of Maui happened by the demigod Maui's attempt to catch a fish by the name of Pīmoe, for his mother Hina. He, along with his brothers attempted to find this magical fish, only to break the spell and have Pīmoe turn into 8 major islands and some 125 minor islands. Maui's response to his mother's dismay was simply this, "we no longer need a large fish to eat; we have the land that will be here for generations to come." What needs to be made clear here is the importance and relevance of the ʻāina to its people. The relationship of the ʻāina that the demigod Maui furnished to his mother can be experienced right up until this very day.

In the context of Papa and Wākea's story, these two "people" are the parents of islands. Therefore, when the ʻāina is hurt, so are the siblings – *Kanaka Hawaiʻi*[12]. According to Dr. Lilikalā Kameʻeleihiwa's statement before the United States Commission on Civil Rights stated:

> From time immemorial, Native Hawaiians have had a special genealogical relationship to the Hawaiian Islands…As such, we have an ancient duty to love, cherish and cultivate our beloved grandmother, the land… And in the reciprocal relationship, when we Native Hawaiians care for and cultivate the land, she feeds and protects us.[13]

---

8 Kumulipo is the origin, genesis, source of life, or mystery.

9 Mānaiakalani is the name of the fishhook used by the Demi-God Māui, to pull up the islands known as Hawaiʻi.

10 People of Old

11 Pūkuʻi, Mary Kawena, et al. ʻŌlelo Noʻeau: Hawaiian Proverbs and Poetical Sayings. Bishop Museum Press, Honlulu, Hawaiʻi, 1983. [Glossary: Term]

12 Native Hawaiians

13 Kameʻeleihiwa, Lilikalā, Ph.D., statement before the Hawaiʻi Advisory Committee to the U.S. Commission on Civil Rights, " The Impact of the

From Maui's expressions to his mother, Dr. Kame'eleihiwa's expression of Hawaiians' relationship to the ʻāina correlates the significance of care, and protection that Hawaiians have for their ʻāina. Therefore, Hawaiians have every right to analyze the use of their most sacred lands. With that mentioned, Haleakalā will now be studied in depth.

Decision in Rice v. Cayetano on Entitlements," community forum, Honolulu, HI, Sept. 29 2000, transcript.

Cultural and Historical Information

Māuiākamalo

Haleakalā is the location of one of Polynesia's[14] most famous stories. The demigod Maui managed to snare the sun after repeated verbal foresights of failure. Haleakalā became the focal point of the Universe; it is the beginning of the sun.

Some may not believe this legend, primarily because it is "fictitious." Given that point, the moral behind the story is not fictitious. In an anthropological sense, legends tell the habitual lifestyles of the people in focus. In this case, Maui's legend tells a lot about the importance of the sun to Hawaiians, hence the name: Haleakalā – House of the Sun.

Haleakalā's Importance:

Haleakalā is the sacred home of our Sun, and the ancient Path to Calling the Sun as depicted in its ancient name: Ala Hea Ka Lā. Why is this critical to our survival? The Sun's energy is the source of all life, and governs our most basic rhythm of day and night. Ancient cultures have venerated its being, and we as a human race follow its course without thought and are insignificant in respect of its power. However, our Native Hawaiian Culture praises its existence, until this very day the sun is praised for its cycle.

[14] Point of clarification: Most believe the story of Maui's snaring of the Sun is a Hawai'i-centric story. However, Maui was not only a Hawai'i demigod, he was a demigod of all of Polynesia. Therefore, Haleakalā is a pinnacle of power for all of Polynesia.

E ala e

E ala e
Ka lā I kahikina
I ka moana
Ka moana hōhonu
Piʻi ka lewa
Ka lewa nuʻu
I kahikina
A I ka lā
E ala e

Rise
The sun at the east
At the ocean
At the deep ocean
As it climbs
To the highest
In the east
Is the Sun
Rise

As the chants explicates the cycle of the rise of the sun. That is still honored through chants like the one shown above. "E ala e" was written in the late 1980's by Hawaiian scholar, historian and *Kumu Hula*[15], Pualani Kanakaʻole Kanahele. The sun's appreciation and worship is not something of the past, but very tangible and real.

The ancient spiritual use of the mountain is for meditation and receiving of spiritual information by Kahuna Poʻo. It is a place where the tones of ancient prayer are balanced within the vortex of energy for spiritual manifestations. In ancient times, only Kahuna and their haumāna, or students, lived at Haleakalā, for initiation rites and practices.

Pele

It is said through chants that Pele created every *puʻu*[16] in the Kilohana region on Maui. During Pele's first visit to Haleakalā she began to dig a deep pit and made sixteen cinder cones that stand to this day. She went below Paukela, Naholaku and Maua from Kaumunui to Paukela. These puʻu are in a sacred alignment with the tip of Haneoʻo for about 30 miles into the ocean. We are beginning to relearn the significance of the astro-archaeology of that period and how these points are interrelated with the many *Heiau*[17]. On the east side of Haleakalā, there are over 300 *Heiau* - a higher concentration of ancient temples than any place else on the planet.

Pele's going down to Hāna, Maui, was said by the ancients to be her very first experience in going under the earth from Haleakalā to the north-western side of the peak of Kahuakalā (the Sun's nose). On the northwest side of the peak is Hale o Pele (Pele's House). From there, she caused a flow of lava to pour as far as Kawaipapa, Wakiu, Honokalani, Kaʻeleku and between Honomaʻele and Makapuʻu in ʻUlaʻino and the bed of Akiala. During this flow she also made Olopawa, Hinaʻi, Kaiwiopele, Lehoʻula and Alau. These are all consequences of and interrelated with the crater and its activities. She also returned and died at Haleakalā later in history in a battle between her rival sister *Namakaokaha*ʻi[18] - where her and the *iwi*[19] of Hiʻiakaikapoliopele were scattered through the crater and the hill at Aleamae named Kaiwiopele.

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[15] Hula Master
[16] n. Any kind of a protuberance from a pimple (puʻu 2) to a hill: hill, peak, cone, hump, mound, bulge, heap, pile, portion, bulk, mass, quantity, clot, bunch, knob; heaped, piled, lumped, bulging; pregnant; to pucker.
[17] n. Pre-Christian place of worship, shrine; some heiau were elaborately constructed stone platforms, others simple earth terraces. Many are preserved today.
[18] Goddess of the Ocean; Pele's nemesis and sister.
[19] Bone; carcass (as of a chicken); core (as of a speech). The bones of the dead, considered the most cherished possession, were hidden, and hence there are many figurative expressions with iwi meaning life, old age: Na wai e hoʻōla i nā iwi? Who will save the bones? [Who will care for one in old age and in death?] Maʻaneʻi au me ʻoe a waiho nā iwi, here I am with you until leaving the bones [death]. ʻO ʻoe nō kuʻu iwi, a me kuʻu ʻiʻo (Kin. 29.14), thou art my bone and my flesh. Holehole iwi, to strip bones of flesh [to speak ill

Burial Pit:

Haleakalā was well known for its *lua meki*[20], according to Hawaiian scholar Samuel Mānaiakalani Kamākau.

> The disposal pit of Kaʻaʻawa is a deep disposal pit inside the crater of Haleakalā. It is on top of a lava mound in a pit on the north side, close to *Waiʻaleʻale*[21] on the eastern edge of the Keʻanae gap that opens at Koʻolau…several miles deep, with fresh or sea water at the bottom. Because of the taste of the waters, some people have supposed that the waters of Waiu and Waipu at Kaupō have their source at this pit of *Kaʻaʻawa*…[22]

This is one account of the noted by Samuel Kamākau. To support this piece of evidence E.S. Craighill Handy et al., has also noted events similar as mention by Kamākau.

> …Maui natives of the Kula and Honuaʻula areas journeyed during the nighttime to toss into the crater the bones of their dead. The Maui people living on the semi-arid leeward slopes, who threw their bundles into the pit of the extinct volcano, were presumably of the "Clan of Pele."[23]

Haleakalā is not only significant for its purpose as a sacred area, it is a burial site as well. Hawaiians treated their bones with much respect for it was the purest form of *mana.*

Ala Hea Ka Lā:

It is said, through oral tradition[24], that Haleakalā's traditional name was Ala Hea Ka Lā, "the path to calling the sun."

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of one's kin]. Pili i nā iwi, to wager one's bones [one's life]. Many phrases and compounds with iwi are listed below.Cf. *kaulaʻi iwi*. Kona iwi, his [own] bone. Kāna iwi, his bone [as a chicken bone he is chewing on]. Iwi koko, bloody bones [a living person]. Iwi koko ʻole, bones without blood [a dead person] . Kō iwi, your own interests, your own. Hana nō i kā kō iwi, do for your own bones [take care of your own interests]. Kō kō iwi ʻāina hānau, your own land of birth (PPN iwi.)

[20] n. Deep pit or cave.

[21] A swamp just outside the crater wall

[22] Kamākau, Samuel Mānaiakalani. Ka Poʻe Kahiko: The People of Old. Bishop Museum Press. Honolulu, Hawai'i, 2000.

[23] Handy, E.S. Craighill, et al. Native Planters: In old Hawai'i – their life, lore, and environment. Bishop Museum Press, Honolulu, Hawai'i, 1972: 336-337.

[24] Made mention on numerous occasions by the late Kahu David Kāwika Kaʻalakea.

In the Hawaiian religion, physically higher places were always sacred. If one were to notice the structure of the traditional homes of the *aliʻi*, or chief, or the structure of various heiau, the structures always reached for the sky above. This vicinity was the area of the *wao akua*[25]*;* it is the dwelling of the gods, the home to where all formations of each of the 40,000 Hawaiian gods and goddesses placed their powers. Haleakalā was not only "home of the sun," it was also home to the gods.

Ke Koʻi (The Adz)

Adzes were an important part of the lives of all traditional Hawaiians. Archival records at the Hāna Cultural Center say, "The Hawaiians were the finest stone adz makers in Polynesia. One of the best quarries was atop Haleakalā." The various quarries throughout the islands were incomparable to Haleakalā's second-to-none quarry.

There were certain protocols to commence prior to excavating basalt rock to create the adzes. The following is a chant from David Malo's Hawaiian Antiquities.

E Kāne uakea, Eia ka ʻālana
He moa ualehu. He moa uakea, He moa ʻula hiwa.
He ʻālana kēia iā ʻoe Kāne,
No ke koʻi kalai,
Koʻi kua,
Koʻi kikoni,
Koʻi lou,
He koʻi e kai e, kalai ai ke kiʻi,
He koʻi ou e Kāne,
ke Akua ola.
ke Akua mana,
ke Akua noho i ka ʻiuʻiu,
ke Akua i ke ao polohiwa.

This is a praise given to Kāne, who was responsible for the excavation and making of the koʻi. The chant explicates, "He ʻālana kēia iā ʻoe Kāne," an offering to you, Kāne.

Hawaiians were extremely skilled in constructing the adz. As historic sculpture reveals, the carving techniques of ancient Hawaiʻi were not crude, nor did they hinder the control of the medium. Carvers of the large temple images, and probably of many smaller types, were not mere craftsmen, they were Kahuna Kalai (Priest Carvers) - selected by traditional methods, trained and initiated in the rites of the order of the type of work they would do.

It is interesting to note that there are no differences found in the quality of tools used for and by Kahuna and Aliʻi as for Farmers, Fishermen and other professions. All maintain the

[25] Physical land masses where the heavens would touch the earth.

same high quality across the lines of what western society terms as class distinction - none are found.

Adzes are older than the time of Wākea. The adzes used to hew Kumuʻeli and Kaloliamaiele [Kaloloamaile] - the canoes of Wākea et al - were koʻi meki, of iron, possibly. Their names were Haumeku and ʻOlopu, and they were adzes that belonged to Hawaiʻi nei from remote times. Makilihoahoaʻaikalani was the large chisel, kila nui, that gouged the canoes; it was also iron.

As shown through the chants, and the relation of Wākea's adzes, there is a strong bond between the tool and the kanaka. So was the process and the areas of gathering the basalt rocks to make the koʻi. Haleakalā was and has been mentioned, to be the prime spot to gather the rocks to create these useful tools.

<u>Historical Reference</u>

Because Haleakalā yields an intense epicenter of spiritual, physical and awe-inspiring power, it is not a surprise that the aspects and references are varied and abundant.

Haleakalā's use in a historical and cultural context is extremely difficult to explicate into tangible and malleable terms because many practices were commenced yet seldom mentioned.

<u>Kanikau</u>

The following written piece reflects the belief of many families of the time (circa mid 19^{th} century).

He kanikau aloha no S. P. K. i make.

> He kanikau aloha keia nou e Solomona e,
> Kuu keiki hoi, kuu minamina nalo ole e,
> O kunukunu, o naenae, o puai hanu ole e.
> O a iliili, o moemalie, o ke aho o lele loa,
> I ke ahiahi i ka napoo ana a ka la ka helena,
> Hele nalo ikea hou ole mai oe e,
> O ka uwe a Laisa, ka makuahine e,
> Aloha ino no kuu keiki e,
> Kuu keiki no hoi o ka wa naaupo,
> I hoao aku hoi i ka hanai keiki ana ia oe,
> Kii ke Akua lawe i kana o ka uhane,
> Hapuku wale ana i ko kino pono ole e,
> Pono ole ka manao paa ole ka waimaka,
> He kuaua ka waimaka a pau ae e,
> Aloha oe i ka ike ole ia.

Uwe helu ae nei o Hakaleleponi,
Aloha ino no kuu keiki e,
Na o'u kaikuaana hoi ke keiki o oe e,
He hanai keiki au na laua,
Enenenele ana ka makou ia oe e,
Nou ka ka uhane hele ahiahi,
Me he opua ala iluna o Haleakalā,
E nana ana paha i ka wai o Helaini e,
I ka luana a na wahine i ka lua,
Elua no kaua i ke anu me ke koekoe e,
I ka po loloa o ka hooilo ke moe ia,
Wehe mai nei oe i ka pili me na makua,
Haalele i ka poli ou kupuna e,
E hoomakua ana i ko ka lani,
He lani ko aloha ia'u e noho nei,
Nou paha ka uhane i Hiikua, Hiialo e,
I ka lewa a nuu i ka lewa lani,
I ka paa iluna i ka paa ilalo e,
Halawai aku la paha oe me ou kini,
Me na puali anela pau ole i ka helu,
E ku ana imua o ka Haku Sabati,
Ia Iehova ke Akua, a mau aku.

Ia Iehova ke Akua, a mau aku.

HE MAHELE.

Ooki ke anu ka hau o Kula e,
Puku ka io i ka wai o Kupalaia.
Alahia ka manao pono ole ia oe.
Kuu keikiki o ka wai o Muliwai.
O ka piha kanaka nui o Kalou.
Loua iho nei au la e ko aloha.
Hoaloha wale oe ia'u e,
Aloha ko kino i ka ike ole ia.

H. PAULO.
Nuu, Kaupo, Dek. 31, 1861.[26]

[26] Because this is such a personal matter, the entire lament will not be translated, just the portion which is relevant to this report. Nor was it fair to remove just the section of the kanikau to make a proverbial point in this report, to honor the author and the one lamented, the entire text of the lament has been included.

This kanikau, or written lament, is a prime example in depicting how relative Haleakalā was in an "everyday" culturally-steered society. Haleakalā was more than just the mountain on Maui, let alone it being the highest peak. Haleakalā represented everything that was near to the *waoakua* (certain stratosphere of earth where the gods and goddesses ruled would encompass that which was earthly).

Once again, in reference to our sited material above, the underlined portion of the text translates as follows:

> We are deprived without you,
> Your spirit will travel in the night to find solemn rest,
> Among the rising clouds of Haleakalā.

Perhaps any other reference in a casual article may not have held as much weight to the author of this report, in order to show the depth of significance Haleakalā played in a day-to-day historical context. However, for a topic such as a lament, something that is so personal and obviously a huge void to this person, the author of the *kanikau* lists the need to mention Haleakalā and what it will mean to the deceased.

Palikū Order

There is said to have been a priestly order, which commenced its spiritual practices atop Haleakalā. Not much is written of this order, nor what is written of this priesthood delves into any specific details of its spiritual practices.

In an interview conducted by the author of this report with a Mrs. Charlotte Nina Maxwell of Pukalani, Mau,i she mentioned of the Palikū Order in the following fashion:

> The Order of Palikū, a priestly order, conducted their ceremonies upon this mountain top. They painted their bodies red with lepo ʻālae, wore white kapa, carried a ki'i mounted with a pig's head and ceremoniously walked around the crater rim, Kolekole and the entire crater area. They usually performed this ritual during Makahiki.[27]

Kumu Hula Maxwell lends a unique perspective to this orderly clan. An article written in 1834 in a prominent Hawaiian newspaper however satisfies her details.

The reference that Maxwell makes to the Makahiki season is also reiterated in following newspaper article of 1834. This is an interesting notation, in part because this would mean that this priesthood would have been a more peaceful order.

[27] Maxwell, Charlotte Nina, Kumu Hula: Pukalani Hula Hale. Pukalani, Makawao, Maui. Interview with Kahu (Rev.) Charles Kauluwehi Maxwell, Sr. December 28, 2002.

Aia i Maui Hikina, oia no o Haleakala.
Haleakala a ka lehua.
Oia kekahi noho papa kahuna mai Nuu mai.
Oia ka noho papa a Paliku kahuna no hoi.
I ka wa makahiki, nui na hana koikoi a lakou.
Oia no i keia mau la, oia ka pilina me ka makou Alii.[28]

Translation:

There in Maui of the east, there resides Haleakalā. Haleakalā of the lehua blossom. There resides a class of priests from Nu'u. It is the class of Palikū priests indeed. In the winter months (time of peace), there was a heavy responsibility of them. It should be so in these days, the closeness of our leaders.

This article was of a political genre as the last lines indicate a need of the Ali'i class to resemble the heavy responsibilities as did the priesthood of Palikū.

The article uses a unique phrase to describe responsibility, *hana ko'iko'i*, or translated to mean heavy work or duties or prominent work or duties. This alludes to a more in-depth query as to what was the prominence or heavy burden carried out by this priestly order. No written context has shed light on such an inquiry.

Current References:

While portions of Haleakalā is consumed by the constant reminders of Western society's ever encroaching and at times intrusive methods, there is a need and a revival to *mālama mau ka la'a,* or preserve the sacredness, especially of areas such as Haleakalā.

Recently two *ahu* or altars were constructed. The latest construction completed in mid October of 2005. The two *ahu* face pivotal points in Hawaiian cultural protocol, one faces the east where the sun rises, this was the last of the two to be constructed in a culturally appropriate and manner. The former faces the west where the sun sets everyday.

A cultural protocol and ceremony commenced on July 17, 2005, to dedicate the ahu that faces the west, which is the female aspect. The *ahu* was dedicated to the goddess Hina. The name of the *ahu* is Hinala'anui, or Hina of immense sacredness.

On October 30, 2005, a cultural protocol and ceremony commenced to dedicate the ahu Pā'ele Kū Ai I Ka Moku, that faces the east, which is the male aspect. Pā'ele Kū Ai I Ka Moku has several meanings. Pā'ele Kū is in reference to Pi'ilani's warriors who were tattooed in large quantities. Ai I ka Moku means to acquire the island.

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[28] Ka Nūpepa Kū'oko'a. Ka Papa Ali'i, *Ka Nūpepa Kūoko'a*, v. 1, n. 11, p. 3. 24 March 1834.

These acts of responsibility are actual and tangible. It is a way to reconcile the need to have presence, and more than just a physical presence, but to remain and sustain a cultural presence. One can practice their spirituality anywhere in Hawai'i. It is certainly true if you look at specific sites that have been constructed in memoriam of those past or to honor a god or goddess. This does not mean, however, that a cultural structure can be built at any development to appease what is culturally appropriate. There is however, a fine yet steady balance between being a practitioner and constructing areas of a spiritual epicenter. This is all wrapped up into one statement, e mālama mau ka la'a.

Poetical References

Today, Haleakalā is not only known for its spirituality and as a place where primordial gods and goddesses encountered earthly happenings, but it is also revered as a majestic and serene mountain.

Famed over and over again in modern songs and dances, Haleakalā has surpassed its physical stature with its honors and glory.

From famed Hawaiian music scholar Charles E. King's melodic song "Lei Lokelani" in which he pays honor and homage to "Kilakila Haleakalā ma ka hikina – Majestic Haleakalā in the east."

To the revered Maui songwriter Alice Johnson's well known "Aloha 'ia Nō O Maui" wherein she describes Halekalā and lovingly taunts the mountain for its windy ascending roads in the following:

Kilakila Haleakalā
Kuahiwi nani o Maui
Kaulana kou inoa puni o Hawai'i
I ke alanui kīke'eke'e

Majestic is Haleakalā
Lovely Mountain of Maui
Famous is your name through all Hawai'i
And the road which zigzags

To the revered songwriter and Hula Master Aunty Alice Namakelua's rendition of her thoughts of Haleakalā and its sub districts in the following song composed in 1941:

Kuahiwi nani `oe Haleakalā Kaulana ho`i `oe kū kilakila	You are a beautiful mountain, Haleakala You are famous and stand majestically
`O Makawao ia ua kaulana I kāohi ia iho o ka lā`au	At Makawao, this rain is well known It falls gently on the trees
He `ūkiu e ka ua o ka `āina Me ka makani aheahe `olu`olu	`Ūkiu is the name of the rain of this land Here the wind is soft and cool
E aho no `oe a e komo mai A e ho`ola`i ka malu o ke ao	You should come in Relax in the shade of the clouds
Puana ka inoa i lohe `ia Kuahiwi nani `oe Haleakalā	Tell the name so that it can be heard You are a beautiful mountain, Haleakala

New groups fascinated with the art of *haku mele* or song compositions, continue to write of Haleakalā's beauty and majesty. It is a forever-fascinating encounter to stare up to its highest peak and a gratifying reward to be able to look down to all that encompasses Haleakalā Kū Kilakila – Haleakalā Standing Majestically.

There is no doubt that it is because of this long history, the respect that Haleakalā demands and the want and need to continue and revive all that is cultural that all must *e mālama mau ka la'a* – preserve the sacredness!

Native Vegetation and Habitat

The vegetation in the Kolekole/Haleakalā area does not flourish as generously as various other ahupuaʻa on Maui. However, Haleakalā is known to have endemic plants and wildlife, along with some of the world's most rare plants and animals.

Every aspect of the traditional Kanaka Hawaiʻi culture was closely interconnected with the life forms of these islands. The saying "He Hawaiʻi Au" - I Am Hawaiʻi - reveals this basic truth: the people and their environment are one, as previously made clear. All of the needs of the population (which numbered nearly as many as inhabit Hawaiʻi today) were provided for abundantly from the life of the land and ocean, passing on the stored energy of the lā[29] in multitudes of useful and beautiful forms.

Due to the geographic location as the most isolated land in the world, approximately 2,600 nautical miles from the nearest continent, the Hawaiian archipelago evolved incredibly diverse and unique ecosystems, with myriad species of flora and fauna found nowhere else on the planet.

Today Hawaiʻi is known as the extinction capital, with more extinct and endangered species than all the rest of the United States put together. More than sixty species of endemic Hawaiian birds have become extinct, and an additional 29 are endangered, totaling over 80 percent of Hawaiʻi's unique bird fauna. Ten new species on Maui have just been nominated for the endangered species list this year.

This signifies a deep rending of the fabric of life that can never be repaired in human periods, and vanishing with these species are the cultural interrelations that developed with them through the generations over hundreds of years.

In the delicate ecology of the alpine climate of Haleakalā's Mountaintop, there are over thirty plants, as well as seven bird species and numerous insects, listed as endangered species just within the National Park boundaries, with others listed as threatened species or species of concern.

Plants found on Haleakalā mountain, many of which are endemic (native and unique) to this part of the island were used for a variety of cultural purposes.

A well-known tree is the sandalwood (Santalum freycinetianum), known in Hawaiian as ʻIliahi. The wood was traditionally used to scent tapa cloth. It was sometimes used to make ʻukeke, a musical bow, the only traditional Hawaiian stringed instrument. The leaves and wood of Sandalwood trees were also used medicinally, often in combination with ʻawa and other woods. One variety of Sandalwood occurs near the Park headquarters and Hosmer's Grove. The lanaiense variety, with a red flower, found only on East Maui

[29] Lä- nvs. Sun, sun heat; sunny, solar.

and Lānaʻi, is endangered. Only around 100 plants survive today, with a population found on the south slope of Haleakalā.

Other medicinal plants from this area include the *ʻAhina Kuahiwi* (*Gunnera petaloidea*), also called *Kaʻapeʻape* or *ʻApeʻape*, and the *Mauʻu Laʻili* (Sisyrinchium acre), a crawling grass (native Iris) found on top of the mountain, which was used to treat skin disorders.

The durable wood of the golden-flowered lacy *Mamane* or *Kolomona* tree (*Sophora chrysophylla*) was utilized to make oʻo, or digging sticks, house poles, and hōlua, or sleds. One of the most outstanding examples of a hōlua slide was just recently discovered on the southeast slope of Haleakalā mountain.

Many plants found on Haleakalā were traditionally, and are still, used in lei making. The *Pukiawe* (*Styphelia tameiameiae*), the Park's most abundant shrub, is a popular element in elaborate haku lei, as well as being food for the endangered Nēnē (*Nesochen sandvicensis*), the Hawaiian Goose, Hawaiʻi's state bird.

The famous *ʻAhinahina* - Haleakalā Silversword (*Argyroxiphium sandwicense* ssp. *macrocephalum*) - a variety found only on Maui was also used to make leis, but overexploitation by outsiders contributed greatly to its near demise. Once numbering less than 100 plants, it is now listed as threatened, with a recovering population of around 65,000 plants.

For some endangered flora and fauna, it may already be too late, as the ebb of human predominance elucidates its presence to untouched history beyond the common understanding. However, as long as the endangered flora and fauna continue to survive, we must do our utmost to protect and restore these species.

On March 20, 1999, Earth Law, Inc.'s[30] staff attorney, Debbie Sivas[31], made mention to their supporters in a letter (regarding airplane flights near Haleakalā), of Haleakalā's fragility:

> Haleakalā protects more imperiled species than any other national park -- six endangered bird species, 12 endangered plant species, and many rare invertebrate and plant "species of concern." Some 90 percent of the Haleakalā's 650 plant species and 800 invertebrate species live only on the Hawaiian Islands. Eight forest birds reside only within the park's borders. Its little wonder that the park has been designated an International Biosphere Reserve.

[30] Formerly Earth Law, Inc., has since merged with Earth Justice, Inc.
[31] http://www.earthlaw.org/Newslett/letter22.htm

Sivas continued to state:

> This is the reason we brought an action on behalf of the National Parks and Conservation Association and Maui Mālama Pono, a Hawaiian grassroots organization that promotes slow growth, to block the creation of an international airport on Maui.

One might wonder what tangent these quotes would have to a composition of this sort. In this particular case, a lawsuit was filed because the Kahului Airport had plans to expand. According to Sivas, many were concerned about what the indirect impact on Haleakalā might be. Come some three years now, and Haleakalā is in direct impact with the proposal to build new infrastructure.

The flora and fauna mentioned and more thrive in this very fragile environment. Many may be brought back from the brink of extinction if their habitat is preserved and restored. To build any more infrastructures at Haleakalā would only be adding "fuel to the fire." Both the Silversword and the Nēnē goose are examples of species on Haleakalā that nearly became extinct from human exploitation, which are now increasing in numbers due to our positive intervention.

ARCHAEOLOGICAL ASSESSMENT OF SITE

There are no significant archaeological sites found where the proposed ATST is to be built. There are numerous evidence that the entire Kolekole area was used in ancient times by the wind-shelters, and habitation sites that are found in the general area. It substantiates the mo'olelo, or stories, how the Kahuna Po'o, or high priest, used this area to teach students about the heavens and the universe. For more detailed information, refer to the Archaeological Report submitted by Eric Frederickson of Xamanek Researchers.

E Mālama Mau Ka La'a

Preserve the Sacredness

Interviews of Informants

Rowell T. Kim
Installer – Oceanic Time Warner Cable Television
504 Kaulana St., Kahului, Hi 96732

October 7, 2005 at 7:00 p.m., interviewed at 504 Kaulana St., Kahului, Maui:

He related that he was born on Oahu and moved to Maui about 20 years ago. He had traveled to Haleakalā on numerous occasions and had marveled at the beauty of this majestic mountain. From his girlfriend, he learned how sacred the mountain was and numerous legends were connected to this place. That the Hawaiian Goddess Pele lived in the crater and other gods that the Hawaiian people worship. Hopefully, they do not over build the top of the mountain and make it into another Mauna Kea on the island of Hawai'i. Concluded by saying that they should teach the children in the Maui Schools about what is happening on top of the mountain so that they can be allowed to work in the facilities in "science city". Ended by saying that not only the needs of science should be taken cared of but also the local people should benefit for using their mountain.

David Kaahuula Dutro
Retired – Young Brothers Inc.
3379 Anuwanu St. Pukalani, Maui 96768

October 9, 2005 at 10:00 a.m., interviewed at 157 Alea Place, Pukalani, Maui:

He stated that he was born in Wailuku on September 19, 1935. He had lived and worked on Maui all his life. He really has no opinion about the telescopes on Haleakalā but hope that it is for something that will benefit us and improve our lifestyle. That the main thing is, they adhere to the cultural rules that are set for the mountain.

Oliver Harold Cummings Sr.
Retired U.S. Post Service
617 S. Oahu St., Kahului, Hawai'i 96732

October 9, 2005 at 3:00 p.m., interviewed at 617 S. Oahu St., Kahului, Maui:

He stated he was born January 5, 1930 in Kahului. That he remembers visiting Halekalā with his family on many occasions and had heard that it was a sacred place because of the gods that live there. He felt strongly that whatever is built on top of the mountain, they build it with respect for the sacredness of the place. He is afraid that the top will be cluttered with buildings and the sacredness will be lost.

Jennifer L. Paet
Loan Officer – Atmic Lending Corporation
25 West Makahehi Place, Kahului, Hi 96732

October 9, 2005 at 8:00 p.m., interviewed at 25 West Makahehi Place, Kahului, Maui:

She related that she was born and raised on Maui and that she can remember from a young age her fascination with Halekalā because it overpowers the rest of Maui. She had heard how sacred the mountains are to the native Hawaiian people and being a hula dancer, she really respects the Hawaiian culture.

She occasionally chants and dances about the Goddess of the Volcano Pele and knows about her travels throughout the pacific because of hula. She hopes that they take care of the spirituality of Haleakalā when building any facilities.

Hokulani Holt-Padilla
Cultural Program Director – Maui Arts & Cultural Center
659-Pohala St., Wailuku, Maui 96793

October 12, 2005 at 3:00 p.m., interviewed at her office:

She related that it is an abomination to this mountain because it is this mountain that allows this land to exist and with out the land we as a people cannot exist. When you put this foreign material on this mountain that makes it more important then the mountain itself, that is unacceptable behavior and in Hawaiian Culture that is maha'oi (rude). You go to a place that does not belong to you. In addition, there is nothing that brings honor and beauty to this mountain and it is being used because it is a high place and you can get a clear view.

When our Kupuna went to use this place, they used it in order to communicate with their Akua to communicate with their Kupuna, and even when they passed through the mountain to go from one side of the island to the next, they new that they were always passing the realm of the gods, the Wao Akua 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, so to put something up there is to put a mark that does not blend and does not belong on Haleakalā.

These structures on Haleakalā does not take away from the spirituality of it, but it does prevent full spiritual use of it, the mountain is greater than all of us. We will come and go the mountain will remain, it is greater than all of us. We go there to find spirituality or reconnect is still possible, but it is more difficult with this up here because it is not part of the mountain. If it were gone, we would have direct connection to our Kupuna. If it were gone, which I would hope to happen, then we would have direct connection to our gods, direct connection to our Kupuna without this kind of disturbance. Continued use of it like everything else, eats away at the spirituality of it.

Having the telescope up there as I have been told, will contribute to the Western intelligence scientifically. What they learn from the information they gather from this telescope in understanding this world and other planets in the universe. That's well and good, but what does it contribute to our culture? I personally don't think it supports a whole lot of our culture. So, if the western culture is learning a lot about what goes on in the universe from these telescope, then the western culture must support the perpetuation of our culture. They must support our efforts as Native People of this land so that we as people can learn the things that we need to learn so we can have the knowledge to teach our children what was taught to us by our ancestors, for the sake of future generations.

Whatever the building of the telescopes on Haleakalā means to the scienctific community, it is double important to the Hawaiian people as a place of revereance. The education of the children should be supported by these facilities in having programs throughout our schools system and directly support programs that are perpetuating, preserving and educating the Hawaiian people and their children in the culture of Hawai'i.

Concluded by saying that in the past, Hawaiians were barred from these spiritual places. It does not mean that they did not want to do anything and I truly feel that it is our responsibility to prepare the ground for what our children need to know. We prepare the ground for having the Ahu built up there so if they want to go back to the past, they can do so and it will be available for them if they want to in the future. We must teach our children the importance of our culture because if we don't teach them they won't know.

Supporting educating does not mean going to Haleakalā 3 times a year and participating in programs. It means that these facilities should support Hawaiian education in any way they can. If it is going to be built anyway, by using this sacred place, they have to contribute in perpetuation of the Hawaiian Culture.

Adrian Kamalaniikekai Kamali'i
Publicist - YK Communications L.L.P.
1050 Kina'u St., Honolulu 96814

<u>October 11, 2005 at 2:15 p.m., interviewed at 157 Alea Place, Pukalani, Maui:</u>

He related that he was born and raised in Kahului, Maui and that he attended Kamehameha School, and completed two years college at Hawai'i Pacific University. He is the Associate Researcher on this project.

Having been raised on Maui, the dominance of Halekalā is always present and at a very young age was instilled by his mother and grandparents the cultural importance it has to the Hawaiian Culture.

He strongly feels that no matter what the objections to the building of the ATST on Halekalā, it will get built anyway, if not on Haleakalā or some other mountain like Mauna Kea on the island of Hawaiʻi. Both of those places provide ideal sites for them to do whatever work they need to do. So there is no question whether its going too built or not.

Spirituality can be practiced anywhere, in the middle of Waikiki where burials are preserved or in downtown Honolulu or other bustling cities where a heiau is there, that does not mean we cannot practice our spirituality.

Actually looking at the visual impact of the pictures I thought that it would be more noticeable from the valley area, and of course, these are at a distance. The visual impact is actually in the psychic of one's mind that it is more hurtful to see something like that large on the mountain and some would argue that it could ruin the spirituality but some might argue that one can still be spiritual because the place dictates it. Like anywhere else you can hold your sacred ceremonies and the focus would have to be on spirituality, nothing else. Lord! look at Iao Valley with all the buildings and visitors that go there we still practiced our culture and can still do so even with these "distractions."

The work ethic on Haleakalā must always be focused on the sense of place that this telescope is being built on Hawaiian soil and not anywhere in the U.S.A. That they have to follow the cultural protocol set up for this mountain whenever work is conducted at this sacred site. They have to have a sense of obligation working at Haleakalā and realize that they are in a very culturally sensitive area and utmost care must be used before, during and after their work day at the site.

If someone backs this project, its easy to call them sell outs however at the end of the day if you only protest and try not to be involved in assuring the proper cultural procedures are followed, then the culture would lose and construction takes place anyway.

We must strive to give notice to all construction in Hawaiʻi that standards must be followed when working in highly sensitive areas like Haleakalā. My wish is that modern technology some day will be able to view the stars without building on the tops of our mountains which is sacred to us. That whoever constructs facilities in places like Haleakalā should understand that we should reserve the right to say what pono is and what is not.

Clarence Keliʻionamoku Solomon
Manager – Sewage Plant, County of Maui
516 South Kikānia Place, Waiheʻe, Maui

<u>October 12, 2005 at 4:00 p.m., interviewed at Velma Santos Community Center, Wailuku, Maui:</u>

He related that being involved in different groups for sovereignty and fighting for things that should not be built on sacred sites; we have failed to stop the building of these projects, and its time that we take a different approach. The Hawaiian people are on the outside and are tired of losing to the State, County and Department of Land and Natural Resources. That as native people of this land, we should try to get something for the Hawaiian culture and fund Hawaiian cultural programs, funding for educating our children in cultural things and using these faculties to further their education.

That if the telescope is going to be built, they must contribute financial resources to fund cultural programs and education in the school. That as Hawaiians we should have a seat at the table to decide how funds could be directed to further the cause of the Native Hawaiians education.

The hard part is for us to convince our people to take a different approach and join forces to sit on the bargaining table to get something for us. It is not a matter of selling out; it's a matter of waking up and making the facilities pay impact fees for the use of Haleakalā. Our children should be trained and some day could take over the management of Haleakalā so that they truly can "give back" to the culture.

He concluded by saying that scholarships and programs should be created for native Hawaiian children to further their education in the field of astronomy and work up at Haleakalā.

Verna Nalani Podlewski
Secretary - Maui Land & Pineapple Co.
918 Nenelea St., Haliʻimaile Maui, Hawaiʻi

<u>October 13, 2005 at 3:15 p.m., interviewed at 157 Alea Place, Pukalani, Maui:</u>

She related that as a Native Hawaiian she is very concerned with this new technology that may come to Haleakalā. After reading the article in the Maui News, about the telescope, she had fear and anger instilled in her. Her biggest fear is huge structures that will forever be in our memory each time she looks at our precious mountain. She also does not like the fact that a major facet of this structure will be the mirror. As it has been taught to her, Haleakalā is the house of the sun, where Maui captured the sun and asked the sun to slow down so Kanaka could benefit from the sun's power rays and each day she gain her strength and warmth from the sun. It's a scary thought that this mirror shall tell the sun that she is no longer welcome in her home. Ehu ku'u pu'uwai a uwe Nalani.

Concluded that she is new at this and is trying to learn the cultural protocol to her culture.

Elizabeth Keala Han
Examiner of Chauffer – County Of Maui
272 Hiolani St., Pukalani, Maui Hawai'i 96768

<u>October 16, 2005 at 5:00 p.m., interviewed at 272 Hiolani St., Pukalani, Maui:</u>

She stated that she was born in Lahaina and at a young age moved up to Waiakoa Kula. That she attended Kealahou School and Maui High School in Hamakuapoko. She remembers her mother and father talking about the sacredness of Haleakalā but did not know much about what happened in ancient times. She hopes that whatever is built on the top of the mountain that they care for the sacredness of the place.

Eric Fredrickson
Archaeologist – Xamanek Researchers L.L.C.
P.O.Box 880131, Pukalani, Maui, Hawai'i 96768

<u>December 20, 2005 at 8:40 a.m., conducted a telephone interview.</u>

He stated that he had been to the site on several occasions and that the last time was December 15, 2005 with CKM Cultural Resources L.L.C. monitor Dane Maxwell. They checked the entire area, and found that the only historical site being over 50 years old is Reber Circle (50-50-11, 5443 State of Hawaii historical site number). There were no archaeological sites found but possible site below Mees Observatory next to the roadway was noticed and information on this site will be submitted in his report.

He concluded that the entire Kolekole area consisted of numerous wind shelters and temporary shelter sites that indicate that the ancient Hawaiian people used the mountaintop heavily in pre-contact times. The two altars that have been recently built within the last several years should contain placards to indicate its presence.

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakala

PERSON INTERVIEWED: Rowell T. Kim

ADDRESS & E-MAIL, PHONE 504 Kaulana St, Kihei, HI. 96732
rokim@hawaii.rr.com

DATE & TIME OF INTERVIEW: 10/09/05 7:00 pm

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

I HEREBY GIVE PERMISSION TO CKM CULTURAL RESOURCES L.L.C., TO USE THE INFORMATION FROM THIS INTERVIEW IN PREPARING A CULTURAL IMPACT ASSESSESMENT REPORT FOR THE SUBJECT PROJECT. I FURTHER UNDERSTAND THAT I WILL BE GIVEN A COPY OF MY COMMENTS UPON REQUEST.

Yes__________ No__________

Person Interviewed Print name: Rowell T. Kim

Signature: [signature]

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

Interview Consent Form for Rowell T. Kim

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakala

PERSON INTERVIEWED: David K. Dutro

ADDRESS & E-MAIL, PHONE 3379 Anuanu St.
Pukalani 96768

DATE & TIME OF INTERVIEW: 10/9/05 1:00 pm.

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

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Yes________ No ✓

Person Interviewed Print name: David K. Dutro

Signature: David K. Dutro

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

Interview Consent Form for David K. Dutro

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakala

PERSON INTERVIEWED: Oliver H. Cummings Sr.

ADDRESS & E-MAIL, PHONE 617 So. Oahu St, Kahului Hawaii 96732

DATE & TIME OF INTERVIEW: 10-9-05 3:00 pm

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

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Yes ✓ No ____

Person Interviewed Print name: Oliver H. Cummings Sr.

Signature: Oliver H Cummings Sr

Kahu Charles Kauluwehi Maxwell, Sr.
157 Alea Place · Pukalani, Maui, HI 96768
Phone: (808) 572-8038 · Fax: (808) 572-0602 · Cell: 870-3345
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Interview Consent Form for Oliver H. Cummings Sr.

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakala

PERSON INTERVIEWED: Jennifer L. Paet

ADDRESS & E-MAIL, PHONE 25 West Makaheni Place
Kahului, HI 96732
jaden 217@hotmail.com

DATE & TIME OF INTERVIEW: 10/09/05 8:00 p.m.

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

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Yes X No ____

Person Interviewed Print name: Jennifer L. Paet

Signature: Jennifer L. Paet

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Interview Consent Form for Jennifer L. Paet

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakalā

PERSON INTERVIEWED: Hōkūlani Holt-Padilla

ADDRESS & E-MAIL, PHONE 659 Pohala St.
hokulani@mauiarts.org Wailuku, HI 96793

DATE & TIME OF INTERVIEW: Oct. 12, 2005 3pm

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

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Yes HHP No ________

Person Interviewed Print name: Hōkūlani Holt-Padilla

Signature: Hokulani Holt-Padilla

Kahu Charles Kauluwehi Maxwell, Sr.
157 Alea Place · Pukalani, Maui, HI 96768
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Email: kale@moolelo.com · Website: www.moolelo.com

Interview Consent Form for Hokulani Holt-Padilla

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakalā

PERSON INTERVIEWED: Adrian Kamalaniikekai Kamaliʻi

ADDRESS & E-MAIL, PHONE akamalii@hawaii.rr.com
808.722.8604

DATE & TIME OF INTERVIEW: 10/11/05 2:15pm

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

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Yes X No ______

Person Interviewed Print name: Adrian Kamalaniikekai Kamaliʻi

Signature: [signature]

Kahu Charles Kauluwehi Maxwell, Sr.
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Interview Consent Form for Adrian Kamalaniikekai Kamaliʻi

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakala

PERSON INTERVIEWED: Clarence Keli'ionamoku Solomon

ADDRESS & E-MAIL, PHONE keli1_s@hotmail.com / cell 264-1302

DATE & TIME OF INTERVIEW: 10/12/05 4:00pm

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

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Yes ✓ No ______

Person Interviewed Print name: Clarence Keliionamoku Solomon

Signature: Clarence K. Solomon

Kahu Charles Kauluwehi Maxwell, Sr.
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Phone: (808) 572-8038 · Fax: (808) 572-0602 · Cell: 870-3345
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Interview Consent Form for Clarence Keliʻionamoku Solomon

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakalā

PERSON INTERVIEWED: Verna Nalani Podlewski

ADDRESS & E-MAIL, PHONE 918 Nenelea St, Haliimaile 96768
vpodlewski@mlpmaui.com

DATE & TIME OF INTERVIEW: 10/13/05 3:30pm

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

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Yes vnp No ______

Person Interviewed Print name: Verna Nalani Podlewski

Signature: Vern Nalani Podlewski

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Interview Consent Form for Verna Nalani Podlewski

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INTERVIEW SUMMARY AND CONSENT FORM

JOB NAME: ATST at Haleakalā

PERSON INTERVIEWED: Elizabeth K. Han

ADDRESS & E-MAIL, PHONE 272 Awalani St.
Pukalani, HI 96768 572-2288

DATE & TIME OF INTERVIEW: 10/16/05 5:00 pm.

INTERVIEWER: CKM CULTURAL RESOURCE L.L.C. - C. K. Maxwell

PURPOSE OF INTERVIEWE: CULTURAL IMPACT ASSESSMENT

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Yes X No ____

Person Interviewed Print name: Elizabeth K. Han

Signature: Elizabeth K. Han

Kahu Charles Kauluwehi Maxwell, Sr.
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Interview Consent Form for Elizabeth K. Han

E Mālama Mau Ka La'a

Preserve the Sacredness

CULTURAL PROTOCOL, BEFORE, DURING AND AFTER CONSTRUCTION

Kolekole is considered to be a *wahi pana,* or a sacred place and a *wao akua,* where the gods live, which is why it is of the utmost importance that proper respect and reverence be given to this place. The *kāpo'e kahiko,* or ancient people, treated this place with great respect and admiration.

Today, the need to build telescopes and observatories for scientific purposes should not diminish the Hawaiian feeling for this sacred area. Proper consultations should occur prior to construction on the site taking into account the spiritual and cultural rules that must be followed.

Sense of place training classes is held for everyone that is working on the site. Workers are also taught about working in cultural sensitive environments. During orientation for workers, prayers must be performed before and after each work day.

A cultural monitor will be present in all phases of construction until the completion of the ATST project.

E Mālama Mau Ka La'a

Preserve the Sacredness

Reber Circle

In consultation with the construction engineer who would be working on the proposed ATST site, the *pu'u,* or hill, where Reber circle lies could be restored with the excavated materials, which could be kept on site.

The following three pages are excerpted from:

Geological Setting at Primary and Alternative
Advanced Technology Solar Telescope (ATST) Sites,
Haleakal**ā** High Altitude Observatories

By: Ron Terry, Ph.D., Geometrician Associates
November 2005
Prepared for KC Environmental, Inc.

According to project plans, if the ATST facility is located on the primary site, the Reber Circle site may be available for placement of excavated material. This material would be placed to restore the *pu'u*, or hill that previously existed at this location before the construction of the Reber circle experiment. The shape of the hill would be determined as much as possible from historical photographs and geological records, and would extend the contours of the existing adjacent slopes for a natural effect. The remains of the concrete Reber circle ring and the rock building at the northeast end of the site would be removed. As part of this analysis, KC Environmental, Inc. asked whether it would be possible to determine the appearance of the *pu'u* landform that was present at the Reber Circle site before it was graded. Although it is only speculation, the photographs in Figures 10 and 11, taken of nearby small promontories, are probably similar to the removed landform and could be used as rough analogues. Such features are often between 20 and 50 feet in height. The "soil placement" area illustrated in Figure 12, which shows a landform reconstructed from about 4,000 cubic yards of cut rock and "soil" generated from material at the primary site that would be 24-feet high and 13,400 square feet in area at the base, would provide a reasonable simulation of the previously existing topography.

Figure 10. Analogue I to Pre-Grading Landform at Reber Circle

Figure 11. Analogue I to Pre-Grading Landform at Reber Circle

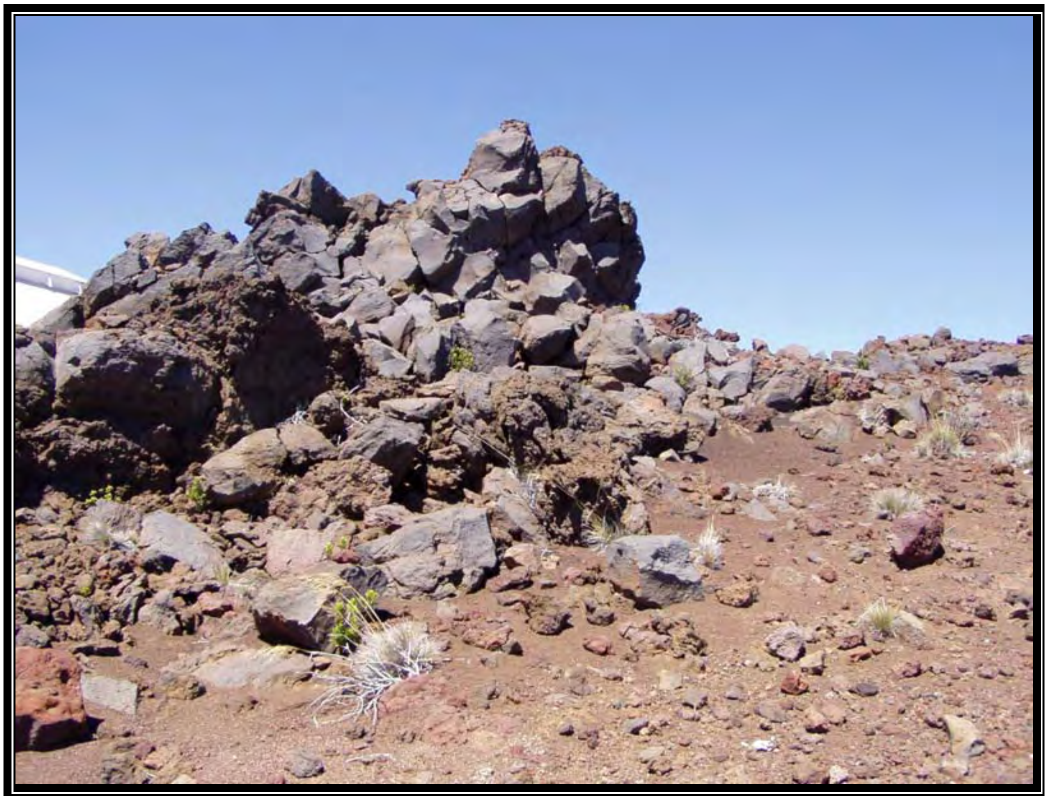
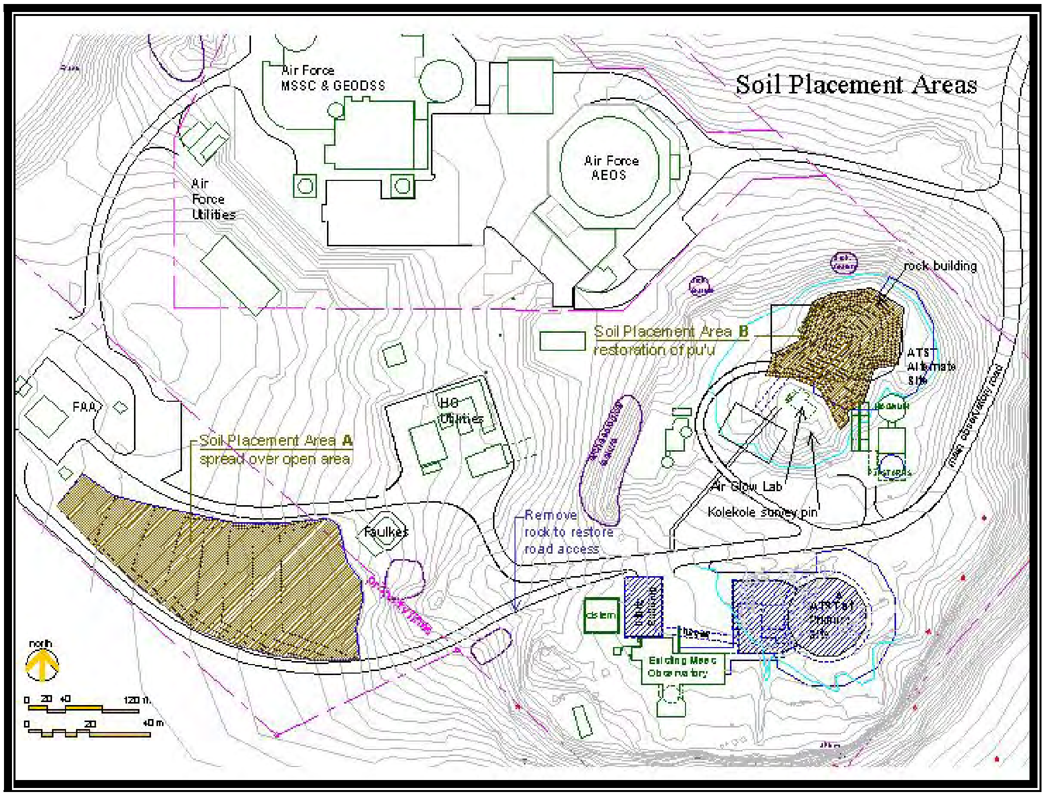


Figure 12. Soil Placement Areas



E Mālama Mau Ka La‘a

Preserve the Sacredness

Ahu on Kolekole (Haleakalā)

On July 17th 2005, a cultural protocol and ceremony commenced to dedicate the ahu which faces the West, which is the female aspect of this mountain. The *ahu* was dedicated to the goddess Hina. The name of the *ahu* is Hinala‘anui or Hina of immense sacredness.

Hinala‘anui

On October 30, 2005 a cultural protocol and ceremony commenced to dedicate the ahu which faces the East. This Ahu was named: Pāʻele Kū Ai I Ka Moku

It is a mix of meanings:

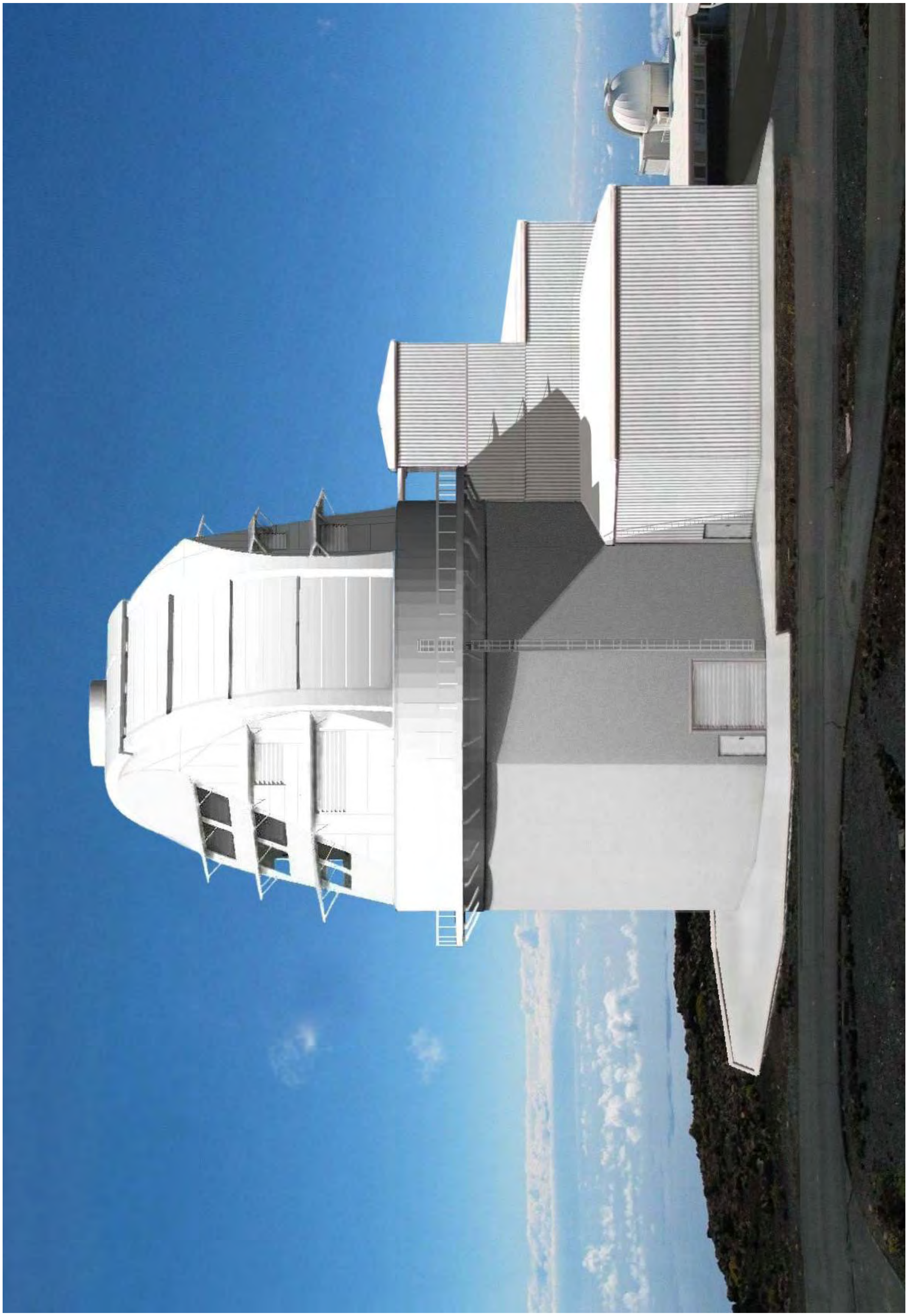
Pāʻele Kū is in reference to Piʻilani's warriors who were tattooed in large quantities.
Ai I Ka Moku literally means to acquire the island.

So in reference it means that Piʻilani's warriors will one day acquire the island, and what a better place to declare that than from its highest peak, all under the watchful eye of Kū!

Site A has a single cultural site, which consists of an altar and a pathway that leads to it. This altar was constructed on October 30, 2005, and is used for different religious Hawaiian practices. The surrounding area mostly consists of shrubbery and medium to large boulders. A few dark-romped petrels or *Ua'u*, inhabit the outer skirts of the south side of this site.

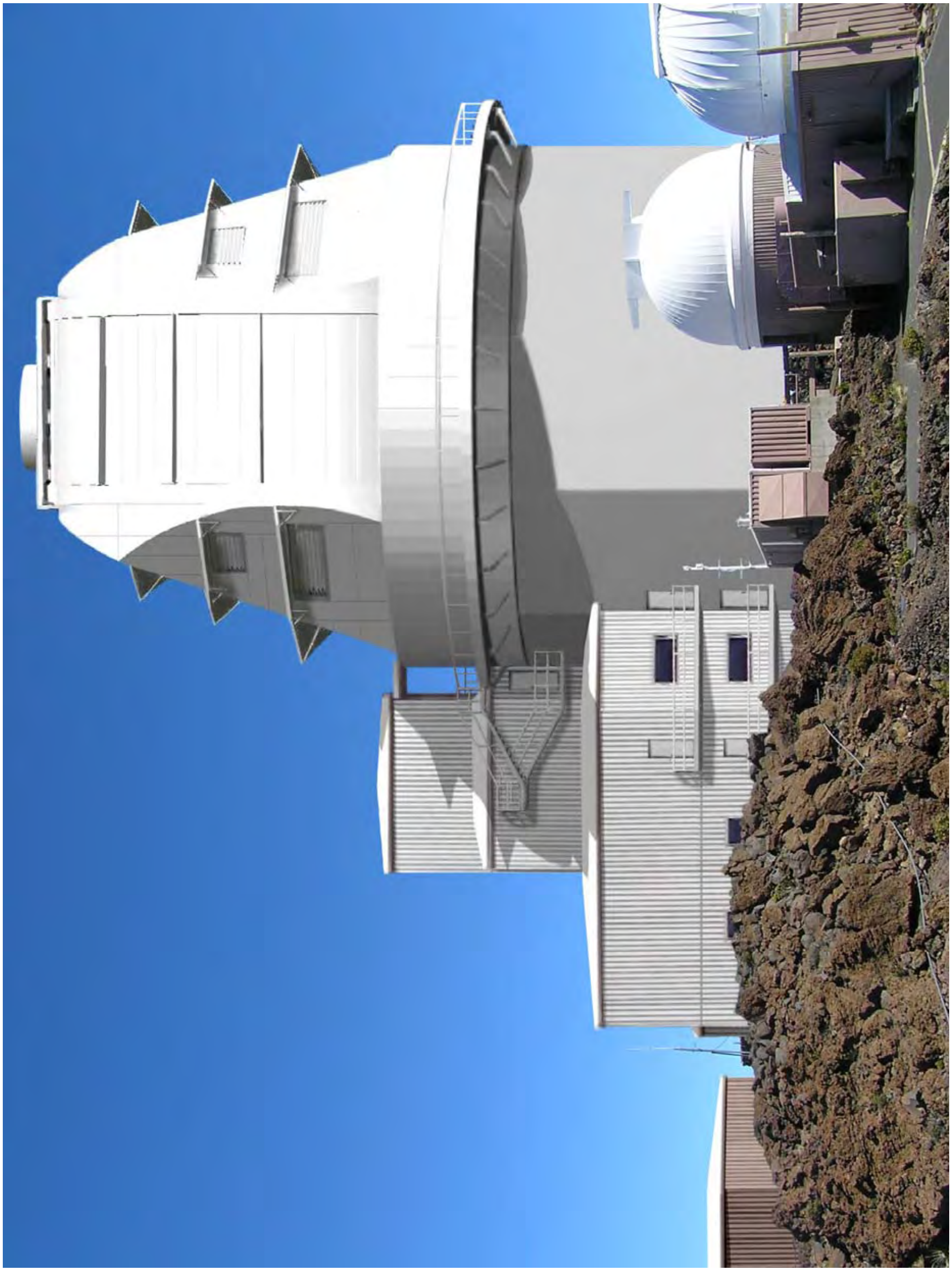
Pāʻele Kū Ai I Ka Moku

Pāʻele Kū Ai I Ka Moku



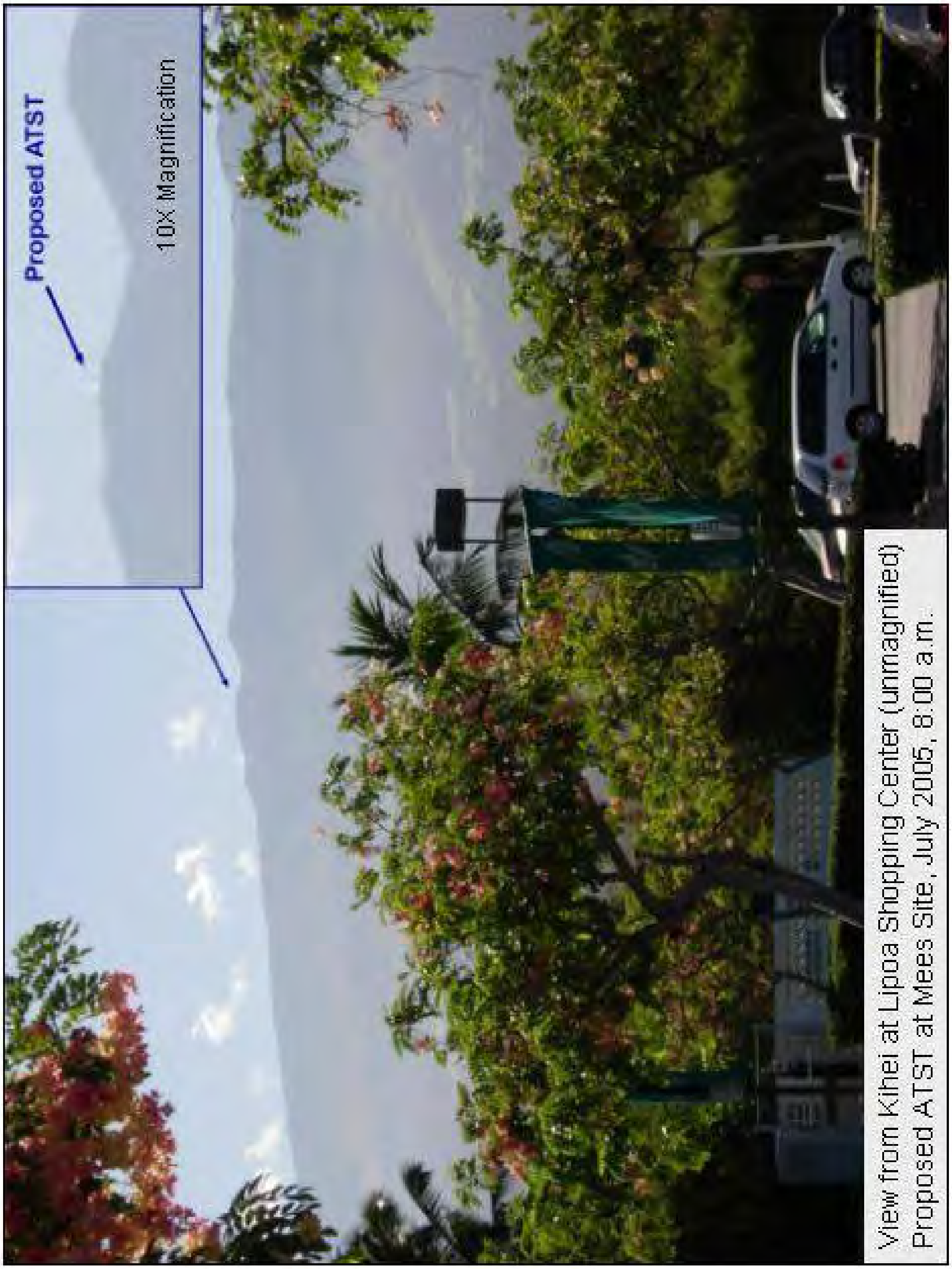
Proposed ATST Site A

Proposed ATST Site A



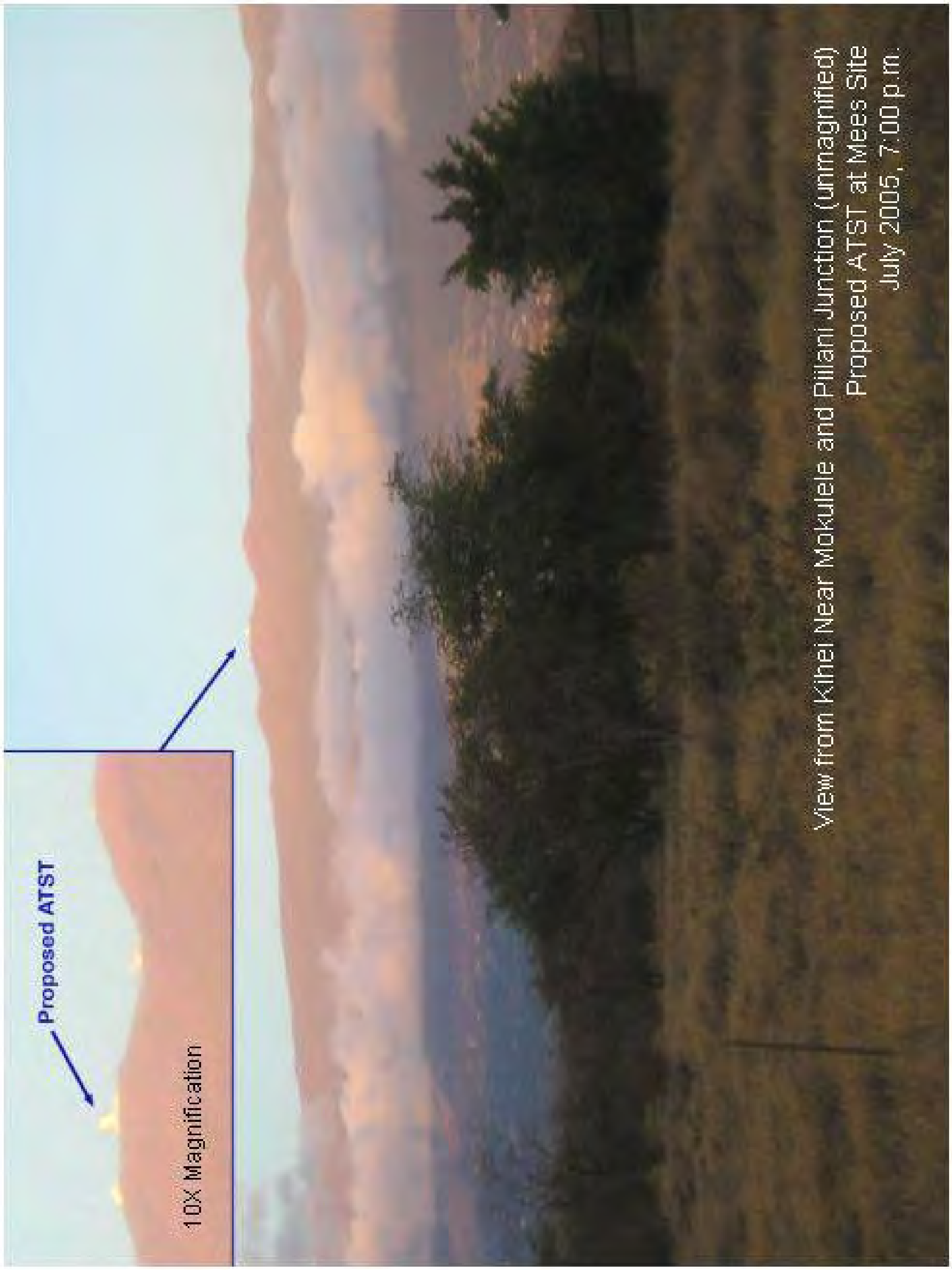
Proposed ATST Site B


Proposed ATST
10X Magnification
View from Kula Adjacent to Kamehameha Schools (unmagnified)
Proposed ATST at Mees Site
July 2005, 7:45 a.m.



View from Kihei at Lipoa Shopping Center (unmagnified)
Proposed ATST at Mees Site, July 2005, 8:00 a.m.


Proposed ATST
10X Magnification
View from Maalaea Harbor (unmagnified)
Proposed ATST at Mees Site
July 2005, 6:30 p.m.


10X Magnification
Proposed ATST
View from Kihei Near Mokulele and Piilani Junction (unmagnified)
Proposed ATST at Mees Site
July 2005, 7:00 p.m.

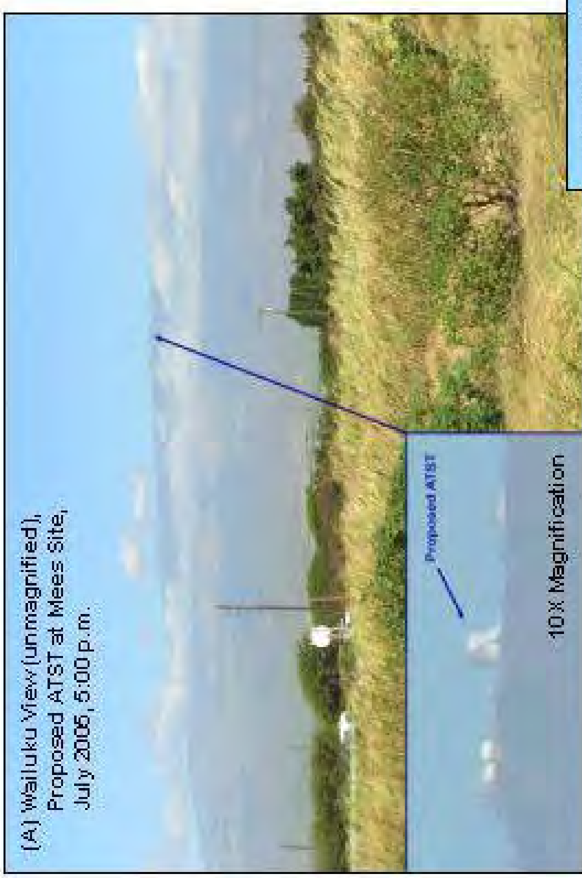

View from Makawao, Piiholo Road (unmagnified)
Proposed ATST at Mees Site
July 2005, 8:00 a.m.
Proposed ATST
10X Magnification

(A) Pukalani View (unmagnified), Proposed ATST at Mees Site, July 2005, 7:30 a.m.

(B) Pukalani View (unmagnified), Proposed ATST at Reber Circle, July 2005, 7:30 a.m.

Picture of silversword

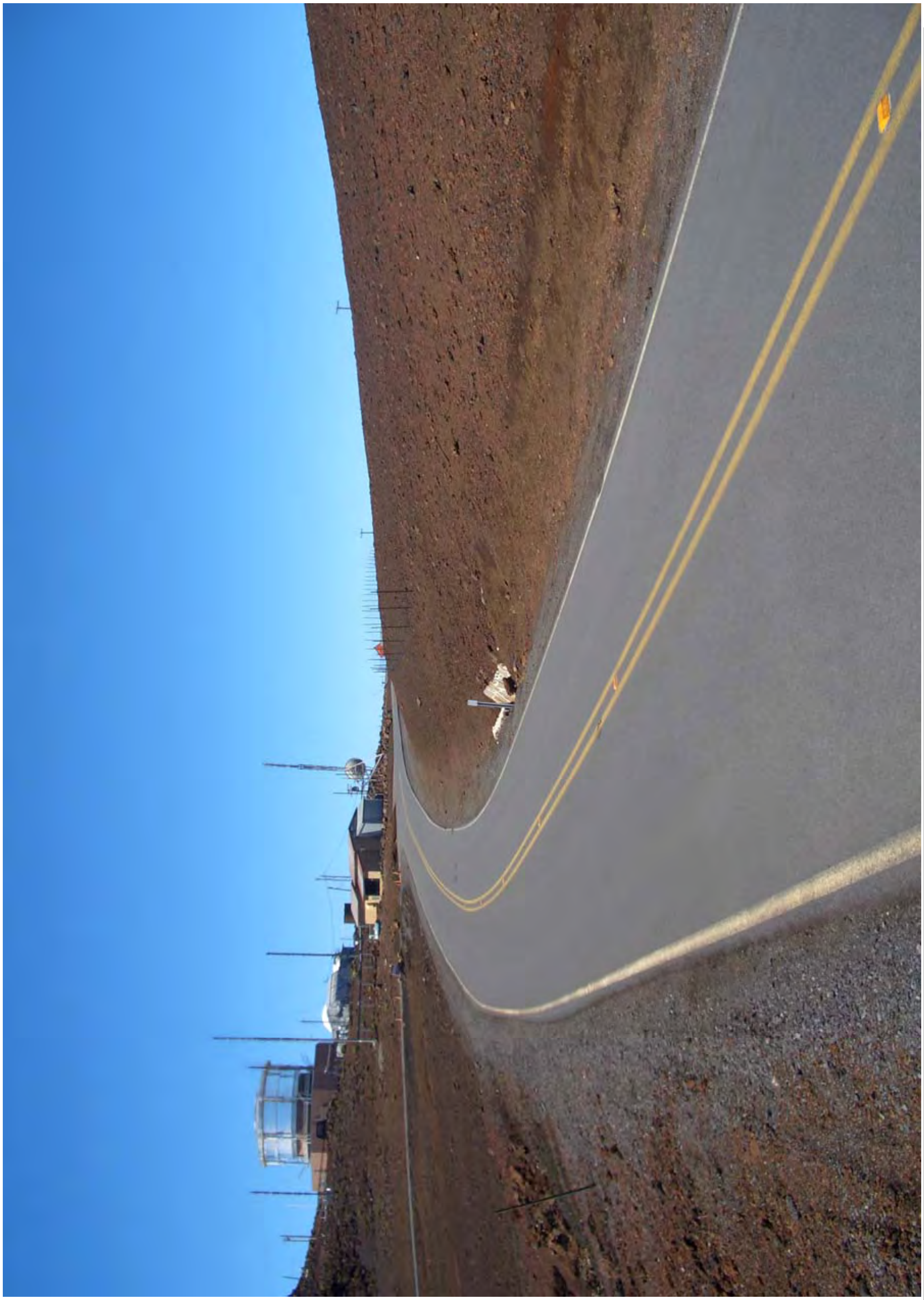
Maui Contour Map with ATST View Plane


(A) Wailuku View (unmagnified),
Proposed ATST at Mees Site,
July 2006, 5:00 p.m.
Proposed ATST
10 X Magnification


(B) Wailuku View (unmagnified),
Proposed ATST at Reber Circle Site,
July 2006, 5:00 p.m.
Proposed ATST
10 X Magnification

Entry to Kolekole

Entry sign to Kolekole



Road to Kolekole


HALEAKALA OBSERVATORY
INSTITUTE FOR ASTRONOMY
UNIVERSITY OF HAWAII
NO LIGHTS PLEASE
LIGHT SENSITIVE OBSERVATIONS IN PROGRESS

UH-IFA sign

E Mālama Mau Ka La‘a

Preserve the Sacredness

CONCLUSION

In conclusion, the fact remains that any building or structure built on this site is an intrusion on the sacredness and spirituality of this mountain revered by the Hawaiian people past and present. One must find the balance of building on this site and at the same time protect at best the cultural impact and methods used to mitigate these impacts.

These mitigation measures must include the delicate balance of digging into the lava, which is the essence of the Goddess Pele, saying the proper prayers to mitigate the impact.

During the period of construction all workers MUST be aware of cultural rules that are present in a spiritually, culturally, sensitive area. (Workers will be well versed on the cultural rules during sense of place classes).

The Hawaiian population must be aware that these cultural methods are being followed while construction is occurring so that a better understanding can occur with the scientific communities.

A gesture of rebuilding the *pu‘u,* or hill, at Reber Circle is an indication that efforts are being used to restore some of the natural habitat on the site. Focus on this sacred site should be the least impact as possible on the natural features found on Kolekole.

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APPENDIX F(2)

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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Management Summary

Report Reference	Supplemental Cultural Impact Assessment for the Proposed Advanced Technology Solar Telescope (ATST) at Haleakalā High Altitude Observatories Papaʻanui Ahupuaʻa, 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: Puʻu 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 Hawaiʻi
Agencies	National Science Foundation (NSF) – Proposing Agency Association of Universities for Research in Astronomy (AURA) – Proposing Agency University of Hawaiʻi 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 Hawaiʻi 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 Hawaiʻi 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 Hawaiʻi Environmental Regulations, this undertaking is subject to Hawaiʻi Administrative Rules (HAR) Title 11 Chapter 200-4(a) and Chapter 343 of the Hawaiʻi 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.

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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).

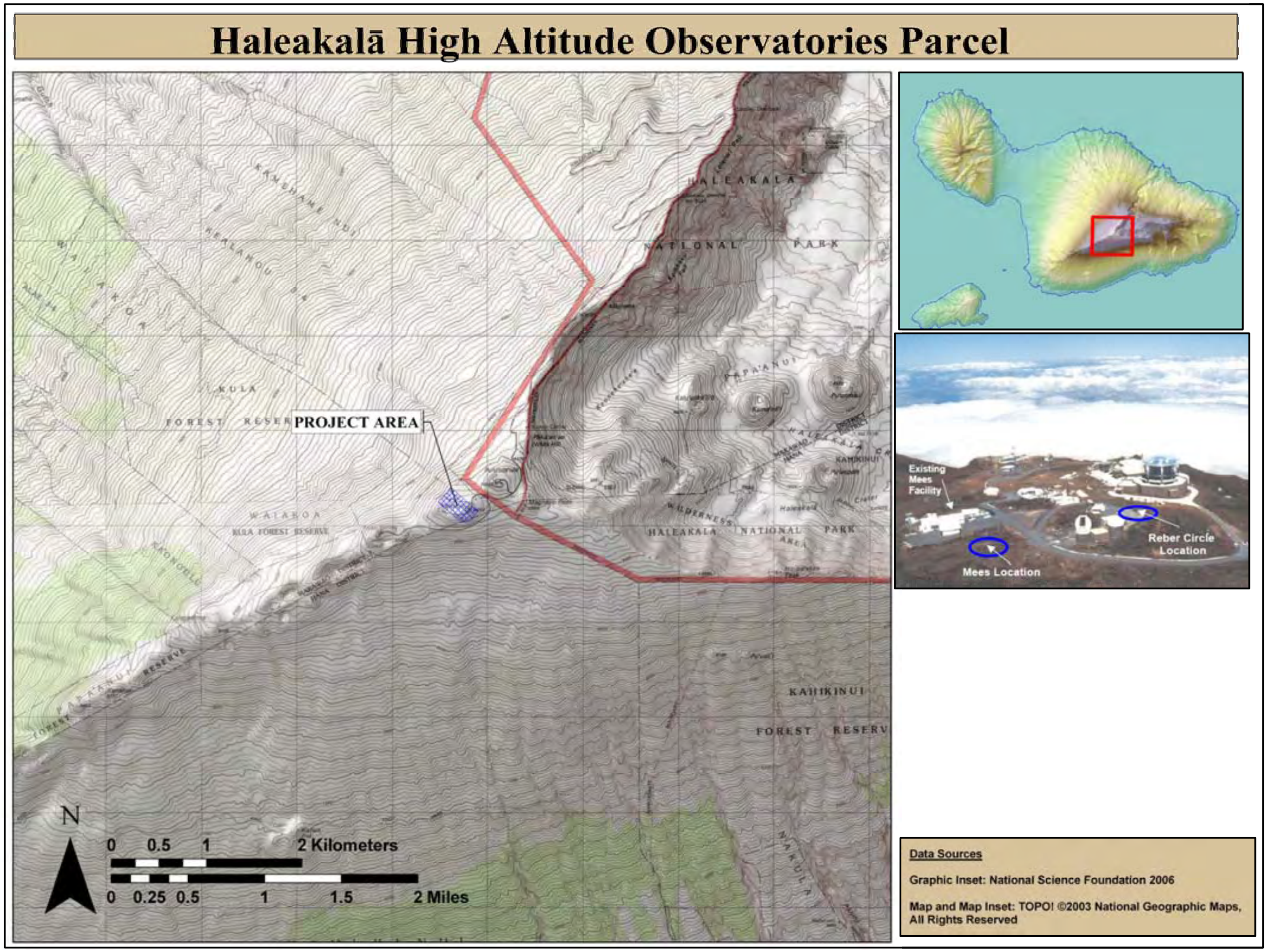

Figure 1. Portions Kilohana (1983) and Lualailua Hills (1983) 7.5-minute USGS topographic quadrangles with project location indicated by blue shaded area.

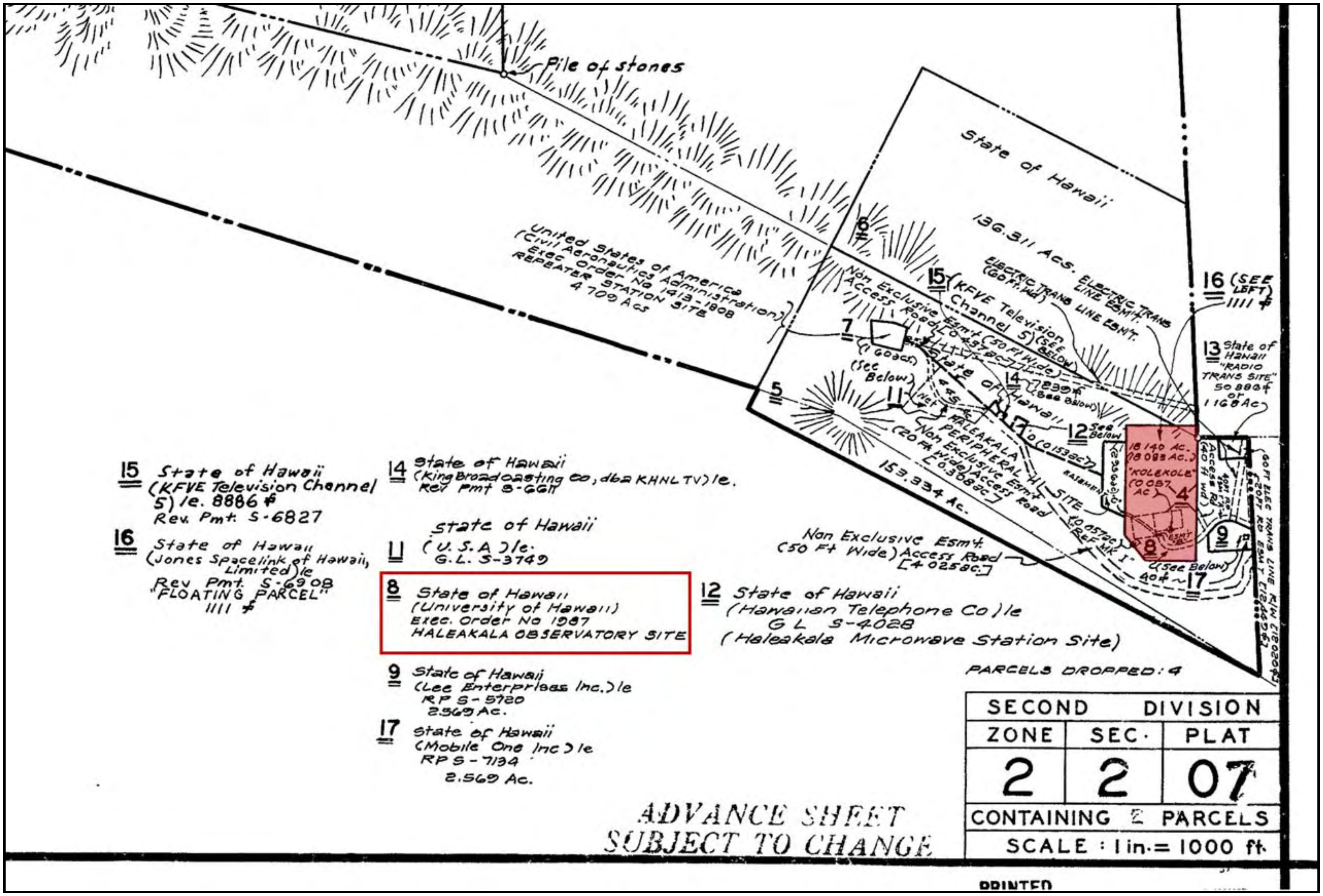

Figure 2. TMK (2) 2-2-07 showing loction of project area shaded in red

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 Pu‘u 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 *ʻalehe* is a variant form of *ʻahele.* 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 Puʻu ʻUlaʻula to see the sunrise, by both tourist and *kamaʻāina*, 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 "Haleʻa-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 Hawaiʻi. 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 ʻōpua") 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 ʻōpua") 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 ʻōpua".
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 Hawaiʻi. 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 [Hawaiʻi] 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 Kahinaliʻi")	Thrum, Thomas ("Hawaiian Folk Tales")	36-38	Pele travels to Hawaiʻi 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 Hawai‘i 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 Hawai‘i. 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 [Hawai‘i] 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 [Hawaiʻi] 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 [Hawaiʻi] 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 Hawaiʻi 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.

Hawaiʻi is the name of the largest island in the Hawaiian Island Chain. In the language of Aotearoa, Hawaiʻi 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 Hawaiʻi. Ellis noted that Pele frequently remained on the tops of the "snow-covered mountains" of Hawaiʻi, 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 Hawaiʻi. 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 *ʻUa ʻu* birds from the uplands of Maui, and sought advice from the high-priest Luahoʻomoe as to their probable habitation.

Luahoʻomoe'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 Luahoʻomoe 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.

Luahoʻomoe 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 Hawaiʻi, the drought followed him. After three years of wandering, he finally died of thirst and starvation.

One of Luahoʻomoe'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 Luahoʻomoe 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 Luahoʻomoe'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 *naʻenaʻe*], 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 Hawai‘i 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 Ko‘olau and Kaupō gaps were described, and the location of Pu‘u ‘Ula‘ula 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 [Pu‘u ‘Ula‘ula]. 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 Ke‘anae and Kaupō regions of the mountain began to carve away two valleys, soon joined by erosional valleys at Kīpahulu and Waiho‘i (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 Ke‘anae, Stearns theorized that the same type of event probably occurred to create the Ko‘olau 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 Ke‘anae 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 Pu‘u ‘Ula‘ula , 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 Pu‘u ‘Ula‘ula 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 Lāʻie Group

Four platforms, having their long dimensions east and west, were recorded by Emory on the margin of the Kalua o ʻUmi lava flow, between Lāʻie Cave and the upper trail to Lāʻie. 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 Nuʻu 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 Halemauʻu 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 Papa'anui 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 Papa'anui Ahupua'a.

Field inspections of localities at Haleakalā for the installation of Remote Weather Stations included one locality within Papa'anui Ahupua'a (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.

Section 5 Scoping Meetings and Section 106 Testimony

During July 2005, and March, May and September of 2006, KC Environmental organized a total of eight community meetings to obtain public testimony on the proposed ATST. On October 12, 2006, KC Environmental also brought the Draft Environmental Impact Statement before the Maui County Cultural Resource Commission (CRC) for their review and additional public comment. Two of these meetings (March and May 2006) were meant to fulfill the Section 106 review process. Meeting notices were published in Maui Island Newspapers (e.g. Maui Weekly, the Maui News and the Haleakalā Times) and postcards were sent to a number of Hawaiian organizations and individuals in an effort to inform the public and the Hawaiian communities about the meetings (NSF DEIS 2006: sec. 5.0).

The following tables (Table 3 through Table 12) reflect public testimony given at the scoping meetings held in July 2005, Section 106 meetings held from March to May 2006, and the CRC DEIS review in October 2006. The testimonies presented here have been summarized to reflect views and cultural concerns of either individual community members or Native Hawaiian organizations for the proposed ATST[1].

It is important to note that in addition to the scoping and Section 106 meetings mentioned above, additional informational meetings were conducted and mailouts were prepared and sent out by KC Environmental. For a complete list of recipients, public comments, proposals, and responses see Appendix K, NSF DEIS 2006.

[1] Hawaiian words in the testimonies have been italicized and edited to reflect the correct spelling.

Table 3. Cameron Center - July 12, 2005

Agency/ Individual	Summary of View and Cultural Comment	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Kahu Charles Kauluwehe Maxwell	Kahu Maxwell notes that there are burials, shelter sites and continuing cultural ceremonies at the 18-acre UH parcel.		None		X	None
Mr. Edward Lindsey	Mr. Lindsey asks how many stories the building will be and states that he would rather have it built somewhere else. He feels that, in supporting a project like this, there is complete disregard by the federal government of the Hawaiian people and the Maui community. He is concerned about more cultural sites being destroyed and the area being ceded lands. Asks what the carrying capacity is at the site. Mr. Lindsey explains that the Hawaiian culture is not the only culture that views Haleakalā as a sacred place. He explains that the Maori people of Aotearoa also have cultural beliefs about Haleakalā. Māui, the demi-god, also brought Aotearoa up from the sea. He describes, "It is a spiritual entity that crisscrosses and has deep spiritual meaning to cultures not only here...but throughout Polynesia."	X	None			None
Mr. Leslie Kuloloio	Mr. Kuloloio is concerned about the visibility of ATST, the proposed white color, asks if there is anything else that could be done so that it might be another color; he asks if Reber Circle would be preserved if that site is used; Mr. Kuloloio asks how deep excavations will go; Mr. Kuloloio asks how the land partnerships work on this parcel. Another concern is for the *ʻuaʻu*, or native petrel that burrows in the area. Mr. Kuloloio states that the *ʻuaʻu* are a symbolic Hawaiian figure: "That represents old Hawaii." After being informed that the HO lands are ceded lands, Mr. Kuloloio states that this is another cultural concern. He also inquires as to why the general public was not targeted for their comments.		None		X	None
Mr. Tim Bailey	Mr. Bailey has concerns about the petrel burrows and the native bat.		None		X	None
Ms. Puanani Lindsey	Ms. Lindsey is concerned that in the process of construction the height of the telescope might be changed due to advances in technology.		None		X	None

Table 4. Kula Community Center - July 13, 2005

Agency/ Individual	Summary of View and Cultural Comments	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Kahu Charles Kauluwehi Maxwell	Kahu Maxwell describes an incident when, while working as a cultural consultant for AEOS, 150 tons of rock considered to be sacred were taken from Haleakalā and crushed at Pu‘unene, "…it was such a cultural insult." This crushed rock was eventually returned and used by the National Park to cover trails. Kahu Maxwell states that in ancient times Haleakalā was used by, "*kahuna po‘o* or the teaching *kahuna*. It was so sacred, that site, that nobody could even go up there. So for Native Hawaiians to look at things that are being built there, it's really an insult."		None			None
Mr. Frank Rizzo	Mr. Rizzo asks the panel if silver could be used instead of white for the exterior of ATST. Mr. Rizzo asks if solar panels will be used to offset energy dependency. Another concern was the height of ATST. And the question was asked as to why the NSF doesn't send a satellite into space to do the same type of work.		None		X	None
Mr. George Manulani Kaimiola	Mr. Kaimiola asks if anyone has asked the Mountain itself if this project is right for it. Mr. Kaimiola is concerned about the true need for ATST; and if positive economic impacts will actually make it to the community level.		None		X	None
Mr. John Wilson	Mr. Wilson is a member of the Kula Community Association. He is concerned about the mirror coating shop that is being considered for the Air Force facility and if the proposed ATST project would need a shop similar to this. He is concerned about power line requirements and the potential for a need of a transmission facility in addition to ATST. Mr. Wilson is wondering if ATST will be replacing the Mees Observatory and he also suggests presenting renderings of ATST from different locations so visual site lines can be represented.		None		X	None
Mr. Rod Rikowski	Mr. Rikowski would like to know if kids will have the opportunity to use the telescope.		None		X	None
Mr. Stan Truitt	Mr. Truitt is concerned about the power ATST would need to operate. Mr. Truitt asks about active petrel burrows.		None		X	None
Ms. Lori Bragg	Ms. Bragg comments about the visual site lines stating that she would like to see renderings from Kihei or Lahaina. Ms. Bragg asks how large the work force for ATST would be.		None		X	None
Sergeant Mitch	Sergeant Pelazar is a police officer with the Maui Police Department and is concerned about pedestrian and automobile traffic safety during construction of		None		X	None

Agency/ Individual	Summary of View and Cultural Comments	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Pelazar	ATST. He would like to know how will bike tours and tourist traffic be impacted. Sergeant Pelazar asks if Haleakalā will become a terrorist target.					

Table 5. Pukalani Community Center - July 14, 2005

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Kahu Charles Kauluwehi Maxwell	Relates story of 150 tons of rock excavated from Haleakalā, hauled to Pu‘unene and crushed. This rock was then returned and used to fill cracks in the pavement at the National Park in an effort to return the rock, Pele’s form, back to where it belongs.	X	None			None
Mr. Dick Mayer	Professor Mayer is concerned that the ATST renderings do not accurately portray the size of ATST because they are taken from an aerial view. He also states that the height of ATST does not coincide with the upcountry community plan and refers to page 25 of this community plan as it states, “Encourage federal, state and county cooperation in the preparation of a comprehensive Haleakalā summit master plan to promote orderly and sensitive development which is compatible with the natural and native Hawaiian cultural environment of Haleakalā National Park.” Professor Mayer states that this has not yet been done. Requests that NSF help in preparing a master plan for the summit.		None		X	None
Mr. Ed Orszula	Concerned about how many people ATST operations will bring to Maui to compete for housing and such.		None		X	None
Mr. Stan Truitt	Comments on the renderings, angles and views.		None		X	None
Mr. Walter Pacheco	Concerned that work, construction and other, performed at the higher UH site will impact their lower site. Also concerned about electrical power usage.		None		X	None
Ms. Carol Suzuki	How will the proposed ATST benefit the economy and people of Maui, jobs and education?		None		X	None
Ms. Karen Hue Sing-Ledesma	Ms. Sing-Ledesma states that she is Native Hawaiian and would rather the NSF build the ATST somewhere else and not disturb the sacredness of Haleakalā.	X	None			None
Ms. Keala Han	Responds to Mr. Orszula's concern stating that there is no way to control how many people come to Maui.		None		X	None
Ms. Martha	“I wish you would bring it somewhere else and not on Haleakalā…”	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Martin						
Ms. Prentise Wylie	Not clear on the benefits of studying the sun.		None		X	None

Table 6. Mayor Hannibal Tavares Community Center - March 28, 2006

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Kahu Charles Kauluwehe Maxwell	Kahu Maxwell introduces himself and states that he was hired to do the Cultural Resources Evaluation (CRE). Mr. Maxwell explains that although he is dong the CRE, he is not in favor of the ATST project. Mr. Maxwell states that there are burial caves in Haleakalā Crater. He goes on to describe the gradual development of Haleakalā and his involvement as a consultant on other construction projects at Haleakalā and in this capacity informed work crews of the cultural importance of Haleakalā. Mr. Maxwell explains that his knowledge of the area was taught to him by Papa Kaalakea. He says that Haleakalā is traditionally known as Alahelekala or The Calling of the Sun. He describes an incident where 150 tons of excavated rock were taken from Haleakalā and relocated off the mountain and crushed. In an effort to have the rock replaced he had it donated to the National Park to be used to fill cracks in the road. Later in the meeting Kahu Maxwell responds to Ms. Mikahala Helm's comments and says about the EOS and Faulkes: “This is the same feeling I had when EOS and when Faulkes was built on there, but it is built. Whether we liked it or not, it is built. I don't want to see this happen again, and that's the reason why I put that in my report.” “If you had years of fighting these people and then winding up with nothing you would feel the same what that I do.” With regard to his proposed Center for Traditional Hawaiian Navigation and Astronomy as a mitigation measure (see Mitigation Comments, this table) Mr. Maxwell asserts: “(W)e should need something like this to help us to regain what we lost.” Mr. Maxwell mentions that he spoke with master navigator Nainoa Thompson and ran his idea for a Traditional Hawaiian Navigation and Astronomy center by him. Mr. Thompson said that he thought it was a great idea and essentially the missing link for, “...teaching the youth of Hawaii about the brilliance and resilience of their ancestors, and the enormous feat they accomplished thousands of years ago.” And Mr. Thompson committed his support and the support of the Polynesian Voyaging Society to the proposed Navigation center on Haleakalā, stating, “Uncle Charlie, can you imagine, yeah, a scientist that's working up Haleakalā can navigate the Hokulea at the same time because he's kanaka. Can you imaging that?” Mr. Maxwell states, “The potential outreach of this session could be enormous, but the more compelling reason is because it is right. A center of this magnitude possibly will produce world class Hawaii Maui-based scientists in this subject matter. Because of the training in	X	X			“To create Halau Ehime Na Nahoku, Center for Traditional Hawaiian Navigation and Astronomy … a collaboration of community and cultural resources to provide a venue to Ehime Na Nahoku, or to search or gather knowledge about the bright stars above us.” “To create and manage a scholarship fund for individuals seeking a post-high school education on the island of

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
	these two worlds, Polynesian discovery and modern science, these future scientist and astronomers could bridge the past to the present and beyond.”					Maui. ...
Mr. Clarence Solomon	Mr. Solomon is not clear on the purpose of ATST and how it will benefit mankind. “If you are going to desecrate that mountain, I need to know why.”		None		X	None
Mr. Edwin Lindsey	Mr. Lindsey notes that the Hawaiian community turnout is small and does not represent enough *kanaka maoli*. Mr. Lindsey takes offense at this, “This can only be shown as how hurtful that this telescope and this project is to our Hawaiian people. Today I called ten Hawaiian people that was close to me, and not one of them stated that they think it's a good idea. Not one. The all stated, ‘Are you crazy? What are they doing? Why are they destroying our mountain?’ And as far as the trade-offs, as I have said previously, I oppose this project. I respect gaining scientific knowledge, I respect what can come out of it, but not up at Haleakalā. 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.”	X	None			None
Mr. Keahi Bustamente	“…I'm Native Hawaiian, and I don't want it.” “I want to know between now and May 1st or 2nd…what are you guys going to do to inform the community? Because as you can see, it's not the community here.” Mr. Bustamente recommends having a meeting at a Hawaiian Homes community center. Mr. Bustamente also asks how ATST will benefit him.	X	None			None
Mr. Stanley H. Kiʻope Raymond	“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.” Mr. Raymond mentions a site feasibility report in which the six top sites for ATST were assessed. In this report Mr. Raymond states that the author wrote “...the entire Haleakalā mountain is rich in traditional and spiritual significance to the indigenous Hawaiian culture.” He continues, “Then I looked at all the other site feasibility reports...I didn't see any other site that said sacred. La Palma did not say sacred. Big Bear did not say sacred. Haleakalā, sacred.” Point being, that the NSF and NSO have known since 2003 that one of their top proposed ATST locations was a mountain considered sacred to Hawaiians.	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Mr. Warren Shibuya	"I am a returning Maui resident…" "I support basic and applied research and the proposed housing of the Advanced Technology Solar Telescope systems…at the summit of Mount Haleakalā." "[The] summit, of Kolekole, is *wao akua*, a level of earth's stratosphere where gods and goddesses are believed to reside and culturally guide everyday living. Ala Hea Ka La, "The path to calling the sun," presents basic rhythms of night and day, and establishes the sun being the source for life for *Kanaka Maoli*, Hawaiians, and citizens of Maui and Hawaii." Mr. Shibuya also comments on the EIS and point out that in it paragraph 2.6, Table 2, cost estimate breakdown states, "Educational and public outreach set at zero dollars." With regard to mitigation (see Mitigation Comments), Mr. Shibuya stresses that proper cultural respect should be demonstrated by the ATST project …behave respectfully and *malama mau ka la a*, preserve the sacredness of Haleakalā, specifically the summit area."		X	X		"Astronomy, aerospace and solar study efforts at Kolekole should be respectful of *wao akua*, the sacred area above the summit and lava, the essence of Goddess Pele, despite her current home at Kilauea caldera." "Special care should be exercised in digging, saving lava, and restoring earlier *pu'u* and hills and *wahi pana*, and minimizing invading air space, and restoring all sacred places."

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Ms. Keala Han	“…for years our Hawaiians had nothing, our Hawaiians didn't stand up for themselves. They let them build and build and build, and there was no education attached. But I thought it was a good proposal, and I want to thank you folks for all that respect shown to our Native Hawaiians.”		X		X	Ms. Han states that she likes Mr. Maxwell's proposal
Ms. Mikahala Helm	“I was born and raised here on Maui. I am opposed to the proposed Advanced Technology Solar Telescope, ATST project. It negated the needs of the Hawaiian culture for the needs of everyone else. Once again, the needs of science are seen as more important that the needs of the Hawaiian people.” “I do not believe that there is mitigation or a way to make the development of the proposed ATST less severe or intense.” “I would like to ask for more time, an extreme extension of time, because there are other Hawaiians who want to testify...” “Some 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.”	X	None			Damage cannot be mitigated

Table 7. Paūkukalo Community Center - May 1, 2006

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Audience Speaker	The speaker explains that at the first meeting at the Cameron Center, 2005, this person had asked "…the question about the heat exchange that you have for this building and I had wondered if they could not increase the size of the heat exchanges in order to cool the building more... That way could have a color other than white paint."		None		X	None
Audience Speaker	A person in the audience gets frustrated because Ms. Carney-Nunes is referring to "Native Hawaiians and Indian Tribes". This person explains, "You know, you keep on referring to Indian tribes or Native Hawaiians. You're talking about the wrong people. We're not Native - You folks have categorized us. Aboriginal, native, indigenous; these are terminologies that you people have put on us, labeled us. We're *Kanaka Maoli Hawaiʻi*. We're not Native Hawaiians." The speaker goes on, "You're belligerently occupying this place. 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?"	X	None		X	None
Audience Speaker	An audience member asks the question, "When is a site too sacred to be built upon? Obviously there has to be something in the language that describes when it's alright to, when it's not all right to." For example, the speaker asks, "Would you construct this on Machu Picchu, Stonehenge, Pasapa, Mt. Fuji, Mt. Everest, and Mt. Sion?"		None		X	None
Audience Speaker	An audience member asks, "…tell us again if you feel that a meeting like this is important for everybody and if this project were to go through anyway and it doesn't matter what we say, how we feel or how much it's going to hurt us -- now you as a lawyer come and tell me if this means that we can stop it because we don't want it to happen, or you tell me right now that the government doesn't give a damn and it's going to be built anyway."	X	None			None
Audience Speaker	"…according to the section 106 process, preserving and enhancing productive use of historical and cultural properties. … how is a 14-story telescope going to enhance it at all?" "The other thing, too, is Haleakalā legally is a TCP, traditional cultural property, federally recognized as a TCP."		None		X	None
Audience	This speaker would like to know why the other sites were not looked into more		None		X	None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Speaker	closely and had questions about the details of those sites.					
Audience Speaker	The speaker asks, "How were the cultural uses and resources assessed in your determination for selection of the six sites?" The concern of the audience speaker is that the same emphasis that was placed on the scientific feasibility of the Haleakalā was not placed on the cultural resources of Haleakalā. Mr. Wagner mentions a report that was written that addresses the cultural aspects of Haleakalā, a site evaluation report, a report that Mr. Jeff Barr prepared in which he stated that the spiritual significance of the mountain would be an issue during the public review. According to this speaker, who had actually had a chance to review this particular report, the report stated, "...the entire Haleakalā mountain is rich in traditional and spiritual significance to the indigenous Hawaiian culture" and also, "The presence of observatories on the summit is considered a desecration by some." This discussion goes on to explain that those making the decision to use Halakalā knew the cultural issues since 2003. The discussion then goes on to discuss concerns about sound levels in the areas surrounding the two *ahu.*		None		X	None
Audience Speaker	This speaker states, "You're trying to sell us a monstrosity….You're trying to turn a negative into a positive. You can feel the energy. I mean, you can really feel the energy. It's not positive."	X	None			None
Audience Speaker	The speaker calls attention to the state of the meeting, pointing out that people are getting impatient and leaving the meeting. The speaker says, "[p]eople came out here -- People are leaving now. What's your purpose here? To listen or no listen or to listen to yourself talk? You should know already what the feeling is. Let's get on with the program. Listen to the people."	X	None			None
Audience Speaker	A person in the audience gives what seems to be an emotional testimony about seeing his tutu crying.		None		X	None
Audience Speaker	"Good science. Wrong place" "…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."	X	None			None
Audience Speaker	"…we are real people with a real memory. It will not be erased. We will not stand here and act as if that mountain is not important to our people, because it is. And no matter what kind of projects they propose, it's important to us. We are people."		None		X	None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Audience Speaker	Speaker is concerned about all the utilities slated to be placed underground. "We're all opposing it."	X	None			None
Audience Speaker	A speaker who says he has already given his testimony at other meetings is concerned about finding out about future public meetings and also wondering how much time and money has been invested in the section 106 process. He wants more to be spent to let the Hawaiian community know about ATST and the meetings.		None		X	None
Kahu Charles Kauluwehi Maxwell	Mr. Maxwell explains the reason for the tension of some of the community members in the audience is due to the "…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." Mr. Maxwell explains why some Hawaiians don't recognize this type of ownership of land and still believe it should be in Hawaiian control. Mr. Maxwell continues later in the meeting to explain that although none of the other projects atop Haleakalā went through the section 106 process, this one is going through that process and trying to involve the Hawaiian community. He states that although he is not in favor of ATST, he would rather be someone who has a say in the process and has a say in how the Hawaiian community might benefit from it. Mr. Maxwell explains that he has submitted his own proposal for an educational component that NSF can consider funding.		X		X	For Hawaiians to be involved in all phased of the project and submit proposals for mitigation.
Maile	Maile states that she is a student at Maui Community College, "…I just want to say some things. Jerry, your mother might have given you a telescope. Our *kupuna* gave us that *mauka*."		None		X	None
Melia	"… [O]ur *ohana* used to go up to Haleakalā every single year, maybe sometimes every month. But, you know, I was so disturbed when park ranger said that our ohana cannot go on -- beyond the restricted lines or whatever, you know. I am disturbed by that ever since that year when -- that was when I was 14. Right now I'm 18. ...And you know, we used to go up there to that mountain, Haleakalā, and we used to greet our ancestors, our *kupuna* and also the sun, you know." "...It's not our fault that you guys decide we can't go up there, you know. So, please, don't build that up there. We don't need any more restrictions. We like to go up to that mountain and say *a ala ai* [*e ala e*] to our *kupuna*, you know."	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Mr. Ed Lindsay	"…I would like to speak against this project. … in rape there's no concurrence."	X	None			None
Mr. Lui Hokoana	Representing the Maui District Council of the Association of Hawaiian Civic Clubs: "I am here this evening to strongly urge that this telescope not be built at Haleakalā. We believe that the telescope will interfere with the natural beauty of the mountain, has the potential to impact on our economy negatively and intrudes on the *manaʻo* of spirituality of the Native Hawaiian." Mr. Hokoana is concerned about how tourists might react to ATST. "I was taught to revere the mountain because it is a place where gods dwell." "This telescope is an affront to all Native Hawaiians because it tries to prioritize science ahead of our spirituality and *manaʻo*. All Native Hawaiians are concerned about making sure that future generations can experience the *manaʻo* of this mountain without intrusion from man." "The Central Maui Hawaiian Civic Club, the Lahaina Hawaiian Civic Club, the Hoʻolehua Hawaiian Civic Club in conjunction with the Association of Hawaiian Civic Clubs strongly urges that this telescope not be built at Haleakalā. The telescope will interfere with the beauty of our Haleakalā, may impact our economy negatively, and is an intrusion to the Native Hawaiian spirituality."	X	None			None
Mr. Nikhi Landa	"…I object to what this process is doing and will do. … I personally feel that you're insulting as you continue with the presentation because I think the key feeling here is we don't want it. So would it not be just easier for you to wrap up with the consensus that we don't want it here?"	X	None			None
Mr. Oliver Dukelow	"I was born here on Maui. I've lived here all my life. I assume in listening to what you're saying…that you have ownership to the land….Before we can discuss anything, I would like to see your title to that land."		None		X	None
Ms. Puʻunene Lindsay	"I'm sorry some of our people left without being able to testify here." "…I don't want to say…yes, I want something out of it. No, I don't want anything out of it. I don't even want it there. That's the bottom line. We don't need it here on Maui. Go to site No. 2."	X	None			None
Ms. Suzanne Burns	Ms. Burns states that she is a Native Hawaiian and had a question about the advisory council participation. She asks if they are they going to participate.		None		X	None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Ms. Toni Dizon	"I'm actually from Lahaina. I'm born and raised on Maui. I'm against this project totally. You guys don't belong there at all." "You got $170 million to offer these gentlemen to do scientific things, then do it off the water that they polluted, do it off the land that they polluted. We need that agriculture major at Maui Community College." "...Give us the money so I can get my bachelor's degree, my master's, and the future of the land and the water. These guys ...they damn well don't belong on Haleakalā. That's sacrilegious to Pele itself as much as Maui." "But as a -- as an agriculture major, I'm pretty sure none of this should not be financed at all. Give it back to the people. You say it's for the community. Give us the money to buy our taro, give us back our taro. Give us the money to buy -- for us to finish our science degrees in agriculture and also for marine biology so we can clean our water besides our land." "...Don't give them the money. ...And they rightly should not be up there. That's cultural. Besides me being Hawaiian -- I'm proud to be Hawaiian. And s far as my *kupuna* and then my future, they're going to take that away from me and they don't deserve it at all."	X	None			None
Princess Lehuanani	Princess Lehuanani introduces herself as being from the village of Mokula [Mokuʻula?] and she recalls the bombing of Kahoʻolawe and how she experienced this as an eight year old child. "Haleakalā is right in the middle of our island. Please, that is the heart of our people and of our land." Wants respect and honor to ancestors and *kupuna*.		None		X	None

Table 8. Cameron Center - September 27, 2006

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
A Voice	A person in the audience is concerned about mercury being used as a cleaning agent for parts of the telescope. The audience member states that they are concerned and have trouble trusting that it will not be used because it was used on Mauna kea after those scientists had said it was not being used. "You understand our concern because we were told over and over again that there was no mercury being used, and then we found out in the documents it was not only used but it had leached into the ground."		None		X	None
A Voice	Someone voices their concern about the dangers of observing the sun and asks how the intense amount of solar power is handled when viewing the sun through a telescope. "Will this facility or any other facility that you may build in the future be used to capture of harness the sun's power?" "...I'm not confident. Even more so, I'm even more scared and more opposed now than I was two hours ago when I walked in. And I don't want nobody hurt. So the safety factor is extremely important."		None		X	None
A Voice	An audience member states, "I just want to make sure that the objections to the timing of this get entered into the public record." This person is also very concerned about how the comments will be addressed in the EIS. This person wants these comments to appear in the EIS.		None		X	None
Kaho'okipa' olu'olu Kamakawi waole	Concerned about power usage ATST will demand. "The other thing is, I just came from the Northwestern Hawaiian Islands meeting and what kills me is to compare it to the Haleakalā meeting that I was there last night. The bottom line is all of these people are trying to do something to save things, something now. It's a reactive situation now, because all of them know from the start the destruction that has happened. And I'm not saying that it's because of all outsiders. ...Maybe as Hawaiians we need to be...better educated to take care of our own *aina*. ...All of a sudden everybody is like, whoa, we gotta save Hawaii. ... My *manaʻo* is, who we going to build this thing and then years from now we're going to say, you know, we gotta save Haleakalā. ... I'm very opposed to this building for that reason."	X	None			None
Kapali Keahi	Kapali Keahi is from Lāhainā: "…I never read the EIS, but I no really read EIS. To tell you the truth, like, what I know is, like, we always confronted with development that is really not in our best interest and not in our favor. So we always shoot 'em down from the get go. And mainly we like see things happen the way we want it to happen. And right now, it's not a good time for you guys. It's never going to be. As long as that flag is waving, it's never going to be one good time for you guys. And	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
	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.” “...We no need you guys. One house costs $800,000.00 over here. You think we worried about what the sun is doing? ...I really don't see what impact, positive or negative, this development will eventually do to our social well-being. But, right now, I mean, already get stuff up there and that never do nothing for us anyway. And, in fact, instead of adding stuff on, we should be taking stuff off. And, well, frankly, just you guys should just go back to where you come from and stay there.”					
Mr. Albert Napahi Dizon	“I'm a sixth generation. Any time somebody poke a hole in the aina, I cry. Every time when they try to build, whether it's for water and now another telescope, it hurts me inside because I am of this land. I am *kanaka maoli*. I'm born of this land. And to build something up there where only the Gods live, we Hawaiians know when the Gods out there, yeah, we know it's only for the Gods, not to put another telescope.” “*‘A‘ole*, which means no. I'm against, I'm opposed of this because there's always recognition for astronomers who went to school. There's no respect for the kupuna who has the gifts.” “...You damaging Hawaii nei by building more of these things. And it's not for us...*Ke akua*, there's a triangle that we go by. Ke akua, ohana, aina.”	X	None			None
Mr. Bill Kauakea Medeiros	Mr. Medeiros stated that he is from Ke‘anae, Hana. He expressed his frustration about the section 106 meetings being scheduled on the same weekend as the county fair, “the largest annual event on Maui.” “We were taught by our *kupuna* to respect our *‘āina*, our sacred places where there was *kapu*, and to respect the *kuleana* that we carry. We were also taught to protect and be good stewards of the *‘āina*, of the land. I ask you, as you consider this project, that you need to respect the Hawaiian people and the culture of these islands. We as Hawaiians plan for seven generations so that we can leave a legacy for our children and grandchildren seven generations down the road. We were taught by our kupuna to also keep our *‘āina*, our land, as natural and undisturbed as possible. Hawaiians were great astronomers, environmentalist and conservationists.” “...I would say that for the proponents of this project that say that there's nothing connected to a defense system, I would say that even if it was, you would not know that or you would not be an authority to disclose that information.” “So what I say is respect the voices of the Hawaiian people, our ancestors and our ‘*‘aumakua* [sic], and I join with the rest of them as I say that I oppose this project.”	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Mr. Dan Sytze	Mr. Sytze is concerned that the EIS does not accurately address the issue of environmental justice. "And when it comes to the environment in Hawaiian thinking-I'm obviously Caucasian, so all I can do is tell you what I have learned from my Hawaiian friends and my teacher and the *kupunas* and the older people of Hawaii. *Aloha aina* is -- that's like part of the religion. That's part of the spirituality. It's love of the land, caring for the land...And we have a mountain here that is revered. It's known throughout Polynesian and considered sacred throughout Polynesia from all over." Mr. Sytze also stated his concerns about ATST potentially being used for the military purposes, "...if this is a military operation up here, I'm not taking a stand for or against what you are proposing doing...or against what is happening up there right now, but I'm just saying that if that is a military -- especially an offensive military type of operation up there, that there's going to be nuclear weapons targeted at it, and that should be taken into account in the environmental impact statement."		None		X	None
Mr. Don Kanahele	"…I don't feel comfortable about the selection of Haleakalā because of the importance of that mountain as well as other mountains here in the Hawaiian islands have to the people that live here. Not only to the Hawaiians by blood but the Hawaiians at heart. So for us this is something that is disconcerting. It's very serious." "Maui is a popular place for many, many reasons and to many, many people. And the impact of that popularity is felt in many areas by those who live here. There's a tremendous impact and, I guess, from my perspective I'm concerned about the cultural impact by those who live here and those who have been connected to these islands for many, many generations." "...I do, at this time, oppose the building of any telescope on Haleakalā."	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Mr. Foster Ampong	Mr. Ampong introduces himself and explains that he is "…born and raised and presently residing on the island of Maui. Normally I would just speak from my *naʻau*, from my gut, because that's the way we speak the truth." Mr. Ampong also states his concerns about the proper disposal of waste and hazardous materials, "...I would like to be reassured with specifics. When you say properly contained and disposed of by private contractor, where exactly -- what is it contained in? Is it a 55-gallon barrel? Is this going to be trucked down to Kahului, put on a barge, and removed from the state? Is it going to be trucked down two miles from the summit and stored -- I think what we want to hear is the specific, something definitive about the hazardous material, how it's going to be removed, and where its going to be moved to." He continues, "...we need some honest, sincere, definitive explanations in the DEIS, period, before you go any further." Mr. Ampong notes that 15 speakers have been against ATST and that amounts to 99% of those who spoke out.		None		X	None
Mr. Haumea Hanakahi	Ms. Hanakahi explains that she is from the Island of Hawaiʻi but now resides on Maui. "The first thing that we found on the big island, many of us, is that we have to begin with a *pule*. The *pule* is filled with respect, and it's remembering that the *maunas* are not ours. That's not the ground of mankind. The *maunas* are the realm of *akua*. And so as we give that back to *akua* in recognition and acknowledgement, then that changes everything, and it gives it to *akua* to decide what is right and what will happen." "...And to arrogantly go and build upon a land that has always been considered sacred is a desecration. Period. Hawaiians have always held education as a noble endeavor, and this is not about astronomy. This is a land use issue." "Hawaiʻi is tired of hearing about astronomers behaving badly, whether it's on Mauna Kea or Haleakalā. So I open this in the hopes that truly we can make this *kākou* and inclusive. Make it something that we truly can reach out to each other's hearts about because truly we don't want to stop education, stop exploration. Polynesians were exploring these vast oceans by the same science of which you desecrate our mountain with." Ms. Hanakahi raises strong concerns about mercury being used for ATST as it was on Mauna Kea.		None		X	Need more comprehensive mitigation plans

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Mr. Jonah Kamakahi‘i kaika o kalani Kapu	“I'm the seventh generation. I'm from Lahaina. I might be on the west side…but I still get something for say.” Mr. Kapu continues, “…what if the thing get passed? What, next two years after that going have one other one coming up, one other one coming up just like Mauna Kea? Get four of five of them over there. No need one. I no like drive around Maui looking at Haleakalā and all you see is this big white ball. Come on now. I been on big island, I seen Mauna Kea, and it's like I just like broke that. I no care about this.” “Right now this is not *pono*.” Mr. Kapu also states his concern about mercury contamination.	X	None			None
Mr. Kaleikoa Kaeo	“…A fool is anyone who disrespects, doesn’t listen, doesn't adhere to what I have said many time before. So if I come here and I sound angry, I am. …This is part of a large major campaign which have been perpetrated on my people for generations. Other native peoples have been pissed on and shit on across the islands, across the Pacific, across north America, across the world since the time of that great supposed European explorer Columbus. Looking for gold, god and glory, who cut off the hands of the native, who sicked his maddening dogs on the women and children for the sake of science.” “That's your history. That's the history of our peoples that we have had to endure, and we still endure. But the good news is we still resist.” “There is no -- I challenge NSF do one title insurance deed, find out how does the State of Hawaii through executive order -- they don't have title to the land. That's what the DLNR manages as part of -- they have no title to those lands. So they have unlawful control of these lands.” “What the NSF is funding right now is exactly the continuation of this kind of mentality that somehow the *haole* world had some kind of right to what is not theirs because their science says so. ... If you got the title, put your paper down and I will walk away forever. I won't challenge it.” “Our people will fight. ...If it means civil disobedience, that's what it's going to take.”	X	None			None
Mr. Keahi Bustamente	“As a Hawaiian, I believe that I came from the stuff that that mountain came from. The creatures, the *koa*, the *‘ōhi‘a*, the *weke‘ ula* I came from that.” “I would like all of you to know that on behalf of Na Kupuna o Maui, Patty Nishiyama, who couldn't make it today, have also submit written comments...we oppose the construction of building development of the ATST on Haleakalā.” “I feel that this proposed project will exasperate (sic) adverse effects presently plaguing our community and the environment socially, culturally, and at the very core of our existence, spiritually.”	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Mr. Richard McCarty	“This is your problem to show respect for this area. And to think about what is happening. Throughout history, if somebody wanted to desecrate a culture, what would they do? They would tear down the statues of their heroes, they'd go into their sacred spots and desecrate them. Because once you take that away, the culture is gone. They can't survive, once you take the special areas away and the things that are important to a culture.” Mr. McCarty concludes, “...lets leave this site alone.”	X	None			None
Mr. Walter Kanamu	“…the life of the land is perpetuated in righteousness. Not only in righteous but by the righteous. You see, from long time ago, I believe *akua* led the Hawaiians to this land. God led the Hawaiians to this land. He gave this land to the Hawaiians knowing that they were the people that would *mālama ‘āina* and *aloha ‘āina*. And that's why we're here today, because we are going to *mālama ‘āina* and *aloha ‘āina*.” “...I have a 501(c) (3) [non-profit corporation]. ... Your whole southern boundary 7,000 acres is mine. I have the lease for 7,000 acres of that land. Did you guys know that? From the summit down to 3,500 feet of Kahikinui, Hawaiian homelands, belongs to life living in this forest ecosystem [LIFE]. ... Today I'm introducing myself as the lessee for the land that abuts your boundary. Make sure you stay on your boundary now, and I want to see that. I want to see all the boundaries all drawn out because I went through your entire draft and it was very vague. ... In your draft statement, in your picture, you don't have one picture depicting Kahikinui right below you. ... when you get one spill, when your sewer systems overflows, when your hydraulic leaks, all of that stuff is going to affect me. ... In your entire proposal it says that everything you do will not have a significant affect. Well it's already affecting, and you have not even started.” Mr. Kanamu adds more at the end of the meeting, “...and you be still and you be quiet and you listen, guess what you can hear? Everything that goes on in the observatory. You can hear the grinding; you can hear the rumbling in the earth. The sounds emitted up there travel all the way down. All the way down and affects us.”	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Ms. Brianna Welker	"…What I have to say tonight is not for a permanent record. It's for you four who are sitting in front of us today. Because there is a huge thing that's lost in translation on paper. And that's the passion of everyone who stands before you. We're not going to be able to take that home on paper. You are the only people that are going to take that home." "So I challenge you to look at me not with furrowed brows but really look at me. Not me personally. Everyone who is here now. Everyone who talked here tonight. And understand where they are coming from. Not hear where they are coming from, but try to feel it. Try to think of something that makes you half as passionate as all the people in this room. ... I am not *kanaka maoli*, but I was born here. This is my home. I can feel it up there. So the very last thing that I would challenge you to do is go to Haleakalā. Don't go to the site of your telescope. Go to the mountain that these people are talking about. I don't care how long you are here for. Find the time for it. And maybe, just maybe, you'll begin to understand what these people are talking about."		None		X	None
Ms. Kamaile Kekahua	Ms. Kekahua makes the statement "…for the life of me I cannot understand how it is that Pele is for education in a way where she would allow and want for a structure that is 15 stories tall to be built right on top of what exactly she is." "…A lot of times scientists that have come to Hawaii have tried to play exactly that role as a god, to dictate the ways that we do things instead of learning exactly from that ancient wisdom that was here prior to any kind of impact to Hawaii. Scientists have brought their foreign concepts here, some have worked, a lot hasn't. ... As it was earlier mentioned, is it for us? Because it is not for us. It is not for the Hawaiian people. ... And I just have to end too with saying I resist, I resist for my generation, I resist for my son's generation, and I resist as a *keiki*."	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Ms. Mikahala Helm	"My concern is this: The meetings that are held -- that are scheduled today or tomorrow or the next day, I don't know which days you are having Section 106 meetings, are limited to those who have submitted…Mitigation and minimization proposals. My concern is where is the voice that you continue to hear this evening? Where is the voice in that DEIS, besides small little sentences that say the consultation occurred?" "And so my concern -- I hope you will address this -- is with how this whole DEIS comment period is being addressed, the sincerity in getting our communities input both from Section 106 for Hawaiians and non-Hawaiians alike, then I think that we need to be sure that in the environmental impact statement that these are clearly listed there. The oral testimony and everything must be listed there to show the depth of concern and support for avoiding this telescope on Haleakalā." Ms. Helm also raised the concern that the meetings were scheduled the same weekend of the Maui County Fair and the Super Ferry meeting.	X	None			None
Ms. Verna Kaiulani Nahulu	States that she speaks for the children of Maui, and that they should be allowed to learn all they can from this, "And as a Native Hawaiian, I see that there is so much that we were not allowed to learn because in our time our grandparents kept us tied in with their past and we were not allowed to go forward into our own future."		None	X		None
Ms. Vicki McCarty	"…I came from Lahaina. You've not had any meeting in Lahaina. You've ignored places on this island that have much to say about this telescope. You've been dismissive here this evening about families and communities and organizations that wait all year to raise money for their families and for their clubs and for their *keiki* at the fair. ... You don't understand this community, and you don't understand what is at stake here. Shame on you. It's a sacred place. It is a sacred place. It is a sacred place. Your own literature describes it as a sacred place." Ms. McCarty is also concerned about hazardous waste, "...What gives you or anyone the right to interfere with the cultural practices and the sacredness of this site? What gives you the right to put an emergency spill plan in place and perhaps deny all of the children that will come after us to enjoy the sacred place?"	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Nameaina Hshino	"…This place Haleakalā is house of the sun. You guys like look at the sun? What that prove to you, brah? Proving nothing. This place is a sacred place, brah. And what the thing going do for our culture, huh?...You know how pissed off it makes us, huh?...I no can see this thing passing because we get hard times already, this developing. Our water issues, us, we no can sustain right now. ... I'm going to try everything in my power for stop that thing from being built." "You guys no more right for build up there. This is our *aina*."	X	None			None

Table 9. Mayor Hannibal Tavares Community Center - September 28, 2006

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Kahookipa Olu Kamakawiwoole,	Kahookipa does not want ATST, and is skeptical of NFS commitment to potential programs for Native Hawaiians. Kahookipa makes the statement, "…Princess Pauhi in her personal monies cannot even provide for Native Hawaiian programs, the school that she provided for. She cannot even do that now. That same federal government is fighting us and telling us we cannot do that with somebody's personal money. But yet you guys are a federal agency saying you guys going to come to Maui and give us this program."	X	None			None
Mr. Frank Skowronski	Mr. Skowronski introduces himself and states that he is the principal of a small tech firm. He makes comparisons of size of ATST and states that it will be the tallest structure on Maui.		None		X	None
Mr. Penrod Vladika	Mr. Vladika is the Principal at Kalama Intermediate School. He formed astronomy club at school. He is very excited about ATST, says kids are excited too: "[a]nd that's what it's all about for me is to have this opportunity for children to learn and to discover." "I see there is a unification of science and the mountain also. It's called House of the Sun. You know, to me it's an addition, it's unifying in a way and it's very spiritual also to me as just an average citizen."		None	X		None
Mr. Richard Lucas	Mr. Lucas is from Haiku, Maui and voices his concern about the electrical power ATST will need to function, and asks what will NSF do to offset energy consumption.		None		X	None
Ms. Marilyn Parris	Ms. Parris is the Superintendent of Haleakalā National Park; "The park's purpose as established by law is to preserve the scenic character and associated Hawaiian culture, while simultaneously providing educational, inspirational, and recreational opportunities compatible with preserving the natural and cultural resources and values within the park." "Haleakalā is Maui's number one tourist destination and an integral part of the tourist-based island economy. The National Park Service's primary mission at Haleakalā National Park is to ensure these resources and values remain authentically represented and available for the enjoyment of all peoples in perpetuity. The preservation of Haleakalā nurtures the mind, body and spirit of these islands, her unique environment, and her many peoples." "It is the National Park Service's contention that this Draft EIS falls far short in adequately evaluation	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
	the numerous cumulative impacts to our resources, our visitor's experiences, and our overall park operations with the construction of this ATST. Therefore, the National Parks Service must strongly oppose the construction of this facility adjacent to our boundary based on the information presented within the Draft EIS."					
Ms. Mary Evanson	Ms. Evanson read her public comment from a letter previously composed: Ms. Evanson feels protective of Haleakalā, "this project is so huge it will change Haleakalā forever. Please find another site." Again Ms. Evanson states that she is "deeply troubled" by the DEIS as it is full of errors. She is concerned that these errors will get circulated and perpetuated.	X	None			None
Ms. Mele Stokesberry	Ms. Stokesberry explains that the renderings of ATST are deceiving and that ATST is going to look much larger than it is portrayed in the renderings. She feels that ATST will have a tremendous impact on the native petrels, the view plane, and the overall serenity and sacredness of the mountain.	X	None			None
Ms. Suzanne Burns	Ms. Burns states that she is part-Hawaiian and explains that Haleakalā is a special, sacred place and that it should be left as it is.	X	None			None
Ms. Verna Nahulu,	Ms. Nahulu is a retired elementary school teacher from Keokea, Maui. She states that she speaks for the children of Maui, and that they should be allowed to learn all they can from the proposed ATST, "[a]nd as a Native Hawaiian, I see that there is so much that we were not allowed to learn because in our time our grandparents kept us tied in with their past and we were not allowed to go forward into our own future."		None	X		None

Table 10. Kula Community Center - September 29, 2006

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Kahookipa Olu Kamakawiwoole	Kahookipa does not want ATST and is skeptical of NSF commitment to potential programs for Native Hawaiians. Kahookipa makes the statement, "…Princess Pauahi in her personal monies cannot even provide for Native Hawaiian programs, the school that she provided for. She cannot even do that now. That same federal government is fighting us and telling us we cannot do that with somebody's personal money. But yet you guys are a federal agency saying you guys going to come to Maui and give us this program."	X	None			None
Mr. Dick Mayer	Mr. Mayer is the Vice-President of the Kula Community Association and in his personal testimony he explains that misleading info was given during the scoping meetings, and that the public was lead to believe ATST would be 92 feet high rather that the current 143 ft height. Feels a master plan that includes the landowners at the summit, Hawaiians and other community members' needs to be drafted.		X		X	Locate ATST at a lower elevation on Haleakalā. "…looking at other sites on top of the mountain maybe a mile away from the summit three-quarters of a mile away, further to the south, maybe dropping it to down to 9,800 feet so it wouldn't stick above the top of the mountain

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Mr. Michael Howden	Mr. Howden is from Kula and is a *haumana* with Papa Henry Auwai. He states that Pu‘u Kolekole is a sacred “place of prayer and inner attunement.” “I find this incredible that this European scientific mindset would want to impose upon a sacred landscape what can only be considered in spiritual terms really a monstrosity. This is a place of prayer. It's a place sacred for ceremony. And I think at some point, this madness toward building and accumulation and the carelessness with which this is approached in terms of imposing on this landscape something that would be not only cultural desecration, but an aesthetic and spiritual desecration.”	X	None			None
Mr. Rizzo	Mr. Rizzo has accompanied hundreds of school kids on field trips to Haleakalā, “But what I have seen many, many times are just a small group of these children that are very excited and just really in awe of what's going on up there at the different facilities. And I just think it's an important thing. I believe that this is a great opportunity” “It's opportunity knocking at the door to have a facility like this. How appropriate, a solar observatory state-of-the-art up at the house of the sun.” Mr. Rizzo asks how much of the mountain is sacred.		X	X		“If it could go up in an area around the summit that is respectful to the Hawaiian people…I think that would be a great thing for everybody.”
Mr. Warren Shibuya	Mr. Shibuya serves on Maui’s General Plan Advisory Committee. The following list of mitigation suggestions made up Mr. Shibuya’s comments: 1) Contribute to and subscribe to a work force development program... 2)Employ Maui residents as much as possible and develop ATST work force to a close working relationship 3). Establish a Maui solar and Hawaiian Cultural Center featuring staff multimedia facilities and systems to share information, educate and ignite the passion and encourage Maui students getting needed skills and seek ATST employment 4) ATST adopt and enter in written contract a sunset for the ATST structure and program. Suggest at least four cycles with each cycle is 23.5 years each cycle for a total of approximately 90 years. This sunset clause is precedent setting and requires ATST to remove ATST structures and restore use of summit grounds to original sacred configuration. 5) All streets and facility names be Hawaiian.		X		X	See Summary and View of Cultural Concerns

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Ms. Leslie Ann Bruce	Ms. Bruce is from Hana: "[t]his proposed use of Haleakalā summit for another telescope is undesirable, culturally offensive and ethically questionable. It's undesirable because it is a further covering of our mountain's open space and special viewscapes. It destroys our sense of place. It is culturally offensive because it further intrudes on our sacred Hawaiian *aina*. Haleakalā, as we all know, 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. People I know on the island, including myself, feel hurt, offended an invaded by outsiders' intrusions on our *wahipana*, 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 mountaintop. "	X	None			None
Ms. Mary Evanson	Ms. Evanson, on behalf of the Friends of Haleakalā National Park, read her public comment from a letter previously composed; she feels protective of Haleakalā, "this project is so huge it will change Haleakalā forever. Please find another site." Again Ms. Evanson states that she is "deeply troubled" by the DEIS as it is full of errors. She is concerned that these errors will get circulated and perpetuated.	X	None			None
Ms. Mele Stokesberry	Ms. Stokesberry submitted her testimony via e-mail: "…it must not be built at this location. Its tremendous size cannot be placed on the summit of Haleakalā without irreversible harm of a very serious nature to the endangered petrels whose burrows are all surround the proposed sites." "ATST would also cause ruinous harm to the view planes, serenity and the sacredness of the mountain and it's yet not fully characterized harm to the entire summit environment due to the huge excavation and disturbance it will invade."	X	None			None
Ms. Verna Kai‘ulani Nahulu	Ms. Nahulu is Native Hawaiian and from Keokea, "…I would like to say that my Hawaiian ancestors felt it was so important to know about the sun, to know about the stars and to know the skies, because when we traveled throughout the Pacific, through Easter Island, to Tahiti, to far places, okay, to far places, that it was necessary to know about the sun." Also states that she is a channeler of Pele and explains that, "…very, very early on, I asked her [Pele] what's your take on the ATST. And she says I am strongly in favor of it. She said do everything you can to have them be installed at the summit because I [Pele] feel that Haleakalā is for education." For those people who think Pele's home is Haleakalā , Ms. Nahulu says, "…Pele's home is in Halemaumau [on the Island of Hawaii]." Ms. Nahulu		None	X		None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
	makes a statement in response to comments about the telescopes and Science City being in one's direct view, "I've been to Haleakalā. In order to see Science City, I have to go up further to the 10,000-foot level to see Science City. It is in the back. I see only the summit below me, and I've been up there many times. So I think it is a mistake saying that it is in our faces because it certainly is not. I have to go up to Science City to see those things, and I do."					

Table 11. Maui County Cultural Resource Commission - October 12, 2006

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Mr. Bill Evanson	Mr. Evanson worked in Haleakalā National Park for a time and as a result has walked the entire rim of the crater several times. He describes Haleakalā's beauty, “I would come up over the rise…and look down into Kīpahulu Valley on a clear day and I understand how and why Hawaiians chant because you get these feelings inside you after looking at the beauty and it just like comes rushing out and the mountain is as it has been said celebrated in *mo‘olelo* and *mele* and *hula* and it's a --it's about grandeur, its beauty, its majestic beauty, its open space, it's scenic, and wilderness values, as we like to call them these days.” “...Lots of people appreciate open space, as our island becomes more developed, those are the places we go to seek refuge and get spiritual replenishment.” Mr. Evanson feels ATST will be intrusive to spiritual practices atop Haleakalā.	X	None			None
Mr. Foster Ampong for Na Kupuna O Maui	Mr. Ampong considers Haleakalā sacred and is concerned about safety.	X	None			None
Mr. Michael Howden	Mr. Howden was taught by Papa Henry Auwai. He was taught to respect natural and cultural resources. Mr. Howden feels that the extremely sacred nature of Pu’u Kolekole was not conveyed properly in the cultural evaluation.	X	None			None
Mr. Stanley H. Ki‘ope Raymond	Mr. Raymond states that he believes the cultural evaluation (Maxwell 2006) is inadequate and does not adhere to the Hawaii State Guidelines of the Office of Environmental Quality Control for assessing cultural impacts. He feels that the cultural evaluation does not adequately convey the sacredness of Haleakalā. Mr. Raymond describes a bias that is conveyed by the author that is inappropriate in this type of document. Therefore he believes that the cultural impacts cannot be accurately conveyed by the current cultural evaluation. Mr. Raymond goes on to explain that there are two acts that cause “spiritual pain” regarding construction of ATST. The first, he describes, is the actual excavation of the aina or lava. To Hawaiians, the lava is the “*kino lau* or body form of Pele”. “...Therefore, all of the rock on the mountain has a sacred aspect; intrusive digging is a desecration.” Secondly, he thinks construction of ATST will cause “...the	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
	death of an *aumakua*." He is concerned that the *‘ua‘u* or the Native Petrel may be harmed or killed due to construction of ATST. Mr. Raymond explains the *‘ua‘u* is the only seabird on the U.S. Endangered Species list. Mr. Raymond continues explaining that ATST will be in relatively close proximity to the east *ahu*, less than 100 feet away, and although the views down slope from both ahu are pristine, the view in the opposite direction is strongly impacted by human development. He explains that an entire 360 degrees viewplane from both *ahu* is important and that does not exist and the quietness of the area is disrupted by the noise of chillers from another facility. Mr. Raymond considers the future community at Kahikinui and what they might be dealing with having ATST in their direct view.					
Mr. Tom Cannon	Mr. Cannon knows Haleakalā as a place of legends significant to Hawaiian culture and history. He recalls the legend of the demi-god Māui who snared the sun so that it would move more slowly across the sky so his mother could dry her *kapa*. He goes on to say that the summit of Haleakalā is known to have many, many legends, songs and *hula* written about it and for it, he continues, "I feel that there is no more culturally significant place in Maui County, in the U.S., or in Polynesia that the summit of Haleakalā." Mr. Cannon states that Haleakalā is a legendary mountain, "I understand that it is important to study the sun, but not if it means destroying the Hawaiian sense of place associated with Haleakalā. It is not worth it."	X	None			None
Ms. Jaydeena	Does not want ATST built on Haleakalā.	X	None			None
Ms. Lei‘ohu Ryder	Ms. Ryder introduces herself and explains that she is a cultural and spiritual advisor. She calls Haleakalā "House of the Shadow of the Sun" and "House of the Sun". Ms. Ryder states that her great, great grandfather came to the island of Hawaii from Kauai and trained on Haleakalā in "sacred protocols and prayers". Ms. Ryder describes Haleakalā: "Haleakalā is a symbol of primordial life and humanity's sacred essence..."	X	None			None
Ms. Mary Evanson	Ms. Evanson feels the construction and presence of ATST will "adversely change Haleakalā forever causing irrevocable loss of natural, cultural and scenic resources." Ms. Evanson is concerned about the *‘ua‘u* birds that nest in the area and fears excavation efforts will cause the collapse of *‘ua‘u* burrows. She recalls Haleakalā being known for its high quality of basalt	X	None			None

Agency/ Individual	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
	and speaks of the adze quarries in the crater.					
Ms. Mikahala Helm	Ms. Helm feels ATST is a threat to Haleakalā, "…a threat to our people, to our Hawaiian culture, because we know our kuleana is to protect this sacred mountain." Ms. Helm feels the NSF has not made an adequate assessment of the impacts of ATST in its DEIS. Ms. Helm speaks of song and dances that honor Haleakalā and mentions "Aloha ʻia no ʻo Maui" by composer Auntie Alice Johnson: "Kilakila Haleakalā, Majestic is Haleakalā; Kuahiwi nani o Maui, Lovely mountain of Maui; Kaulana kou inoa puni o Hawaii, Its name is famous throughout Hawaii; I ke alanui kikeʻekeʻe, And the road that zigzags."	X	None			None
Ms. Suzanne Burns	Ms. Burns is offended by the use of the summit of Haleakalā and expresses it in the following statement: "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."	X	None			None
Ms. Uilani Kapu	Ms. Kapu explains that people come from Aotearoa, India and all over the world to visit Haleakalā and they visit for spiritual purposes. Ms. Kapu feels that the current and proposed scientific use of Haleakalā is a desecration to its sacred nature.	X	None			None
Ms. Vicki McCarty	Ms. McCarty explains that Haleakalā is a sacred mountain and you don't enhance Hawaiian culture by desecration of a sacred site. Ms. McCarty mentions the cultural evaluation and that is states that Haleakalā was *kapu* and only for the Gods use. She explains that this project will desecrate an already damaged area. Ms. McCarty states that the West Maui community was not adequately represented.	X	None			None

Table 12. Formal Letters

Agency/ Individual	Date	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
County of Maui, Dept. of Planning, Cultural Resource Commission Comments - Mike Foley, Planning Director	23-Oct-2006	"Based on the information contained in the Draft EIS, and testimony presented by the applicant and the public, the Commission voted to make the following recommendation. The Commission strongly recommends adoption of the No Action alternative contained within the Draft EIS. The basis for this recommendation is as follows: 1. Haleakalā is a sacred place to the Native Hawaiian people. 2. The proposed telescope would be a desecration of the physical and spiritual manifestation of the cultural/historical *mana* of the Native Hawaiians. 3. 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. 4.The proposed telescope could impact the nearby burrows of *‘ua‘u* birds, which are an endangered species."	X	None			None
Friends of Haleakalā National - Ms. Mary Evanson, President	18-Oct-2006	"The friends of Haleakalā National Park (FHNP) strongly opposes location the Advanced Technology Solar Telescope (ATST) Project on Haleakalā." The cultural resource evaluation "lacks credibility as an unbiased expression of the thinking of native Hawaiians." FHNP states, "This project will adversely change the summit of Haleakalā forever, causing irrevocable loss of natural, cultural and scenic resources" The FHNP has concerns for the endangered petrel or *‘ua‘u* and how construction of ATST might affect their nesting sites. The FHNP also comments on the conclusions contained in the DEIS, pages 4-6 to 4-8. FHNP states that the DEIS does not take into account the view of the Hawaiian community, that construction operations will cause impacts that constitute defilement of the cultural and spiritual aspects of Haleakalā. FHNP reflects the Hawaiian community's view stating that these impacts cannot be mitigated.	X	None			None
Kaiini (Kimo) Kaloi, Director, Office of Hawaiian Relations, Dept. of the	31-Oct-2006	The Office of Hawaiian Relations (OHR) comments reflected the National Parks concerns on natural cultural, historic and economic park resources. OHR requested a meeting with NSF due to numerous other concerns.		N/A		X	N/A

Agency/ Individual	Date	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Interior							
Mary Evanson	23-Oct-2006	In this letter Ms. Evanson calls to attention the inadequacies and major geographical errors of the Cultural Review (Appendix F of the DEIS).		None		X	None
Mary Evanson	29-Sep-2006	Ms. Evanson read her public comment from a letter previously composed: Ms. Evanson feels protective of Haleakalā, "this project is so huge it will change Haleakalā forever. Please find another site." Again Ms. Evanson states that she is "deeply troubled" by the DEIS as it is full of errors. She is concerned that these errors will get circulated and perpetuated. (Letter drafted for public hearing)	X	None			None
Mary Evanson	13-Mar-2006	This letter specifically addresses the errors in the Cultural Resource Evaluation.		None		X	None
Maui Cultural Lands,Inc. Edward R.N. Lindsey Jr.	23-Oct-2006	"[i]t is with great concern that many of us *Kanaka Maoli* are compelled to give testimony against a project that is so destructive to the well being of the Hawaiian culture and its sacred sites." "When a culture depends on these natural wonders of their environment for survival and reverent communications to a power higher than themselves, all care must be given to this practice. Haleakalā is noted throughout Polynesia as on 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."	X	None			None
Mr. William D. Evanson	23-Oct-2006	"I believe the DEIS is inadequate and/or insufficient. It is based on faulty assumptions and biased in its conclusion…" Mr. Evanson continues, "Negative impact to historic and cultural significance downplayed..." He feels that the cultural evaluation lacked significant *moʻolelo*, *oli*, and *hula* references to Haleakalā. And he explains, "the fact that the…words used most often in conjunction with Haleakalā are "*kila kila*" (majestic, tall, strong), "*haʻaheo*" (pride) and "*hanohano*" (glorious, magnificent, stately) [proves] Haleakalā is held in high esteem and with great reverence in native Hawaiian history and culture."	X	None			None

Agency/ Individual	Date	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Ms. Mikahala Helm	21-Sep-2006	Ms. Helm proposed "avoidance", "as Hawaiians, loving our land means caring for it. This is essential especially for places like Haleakalā." "How will you address negative impacts on *kupuna*? Hawaiians and community members who have testified against ATST?" "Why was testimony left out of DEIS?" "For centuries the Hawaiian culture has flourished though oral traditions" Ms. Helm feels negative testimonies are being ignored and left out. In her closing statement, Ms. Helm states, "I do not feel that cultural protocol and training staff is enough to rectify the harm that is proposed by the building on the ATST." She continues, "Respect Haleakalā and leave it in its beauty. It is essential to our Hawaiian people, to our culture and practices…".	X	None			None
Office of Hawaiian Affairs - Clyde W. Nāmuʻo	2-Oct-2006	The Office of Hawaiian Affairs (OHA) raises the concern that "…the DEIS was not used as a decision-making tool prior to NFS's decision to build the ATST at Haleakalā, as required by the National Environmental Policy Act (NEPA) and the Council for Environmental Quality Control (CEQ) regulations. In addition, the alternatives presented in the DEIS do not represent a true opportunity for NSF to make an informed choice of location for the ATST, nor for adequate public input in the process." OHA's suggestion is that NSF draft a supplemental DEIS that includes the final three potential sites -- Haleakalā, Big Bear and La Palma -- so a comparison can be made. OHA states, "[u]ntil NSF completes a proper environmental review for the ATST project, OHA opposes this EIS and the project."	X	N/A			N/A
Professor (Emeritus) Dick Mayer	Oct.22 2006	Professor Mayer's view on ATST and the DEIS is that, in general, the DEIS does not address issues adequately, does not meet OEQC standards and contains a noticeable bias. Professor Mayer is concerned about the height of telescope and makes a comparison of the ATST placement on Haleakalā the equivalent to placing it at the Mall in Washington DC, or in front of the Lincoln Memorial, or on Calvary Hill in the city of Jerusalem, or besides the Wailing Wall in Jerusalem, or in the city of Mecca. Professor Mayer sees a problem with land ownership at the proposed site.	X	None			None
Richard Lucas,	23-Oct-2006	Main feelings from this group: Haleakalā is a sacred, spiritual place and like a church or holy city, building a structure on it would be a	X	None			None

Agency/ Individual	Date	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
Kathleen McDuff, Michael Lucas, Sean McDuff, Hanna Bearden		desecration that could not be mitigated in any way.					
State Historic Preservation Division - Mr. Peter Young	Oct.23 2006	“We believe that the cumulative impacts of the project have not been addressed regarding mitigation, and that significant impacts to the historic district/property and traditional cultural property of Haleakalā are not adequately addressed in the document [DEIS].” “Haleakalā Summit unquestionably represents a Traditional Cultural Property.” “We believe additional consultation regarding any newly proposed mitigation of the cumulative impacts posed by the project must occur prior to preparation of a Final Draft EIS and/or Memorandum of Agreement of adverse effect.” (Log No: 2006, Doc No:0610MK17)		None		X	None
U.S. Dept. of the Interior, National Park Service - Marilyn H. Parris, Superintendent	19-Oct-2006	“It is the National Park Services contention this Draft Environmental Impact Statement (DEIS) fall far short in adequacy evaluating the numerous cumulative, adverse impacts to the park's resources, our visitors’ experiences, and overall park operations.” The DEIS does not address the fact that the proposed project area, the entire summit area of Haleakalā, is located in the Crater Historic District (SIHP# 50-50-11/12-1739), listed on the National Register of Historic Places. DEIS does not address the fact that the NPS owns the roadway from the park entrance to the summit and this roadway is eligible for listing under the Historic American Engineering Record (HAER). NPS stated that the EIS does not discuss how ATST construction will impact daily park operations. NPS continues and explains that the DEIS needs to take into account the entire summit area, the Crater Historic District and not just Pu‘u Kolekole. In conclusion, “the NPS must strongly oppose the construction of this facility adjacent to HALE boundary based on the information presented within this DEIS.” NPS suggested a supplemental DEIS and asked to be contacted during the preparation of it.	X	N/A			N/A

Agency/ Individual	Date	Summary of View and Cultural Concerns	No Action	Mitigation Suggestions	For ATST	Not Stated	Mitigation Comments
U.S. Environmental Protection Agency, Region IX - Laura Fugii for Enrique Manzanilla, Director, Communities and Ecosystems Division	30-Oct-2006	The EPA commented on the DEIS and concluded that it had "Insufficient Information". The EPA explains that it is "…concerned about the negative impacts associated with locating additional structures on a site that is considered to be sacred to the Native Hawaiians." The EPA suggests that the Final EIS should include more information on stated topics and Memoranda of Agreement (MOA) for mitigation measures between NSF and the community. EPA suggests the NSF discuss and implement additional mitigation measures to address historical and cultural impacts, "The FEIS should discuss in detail all activities associated with compliance in conjunction with the NHPA. The FEIS should include information about the Section 106 process, consultations with the Native Hawaiians, and references to any MOA which might be implemented at a later date." "EPA recommends that the FEIS describe suggestions from Native Hawaiians and local community and the ways in which the agency will respond to these concerns. Resolution strategies and mitigation plans should be discussed in detail. Mitigation measures could include funding for Hawaiian cultural education programs, improved cultural centers, and research on sacred sites within HO." Concerning the topography "EPA recommends NSF consult with Native Hawaiian organizations and HALE [Haleakalā National Park] personnel concerning the reconstruction of the Pu'u Kolekole cone." Regarding the endangered U'au, "The NSF should work closely with biologists at HALE and the US Fish and Wildlife Service to ensure that the video surveillance does not adversely impact this endangered species." Regarding environmental justice, "The FEIS should include a more thorough and detailed analysis of impacts on the Native Hawaiians, a minority population. The NFS should conduct an Environmental Justice Screening Analysis to more clearly and thoroughly bring into focus the environmental justice impacts on the Proposed Action."		N/A		X	N/A

5.1 Analysis and Summary of Public Testimonies and Formal Letters

The above public testimonies and letters were evaluated and analyzed in an effort to extract the cultural content and personal views of the community members as well as bring to light reoccurring themes noted throughout the testimonies. Testimonies include community members of Hawaiian and non-Hawaiian descent.

5.1.1 Opposition to the Proposed Advanced Technology Solar Telescope (ATST)

It becomes clear that there is an overwhelming opposition to the proposed ATST at the Haleakalā location by those who offered public testimony and submitted formal letters. Testimonies against the construction of the proposed ATST were very emotional, reflecting a deep sense of concern, responsibility, and attachment to Haleakalā. As part of their cultural heritage, Native Hawaiians believe that Haleakalā is a sacred mountain: a *wahi pana* or legendary place, and *wao akua*, a place for the gods and spirits. Haleakalā is a place that was *kapu* to commoners in traditional times. Today, there are Native Hawaiians and non-Hawaiians alike who go to the summit of Haleakalā for solitude, prayer, ceremony, and inner attunement.

Construction of the proposed ATST atop Haleakalā is considered the desecration of a sacred mountain by most who offered testimony. Many considered the proposed project a personal affront, an insult and an attack on their culture. As reflected in these testimonies, the majority of those within the Hawaiian community who participated in the scoping and public comment period of the draft review process strongly oppose the proposed ATST atop Haleakalā.

5.1.2 Support for Proposed Advanced Technology Solar Telescope (ATST)

Support for the proposed ATST came from four individuals who felt excited about having a world class solar telescope here on Maui. These individuals explained that a solar telescope could not have a more appropriate location than at the House of the Sun, and remind us that Hawaiians were expert astronomers and made their way throughout Polynesia using the sun and stars as guides. The testimonies supporting ATST lean heavily towards using the telescope to encourage education in the sciences, and to encourage discovery. It was said that in the past traditional Hawaiian beliefs had discouraged the learning of new knowledge and today’s children have the right and should have the opportunity to learn as much as they can. Three of the four individuals supporting the proposed ATST explain that they have worked with children and take them on field trips up to Haleakalā to see the observatories. They further describe how excited the children are and how eager they are to learn and discover. Those in support of ATST see it as an incredible opportunity to unite Haleakalā and the sciences.

5.2 Petitions Supporting and Opposing ATST

Petitions supporting and opposing the proposed ATST were circulated during different phases of project planning. Although the individuals or organizations responsible for circulating petitions in support of ATST are unknown, Kilakila O Haleakaāa (a non-profit group formed to protect Haleakalā from further development) circulated the petitions opposing ATST. Only petitions collected after DEIS publication have been represented in this report, as they represent the majority of petitions collected.

There were three different petitions circulated during the public comment period for the DEIS:

1. A petition stating the individuals support of ATST (Figure 4);
2. A petition (Kilakila O Haleakalā Petition A) opposing ATST, supporting the “No Action Alternative” as described in the DEIS (NSF 2006) (Figure 5); and
3. A petition (Kilakila O Haleakalā Petition B) B, opposing ATST , supporting the “No Action Alternative” with a clause that states, “I am interested in becoming a consulting party regarding the religious [word religious is crossed out] and cultural significance of Haleakalā, as a traditional cultural place, through the Section 106 process” (Figure 6).

Dr. Craig B. Foltz
National Science Foundation
4201 Wilson Boulevard, Room 1045
Arlington, VA 22230

RE: Advanced Technology Solar Telescope on Haleakala¯, Maui

Dear Dr. Foltz:

I SUPPORT the proposed construction of the ATST on Haleakala¯. I believe the proposed project will result in major advances in solar research toward understanding space weather and how it affects life on Earth. It will be beneficial for educational outreach and will be a source of continued employment in the hi-tech field already on Maui. In summary, ATST is a worthy project for Maui.

Figure 4. Petition from an unknown distributor in support of ATST.

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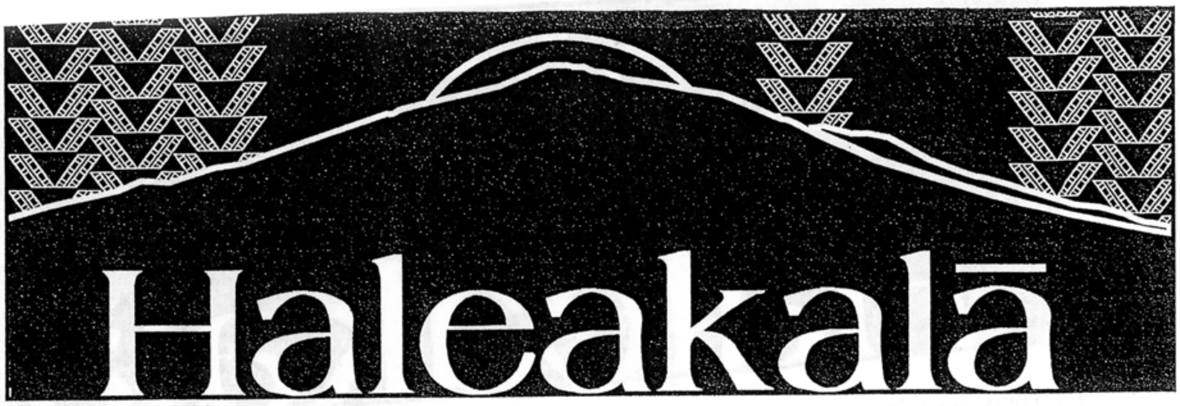
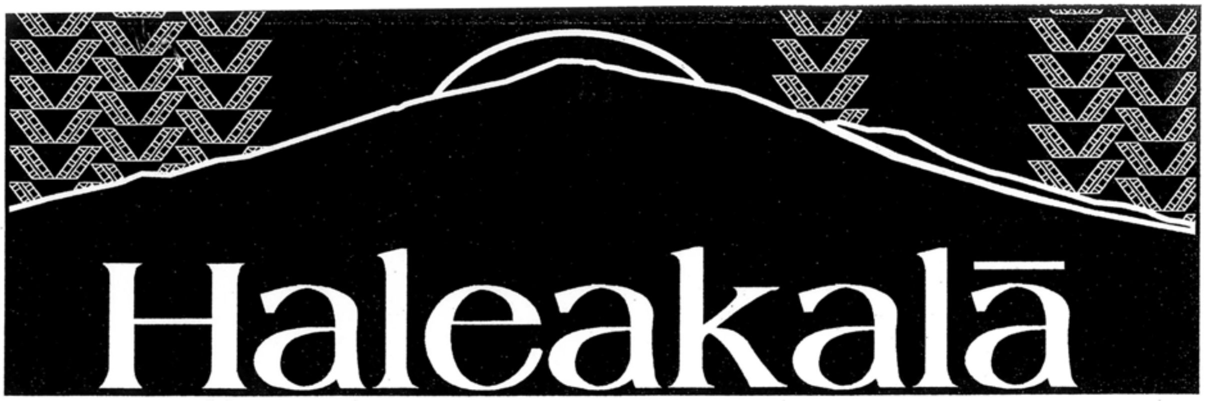


I am opposed to the proposed Advanced Technology Solar Telescope (ATST) because it would be a desecration of Haleakalā on Maui, one of the most sacred and spiritual places of Hawai'i. The approximately 14-story tall ATST structure would have a negative impact on our community through the disturbance, alteration and removal of sacred natural resources (i.e. soil, rocks) and possible cultural artifacts. A significant cumulative consequence of the proposed development would be the adverse and devastating visual effect caused by the addition of this intrusive and culturally inappropriate structure.

Aloha 'āina. Aloha Haleakalā.
(Love of the land. Love for Haleakalā)

Figure 5. Kilakila O Haleakalā Petition A, opposing the proposed ATST atop Haleakalā.



Section 106 - Proposal
for the Advanced Technology Solar Telescope (ATST)

I understand that there are three alternatives regarding the proposed ATST: avoidance, mitigation and minimization. I am submitting this proposal for avoidance to prevent the building of this telescope because it would be a desecration to sacred Haleakalā on Maui. The approximately 14-story tall ATST structure would have a negative impact on our community through the disturbance, alteration and removal of sacred natural resources (i.e. soil, rocks) and possible cultural artifacts. A significant cumulative consequence of the proposed development would be the adverse and devastating visual effect caused by the addition of this intrusive and culturally inappropriate structure.

I am interested in becoming a consulting party regarding the ~~religious~~ and cultural significance of Haleakalā, as a traditional cultural place, through the Section 106 process.

Aloha ʻāina. Aloha Haleakalā.

(Love of the land. Love for Haleakalā)

Figure 6. Kilakila O Haleakalā Petition B; opposing the proposed ATST atop Haleakalā with Section 106 Clause.

5.2.1 Cultural Implications of Petitions

Petitions from individuals in support of ATST totaled 105 (Figure 4, see Appendix A ATST Petition – Unknown Origin). A total of 691 individual signed the petitions circulated by Kilakila O Haleakalā. Of the people who responded to the petitions opposing the construction of the proposed ATST, 632 signed Petition A (Figure 5, see Appendix B Kilakila O Haleakalā Petition: Table B-1), and a total of 59 individuals signed petition B (Figure 6, Appendix B Kilakila O Haleakalā Petition: Table B-2).

In summary, the petitions represent a majority that is deeply opposed to the proposed ATST project. The theme in which opposition is based is identical to the theme revealed in public testimonies. It is the idea that a structure such as ATST is “culturally inappropriate” atop Haleakalā because it is considered a sacred mountain. Although there are those who support ATST because of its enormous potential for advances in solar research and potential educational value on a local scale, its strong opposition cannot be ignored. It is believed that negative impacts to natural resources; viewplanes, soil, rocks, and cultural artifacts will be devastating. Overall, construction of ATST is viewed as a desecration of Haleakalā.

Section 6 Community Contacts and Consultations

As a part of the current study, an additional effort was made to gather supplementary information, community input and knowledge of the summit area in order to more adequately address the impacts of the proposed ATST facility atop Haleakalā. The following section presents the results of the community consultations that were conducted by Cultural Surveys Hawaiʻi staff. The following table includes an overview of preliminary results of the community consultations.

Table 13. Preliminary Results of Community Consultations

Name	Affiliation	Contacted[2]	Personal Knowledge	Comments
Ms.Wallette Pelegrino	Cooperative Education Program Coordinator-Maui Community College	Y	S	CSH sent letter of inquiry. Informal interview, see Section 6.1.
Ms. Rose Marie Duey	Alu Like, Inc.	D	N	CSH sent letter of inquiry. Ms. Duey states that Alu Like cannot comment on the subject. Ms. Duey recommended talking with Hokulani Holt-Padilla, Charlie Maxwell or Kealiʻi Taua for more specific cultural practices information.
Ms. Rose Marie Duey	Kamaʻāina	Y	S	As an individual Ms. Duey is opposed to ATST due to the sacred beliefs attached to Haleakalā.
Ms. Sheila Ople	A'o A'o O Na Loko I'a O Maui	U		CSH sent letter of inquiry. Letter of inquiry was returned 3/19.
Ms. Vanessa Medeiros	Dept. of Hawaiian Homelands	N		CSH sent letter of inquiry.

[2] **Key:**
Y=Yes
N=No
A=Attempted (at least 3 attempts were made to contact individual, with no response)
S=Some knowledge of project area
D=Declined to comment
U=Unable to contact, i.e., no phone or forwarding address, phone number unknown

Name	Affiliation	Contacted[2]	Personal Knowledge	Comments
				Mr. John Hirota explained that Ms. Medeiros resigned and no one has filled her position yet. Mr. Hirota did refer me to Darrell Yagodich-Planner with DHHL, Linda Chinn-Land Management, Larry Fumida and Looyde Yonenaka-Information and Relations. CSH personnel spoke with Mr. Yonenaka and he explained that the DHHL has not made any official comments on the proposed ATST. E-mailed Mr. Yonenaka's secretary letter of inquiry.
Mr. Hinano Rodrigues	Dept. of Land and Natural Resources, SHPD	Y	Y	CSH sent letter of inquiry. E-mailed response, see Section 6.1.
Mr.Akoni Akana	Executive Director, Friends of Moku'ula	D		CHS lent letter of inquiry.
Mr. Patrick Ryan	Fishpond Ohana	Y	N	CHS lent letter of inquiry. Mr. Ryan stated that he does not know of any cultural practices or resources atop Haleakalā. He explained that he only knows about fishponds in Kihei.
Mr. Brian Jenkins	Friends of Polipoli, President	Y	Y	CSH sent letter of inquiry. E-mailed response, see Section 6.1.
Mr. Jim Wagele	Hawaiian Community Assets, Inc.	A		CSH sent letter of inquiry. Forwarded letter to board members.

Name	Affiliation	Contacted[2]	Personal Knowledge	Comments
Mr. Clifford Naeʻole	Hawaiian Cultural Advisor, Ritz-Carlton Resorts	A		CSH sent letter of inquiry.
Kekealani Ishizaka	Hawaiian Homes Waiehu Kou 1	A		CSH sent letter of inquiry. Contacted Department of Hawaiian Homes Information and Community Relations and asked them to forward CSH Maui office phone number to Maui homestead community presidents.
Ms. Blossom Feiteira	Hui Kako'o 'Aina Ho'opulapula and Na Po'e Kokua	U		CSH sent letter of inquiry.
Mr. Edward Ayau	Hui Malama I Na Kupuna o Hawaii Nei	A		CSH e-mailed letter of inquiry.
Ms. Julie Oliveira	Hui No Ke Ola Pono	Y	N	CSH sent letter of inquiry.
Mr. Don Atai	Hui o Vaʻa Kaulua	A		CSH sent letter of inquiry.
Ms. Kehaulani Filimoeatu	Hui of Hawaiians	Y	N	CSH sent letter of inquiry.
Ms. Roselle Bailey	Ka Imi Na'auao 'O Hawai'i Nei	Y	Y	CSH sent letter of inquiry. Informal interview, see Section 6.1.
Mr. Norman Abihai	Kahikinui Homesteaders Community President	Y	S	CSH sent letter of inquiry. Informal interview, see Section 6.1.
Ms. C. Mikahala Kermabon	Kahikinui Resident	Y	N	Informal interview, see Section 6.1.
Mr. Quintin Kiili	Kahikinui Resident	Y	N	Informal interview, see Section 6.1.
Mr. Aimoku Pali and Mrs. Lehua Pali	Kahikinui Resident	Y	S	Informal interview, see Section 6.1.
Mr. Earl Mo Moler	Kahikinui Resident	Y	S	Informal interview, see Section 6.1.
Ms. Donna Sterling	Kahikinui Resident	Y	S	Informal interview, see Section 6.1.

Name	Affiliation	Contacted[2]	Personal Knowledge	Comments
Ms. Chad Newman	Kahikinui Resident	Y	N	Informal interview, see Section 6.1.
Mr. Charlie Lindsey	Kahoʻolawe Island Reserve Commission	Y	N	CSH sent letter of inquiry. Informal interview, see Section 6.1.
Dr. Rod Chamberlain	Kamehameha Schools Oahu Campus	Y	N	CSH sent letter of inquiry. Mr. Chamberlain referred CSH to new Maui headmaster, Ms. LeeAnn Delima.
Ms. LeeAnn Delima	Kamehameha Schools Maui Campus	Y	N	CSH sent letter of inquiry.
Ms. Dancine Takahashi	Kamehameha Schools Alumni	Y	N	CSH sent letter of inquiry.
Robin Newhouse	Keokea Hawaiian Homes	U		CSH sent letter of inquiry. Contacted Department of Hawaiian Homes Information and Community Relations and asked them to forward CSH Maui office phone number to Maui homestead community presidents.
Mr. Alan Kaufman	Kula Community Association President	Y	Y	CSH sent letter of inquiry. E-mailed response, see Section 6.1.
Ms. Uilani Kapu	Kuleana Kuʻikahi LLC	Y	Y	CSH sent letter of inquiry. Ms. Kapu composed and mailed letter but CSH staff did not receive it.
Ms. Kamaile Sombelon	Lokahi Pacific	D		
Mr. Lui Hokoana	Maui Community College and Hawaiian Civic Club	A		CSH sent letter of inquiry. Mr. Hokoana gave testimony at public meeting.

Name	Affiliation	Contacted[2]	Personal Knowledge	Comments
Mr. Stan Solamillo	Maui County Cultural Resource Commission	Y	N	CSH sent letter of inquiry. On March 1, 2007 CSH staff members Colleen Dagan and Tanya Lee-Greig presented project to the Cultural Resource Commission seeking public comment. There was no public turnout. Commission members suggested re-presenting it with at least one month's notice.
Ms. Patty Nishiyama	Na Kupuna O Maui	A		CSH sent letter of inquiry.
Ms. Lei Ishikawa	Na Leo Pulama	A		CSH sent letter of inquiry.
Ms. Ohua Morando	Na Pua No'eau	Y	N	CSH sent letter of inquiry. Ms. Morando said she was collecting information for CSH, but none has been received.
Mr. David Keala	Native Hawaiian Educational Council	U		CSH sent letter of inquiry.
Ms. Velma Mariano	Paukukalo Hawaiian Homestead Community Association	U		CSH sent letter of inquiry. Contacted Department of Hawaiian Homes Information and Community Relations and asked them to forward CSH Maui office phone number to Maui homestead community presidents.
Mr. Nainoa Thompson	Polynesian Voyaging Society	A		CSH sent letter of inquiry. Although Mr. Thompson could not be reached due to his Micronesia/Japan voyage, Kahu Maxwell had mentioned talking to him, see Table 4.

Name	Affiliation	Contacted[2]	Personal Knowledge	Comments
Ms. Kili Namauu	Punana Leo O Maui	Y		CSH sent letter of inquiry.
Ms. Iris Mountcastle	Queen Lili'uokalani Children's Center	D		CSH sent letter of inquiry. Ms. Mountcastle explained that her organization's mission deals directly with child welfare issues and concerns, giving preference to Native Hawaiian orphans and destitute children.
Kahu Po‘o Iki Clarence Solomon	Royal Order of Kamehameha	A		CSH sent letter of inquiry. Mr. Solomon gave testimony at a public meeting.
Ali‘i Sir William Garcia Jr. CK	Royal Order of Kamehameha Office of the Ku'auhau Nui	Y	N	CSH sent letter of inquiry. Mr. Garcia referred CSH to Kaponoai Molitau.
Mr. Leslie Kuloloio	Hawaiian Cultural Practitioner	Y	Y	CSH sent letter of inquiry. Informal interview, see Section 6.1.
Mr. Stanley H. Ki‘ope Raymond	Hawaiian Language Professor, Maui Community College	Y	Y	CSH sent letter of inquiry. Informal interview, see Section 6.1.
Mr. Sam Ka‘ai	Hawaiian Cultural Practitioner			CSH sent letter of inquiry. Informal interview, see Section 6.1.
Pastor Wayne Carroll	Pastor, Kahana Door of Faith/Hawaiian Cultural Practitioner	Y		CSH sent letter of inquiry.
Mr. Ke’eamoku Kapu	Hawaiian Cultural Practitioner	A		CSH sent letter of inquiry.
Mr. Ka‘i‘ini (Kimo) Kaloi	US Department of the Interior Office of Hawaiian Relations	Y	S	CSH sent letter of inquiry.
Mr. Perry O. Artates	Hawaiian Homes Waiohuli	A		

Name	Affiliation	Contacted[2]	Personal Knowledge	Comments
Uwekoolani Family	Kamaʻāina	Y	N	CHS personnel called all 8 members listed in phonebook. Only contacted Rodney K. who said he did not know anything.
Cecilia K. Hapakuka	Kamaʻāina	U		
Kali Hapakuka	Kamaʻāina	Y	N	Ms. Hapakuka said she was raised at ʻUlupalakua and now resides in Kula at the Waiohuli homestead. She said she didn't know anything about Haleakalā but referred CSH to Michael Purdy and Merton Kekiwi.
Michael Purdy	Kamaʻāina	Y	N	
Merton Kekiwi	Kamaʻāina	Y	N	
AK Kahula	Kamaʻāina	N		
Clyde Kahula	Kamaʻāina	Y	N	Mr. Kahula explained that his family is not from area in study.
Lisa Marie Kahula	Kamaʻāina	U		
Jacob Mau	Kamaʻāina	U		
Ms. Gordine Bailey	Kamaʻāina	Y	N	Mentioned petitions opposing ATST. Referred her son Tim Bailey.
Mr. Tim Bailey	Kamaʻāina	Y	Y	Testimony given at meetings. Informal interview, see Section 6.1.
Mrs. Kathleen Bailey	Haleakalā National Park Wildlife Biologist	Y	Y	General information on *ʻuaʻu* burrows.
Mr. Walter Kanamu	Living Indigenous Forest Ecosystem (LIFE)	N	Y	Testimony given at meetings.
Mr. Kawika Davidson	Kahikinui Game and Land Management, Kama'aina	Y	Y	Informal interview, see Section 6.1.

Name	Affiliation	Contacted[2]	Personal Knowledge	Comments
Mr. George Kaimiola	Kamaʻāina	N		
Mr. Kaponoai Molitau	Cultural Advisor for the Kahoʻolawe Island Reserve Commission	A		
Mr. Ethan Romanchak	Kamaʻāina	Y	S	Mr. Romanchak recalls the sandalwood trade, and describes that *ʻōhelo* berries and *akala* berries were used for food. He notes that there are several dye plants found in the upper forest but cannot recall their names. He said the he knows people who collect *ʻaʻaliʻi* and other plants for *haku leis* and wreaths.

Interviews and consultations were conducted by Colleen Dagan, B.S. from February through the first week in April. Presented below are summaries and excerpts from informal telephone interviews and e-mailed responses by different community members. The summaries focus on the information in the interviews related to land uses and traditional cultural resources, practices and beliefs related to Haleakalā , Puʻu Kolekole, Puʻu Ula and the surrounding uplands.

6.1 Summaries of Informal Interviews

6.1.1 Ms. Wallette Pelegrino

Ms. Pelegrino stated that she would share the CSH contact letter with a group of colleagues. Ms. Pelegrino said that she has visited Haleakalā throughout her life to watch the sunrise. She continues to visit Haleakalā once a year to watch the sunrise. As a teenager at St. Anthony's she visited the crater with her school and experienced the Brocken phenomenon. The Spectre of the Brocken, as it is known, is a natural phenomenon that can be witnessed in the late afternoon at the summit of Haleakalā Crater. With the sun at your back and facing the crater, a huge shadow of yourself is cast in the clouds and encircled by a rainbow.

6.1.2 Mr. Leslie Kuloloio

Born and raised on Maui, Mr. Kuloloio has ancestral ties to Honuaʻula Moku and sits as a member on the Maui/Lānaʻi Islands Burial Council. Mr. Kuloloio spoke of the importance of Haleakalā as a sacred place that brings forth life and ties together the features of the landscape of Honuaʻula and the birth of the lands below. With regard to East Maui in its entirety, Mr. Kuloloio makes specific mention of Pohaku Palaha, the point at which all of the *moku* of East Maui begins. Mr. Kuloloio also mentions the significance of Haleakalā as a burial ground. While not disclosing the exact location of burials within the crater and along the summit, Mr. Kuloloio notes that they are there and has concerns about the protection of these gravesites.

6.1.3 Mr. Hinano Rodrigues

Mr. Rodrigues explained that it may not be the presence of archaeological sites atop Haleakalā that indicates its cultural importance, but rather the lack thereof: "…sometimes the absence of any tangible cultural and archaeological feature is a manifestation of the importance and sacredness of the area. Haleakalā is one of those areas." Mr. Rodrigues describes Haleakalā as a *wao akua*, a place of the gods. This is why you find only a limited number of archaeological sites. The presence of any man-made structures takes away from the sacredness of the *wao akua*. "To many *Kanaka Maoli*, the very unobstructed view of the *mauna* itself is a part of their daily religious observations." Mr. Rodrigues feels that another structure atop Haleakalā will take away from the sacredness of this mountain.

6.1.4 Mr. Brian Jenkins

Mr. Jenkins relates that he was born and raised on Maui and explains that his family has lived on Maui for three generations. He has spent his lifetime hiking and hunting on the slopes of Haleakalā. He states that hunting is the general trend in the area. Mr. Jenkins explains, "These traditions are hunting and hiking and just finding a quiet, pure, pristine place in the wilderness to be alone with one's thoughts." He states that one of the favorite hunting areas is the Kahikinui Forest Reserve because of its "pristine wilderness character". He feels that ATST with its proposed 14-story height will have a "tremendous negative impact on that sense of wilderness that is currently enjoyed. This negative visual impact will also affect much on the Skyline Trail and views from the Upper Waiohuli Trail in the Kula Forest Reserve." Mr. Jenkins is equally concerned with the present restrictions on roadway access to the Skyline Trail. He wonders if future development at the summit may potentially block access to the Skyline Trail. He goes on to explain that the Skyline Trail is one of the favorite hiking trails of local people and has been used for hunting access for decades. He describes how it is used by hunters and explains that if some of the older hunters were forced to hike in from the lower gate that they would essentially be barred from hunting this area because the terrain from the lower gate access is too dangerous for them. Mr. Jenkins says that chuckers, francolin, pheasant, goats and pigs are all hunted in this area and used for food. In addition, pheasant feathers are prized for their use as hat bands, a paniolo tradition.

6.1.5 Ms. Roselle Bailey

Ms. Bailey is a *kumu hula* and admits the proposed ATST has been on her mind. She explains that she is not necessarily for or against it. She goes on to explain, our Hawaiian ancestors had extensive knowledge of the sun and stars. Ms. Bailey expressed her frustration with what she referred to as "foreign law" and how it requires the section 106 process and cultural impact assessments. She explains that these requirements essentially ask Hawaiian people to prove their cultural beliefs, in this case, why Haleakalā is considered sacred. Ms. Bailey does not feel that it is right for anybody, especially the host culture, to have to prove their beliefs in order to maintain the integrity of a site they consider sacred.

She does not feel qualified to speak about Haleakalā because she is from Lahaina. She suggested speaking to families from the area and shared some of those families' names:

Uwekoolani, Hapakuka, Santos and Kahula. She is concerned about the development of the summit and asks "when does it stop?" She is concerned about ATST being used by the military and putting Maui and the entire state in danger. Ms. Bailey describes feelings of mistrust of the government. Ms. Bailey made mention of a significant rock located at the summit of Haleakalā and described this rock as a marker set at the point where all the east Maui ahupua‘a meet. Ms. Bailey also explained that Haleakalā Crater was traditionally used as a calendar and that Hawaiians tracked the path of the sun by observing the shadows on the crater floor. Times of special significance at the summit were during the solstices and equinoxes and she stated that on the solstice the sun's rays hit Pu‘ukukui directly. Ms. Bailey states that the proposed ATST must interfere with this use of Haleakalā crater as a calendar.

Ms. Bailey makes reference to a Hawaiian proverb about Pele:

> ‘A‘ohe o kāhi nānā o luna o ka pali;
> iho mai a lalo nei;
> ‘ike i ke au nui ke au iki, he alo a he alo.
>
> The top of the cliff isn't the place to look at us;
> come down here and learn of the big and little current,
> face to face" (Pukui 1983: 24).

This is meant to be an invitation to discuss something or learn the details of a matter. "Pele said this to Pā‘oa when he came to seek the lava-encased remains of his friend Lohi‘au" (Pukui 1983: 24). Ms. Bailey says this of the scientists on Haleakalā and those who propose ATST, she would like to see them come down and talk to the people, particularly elementary school students, "come down off the high mountain and teach the young people at their level".

6.1.6 Mr. Charlie Lindsey

Mr. Charlie Lindsey considers Haleakalā sacred and does not want another observatory built there. Mr. Lindsey feels that there is too much up there now and if anything else is built, then something else should come down.

6.1.7 Dr. Alan Kaufman

Dr. Kaufman explained that he goes to Haleakalā for recreation and stated that he has taken his older children on overnight camping trips in the crater. He said that he takes visiting guests to the crater one to two times a year. Dr. Kaufman's youngest son is part-Hawaiian and they have visited the *ahu* at the summit. Dr. Kaufman explains that he wants his son to have memories and experiences that "give him a sense of place and belonging." Dr. Kaufman also explained that he had passed our Community Contact Letter out at the last community meeting and no other members had any comments to share on the subject.

6.1.8 Mr. Stanly H. Ki‘ope Raymond

In addition to Mr. Raymond's public comments and letters on behalf of Maui Community College's Hawaiian Studies Program, Mr. Raymond shared that he has visited the summit of Haleakalā annually since he was a child. Growing up in Lahaina, Mr. Raymond explained that it was quite a journey to the summit. As an adult Mr. Raymond goes there for spiritual purposes, to pay respects to ancestors and the different Hawaiian deities. He uses the two *Ahu*. He also describes the significance of Paeloko, a coconut grove located at Waihe‘e in which the sennit from this particular coconut grove was used to make the lasso or cordage that Maui used to snare the sun.

In an e-mailed letter, Mr. Rayomond suggests having an English translation of the welcome sign (currently only in the Hawaiian language) at the entrance to Science City. He explains that the majority of Hawaiians cannot read Hawaiian and therefore may not know they are allowed in this area. He says signs in both English and Hawaiian would allow the public to understand who can enter and for what purpose.

6.1.9 Mr. Sam Ka‘ai

Mr. Ka‘ai explained that Haleakalā is a sacred mountain and that “sacred mountains are praying places.” He explains 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. He describes the great pain that the Hawaiian people experience when a sacred place such as ‘Īao or Haleakalā are desecrated as these have been. He relays his frustration with the laws requiring cultural impact assessments and the section 106 process. He explains, people take their time and share their knowledge only to find that it doesn't make a difference in the outcome of a project. Mr. Ka‘ai explained that these people increasingly feel they are wasting their time, because, he stresses, “no one listens!” Mr. Ka‘ai spoke of the rock at Haleakalā that marks the point where the eight Moku of east Maui meet and speaks of its importance in Hawaiian culture. He also mentions Pa‘a Kea, a rock or rock mound where priests would go on the summer solstice to pray. He talks of Pu’u Ula, explaining that it is also called Red Hill or Sacred Hill. Mr. Ka‘ai states the summit area of Haleakalā is where angels walk and was *kapu* to commoners. Lastly Mr. Ka‘ai mentions that his family used to own land from Palikū, down the mountain.

6.1.10 Mr. Kawika Davidson

Mr. Davidson is the president of Kahikinui Game and Land Management. This group has rights to access the Kahikinui Forest Reserve for the purpose of hunting and gathering plants from the area. Mr. Davidson relays his knowledge of Haleakalā as *wao akua*, “a fragile part of the upper forest to the summit.” He explains that in traditional times this area was *kapu* to all except *ali‘i*, *kahuna* and messengers. Mr. Davidson describes using the Skyline Trail for access to hunting grounds. He hunts goats, pigs, deer, pheasant, chucker and other variety of game birds. He also says that he uses this area to collect *‘ōhelo* berries, ferns, *pūkeawe*, *pōpolo*, *māmane* and *‘a‘ali‘i*. Mr. Davidson uses the plants for a variety of purposes and hunts for food. He recalls, that traditionally only certain parts of the forest could be accessed by man. Mr. Davidson feels the proposed ATST will be an eyesore.

6.1.11 Mr. Timothy Bailey

Mr. Bailey is a Haleakalā National Park (HNP) employee of 16 years. He currently heads the Feral Animal Removal Program. In his time employed at HNP, Mr. Bailey has had the opportunity to hike the entire crater rim, traverse the carter, and has accessed the surrounding slopes of Haleakalā . Over the years he has become intimately familiar with the greater Haleakalā region. He shared some of his cultural knowledge of the area with CSH staff.

Mr. Bailey began by describing the Pohaku Palaha, a flat, circular plateau that marks the "*piko*" of east Maui. This is the spot where all eight east Maui *moku* meet. It is located at the top of the northeastern rim of the crater, at Lauʻulu Paliku. Its name is said to represents the *he'e*, or octopus, and describes how the *heʻe* clings on to a rock when hiding or when being hunted. Its eight tentacles spread out over the rock and its mouth, its center, representing the *piko*, locks onto the rock making it extremely difficult to pry loose. Like the tentacles of the *heʻe* spread out over a rock, Pōhaku Pālaha is the *piko* from which the eight east Maui *moku* fan out.

Mr. Bailey went on to describe the migration pattern of the *ʻuaʻu*. He explained that Hawaiians observed animals' migration patterns and used them in combination with other natural cycles to keep track of seasons and time. It was known that when the *koholā* or humpback whale, left Hawaiian waters, the *ʻuaʻu* would be arriving to nest and when the *ʻuaʻu* left, the *koholā* would be returning. Therefore, Hawaiians knew not to waste their time hunting for *ʻuaʻu* while the *koholā* were still around. Mr. Bailey explained that a mother *ʻuaʻu* is referred to as *kaini* and traditional hunters were careful not to kill as they were needed to raise their young. Although *ʻuaʻu* chicks and males were hunted for food, traditional hunting practices made sure populations continued to thrive.

Mr. Bailey explains that *ʻuaʻu* were hunted for food and for feathers. They were eaten exclusively by the *aliʻi*, and their feathers were used as adornments for *hula* and *lua* instruments as well as feather capes. *ʻUaʻu* and *ʻuaʻu* feathers were the *hōʻailona*, or the insignia of some *aliʻi*. And in the same way feather cape patterns identified the rank of an *aliʻi*, the particular color of the feathers also indicated the rank of an *aliʻi*. *ʻUaʻu* were also the *ʻaumakua*, or family god, of some families. Birds were caught using snares and basket traps. In a third technique, a stick was used by inserting it into the burrow and placing it into the birds downy feathers. One would then twirl the stick and the feathers or *huluhulu* would become entangled around the stick and the bird could then be pulled out. Mr. Bailey referred to this as "*wiliwili* the *huluhulu*". Mr. Bailey noted the many sling stones he has observed in the crater. He thinks they might have been used for hunting *ʻuaʻu*. Their name, he believes, is simply the sound of their call, *ʻuaʻu*.

Mr. Bailey continued to describe some *ʻalaea* ("red ocherous earth"; Pukui and Elbert 1986:17) pictographs located near Kapalaoa Notch. He has studied these pictographs and thinks they look like *ʻuaʻu* birds. He also described a variation of the place name Kapalaoa. He said he has known the area as Ka palaoa, two words meaning the *palaoa*, likened to the prized whale ivory pendant, *lei palaoa*. Ka palaoa Notch, he explained, is a notch in the cliffs of that area shaped like a palaoa pendant. Mr. Bailey also described a spring that feeds the Kapalaoa cabin called Wai palaoa and a *heiau* located atop Kapalaoa ridge.

During his time with the park service, Mr. Bailey has noticed what he believes are old Hawaiian trails. Trails, he states, that are well made and have managed to withstand the ages. Mr. Bailey believes that one trail in particular follows the flight path of the *ʻuaʻu* from the old fishing village at Nu'u, to their nesting ground at Haupaʻakea, on the southern rim of the crater. He has followed sections of the trail on foot and from a helicopter. He has hiked from Haupaʻakea to Nuʻu in a day's time proving that Hawaiians could get to Haleakalā Crater and summit area fairly quickly. Mrs. Kathleen Bailey, Mr. Bailey's wife, is a wildlife biologist at Haleakalā National Park. She noted that there are 27 active *ʻuaʻu* burrows at the preferred Mees site location.

6.2 Kahikinui Homestead Community Meeting

On March 17, 2007 CSH staff members Colleen Dagan and Tanya Lee-Greig attended the Kahikinui Community Board meeting. Individuals in attendance included community president Mr. Norman Abihai, Mr. Quintin Kiili, Mr. Earl Mo Moler, Mr. Aimoku Pali and his wife Mrs. Lehua Pali, Ms. C. Mikahala Kermabon, Mr. George Namauu and his wife Mrs. Gerturde Uwekoolani Namauu. (Individuals not in attendance but who were contacted by phone include Ms. Chad Newman and Ms. Donna Sterling. Individual testimonies are detailed below.)

The community expressed their concerns and opposition. There was the overall feeling that there was nothing they could do to stop ATST from being built, it being a “done deal”. As a community they felt they were not properly informed as the only information they had received about the proposed ATST was from another community member, Ms. Chad Newman. Ms. Newman had given community members some information on ATST back in 2005. As a community they would have liked the National Science Foundation to come out to Kahikinui and discuss ATST with them. They would have liked the NSF to be available to answer questions. Ms. Dagan and Ms. Lee-Greig referred community members to NSF's ATST website.

Community members felt the NSF should have asked for permission for use of the site before any other planning was completed. Feelings towards the land ran deep and Mrs. Pali explained that it's not right to disrupt the *aina*. She stated, “hurts the heart” to see the various development projects happening on Maui.

Community members were concerned about hazardous waste. They wanted to know what the potential for hazardous waste spills would be and how these accidents might affect their community. The community was concerned about impacts to the Kahikinui Forest Reserve, and to plants, animals and the environment overall. There were concerns about radiation. They asked if ATST would emit any harmful “rays”.

Although as individuals they oppose the ATST at Haleakalā, they were able to come together and make a few suggestions about what they would like from the NSF in return for the Haleakalā site. The community would like to see educational programs, scholarships, and mentorships given to Native Hawaiian children and adults. They explained that the general public should also benefit in the same ways. There were suggestions made about employing local residents in professional positions, and training those residents in professional fields by way of mentorships and apprenticeships. They would encourage the NSF not only to accept the smartest students or adults, but also train the average or even at-risk individuals. They would like to see preference for participation in these programs given to residents of Kahikinui. They would also like to see support given for infrastructure and utilities (installation of water lines, electricity and roads) for Kahikinui homestead lands.

6.2.1 Mr. Norman Abihai

Mr. Abihai expressed deep frustration with the proposed ATST site. He added, the area in study is ceded lands, and he does not want it built.

6.2.2 Ms. C. Mikahala Kermabon

Ms. Kermabon is concerned about the impacts ATST might have on trails and archaeological sites in the Kahikinui Forest Reserve and on Kahikinui homestead lands. She describes the strong winds in the area and expresses concern about hazardous material spills and the rate an airborne pollutant might spread.

6.2.3 Mr. Quintin Kiili

Mr. Quintin would like to see an ATST rendering from Kahikinui showing homes in the area and their relation to the summit and ATST.

6.2.4 Mr. Aimoku Pali and Mrs. Lehua Pali

Mr. and Mrs. Pali believe Haleakalā is sacred. Mrs. Pali reminds us that Haleakalā was left pure by traditional people. They would like NSF to invest whatever it takes to change the color of the telescope so that it would not be as visible. They suggest NSF building their own power plant to cool ATST. They strongly encourage NSF to develop programs that provide mentorships for *keiki* and apprenticeships for adults so the local people can hold professional jobs with the NSF on Maui.

6.2.5 Mr. Earl Mo Moler

Mr. Moler feels his community will have little or no effect on stopping ATST from being built. He would like to see ATST moved away from the edge of the Pu’u. Mr. Moler advocates protecting sacred Hawaiian lands, so these lands can continue to be used as spiritual places. He would like to see the natural resources of Haleakalā protected as Kahikinui residents and Hawaiians remain a gathering people. He stresses, “Stop the raping of our natural and sacred areas!”

6.2.6 Ms. Donna Sterling

Ms. Sterling referred CSH staff to Walter Kanamu and Art Medeiros of Living Indigenous Forest Ecosystem (LIFE), Kawika Davidson of Kahikinui Game and Land Management, JoAnn Kahanamoku Sterling, and Gordine Bailey. Ms. Sterling described a rock located at Haleakalā that serves as a marker of the point where the eight east Maui *moku* meet. She says that this point has cultural significance. She also recalls going to the summit with Kahu Maxwell years ago to chant “e ala e”. Ms. Sterling's husband, Leon Sterling recalls the ‘Ua‘u and notes they are territorial. Ms. Sterling raised a concern about nighttime light shed from the proposed ATST. She explains that the Kahikinui area is dark, there are no lights at night and this darkness supports certain animals with nighttime habits.

6.2.7 Ms. Chad Newman

Because Ms. Newman is from Molokai she does not know about cultural practices or cultural resources at Haleakalā. Ms. Newman expresses some excitement about ATST. She feels that the potential benefits of ATST to mankind on a global scale are extremely important. She feels it is crucial to learn about the future of our environment. She explains, if ATST will be able to help us understand things like global warming and sea level changes and help us learn what we can do to prepare for climate changes, than it seems it would be an essential tool to have. As a Native Hawaiian with two young daughters, Ms. Newman is also excited about the possibilities of educational programs developed as a result of ATST.

6.3 Maui Community College (MCC)-Hawaiian Studies Program

The Hawaiian Studies Department at MCC responded to CSH's letter of inquiry and included four individual students' feelings regarding the proposed ATST. The Hawaiian Studies Program e-mailed their response stating they oppose the proposed ATST, "…it would be a descration of Haleakalā on Maui one of the most sacred and spiritual places of Hawaiʻi. The approximately 14 story tall ATST structure would have a negative impact through the disturbance, alteration and removal of sacred natural resources …soil, rocks, and possible cultural artifacts. Significant cumulative consequences of the proposed development would be the adverse and devastating visual effect caused by the addition of this intrusive and culturally inappropriate structure."

6.3.1 Kamaʻāina, Student

This individual explains he or she was born and raised on Maui, and has ancestral roots in Kahakuloa. The individual hopes to attain a degree in environmental conservation and opposes ATST. Oppositon is based on the precieved negative impacts ATST would have on cultural practices, the environment, and the ʻUaʻu. The individual explains that Haleakalā has great spiritual value to Hawaiians and concludes by stating, "…I am not against good science, but I don't think good science should threaten a species and offend the host culture."

6.3.2 Ms.Cheynne Sylva

Ms. Sylva explains that "Hawaiian people have suffered more that it seems like you folks know. If you understood the Hawaiian people and our history, you would know that asking to build a four-teen story building on…our sacred mountain, is extremely insulting." Ms. Sylva explains that Haleakalā caters to tourists every day and declares: "[o]ur mountain is not an amusement park…" Ms. Sylva says Haleakalā is a sacred place and she does not want ATST built there.

6.3.3 Mr. Walter Kozik

Mr. Kozik begins his testimony by stating, "How many more times do the indigenous peoples of the world have to face the hungry eye of Science and watch, powerless, as it's great mouth devours those places and beliefs that make up the identity of the people themselves?" Mr. Kozik speaks of a type of western scientific manifest destiny, where all things on earth will soon be conquered by western science and western man. Point being, that science does not have all the ansewers, and in fact indigenous knowledge is equally valuable.

6.3.4 Ms. Kathleen Zwick

Ms. Zwick, who states she is not Native Hawaiian, feels that ATST will have a considerable negative impact on Hawaiians. She feels ATST will negatively impact the islands endangered species. Ms. Zwick understands that Haleakalā is the only location proposed where the host culture attatches sacred beliefs to it. Ms. Zwick does not think it is appropriate to build ATST against the protests of the Hawaiian people.

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 *ʻōhelo* berries, *lehua*, *ʻaʻaliʻi*, *pūkeawe*, *pōpolo*, *māmane* and various species of fern. *ʻŌhelo* 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 *ʻaʻaliʻi* (*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 *laʻau lapaʻau*, 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 *maʻa* (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 *ʻUaʻu*, 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 *ʻuaʻu*:

> The natives inform me that the *ʻuaʻu* 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 ʻuaʻu 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 *ʻuaʻu*. He explained that a mother *ʻuaʻu* 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, *ʻuaʻu* were also hunted for their feathers. The *ʻuaʻu* were the *hōʻailona*, or the insignia, of some *aliʻi*, and thus, used by them in personal adornments such as capes. Certain *aliʻi* 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. *ʻUaʻu* feathers were also used as adornments on *hula* and *lua* instruments. Because of of the birds' migratory nature, following the seasons, *ʻuaʻu* feathers might have been used to represent the season in which they appear. Lastly, *ʻUaʻu* were considered *ʻaumakua*, a family or personal god (Pukui and Elbert 1986), who acted as a guardian. Today, it is illegal to harm or kill the *ʻuaʻu* as they are an endangered species and are protected by State and Federal laws.

Concern for the *ʻuaʻu* was raised throughout the testimonies. Mr. Kiʻope Raymond stressed that the ʻUaʻu is an *ʻaumakua* 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 ʻUaʻu, "[t]hat represents old Hawaiʻi" (Table 3). Mr. Tim Bailey voices his concern about the ʻUaʻu and the Native bat, *ʻōpeʻapeʻa* (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 Hawaiʻi 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 Pu‘u 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 *he‘e* 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 *he‘e* 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, Moloka‘i, Lana‘i, and Kaho‘olawe). 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
Pi‘i ka lewa	As it climbs
Ka lewa nu‘u	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. Ka‘ohulani 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 *‘awa* 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. Ka‘ai 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 25th, or 27th 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).

7.12 Economic Concerns

There is concern over the amount of money that will be spent on ATST. Some feel the money should be spent to help Hawaiians get a college education, "…[g]ive us the money so I can get my bachelor's degree, my master's, and the future of the land and the water." Ms. Toni Dizon makes this statement explaining that the money would be better spent on Hawaiians who want to get an education so that they can help the community themselves (Table 7. Paūkukalo Community Center - May 1, 2006).

Section 8 Summary and Recommendations

It is clear that Mauna Haleakalā, from past to present, is a significant part of traditional Hawaiian culture and that to the majority of the Native Hawaiian community who participated in this process, the construction and operation of the proposed ATST presents a negative impact on the summit of Haleakalā. The mountain and summit play significant roles in traditional Hawaiian lore and epic battles between the elements and the gods. From traditional times to the present day, *kanaka maoli* (Native Hawaiians) ascend the mountain to engage in ceremonial activities either within a group setting (e.g. with *hula halau* or to observe the *Makahiki*) or in solitude. The magnificence and serenity of the mountain is voiced not only from Native Hawaiian people, but from non-Hawaiians as well. Narratives from non-Hawaiians as far back as the first missionary accounts of their first view and ascent of the mountain attest to the majestic presence of Haleakalā (see Section 3.3 Early Historic Era to the Late-1800's.). This is clearly felt into the present time as visitors to Maui continue to make the trek to the summit to greet the day.

It is apparent that significant immediate and cumulative impacts are expected by the proposed ATST facility atop Haleakalā. Immediate and short-term impacts to the summit of Haleakalā would be associated with activities directly related to the construction of the facility itself, as well as the potential impacts to the surrounding infrastructure during the construction phase (i.e. soil and construction staging areas and/or increased use of the roadways). For the *kanaka maoli*, the physical excavation of the cinder itself is seen as a descration of the *kinolau* or body of Pele herself (see Section 5 Scoping Meetings and Section 106 Testimony). There are disagreements within the community as to the degree to which this type of impact can be mitigated, if at all. Steps toward preservation and education with regard to Native Hawaiian cultural beliefs and sense of place have been put forth in *"Ku I Ka Mauna" Upright At the Mountain. Cultural Resources Evaluation for the Summit of Haleakalā* (Maxwell 2003), a document prepared as a part of the Haleakalā High Altitude Observatory Site Long Range Development Plan (KC Environmental 2005)

To limit the assessment of the cumulative and long-term impacts of the proposed ATST undertaking to the 18.166-acre area would be difficult, as the overall size and color of proposed facility would have a more wide-ranging effect and need to take into account the whole of the summit and crater area. Based on the testimony presented by the community, there is a necessity for an unimpeded viewplane from mountain to ocean, particularly in the context of ceremonial activities at the east and west *ahu* within the HO parcel itself. It is clear that the height and color of the proposed facility would impede the viewplane and is seen by some as a personal affront to their cultural beliefs. From a traditional Hawaiian viewpoint, the unaesthetic nature of the facility has led to further objections to the observatory as an additional "eye sore" to the summit area. It would compound the negative impacts of the already existing facilities.

The anticipated negative impacts to Haleakalā that would result from the construction and day-to-day use of the ATST facility brought forth strong opposition from the majority of the Native Hawaiian community who participated in the scoping and public commentary period. Responses to the proposed facility were deeply emotional and, for some, the idea of an additional building atop the summit was physically painful. Overall, there is a belief that to go forward with the proposed undertaking would be a descretation of a sacred site, with some equating the impacts to building an observatory next to the Wailing Wall in Jerusalem or within the city of Mecca.

Although testimony in support of ATST was scarce, it was as convincing and equally heart-felt as the opposition. In most instances, supporters strongly rallied for education of Hawai‘i’s youth and the possible opportunity that such a facility might bring to Native Hawaiians.

Along these lines, two proposals, submitted by Mr. Warren Shibuya and Kahu Charlie Maxwell, were put forth as a potential means to mitigate the impacts of the proposed undertaking. While these individuals may not agree with or support the construction of the ATST, there is a feeling that Native Hawaiians may be able to gain some compensation in the form of educational facilities from allowing for the use of the summit for astronomy and observation. Mr. Shibuya suggested policies that include: hiring Maui residents for all phases of work; establishing a Maui Solar and Hawaiian Cultural Center; to require ATST to develop a sunset clause, where at a determined time ATST is removed and the site is restored to its natural state; and that all streets and facilities be given Hawaiian names.

Kahu Maxwell proposed the development of Hālau ‘Imi ‘Ike Hōkū, Center for Traditional Hawaiian Navigation and Astronomy. This center would aim to bring traditional Hawaiian celestial knowledge together with modern science and astronomy. It would include a planetarium and provide schloraships to Maui residents for post high-school education (KC Environmental, FIES in press).

Informal proposals presented in a talk-story format by the Kahikinui Homestead Community included full-ride scholarships for Native Hawaiian students with an award preference to the students and youth of Kahikinui, as well as the development of a mentorship program between Native Hawaiian students and scientists working atop Haleakalā. The goal of the proposed programs would be to even the educational field and, as Kahu Maxwell points out in his proposal, make it possible for Native Hawaiians to become experts in the subject. The implication being that someday, those studying and operating the observatory facility would be *kanaka maoli*.

8.1 Recommendations

In order determine the level to which there are either beneficial (positive) or adverse (negative) impacts resulting from the proposed undertaking the following was proposed during in the DEIS (KC Environmental 2006: 4-3):

1. Significant impact;
2. Significant impact but mitigable to less than significant;
3. Less than significant impact;
4. No impact; or
5. Beneficial impact

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 this 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 through out the operational time span of the facility itself.

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Appendix A ATST Petition – Unknown Origin

Table A- 1. Petition in Support of ATST

Last Name	First Name	Last Name	First Name	Last Name	First Name
Aguinaldo	Sheila	Gentry	Kristopher	Mathews	Geoffrey
Ah Loy	Darleen	Gibbs	Francina	Maune	Kay
Anger	Robert	Gresham	Mike	McCreight	David
Bangerter	Bob	Guenther	Kirsten	McLaren	Robert
Bernardo	Kristin	Hallett	Illegible	Meola	Gary
Bobbio	Kate	Hamai	Jean	Moessner	Debra
Bourque	Monique	Heafey	Derek	Mooney	Wendy
Brandenburg	Donald	Heasley	James	Morales	Desiree
Cameron	Ashley	Hofmann	Andrea	Morales	Nancy
Cameron	Jyl	Hogan	Lauren	Munger	Kelly
Carrajal	Christina	Illegible	Willie	Nagasaki	D.
Ceravolo	Debra	Illegible	William	Nassir	Michael
Ceravolo	Peter	Illegible	James	Nathan	Melidee
Conrad	Cynthia	Illegible		Nitta	Gary
Cost	Curtis	Illegible	Stephen	Orwig	Darrell
Cost	Elliott	Inskie	Karen	Perreira	Warren
Currell	Illegible	Janoski	Darlene	Pope	Julian
Currell	Pat	Javier	Paul	Popkipala	Jean
DeAngelis	Pierpaolo	Jedicke	Robert	Putris	Xander
Devey	Graham	Jennings	Karen	Quimby	Larry
Domsitz	Nikki	Jennings	R. Virginia	Rafaman	Chester
Doran	James	Kadooka	Mary Ann	Reeve	Clara
Doyle	Linda	Kamibayashi	Jacob	Resta	Piero
Dunn	Sara	Kanen	Randi	Rogers	Colin
Durish	Gary	Kasprzycki	Jan	Sanchez	Johna
Elkins	Robert	Kikuyama	Ben	Sattler	Kay
Erickson	Becky	King	Dorian	Smith	Ron
Filler	Tim	Kolahi	Bobby	Souza	Lisa
Findley	Malcolm	Kornreich	Steven	Talbot	Kristina
Flanders	Carmen	Land	Larry	Talbot	Thomas
Fleming	Shaun	Lite	Gary	Wagstaff	Winnie
Foreman	Craig	Lombardi	Henry	White	Dennis
Frost	Karen	Long	William	Young III	Louis
Fujuhara	Gary	Makaena	Felisha		
Garcia	Megan	Marie	Lynnie		
Gaxion	Cesar	Martinez	Sal		

Appendix B Kilakila O Haleakalā Petition

Table B- 1 Petition Supporting "No Action" Alternative

Last Name	First Name	Last Name	First Name	Last Name	First Name
`Aikala	Manaloa	Auhoon	Gardenia	Calvan	Roger
`Akahi	Pomaikai	Auwae	Makamae	Cantor	Anna
Abraham	Susan	Avieiro	Scott	Capertina	Hulu/Theodore
Ackermann	Dieter	Bailey	John	Cappadocia	Ragita
Acopan	Janice	Baker	Amy	Carbonni	Christopher
Adkins	Allen	Bal	Brandon	Carrion	Kili`ohu
Adkins	Reiko	Bassil	Galal	Carter	Jamie "Kamiki"
Agcaoili	Regina	Bayly	Katy	Casayuran	Jesse
Aiwohi	Ka`apuni	Beck	Karen	Cashman	Ed
Aiwohi	Maile	Bell-Cockett	Palika	Castro	Chaz
Aiwohi	Pi`imauna	Belmonte	Jake	Chambers	Nancy
Aiwohi-Kolt	Hi`ilei	Benavides	Burke	Chappell	Graham
Akita-Kealiha	Thelma	Benavides	Carlotta	Char	Corey
Akiu	Renee	Benavides	Roxane	Chargualaf	Christen
Alexander	Elena	Biga	Jaydina	Chin	Loretta
Alo-Palau	Myrlynette	Bissen	Isabella	Chong Kee	Kenneth
Altinbay	Tan	Boller	James	Chong Kee	Rhoda
Amakawa	Mayumi	Bolos	Laurie	Chow	Nara
Amaral	Debbi	Bolos	Robin	Chun-Gilliland	Chalice
Ambrose	Kristlyn	Bonillon	Cheryl	Clark	April
Anakalea	Clyde	Brada	Garett	Cohen	Joanne
Anseth	Andrew	Bras	R. Kalei	Collier	Kiai
Anthony	Iliahi	Brault	Sachiko	Collins	Lance
Anzai	Harriette	Brown	Debbie	Cornelio	Jeffrey
Apo	Alexander	Buetzer	Hans	Cravalho	Carmelita
Apo	Kelsey	Bush	Alana	Crow	Diana
Aquino	Princess Lehuanani	Bush	Nana	Cusi	Karen
Arakaki	Jaye	Bush	Roger	Czok	Jutta
Armitage	Malia	Bustamente	Keahi	Davidson	Malia
Armstrong	Elisabeth	Butterman	Ansgar	Davis	Jonathan
Armstrong	Sue	Butterman	Ieka	De Journette	Marie
Asis	Joe	Cabrera	Ryan	DeFries	Heather
Astrella	Rachael	Cadiz	Corinna	DeFries	Jacob
Atay	Daniela	Cagasan	Ed	Dela Cruz	Joelyn
Atay	Don	Calabrese	Margo	Dela Cruz	Michal
Athearn	Jamie	Calandrella	Leanne	Dela Cruz	Moi Maikai

Last Name	First Name	Last Name	First Name	Last Name	First Name
Dela Cruz	Robert	Faye	Hoku	Harima	Keiko
Delapinia	Thomas	Fazio	Tara	Harrowby	Cailtin
Delos Santos	Lesley	Feiteira	Jessie	Hartman	Robert
DeMello	Bessie	Feliciano	Joella	Haus	Dorothee
DeMello	Melany	Fenzl	Ronnie	Haus	Werner
deNaie	Lucienne	Ferreira	Chad	Hawkins	Anna
DeShayne	Nece	Figuracion	Dimpag	Heffman	Jennifer
DeStephano	Clara	Filimoe`atu	Kehaulani	Helm	Kandy
Dias	Pohai	Flores	Ariana	Helm	Rusty
Diego	Maile	Fratantonio	Robert	Helm	Violet
Drake	Lee	Fujimoto	Karen	Helm	Wilfred
Dukelow	Jamie	Fujiyama	Michelle	Henderson	Jason
Dukelow	John	Furukawa	Colleen	Hewahewa	Kepa
Dukelow	Kapualokeokuuleinani	Gacek	Claudia	Higa	Mike
Dumangeng	Percival	Gaddis	Summer	Higa	Rhys
Duquette	Jason	Gangini	Carla	Higgins	Roberta
Duranleau	Nicole	Garalde	Brian	Hill	Richard
Dye	Rachael	Garnet	Tom	Hinaga	Garrick
Eaton	Cleighton	Garrison	Charles	Hinau	Curtis
Eaton	June	Gilliland	Puanani	Ho	Holiann
Eaton	Kalena	Godinez	Marcia	Ho	Kaipo
Eaton	Kaua	Goebel	Michael	Ho	Renfred
Eaton	Keomailani	Goldberg	Tasha	Ho`pai	Kapono
Edlao	Gail	Gonzales	Rosa	Hoe	Kawaiolima
Edlao	Heather	Gormley	Kapa`ia	Hoisington	Wendy
Elliott	Bill	Gottlieb	Brookelin	Hokoana	Queenie
Ellis	Leilani	Goudreau	Vincent	Holi	Puanani
Emata	Gerilyn	Goya	Ernesto	Hong	Leah
Emata	Grace	Greenleaf	Masta	Hong	Leinani
Ennehoser	Carolin	Gusman	Brenda	Hooks	Ash
Enos	Vicky	Haake	Kekuulani	Hu`eu	Jonah
Esotov-Chang	Maria	Habbwitz	Jeanette	Hubin	Sheila
Evangelista	Danny	Hagerty	Patrick	Huerter	Carissa
Evangelista	Ernesto	Halbitter	Ute	Hueter	Samantha
Evangelista	Justina	Haleakala	Jaevin	Hueu	Sunnie
Evangelista	Teri	Hamoru	Charlotte	Hunt	Corinne
Evanson	Mary	Hara	Kuninori	Iao	Maydeen
Ewaliko	Catalina	Hara	Maui	Ichiki	Vivian
Farin	Lokalia	Hara	Mitsuko	Ige	Stan

Last Name	First Name	Last Name	First Name	Last Name	First Name
Illegible	D. Ann	Kaiwi	Jasmyn	Kenolio	Punahele
Illegible	Mathew	Kalua	Manaiakalani	Kepano	Doreen
Illegible	Jared	Kama	Jeremiah	Khalafalla	Ryoko
Inacker	Dr. Matthias	Kamakana	Liane	Kiakona	Pa`ele
Inouye	Nichole	Kamakana	Veronica	Kimokeo	Aliiloa
Irwin	Julie	Kamalii	Jeremiah	Kimokeo	Puawehiwa
Ishii	Richard	Kamalii	Robert	Kimokeo	Sommer
Ishikawa	Noelle	Kana	Charlene	Kincaid	Kaipo
Ishikawa	Trina	Kanekoa	Kamalani	Kneubuhl	Robyn
Ishikawa	Wayne	Kanekoa	Noelani	Koki	Claire
Jamgochian	Jamie "Kamiki"	Kaniaupio-Crozier	Jeriann	Kolt	Gaylord
Jamgochian	Mark	Kaniaupio-Crozier	Kaleialoha	Kong	Leinoa
Jarvier-Grodan	Anna	Kaniho	Natassja	Kuaana	Danielle
Javier	Nic	Kaniho	Tiffany	Kuailani	Steven Kapena
Jennifer	Adamson	Kantarova	Pamela	Kuali`i	Kipukai
Jensen	Jennifer	Kapaku	Kenda	Kuamo`o	Pi`imaana
Jeremiah	Debra Pua	Kapaku-Kahu	David	Kukea-Shultz	Jonathan
Johnson	Daryl	Kapu	Rochelle	Kupahu	Kahiwaonalani
Johnson	Faryn Kalei	Kare	Britta	Kusunoki	Mea
Johnson	Ginger	Kasai	Katsuharu	Kutsutani	Michelle
Johnson	Kaylee	Kato	Mr. and Mrs. Gary	Lani	Pasha
Johnson	Kiana	Katsutani	Michelle	Larin	Cherrie Ann
Johnson	Melia	Kaufmann	Merrill	Laymon	Lynn
Johnson	Tanya	Kauhane	Keith	Leahy	Chris
Jones	Sarah	Kauhane	Patti	Lee	Carol-Marie
Joy	Lawakua	Kawa`a	Kamalani	Lee	J. K. L.
Kahakauwila	Aulii	Kawa`a	Luana	Lee	Jovel
Kahula	Patience	Kawachi	Kurt	Lee	Ka`uhano
Kahalehau	Kaha	Kealoha	Daniel	Lee	Kimoku
Kaho`ohalahala	Haaheo	Keany	Mary	Lee	Noelani
Kaho`ohalahala	Lynn	Kehahuna	Lono	Lees	Laura
Kaho`ohalahala	Pualani	Kekahuna	Ashley	Lemmo	Roni
Kaho`ohalahala	Sol	Kekahuna	Erika-Lei	Leong	Debra
Kaho`ohanohano	Iris	Kekahuna	Haokeakumehokealani	Levin	Penny
Kaho`ohanohano	Suzette	Kekahuna	Ilikea	Lewis	Ashley
Kaholokua	William	Kekahuna	N. Lonohiwa	Lewis	Lori
Kahula	Illegible	Kekahuna	S. Kamaile	Librando-Souza	Kalani
Kaikala	Pohai	Kekoolani	Tine	Life	Kaiuipuni
Kaina	Orpha	Keller	Karen	Lincoln	Jody

Last Name	First Name	Last Name	First Name	Last Name	First Name
Lincoln	Travis	Mederiros	Kanoelani	Nakoa	Peter
Llego	Shannon	Mederiros	Reina	Namau`u	Daunserly
Lockard	Jordan	Mercier	Deanne	Needham	Kimo
Logotala, Jr.	Faalata	Meyer	Stacy	Newlight	Nadine
Lorenzana	Ashley	Michaels	Lesley	Nickens	Ivy
Lovell	Robert	Michaelson	Paul	Nikaido	Mark
Lu`uwai	Leona	Michimoto	Glenn	Nishida-Magaoay	Crystal
Lucas	Richard	Michimoto	Ryan	Nishikawa	Lois
Lussich-Pretre	Nohea	Michimoto	Sandra	Noneza	Carmela
Lyman	Kahala	Miftahittin	Shariff	O`Rourke	Ann
Macik	Tyndale Mathew	Miguel	Edward	Oana	Rosean
Maeda	Doris	Miguel	Laura Ann	Offerman	Robert
Maeda	Richard	Miguel	Lori Michelle	Offerman	Susan
Maio	Bernadine	Miguel	Shari	Okamura	Gain
Maldonado-Morgan	Justine	Mikell	Bob	Okimoto	Andrew
Manloue	Christina	Miles	Sara	Oliveros	Geraldine
Manoa	Brittney	Minker-Scorzelli	Margaret	Oliveros	Lisa Ann
Manuel	William	Mitnick	Robert	Oliveros	Pedro
Marchetti	Kathy	Miyagawa	Doreen	Orikasa	Yoshimichi
Marks	Mayumi	Mjehovich	Carol	Orikasa	Yukie
Marks	Richard	Moleta	Chazz	Ornellas	Barbara
Marmack	Tim	Molina	Jordan	Ornellas	Uluwehi
Marple	Puanani	Molitau	Kapono`ai	Osterteus	Hoku
Marrotte	Karla	Moniz	Jaymie	Otsu	Clara
Martin	Martha E.	Montalvo	Yvette	Paahana-Lake	Shirley
Martin	Joan	Montira	Gary	Pacheco, Sr.	Stanley James
Martin	Makana	Morrison	Pua	Pagaduan	Michelle
Martinson	Lawrence	Muecher	Miriam	Page	Charles
Matsumoto	Amy	Murata	Akiyo	Paladin	Ginger
McBride	Dolores	Muromoto	Liane	Pali	Pikake
McCarty	Vicki	Nae`ole	Joshua	Palmeira	Chris
McDuff	Kathleen	Naeole	Danileigh Kahealani	Pamat	Mark
McKeown	Thomas	Nahoopii	Michael	Pang	Chadwick
McLean	Glenn	Nakagawa	Layne	Papaia	Elizabeth
McLean	Iliahi	Nakagawa	Melissa	Pardillo	Jobelle
McLean	Luke	Nakamoto	Ian	Parker	Alvin
McLinden	Michelle	Nakamura	Rachel	Parker	Lapree Pua`olena
Medeiros	Art	Nakamura	Wilma	Parker	Scott
Mederiros	Ashley	Nakoa	Noelani	Pasco	Ke`ala

Last Name	First Name	Last Name	First Name	Last Name	First Name
Pascual	Cyrila	Ritte-Camara	Starr	Slate	Isaiah
Patrick	Katherine	Rivera	Isabelle	Smith	Deborha
Paul	Anne	Robinson	Curtis	Sneed	Margaret
Peck	Shannon	Robinson	Kelly	Soriano	Cody
Perny	Deandra	Rogers	Sandra	Sousa	Keoki
Perrerira	Hulali	Romanchak	Abigail	Souza	Jonah
Peterson	Leah	Romanchak	Ethan	Souza	Kennethy
Pittman	Lea	Romanchak	Wendy	Souza	Michael
Pitzer	Frances	Roush	Stephen	Speed	Lihinoe
Plunkett	Kona	Rozel	Kia`aina	Stice	Brianna
Plunkett	Leilani	Ruhnau	Hanne	Stokesberry	Mele
Ponce	Cecelia	Rust-Sipili	Toni	Straatmann	Maria
Ponce	Maile	Ryan	Kaina	Subega	Mikiala
Porter	Nicholas	Ryder	Frank	Subiono	Anna
Potler-Dunpop	Julie	Ryder	Miriam	Suda	Ronnelle
Pratt	Abigail	Saffery	Maya	Summers	Ka`ohu
Prest	Ikaika	Sagadraca	Kahiaikapili	Suzuki	Shawn
Puaa-Freitas	Kaulana	Saiki	Molly	Sylva	Cheyenne
Pule	Thomas	Saito	Robert	Taasan	Koanani
Purdy	Kaimana	Sakamoto-Ribao	Courtnee	Tabisola	Allen
Purugganan	Frank	Salzer	Paul	Tabosa	Laycie Ann
Purugganan	Leone	Sandi	Sasha	Tachera	Cherilyn
Pyle	Laura	Savaki-Kashiwa	Dawn	Tada	Robert
Quenga	`Ulili	Scattergood	Hakem	Tagalan	Monica Ku`uliekaimana
Quinto	Hannah	Schaff	R. Lavender	Takahashi	Kazihisa
Raisbeck	Sarah	Schamber	Dean	Takamoto	Courtney
Ralan	Derrick	Scott	Linda	Talon	Konrad
Ramos	Glenda	Sebstad	Jeanene	Tanida	Aki
Randall	Brent	Seelbach	Tanda	Taua	Hokuloa
Range	Kealoha	Shaffer	Tracy	Taua	Rainee
Ranney	Keith	Sheppard	Earl	Tavares	Helen
Rano	Illegible	Shibano	Linda	Taylor	Miki`ala
Raymond	Kala	Shigematsu	Kikue	Teves	Pilialoha
Reader	Carla	Shim	Ramiah	Thoma	Marie
Redwell	Ronald	Silva	Jeffrey	Thomas	Kimberly
Reeser	Donald	Simon	Andie	Tihada	Kahikina
Reid	Joy	Skaff	Joshua	Tinsley	Jazmin
Riga	Lanakila	Skowronski	Francis	Toll	Rachel

Last Name	First Name	Last Name	First Name	Last Name	First Name
Tome	Louise	Villiers	Sara	Wong	Justine-Marie
Tsutsui	Ayako	Wailani Farm		Wong	Kalani
Turrieta	Gregory	Wainui	Taiva	Wong	Mathew Kainoa
Urquijo	Eva	Walden	Linda	Wood	Debra-Jean
Uyehara-Keliikea	Ha`aheo	Walin	Janice	Wood	Paul
Valle	Cassie	Wallace	Jodi	Woolsey	Hope
Vallente	Coral	Watson	Jesse	Wright	Chelsea
Van Ambrugh	Todd	Welker	Briana	Wright	Leipualokelani
Van Buren	Chelsie Ann	Wicklund	Cheryl	Wright	Palani
VanHoose	Don	Wikker	Susan	Wyroster	Evy
Vargas	Daniel	Wilder	Kathryn	Yamamura	Cheryl
Varholak-Madani	Laurie	Williams	Elizabeth	Yasalk	Kuakea
Ventura	Daphne	Williams	Ronald	Yonemura	Lloyd
Verbena	Melissa	Williams	Steven Kapena	Yonemura	Satoshi
Verzoga	Paulino	Wilson	Dee	Yoshida	Rosalie
Viernes	Darlene	Wilson	Janelle	Yoshioka	Melissa
Viernes	Kayla	Wilson	John	Zane	Kuhao
Villa	Alex	Wilson	Sabrina	Zimmer	Ute
Villanueva	Mililani	Wittler	Rosario	Zwick	Kathie
Villanueva, Jr.	Catalino	Wong	Donovan		

Table B- 2. Petition Supporting "No Action" Alternative with Request to Become a Consulting Party.

Last Name	First Name	Last Name	First Name	Last Name	First Name
Agalerai	Melinda	Gibson	Lehua	Morando	Po`ouiokaohuaino "Ohua"
Ahue	Cliff Pali	Heintz	Heather	Murray	Heather Ku`ulei Makamae
Ampong	Paulette "Leihua"	Helm	Mikahala	Oliveira	Katrina
Bailey	Gordean	Hokoana	Lui	Orme	Maile
Baker	Chris	Ishikawa	Lei	Pulama-Collier	Wanda S.
Barnard Ki`inani o Kalani	Christy	Ka`auwai	Kristen	Rabold	Jeanne
Bass	Ron	Kailihou	Clara-Leen	Rasmussen	Lena
Benz	Kylie	Kaina	DeAnn	Ryder	Leiohu
Biga	Jordan	Kanoa	Beverly-Ann	Sampson	Rina
Boteilho	Rose	Kaohu	Kathy	Souza	Eula
Bulawan	Mary Frances M.	Karratti	Margaret	Subiono	David Kea
Bulawan, Sr.	Bernard	Kerr	Cheryl	Thongtrakul	Leimomi
Callo	Kiana	Kneubuhl	Alesa, Buzzy, and Robyn	Thyne	Jacquelynn
Chock	April	Lee	Gordon	Tsuha	JoAnna, Kawaiokeolalani, and Mark
Delapinia	Kaulana	Makanani	Attwood M.	Whittle-Wagner	Jamie Moanikeala
Edwards	Dylan	Miller	Ane	Wong	Annette
Escobar, Jr.	Sharon and Fausto	Miller	Chuck and Terry	Wong	Kerry
Gerard	Sheila	Mirkovich	Sincerity	Wong	Newton and Jodean

Appendix C E-Mail and Letter Responses to Current Study Mail-Out Inquiries

Colleen Dagan

From: Brian Jenkins [lawmaui@maui.net]
Sent: Thursday, March 08, 2007 4:03 PM
To: cdagan@culturalsurveys.com
Subject: SPAM-LOW: Supp. Cultural Impact Assessment for Proposed ATST at Haleakala High Altitude Observatory Site

Dear Ms. Dagan:

Thank you for your letter dated February 13, 2007.

The concerns regarding the large ATST facility at the Haleakala High Altitude Site relate to two separate impacts: 1) visual and 2) the impact on access to the upper Skyline Trail trailhead.

As someone who was born and raised here on Maui and whose father and grandfather lived on Maui, I am familiar with many of the local traditions concerning the summit area. Since I was a child, I have hiked and hunted in this area (by which I mean the entire area around the proposed site) and know and count as friends many others who have hiked and hunted in this area. These traditions are hunting and hiking and just finding a quiet, pure, pristine place in the wilderness to be alone with one's thoughts. One of the favorite hunting areas is the former Kahikinui Forest Reserve which is now partially managed by the Kahikinui Game and Land Management Ohana with permission from Hawaiian Homes. The appeal of this area is its pristine wilderness character. Being there is a chance to see the upper native forest in a mostly intact condition. While some of the existing observatories are visible from the upper Kahikinui area, they are nothing compared to the proposed 14 story gleaming white colossus that is planned in connection with the ATST. The visual blight that is sought to be built will have a tremendous negative impact on that sense of wilderness that is currently enjoyed. This negative visual impact will also affect much of the Skyline Trail and views from the Upper Waiohuli Trail in the Kula Forest Reserve.

The second major concern is the impact of the increased development at the high altitude site. As the high altitude site becomes more developed with facilities that may have national security or advanced scientific applications, there will be a tendency by the operating managers to want to keep the public as far away from the facilities as possible. Currently, there is already a sign at the newly constructed green cattleguard that is located at the beginning of the road that provides the sole access to the upper Skyline Trail trailhead that warns people that they will be prosecuted if they travel on the road. While is sign is widely ignored and there have been no known arrests or prosecutions, there is good reason to believe that there will be a push for increased security during and subsequent to the construction of the proposed ATST. Access to the Skyline Trail is a cultural tradition and one of the favorite hiking and hunting areas of local people. Many times, it would be coordinated so that a hunter or hiker would be dropped off at the upper trailhead and he or she would be met by family or friends at the lower of the two gates on Skyline Trail after a day of slowly walking down from the top. Due to the high elevation, steep terrain and loose cinder conditions, it is a difficult hike to access the upper areas from the lower gate. If access were lost to the Upper trailhead, many local hunters and hikers (especially older ones) would effectively be barred from a favorite area. The game in this upper area are game birds such as

1

Chucker and Pheasant as well as goats and pigs. The purpose of hunting in this area is sustenance and feathers. Feathers, especially pheasant feathers, are prized for the making of hat bands.

Thank you for the opportunity to provide input to your Cultural Survey.

Brian R. Jenkins, President
Friends of Polipoli
P.O. Box 431
Wailuku, Hawaii 96793

Page 1 of 2

Colleen Dagan

From: Alan Kaufman, DVM, R(B), ABR, CRS, GRI [kaufman@maui.net]
Sent: Tuesday, March 13, 2007 5:32 PM
To: 'Colleen Dagan'
Subject: SPAM-LOW: RE:

Colleen,
I am sending your request to the KCA Board for members to respond as individuals.

My individual response:
"I have used the mountain for recreation. My older children have joined me on overnights in the crater. I take visiting guests to the summit two or fewer times per year. My youngest son is part Hawaiian and I take him to the ahu at the summit so as he grows he will have memories that give him a sense of place and belonging.

Regards,
Alan

Alan Kaufman, DVM
Realtor(B), ABR, CRS, GRI

University of Hawaiʻi
MAUI COMMUNITY COLLEGE
MĀHELE HAWAIʻI - HAWAIIAN STUDIES

30 March 2007

Ms. Colleen Dagan

Archeologist-Cultural Surveys Hawaiʻi, Inc.

16 S. Market Street, Suite 2N

Wailuku, HI 96793

Mahalo for the opportunity to provide input for the Supplemental Cultural Impact Assessment for the Proposed Advanced Technology Solar Telescope (ATST) at the Haleakalā High Altitude Observatory Site, Papaʻanui Ahupuaʻa, Makawao District, Island of Maui, TMK (2) 2-2-007: por. 008

The Hawaiian Studies Department at Maui Community College is opposed to the proposed ATST because it would be a desecration of Haleakalā on Maui, one of the most sacred and spiritual places of Hawaiʻi. The approximately 14-story tall ATST structure would have a negative impact through the disturbance, alteration and removal of sacred natural resources (i.e. soil, rocks) and possible cultural artifacts. A significant cumulative consequence of the proposed development would be the adverse and devastating visual effect caused by the addition of this intrusive and culturally inappropriate structure.

Me ka mahalo,

Kīope Raymond

Chair, Hawaiian Studies

310 Kaʻahumanu Avenue, Kahului, HI 96732
Telephone: (808) 984-3370, Facsimile: (808) 244-3228, http://mauicc.hawaii.edu
An Equal Opportunity/Affirmative Action Institution

30 March 2007

Ms. Colleen Dagan
Archeologist-Cultural Surveys Hawaiʻi
16 S. Market St., Suite 2N
Wailuku, HI 96793

Aloha Colleen,

I would like to have the following inserted into the Supplemental Cultural Impact Assessment for the proposed Advanced Technology Solar Telescope.

The entry sign to Kolekole (see page 59 of E Mālama Mau Ka Laʻa) has engraved, in Hawaiian, the words:

"I na ʻōiwi Hawaiʻi aloha ʻāina
E kipa mai!"

As one who can translate Hawaiian, I understand the inscription to literally invite land-loving native Hawaiians to visit. However, I believe the intent is to allow any Hawaiian who wishes to access the shrines - to pay respects to ancestors or engage in religious practices - to do so.

Unfortunately, without the English translation to the words, any Hawaiian who might wish to access the two shrines - but could not translate the Hawaiian language to English - would not know they were being welcomed to access the altars. There is ample evidence to show that the vast majority of Hawaiians cannot read the Hawaiian language. They are being unnecessarily kept from entry. I base this on the fact that the signs above and below the one in Hawaiian address authorized entry only and the prohibition of recreational activities. What is a Hawaiian who cannot translate Hawaiian to think? They would think - I should not enter - of course!

An English translation must be provided on the entry sign so that Hawaiians know - in both Hawaiian and English - that they can enter. They are welcomed to enter. It is wrong to proceed on deliberations of the impact on cultural practices, or come to any conclusions regarding current usage of the Kolekole area as a spiritual and/or Hawaiian religious site for the 21st century without providing the Hawaiian and non-Hawaiian public full disclosure about who can access; and for what purposes.

Mahalo,

Kīʻope Raymond
740 Copp Road
Kula, HI 96790

30 March 2007

Ms. Colleen Dagan
Archeologist - Cultural Surveys Hawaii, Inc.
16 S. Market St. Suite 2N
Wailuku, HI 96793

Alohs Colleen,

The following quotes are from four students in the Spring 2007 Hawaiian Studies 262 course. Please include them in the Supplemental Cultural Impact Statement being prepared for the proposed Advanced Technology Solar Telescope.

"I was born and raised on the island of Maui and I have Hawaiian ancestry from Kahakuloa. I currently attend Maui Community College, and hope to pursue a career in science focused on environmental conservation. I oppose the proposed ATST because of the negative cultural and environmental impact it will have on Maui. Haleakala has been a spiritual summit for Hawaiians for over a thousand years. Stories, songs, and traditions of origins from long ago show how deep the spiritual roots of Maui's native people go in reverence for Haleakala. To build a 14-story tall building at the peak of Maui will send a clear message to our community that astronomical scientists have a willful disregard for Hawaiian culture and the values of our community. There are also environmental consequences to this project. The only sea bird to be on the endangered species list, Pterodroma phaeopygia depends on Haleakala's landscape for its delicate burrows, which may be adversely impacted by the heavy earth shattering construction of the ATST. Is this project worth the destruction of a species, to me it is not. Scientists claim this project will help to better understand the sun, I am not against good science, but I don't think good science should threaten a species and offend the host culture. To me, that is not good science. I ask that you choose to avoid Haleakala as the site for your telescope, please do not choose a site that is sacred to native people. By disregarding native sovereignty, you are compelling ever-changing forms of colonialism."

Cheynne Sylva
"I am a Hawaiian student currently enrolled at M.C.C. and I oppose the proposed ATST. The Hawaiian people have suffered more then it seems like you folks know. If you understood the Hawaiian people and our history, you would know that asking to build a four-teen story building on one our sacred mountain, is extremely insulting. These scientists only care about their work, not about this land and its people's culture. Haleakala caters to tourist every single day. People ride through there with their cars, bicycles, and horses with no understanding of what type of place there are at. Our mountain is not an amusement park for the tourist like the rest of lands. It is a sacred place for everybody and you have no right to do this. This is another selfish act the Hawaiian people have to fight again. Foreigners have come here and built their ugly buildings on our beautiful land with no thought of how they could have built buildings that would of flowed with the natural surroundings and now you folks want to build the ugliest of them all on top of our mountain! Who do you think you are? Go back to your home and go to your church, cemetery or whatever is a sacred area to your family and build you telescope there! Too bad for you guys that Hawaii is in the prime area for this project, we as the people of this land and we say NO! NO WE DON'T WANT IT! So try to understand our words! Because we speak on be-half our kupuna and our children."

Walter Kozik
"How many more times do the indigenous peoples of the world have to face the hungry eye of Science and watch, powerless, as it's great mouth devours those places and beliefs that make up the identity of the people themselves? And all of this in the name of increasing knowledge. Unfortunately and perhaps most ironically, Science fails to include the ancient and tested knowledge that lay within the indigenous viewpoint. For all of its equivocal non-bias, the empirical slant of Science is painfully obvious. Seeking a unified theory of all, Science misses the point completely. To the indigenous person it is clear that this mandate to conquer the Universe with our own technology and to own all knowledge is wholly imparted to the Scientist by means of Western Culture itself. The Westerner is given the mandate to conquer by the Bible itself. All beings and the Earth in its entirety are subject to the dominion of Mankind. Therefore, all things of the Earth are destined to be in the control of (the Western) Man. This Manifest Destiny has led to the annihilation or assimilation of countless Indigenous Cultures, all of who were seen as "primitive" and "ignorant". This tragedy has not ceased. Today, with no land left undiscovered, the new terrain of choice for colonization is our minds themselves. Science and the Westerner would have us chain all of our thoughts to their perspective while denying our heritage and culture. This Conditioning, this remaking of the World to fit the Dominant Paradigm View is *the* disease of the Westerner. Perhaps, before all alternative views are lost and all societies become homogenous, some Scientist somewhere will "realize" the scientific value of indigenous beliefs. Until then, we who are outside of the technocracy can only hope and continue to pray in the manner that our ancestors have kept for us."

Kathleen Zwick
"I am currently a student at Maui Community College and a resident of Hawaii. Although I am not a native Hawaiian, I can se that the ATST will have considerable impact on the people here. One does not need to be a native Hawaiian to see and feel the impact that this telescope will have. The biological impact will be horrendous. Hawaii is the one place on the planet with the most endangered species. Because of the remote location of the islands, there are species found here that are not found anywhere else. Hawaii has the dubious honour of being the endangered species capital of the world. Hawaii has only 0.2 percent of the landmass of the United States, but 75 percent of the country's plant and bird extinctions are of Hawaiian species. According to your survey, Appendix E, Botanical Survey 2005, "*Areas of both sites where construction has occurred generally show signs of disturbance by heavy machinery, support fewer native species, and contain more weeds.*" Certainly, as scientists, you must see the potential devastating environmental impact that this could have on all of our futures. October 1, 2006, as reported in the Maui News: "Haleakala *National Park Superintendent Marilyn Parris said the park opposes a proposed solar telescope on the sensitive Haleakala summit and called a draft environmental impact statement on the project inadequate.*"
Within your own statement, Haleakala was the only site that is a sacred site, and yet it was chosen to be the recipient of the ATST. By placing this telescope on the sacred site, you are turning a blind eye to both the culture and voice of the people of Hawaii, as will as condemning endangered species to an untimely death. According to your own records, the expected lifetime of the ATST will be 30 – 40 years. The expected lifetime of the changes to the landscape and the cultural aspects of Haleakala will be forever. Within your records, you state, "… no single site may exist that provides all of the desired characteristics… trade offs will be performed within the site selection process and will be based on science priorities and feasibilities considerations." It appears to me that you have chosen the worst possible site for the ATST. You have chosen the site that will have the most devastating impact on both the environment of the land and the cultural of the Hawaiian People. What we do to one, we do to all. The world has become a global village, and the impact to Haleakala will, in time, impact the world. I am imploring you to rethink the ATST site. Why continue with the one site that will have the most devastating impact on our future world?"

Mahalo,

Kiope Raymond

Page 1 of 3

Colleen Dagan

From: Hinano.R.Rodrigues@hawaii.gov
Sent: Thursday, March 22, 2007 11:33 AM
To: Colleen Dagan
Subject: RE: Supplemental Cultural Impact Assessment (SCIA) for the proposed ATST

Aloha e Colleen:

Thank you for the opportunity to comment on this project.

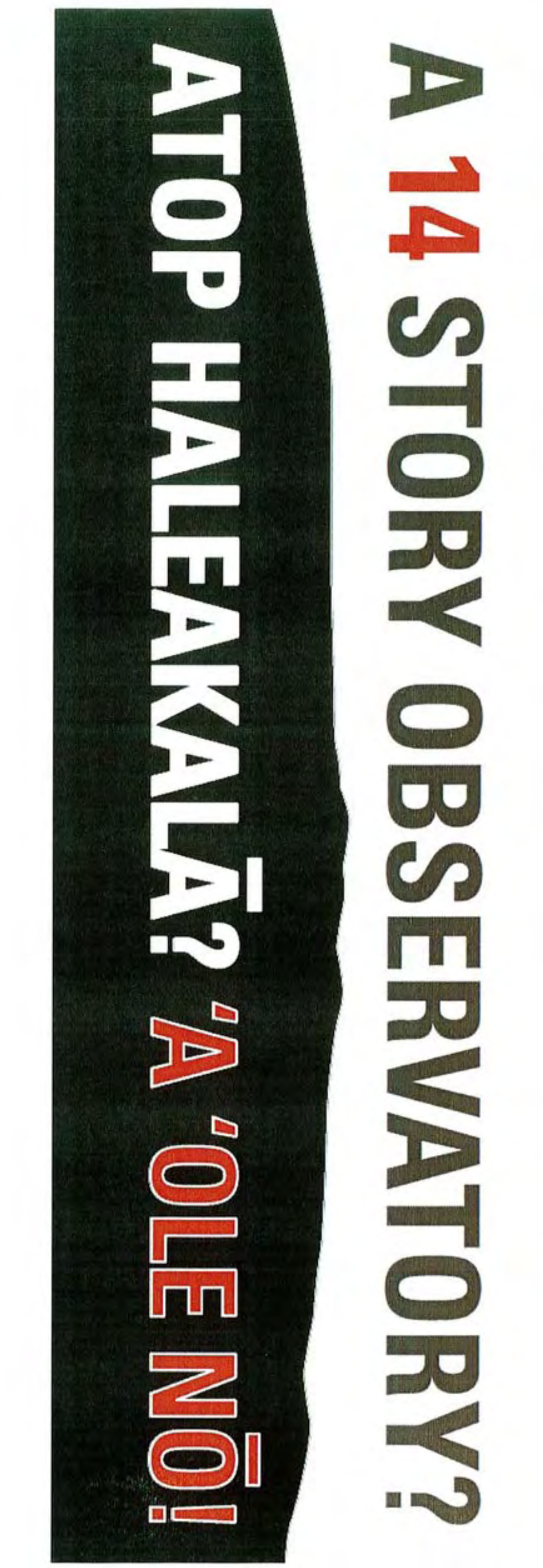
While most will view the existence of cultural and archaeological features at a specific site as an indication of cultural importance, nothing can be further from the truth. Rather, sometimes the absence of any tangible cultural and archaeological feature is a manifestation of the importance and sacredness of the area. Haleakala is one of those areas.

Cultural and religiously speaking, places of high elevation and isolation have always been considered as wao akua, forests or place of the gods. Obviously Haleakala is a wao akua. That is the reason why you can only find a limited number of cultural or archaeological features. The very presence of any man-made structure takes away this sacredness. Especially a structure so pronounced as the ATST.

Granted, there already exists man-made structures at the site today. And some may argue that another structure may make only a small difference. I believe there is correlation between quantity and quality. In other words, another structure will, by quantification, affect the quality of the sacredness. Haleakala must be kept sacred by restricting the development of the crater area. To many Kanaka Maoli, the very unobstructed view of the mauna itself, is a part of their daily religious observations. To allow any more construction at the crater site is tantamount to allowing a modern office building on the site of Iolani Palace.

Hope this is clear and helps in your SCIA.

Hinano Rodrigues
Cultural Historian
DLNR-State Historic Preservation Division-Maui
(808) 243-4640
(808) 243-5838 (fax)


A 14 STORY OBSERVATORY?
ATOP HALEAKALĀ? 'A 'OLE NŌ!

<u>APPENDIX G</u>

GEOLOGICAL REPORT

Geological Setting at Primary and Alternative Advanced Technology Solar Telescope (ATST) Sites, Haleakalā High Altitude Observatories

by Ron Terry, Ph.D., Geometrician Associates
November 2005
Prepared for KC Environmental, Inc.

This report is in response to a request from KC Environmental, Inc. to review the geological setting at the ATST primary and alternative sites (east side of Mees Observatory and Reber Circle, respectively) at the Haleakalā High Altitude Observatories (HO), on Kolekole Cinder Cone in Maui. My evaluation is based on primary and secondary information presented in the Environmental Impact Statement Notice of Preparation for the ATST, additional published sources, and one day of fieldwork on the site.

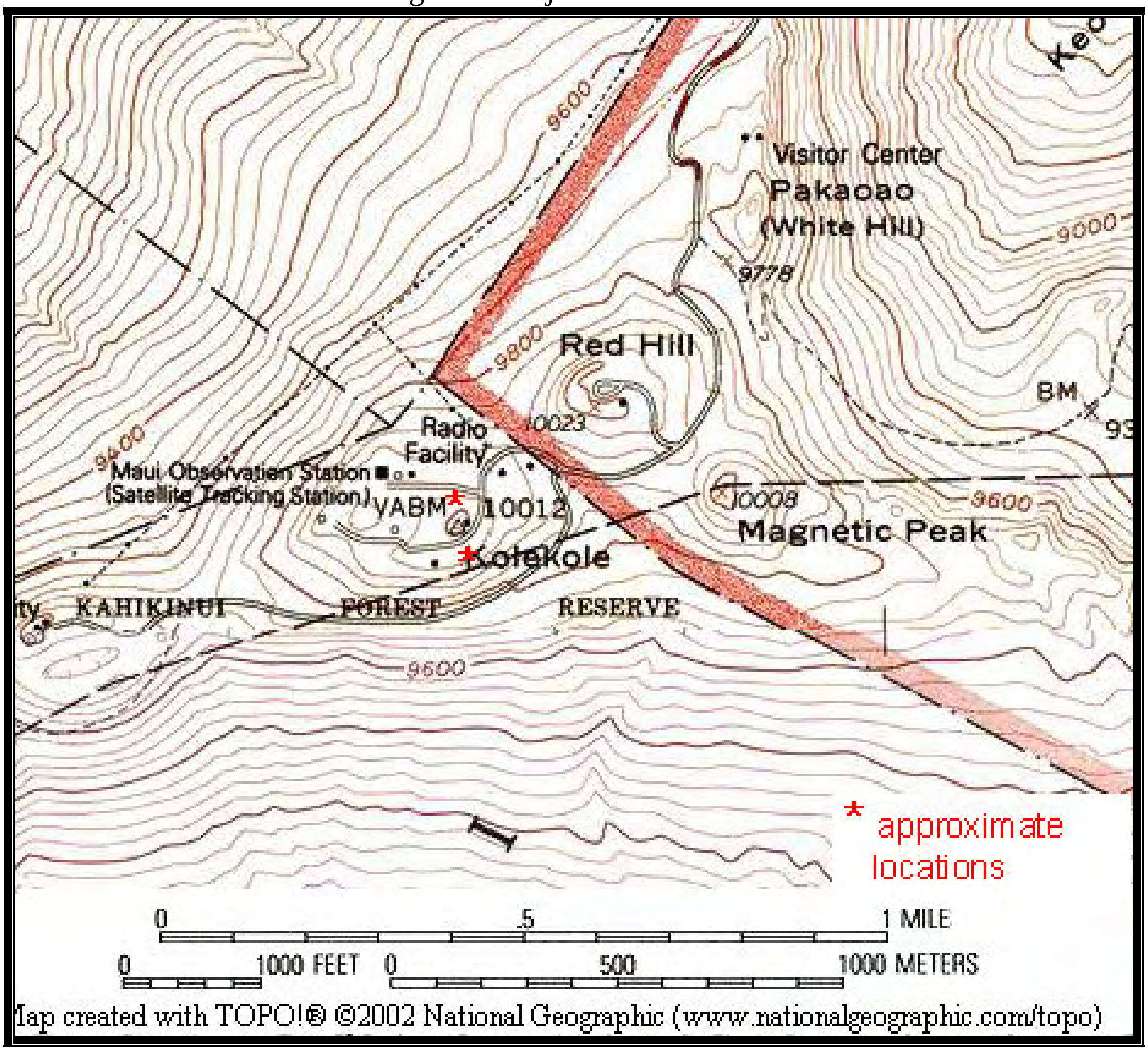
Over the course of Haleakalā's formation, three distinct phases of eruption have taken place. The first, called the Honomanu Volcanic Series, is responsible for the formation of Haleakalā's primitive shield and most likely, its three prominent rift zones. Honomanu lavas are exposed over less than 1 percent 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, leading to the formation of Haleakalā Crater and great valleys leading to the coast. After a period of quiescence, now thought to be 120-150 ka in length (Sherrod et al 2003), additional eruptions, called the Hana Volcanic Series, partially filled the deep valleys. Ash layers and cinder cones ranging from a few feet high to more than a mile across at the base and 600 feet high were deposited in the East and Southwest Rift Zones. Lava flows within the Haleakalā Southwest Rift Zone vary from perhaps 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 indicate that Haleakalā volcano may still be active, in light of the numerous eruptions during the last 8,000 years (Bergmanis, E.C., J. M. Sinton and F. A. Trusdell 2000: 239-235).

Kolekole Cinder Cone, the crater of which is the site of the Haleakalā High Altitude Observatories (Fig. 1), consists of cinder overlying alkalic lava flows classified as ankaramite and dated to 128 ka +/-6 ka (Sherrod et al 2003). Its age and chemical composition (Chatterjee et al 2005) indicates that it is probably part of the early Hana Volcanic series rather than the Kula Volcanics, in which it was previously classified. A detailed study of Kolekole Cinder Cone was undertaken as part of the *Haleakalā Long Range Development Plan* (LRDP, Appendix A, Bhattacharji). The asymmetric cinder cone has steeper slopes on its western and northwestern rims, with gentler slopes on the eastern and southern rims. According to report:

"…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 the 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."

Figure 1. Project Site Location



The report included a geological map and a cross-section of Kolekole Cinder Cone, which are reproduced as Figures 2 and 3. The primary site for the ATST is just south of site "H" in Figure 1, in an area of mixed massive lava flows and cinder cones. A photograph of the typical surface is shown in Figures 4 and 5. The proposed site consists of polygonal to sub-columnar lava horizons which are broken into large blocks along horizontal and vertical joints. The near horizontal ankaramite lava is ponded and agglutinated with spatter and some cinder as well (*IfA's Haleakalā Long Range Development Plan* (LRDP), Appendix A). Subsurface coring completed during the site selection phase of ATST indicates that these lava horizons are several feet thick and intermixed with cinder beds. Figure 6 is a view of the primary site from below, showing how the massive horizontal surface lavas are a cap on a slope that reveals a mixture of lavas and pyroclastic layers.

The alternate ATST site at Reber Circle is located just southeast of "A" on Figure 2, and is illustrated in the photographs of Figures 7 and 8. This is an area of spatter and massive lava flows, but it has been heavily altered by grading away of a local lava flow peak, and the site is now flat and covered with graded material. A lava bomb from the site is illustrated in Figure 9.

Figure 2. Geologic Map (from Bhattacharji)

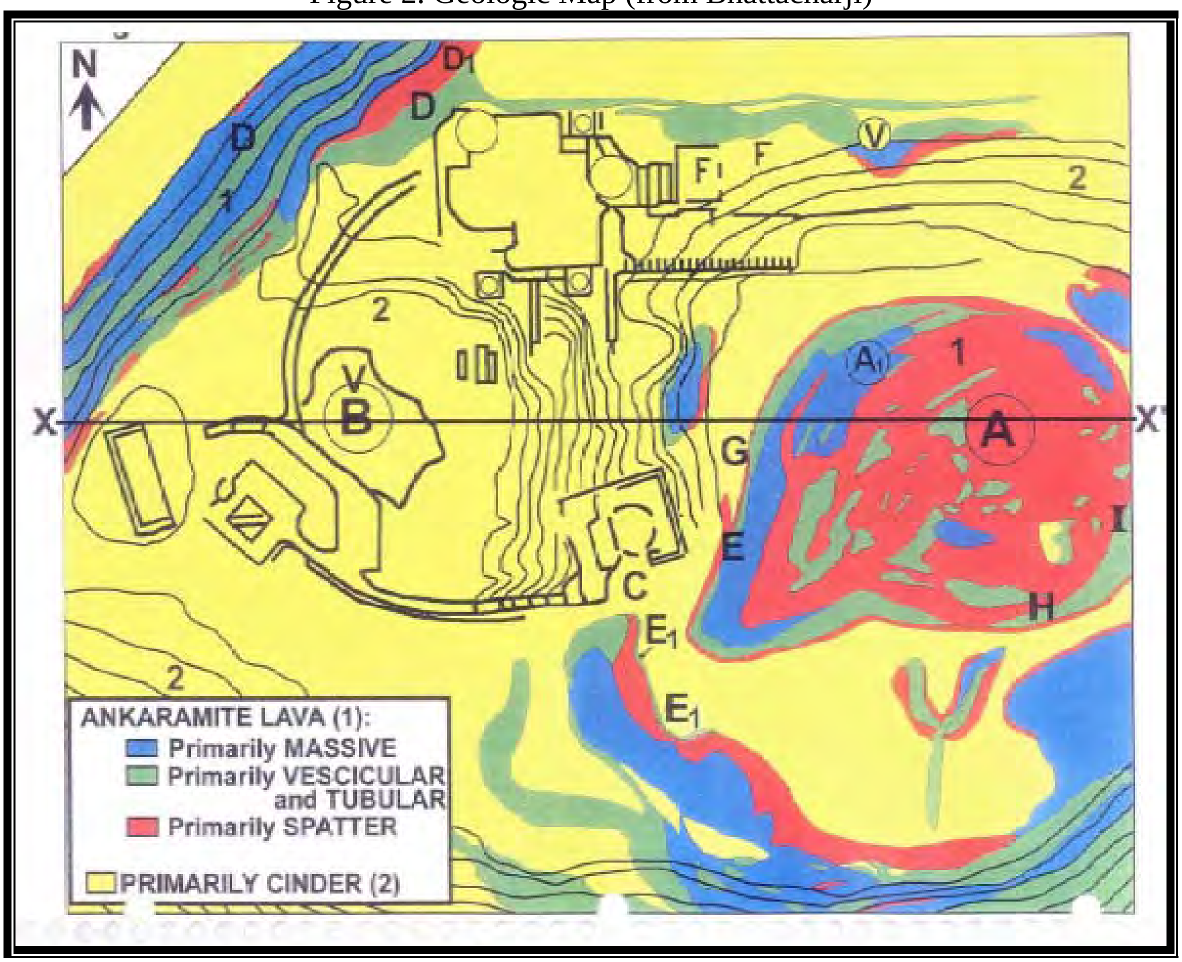


Figure 3. Cross Section (from Bhattacharji)

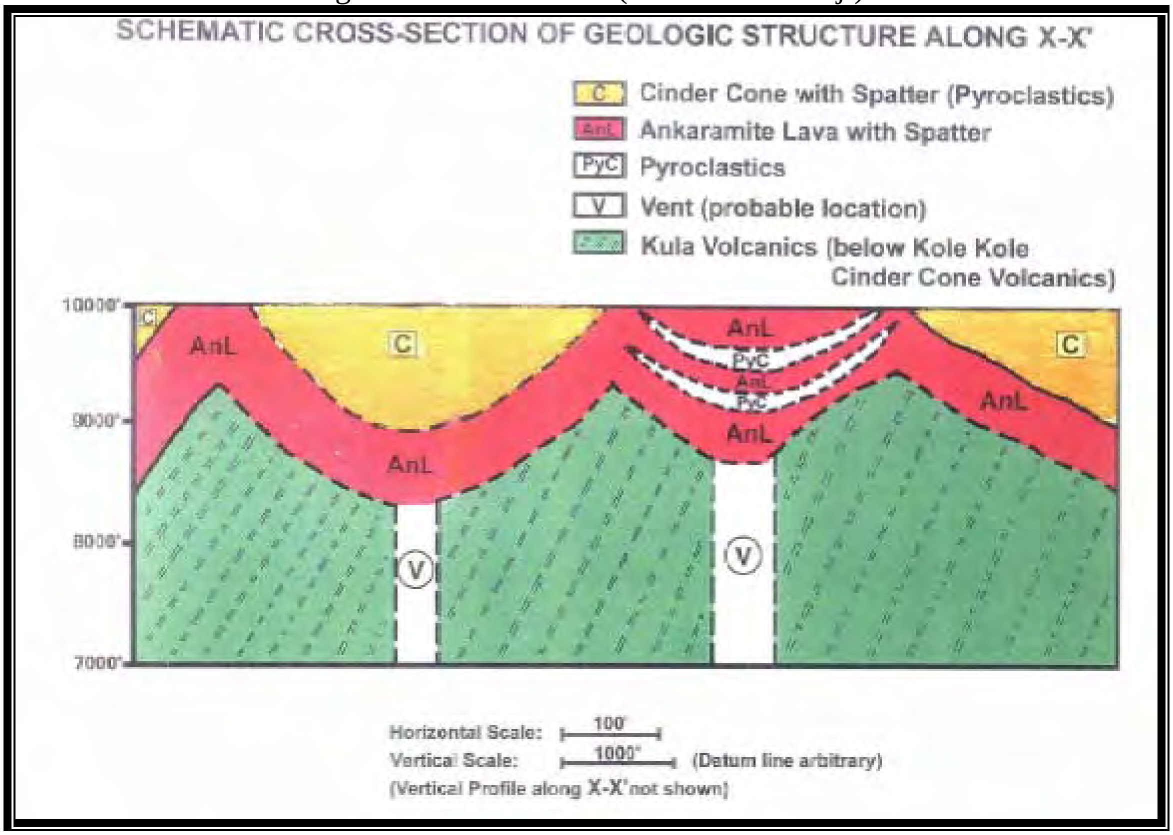


Figure 4. Photograph I of Primary Site

Figure 5. Photograph II of Primary Site

Figure 6. Photograph III of Primary Site

Figure 7. Photograph I of Alternative Site (Reber Circle)

Figure 8. Photograph II of Alternative Site (Reber Circle)

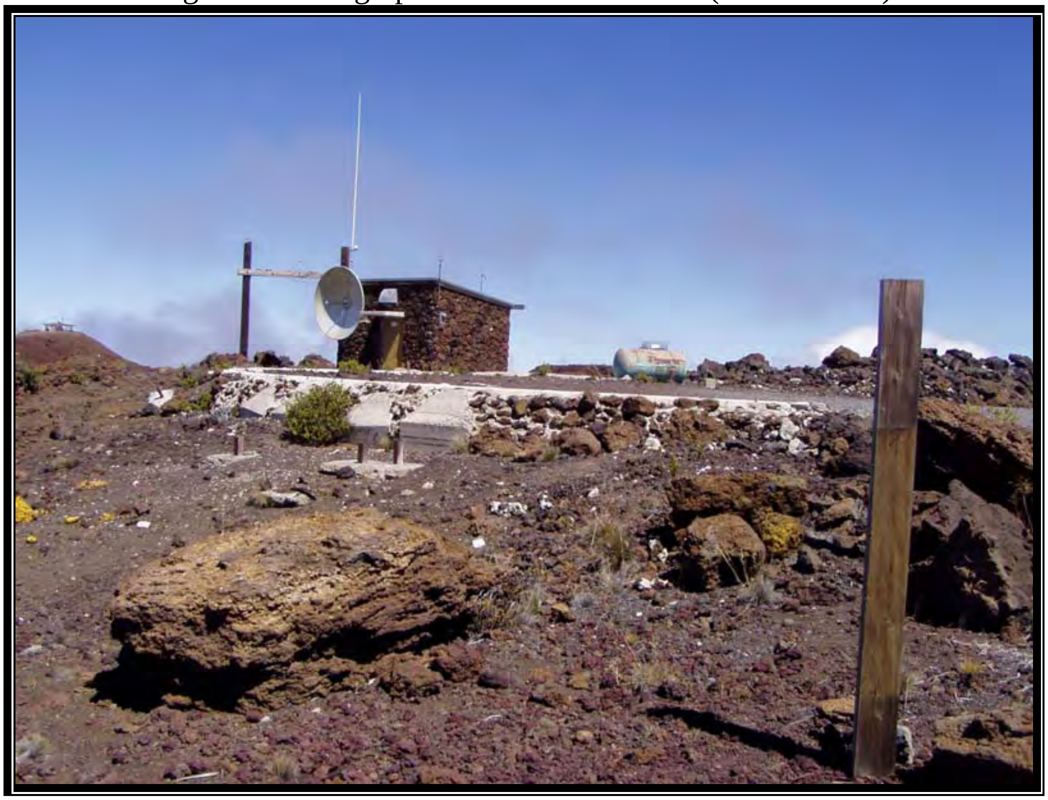


Figure 9. Volcanic Bomb at Alternative Site (Reber Circle)

Neither site shows gross evidence of faulting, instability or mass wasting, and in a human-referenced time scale, they do not appear to be geologically unsuitable sites. However, it should be recognized that the Southwest Rift Zone of Haleakalā is considered by many to be an active volcanic risk zone (Bhattacharji n.d.), and eruptions will eventually occur again.

According to project plans, if the ATST facility is located the primary site, the Reber Circle site may be available for placement of excavated material. This material would be placed so as to restore the *pu'u* (hill) that previously existed at this location before the construction of the Reber circle experiment. The shape of the hill would be determined as much as possible from historical photographs and geological records, and would extend the contours of the existing adjacent slopes for a natural effect. The remains of the concrete Reber circle ring and the rock building at the northeast end of the site would be removed. As part of this analysis, KC Environmental, Inc. asked whether it would be possible to determine the appearance of the *pu'u* landform that was present at the Reber Circle site before it was graded. Although it is only speculation, the photographs in Figures 10 and 11, taken of nearby small promontories, are probably similar to the removed landform and could be used as rough analogues. Such features are often between 20 and 50 feet in height. The "soil placement" area illustrated in Figure 12, which shows a landform reconstructed from about 4,000 cubic yards of cut rock and "soil" generated from material at the primary site that would be 24-feet high and 13,400 square feet in area at the base, would provide a reasonable simulation of the previously existing topography.

Figure 10. Analogue I to Pre-Grading Landform at Reber Circle

Figure 11. Analogue I to Pre-Grading Landform at Reber Circle

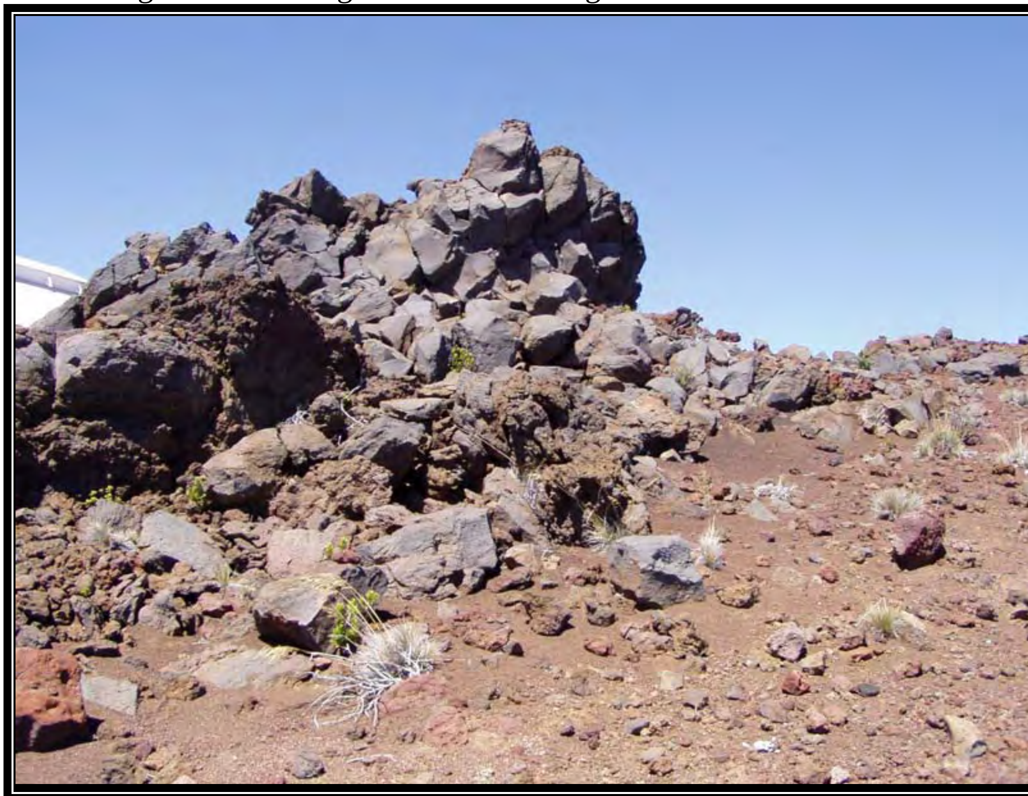
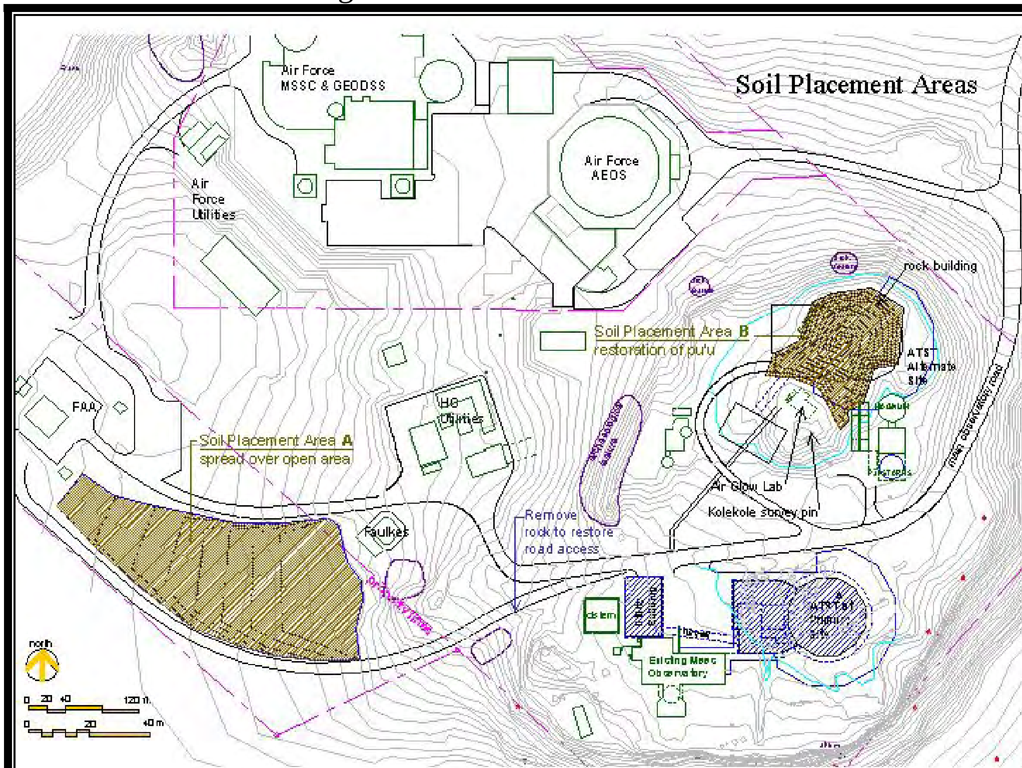


Figure 12. Soil Placement Areas



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APPENDIX H

MOVEMENTS 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

Prepared for

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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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APPENDIX H:
MOVEMENT OF HAWAIIAN PETRELS

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ACKNOWLEDGMENTS

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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).

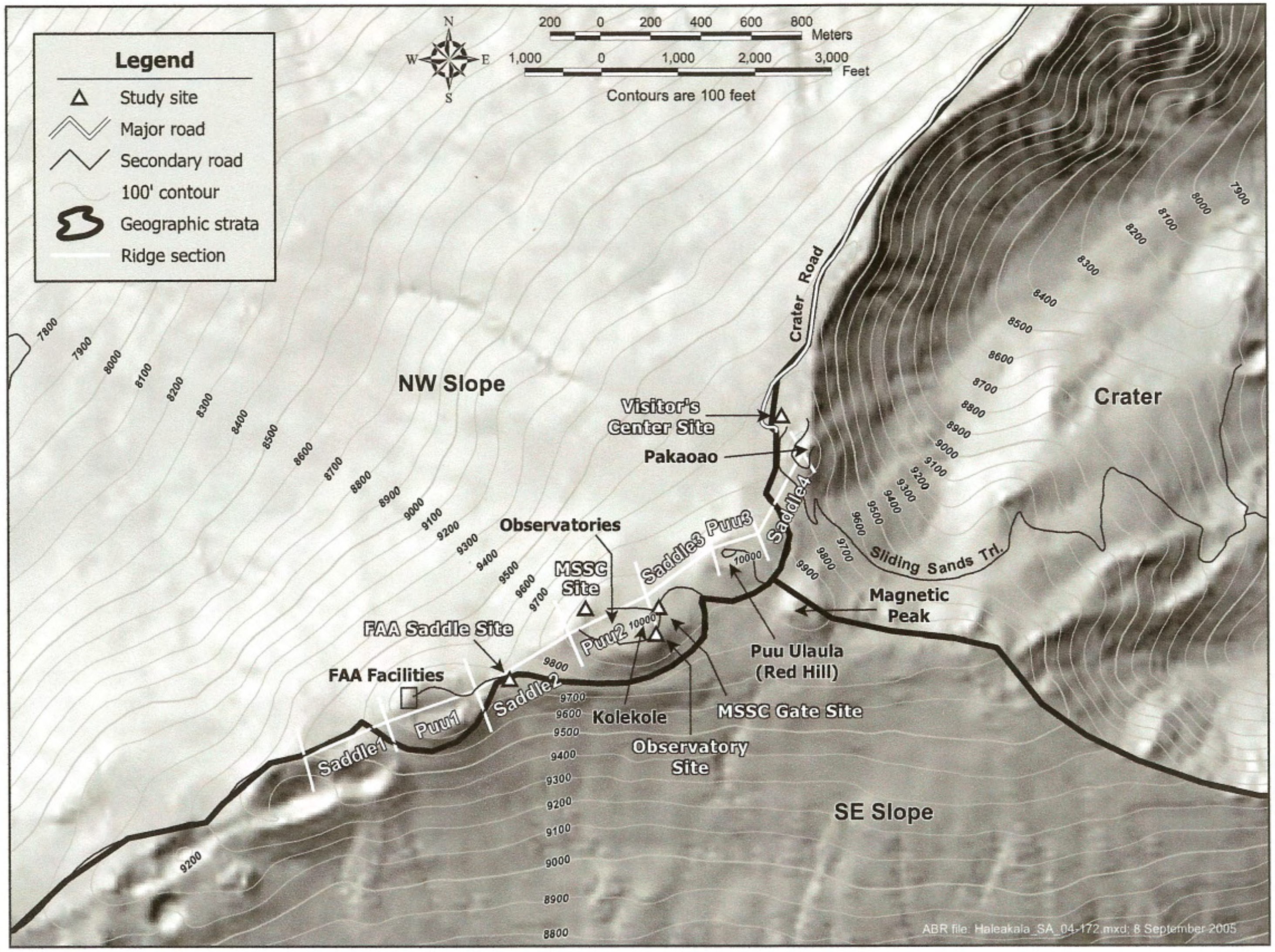

Figure 1. Study area and sampling sites near the summit of Haleakala, Maui Island, Hawaii, fall 2004 and spring 2005. Also shown are the locations of the three geographic strata and the seven ridge-crossing segments used in some analyses.

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*) Surveillance radar	Vertical radar	Visual	Comments
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

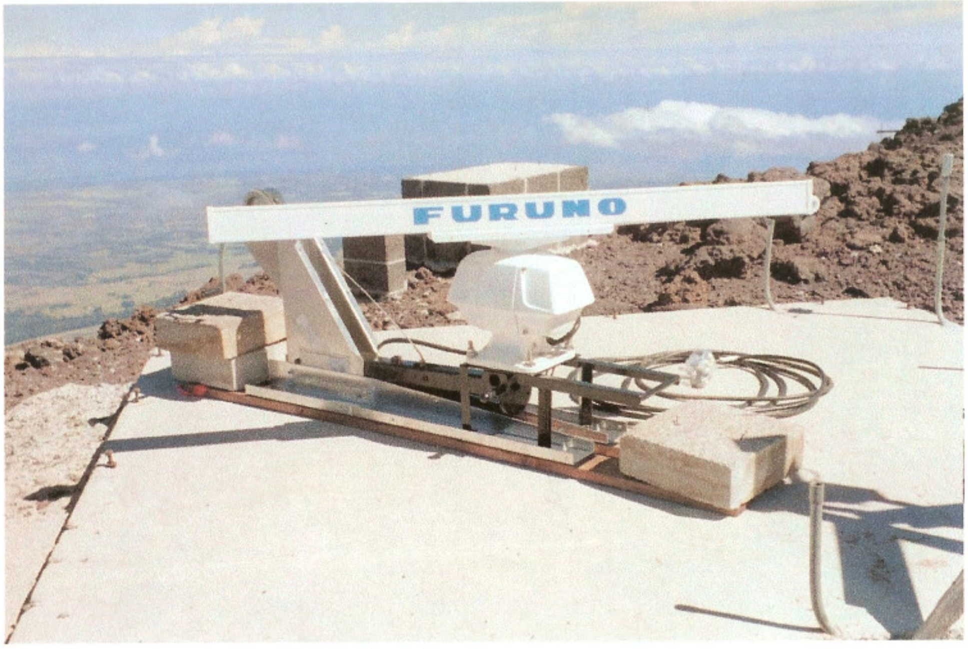

Figure 2. Vertical radar mount in folded position.

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

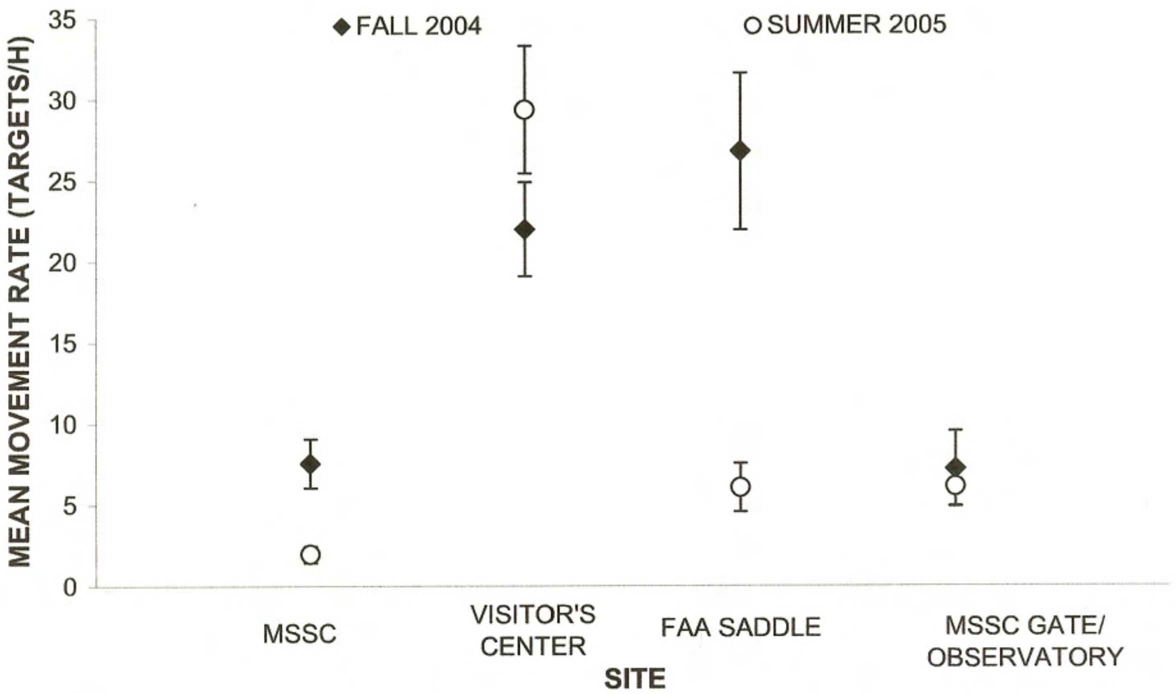

Figure 5. Mean movement rate (targets/h) of Hawaiian Petrel radar targets near four sites near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by site and season. Data are plotted as mean ± 1 SE. The MSSC Gate and Observatory sites were located nearby and were considered to be the same 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.

Site	Date	Movement rate (targets/h)		
		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).

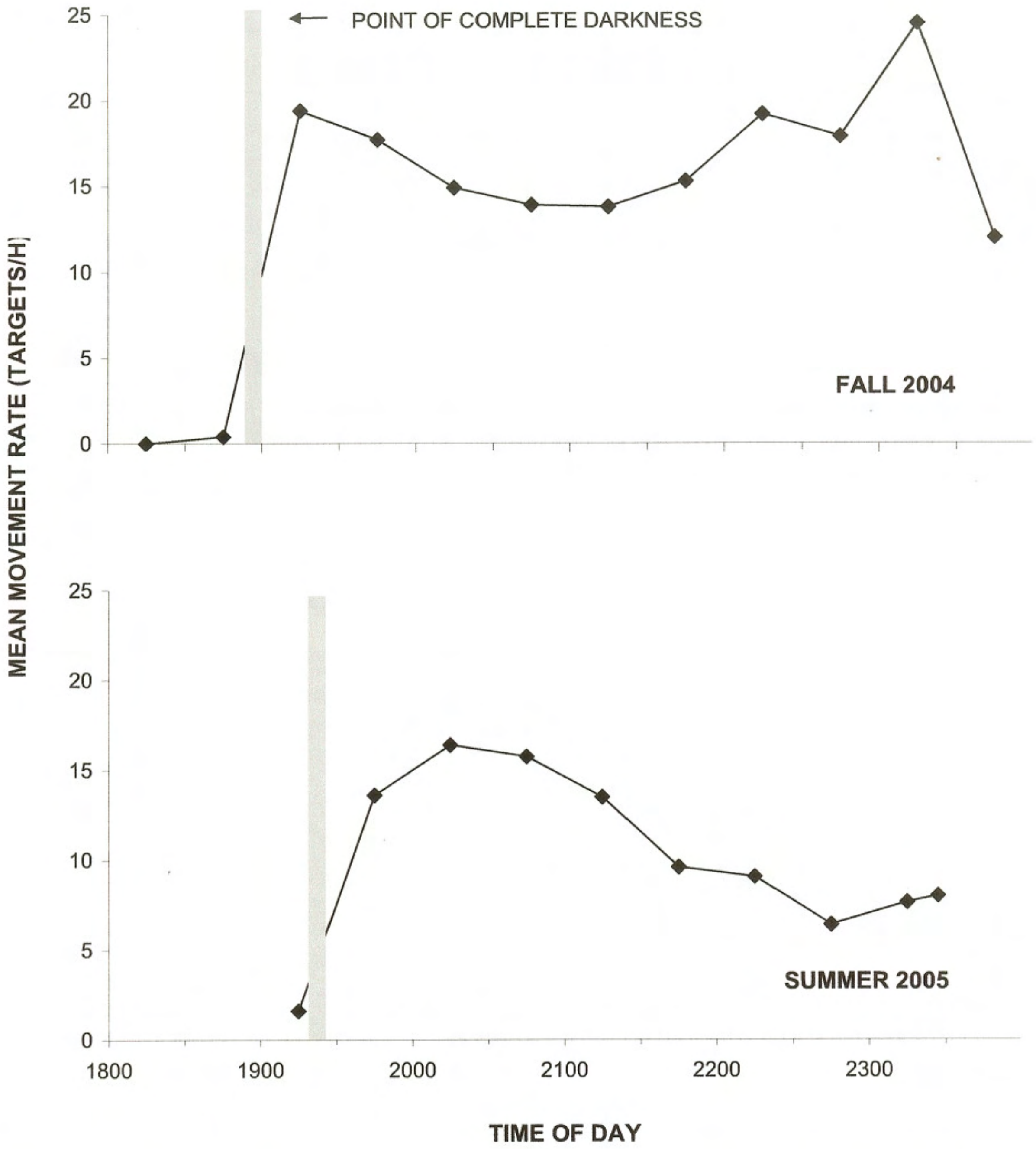

Figure 6. Mean movement rate (targets/h) of Hawaiian Petrel radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by time of the day. Data are plotted as the mean and are for all sites combined; for reference, the point of complete darkness (that period when twilight ends 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,

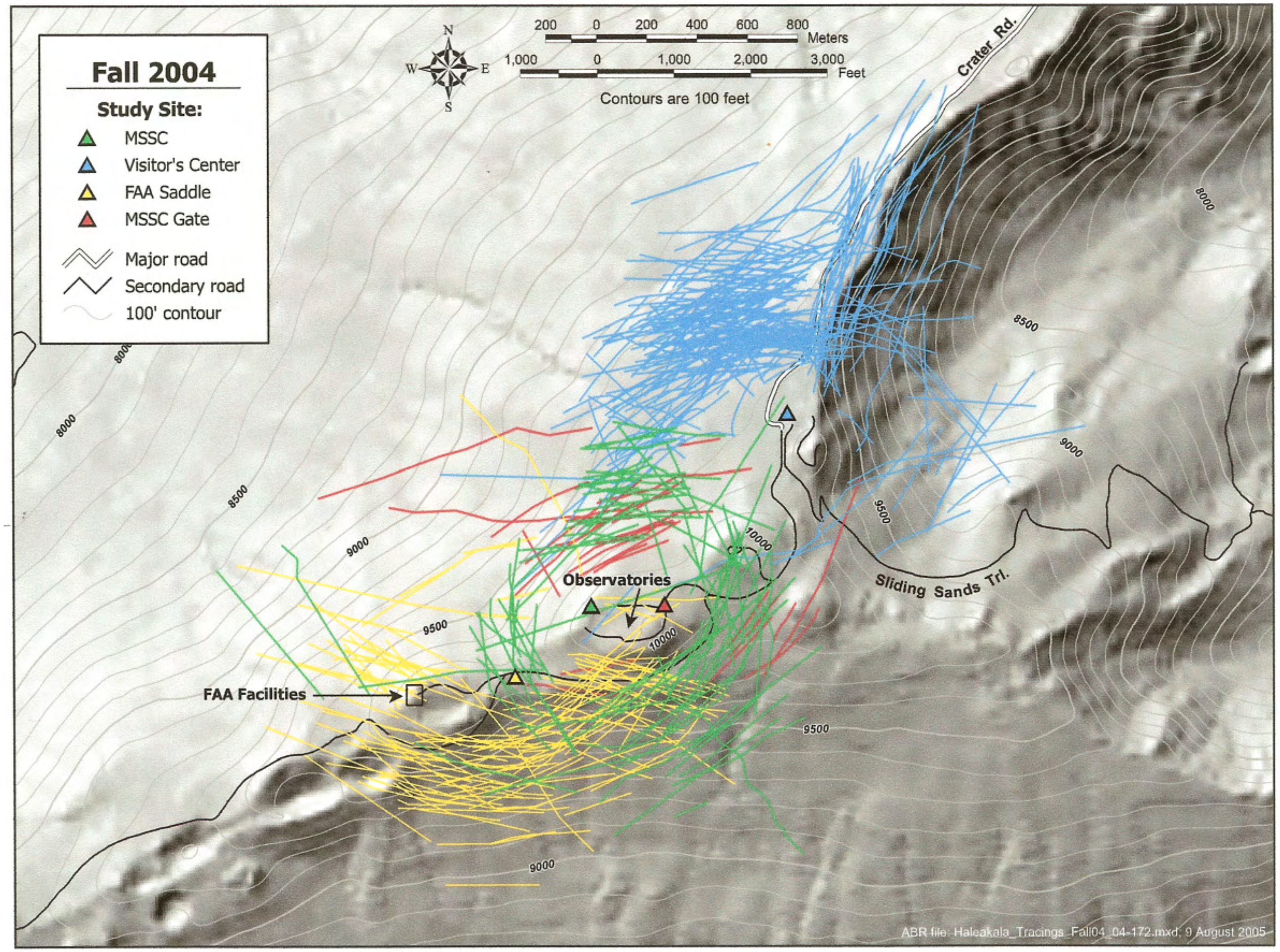

Figure 7. Flight tracklines of Hawaiian Petrels flying near the summit of Haleakala, Maui Island, fall 2004. Tracklines are colored to match the site (colored triangles) at which they were recorded.

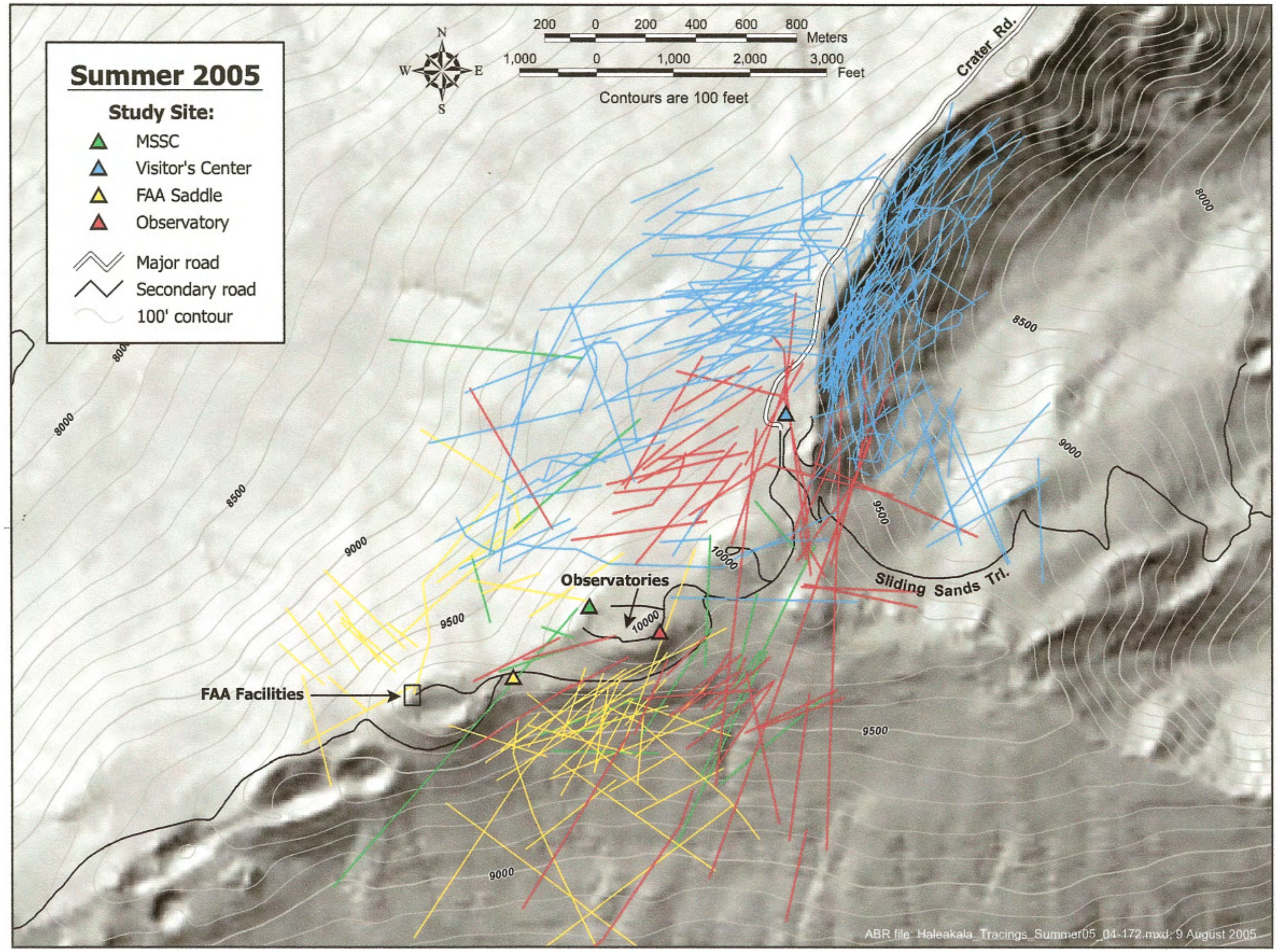

Figure 8. Flight tracklines of Hawaiian Petrels flying near the summit of Haleakala, Maui Island, summer 2005. Tracklines are colored to match the site (colored triangles) at which they were recorded.

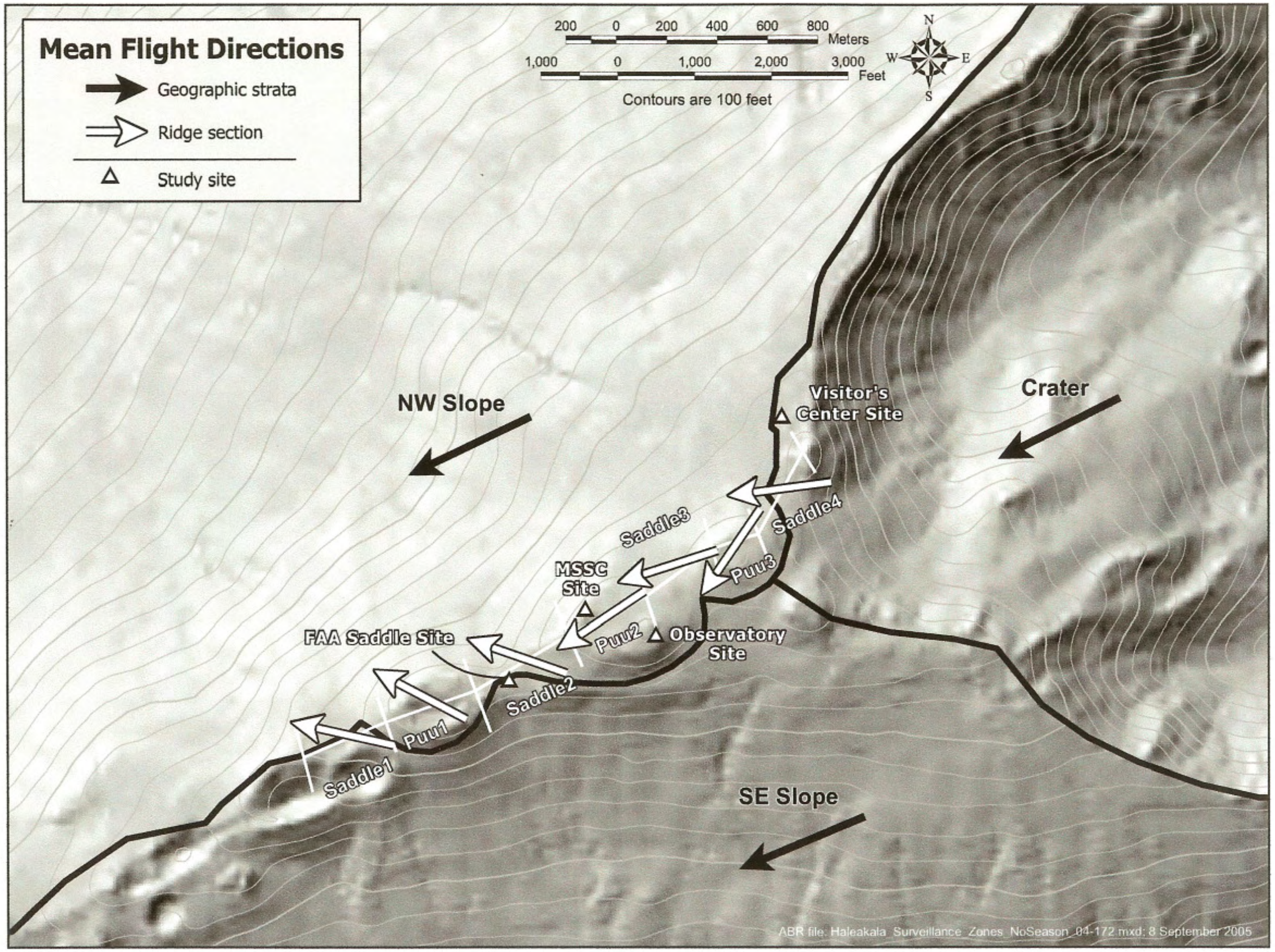

Figure 9. Flight directions of Hawaiian Petrel radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005 combined. Arrows show mean flight directions for the three geographic strata and the seven ridge sections.

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 ($\leq \pm$ 62° of the mean), traveling away from ($\leq \pm$62° of [the mean – 180]), and traveling perpendicular to ($\leq \pm$ 22° of [the mean $\leq \pm$ 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

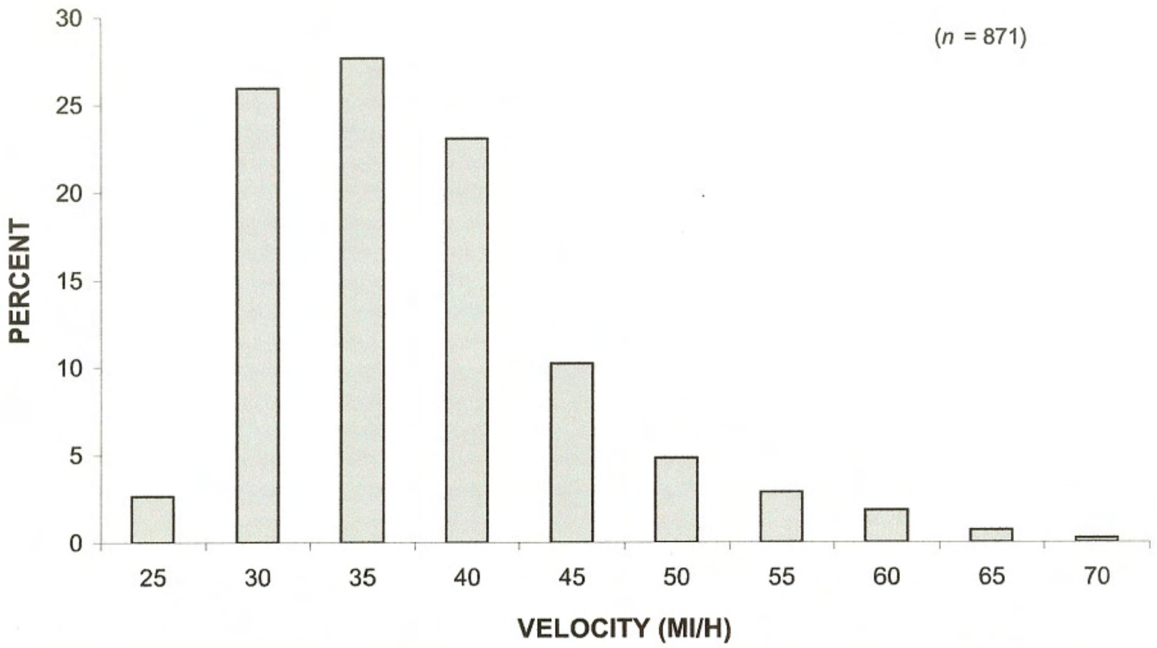

Figure 10. Velocity (mi/h) of Hawaiian Petrel radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005 combined. Data are presented as the percentage of all targets in each velocity category.

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,

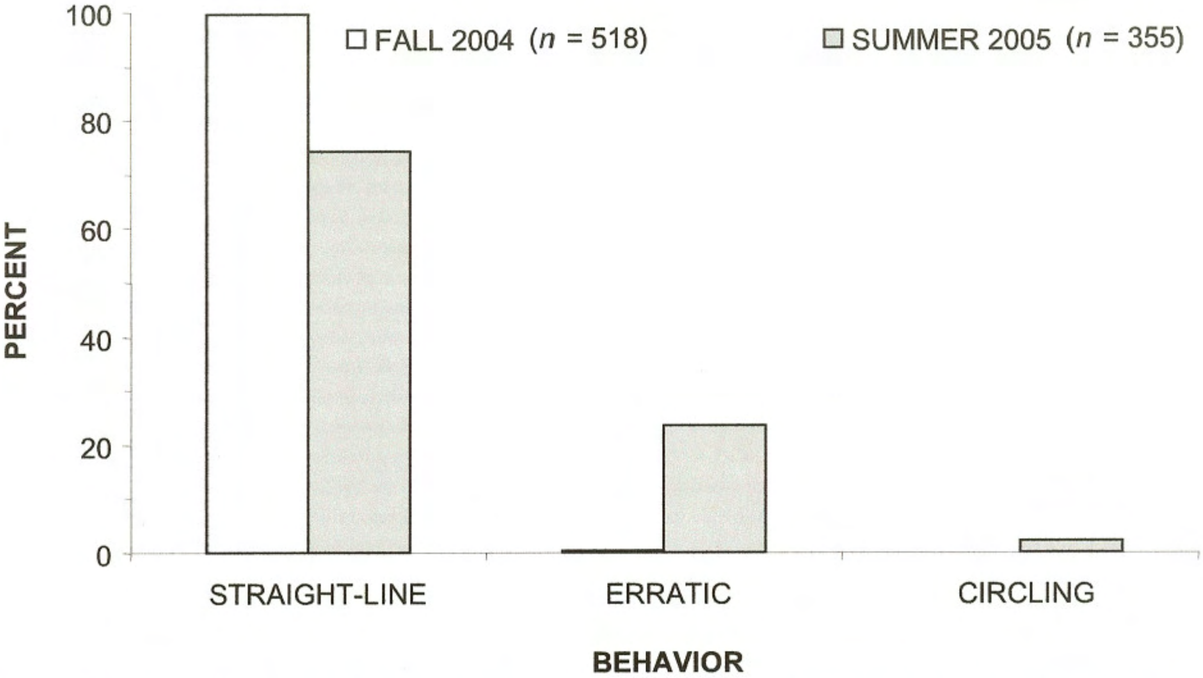

Figure 11. Behavior of Hawaiian Petrel radar targets near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by season.

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

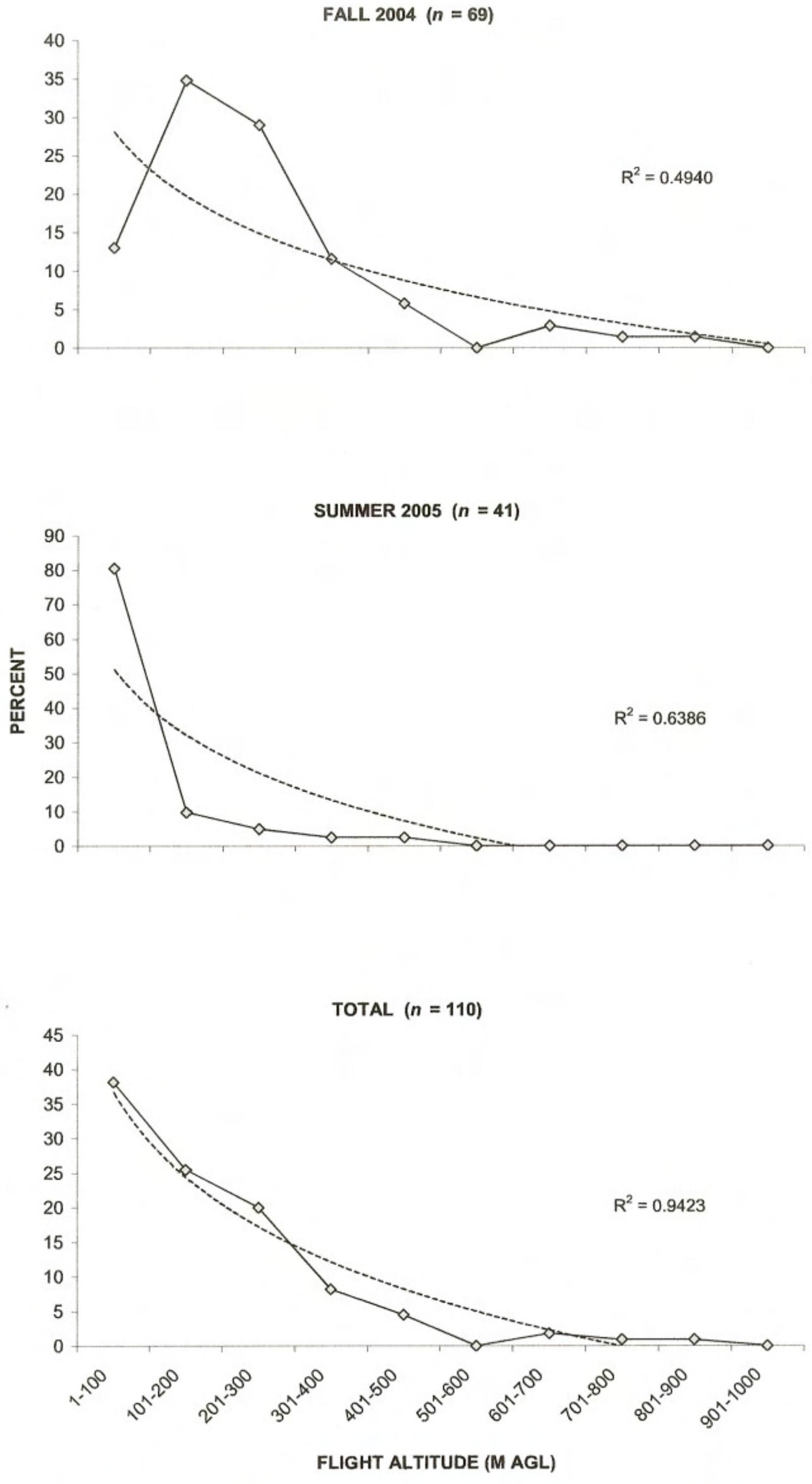

Figure 12. Minimal flight altitudes (meters agl) of Hawaiian Petrel radar targets measured on the vertical radar near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, by season and combined. Data are plotted as the percentage of all targets flying that minimal altitude in each altitude category. A fitted logarithmic curve also is included; the Coefficient of Determination (R^2) is listed for this curve fitted to the categorical data.

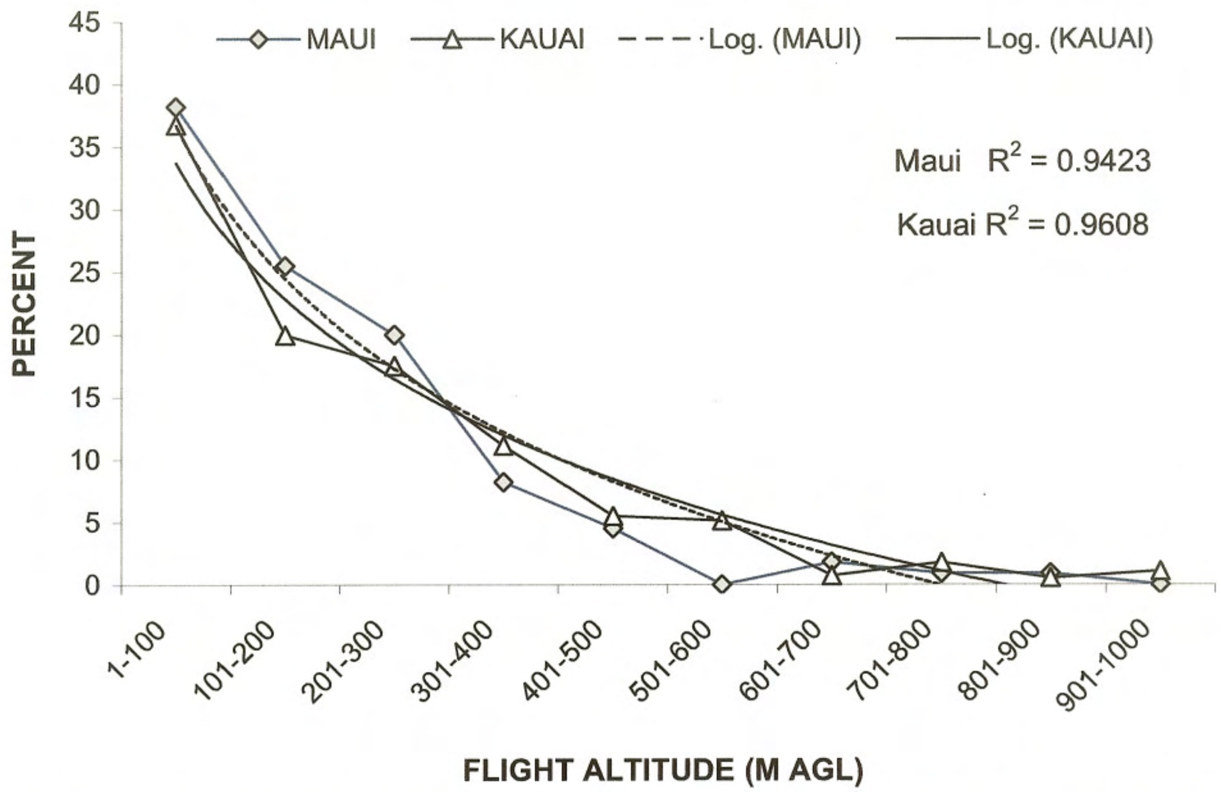

Figure 13. Minimal flight altitudes (meters agl) of Hawaiian Petrel targets measured on the vertical radar near the summit of Haleakala, Maui Island, fall 2004 and summer 2005, and flight altitudes estimated visually for flying birds observed at Kaua'i Island, 1992–2002. Data are plotted as the percentage 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

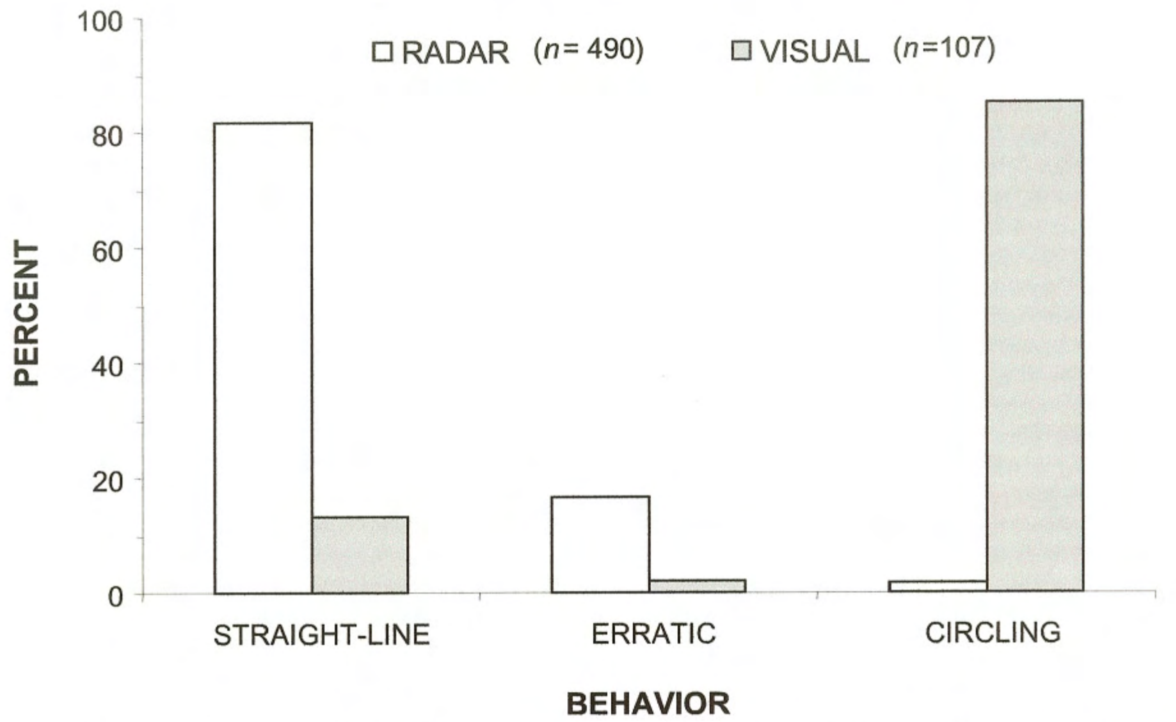

Figure 14. Behavior of Hawaiian Petrel radar targets and behavior of visually-observed birds at the Visitor's Center Site near the summit of Haleakala, Maui Island, in summer 2005.

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

PETREL MONITORING PLAN

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November 10, 2005

Proposal to Use Video Surveillance to Monitor ʻUaʻu (Hawaiian Dark-rumped Petrel) in the Vicinity of the Proposed Advanced Technology Solar Telescope (ATST) Construction Site at the Haleakalā High Altitude Observatories (HO)

KC Environmental, Inc. (KCE) is pleased to submit this proposal to the National Solar Observatory for the use of video surveillance to monitor ʻuaʻu (Hawaiian Dark-rumped Petrel) in the vicinity of the proposed Advanced Technology Solar Telescope (ATST) construction site at Haleakalā High Altitude Observatories (HO).

Introduction

The Advanced Technology Solar Telescope (ATST) project is proposed for construction at either a site west of Mees Observatory or at Reber Circle. ʻUaʻu (Hawaiian Dark-rumped Petrel) burrows are around and within the Haleakalā High Altitude Observatories (HO) property near the proposed ATST primary (Mees) construction site. Haleakalā National Park (HNP) resource personnel and U.S. Fish and Wildlife Service (USF&WS) biologists have expressed concerns that construction activity may adversely affect nesting ʻuaʻu.

During the September 16, 2005 EIS site consultation visit by a USF&WS biologist and HNP resource specialist, they suggested that a video monitoring system could be used to evaluate the effects ATST construction activity may have upon ʻuaʻu activity, nesting ʻuaʻu, and fledging success. Fledgling success is defined as the number of active burrows showing signs of fledging chicks.

ʻUaʻu at Haleakalā

The ʻuaʻu, or Hawaiian Dark-rumped Petrel *(Pterodoma phaeopygia sandwichensis*), is the only seabird that is federally listed as an endangered species. Once numerous throughout the Hawaiian Islands, the species is now confined to higher elevations (Ref. 1). Most of the population is within Haleakalā National Park boundaries (Figure 1). About 55 burrows are within ¼-mile (400 meters) of the Haleakalā Observatories, a few of which are inside HO boundaries. These are considered part of the "Haleakalā population." Haleakalā National Park biologists have been conducting regular monitoring and searches of ʻuaʻu nests since 1988. The burrows immediately surrounding HO are shown in Figure 2 (indicated by the numbering in red.) Burrow locations were derived from data obtained by GPS mapping by HNP personnel.

The ‘ua‘u reside at the Haleakalā colony from February through October of each year and, hence, are absent from November through January. The birds make their nests in burrows and tend to use the same burrow year after year. Not all burrows are occupied. Regular HNP monitoring includes monthly checks of whether or not burrows are occupied, and which nests successfully fledge young birds. The ‘ua‘u fly at night. They fly from the ocean to the Haleakalā colony just before sunset and leave the colony for the ocean just before sunrise. These birds fly up the slopes of Haleakalā, some passing near the Haleakalā Observatories (Ref. 2, 3).

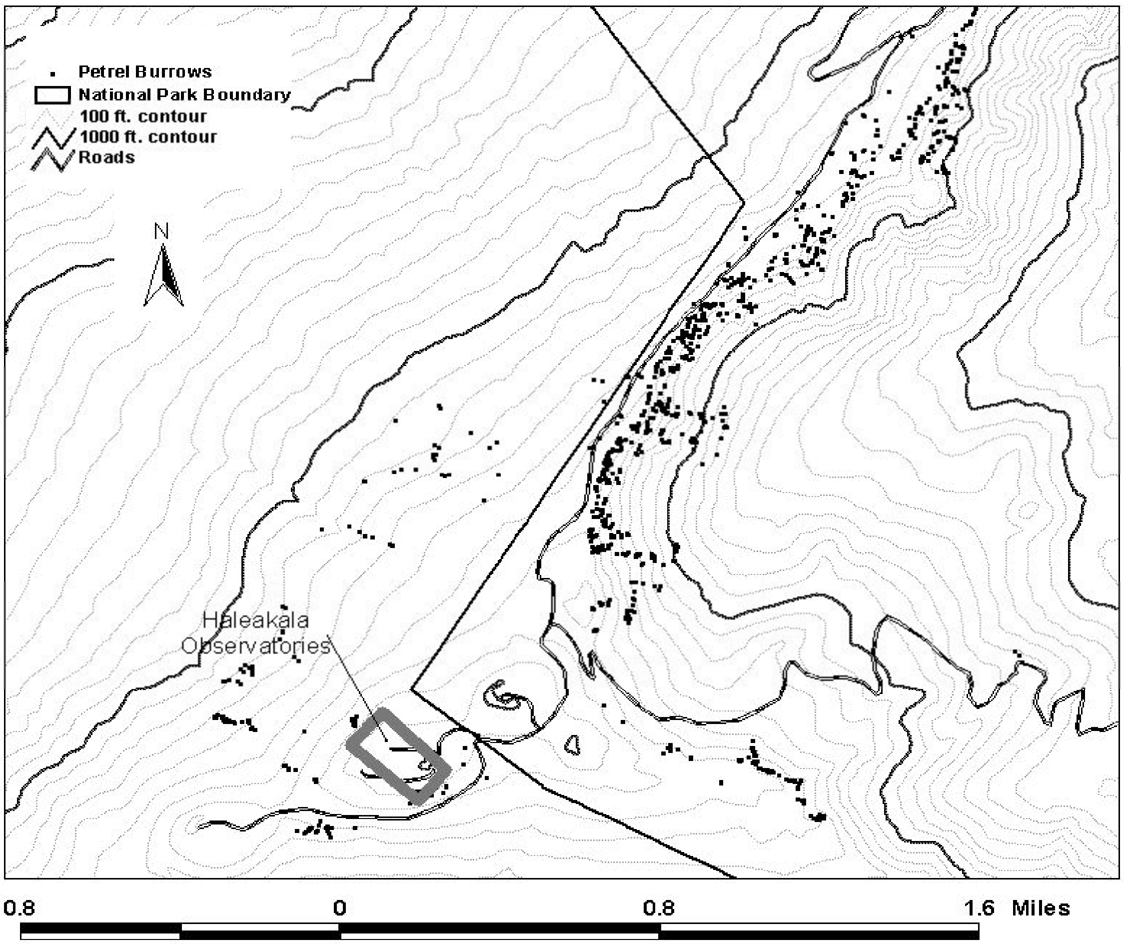

Figure 1. Petrel Burrows Within Two Miles of Haleakalā Observatories.

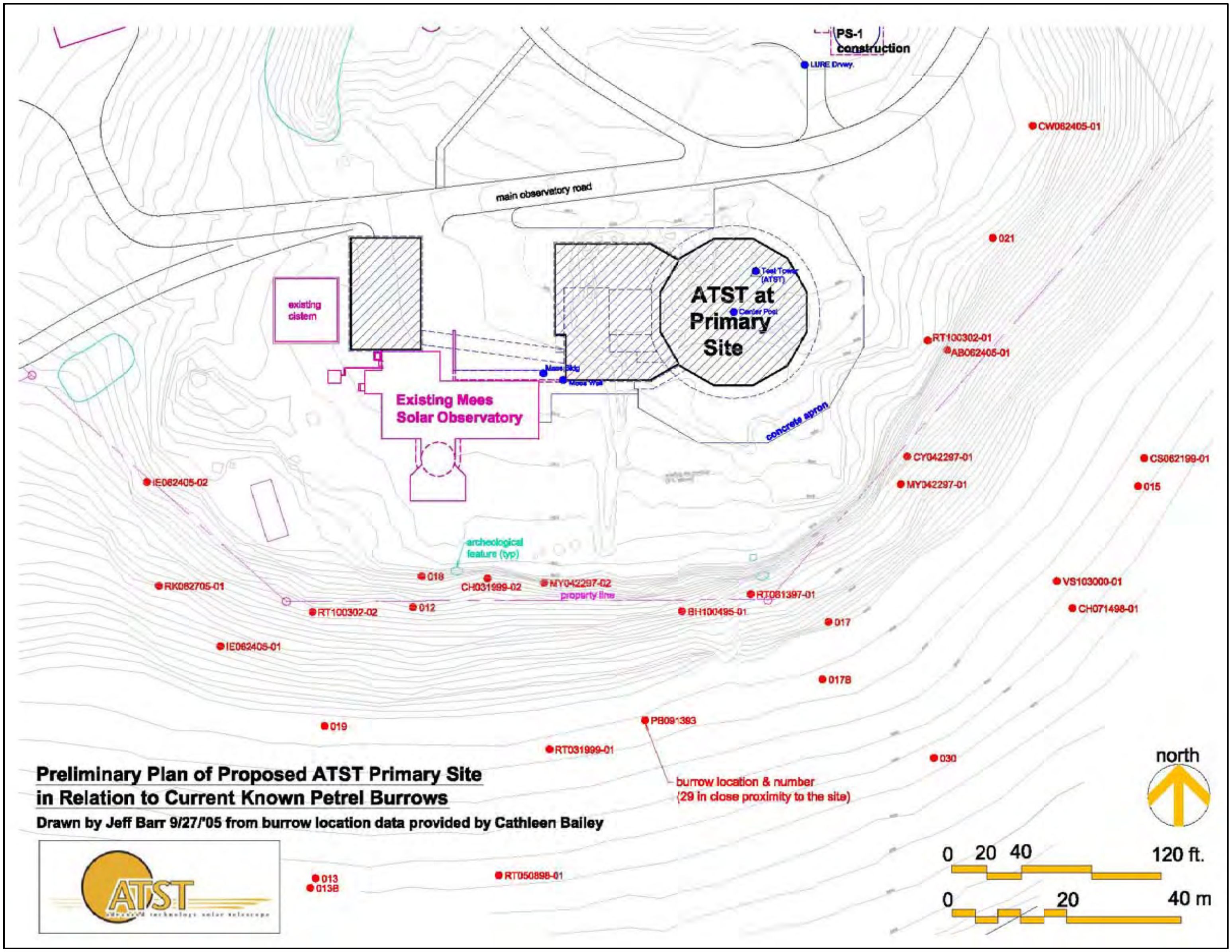

Figure 2. Location of Petrel Burrows in Relation to Haleakalā Observatories.

Potential Impacts from ATST Construction Activity

The proposed ATST construction activities that may impact fledgling success and burrow activity near the burrows shown in Figure 2 include, but may not be limited to the following:

1) Excavation for site preparation and soil removal to create a level platform. Excavated soil would be utilized for fill material at the building site or would be trucked to a designated soil placement area with the HO boundary.

2) A large temporary construction staging area for materials and equipment would be designated in an area west of the Faulkes Telescope Facility. A smaller temporary construction staging area would be located just west of the proposed telescope dome facility at the Mees site.

Objectives for the Petrel Monitoring System

The objectives of this study would be to determine if there are significant differences between the proposed construction site and a control site by observing and analyzing:

1) ‘Ua‘u activity at burrows; and,

2) Fledging success of active burrows.

‘Ua‘u activity and fledging success would be compared at the two sites: One site would be the colony near the proposed construction activity; and the second would be a control site located near and below the Haleakalā Visitors Center near Pa Ka‘oao (White Hill). This latter site would be sufficiently removed from the proposed construction activity to permit simultaneous observation of petrel activities that would not likely to be impacted by construction activities. Construction activity includes any vehicular or personnel activity associated with the construction.

The level of ‘ua‘u activity will be estimated for each site by examining the video record of ‘ua‘u movements. The number of active burrows that show signs of fledging chicks would determine fledging success. ‘Ua‘u activity and fledging success would be determined during nesting seasons before and during construction activity. The differences between the two sites would be examined.

Methodology

To determine ‘ua‘u activity, individual day/night cameras would be placed to view about 30 randomly-selected, active burrows at the proposed construction site and 30 active burrows at the control site. The cameras would be motion-sensitive to record ‘ua‘u activity, which is defined by a number of actions, i.e., ‘ua‘u moving in or out of burrows, ‘ua‘u remaining in burrows, ‘ua‘u returning or not returning to burrows after being pushed out of nests, ‘ua‘u digging at burrows, ‘ua‘u defecating at burrows, etc. An additional two cameras at each site would record daily activities such as traffic, staff movement, equipment repairs, etc. prior to and during construction.

When the regional National Park biologists and air and sound quality engineers evaluated the proposed monitoring methodology, they suggested that measuring noise levels before and during construction would be a useful measurement to correlate with ‘ua‘u activity and fledging success. Therefore, we have included the option of installing two recommended in-situ sound measuring devices within each site to monitor sound levels before and during construction to help quantify potential impact. Data from all sensors would be collected during a three-year period:

1) The first nesting season efforts (FY 06) could be coincident with some Air Force construction at HO early in 2006. However, the objectives would be to validate monitoring system performance and to provide the data analysts with sufficient information to begin establishing statistical models for ‘ua‘u activities within the Haleakalā colony. In addition, KCE will perform system adjustments, i.e., camera location, motion-detection sensitivity, data storage, etc., over a several month period to ensure that the broad range of daily petrel activities is accurately captured.

2) The second year of data collection (FY 07) would be during a season with no planned construction, which would serve as a baseline for ‘ua‘u activity at HO.

3) The third year of data collection (FY 08 or later) would monitor construction. Visual records of date, time, and type and level of activity would be correlated with recorded burrow activity.

To help determine fledging success, video data from the burrows will be examined throughout each season, in addition to routine site visits by HNP personnel. Data will be stored on the four 16-channel digital video recorder hard drives and will be transferable to CD-ROM or DVD. The data from the proposed ATST site will also be ported to the Internet for real-time viewing of ‘ua‘u behavior, and statistical analysis techniques will be applied to validate and quantify the data.

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APPENDIX J

PROPOSED ATST PROJECT AND ALTERNATIVES SUPPLEMENTARY DOCUMENTATION

(1) SITES EVALUATED FOR SCIENCE CRITERIA

(2) SUPPLEMENTAL DISCUSSION OF THE CONSTRAINTS OF SOLAR SCIENCE DEVELOPMENT

(3) HALEAKALĀ vs. LA PALMA DUST COMPARISON

(4) SUPPLEMENTAL DESCRIPTION OF ATST EQUIPMENT AND INFRASTRUCTURE

(1) PROPOSED ATST PROJECT AND ALTERNATIVES: SITES EVALUATED FOR SCIENCE CRITERIA

In order to identify the site with the best conditions, well-established selection criteria were applied. One leading selection criterion is high altitude, in order to place the telescope above much of the atmosphere. Since the atmosphere acts as a blurring lens that distorts images, each candidate site was on top of or within mountains that provide adequate elevation above a significant fraction of the atmosphere. Other criteria include:

1. Surrounding bodies of water to reduce turbulent convection;
2. Low humidity;
3. Few aircraft contrails;
4. Low dust or aerosol levels, which scatter light and obscure the Sun's corona;
5. Minimal cloud cover;
6. Many continuous hours of sunshine;
7. Excellent average "seeing" conditions (a term used by astronomers as a measure of transparency through the atmosphere); and,
8. Good infrared transparency.

The final selection of a site represents the best combination of these factors.

Initially, 72 sites around the world were evaluated with respect to the science criteria above. The list was culled down primarily by considerations of feasibility and observing conditions that meet the aforementioned criteria. Table 1 provides a full list of the sites considered, including common preliminary characteristics considered at each site.

Table 1. Sites Evaluated for Science Criteria.

Site Name	ID	Elevation (ft)	Lake area (Acres)	Shortest Distance to Ocean	Annual Sunshine Hours	Number of Ocean Sides (<100 miles away)
Normalization		*5,000*	*1000.00*	*25*	*3000*	*4*
Power		*1*	*0.50*	*1*	*2*	*1*
Abiquiu Lake, NM	20	6309	6811.40	655	2800	0
Bear Lake, UT	52	5922	82003.20	670	2400	0
Big Bear, CA	30	6781	2725.80	70	2800	0
Caballo Reservoir, NM	1	4190	8115.20	535	3000	0
Castaic Lake, CA	40	1561	3705.60	30	2400	1
Cerro Tololo, Chile	46	7267	0.00	37	3100	1
Cone Peak, Monterey, CA	60	4920	0.00	3	1200	1
El Vado Lake, NM	8	6919	3206.90	650	2800	0
Elephant Butte, NM	4	4360	27027.20	525	3000	0
Great Salt Lake, UT – Carrington Island	69	4708	1280000.00	575	3000	0
Guillermo Haro Obs, MX	55	8136	0.00	285	3200	0
Haleakalā, HI	43	10020	0.00	7	2800	4
Heron Lake, NM	37	7165	4761.60	650	2800	0
Isabella Lake, CA – Rocky Pt. Peninsula	16	2856	7539.20	110	2400	0
Jelm Mountain, WY	53	9593	0.00	900	2200	0
Jungfrau, SW	25	11729	0.00	460	1700	0
Junipero Serra Peak, CA	71	5837	0.00	11	1600	2
Kitt Peak, AZ	36	6955	0.00	275	2600	0
La Crescenta, CA	48	2060	0.00	21	3000	2
La Palma, Canaries	3	7631	0.00	5	2600	4
Laguna Verde, BO	62	13970	5600.00	215	3000	0
Lahontan Reservoir, NV	19	4167	6575.80	215	3200	0
Lake Arrowhead, CA	50	5121	742.40	60	2800	0
Lake Cachuma, CA	63	758	3129.60	9	2400	2
Lake Casitas, CA -Island	68	835	2075.00	6	2600	2
Lake Elsinore, CA	21	1247	4243.20	23	2800	2
Lake Havasu, AZ	31	456	11148.80	195	3600	0
Lake Henshaw, CA – Monkey Hill Island	51	2803	5420.80	35	2800	1
Lake Mathews, CA	22	1398	2499.10	29	2800	2
Lake Mead, AZ	57	1220	148448.00	260	3200	0

Table 1. Sites Evaluated for Science Criteria (cont.).

Site Name	ID	Elevation (ft)	Lake area (Acres)	Shortest Distance to Ocean	Annual Sunshine Hours	Number of Ocean Sides (<100 miles away)
Lake Mohave, AZ	47	650	4780.80	215	3600	0
Lake Pleasant, AZ	61	1561	2176.00	290	3200	0
Lake Powell, AZ	28	3707	66412.80	435	2800	0
Lake Tahoe, CA	10	6240	117856.00	160	2400	0
Lake Titicata, Peru/Bolivia	32	12506	2240000.00	178	2500	0
Lowell Obs, AZ	12	7222	0.00	360	2400	0
Lyman Lake, AZ	45	5984	1295.40	455	2800	0
Manashtash Ridge, WA	64	3187	0.00	175	2000	0
Mauna Kea, HI	17	13828	0.00	17	2800	4
Mauna Loa, HI	33	11000	0.00	24	2800	4
Mono Lake, CA - Paoha Island	70	6595	41184.00	172	2400	0
Mount Locke, TX	24	6766	0.00	460	2800	0
Mt. Graham, AZ	56	10683	0.00	380	2400	0
Mt. Hamilton, CA	26	4188	0.00	30	2000	1
Mt. Hopkins, AZ	2	8349	0.00	290	2400	0
Mt. Laguna, CA	42	6285	0.00	46	2800	1
Mt. Lemmon, AZ	35	9025	0.00	325	2400	0
Mt. Wilson, CA	38	5715	0.00	29	3000	1
Nacimiento Reservoir, CA	9	807	5740.80	16	2000	2
Navajo Lake, NM	58	6093	10112.00	605	2800	0
Panguitch Lake, UT	65	8222	1139.20	410	3200	0
Paranal, Chile	14	8908	0.00	7	3800	1
Pathfinder Reservoir, WY	67	5860	21145.60	875	2200	0
Perris Reservoir, CA - Island	27	1769	2393.60	41	2800	2
Pic Du Midi, FR	5	9386	0.00	130	2500	0
Pine Flat Reservoir, CA	15	958	5600.00	130	2800	0
Pyramid Lake, NV - Island	54	4139	109830.40	215	3200	0
San Antonio Reservoir, CA	39	787	5273.60	18	2000	2
San Carlos lake, AZ	29	2503	9670.40	370	2600	0
San Pedro Mátir, MX	7	9284	0.00	37	2600	2
San Vicente Reservoir, CA - Island	59	656	1203.20	20	2800	1
Santa Rosa Lake, NM	49	4726	11622.40	725	2800	0
Seminoe Reservoir, WY	41	6371	16678.40	880	2200	0
Sierra La Laguna, Baja	72	7500	0.00	18	2500	3

Table 1. Sites Evaluated Science Criteria (cont.).

Site Name	ID	Elevation (ft)	Lake area (Acres)	Shortest Distance to Ocean	Annual Sunshine Hours	Number of Ocean Sides (<100 miles away)
Silverwood Lake, CA	11	3383	889.60	58	2800	1
Strawberry Reservoir, UT - Island	44	7657	13280.00	620	3000	0
Sunspot, NM (Sacramento Peak) ***(Site Name updated for FEIS)***	18	9223	0.00	570	2200	0
Teide, Canaries	23	7858	0.00	8	2600	4
Theodore Roosevelt Lake, AZ	66	2100	12450.50	350	3200	0
Utah Lake, UT	13	4488	84294.40	580	3000	0
Walker Lake, NV	34	3970	35532.80	210	3200	0
White Mountain, CA	6	11327	0.00	160	2000	0

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APPENDIX J(2)

PROPOSED ATST PROJECT AND ALTERNATIVES: SUPPLEMENTAL DISCUSSION OF THE CONSTRAINTS OF SOLAR SCIENCE DEVELOPMENT

Why Solar Science?

Hale's discovery in 1908, that magnetic fields permeate sunspots started a revolution that turned solar science into a field encompassing, and often advancing, many branches of physics. In particular, much of our solar research now involves magnetohydrodynamics (MHD), the study of plasmas (electrically conductive gases) whose shapes and flows are influenced by magnetic fields.

Sunspots, it turns out, are the best-known manifestations of large magnetic systems found in the outer third or so of the Sun. The source of the Sun's energy, hydrogen fusion, occurs only in the core. The remainder of the Sun is a massive blanket serving two functions. First, it compresses the core to keep fusion going; and second, it moderates the flow of energy from the core into space. The outer region of the blanket is the convective zone where giant gas cells circulate like water in a boiling pot, bringing heat to the surface. At the same time, solar rotation moves the cells around the Sun, somewhat like massive weather systems. Because the gas is electrically conductive, this motion produces a series of massive dynamos generating magnetic fields that stretch and shear, disconnect and reconnect.

The strength of the Earth's magnetic field is about 0.5 gauss. A simple bar magnet has a field of about 3,000 gauss, but it drops sharply with distance, and is almost undetectable a few feet away. The magnetic fields inside sunspots range upwards to 4,000 gauss and span a volume several times larger than Earth. This means sunspots are produced by immensely, powerful dynamos.

Magnetic activities below the photosphere are hidden from view because the gas is optically dense: atomic particles are so tightly packed that photons — from gamma rays down to radio waves — are absorbed almost as soon as they are emitted. If not for this, the Sun would rapidly cool. When the gas density drops, light can travel freely and it forms what we see as the visible "surface" of the Sun, the photosphere. Here twisted magnetic fields loop out of the convective zone, into space and back to form an array of features, including sunspots, plages, filaments, and prominences. Magnetic fields reach through the overlying chromosphere and into the corona where they can become unstable and trigger coronal mass ejections, or simply open into interplanetary space. When massive fields pierce the visible surface they often form darkened areas — sunspots — where the magnetic field keeps hot gas from rising from the interior.

All these affect life on Earth. The 11-year sunspot cycle (actually part of a 22-year magnetic cycle) is one of the better-known phenomena. But the various forces that drive the cycle, and determine its intensity and its relationship with conditions around and on Earth, remain poorly understood. Historical evidence indicates that changes in the sunspot cycle impact Earth's climate, although modulated by terrestrial events such as volcanoes. While a number of instruments monitor the Sun's total output, advanced instruments like the Proposed Action are needed so scientists may unravel fundamental drivers that determine that output.

Criteria for ATST Science

The Proposed Action would primarily study the outer layers of the Sun's atmosphere – the photosphere, chromosphere, and corona (the inner workings are inferred from oscillations in the photosphere). All the matter and energy that reach Earth from the Sun have to travel through these regions, which display a dazzling and intriguing array of scientific behaviors that allow us to infer what is happening inside. The Proposed Action's enhanced resolution in space, time, and wavelength would let scientists see what lies beyond the reach of current telescopes. Further, this capability would extend our understanding into the thermal infrared spectrum, thus providing deeper insight into the solar atmosphere.

The solar atmosphere provides an ideal laboratory to study the dynamic interaction of magnetic fields and plasma. Beginning with the generation of the magnetic fields themselves and their cyclic behavior, the Proposed Action would observe the small-scale processes at the solar surface that play a critical role in understanding the overall sunspot cycle. The Proposed Action would contribute to understanding magnetic flux emergence through the turbulent boundary between the solar interior and atmosphere. The Proposed Action would reveal the nature of solar flux tubes, which are generally believed to be the fundamental building blocks of magnetic structure in the atmosphere and the progenitors of solar activity. The capabilities of the Proposed Action would observe the interaction of flux tubes with convective motions and waves and would determine how energy is transferred from turbulent gas motions to the magnetic field.

By exploiting the broad spectral coverage planned for the Proposed Action, we could observe how these processes can vary with height and measure their role in determining the structure, dynamics, and heating of the chromosphere and the corona. The near-IR spectrum at wavelengths around 1,500 nanometer (1 nanometer = 1 billionth of a meter) has many advantages particularly for precise measurements of the recently discovered weak, small-scale magnetic fields that cover the entire solar surface and which could be the signature of local dynamo action. A 4-meter aperture is needed to clearly resolve these features at 0.1 arc-seconds in the near-infrared. Furthermore, the infrared at wavelengths longer than 1,500 nanometer provides particularly powerful diagnostics of magnetic field, temperature, and velocity at the upper layers of the solar atmosphere. The Proposed Action's infrared capabilities would be used to measure the cool chromospheric component and provide critically needed measurements of coronal magnetic fields. The dynamics and heating of these outer layers of the solar atmosphere in turn result in the violent flux expulsions we see as flares and mass ejections. All of these processes are tied together by the behavior of magnetic flux in the dynamic plasma at the solar surface. The Proposed Action would also impact other areas of astrophysics, space science, and plasma physics and would provide input data needed to refine space weather models.

Criteria and Alternatives Selection

In compliance with the provisions of Title 11, Department of Health, Chapter 200, Environmental Impact Statement Rules, Section 11-200-17(f), the following is a discussion of the alternatives to the use of the site for the Proposed Action.

In order to explain why there are no reasonable alternatives to siting the Proposed Action at sites other than at HO, it is first necessary to describe the general principles that governed the process by which numerous alternatives were considered, and to discuss some of the potential alternatives that were unsuitable.

It is incontrovertible that daytime seeing is inferior to nighttime seeing. During the night, the ground and atmosphere quickly reach thermal equilibrium, creating a stable temperature gradient with temperature decreasing with increasing height. This suppresses turbulent convection near the ground, and leaves high-altitude turbulence as the dominant contributor to nighttime seeing. The high-altitude turbulence arises mainly from the inversion of the temperature gradient in the tropopause at 20 kilometers, and the behavior of the zonal jet stream winds.

Daytime seeing is dominated by the conditions in the ground boundary layer which can be as thick as 100 meters. As the ground heats in the sunlight, it quickly becomes hotter than the atmosphere immediately above it. This initiates turbulent convection resulting in thermal fluctuations that cause random changes in the index of refraction of the atmosphere. For comparison of seeing conditions between sites, a measure called the Fried parameter (symbolized r_0) is often used, which corresponds to the diameter of a circular telescope aperture at which atmospheric turbulence begins to seriously limit image resolution. An r_0 value of 10 centimeters for a given site would mean that the best possible resolution of a telescope at that site would be about the same as given by a space-based 10 centimeters telescope. To give a sense of the difference between daytime and nighttime conditions, r_0, is rarely larger than 15 centimeters during the day, while it frequently reaches 30 centimeters at night at the best astronomical seeing sites.

Since ground effects dominate daytime seeing, solar astronomers have naturally come to recognize that processes that reduce the turbulent convection should improve daytime seeing. These processes essentially need to alter the local temperature gradient from convectively unstable to convectively stable. The two major phenomena that can do this on large spatial scales are wind and the presence of water. Wind can substantially alter convective stability by the pressure-driven advection of the atmosphere. Water has higher heat conductivity than soil and rock and allows the rapid redistribution of heat via fluid motions. These two effects result in the near equality of the surface temperature of a body of water and the atmosphere immediately above it, driving the air temperature conditions towards stability. Thus, the two basic assumptions of daytime seeing are that "*water is good*" and "*wind is good*".

Naturally, things are not so simple. Water may be good, but how much water (i.e., how deep and how wide)? What is the optimal spatial relationship between the water and the telescope? How does the presence of water affect the infrared (IR) performance of the telescope? Similar questions arise about the wind: How fast? From which direction? A smooth laminar wind flow is better than a turbulent flow because turbulence degrades seeing. This brings the local topography of the site into the picture. While many landforms create turbulent winds, are there some that are conducive to creating a laminar flow?

In addition to water and wind, it has been noted that uniform thin overcast sky conditions frequently result in superb seeing with a significantly higher scattered light background. This beneficial seeing effect probably results from a higher lateral temperature conductivity created by the water vapor or dust in the overcast layer. The higher conductivity would damp out lateral temperature fluctuations, thereby reducing turbulence and improving the seeing.

Using these considerations, supplemented with observing experience, solar astronomers have postulated a number of common-sense guidelines to estimate the potential daytime seeing at a site. Some of these views can be summarized as follows (Ref. *Environmental Factors Affecting Solar Seeing.)*:

1. Water: Lakes are good. Nearby ocean is good.
2. Wind: Laminar wind near ground is good. High-latitude jet stream is bad.
3. Topography: Good to limit turbulence by being in a topographic "wind duct" to channel wind smoothly over the site. Terrain "roughness" in prevailing wind direction should be low to reduce turbulence. Urban or desert heat plumes are bad.
4. Other: High thin overcast is good.
5. Uncertain: Presence of trees, elevation of site.

In order to apply these principles and to evaluate the empirical data collected to characterize the candidate sites, the ATST Site Survey Working Group (SSWG), representing scientists from all over the world with a broad spectrum of disciplines, was formed. The first task for the SSWG was to oversee the development and construction of instrumentation to measure daytime solar seeing, sky brightness, clear time fraction, dust levels, and water vapor content.

The site survey for the Proposed Action for the remaining six sites was conducted by placing a set of identical instruments to measure the daytime seeing and the weather, with a variety of topographical, meteorological, and environmental characteristics. The instrumentation included:

1. Solar Dual Image Motion Monitor to measure differential motion of the solar image (caused by atmospheric motion) and to derive the Fried parameter (a measure of seeing distortions);
2. A Shadow Band Array and Ranger to estimate turbulence several hundred meters above the site;
3. A coronal photometer to determine sky brightness that would compete with the faint corona; and,
4. Dust and water vapor monitors to measure dust accumulation on optics and humidity that may impact infrared observations.

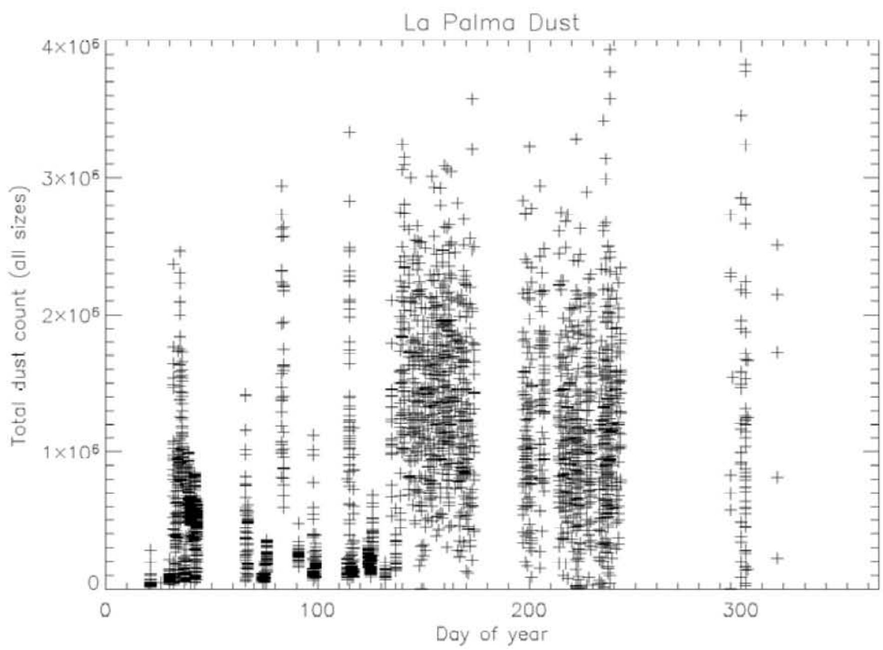
These instruments were mounted on a 6-meter (19.7-foot) tall test stand, and were supplemented by a weather station, a two-point temperature gradient measurement, a sky brightness monitor, and a water vapor meter. When the ATST site survey data became available, the correlations among several variables were investigated. The two goals were to either confirm or disprove the common-sense solar seeing guidelines and to identify the best and most easily measured proxies for excellent daytime seeing.

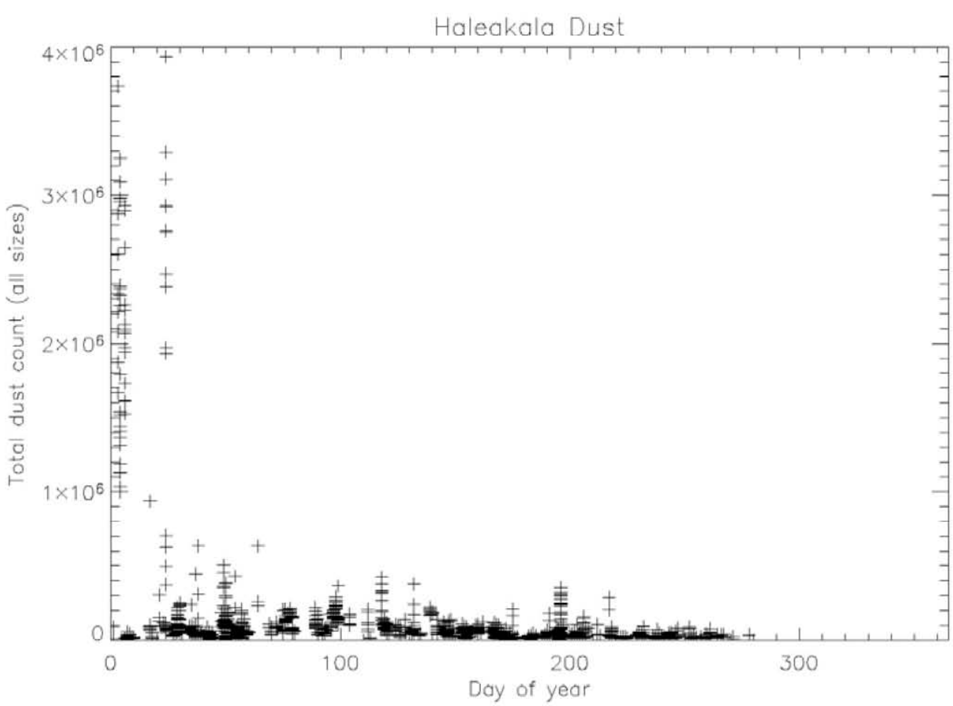
Site testing was conducted for between six months and one year at the six remaining sites. A meeting of the ATST Science Working Group in November 2003 resulted in the recommendation that testing be continued only at the top group of sites: Big Bear, CA; Haleakalā, HI; and, La Palma, Spain. Thus, an additional year of data and additional testing was completed at these three sites to determine which site would fulfill the scientific requirement goals for the Proposed Action. Those goals are:

1. Clear daytime fraction of 70 percent, 3,000 hours annual sunshine.
2. 1,800 annual hours with r_0 (a measure of seeing) >7 cm (at 500 nm, measured at the telescope aperture), including at least 100 continuous 2-hour periods.
3. 200 annual hours with r_0 (500 nanometers) >12 centimeters (measured at the telescope aperture) including at least 10 continuous 4-hour periods.
4. Large isoplanatic angle. In other words, good atmospheric conditions at high altitudes.
5. 480 annual hours with a sky brightness less than or equal to 25 ± 10 millionths at 1.1 radii at 1 μ with a radial profile equal to or steeper than $R^{-0.8}$, including at least 40 continuous 4-hour periods.
6. 600 annual hours with the precipitible water vapor below 5 mm, including at least 40 continuous 4-hour periods.

APPENDIX J(3)

PROPOSED ATST PROJECT AND ALTERNATIVES: HALEAKALĀ vs. LA PALMA DUST COMPARISON





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APPENDIX J(4)

PROPOSED ATST PROJECT AND ALTERNATIVES: SUPPLEMENTAL DESCRIPTION OF ATST EQUIPMENT AND INFRASTRUCTURE

Telescope and Instruments

The proposed ATST Project would include a reflecting Gregorian-type telescope that would deliver images of the sun and the solar corona to instrument stations at the side of the telescope and on a rotating platform below the telescope. The basic telescope design (Fig. 1) is unique in a number of ways. The description in this document concentrates on the aspects of the telescope that are most relevant to the environmental impact analysis, specifically, those factors that determine the dimensions, appearance and operational requirements of the overall proposed facility. More information about the telescope design is available on the project web site http://atst.nso.edu/.

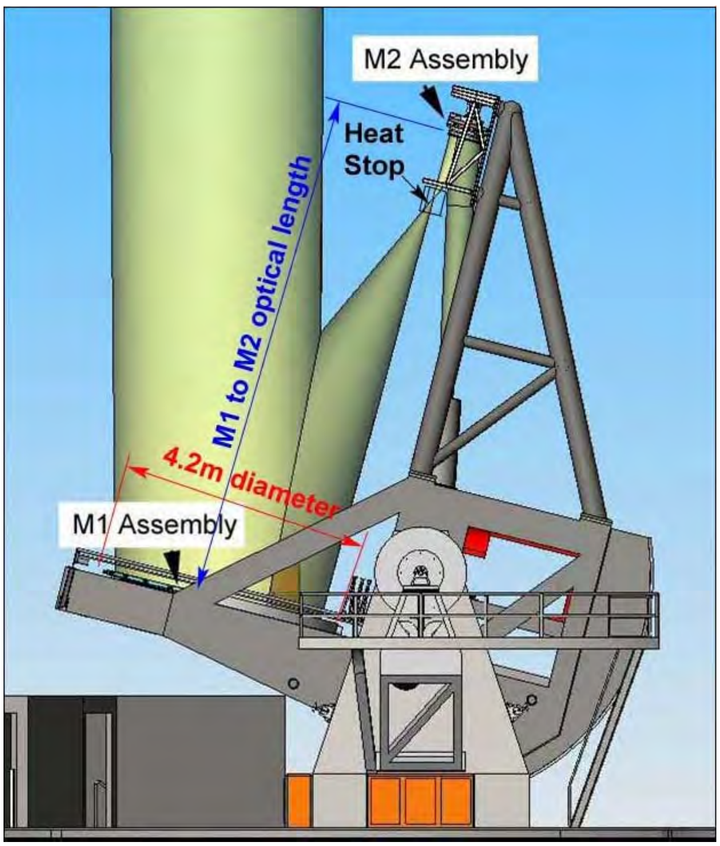

Figure 1. Basic Telescope Design.

To achieve the image resolution dictated by the science requirements, the primary light-collecting mirror (M1) of the telescope would require a minimum clear aperture diameter of 4 meters. This is dictated by the fundamental relationship between the maximum dimension of the light-collecting aperture, the frequency of the light to be observed and the angular resolution that can be achieved. This 4 meter primary aperture would be more than two times larger than that of any existing solar telescope and effectively increases the overall telescope proportions by a similar factor. Further increasing the size of the telescope would be the placement of M1 in an off-axis configuration. This feature would allow sunlight to reach the M1 surface without being blocked or scattered by the support structure and optics mounted above it. The light reflecting off of M1 converges to a prime focus where it passes through a heat stop device that prevents the majority of unwanted heat and light from reaching the subsequent optical elements. On the other side of the heat stop, at the top end of the telescope mount structure, would be a secondary mirror (M2) that would reflect the light vertically downward through the central axis of the telescope where other mirrors direct it to the instrument stations. The distance in front of M1 where the heat stop and M2 would be mounted is determined by the focal length of M1. This focal length is in turn dictated by image resolution requirements and by manufacturing limitations on how precisely the surface of M1 can be shaped. The distance between M1 and M2 (the overall length of the telescope mount), together with the M1 diameter and off-axis mounting, would effectively establish the swing radius and the required height of the telescope (in altitude and azimuth) and the size of the enclosure required to protect it (Fig. 2).

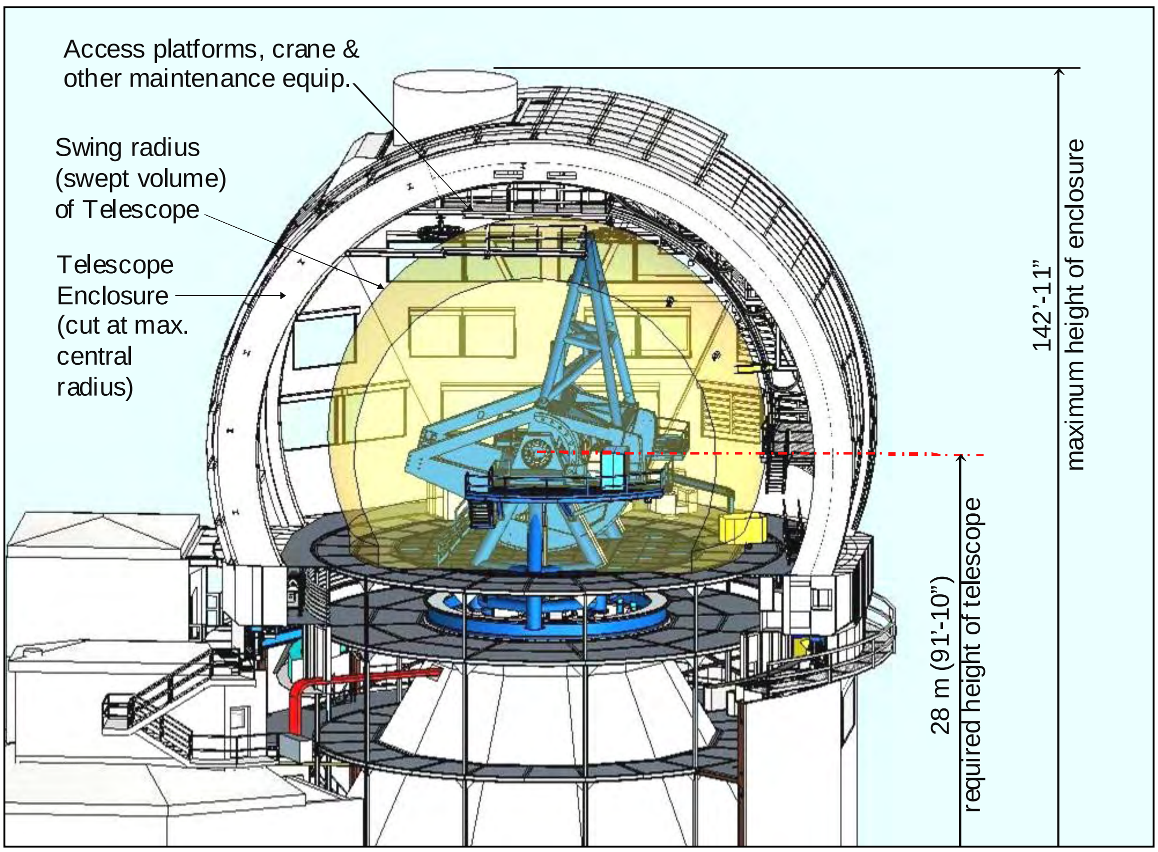

Figure 2. Swept Clearance Radius of Telescope.

The height of the telescope above the ground and the resultant overall height of the enclosure would be determined by factors inherent to the site. The scientific necessity for clear weather and for low levels of sky brightness, dust, and water vapor were key factors in identifying Haleakalā as the optimal site for the proposed ATST Project. At this site, the achievable image resolution is strongly dependent on the height above the ground, as depicted in Figure 3. This is due to a layer of thermal turbulence close to the ground that is caused by the heating of air that comes in contact with the warm dark ground surface. The rising of the heated air causes uneven refraction of light passing through it, which results in the blurring of images formed by that light. With increased height, less of that thermal turbulence and image blurring occurs. Following the selection of the Haleakalā site, the proposed height of the telescope was established to be 28 meters (92 feet), as represented by the intersection of the dotted lines in Figure 3. This was determined to be the minimum height at which the image resolution required to meet the specified science goals could be achieved.

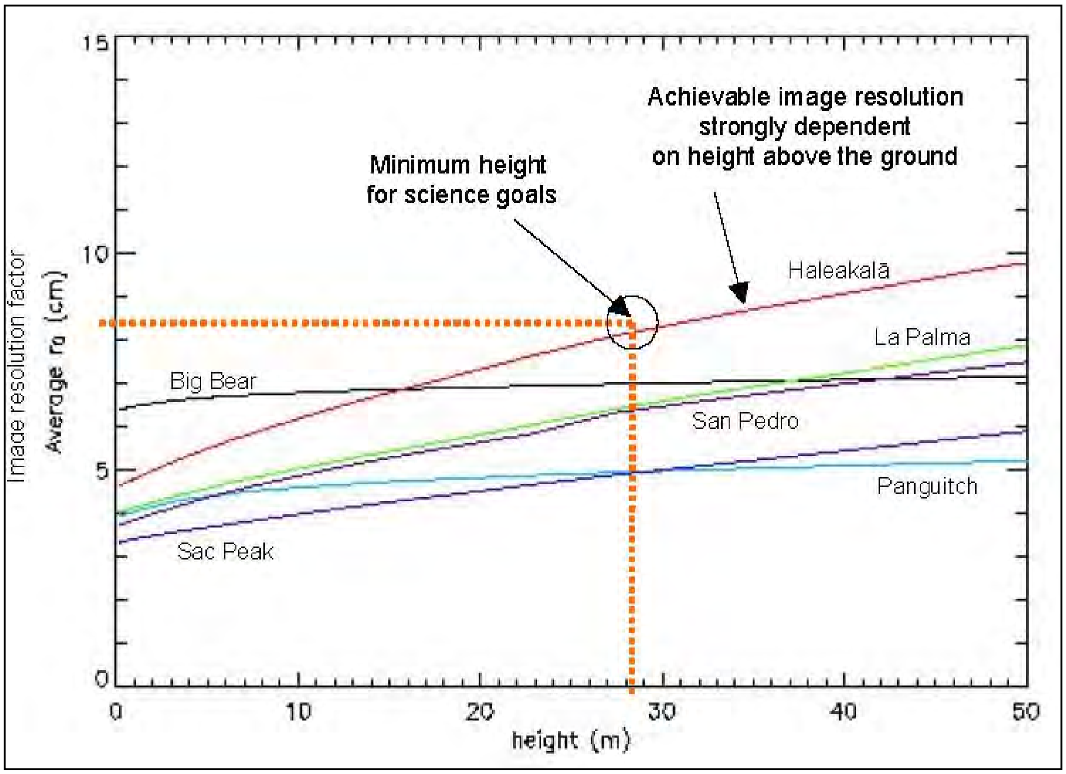

Figure 3. Image Resolution vs. Height Above Ground (for six sites previously considered).

The sunlight collected by the telescope would be focused and directed by a series of mirrors to scientific instruments located either at the sides of the telescope (Nasmyth stations) or on a rotating floor below the telescope (coudé platform) as depicted in Figure 4. These would be either facility or visitor instruments that would be installed in the future by visiting observers. The facility instruments include a visible-light broadband imager, filters, and a set of instruments for spectral and polarization-state analysis in a range of visible and infrared (IR) wavelengths. The defined maximum dimensional envelope for all ATST instruments (5 meters long, 2.4 meters wide, 2.4 meters high) would be large compared to existing solar observing equipment. To accommodate these instruments, the rotating coudé platform, where most of them would be located, requires a diameter of 16.6 meters. This dimension dictates the diameter of the base of the telescope pier, inside which the coudé platform would be located.

The control dimensions for the proposed site location of the center of the telescope pier are as shown in Figure 5. This point also establishes the center of the telescope enclosure and the relative location of the Support and Operations Building, which is attached to the west side of the enclosure.

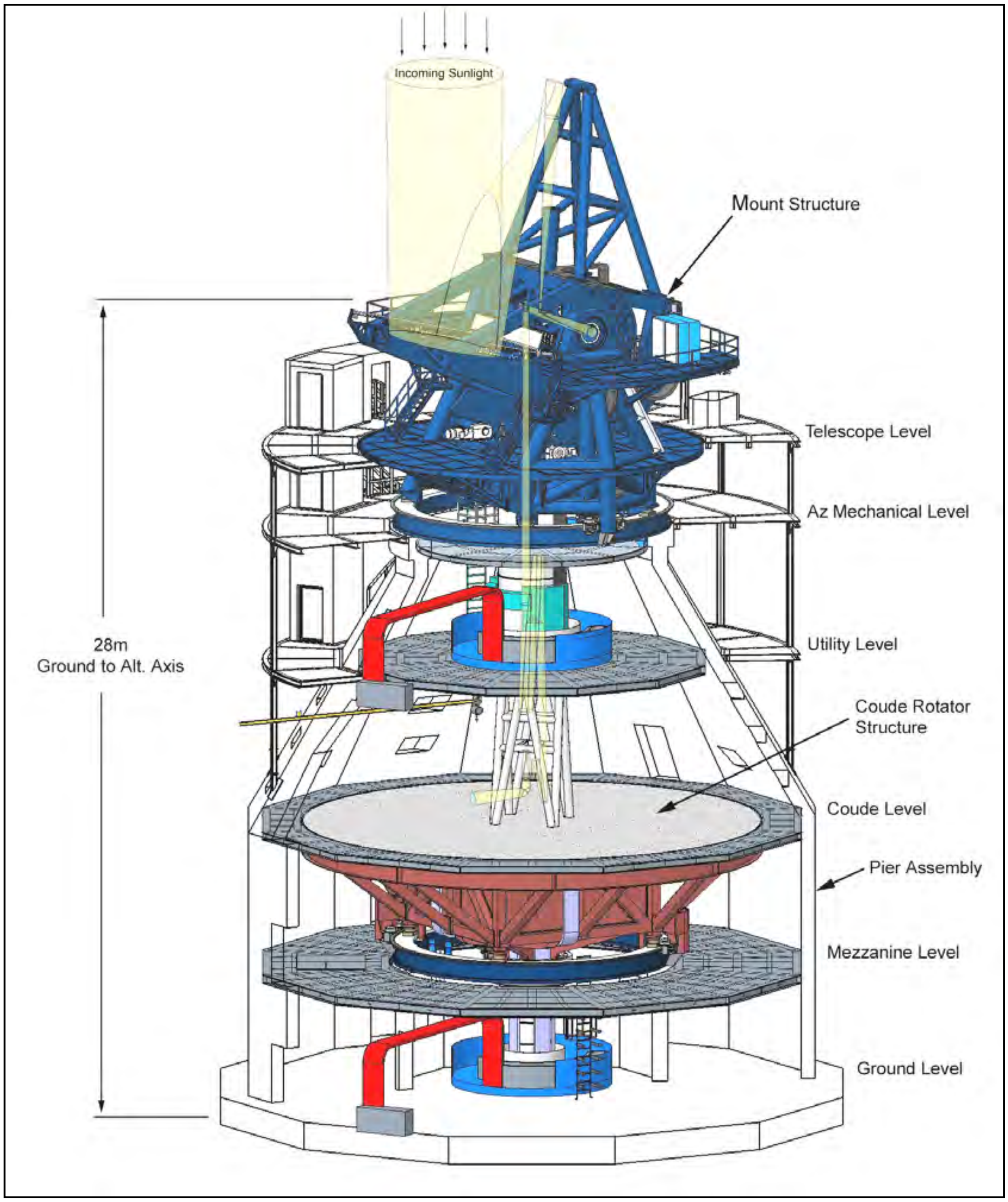

Figure 4. Telescope, Coudé Platform and Pier.

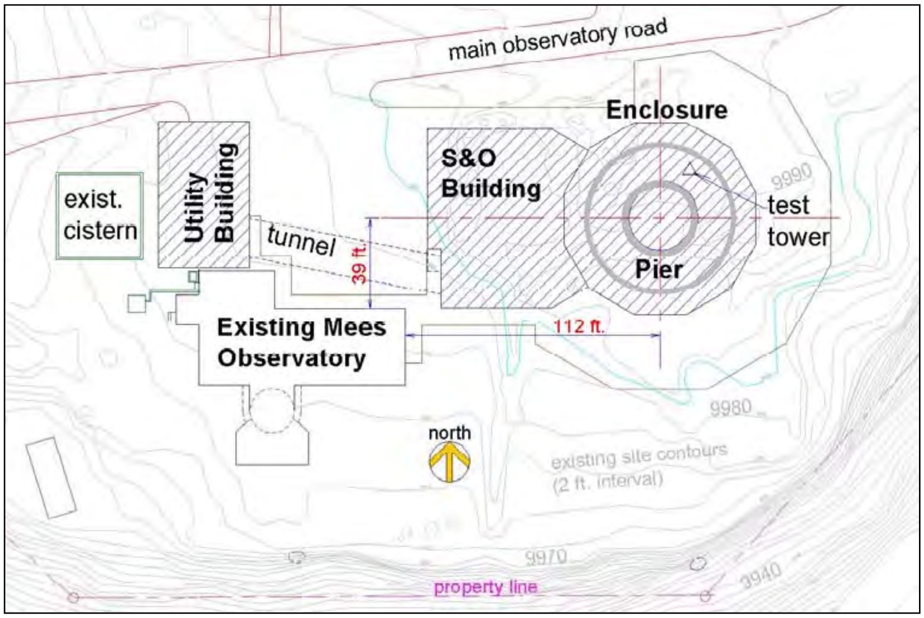

Figure 5. Location of Control Dimensions at Preferred Primary Mees Site.

Telescope Enclosure

The telescope enclosure (Fig. 6) was designed to meet the following basic requirements:

1. Protect the telescope from inclement weather;
2. Provide an observing aperture that tracks with the pointing of the telescope;
3. Provide sufficient space and facilities for maintenance of the telescope and related equipment;
4. Shade all parts of the telescope except the primary mirror from direct solar exposure; and,
5. Minimize the impact of the enclosure itself ("dome seeing") on the performance of the telescope.

The angular wedge-shape of the upper rotating enclosure (carousel), which is 87 feet 6 inches (26.67 meters) in maximum diameter is designed to minimize the amount of surface that is directly facing the sun during observing. The openings (vent gates) on the sides of the carousel allow natural flow-through ventilation around the telescope. The awnings (sun shades) over these openings prevent direct sunlight from striking the telescope or any other interior surfaces. The carousel rotates to track the sun in azimuth. The curved shutter panels that cover the center section of the carousel rotate up or down to track the sun in altitude by pointing the entrance aperture at varying angles. The projection (shown pointing upward) at the top of the shutter panels is a cylindrical entrance aperture tube (Fig. 7) that shields the aperture from the air turbulence immediately around the enclosure surface.

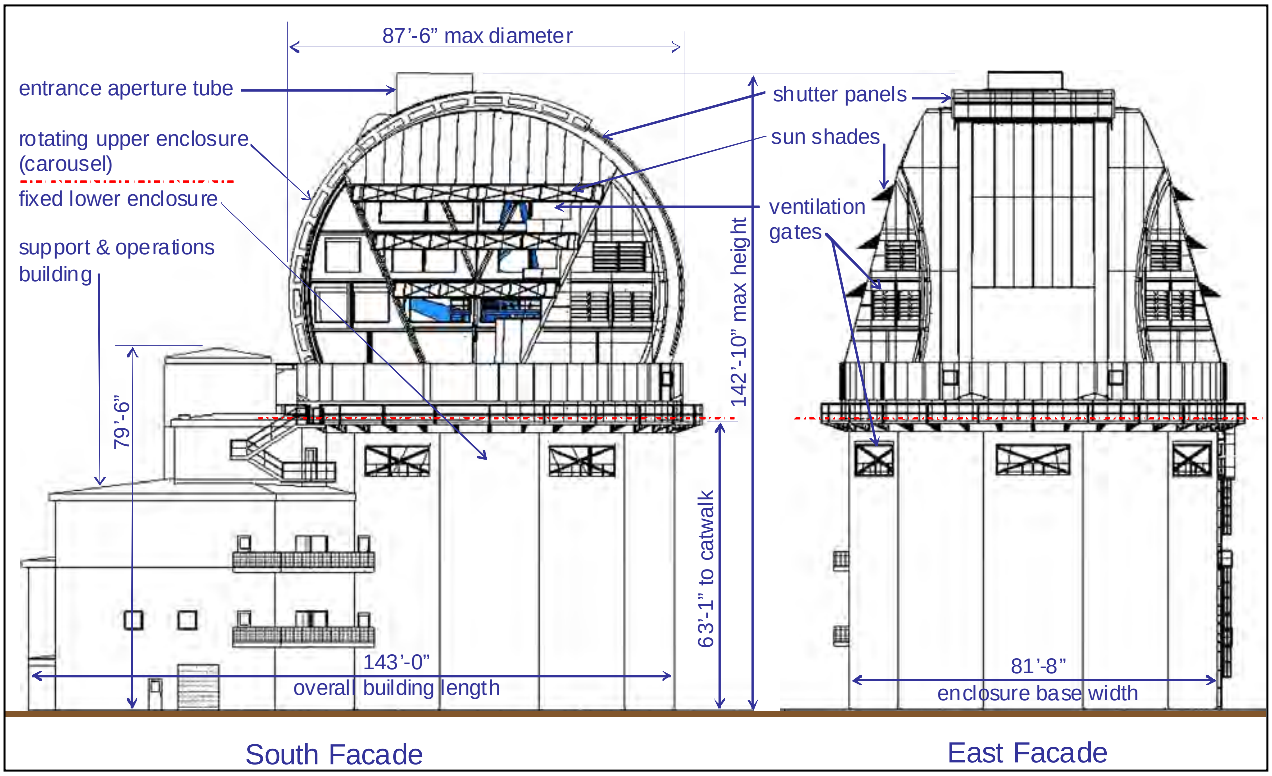

Figure 6. Telescope Enclosure.

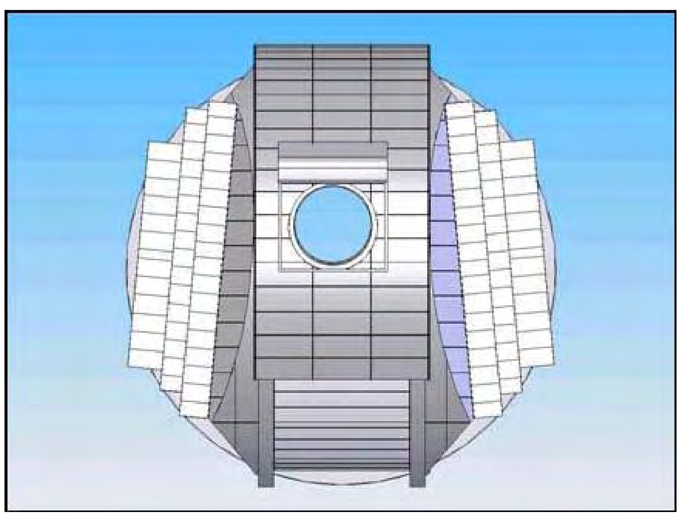

Figure 7. Top View of Enclosure Showing Cylindrical Entrance Aperture Tube.

A maximum height for the enclosure of 43.5 meters (142 feet 8 inches) was determined, by placing the telescope above the thermal turbulence close to the ground, and by providing sufficient clearance within the enclosure for the swing radius of the telescope.

The stability and uniformity of the air temperature in and around the enclosure is extremely critical. The proposed ATST Project is an open-air telescope, in that the light beam does not pass through a vacuum chamber or other temperature-stable media, as is the case for many other solar telescopes. For the required 4-meter diameter aperture, a large enough window into a sealed chamber light path is not feasible. The open-air light path coupled with the high-resolution requirements, imposes a tight tolerance on the variation in the temperature of the air through which the light beam passes. This applies not only to the air around the telescope (inside the enclosure), but also to the air immediately around the outside of the enclosure that could be heated or cooled by contact with its surface. For this reason, all exposed surfaces of the enclosure are designed to absorb a minimum amount of heat during the solar exposure of an observing day. In addition, critical areas of the enclosure surface that are close to the aperture or are subject to higher heat absorption require active cooling to stay within the temperature tolerance.

Computer modeling has been done to compare the thermal performance of different colors of surface coatings. This study has also quantified the extent of cooling required for the surfaces of the enclosure, and explored alternative passive and active methods to keep the enclosure surface temperatures within an acceptable range.

Figure 8 shows a comparison of the thermal modeling of a white-colored coating (figure on the left) on the enclosure versus a brown coating (figure on the right) selected to match the natural color of the volcanic soil on Haleakalā. The colors in the images range from blue (cool) to red (hot). The dark maroon color in the image on the right indicates an induced temperature that was hotter than the maximum allowed by the model parameters. The thermal modeling also generated a numerical summary of the solar-induced heat load.

The numerical summary of the total heat load indicates that the white dome absorbs 250.2 kilowatts of heat, while the brown dome under the same solar exposure absorbs 1,023.4 kilowatts. This means that maintaining the surfaces of a brown enclosure within the acceptable temperature range would require roughly four times as much cooling and electrical power as would be required for a white dome. Other colors were also considered, and in every case there is a significantly higher heat load with coatings other than white. Within the range of available white coatings a number of products have been identified. The proposed coating for the most critical surface areas of the enclosure is AZJ-4020 white epoxy thermal-control coating manufactured by AZ Technology. The remainder of the enclosure surface would be coated with Energy Seal Acu-Shield, a white acrylic elastomeric coating manufactured by Advanced Coating Systems, Inc. Further thermal modeling will be done for other available low-emissivity/low-absorptivity coatings to optimize the coating selection for the upper and lower sections of the enclosure. However, from the modeling to date, it is evident that to affordably achieve the temperature control requirements, the surface of the enclosure essentially needs to be white.

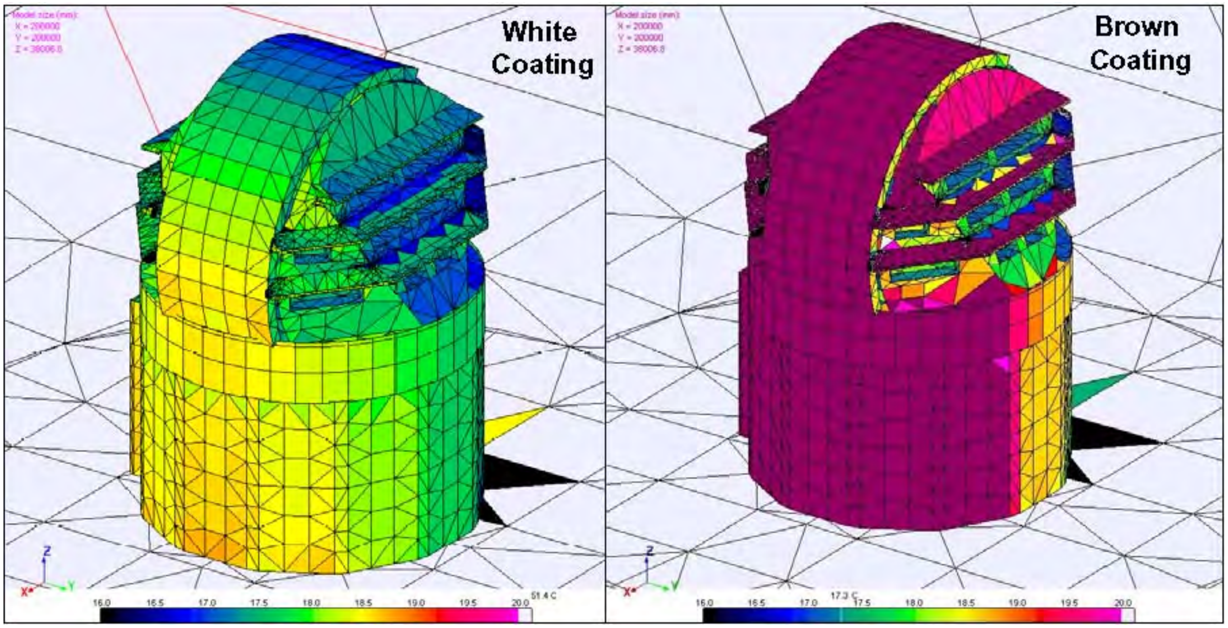

Figure 8. Thermal Modeling of Enclosure Based on Mid-day Exposure Conditions.

The proposed cooling strategies for the carousel (upper section) and for the lower enclosure are different. The surface of the carousel is close to the observing aperture, so the allowable surface temperature tolerance is critical to the imaging performance of the telescope. The derived requirement dictates that the surface of the carousel be maintained in a range from +0° C to -4° C of the current adjacent ambient air temperature. This need to maintain the carousel surface temperature at or just below ambient temperature, combined with the wide range of heat load conditions that occur over its surface, demands a high-capacity cooling system with a fast response time. The proposed method for cooling the carousel is to cover all surfaces which receive insolation (absorbed sunlight) with plate-coil heat exchangers.

Plate-coil is a commercially available product (Fig. 9), which is made up of two sheets of metal separated by a space through which a liquid coolant flows. For the proposed ATST Project, the plate-coil would be manufactured into custom-shaped panels to match the carousel contours and the specified (white) coating would be factory applied. The arrangement and extent of the plate-coil panels is approximately as shown by the rectilinear pattern of lines on the carousel in Figure 10. The proposed heat transfer fluid coolant for this system is a solution of water and propylene glycol (or some other antifreeze agent), which would be cooled by a chiller located in a remote utility building. The heat transfer fluid would be pumped through the plate-coil via a system of supply and return piping equipped with a series of valves to regulate the flow. There would be leak detection sensors and shut-off valves to stop the fluid flow of coolant in the event of a leak.

Figure 9. Sample Plate-coil Heat Exchangers.

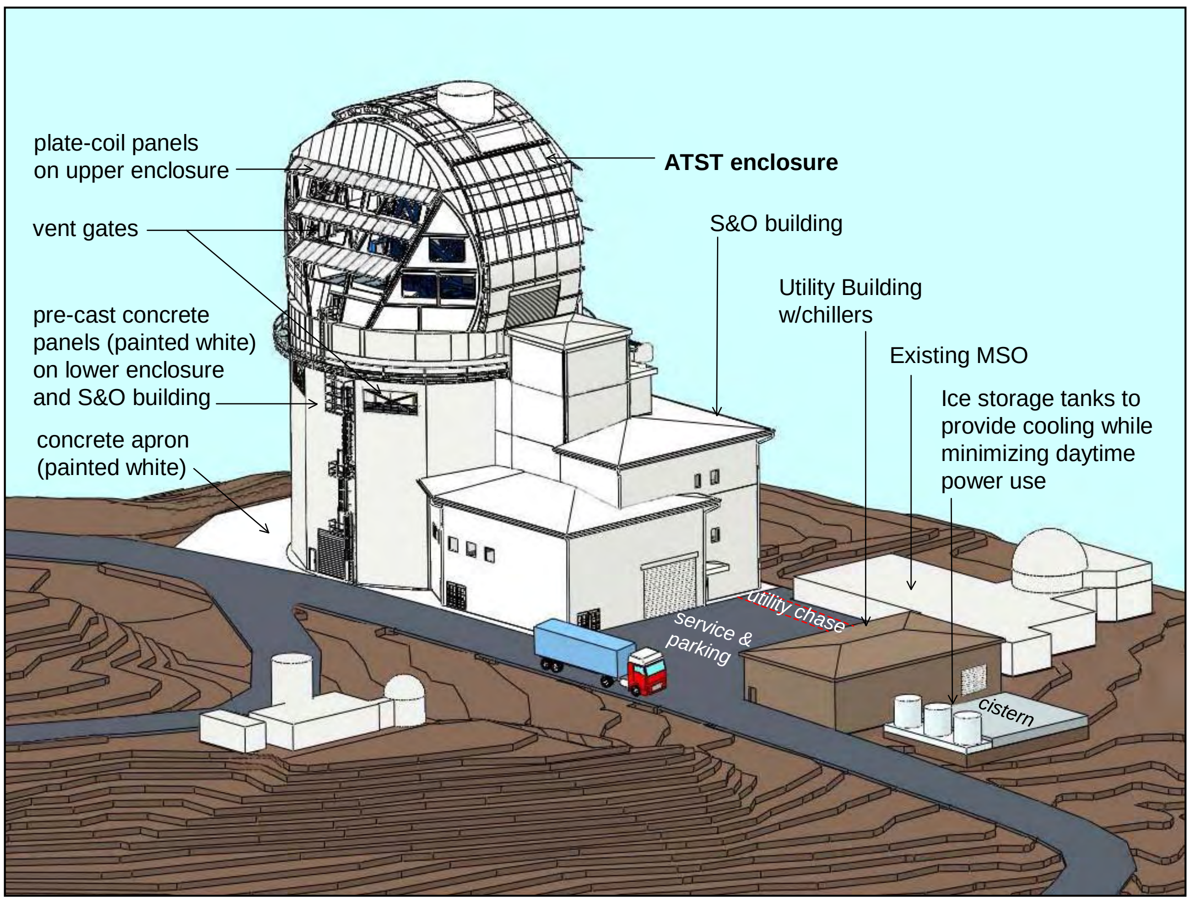

Figure 10. Plate-coil Panels and Other Enclosure Cooling Strategies.

For the lower enclosure, the derived requirement for allowable surface temperature would be +/- 1.5° C of the current ambient air temperature. The latitude to allow its temperature to rise slightly above ambient and the relative uniformity of its heat load would allow the lower enclosure to be cooled with a less expensive and more passive method than the carousel. The lower enclosure would be constructed of 6-inch thick pre-cast concrete panels, which would naturally cool down at night. The thermal mass of the concrete would then keep the surface of the panels cool enough to not require any active cooling during the critical daytime observing period. This passive approach to cooling the lower enclosure is an improvement on the design that was presented in the Draft EIS. By eliminating remote exhaust fans and a ventilation tunnel, it allows for less electrical power use, less equipment noise, and less excavation.

In addition to direct sunlight, heat radiating up from the dark volcanic rock around the enclosure is shown by thermal modeling to be a significant contributor to the heat load on the enclosure surfaces. A simple passive approach is proposed to significantly reduce this heat source. A ground-level concrete apron extending 10 meters (32 feet 10 inches) out from the base of the enclosure would reduce the incident heat on the lower enclosure by approximately 40 percent. This ring of concrete would be painted with a white sealant and would incorporate a trench drain to allow it to serve as a back-up containment method for any potential coolant leakage from the carousel above.

Support and Operations (S&O) Building

The proposed S&O Building (Fig. 11) would be a multi-story structure attached to the lower enclosure, which accommodates observing-related activities that require direct adjacency to the telescope. This building would also provide space for equipment that has to be close to the telescope for reasons of robust rapid data transmission, utility run length, or minimizing transport of critical assemblies. The building would be a steel frame structure with standard manufactured metal siding and roofing. Because of its proximity to the telescope, all exterior surfaces would be painted with the manufacturer’s standard white coating to minimize thermal heat absorption.

The S&O Building would consist of the following levels and spaces:

1. **Ground Floor (lowest level):** Receiving area, mirror coating area, mechanical equipment area, restroom and other ancillary spaces.
2. **Mezzanine (second level):** Offices, open workstation area, personnel break area, restroom.
3. **Coudé (third level):** Control room, computer room, instrument preparation lab, and restroom. This level would be directly adjacent to the rotating coudé platform inside the telescope pier and would be the principle work area of the observatory.
4. **Utility (fourth level):** This would be the highest level of the S&O Building and would only serve to provide access to the upper levels of the telescope enclosure.

The key areas in each of the levels of the proposed S&O Building and their most significant design parameters are further described below.

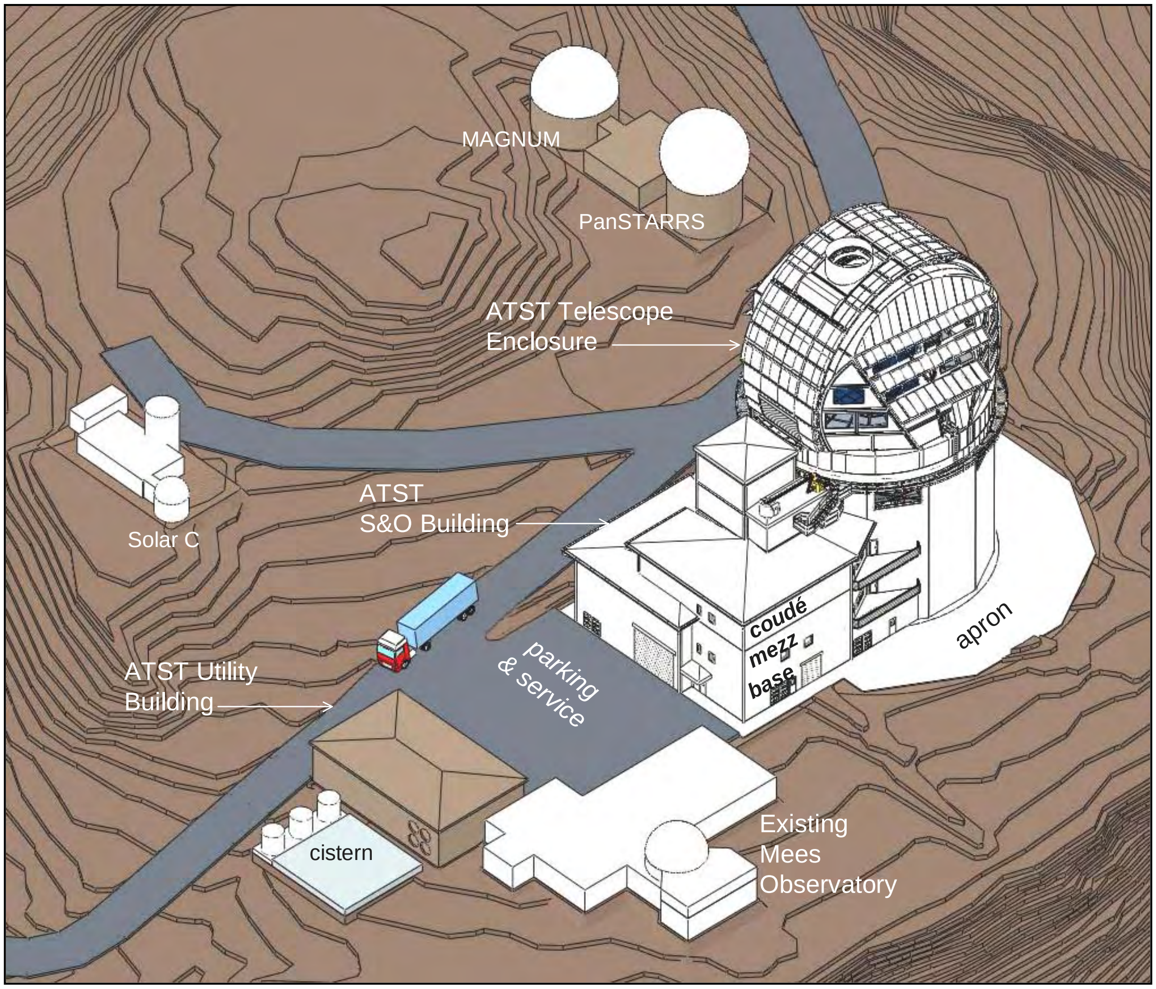

Figure 11. Support & Operations Building.

Ground Level (lowest level)

At the ground level (Fig. 12), a large high-bay receiving area would be required to accommodate handling of large assemblies including: the primary mirror and its support cell, observing instruments, subassemblies of the telescope mount and enclosure, and other observatory equipment. Operations here would include loading, unloading, assembly, disassembly, staging for installation, and transfer of materials onto the platform lift. A 20-ton bridge crane and a large vehicular door opening into the main service area would be required.

Adjacent to the receiving area, a dedicated space would be required for preparation of recoating the primary mirror, which would be necessary approximately every two years. This operation would involve special procedures and equipment for mirror handling and for capturing the effluent from the mirror stripping/washing process. The floor of this area would have a series of gutters and drains to capture the effluent and to convey it to an underground tank. Tanks for deionized water and liquid nitrogen, and a compressor for an air knife drying apparatus would be located in an adjacent exterior area.

A separate room would be required to house mechanical equipment that requires proximity to the telescope but needs to be isolated for sound, vibration, and thermal control. A preliminary list of this equipment includes: a hydrostatic oil pump for the azimuth bearings of the telescope and coudé platform, hydrostatic oil tank, helium compressor for cooling of instruments, and liquid nitrogen tanks. An underground utility chase would connect this mechanical room to the Utility Building.

Fans between the base of the lower enclosure and the ground level of the S&O Building would allow air to be exhausted from the enclosure through a series of sound protected louvers in the exterior walls.

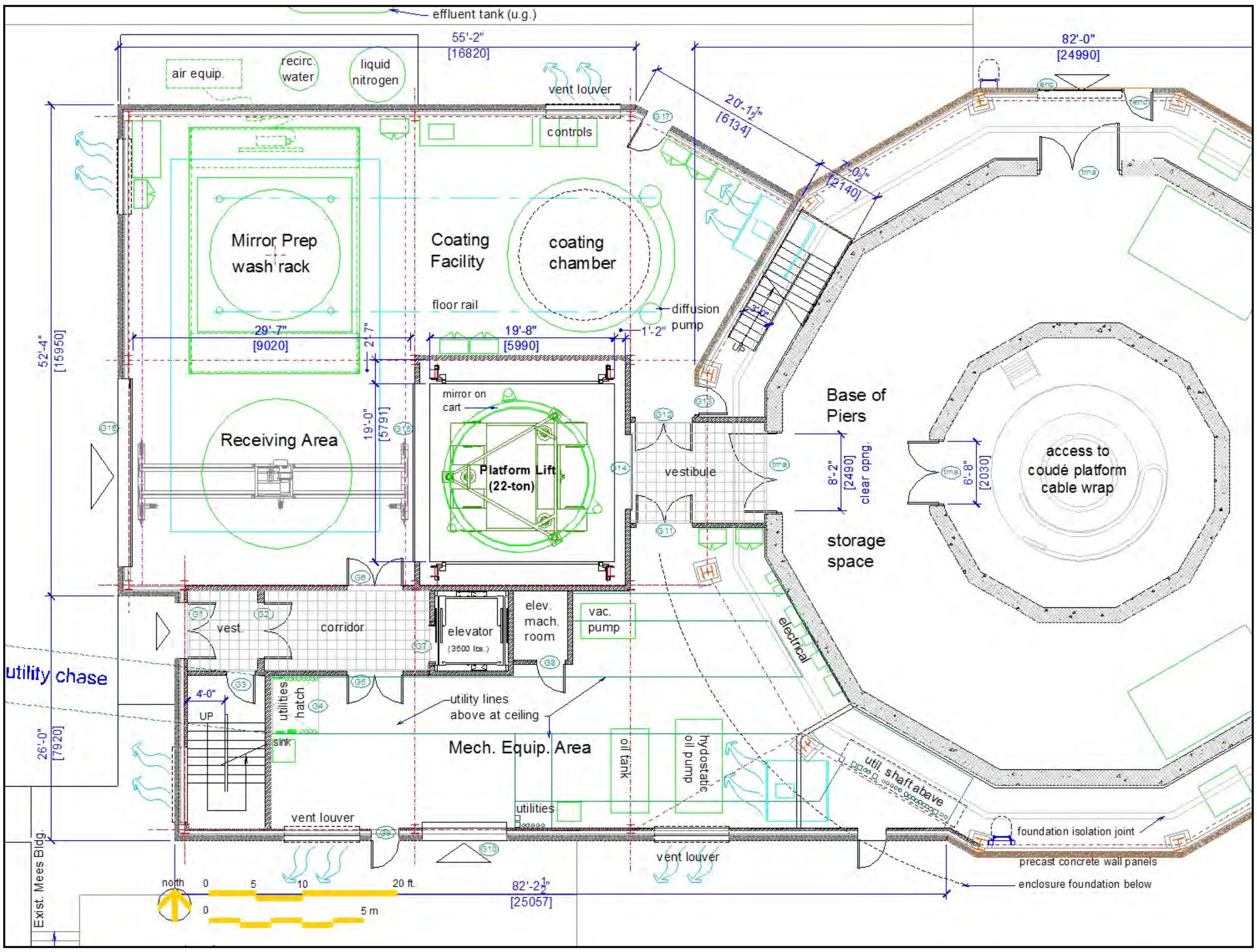

Figure 12. Ground Level, Support & Operations Building.

Mezzanine (second level)
The second level (Fig. 13) of the S&O Building is a mezzanine (partial floor) that would provide space for offices, shared workstations, a break room and a restroom. Some or all of this floor level may be left unpartitioned at the time of initial construction to allow for flexible allocation of this indirect support space as the operational requirements of the observatory are refined.

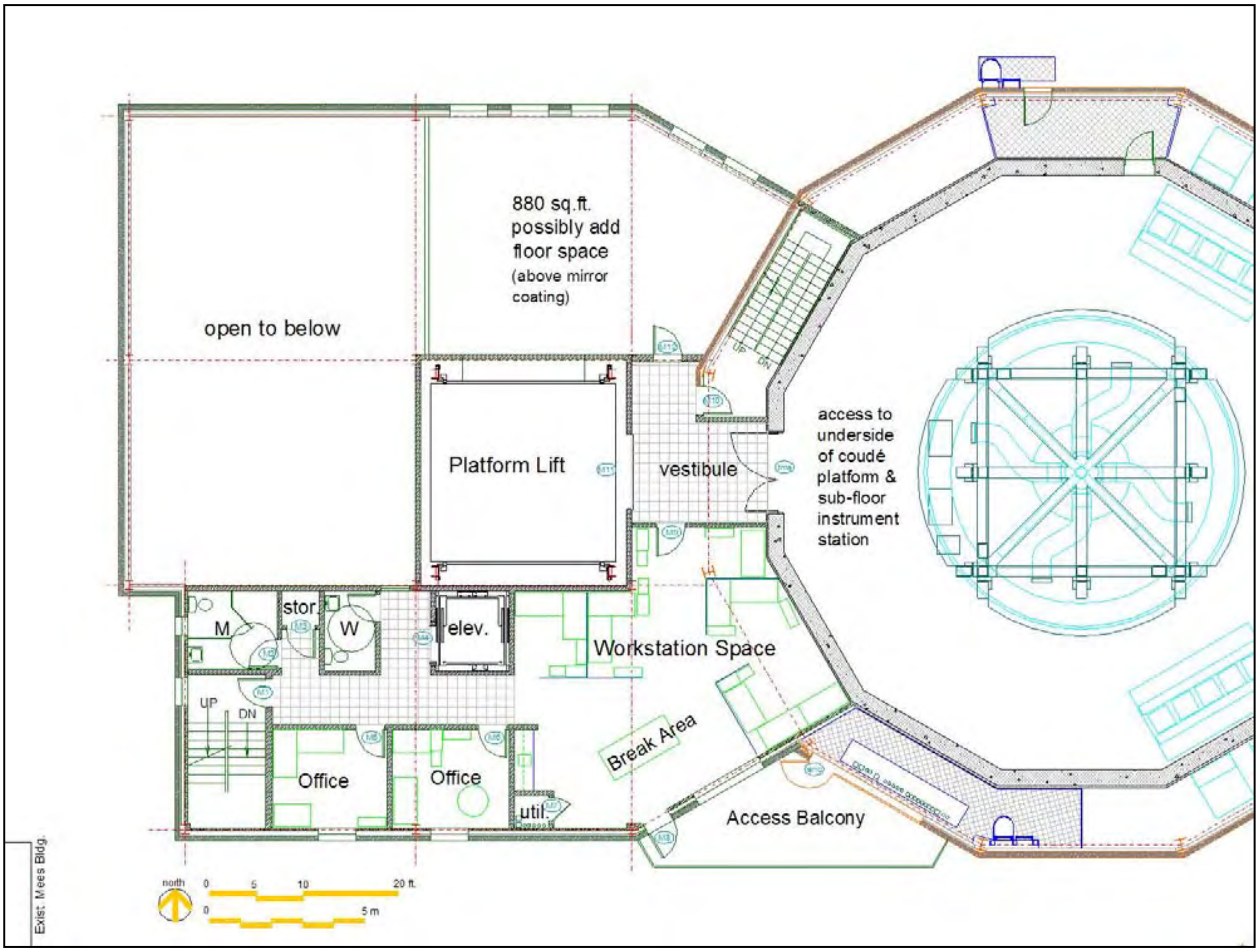

Figure 13. Mezzanine Level, Support & Operations Building.

Coudé (third level)
The third level (Fig. 14) of the S&O Building would be adjacent to the coudé platform inside the telescope pier where the majority of the observing instruments would be located. This level of the facility would be the principle work area of the observatory. A control room for the telescope and instruments would be required here with adequate working space and appropriate accommodations for telescope operators, observing scientists, engineering teams, Information Technology (IT) support personnel and others. A computer room would be required directly adjacent to the control room to house 16 racks of telescope control equipment, and data-processing hardware. An instrument prep lab would be required for repair, testing, and staging of instruments that would be installed on the telescope or coudé platform. A potential future light

feed for instrument testing (coelostat), which would be located on the roof of the instrument lab, is included in the proposed design.

On the south side of the S&O Building exterior, balconies would be provided at the control room and mezzanine level for checking weather, fresh-air work breaks, and as a secondary exit from utility areas inside the enclosure. Windows would be provided in the control room, offices, personnel break area and other spaces for visual relief and day lighting.

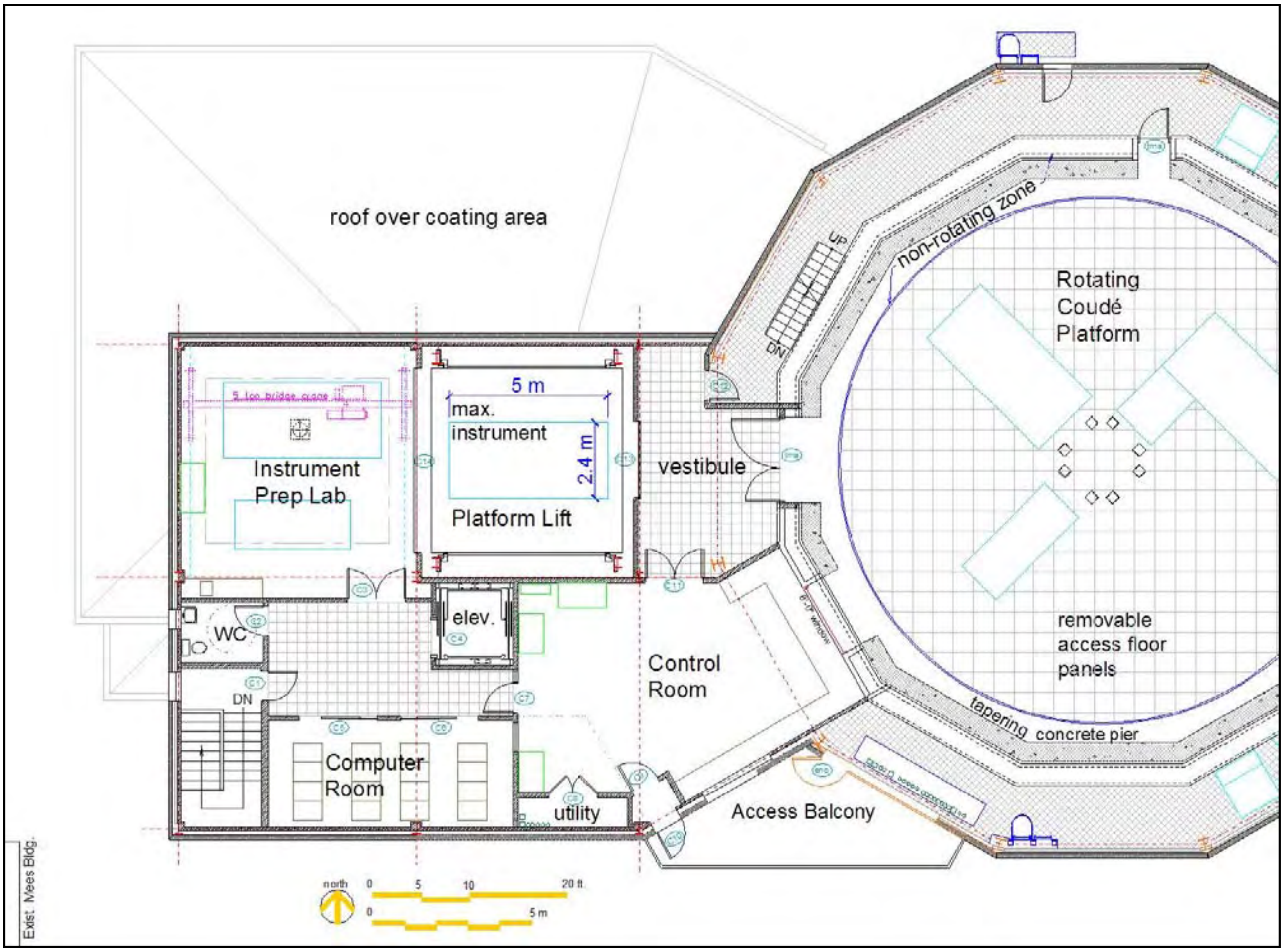

Figure 14. Coudé Level, Support & Operations Building.

Utility (fourth level)

The fourth and highest level (Fig. 15) of the S&O Building would provide access to the upper levels of the telescope enclosure. Stairs and a handicapped-accessible elevator inside the enclosure would extend from this area up to the telescope level inside the rotating carousel above. Exterior stairs on the south side and a ladder on the north side would extend up to the maintenance catwalk at the base of the carousel.

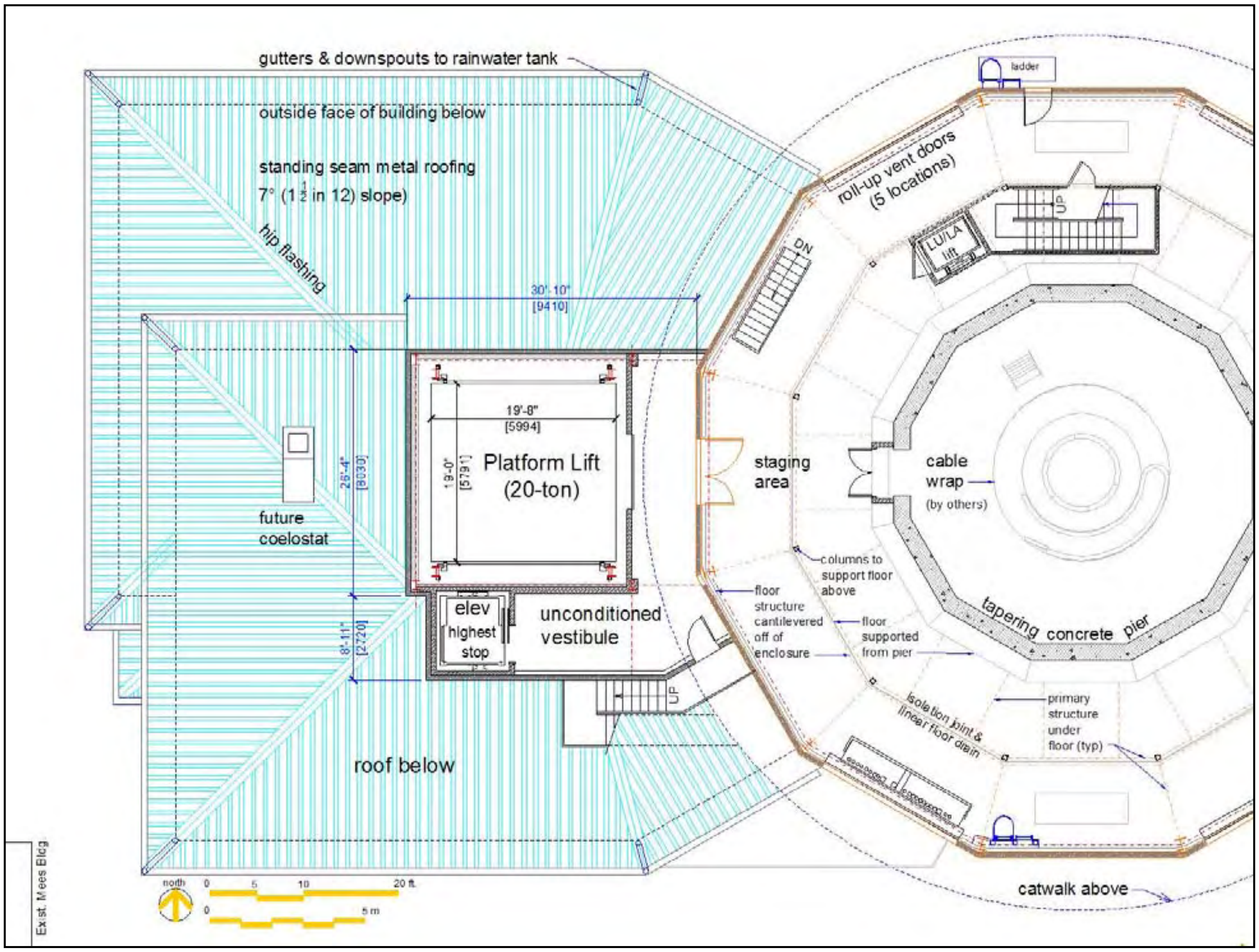

Figure 15. Utility Level, Support & Operations Building.

At the uppermost level of the observatory is the telescope floor. This area is within the rotating enclosure (Fig. 16) and provides service and maintenance access to both the telescope and enclosure. An articulating-boom man lift would be installed on the roof of the S&O Building, south of the platform lift, to provide access to the exterior of the enclosure during construction. This boom lift would possibly also serve for maintenance of the enclosure during operation.

The utility level would be above the sloped metal roof of the S&O Building, which is visible in the cross-section drawing (Fig. 17) of the telescope enclosure and S&O Building.

The tallest part of the S&O Building would be a platform lift located at the center of the building and next to the telescope enclosure. This lift would convey the primary mirror between the base level of the S&O Building and the telescope level in the enclosure and would also be used for instruments and other large telescope-related assemblies. Its dimensions and capacity (19 feet square platform rated for 40,000 pounds) are based on carrying the primary mirror in its support cell riding on a special handling cart. The lift would stop at six levels (base, mezzanine, coudé, utility, catwalk, and telescope), with a maximum vertical travel of approximately 76 feet 6 inches. The design of the lift would incorporate a lift-up roof at the top of the fixed shaft. The maximum height to the top of the roof would be approximately 89 feet above the ground when the roof is in the raised position.

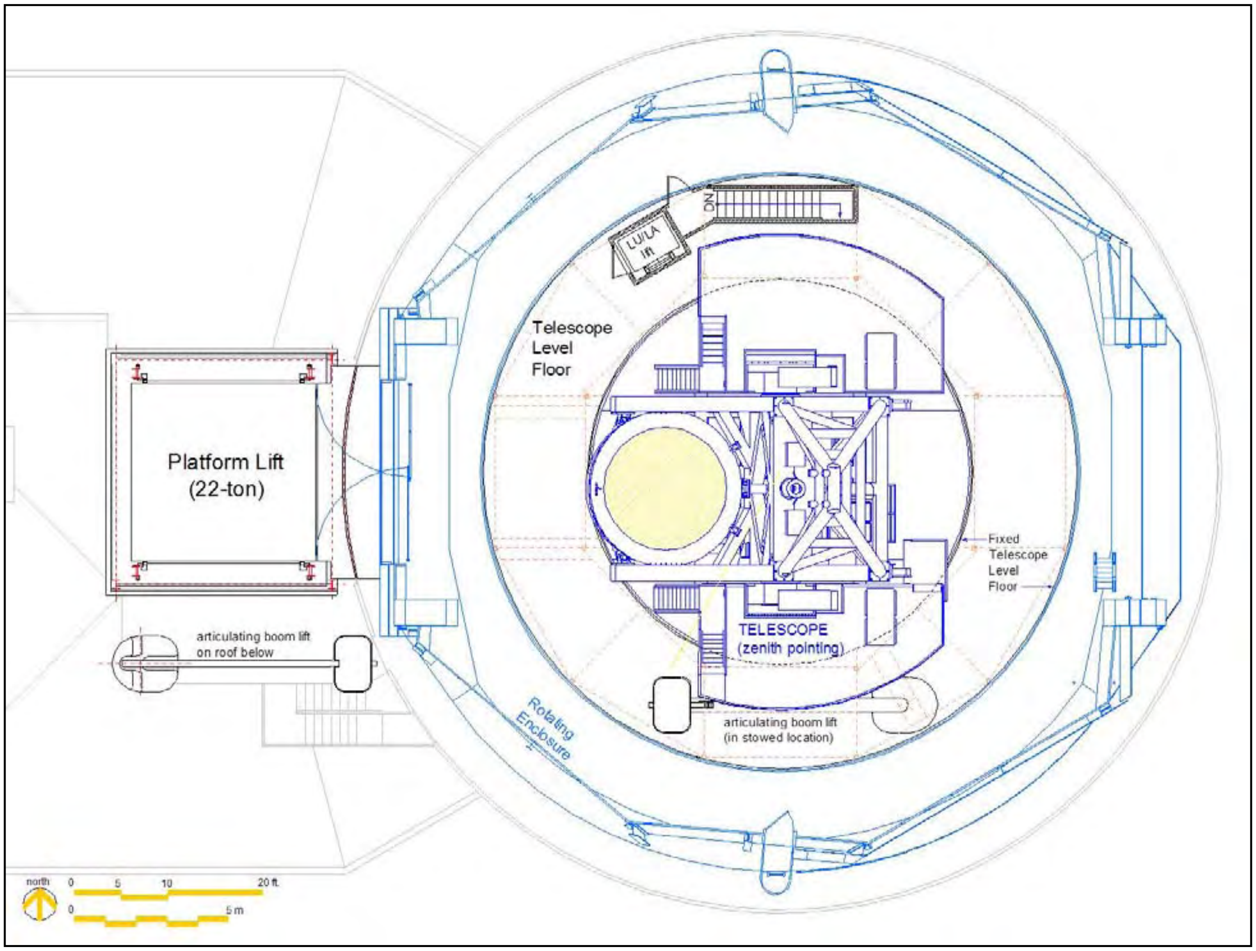

Figure 16. Telescope Level of the Enclosure.

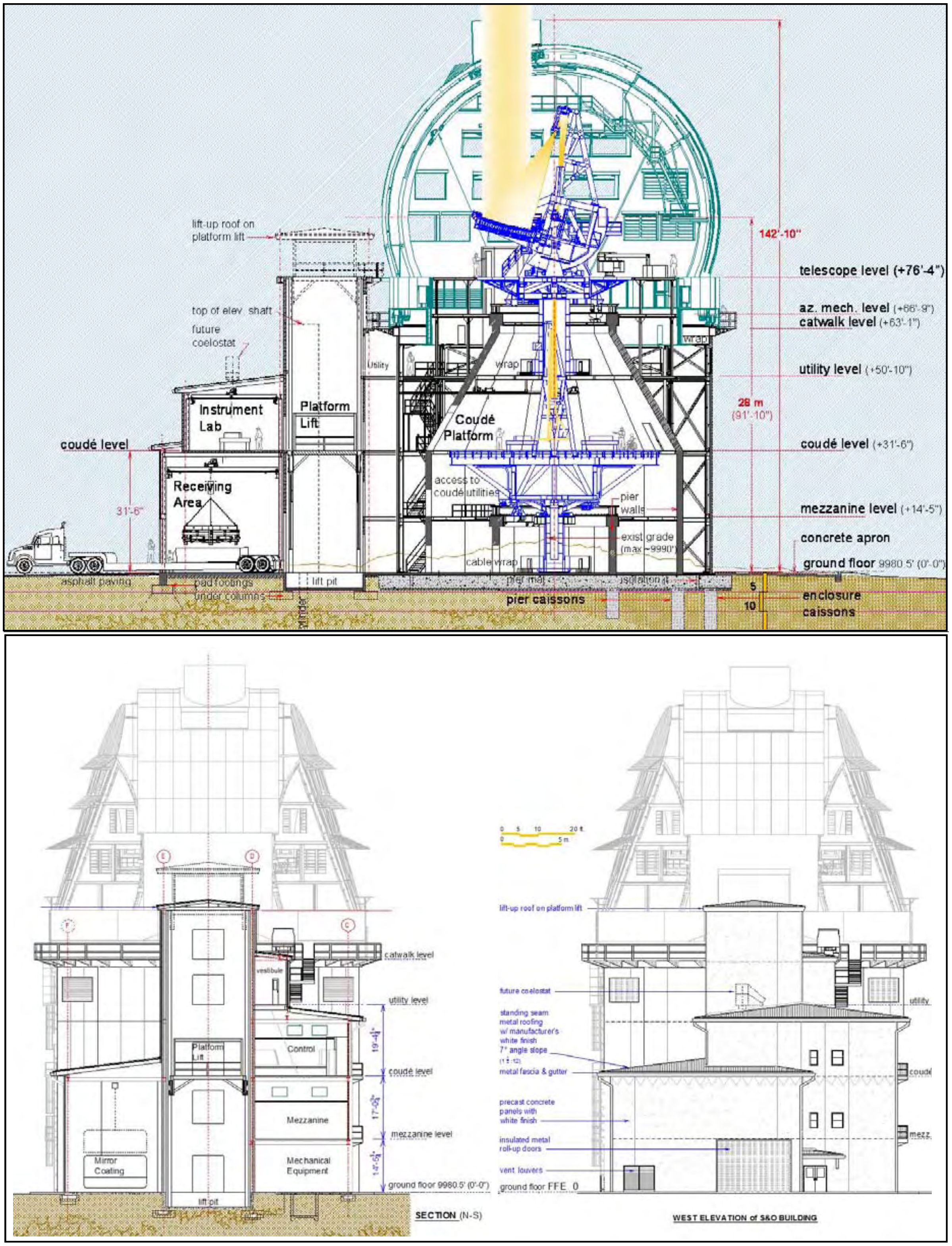

Figure 17. Telescope Enclosure and Support & Operations Building Cross-sections.

Utility Building

The Utility Building would be a rectangular, steel-framed, metal structure that would provide space for mechanical and electrical equipment that would require complete thermal and vibration isolation from the telescope. The Utility Building would be connected to the S&O Building by an underground utility chase.

Potential exterior noise from the equipment in this building is an environmental concern. In addition to sound abatement devices integral to the equipment, the walls and roof of the Utility Building would incorporate effective sound blocking materials. For ventilation of the equipment the west wall would include large louver panels, which are designed to minimize sound transmission. A preliminary list of the equipment to be housed in the Utility Building includes: a 300 kilovolt-ampere generator and associated automatic transfer switchgear, an 80-ton low-temperature chiller, a 15-ton very-low-temperature chiller, a 10-ton heat pump condenser unit, a vane-axial ventilation fan, an air compressor, and 3 uninterruptible power supply (UPS) units. Three ice storage tanks and an electric transformer would be located outside, adjacent to the Utility Building. The layout of the Utility Building area shown in Figure 18 is preliminary.

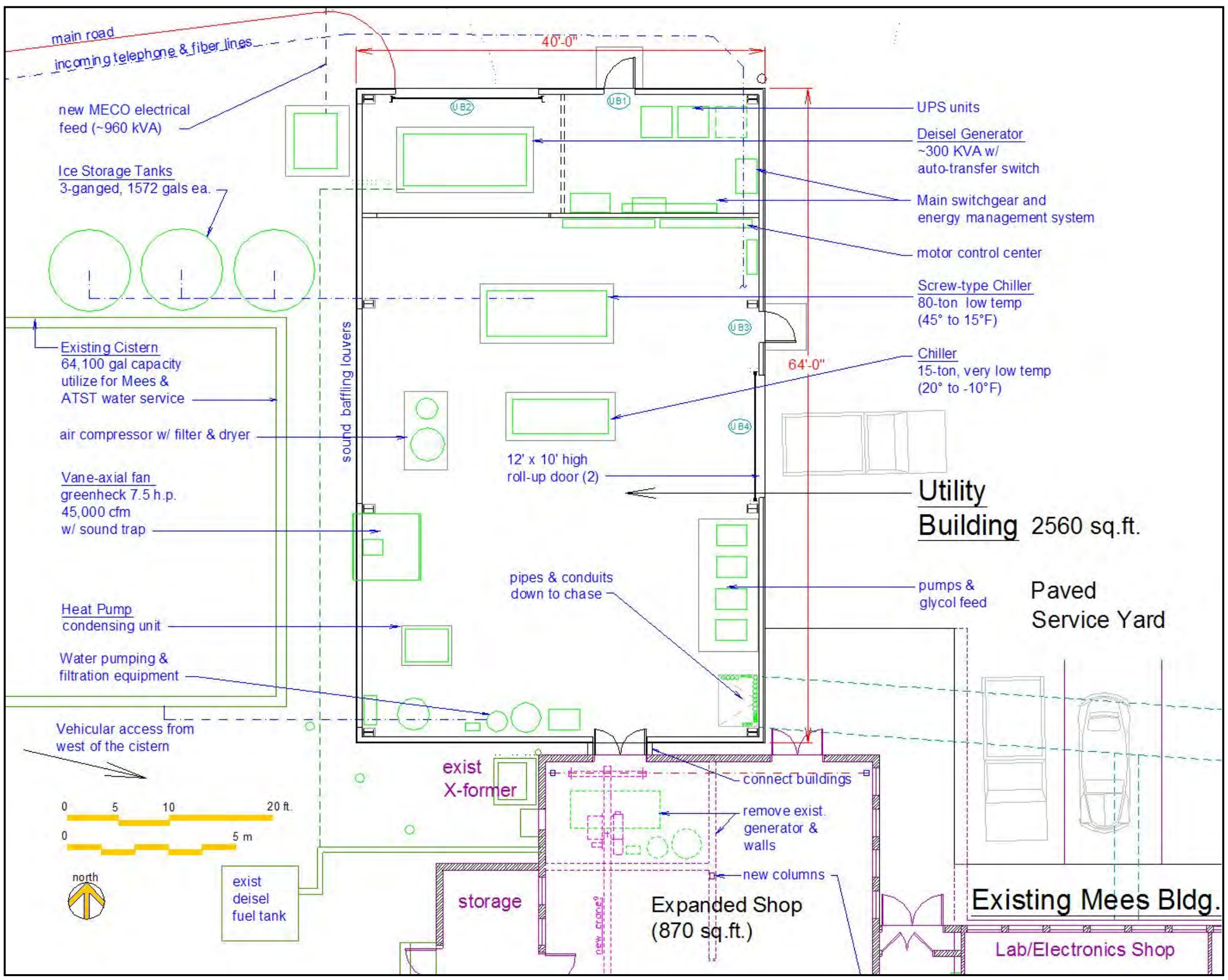

Figure 18. Utility Building With Preliminary Layout.

<u>APPENDIX K</u>

SOILS INVESTIGATION, 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.

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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 (rCI). 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.

<u>Settlement of Support Building Footings</u>

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.

<u>Lateral Resistance</u>

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. Fill and Backfill in Non-Structural Areas: 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 ------------------------------ Plate A

Vicinity Map -- Plate 1

Plot Plan --- Plate 2

SASW & Resistivity Test Plan ------------------- Plate 2A

Appendix

Field Investigation, Laboratory Testing

Logs of Test Borings ------------------------------ Plates 3 thru 9

Laboratory Test Results ---------------------------- Plates 10 thru 18

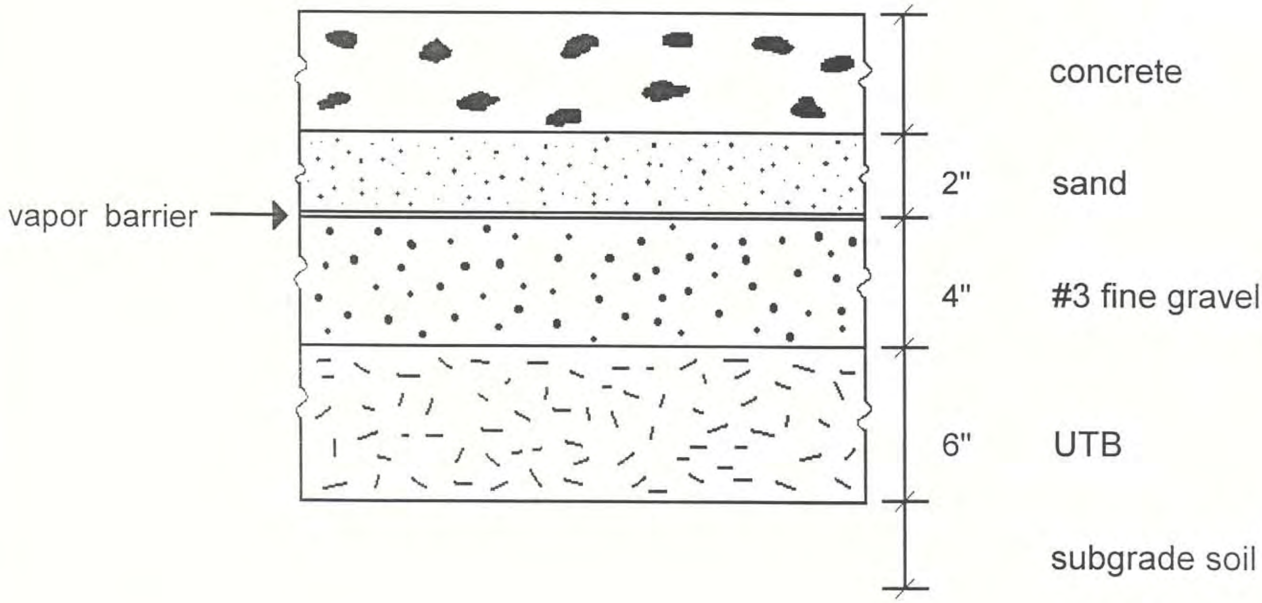
Pictures of Rock Core Samples ------------------ Plates 19 thru 22

Estimated Drilled Shaft Deflection --------------- Plates 23 & 24

Estimated Settlement Model of MAT ------------ Plate 25

Subsurface Seismic Velocity Profile Report by Olson Engineering

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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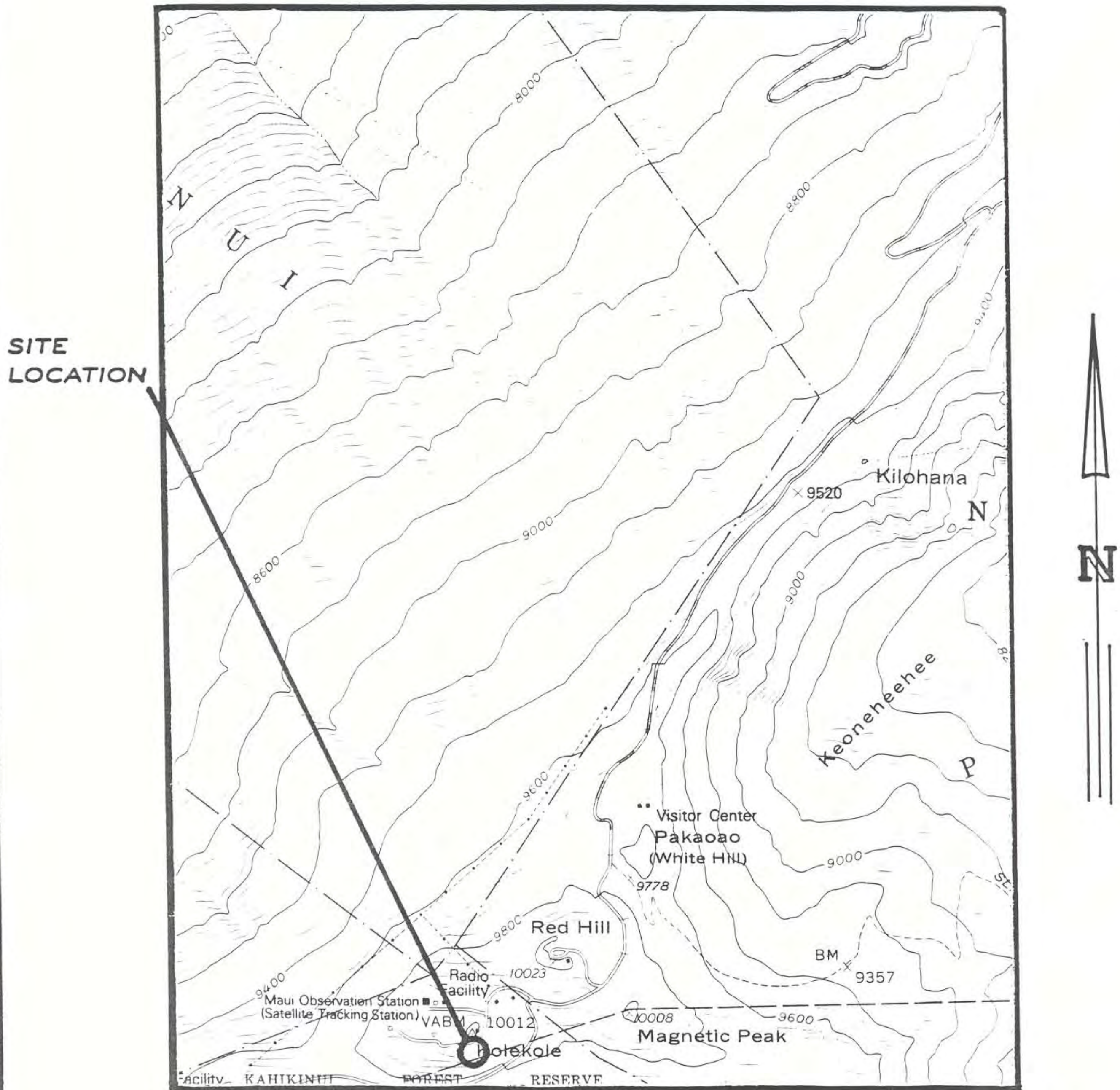
ISLAND GEOTECHNICAL ENGINEERING, INC. | PLATE A

VICINITY MAP

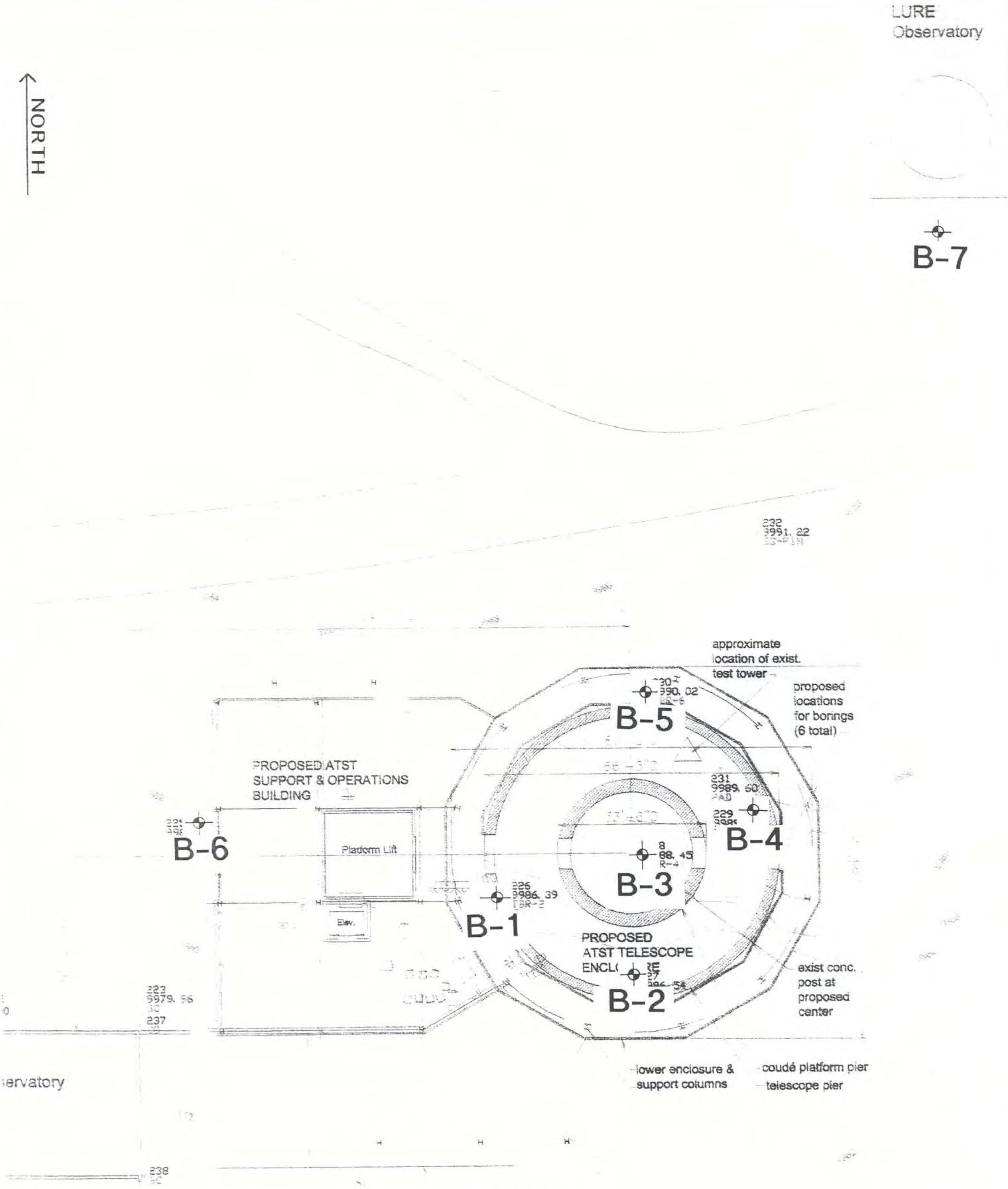


REFERENCE:

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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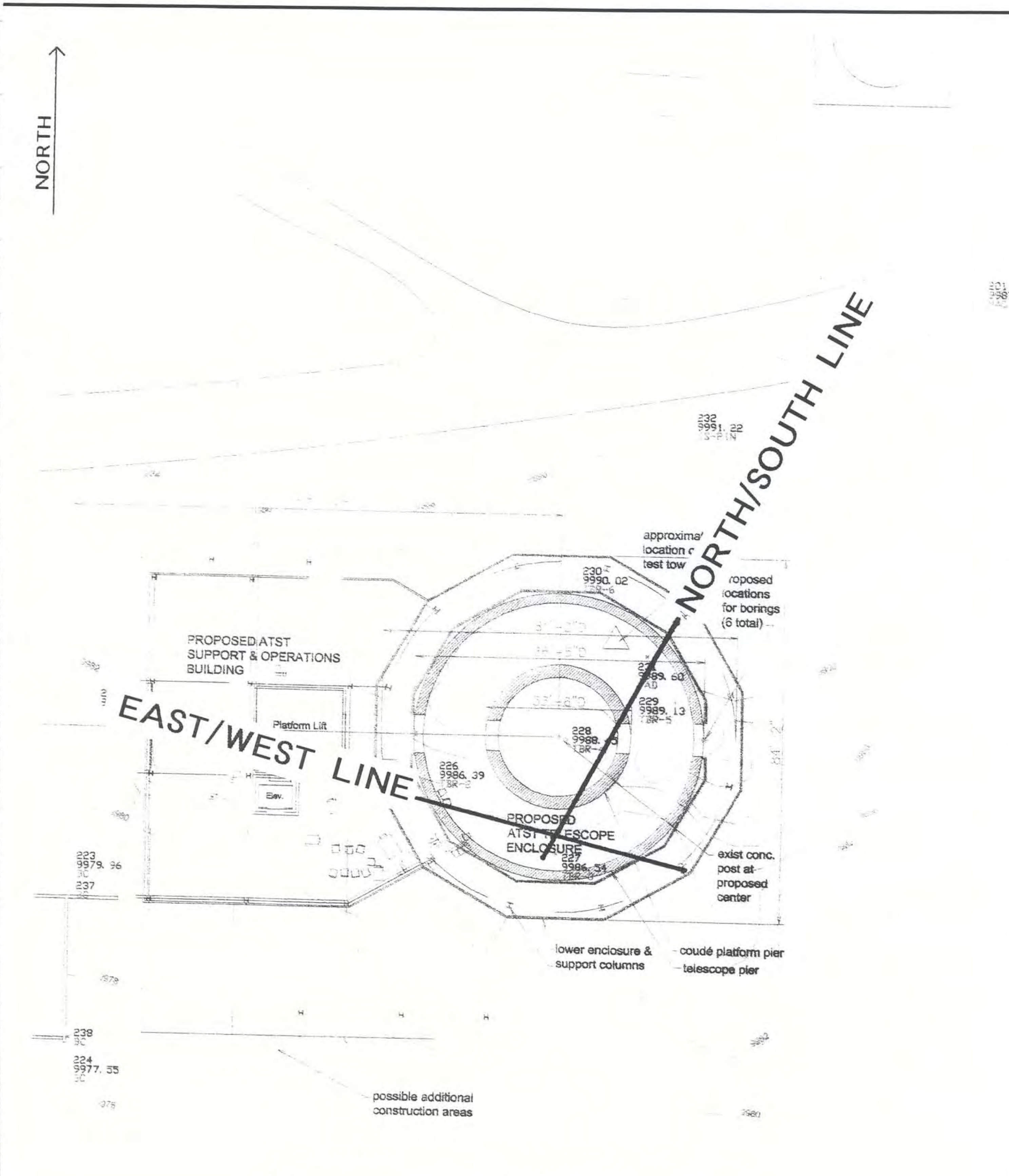
ISLAND GEOTECHNICAL ENGINEERING, INC.

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

ELEVATION: 9986.39

EQUIPMENT USED: Mobile B-59

DEPTH OF BORING (FT.): 30

DATE DRILLED: March 8, 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		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											
28			Core Run from 25' to 30': Rec. = 70% RQD = 20%								
							soft rock or cinder zone				
			END OF TEST BORING								

PROJECT NAME: ATST AT HALEAKALA

PROJECT NO.: 05951-FM

ISLAND GEOTECHNICAL ENGINEERING, INC.

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PLATE 3

LOG OF BORING NO. 2

ELEVATION: 9986.54

EQUIPMENT USED: Mobile B-59

DEPTH OF BORING (FT.): 30

DATE DRILLED: March 9, 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		SM	silty SAND		22	brown	mod. dense	moist	95.7	10.4	
		GP-GM	silty GRAVEL with sand and cobbles							20.7 23.3	
4											
					50/ 6"		very dense			18.3	
8											
						reddish brown					
12		rock	BASALT ROCK		31/ 5"	gray brown	mod. hard rock with zones of soft rock & cinder			15.8	
			Core Run from 11.5' to 15': Rec. = 37% RQD = 29%								
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				
			Core Run from 25' to 30': Rec. = 58% RQD = 25%				mod. hard rock with zones of soft rock & cinder				
28											
			END OF TEST BORING								

PROJECT NAME: ATST AT HALEAKALA

PROJECT NO.: 05951-FM

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PLATE 4

LOG OF BORING NO. 3

ELEVATION: 9988.45

EQUIPMENT USED: Mobile B-59

DEPTH OF BORING (FT.): 28.5

DATE DRILLED: March 10, 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-SP	SAND with gravel and GRAVEL with sand (alternating layers)		25	dark brown	mod. dense	moist	86.1	16.1 28.8 6.2	
					53						
					24						
4					23						
					31						
		SP-SM	poorly graded SAND with silt		17	dusky red				16.2	
8					37		dense				
					48						
					96	dark reddish brown	very dense				
		SW-SM	well-graded SAND with silt and gravel		58					13.1	
12						reddish black				15.8	
		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								

PROJECT NAME: ATST AT HALEAKALA

PROJECT NO.: 05951-FM

ISLAND GEOTECHNICAL ENGINEERING, INC.
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PLATE 5

LOG OF BORING NO. 4

EQUIPMENT USED: Mobile B-59
DATE DRILLED: March 11, 2005
ELEVATION: 9989.13
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	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	moist		41.0 23.6	
4									
			7					26.3	
8									
			64		very dense			14.7	
12		---boulder (12" diameter)							
			23	dark reddish gray	mod. dense			5.5 14.0	
16									
20			25/6"					4.9 7.8	
	rock	BASALT ROCK Core Run from 21' to 25': Rec. = 97% RQD = 83%		gray brown	mod. hard rock with zones of soft rock & cinder				
24									
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

ISLAND GEOTECHNICAL ENGINEERING, INC.
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PLATE 6

LOG OF BORING NO. 5

ELEVATION: 9990.02

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	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

EQUIPMENT USED: Mobile B-59

DATE DRILLED: March 14, 2005

ELEVATION: 9983.11

DEPTH OF BORING (FT.): 37.5

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)
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.

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PLATE 8

LOG OF BORING NO. 6

EQUIPMENT USED: Mobile B-59

DATE DRILLED: March 14, 2005

ELEVATION: 9983.11

DEPTH OF BORING (FT.): 37.5

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.

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PLATE 8

LOG OF BORING NO. 7

EQUIPMENT USED: Mobile B-59

DATE DRILLED: March 21, 2005

ELEVATION: see Plate 2

DEPTH OF BORING (FT.): 15

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%			gray brown	mod. hard rock with zones of soft rock & cinder				
4					39/ 3"						
			Core Run from 5' to 10': Rec. = 37% RQD = 27%								
8		GP-SP	GRAVEL/SAND				mod. dense				
					14						
12											
		rock	BASALT ROCK				mod. hard rock				
			END OF TEST BORING								
16											
20											
24											
28											

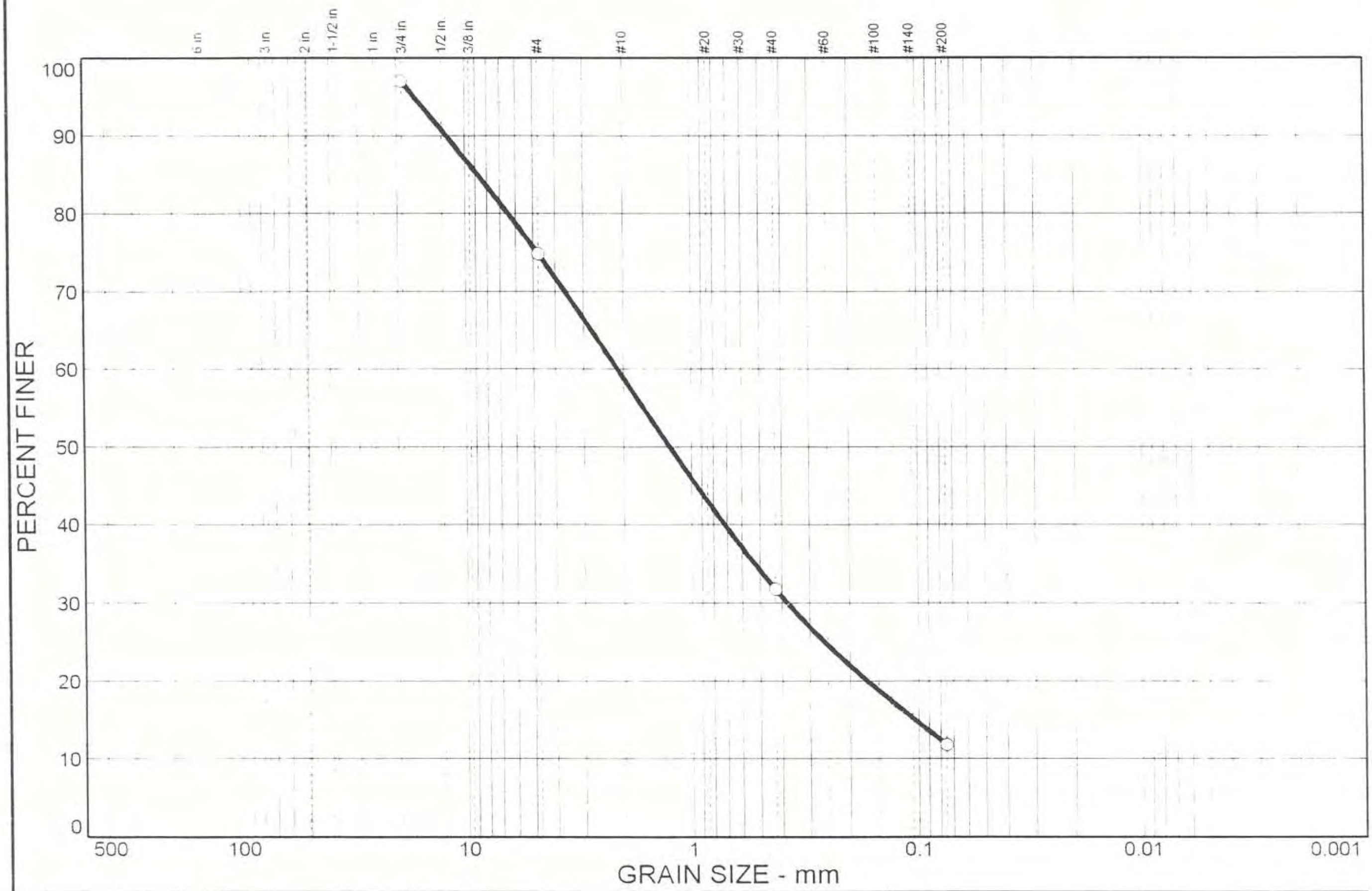
PROJECT NAME: ATST AT HALEAKALA

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

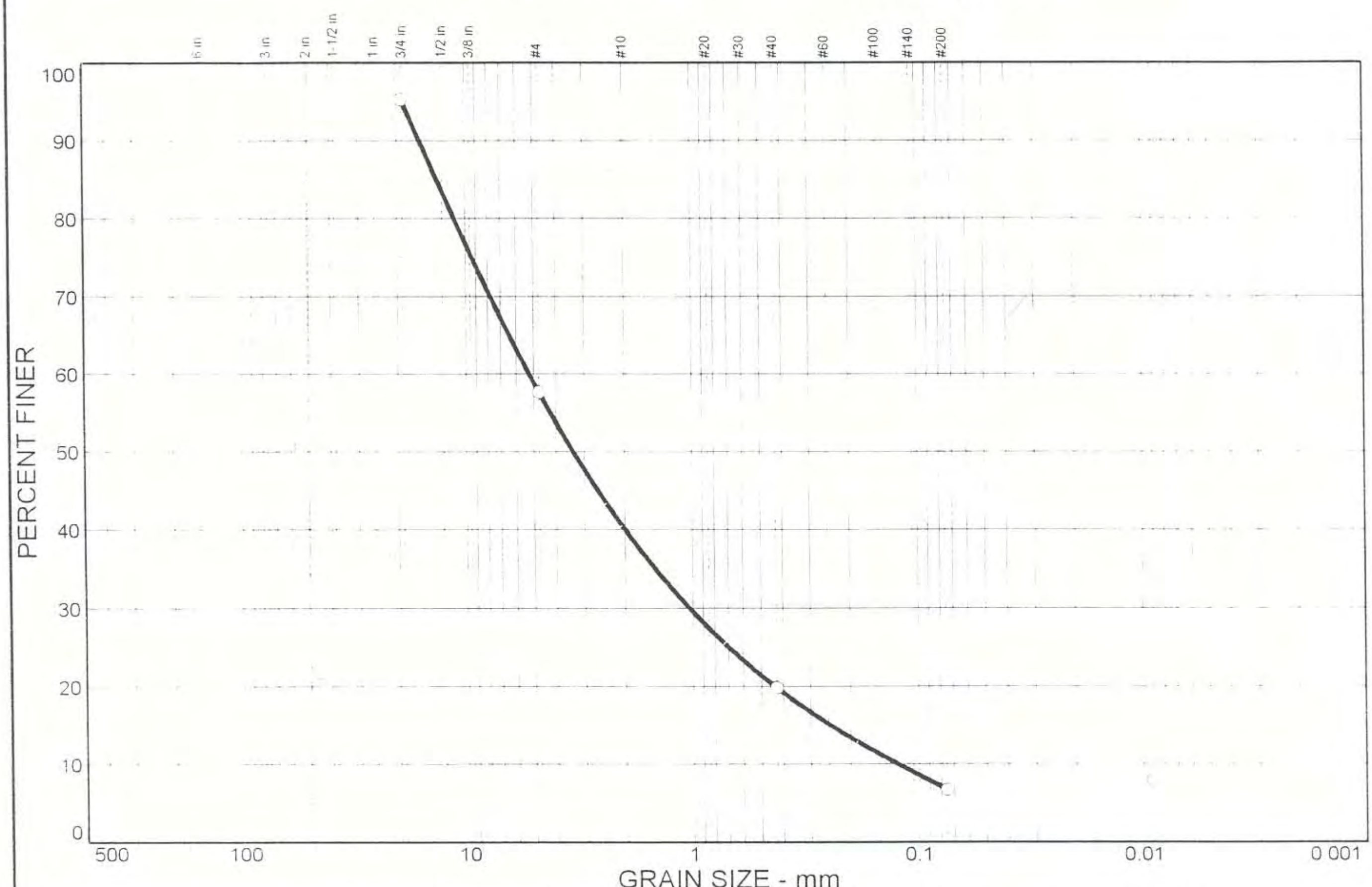
Remarks

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=

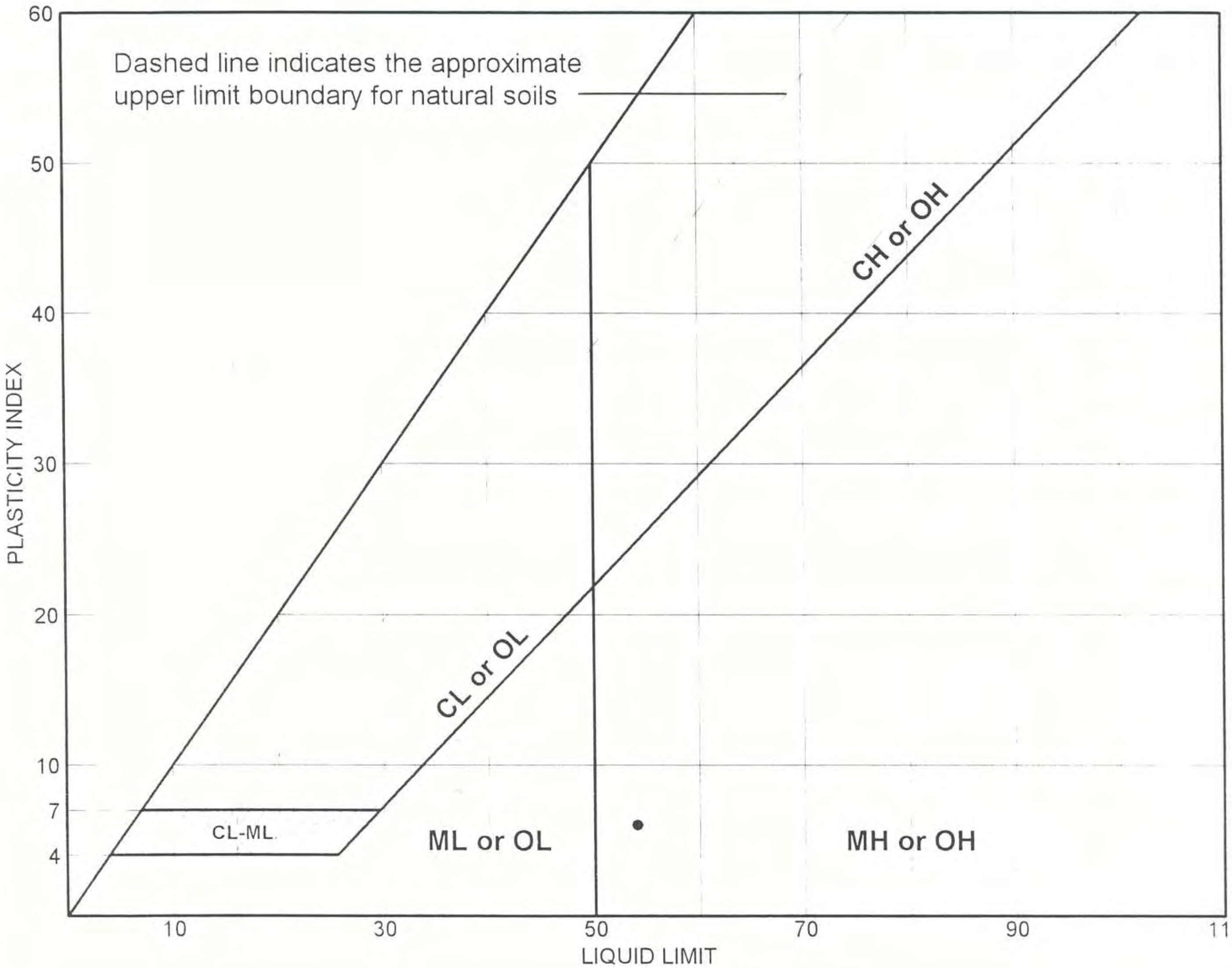
Remarks

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	Client:
Island Geotechnical Engineering, Inc.	**Project:** ATST at Haleakala
	Project No.: 05951-FM **Plate** 12

Unconfined Compressive Strength of Intact Rock Core Specimens

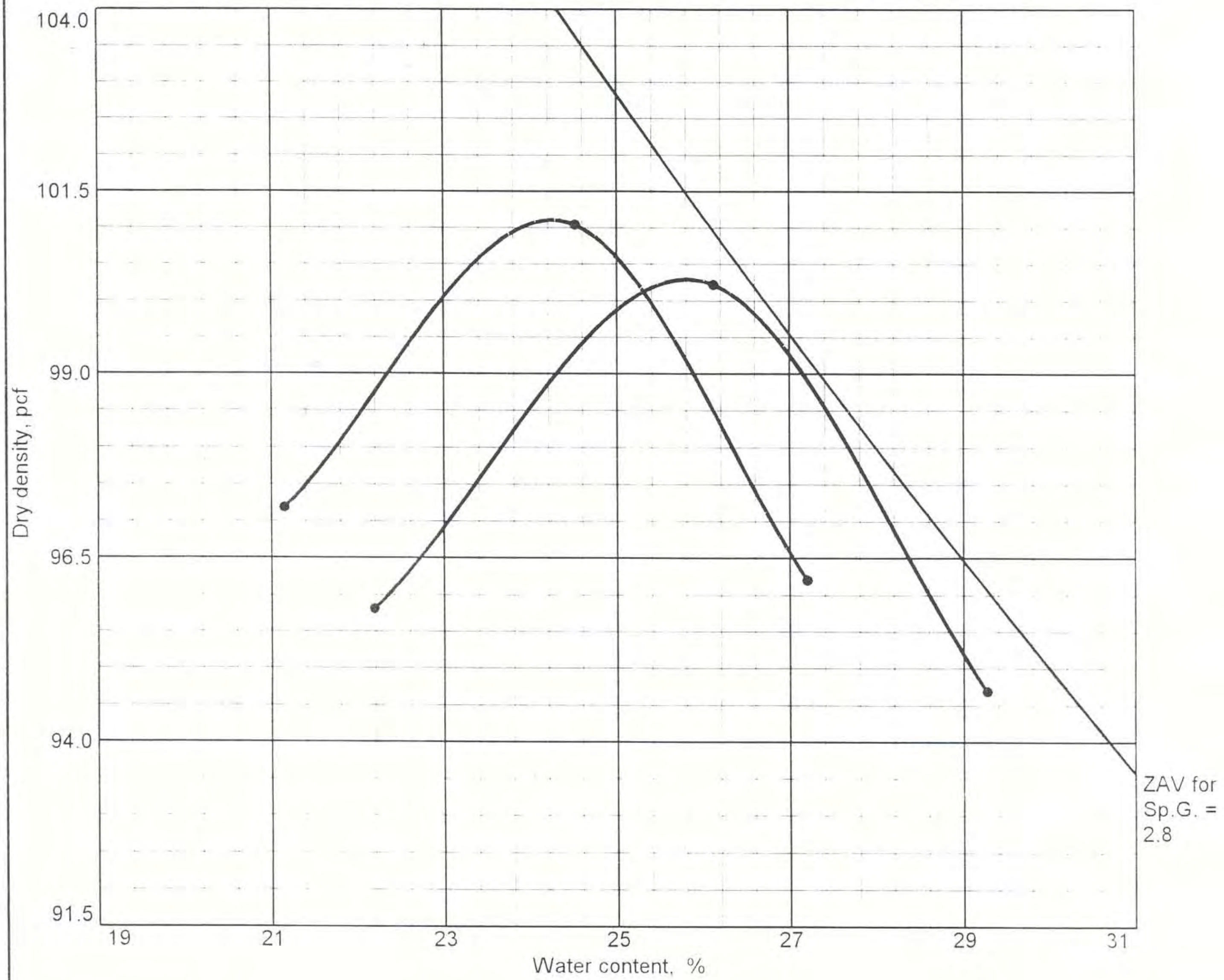
Boring	Sample Depth (feet)	Strength (PSF)
1	15 to 20	377,720
2	16 to 18	556,062
4	25 to 30	387,107
5	12 to 14	506,864

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

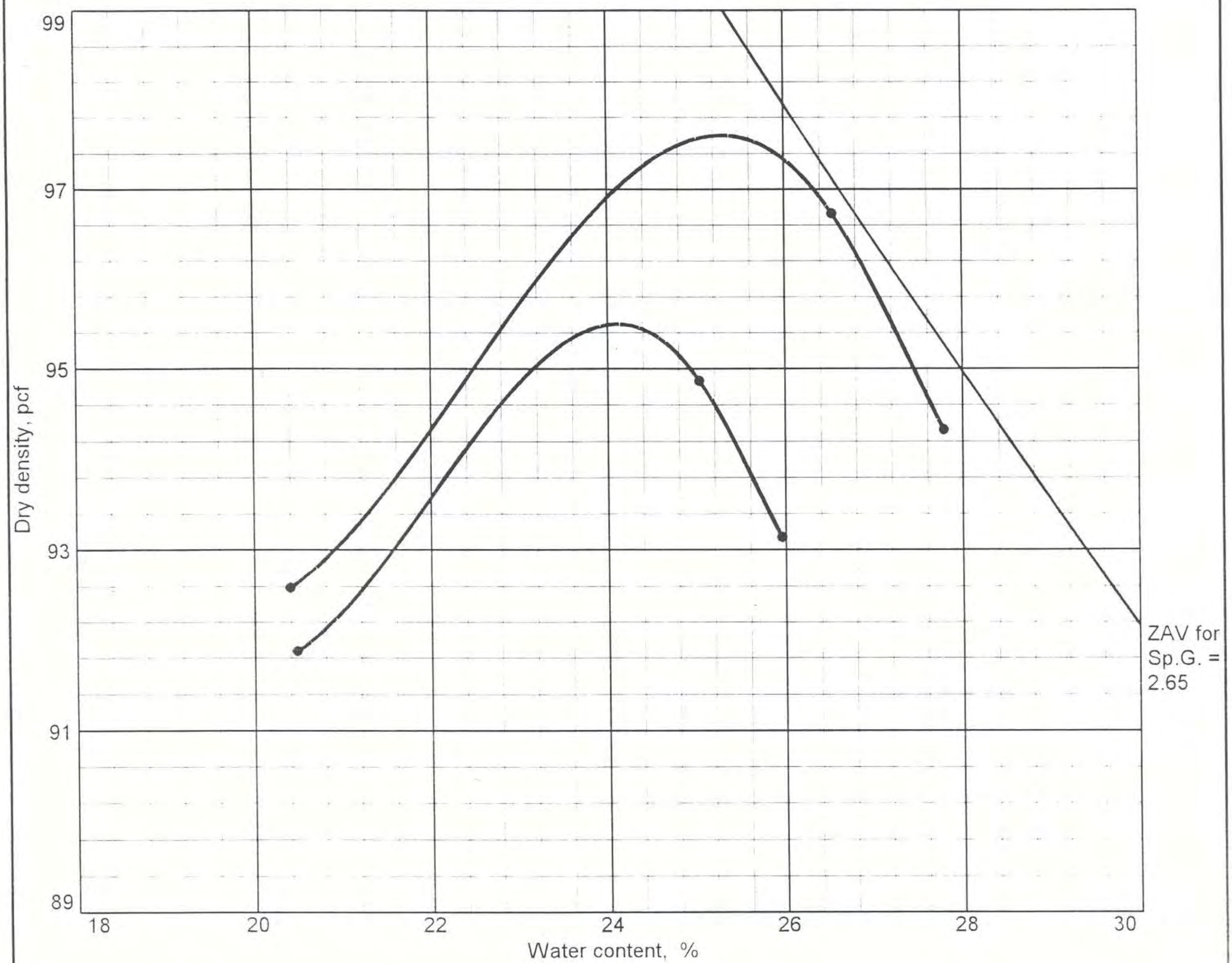
Remarks:
1) Date:April 2005
2) BSG = 1.70, Absorption = 15.1

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

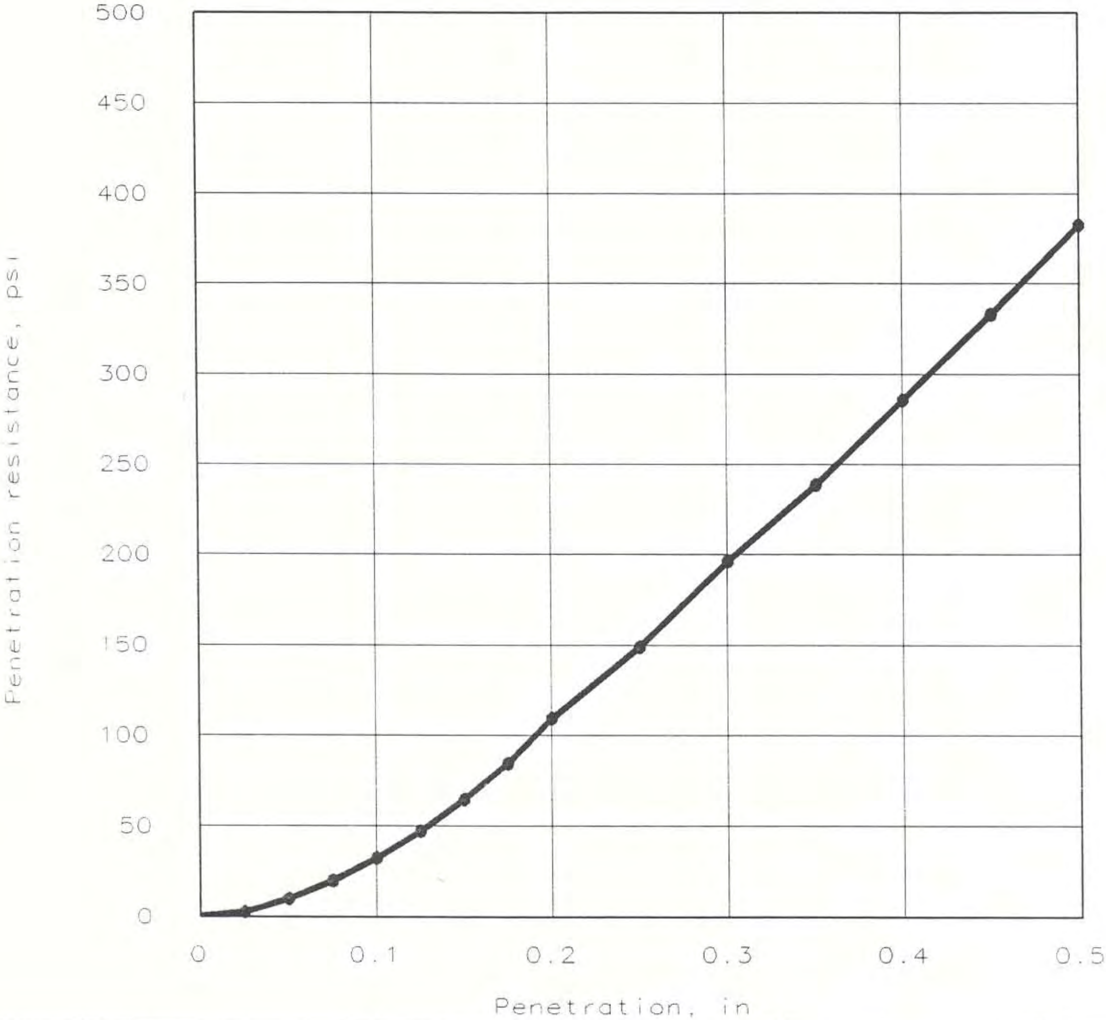
MAXIMUM DRY DENSITY TEST

Island Geotechnical Engineering, Inc.

Remarks:
1) Date April 2005
2) BSG = 1.44, Absorption = 20.7

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

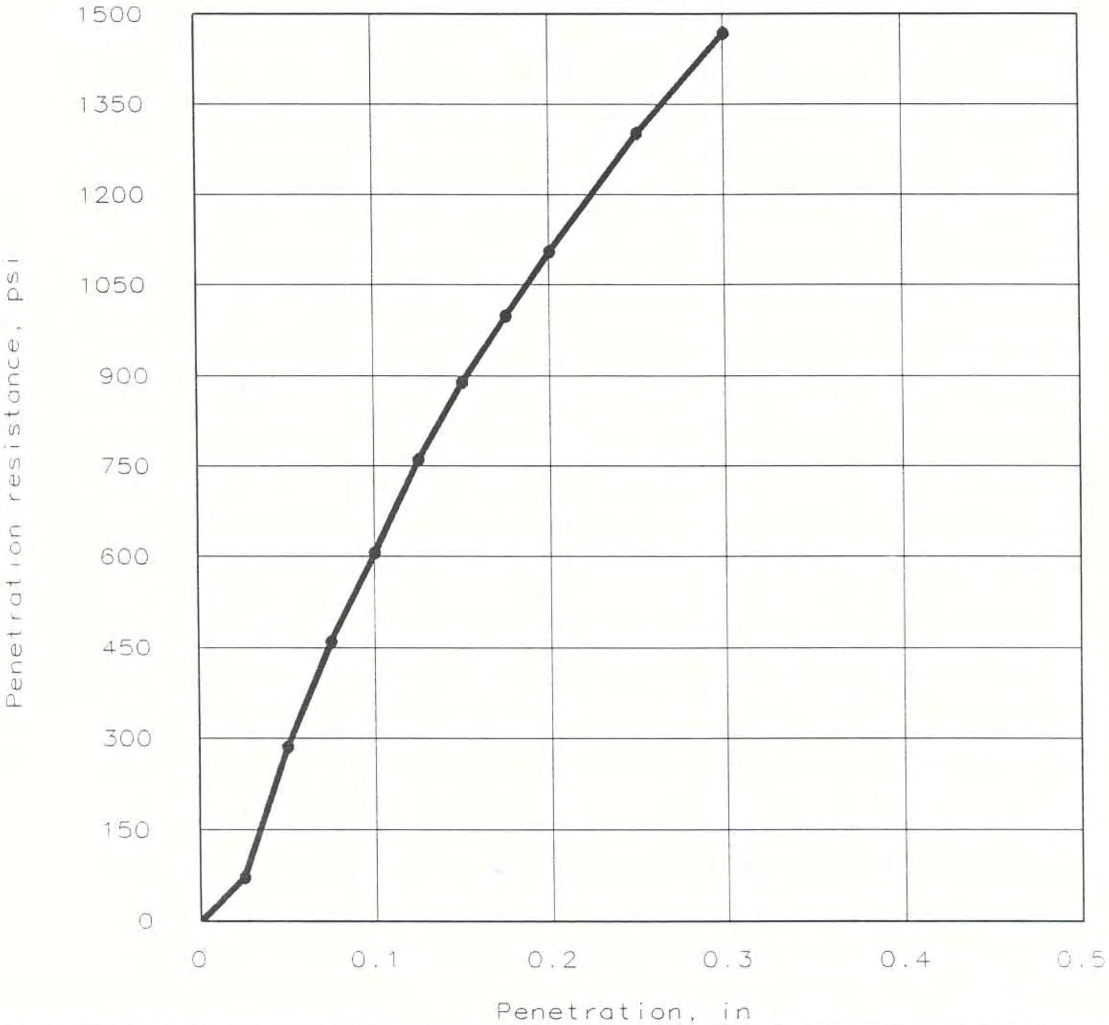
on portion passing

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"

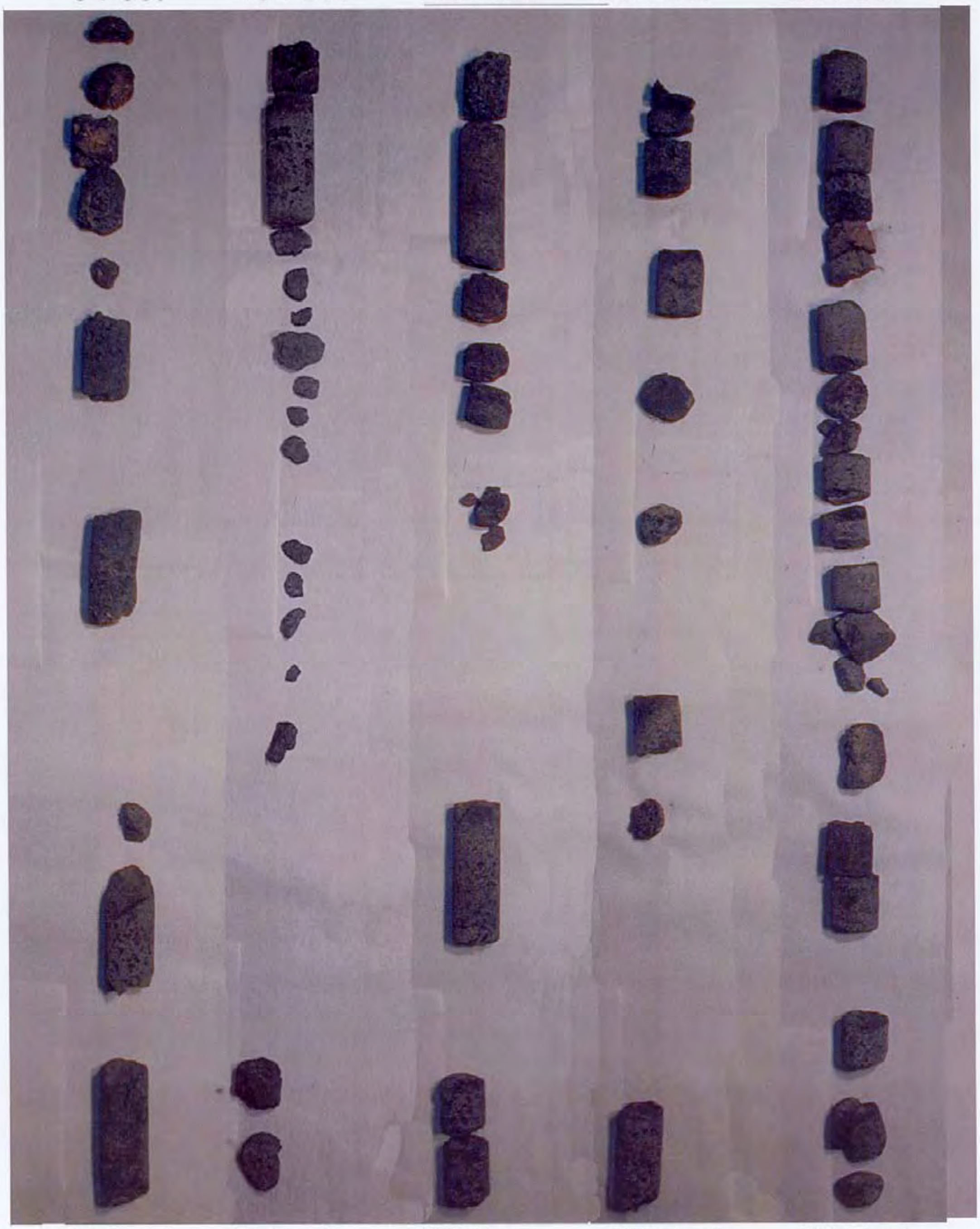
Plate No. 17

Miscellaneous Test Results

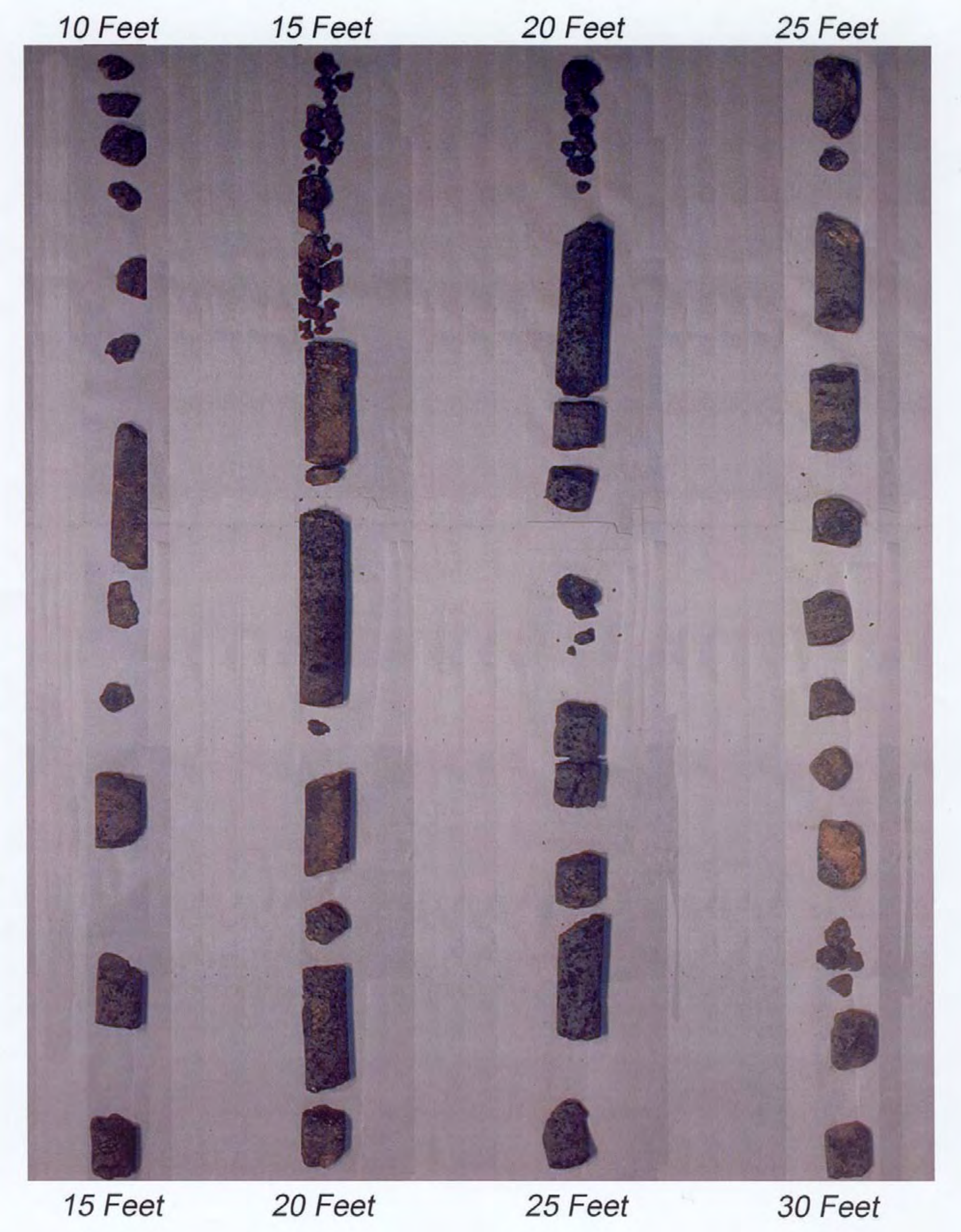
Test Description	Location	Depth	Results
Specific Gravity (ASTM D 854)	Boring 2	0 to 0.75'	3.04
Specific Gravity (ASTM D 854)	Boring 3	0 to 1.0'	3.09
Bulk Specific Gravity Of Coarse Aggregate (ASTM C 127)	Boring 2	0 to 0.75'	BSG = 1.70 Absorption = 15.1%
Bulk Specific Gravity Of Coarse Aggregate (ASTM 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

Project: ATST AT HALEAKALA   Project No.: 05951-FM

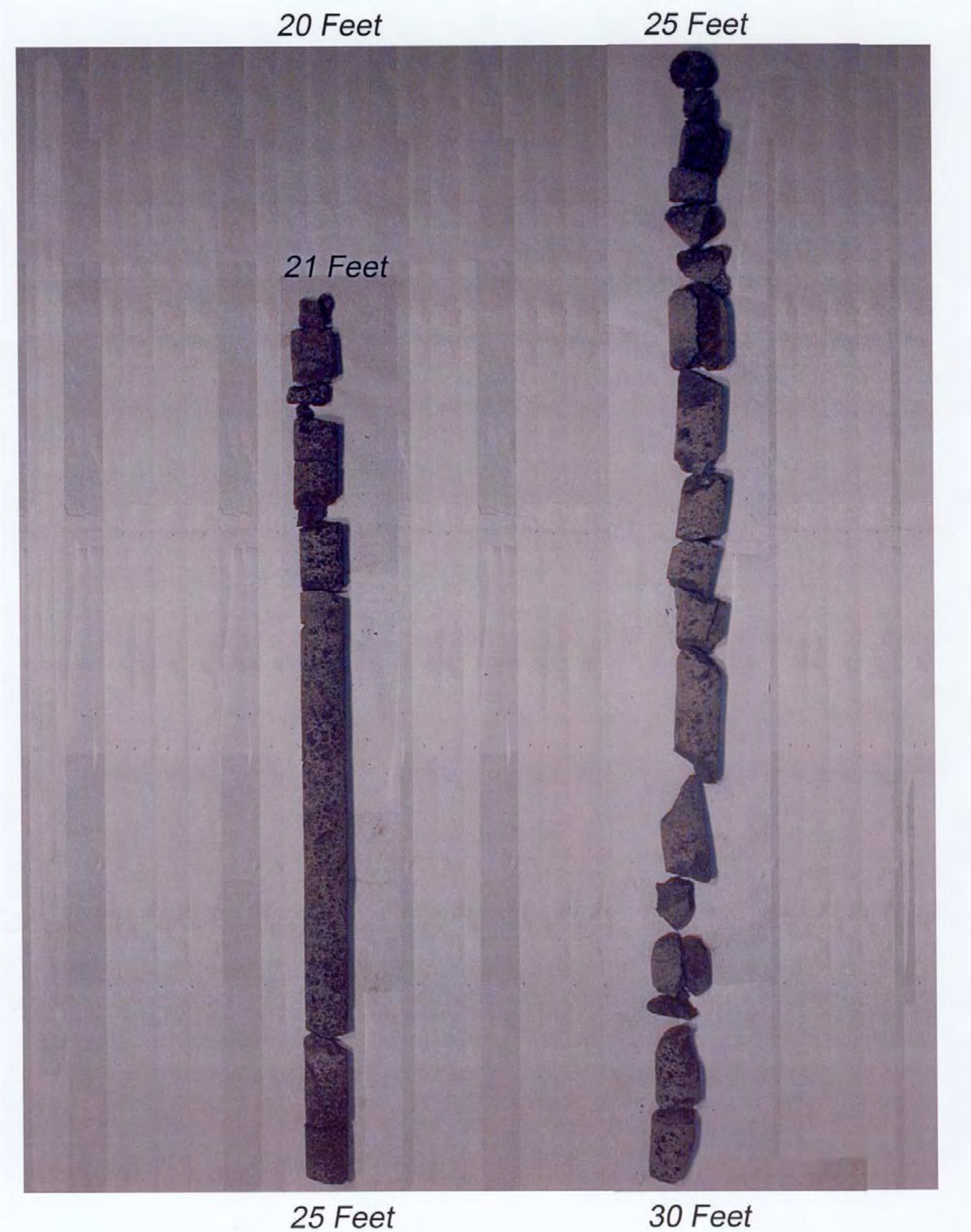
ISLAND GEOTECHNICAL ENGINEERING, INC.   PLATE 18



ATST at Haleakala **Boring 1** **Plate 19**

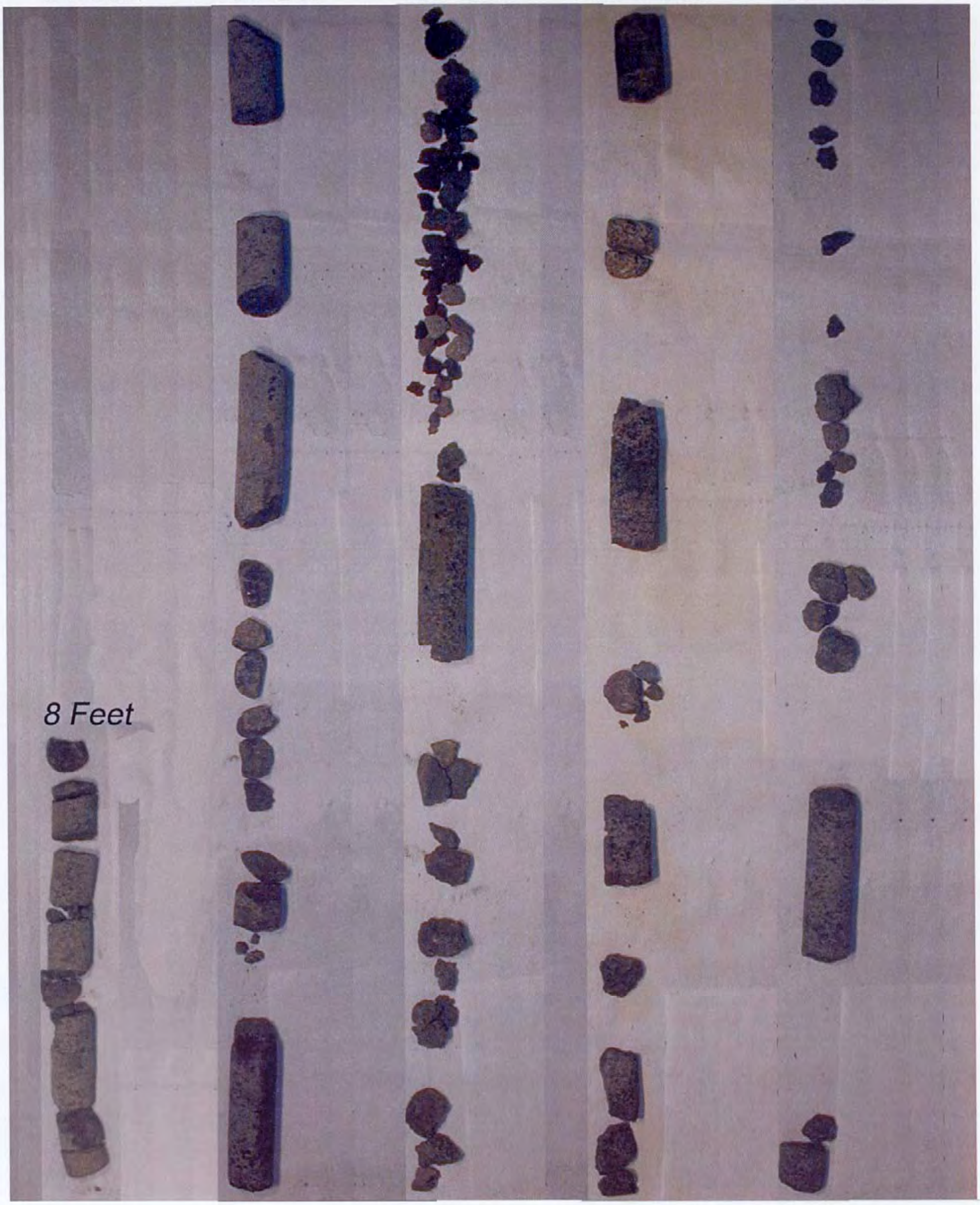


ATST at Haleakala **Boring 2** **Plate 20**



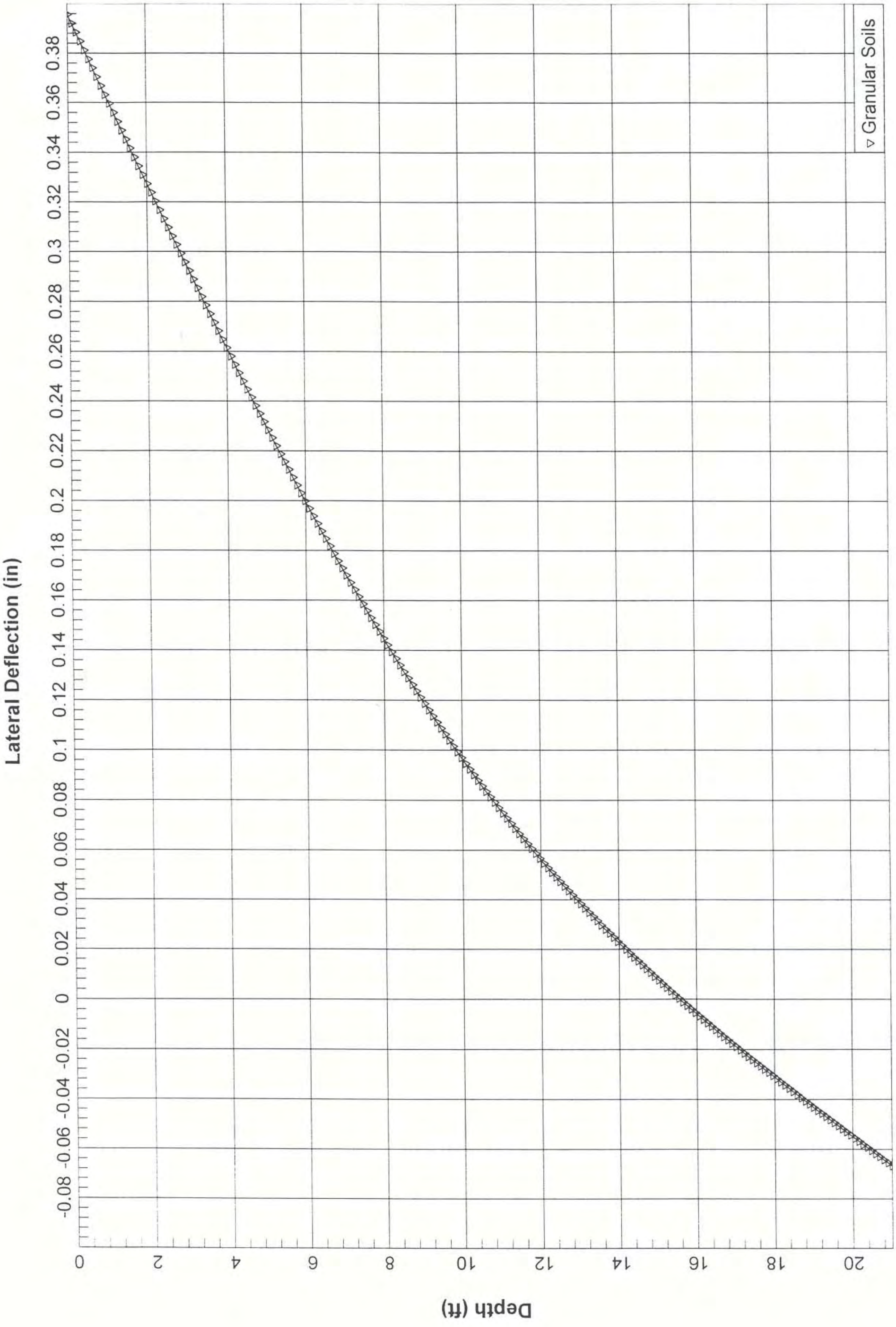
ATST at Haleakala **Boring** 4 **Plate 21**

5 Feet | 10 Feet | 15 Feet | 20 Feet | 25 Feet



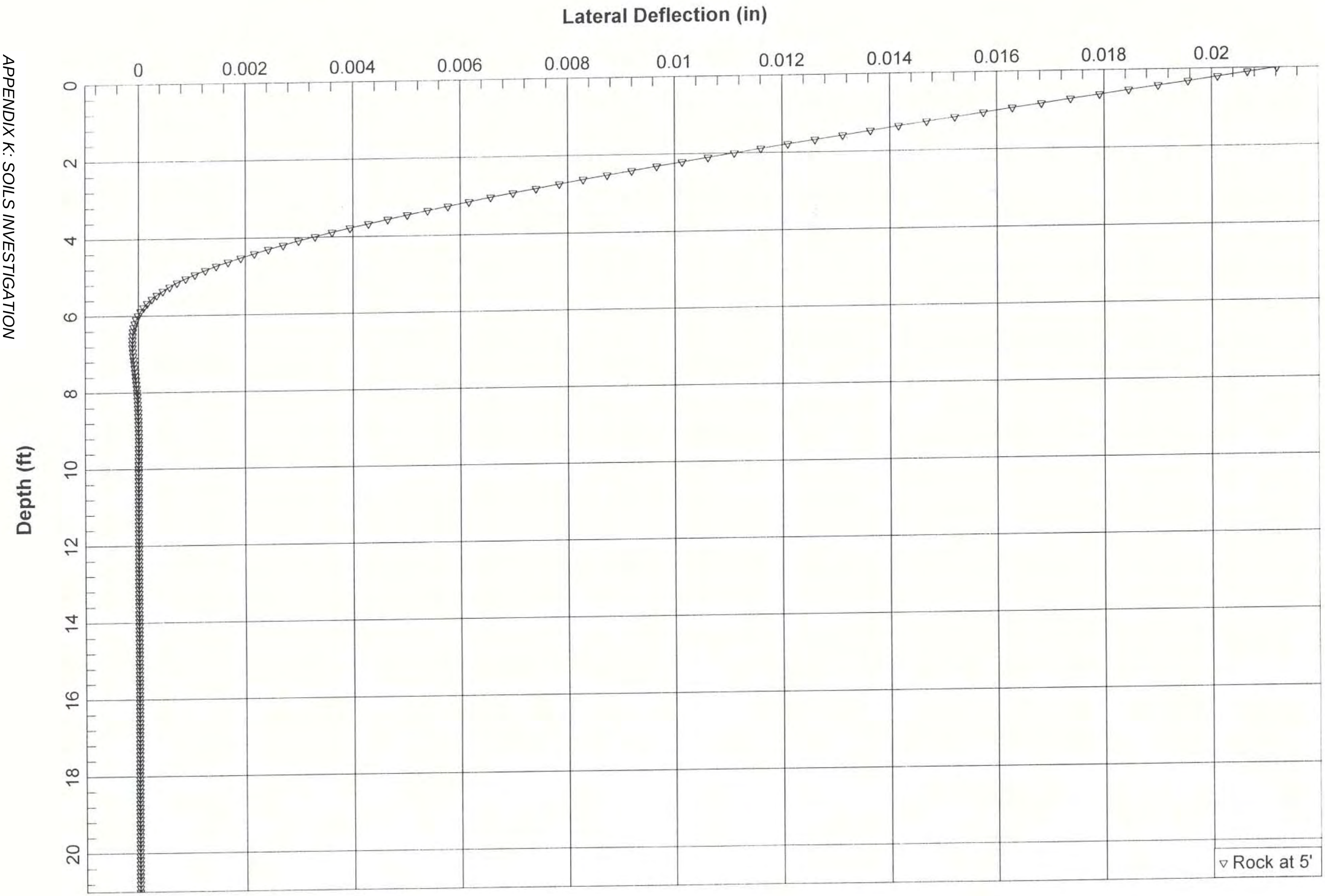
10 Feet | 15 Feet | 20 Feet | 25 Feet | 30 Feet

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

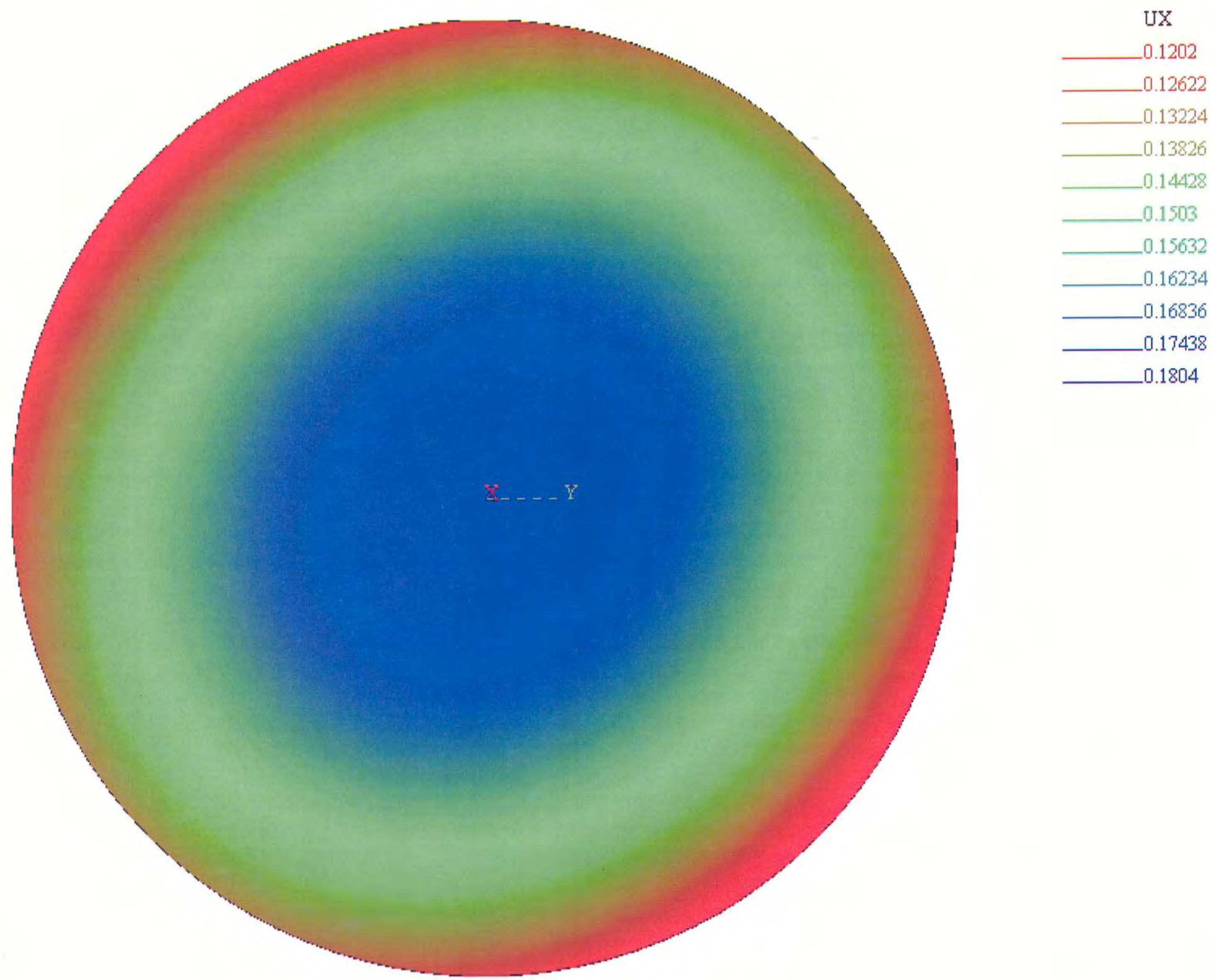


Plate 25

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

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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:

$$V_R \sim 0.9\ Vs \qquad (7)$$

(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.

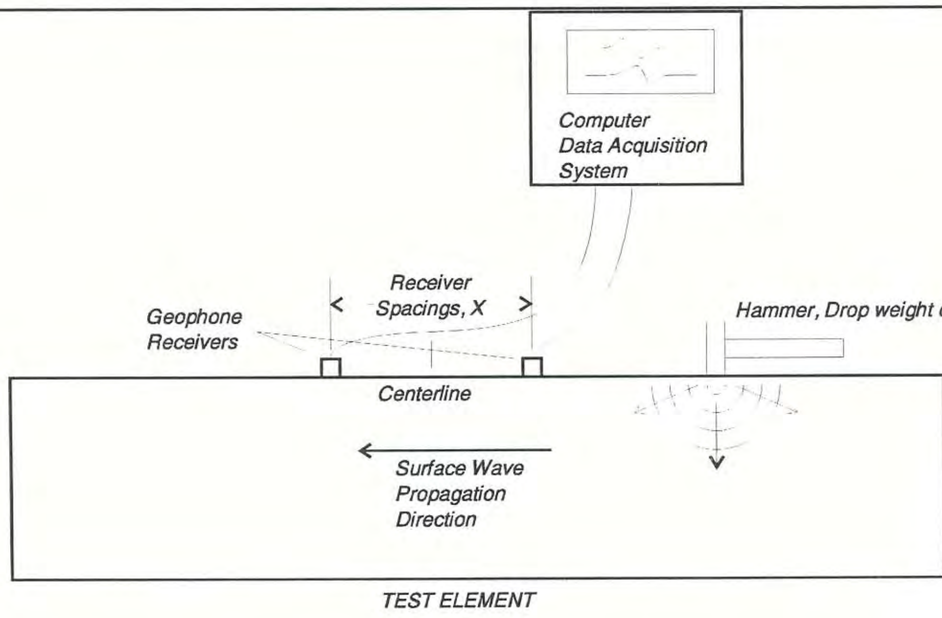


Fig. 1 - Field Arrangement of Source, Receivers and Recording Equipment for Typical SASW Testing

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:

$$Vr = f^*\lambda \qquad (8)$$

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.

2.2.1 Collection of SASW Field Data. 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.

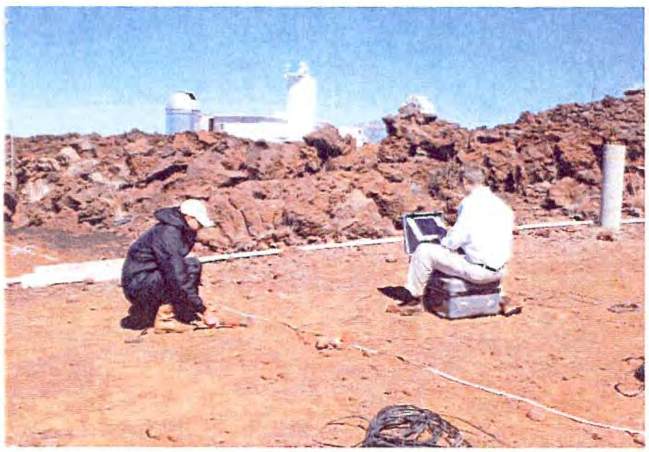


Fig. 2 - SASW on Site 1 E-W with 4 lb Hammer and 4.5 Hz Geophone Pair (orange)

Fig. 3 - Freedom Data PC for SASW Surveys

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:

$$t = \phi / 360 * f \quad (9)$$

Surface wave velocity (Vr) is obtained by dividing the receiver spacing (X) by the travel time at a frequency:

$$Vr = X / t \quad (10)$$

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.

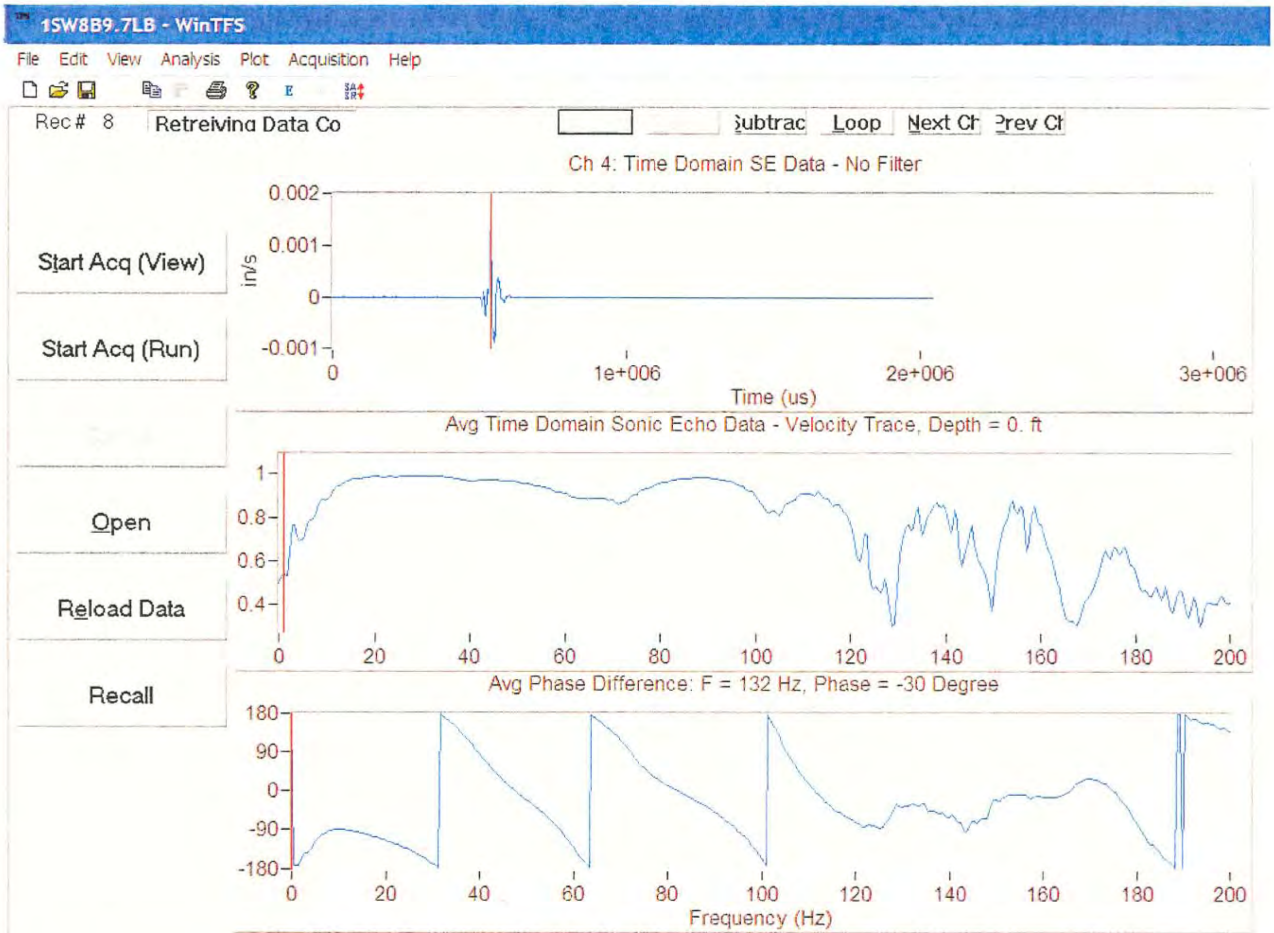


Fig. 6 - Example SASW Geophone Response (top trace), Coherence (middle trace) and Phase (bottom trace) Plots for 8 ft Receiver Spacing and West Traveling Wave at Site 1 E-W

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.
3. S. Nazarian and K.H. Stokoe, II, In Situ Determination of Elastic Moduli of Pavement Systems by SASW Method (Theoretical Aspects), Report 437-2, Center For Transportation Research, The University of Texas at Austin, 1986.

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.

6. Seed, H.B. and Idriss, I.M., "Soil Moduli and Damping Factors for Dynamic Response Analysis", Report No. EERC 70-10, University of California, Berkeley, Sept., 25 p.

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.

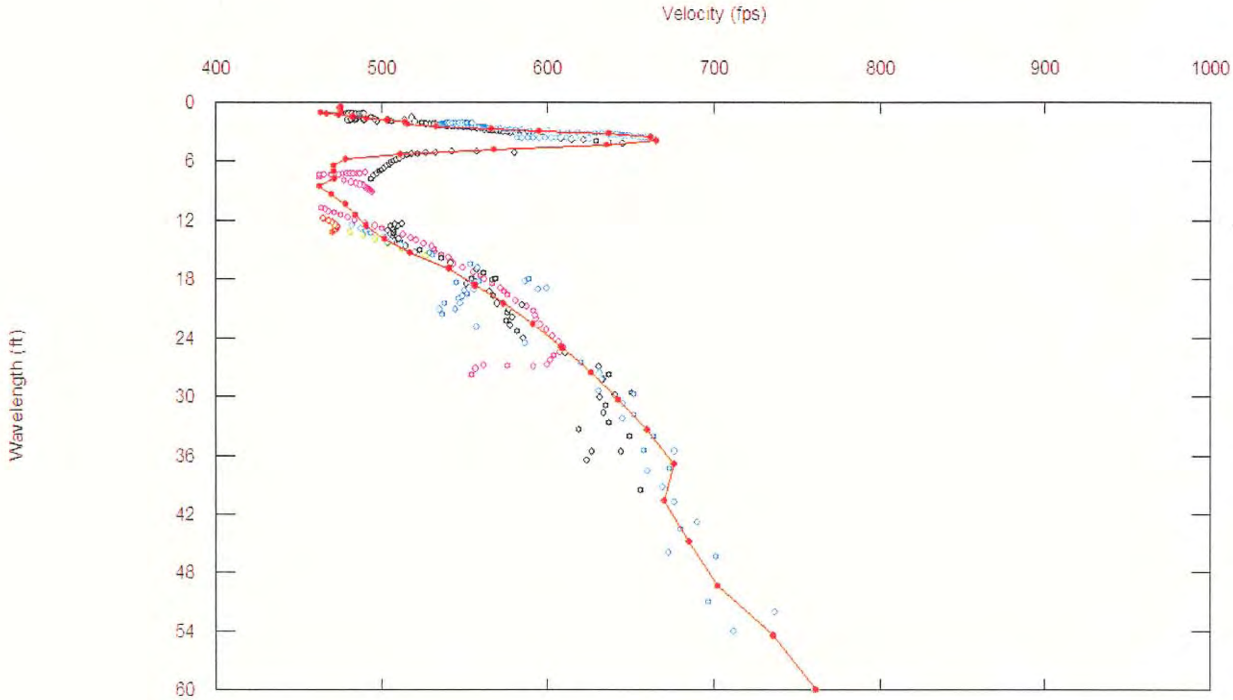


Fig. 7 - Site 1 E-W SASW Experimental (symbols) and Theoretical (symbols with line) Velocity Dispersion Curve Results

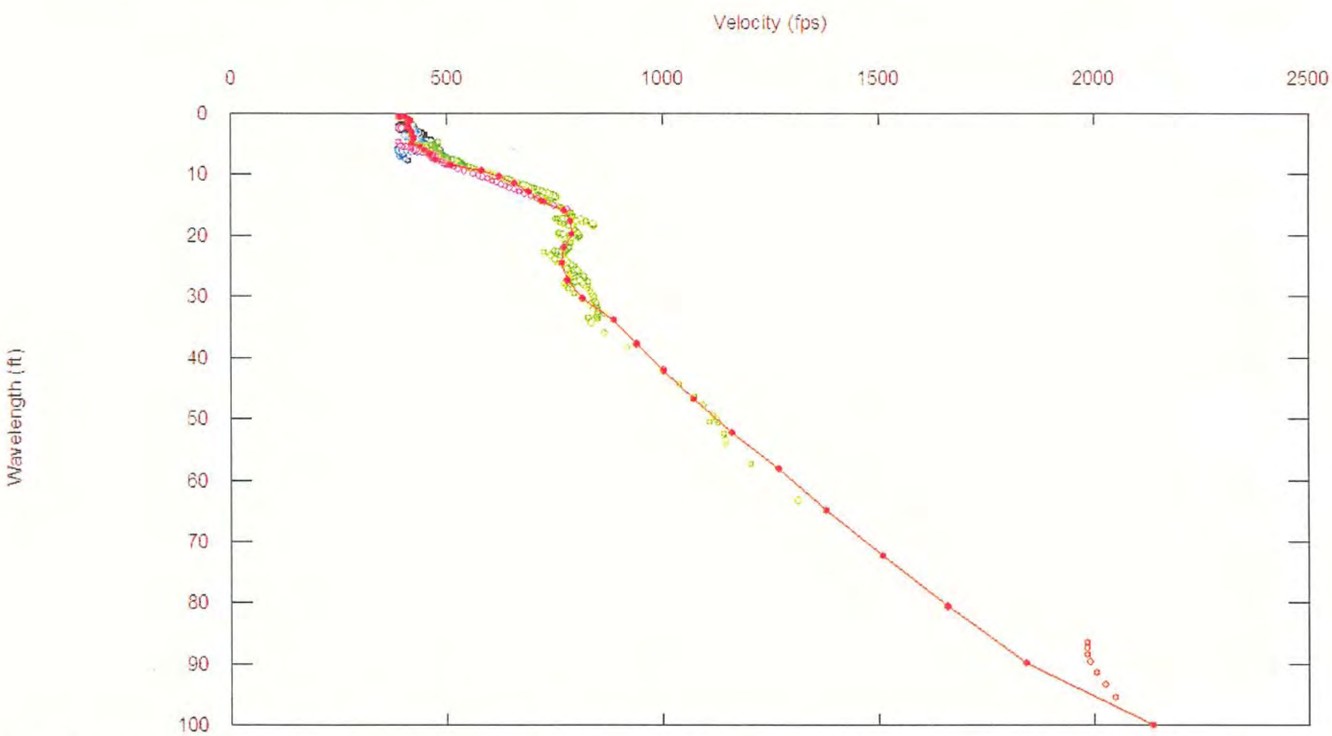


Fig. 8 - Site 2 N-S SASW Experimental (symbols) and Theoretical (symbols with line) Velocity Dispersion Curve Results

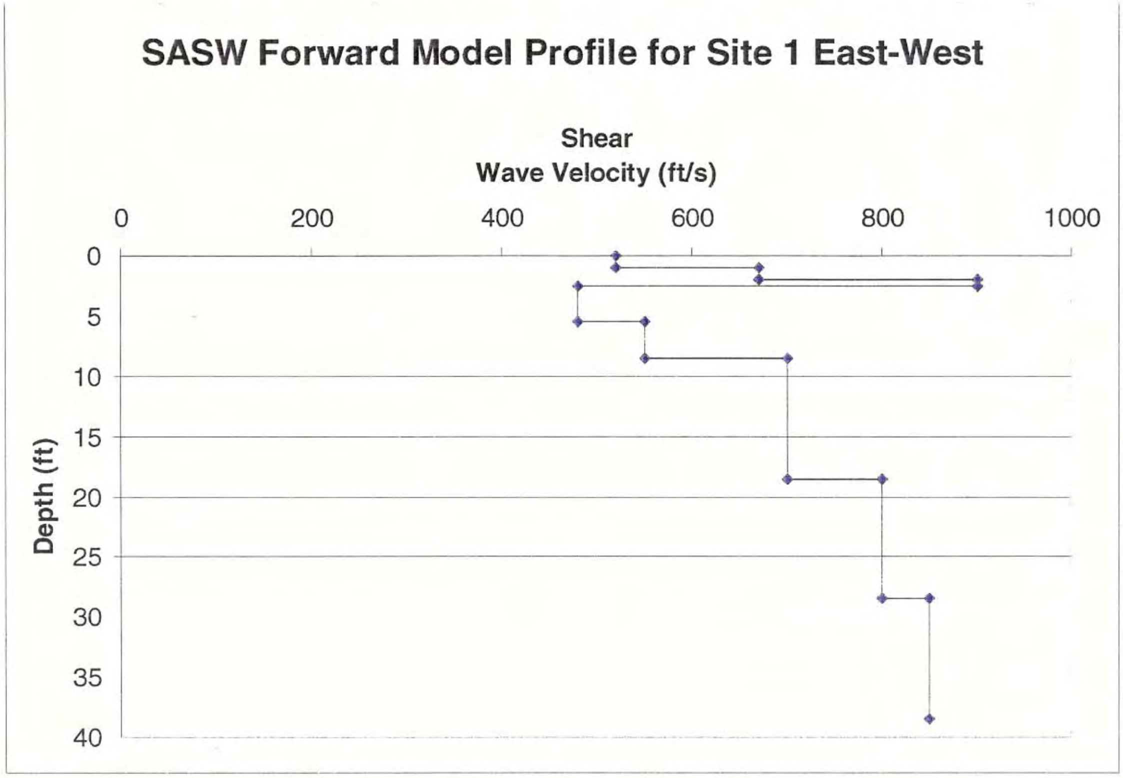


Fig. 9 - Site 1 E-W SASW Theoretical Shear Wave Velocity Profile

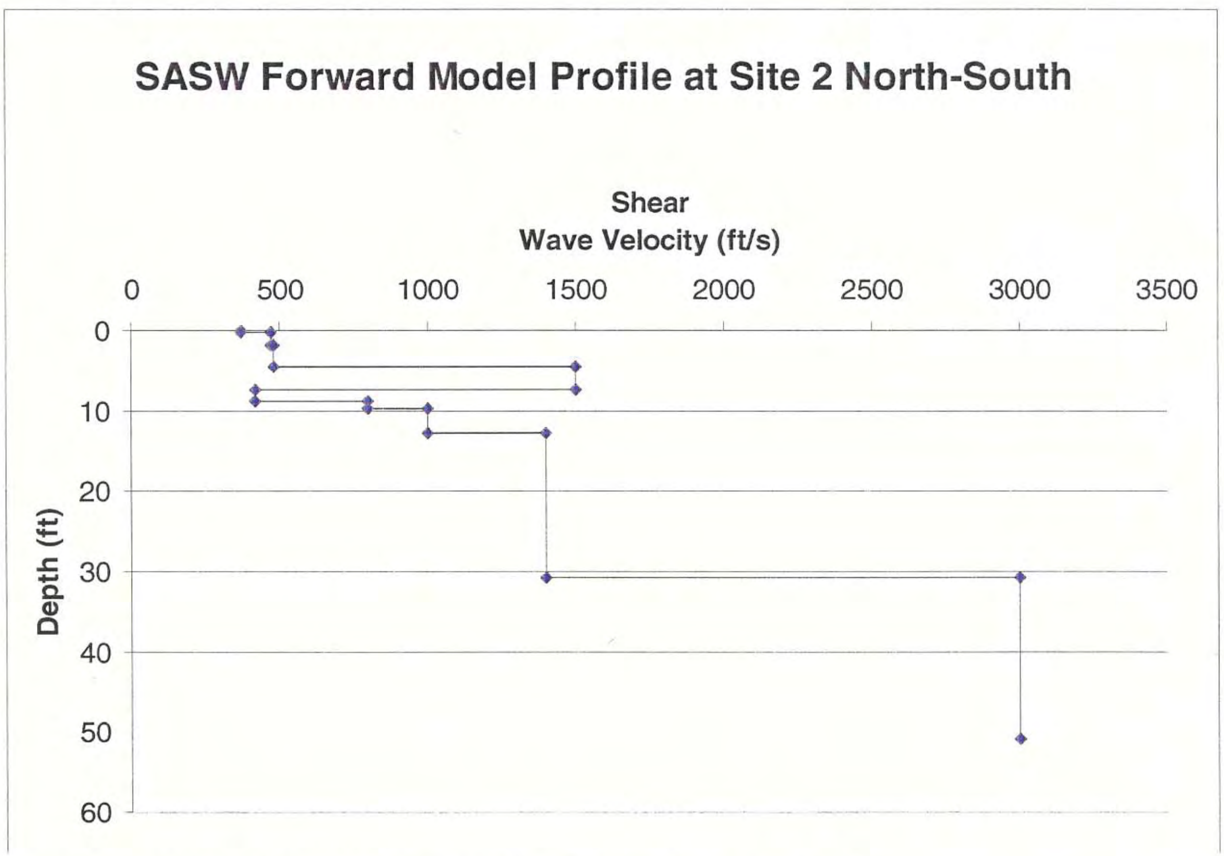


Fig. 10 - Site 2 N-S SASW Theoretical Shear Wave Velocity Profile

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 L

STORMWATER MASTER PLAN
FOR HALEAKALĀ HIGH ALTITUDE OBSERVATORY

Stormwater Master Plan
For Haleakalā High Altitude Observatory

Prepared for

University of Hawaiʻi
Institute for Astronomy

Prepared by

Tetra Tech, Inc.
2828 Paʻa Street, Suite 3080
Honolulu, Hawaiʻi 96819

March 2006

1.0 Introduction

Purpose

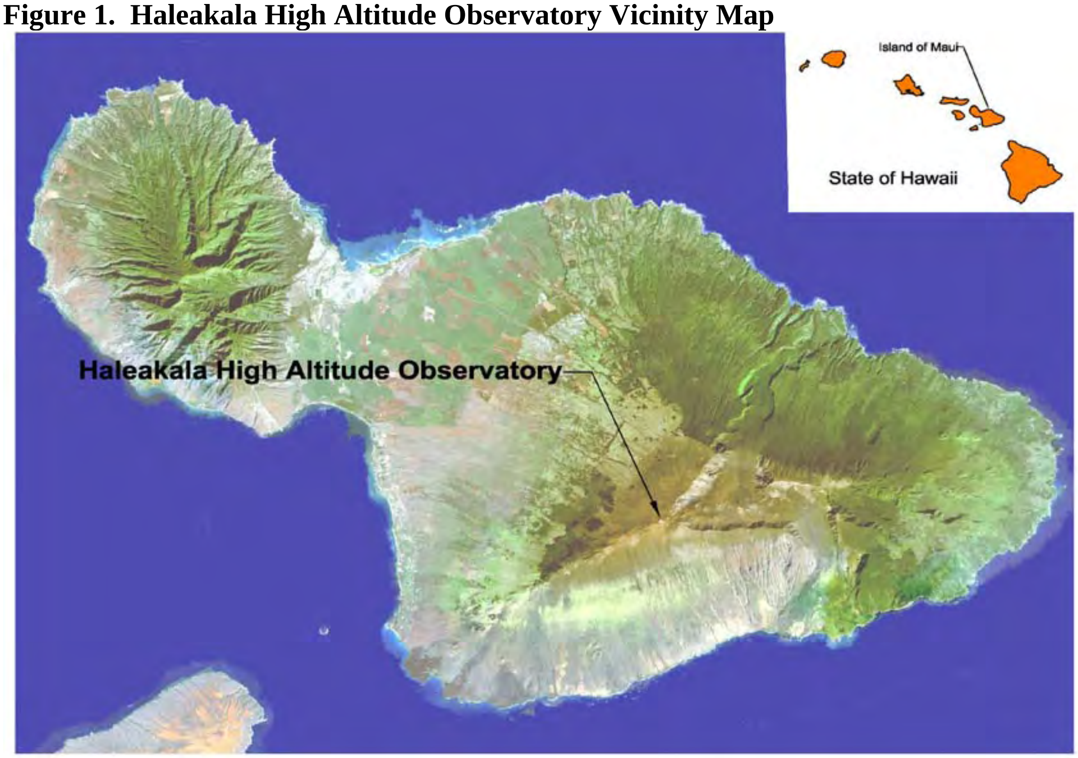
The observatories at the summit of Haleakalā have been an important and valuable asset to astronomers for over 50 years. The Haleakalā area also contains both culturally and environmentally significant assets. In the interest of balancing the need of the astronomy community with the needs to protect cultural and natural resources of the area, the University of Hawaiʻi 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 master 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

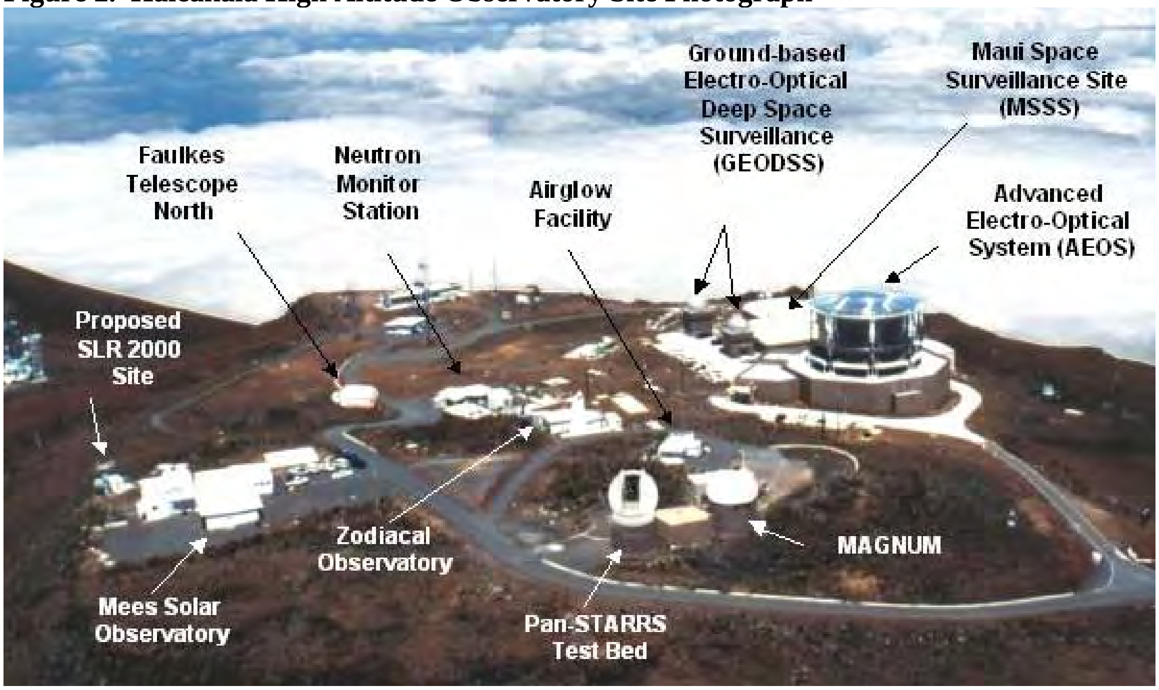
The 18.166 acres of land associated with the HO was given to the University of Hawaiʻi in 1961 for scientific purposes, by Executive Order from Hawaiʻi's Governor. The HO is located on the extinct Kolekole volcanic cinder cone in eastern Maui (Figure 1). The central area of Kolekole crater is a naturally 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.

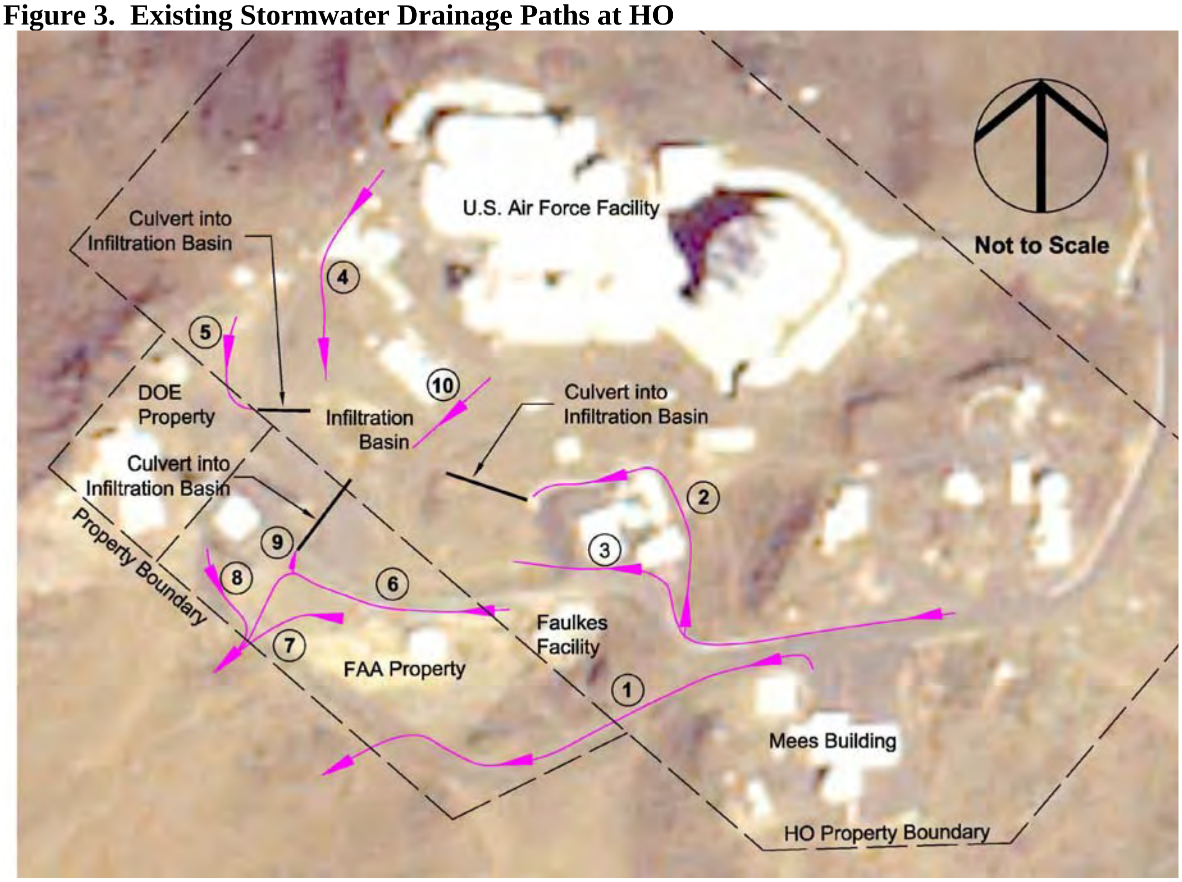
The following sections detail the investigation of the hydrologic characteristics of the HO site. The investigation consisted of identifying runoff flow paths at the facility and assessing infiltration rates at four locations across the facility. Based on the information determined in the field, a hydrologic 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.

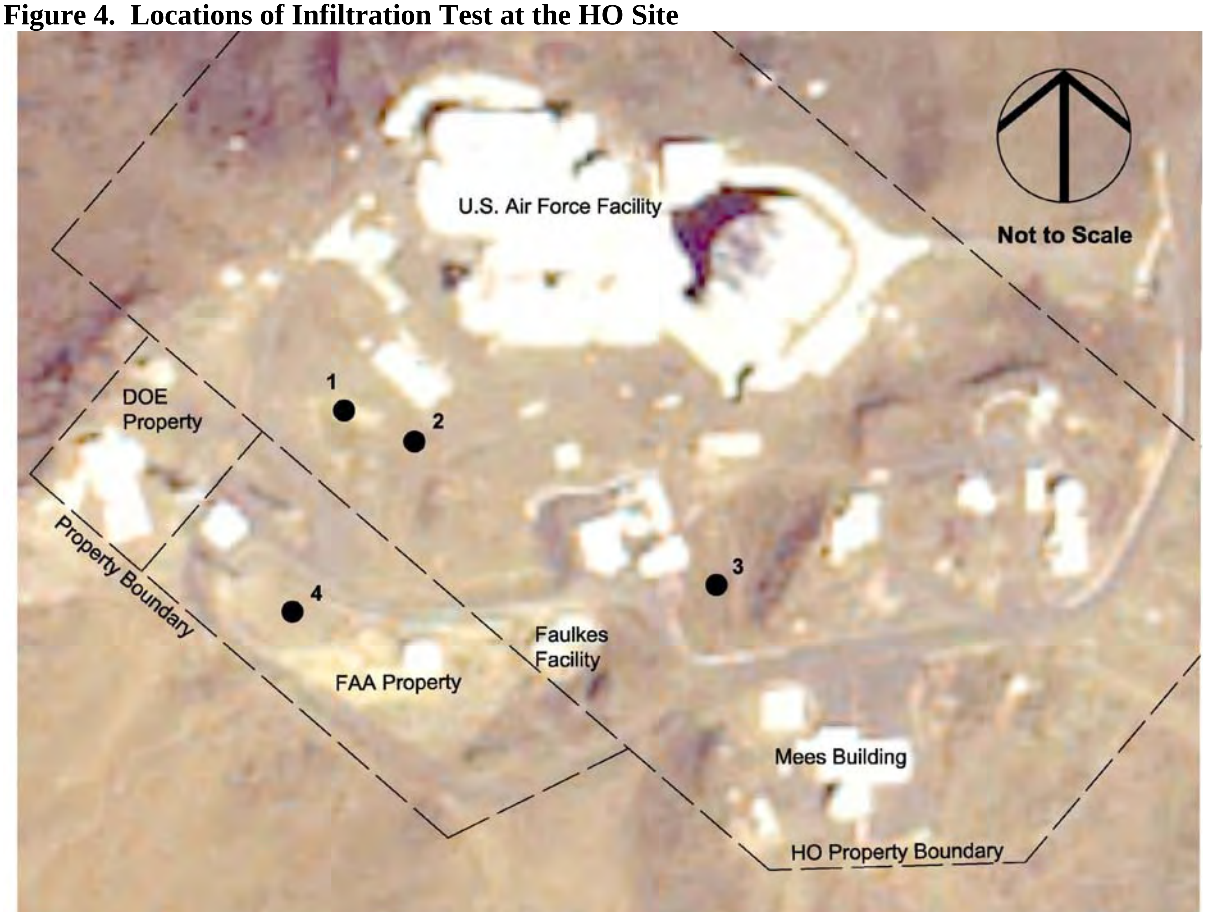
Flow Path 10- A large portion of the Air Force facility generates stormwater runoff that flows into the infiltration basin. The paved surfaces associated with the facility have curbs, which keep the runoff on paved surfaces until it enters the pipe network that discharges into the infiltration basin.

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.

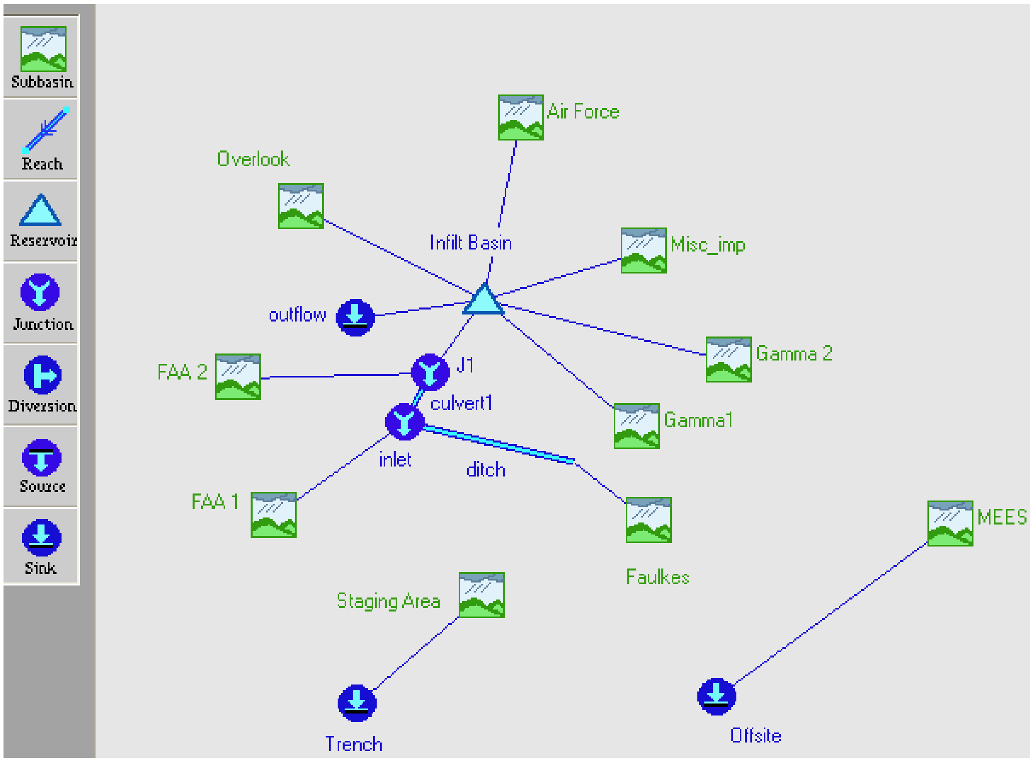
In order to estimate the volume and peak flow rate of stormwater at the HO site, a hydrologic model of the site was developed. The U.S. Army Corps of Engineers' Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) was used to perform the hydrologic analysis of the HO facility. HEC-HMS is 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

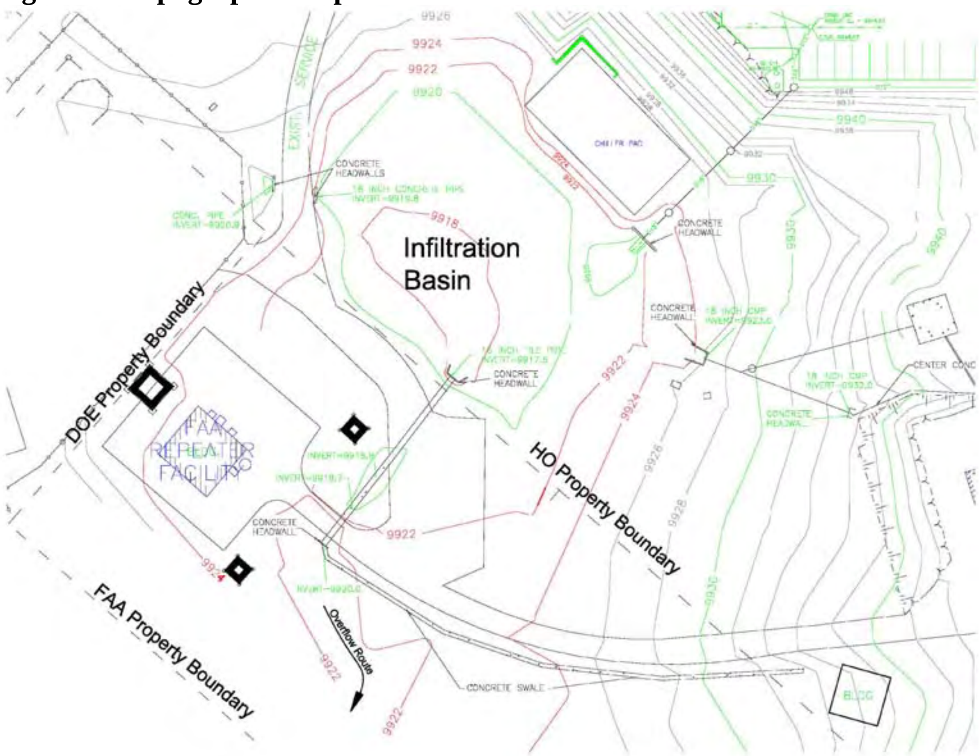
Both UH and the Air Force plan to expand their facilities at the HO site in the future. The Air Force plans to construct a Mirror Coating Facility and associated parking. The Air Force expansions will discharge to the infiltration basin. The UH is planning to construct the proposed Advanced Technology 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.

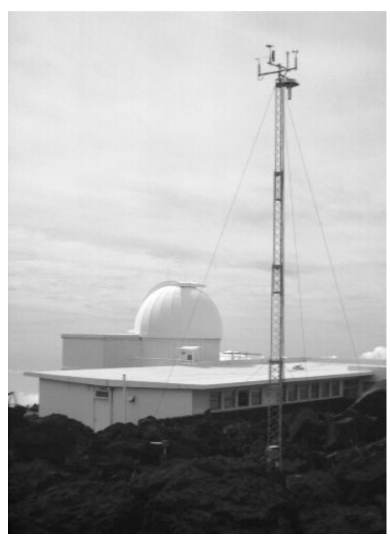
The total storage volume of the infiltration basin is estimated to be 1.5 ac-ft. The estimation assumes the maximum storage occurs at elevation 9922 ft. The topography survey reveals that a water level higher than 9920 feet within the infiltration basin will cause runoff to back up through the culvert 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.

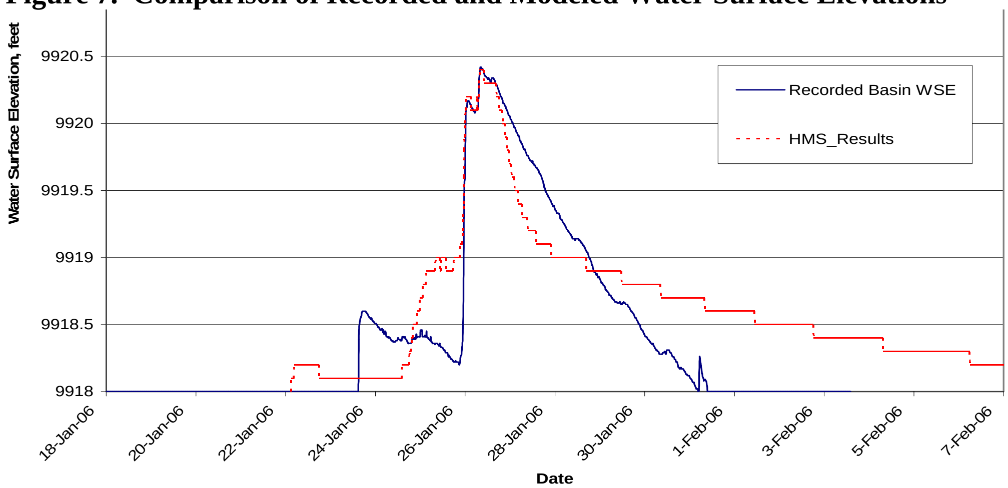
Infiltration Basin Water Level Gage

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 M

U. S. FISH AND WILDLIFE SERVICE,
SECTION 7, INFORMAL CONSULTATION DOCUMENT

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122, Box 50088
Honolulu, Hawaii 96850

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IN AMERICA

In Reply Refer To:
1-2-2007-I-0133

MAR 28 2007

Dr. Craig B. Foltz
Advanced Technology Solar Telescope Program Officer
Division of Astronomical Sciences
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230

Subject: Informal Consultation on the Construction and Operation of the Advanced Technology Solar Telescope at the Haleakala High Altitude Observatories Site on Maui, Hawaii

Dear Dr. Foltz:

On June 15, 2006, you requested initiation of formal consultation for the construction and use of the National Science Foundation's (NSF) proposed Advanced Technology Solar Telescope (ATST) at the Haleakala High Altitude Observatories site on Maui, Hawaii, pursuant to section 7 of the Federal Endangered Species Act of 1973, as amended (16 USC 1531, et seq.). At that time you determined the construction of the ATST could adversely affect the federally endangered Hawaiian petrel (*Pterodroma phaeopygia sandwichensis*) and you included a no effect determination for the following federally endangered species: Hawaiian goose (*Branta sandvicensis* or nene); Hawaiian hoary bat (*Lasiurus cinereus semotus*); and Haleakala silversword (*Argyroxiphium sandwicense* ssp. *macrocephalum*). During the pre-consultation and formal consultation process, the U.S. Fish and Wildlife Service (Service) and the NSF worked cooperatively to develop avoidance and minimization measures to reduce impacts to listed species, specifically for the Hawaiian petrels occupying the 33 known nest chambers in the vicinity of the proposed telescope. The following issues were addressed during our initial consultation process:

- Excessive noise and vibration from construction equipment
- Ground vibration that could collapse Hawaiian petrel burrows
- Flight obstacles
- Increased rat population
- Spread of invasive species from construction equipment and vehicles
- Increased vehicular traffic

Your designated consultant, Dr. Fein from KC Environmental, worked with us for several months to develop avoidance and minimization measures to reduce project impacts to the Hawaiian petrel and Hawaiian goose. These measures include: (1) modification of the construction schedule to avoid the peak petrel nesting period; (2) reduction in vehicular traffic; (3) monitoring of noise and reduction of decibel levels; (4) rat removal by baiting; (5) elimination of weed and invasive species transport to Haleakala, and (6) extensive petrel monitoring and research.

On February 27, 2007, our office participated in a conference call to discuss the aforementioned minimization measures. Dawn Greenlee and Patrice Ashfield, of my staff, yourself and your solicitor, Bijan Gilanshah participated. We concurred with your determination that the inclusion of extensive avoidance and minimization measures had reduced project impacts to a level of insignificance. Although not anticipated, we also discussed that if a Hawaiian petrel or Hawaiian goose was harmed or killed as a result of the ATST construction activities that the Service would be contacted immediately and that work action would cease until we have formally addressed the cause for the take. You also extended our consultation deadline to March 28, 2007, due to the new information and measures to be considered in our consultation process.

Enclosed is a description of the proposed action along with detailed information outlining the avoidance and minimization measures you agreed to implement. We have also included our analysis that led to our concurrence with your determination that this project is not likely to adversely affect the Hawaiian petrel and the Hawaiian goose. Information and documents used in our analysis include: (1) the NSF's September 2006, Draft Environmental Impact Statement for the Advanced Technology Solar Telescope, Haleakala, Maui, Hawaii (NSF 2006a); (2) three risk analysis documents prepared in response to requests by the Service, entitled: a.) Acoustic Evaluation of the ATST Mechanical Equipment Building (Phelps, unpublished); b.) Effect of Lightning Upon Burrowing and Tunneling Birds and Mammals Near ATST (Kithil, National Lightning Safety Institute, unpublished); and c.) Technical Response to Vibration Issues (Barr, unpublished 2006), (3) peer-reviewed journal articles and unpublished literature; (4) information in our files; and (5) meeting notes and correspondence associated with this consultation. A complete administrative record of this consultation is on file in the Service's Pacific Islands Fish and Wildlife Office.

We concur with your determination that the proposed ATST project is not likely to adversely affect the Hawaiian petrel and the Hawaiian goose. You made a no effect determination for the Hawaiian hoary bat, Haleakala silversword, and critical habitat for the Haleakala silversword and the *Geranium multiflorum*. You requested our concurrence on these determinations and you will find this information in the enclosed document.

We thank you for your support and coordination throughout the consultation process. It was a pleasure working with a Federal partner that took additional steps to avoid and minimize project impacts to endangered species. Your efforts reduced potentially adverse effects for the

Hawaiian petrel and Hawaiian goose to a level of discountable effects for these species. We also appreciate the additional measures you incorporated into this consultation such as video nest monitoring that will enhance our understanding of the breeding ecology of Hawaiian petrels. The data gathered from the video monitoring will assist us in our management and recovery efforts of petrel colonies in the future. If you have questions or would like additional information regarding these comments, please contact Dawn Greenlee, Fish and Wildlife Biologist (phone: 808/792-9400; fax: 808/792-9581).

Sincerely,

Marilet A. Zablan

for Patrick Leonard
Field Supervisor

Enclosure

Enclosure for PIFWO Log Number 1-2-2007-I-0133 (March 2007)

Informal Section 7 Consultation on the Construction and Operation of the Advanced Technology Solar Telescope at the Haleakala High Altitude Observatories Site on Maui, Hawaii.

This section 7 informal consultation document provides our U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office (Service) understanding of the proposed action, including all avoidance and minimization measures that will be implemented, and our analysis of the effects to listed species and designated critical habitats occurring within the Action Area.

The National Science Foundation (NSF) is proposing to fund the construction and use of the ATST within the 7.4 hectare (ha) (18.2 acre (ac)) University of Hawaii Institute for Astronomy, Haleakala High Altitude Observatories site, Maui, Hawaii. Near the peak of a large shield volcano, at an elevation of 3,042 m (9,982 ft), the proposed telescope site is one of the prime sites in the world for astronomical and space surveillance activities (Figure 1). The Haleakala High Altitude Observatories site houses seven existing observatories, including astronomical facilities and the Air Force Maui Space Surveillance Complex. Two small adjacent properties host facilities of the U.S. Department of Energy, U.S. Coast Guard, the Federal Aviation Administration, the Maui Police Department, Federal Bureau of Investigation, and other agencies. Haleakala was selected as the preferred location for the ATST project after evaluating 72 sites around the world. As the largest and most capable solar telescope, the ATST will provide researchers with four-kilometer (km) (2.5 mile (mi)) resolution images of the Sun's surface. This high-resolution data will enable scientists to pursue an understanding of the solar magnetic variability that drives space weather and resolutions to fundamental length and time scale questions about the basic physical processes governing variations in solar activity associated with climate changes on Earth.

Figure 1. Haleakala High Altitude Observatories site location near the summit of and adjacent to Haleakala National Park, Maui, Hawaii.

The new facility is proposed for construction on an approximately 0.3 ha (0.7 ac) site consisting of cinder, lava, and ash deposits. The completed observatory enclosure will be a maximum of 43.5 meters (142.7 feet) high and 25.6 meters (84 feet) in diameter (Figure 2). The attached Support and Operations Building will be several stories high in order to accommodate a large receiving bay, large platform lift, offices, and laboratories. The Utility Building will provide space for mechanical and electrical equipment including a generator, very-low-temperature chiller, ice storage tanks, a 10-ton heat pump condenser unit and uninterruptible power supply units. There will be a utility and ventilation tunnel connecting the Utility Building to the Support and Operations Building. Additional support structures will include a subsurface grounding field for observatory equipment that also includes lightning protection, a wastewater treatment plant and infiltration well, and a storm water management system designed to provide potable water to the facility (NSF 2006).

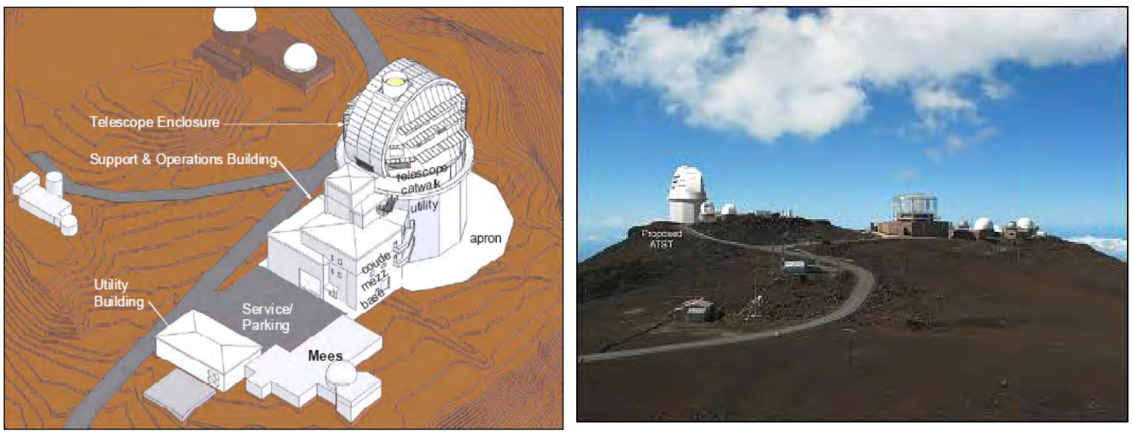

Figure 2. Artist's rendering of proposed ATST telescope enclosure, Support and Operations Building, and Utility Building as they will appear adjacent to several of the existing observatory buildings including the Mees and AEOS facilities. (NSF, 2006).

Project Schedule

Construction is scheduled to begin after October 1, 2008 and will occur in various phases including site preparation and foundation work. It is anticipated that construction of the exteriors of the buildings will be completed within two years. Interior work and telescope integration, testing, and commissioning will then be completed within approximately three to four years. The telescope is then scheduled for operation and use through the year 2039.

Demolition: The existing Mees Solar Observatory driveway, parking area and rock wall borders, the underground cesspool, and other selected items at the Mees Solar Observatory utility area will be demolished and removed. Demolition will be staged and will occur throughout the construction period. Demolition will require the use of bulldozers, dump trucks, bobcats, and other heavy machinery. Demolition work will occur during about 60 total days throughout the duration of the construction project.

Grading and Leveling: The construction will require the creation of a level pad at least 20 feet wider, in all directions, than the footprint of the telescope enclosure and the Support and Operations Building. The grade cut will be made at approximately the 3,042 m (9,980 ft) contour elevation, the removal of a maximum of approximately three meters (10 ft) of material from the highest portions of the site. This will be done using a bulldozer, backhoe, trencher, hoe ram, dump trucks, and other heavy equipment. An estimated eight vehicles will travel to and from the site on a daily basis during a one month period to complete this activity.

Figure 3. ATST construction site.

Excavation and Soil Retention: Initial major excavation will include a total removal of approximately 3,555 cubic meters (4,650 cubic yards) of rock and soil to accommodate the foundation systems for the proposed structures. This work will be done using bulldozers, backhoe, trencher, a truck-mounted auger for drilling down to bedrock, and a hydraulic hammer or jackhammers to break up large rock formations. A relatively undisturbed rocky site will be graded and leveled to approximately 0.6 m (2 ft) above the floor elevation of the Mees building (in the background in Figure 3) to accommodate construction of the ATST enclosure and concrete apron. Additional excavation will be needed in order to trench for utility lines, all of which will be installed underground. The major structural excavation is expected to follow the leveling work and take approximately two months to complete. The rock and soil removed from the construction site will be deposited in designated soil placement areas which are both previously disturbed sites (Figures 4, 5, and 6).

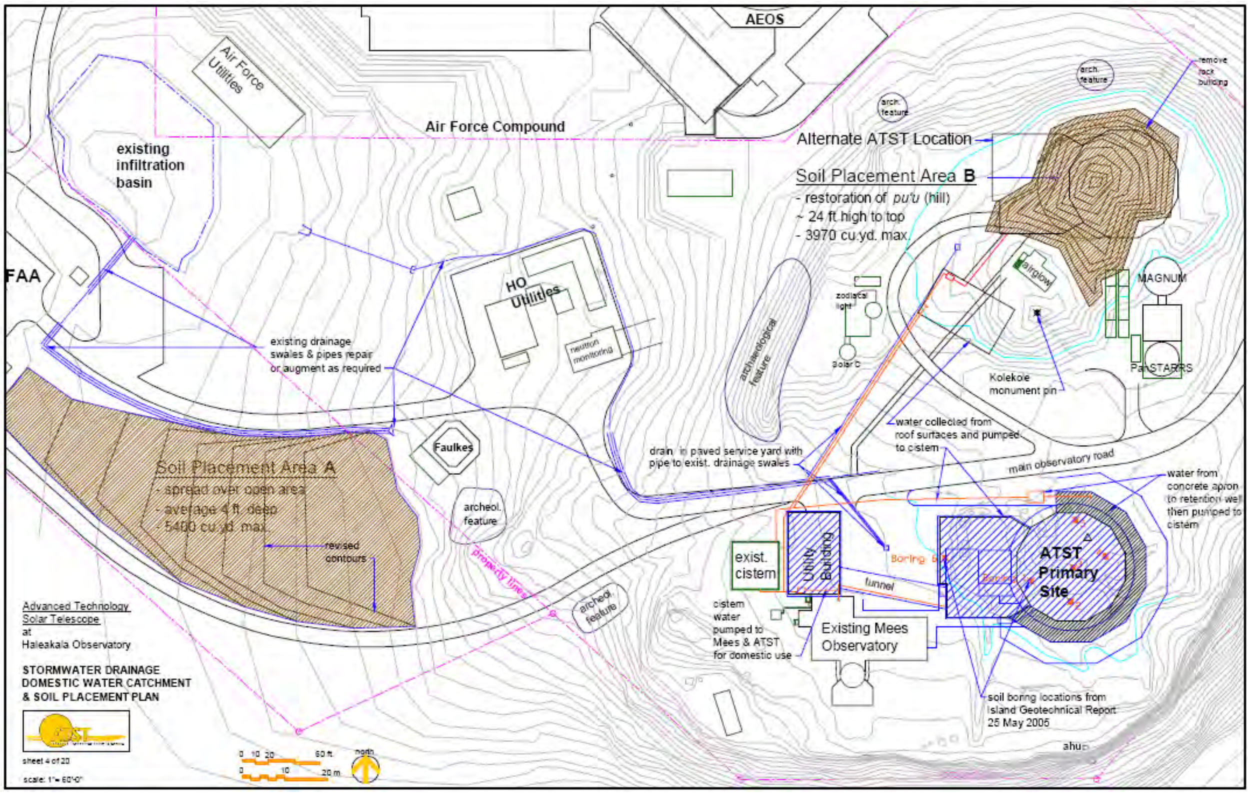

Figure 4. Soil placement areas, totaling 0.3 ha (0.9 ac).


Figure 5. Soil Placement Area A, which will also serve as the equipment staging area - where the truck is parked in this photograph - is a previously disturbed site.


Figure 6. Soil Placement Area B is a previously disturbed site.

Caisson Drilling: Approximately 21 holes will be drilled to a maximum depth of 6 m (20 ft) to reach basalt bedrock so that caissons (support structures) can be poured to support concrete mat foundations below the telescope and enclosure. The Support and Operations and utility buildings, by contrast, will be built on simple concrete pads laid on top of the volcanic rock and gravel of the upper site strata.

Vehicular Activities: It is estimated that during the first two years of construction, eight vehicles will make one round-trip drive to the construction site an average of six days per week. During later construction and integration (approximately a three year period), an average of seven round-trips per day will be necessary. Then during the 30-year operational life of the project approximately five trips per day, seven days per week will be made. A total of 66,294 vehicle round-trips will be made during the entire life of the project. During the construction and integration phases of the project, vehicles will consist primarily of heavy trucks, while during the operational life of the ATST, vehicles will consist primarily of passenger vehicles. Truck traffic will be limited, during all years of the project, between April 20 and July 15, to no more than two truck round-trips per day.

Conservation Measures and Effects Analysis

During the pre-consultation and consultation process, the Service and NSF worked cooperatively to develop avoidance and minimization measures to reduce impacts of the project to listed species, specifically to the endangered Hawaiian petrel. NSF incorporated conservation measures into the proposed action to minimize the impacts of the project and to avoid incidental take of Hawaiian petrel. Avoidance and minimization measures include equipment visibility marking, construction scheduling, Hawaiian petrel monitoring and research, predator control and invasive species interdiction and control (Table 1).

Table 1. Summary of effects of the project which were addressed during the section 7 consultation process.

Possible Effects	Avoidance and Minimization Measures Adopted
Collision of Hawaiian petrels with equipment and buildings	Construction crane will be lowered at night and marked with white visibility polytape. All structures will be painted white. No outdoor lighting will be associated with the project.
Burrow collapse from construction vibration	Engineers set ground vibration threshold for burrow collapse. Vibration will be monitored to ensure that the burrow collapse threshold is not reached.
Noise concerns and incubating Hawaiian petrels	Construction noise will not be louder than ambient wind noise at nest during incubation period (April 20 - July 15). Only two truck round-trips per day will be taken to the construction site during the incubation period.
Predator population increase	Trash will be contained. Rat predation at the Haleakala Observatories Hawaiian petrel colony will decrease as a result of project's predator control efforts.
Transport of invasive species to Haleakala	Cargo will be thoroughly inspected for introduced non-native species. All ATST facilities and grounds with 100 feet of the buildings will be thoroughly inspected for introduced species on an annual basis and any introduced species found will be erradicated.
Driver education	All drivers will receive a briefing and a breeding season refresher to further reduce the chance that a vehicle associated with the project will hit a Hawaiian goose.

Definition of the Action Area

The ATST Action Area (Figure 7) was dictated by the area impacted by the noise associated with the loudest vehicles scheduled to drive the road and the loudest pieces of equipment scheduled for use at the ATST construction site. Pursuant to a thorough literature search (Awbrey and Hunsaker 1997, Mock and Tavares 1997, Delaney *et al*. 1999, South San Francisco Ferry Terminal Project EA 2003), 60 dBA was selected to be a reasonable threshold of avian disturbance. Sound energy level at various frequencies is measured in decibels (dB). The A-weighted decibel scale was developed to represent the response of the human ear to sound.

The loudest truck noise permitted by EPA standards is 83 dBA (when measured at 50 feet), and the loudest equipment proposed for use at the ATST construction site are rock hammers and rock drills, which produce up to 113 dBA (measured at 10 feet). Sound attenuation was assumed to be only 6 dBA per doubling of distance, with no additional attenuation assumed to occur for either atmosphere or vegetation (NSF 2006). The outer edge of the Action Area corresponds with a sound pressure level of 65 dBA out in the open, where there is a clear line of sight to the road or construction site within the burrow during the periods of maximum noise production. Because no specific burrow depth or orientation information was available for the burrows along the road, a burrow attenuation rate of only five dBA was applied to each burrow for the creation of the Action Area: therefore, all nest chambers which would be exposed to a 60 dBA sound as a result of the proposed action were considered to be within the Action Area. Along a 1.5 km (0.9 mile) portion of the Haleakala National Park Road, the Action Area follows a cliff edge, where the terrain serves as a barrier to road noise. Based on these conservative attenuation rates, the Action Area perimeter is 122 m (400 ft) from the road and 780 m (2,560 ft) from the outer edges of the construction site. The total area encompassed by the Action Area is approximately 574 ha (1,418 ac).

Construction was scheduled to further limit the frequency and extent of noise generation at various times of year, in order to minimize impacts to the Hawaiian petrel within the Action Area, particularly to those occupying burrows immediately adjacent to the construction site (Figure 8). Please refer to pages 15 through 25 for a thorough discussion and analysis of noise impacts.

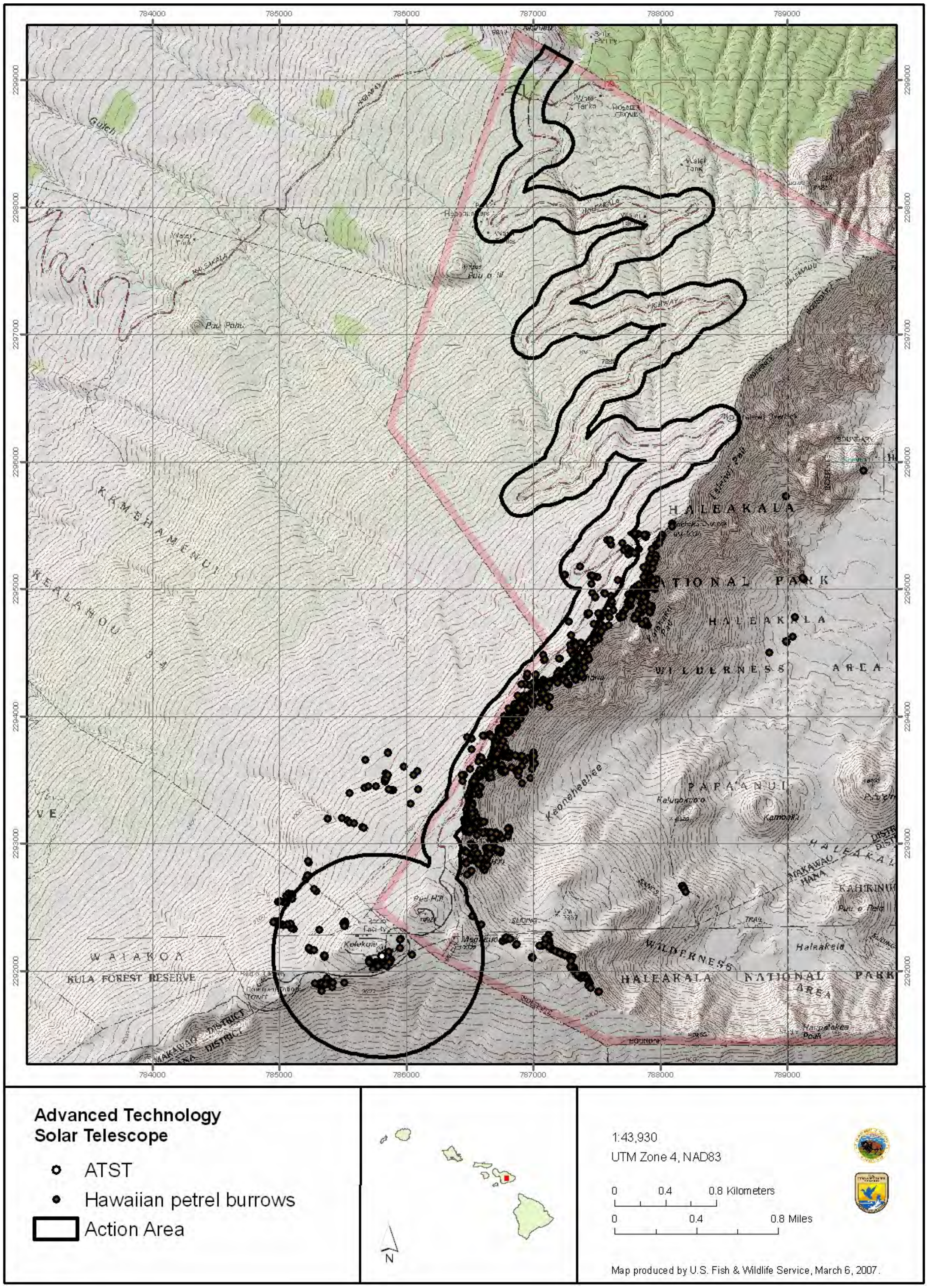

Figure 7. Delineation of the ATST Action Area.

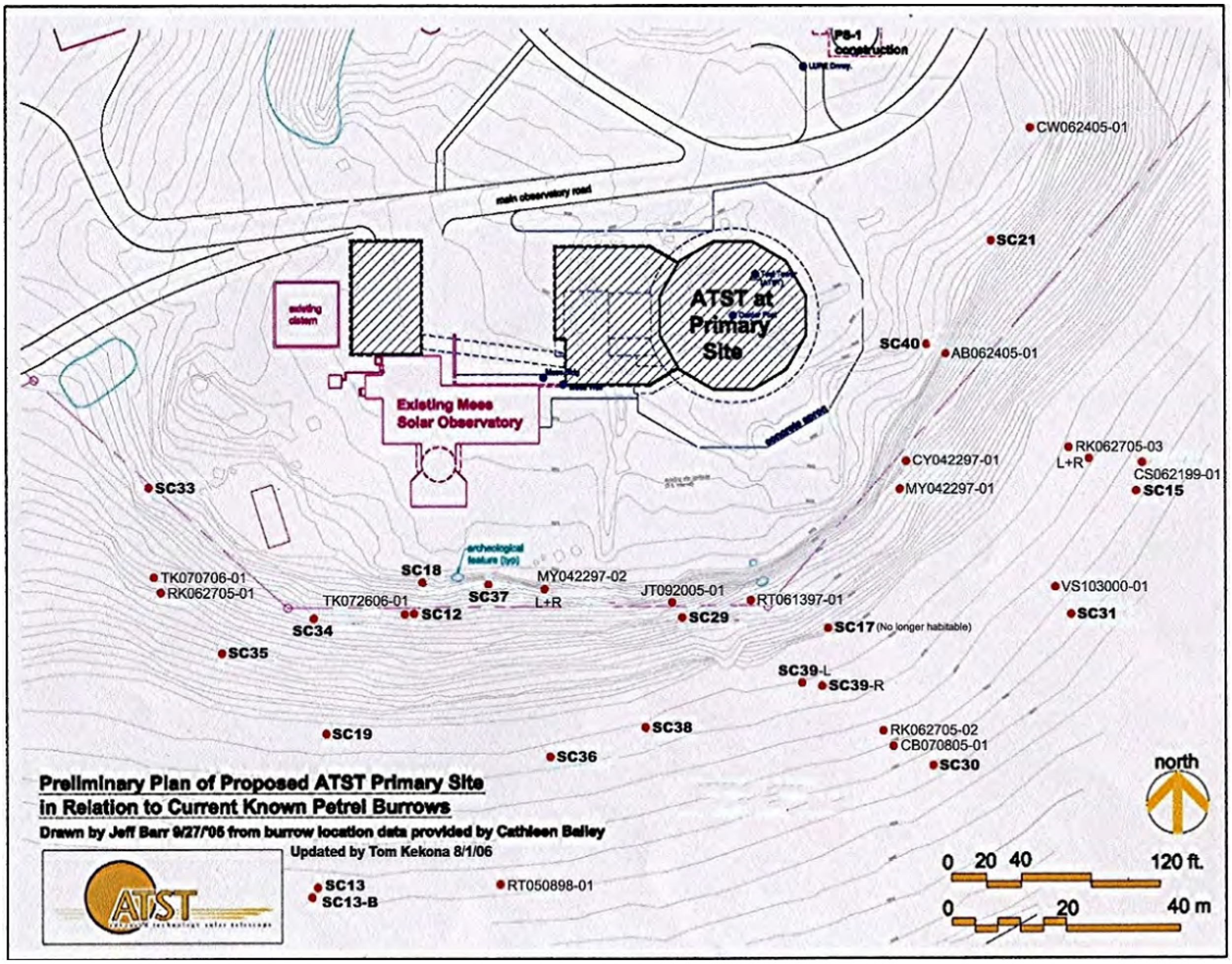

Figure 8. The Hawaiian petrel colony adjacent to the ATST construction site.

Collision with Buildings and Equipment

There is a risk that Hawaiian petrel injury or mortality can occur due to collision with man-made objects. For example, collision with structures such as poles, buildings, vehicles, and lights, accounted for the death of 37 Hawaiian petrels (accounting for 26 percent of all Hawaiian petrel mortality, and the death of an average of 1.1 bird/year), in the vicinity of Haleakala National Park and the Haleakala Observatories site between 1964 and 1996 (Hodges and Nagata 2001). Bailey (pers. comm. 2006b) attributes the death of 26 of those birds to fences containing barbed wire, constructed to exclude ungulates from the Haleakala National Park in the 1980s. After two years, the barbed wire was removed from the fences and Bailey (pers. comm. 2006b) estimates that an average of one Hawaiian petrel per year is lost due to striking the Park's ungulate exclusion fences. A petrel struck a small utility building in the saddle southwest of the ATST site (Bailey pers. comm. 2006b), in an area that is heavily used by birds (Day and Cooper 2004). Additional petrel mortality results during the fledging period, when fledglings collide with structures and rock outcroppings on their first flight to sea (Bailey pers. comm. 2006b).

A construction crane, which will be at the construction site for approximately three and a half years, could pose a flight obstacle to the fast-flying Hawaiian petrels during breeding season. The crane will be located just north of the telescope enclosure, between the enclosure and the access road (Fein pers. comm. 2006c). In order to minimize and avoid the flight risk to birds, the crane's lattice structure will be lowered each night, to a height of 14 feet or less, and the boom will be marked with visible white electric fence polytape, at night, between February 1 and November 30. White, non-reflective electric fencing polytape will be secured in some way to the all sides of the entire boom portion of the crane each night. The polytape strips will form a grid, with vertical and horizontal strips of polytape running a minimum of every 30.5 centimeters (12 inches). The specific method of attachment will be finalized after consultation with the crane contractor. The polytape grid might be sewn to a canvas fabric to be thrown over the crane boom at night, a sewn matrix of tape might be pulled over the boom, or another method may be employed to secure the grid of polytape to the crane.

Ornithological radar and visual data collected during 2004 and 2005 (Day and Cooper 2004a, Day and Cooper 2004b, and Day *et al* 2005) indicate that the ATST construction site does not lie within a heavily used Hawaiian petrel flight path. The ornithological radar data does indicate that birds tend to fly along the sides of the cliffs and through saddles on either side of the proposed construction site, rather than flying over the top of the peak, where the ATST is proposed for construction (Figure 9).

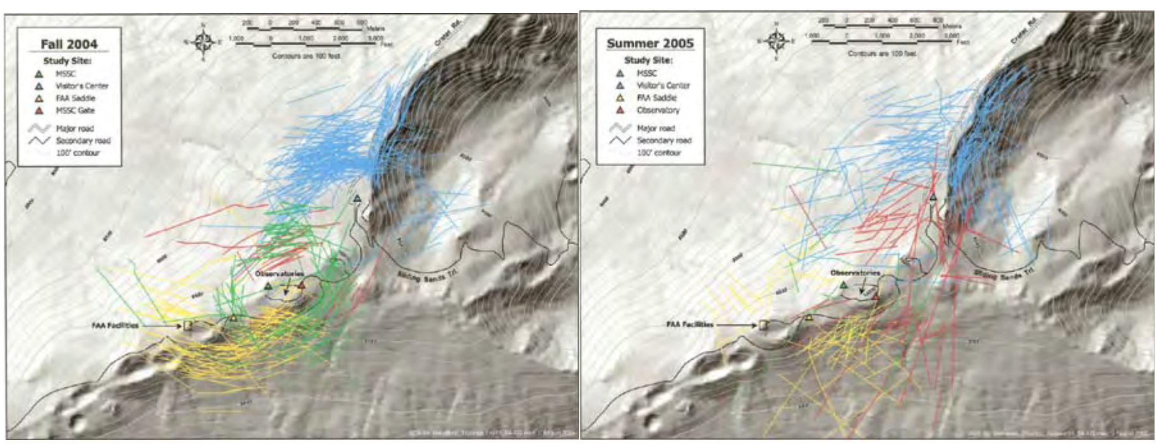

Figure 9. Diagrams from Day *et al*. 2005 indicating all Hawaiian petrel flight paths documented in the vicinity of the observatories site.

Existing Haleakala Observatories telescopes, some in existence for several decades, have not documented any bird strike or petrel mortality associated with the buildings. In addition, there is no outdoor lighting associated with the ATST project which might confuse or attract the seabirds.

Research conducted by Swift (2004) and unpublished observations by Penniman and Duvall 2006 and Penniman (pers. comm.) indicate that Hawaiian petrels avoid collision when objects are visible. Both the Swift (2004) and Penniman and Duvall (2006) applications of visibility marking found that the incorporation of strips of white, non-reflective electric fence polytape or similar material into fences reduced the risk of Hawaiian petrel collision. Before the installation of white visibility tape, birds were heard colliding with a new ungulate exclusion fence in the vicinity of a Hawaiian petrel colony on Lanai on two occasions. Since the white electric fence polytape was installed (Figure 10), no bird collisions with the fence have been heard (Penniman pers. comm.). Swift (2004) noted that birds appear to exhibit late avoidance behaviors when approaching marked fences, which they did not display when approaching unmarked fences, indicating that the apparent 100 percent successful collision avoidance marked fences is due to the birds' visual detection of the white tape. The polytape visibility flagging which will be draped over the ATST construction crane at night between February 1 and November 30 will contain a five times greater density of flagging than the flagging used in the fences studied by Swift (2004) and Penniman (unpublished). Therefore, we anticipate that the crane will be visible to petrels flying in the area.

Figure 10. White electric fence polytape improves visibility of lattice structures (Photograph by Jay Penniman, Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife, 2006).

Because the ATST structures and construction crane will not be located within a heavily used Hawaiian petrel flight paths, and because the petrels have demonstrated that they are able to avoid collision with the large white existing telescope dome structures as well as structures marked with white polytape visibility flagging, we do not anticipate the fatality of petrels associated with collision with the construction equipment or telescope buildings associated with this project.

Potential Burrowing Habitat Modification

GIS assessment of the locations of the proposed activities indicates that 0.31 ha (0.77 ac) of unoccupied, potential burrowing habitat would be lost due the construction of the ATST facilities. Burrowing habitat quality varies throughout the ATST project site, but stable rocks with loose material suitable for burrow excavation are available for future petrel colony expansion within the area which will be disturbed by the proposed project. The ATST project activities will make the site unsuitable for burrowing due to changes in soil structure or access. Impact areas include the telescope enclosure, apron, support and operations building; the portion of utility building and new wastewater treatment plant and infiltration well which will be constructed on ground not previously developed; areas disturbed for the radial field of grounding conductors; and the areas to be excavated for staging areas and equipment use. No storm water or grey water erosion is expected to be associated with the project. The two soil deposition areas were previously disturbed; therefore, no potential burrowing habitat loss will occur in these areas.

Burrow Collapse Due to Vibration

ATST project engineers conducted inspections of the burrows adjacent to the ATST project site to determine probability of burrow collapse due to vibration. They determined that the angular interlocking of separate rock segments which has allowed the borrows to survive seismic events, erosion and other potentially damaging forces over many years would enable them to withstand vibrations with peak particle velocities (PPV) of 0.12 in/sec without damage (Barr, unpublished 2006). PPV is the measure of the strength of ground vibration which is the most often used to gauge the stress experienced by structures. Seismographs are used to measure PPV (Figure 11). The most fragile historic structures can be exposed to PPV of 0.12 in/sec without being damaged (U.S. Department of Transportation Federal Transportation Administration 2006a).

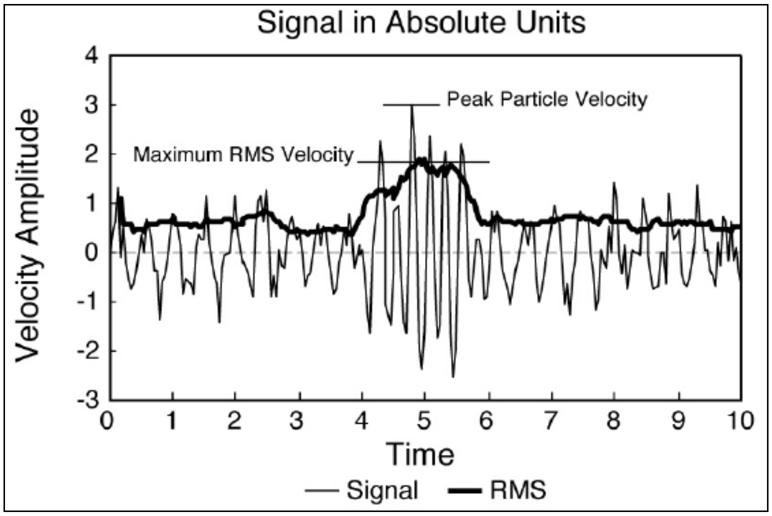

Figure 11. Peak Particle Velocity example (Excerpt from U.S. Department of Transportation Federal Transit Administration 2006a).

Vibration is transmitted through the soil or rock as earth particles are moved as a wave front radiating out from a source of excitation similar to water ripples initiated by a point disturbance. These waves encounter an increasingly larger circumferential surface area as they radiate outward. Therefore, the energy within each wave decreases with the distance from the source of vibration. This decrease, with distance, is called geometric damping, and it is inversely proportional to the square of the distance away from the source (Attewell and Farmer 1973) (Figure 12).

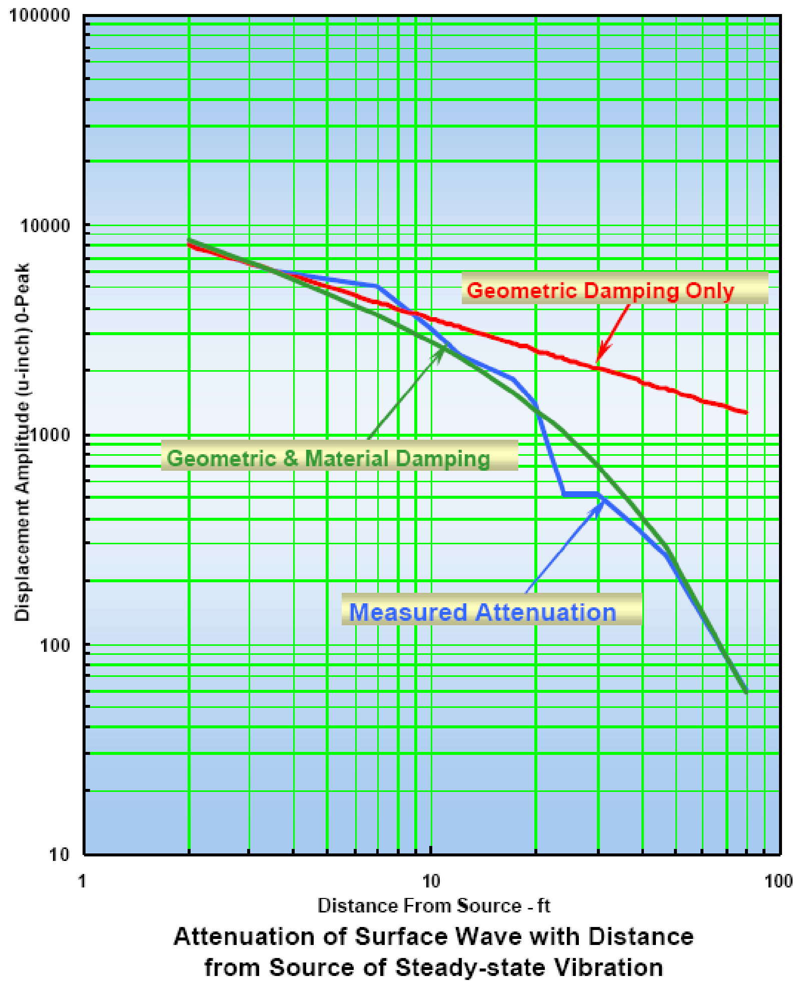

Figure 12. Comparison of geometric and material damping of vibration with distance from source (from ESI Engineering, Inc. unpublished).

Even though the most conservative estimates (Table 2) indicate that caisson drilling would produce vibrations which are less than one twentieth the strength of the engineer's burrow collapse threshold, ATST engineers agreed to relegate all use of rock drill equipment to the December through mid-February season when the Hawaiian petrels are absent from the site. Rock drills are the equipment used to drill holes for caisson pouring. Barr (unpublished, January 31, 2007) produced a map (Figure 13) which indicates the locations of the caissons in relation to the closest Hawaiian petrel burrows. No digging, trenching, or other type of earth removal work, associated with the lightning protection system, will be done within 12 meters (40 feet) of any occupied Hawaiian petrel burrow.

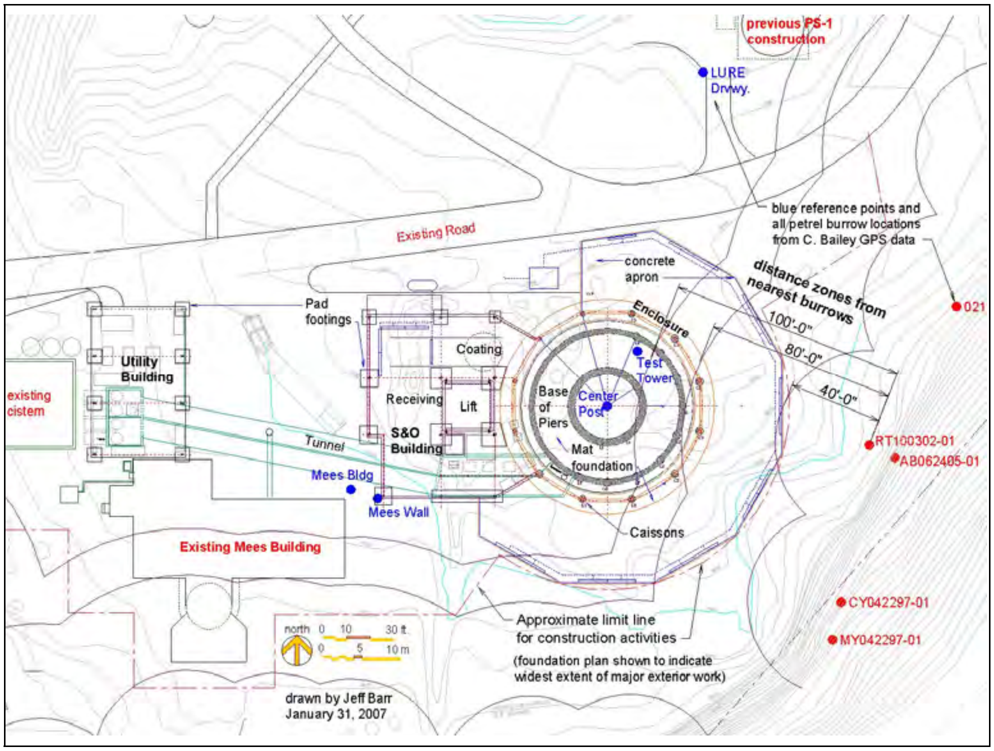

Figure 13. Hawaiian petrel burrows (bright red dots) in relation to the ATST construction site, including caisson drilling locations.

Table 2. Maximum calculated ground vibration expected at various distances from construction equipment.

Equipment or Activity	Maximum Vibration Expected (PPV inches/second) Assuming Geometric Damping Only (Soil Attenuation Not Included)			
	25 ft* (7.6 m)	50 ft (15.2 m)	100 ft (30.5 m)	200 ft (61 m)
Caisson drilling, large bulldozer, hoe ram	0.089	0.022	0.006	0.001
Loaded trucks	0.076	0.019	0.005	0.001
Jackhammer	0.035	0.009	0.002	0.001
Small bulldozer	0.003	0.001	0.000	0.000
* Federal Transit Administration, 2006				

Ground vibration estimates in Table 2 were calculated based on the attenuation of ground vibration resulting from geometric damping alone. As the energy wave moves through the soil, vibration energy is transferred to kinetic energy of soil particles, and additional attenuation occurs (Attewell and Farmer 1973). Jenson (1993) measured vibration of between 0.0009 in/sec and 0.0025 in/sec, 23 meters (75 ft) from large trucks and tour buses driving on a road on Haleakala, approximately four times lower than the vibration values listed in Table 2. The lower observed vibration is likely due to soil attenuation. Given the combination of geometric damping, and additional attenuation of vibration as it moves through the soil, vibration levels at all burrows are expected to remain well below the 0.12 in/sec damage threshold throughout all stages of ATST construction. The incorporation of the noise standard, limiting maximum equipment noise to 83 dBA (at five feet), will eliminate the use of any equipment at the construction site, which would cause a vibration greater than 0.0019 in/sec at any of the closest burrows during the incubation period. Fewer than 20 percent of people can perceive a vibration with a PPV of 0.0019 in/sec (Turunen-Rise *et al* 2003, Klaeboe *et al* 2003).

Vibration Monitoring: Ground vibration will be monitored with seismographic equipment that utilizes either accelerometers or geophones appropriate to detect vibration between 0.001 in/sec and the 0.12 in/sec peak particle velocity burrow safety threshold. The exact equipment has not yet been selected, but it would be similar to the Mini-Seis units manufactured by White Industrial Seismology (http://www.whiteseis.com/Seismographs.html), which are appropriate for monitoring vibration from heavy construction equipment. At least two units will be deployed adjacent to the entrances to the Hawaiian petrel burrows nearest to the source of the vibration. The units will be operational and archiving data during all periods of construction when ground disturbance work is being done, including caisson drilling and excavation. When only concrete pouring and fabrication of the telescope buildings is being done, vibration would not be monitored. Sensors will be equipped with an auto-call feature for reporting events that meet or exceed a defined trigger level. The auto-call feature would send an alert by cell phone or telephone, and e-mail to the ATST Project Site Manager if the sensors register a vibration of 0.08 in/sec. This would provide the Project Site Manager with an early warning that the on-site activity was causing vibration which would warrant close monitoring of the vibration sensor data. A vibration of 0.12 in/sec or greater is not expected to occur at any Hawaiian petrel burrow as a result of ATST construction activity. Any vibration of 0.12 in/sec or greater, measured at a Hawaiian petrel burrow would be reported to the Service by telephone within one hour, and in a follow-up letter.

An ATST biological technician has measured the depths of all 41 of the Hawaiian petrel burrows, leading to 33 nest chambers, located within 80 meters of the ATST construction site. Each winter following any periods of construction, the burrow tunnels will be re-measured and a report will be submitted to the Service summarizing any changes in burrow configuration.

None of the 27 Hawaiian petrel burrow entrances which were being monitored by burrow cameras during the October 15, 2006, 6.8 magnitude earthquake (which had a measured PPV of 3.4 in/sec at a seismograph located adjacent to the Haleakala Observatories site) collapsed or showed any signs of instability. The stronger vibration lasted for 15 to 20 seconds and reduced vibration lasted one minute (U.S. Geological Survey unpublished). Since burrow and tunnel entrances are more susceptible to collapse than the interior tunnel walls and ceilings, this demonstrates that the burrows can withstand a substantial amount of vibration for one minute without collapsing. Many buildings and bridges were damaged by the earthquake (Honolulu Advertiser, 2007). Peak particle velocities produced by earthquakes often exceed 3.0 in/sec (U.S. Geological Survey unpublished). We know of no Hawaiian petrel burrows that have historically been collapsed as a result of any type of local construction project or earthquake (Bailey pers. comm. 2007 and Fein pers. comm. 2006b). Based on our review of the engineering report by ATST engineers, our review of the evidence provided, and our review of vibration physics in current literature, we believe that it is reasonable to conclude that Hawaiian petrel burrow collapse is not likely to occur as a result of proposed ATST construction activities. We believe that the camera and physical measuring monitoring protocols in the proposed project description are adequate to identify any collapse of any portion of the burrows adjacent to the ATST construction site, where exposure vibration above background levels is expected to occur.

Noise and Vibration Disturbance to Hawaiian Petrels

Effect of the proposed construction noise on Hawaiian petrels can be inferred based on our knowledge about petrels, and from studies that addressed the effects of noise to other avian species. The birds' sensitivity to the sounds generated by the proposed project are likely to be associated with factors including the energy level and duration of the sound, how it reacts with topography and burrows, ambient sound levels and individual bird tolerance to sounds due to habituation. Construction and maintenance of the ATST will require use of equipment and large vehicles which introduce increased levels of noise into the environment. We were concerned with sound levels that would result in disturbance to the Hawaiian petrels. We split our analysis of the effects of the project on the petrels into the egg incubation period (April 20 – July 15) and the nestling period (July 1 through the end of November) (Simons 1985), based on the activity that will occur within the Hawaiian petrel burrows during the day, when construction activity will be occurring. Within each period, we further refined our analysis to address differences between the noise impacts to birds occupying burrows along the road portion of the Action Area, and those occupying burrows adjacent to the construction site.

Sound energy level at various frequencies is measured in decibels (dB). For many purposes, sound measurements are A-weighted (dBA) to emphasize the middle portion of the entire sound frequency range, where humans and birds have the greatest sensitivity. The Hawaiian petrel vocalizations are sharp squeaks and nasal clucks (Simons 1985) which are within the central frequency range expressed by dBA sound measurements. This species is not known to use particularly high or low frequency hearing to search for prey or for other life history functions. Because Hawaiian petrels vocalize to each within the human hearing frequencies, the A-weighted dBA scale was appropriate for application to the petrel. Therefore the dBA sound estimates presented in the DEIS (NSF 2006) were considered adequate for our analysis of the effect of construction noise on the Hawaiian petrel. It is important to note that sound (dBA) measurements are always associated with a distance from the source. Two of the standard distances for sound measurements, referred to in this document, are five feet and 50 feet from the source.

Table 3. Noise levels of ATST construction equipment and vehicles (at 50 feet), compared with familiar noise levels.

Noise Source	Decibel (dBA) at 50 feet from source	Reference
Limit to human hearing	0 dBA	US DOT FHA 2006
Closed audiometric booth / bottom of Haleakala Crater	10 dBA	US DOT FHA 2006, NPS unpublished
Rustling leaves, tall grass in a light to moderate wind, and typical daytime urban residential area away from major streets	35 to 55 dBA	Resource Systems Group, Inc. 2006
Ambient noise in front of Hawaiian petrel burrow at Haleakala Observatories Hawaiian petrel colony with 5 mph wind	55 to 68 dBA	Fein, unpublished 2007 data
Office, Restaurant, Library, toilet refilling its tank, air conditioning unit	60 dBA	Wikipedia
Passenger car, traveling at 30 mph	65 dBA	Resource Systems Group, Inc. 2006
Large barking dog	70 dBA	Acoustical Solutions unpuslished
Passenger car, van, jeep at Haleakala	71 to 75 dBA	Fein, unpublished 2007 data
Tour busses at Yosemite National Park	58 to 77 dBA	NPS unpublished
City Bus	80 dBA	FTA 1995
Tour buses at Haleakala	77 to 91 dBA	Fein, unpublished 2007 data
Backhoe, Earth movers	80 dBA	FTA 1995, NSF 2006
Crane	82 dBA	NSF 2006
EPA maximum permissable truck noise level	83 dBA	Bearden 2000
Bulldozer	82 to 85 dBA	FTA 1995, NSF 2006
Jackhammer	97 dBA	NSF 2006
Rock hammers/drills	99 dBA	NSF 2006

Birds habituate to noises and may not respond to stimuli when they do not perceive a direct threat. American black ducks (*Anas rubripes*) reacted to 39 percent of military aircraft overflights on their first day of exposure, but after two weeks they responded only six percent of the time. However, wood ducks (*Aix sponsa*) in the same study, did not habituate to the aircraft noise (Conomy *et al* 1998). Incubating herring gulls (*Larus argentatus*) and great black-backed gulls (*L. marinus*) habituated to the continual presence of humans by modifying their responses, but would continue to be disturbed when they perceived direct approach by a human walking directly toward their nest (Burger and Gochfeld 1981).

Construction Site: From April 20 through July 15, when any of the burrows within 80 meters of the ATST construction site is occupied by an incubating Hawaiian petrel, no noise greater than 83 dBA (measured at five feet from the source) will be generated at the construction site. The noise standard will preclude the use of vehicle reverse signal alarms, loud shouting, and a wide range of power tools (see examples Figure 14), at the construction site. From April 20 through

July 15, during construction the generation of noise, other than vehicle noise, will be restricted to the area bounded by orange in Figure 15.

Noise Monitoring: For equipment and hand tools without published noise levels, field testing will be done to confirm that noise production of all equipment meets the 83 dBA standard. Sound levels will be recorded with a sound meter and datalogger, five feet from the equipment or hand tool, during a continuous thirty minute period of operation, on three different days. Sound measurements will be taken downwind of the equipment, and will be taken on the loudest exposed side of the equipment (for instance, closest to the engine or exhaust). The equipment will be operated in the same manner during the test as it will be during actual construction operations. All documentation from the three thirty minute tests, for each piece of equipment will be archived by the ATST Project Site Manager. Equipment which produces any sound greater than 83 dBA (at five feet) during any period of testing will not be permitted for use at the construction site between April 20 and July 15.

A minimum of two microphones or other type of sound level (dBA) meters will be installed adjacent to Hawaiian petrel burrow SC40. One will be installed within five meters of burrow SC40 at a location where it has a direct line of sight view of the ATST construction site. The other will be installed at the opening to burrow number SC40. The noise monitoring equipment will archive sound data during all years of ATST construction, for confirmation of sound attenuation estimates and for comparison with Hawaiian petrel behavior data.

Tasks (*Trade*)	Average noise level (dBA)	Maximum noise level (dBA)
Installing Trench Conduit (*Electricians*)	95.8	118.6
Operating Work Vehicle (*Bricklayers*)	98.0	116.7
Operating Manlift (*Operating Engineers*)	98.1	117.6
Welding, Burning (*Ironworkers*)	98.4	119.7
Operating Scraper (*Oper. Engineers*)	99.1	108.6
Demolition (*Laborers*)	99.3	112.1
Laying Metal Deck (*Ironworkers*)	99.6	119.9
Grinding (*Masonry Trades*)	99.7	118.6
Operating Bulldozer (*Oper. Engineers*)	100.2	112.5
Chipping Concrete (*Laborers*)	102.9	120.3

Tools	Average noise level (dBA)	Maximum noise level (dBA)
Welding, Cutting Equipment	94.9	122.8
Other Hand Power Tool	95.4	118.3
Hand Power Saw	97.2	114.0
Screw Gun, Drill Motor	97.7	123.7
Rotohammer	97.8	113.5
Chopsaw	98.4	117.7
Rattle Gun	98.4	131.1
Stationary Power Tool	101.8	119.8
Powder Actuated Tool	103.0	112.8
Chipping Gun	103.0	119.2

Figure 14. Examples of construction activities producing noise levels greater than 83 dBA (at five feet).

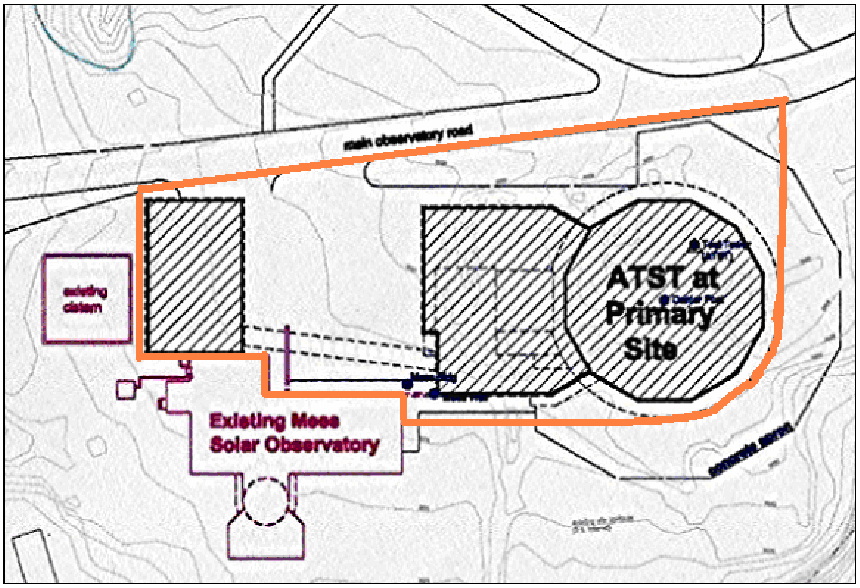

Figure 15. Between April 20 and July 15, construction noise, other than vehicle transportation noise, will not be generated outside the area bounded by orange.

Transportation: From April 20 through July 15, a maximum of two trucks, with maximum sound production of 83 dBA (measured at 50 feet) (pursuant to EPA standards) will make one round trip each, to the ATST site, per day, during any year of the project. These trucks will produce sound louder than 65 dBA at the petrel burrow entrances closest to the road. No truck traffic within the National Park and no construction activities at the ATST site will occur prior to 6:00 am or later than 8:00 pm during late April, May and June. Passenger vehicle access to the site will not be restricted during the incubation period.

Noise and Vibration During Incubation Period: The egg incubation period (April 20 through July 15 (Simons 1985) is the only time of year when adult petrels are at the Haleakala colonies during the day. Adult birds incubate their egg for an uninterrupted shift of one to three weeks, during which time the petrel maintains a low metabolic rate, conserving energy by sleeping 95 percent of the time (Simons 1985). Incubating petrels would be more sensitive to noise and vibration disturbance during this period. Undisturbed birds can lose substantial percentages of body weight during their incubation periods. Sleeping bird metabolism is approximately half that of awake, resting birds (Simons 1985). If birds are frequently awakened by noise or vibration from construction activities during incubation, they could lose enough weight that they would be forced to leave on a foraging trip prior to their mate's return. They would be more likely to leave an egg unattended, for a longer period, due to asynchronous parental incubation, than undisturbed birds. To avoid this problem, ATST project engineers developed a construction schedule to eliminate any equipment which would generate sound greater than 83 dBA (measured at five feet) or vibration greater than 0.0019 in/sec (at the closest burrows) between April 20 and July 15 during all years of construction. Although sound levels of 83 dBA would be produced at five feet from the source, noise attenuation due to distance, terrain shielding, and noise attenuation within the burrow would result in damping of the construction noise. Geometric damping will result in a minimum decrease of 6 dBA for every doubling of distance (10 feet, 20 feet, etc.) for the 83 dBA sound (originally measured at five feet) (NSF 2006, U.S. Department of Transportation Federal Highway Administration Highway 2006 and Fein unpublished). Therefore, burrows closer to the construction site would be exposed to louder sound. All of the nest chambers adjacent to the construction site are shielded from the construction noise by terrain barriers. Burrow entrances face down and away from the construction site, which is on the mountain slope above them. The noise generated at the construction site will reach the nest chamber after it is diffracted around the terrain barriers which include the slopes and the burrow cavities themselves. Fein (unpublished) found that the difference in noise level between line of sight and the burrow entrance was 9 dBA and that the burrow corridor attenuated noise at an average rate of 0.625 dBA per inch of burrow depth. Each burrow's distance from the main area of the ATST construction site, outside which no construction work will occur during the incubation period, was measured. Table 4 shows the maximum calculated noise levels anticipated to occur at the burrow entrances and within the nest chambers of the Hawaiian petrel burrows adjacent to the ATST construction site between April 20 and July 15, given an 83 dBA sound at the outer edge of the construction site.

Table 4. April 20 through July 15 approximate noise levels (dBA) expected in the vicinity of ATST construction site and within Hawaiian petrel burrows.

Hawaiian Petrel Burrow Number	Distance from Construction Site	Burrow Depth (m)	Construction Site Noise (dBA at 5 ft from Source)	Noise Level Expected at the Point Above Burrow Entrance with Line of Sight View of Construction Site (Based on 6 dBA attenuation per doubling of distance) (dBA)	Noise Level Expected at the Burrow Entrance (Based on 9 dBA Sound Attenuation due to Terrain Noise Barrier Characteristics (Fein, unpublished)) (dBA)	Noise Level Expected at the Nest (Based on 0.625 dBA Noise Attenuation per Inch of Burrow Depth (Fein, unpublished)) (dBA)
SC40 - R	20 m	0.914	83	63	54	39
- L	20 m	0.609	83	63	54	47
AB-062405-01	22 m	1.829	83	60	51	21
CY-042297-01	25 m	0.762	83	59	50	46
MY-042297-01	28 m	1.219	83	59	50	35
SC21	32 m	1.524	83	58	49	27
RT-061397-01	35 m	0.457	83	57	48	48
JT-092005-01	37 m	0.914	83	56	47	40
SC37	38 m	0.457	83	56	47	47
SC29	39 m	0.700	83	56	47	47
SC33	43 m	0.305	83	55	46	46
MY-042297-02	44 m	1.524	83	55	46	24
SC18 - R	44 m	0.700	83	55	46	46
- L	44 m	1.524	83	55	46	24
SC 34	46 m	0.305	83	55	46	46
CW-062405-01	48 m	0.762	83	54	45	41
SC12	49 m	0.914	83	53	44	37
TK072606-01	49 m	0.305	83	53	44	44
SC39 - R	50 m	0.762	83	53	44	40
- L	51 m	0.305	83	53	44	44
RK-062705-02 - F	52 m	0.700	83	53	44	44
- L	52 m	0.700	83	53	44	44
SC35	57 m	0.305	83	53	44	44
SC38 - R	58 m	0.305	83	53	44	44
- L	58 m	0.700	83	53	44	44
VS-103000-01	60 m	0.305	83	52	43	43
SC062199-01	61 m	0.305	83	52	43	43
SC15	63 m	0.700	83	52	43	36
SC36	65 m	0.305	83	52	43	43
CB-070805-01	66 m	0.305	83	51	42	42
SC31 - R	66 m	0.305	83	51	42	42
- L	66 m	0.762	83	51	42	38
SC19	67 m	0.305	83	51	42	42
SC30	73 m	0.305	83	51	42	42
TK070706-01	78 m	0.305	83	51	42	42
RK-062705-03 - R	80 m	0.457	83	50	41	41
- L	80 m	0.457	83	50	41	41
RT050898-01	87 m	0.305	83	50	41	41
SC13	92 m	0.305	83	50	41	41
SC13B	93 m	0.305	83	50	41	41

Construction Site Noise Impacts to Incubating Adult Petrels: The maximum construction site noise which is expected to reach the nest chamber of the four closest, shallowest Hawaiian petrel burrows if construction equipment producing the maximum permissible incubation period noise level of 83 dBA is used at the outer perimeter of the ATST construction site would be 47 to 48 dBA (Table 4). During this period, 23 nest chambers would be exposed to maximum noise levels between 40 and 46 dBA, and the remaining six nest chambers would be exposed to maximum construction noise levels between 21 dBA and 37 dBA. No studies of the sensitivity of sleeping Hawaiian petrel to noise have been conducted. Human sensitivity to being awakened from sleep varies among individuals, as shown in Figure 16 (Federal Interagency Committee on Noise 1992, Finegold *et al* 1993, Finegold *et al* 1994, Finegold pers. comm. 2007). Based on this dose response curve, 5.34 percent of sleeping humans would be awakened by a noise event of 48 dBA. Because ambient wind noise levels range from 55 to 68 dBA on Haleakala (Fein, unpublished), ambient noise levels at the burrow entrances and within the nest chambers are expected to be equal to or greater than those originating from the construction site during the incubation period. These factors indicate that the incubating birds that occupy the burrows adjacent to the ATST construction site are not likely to be affected by the telescope construction activities.

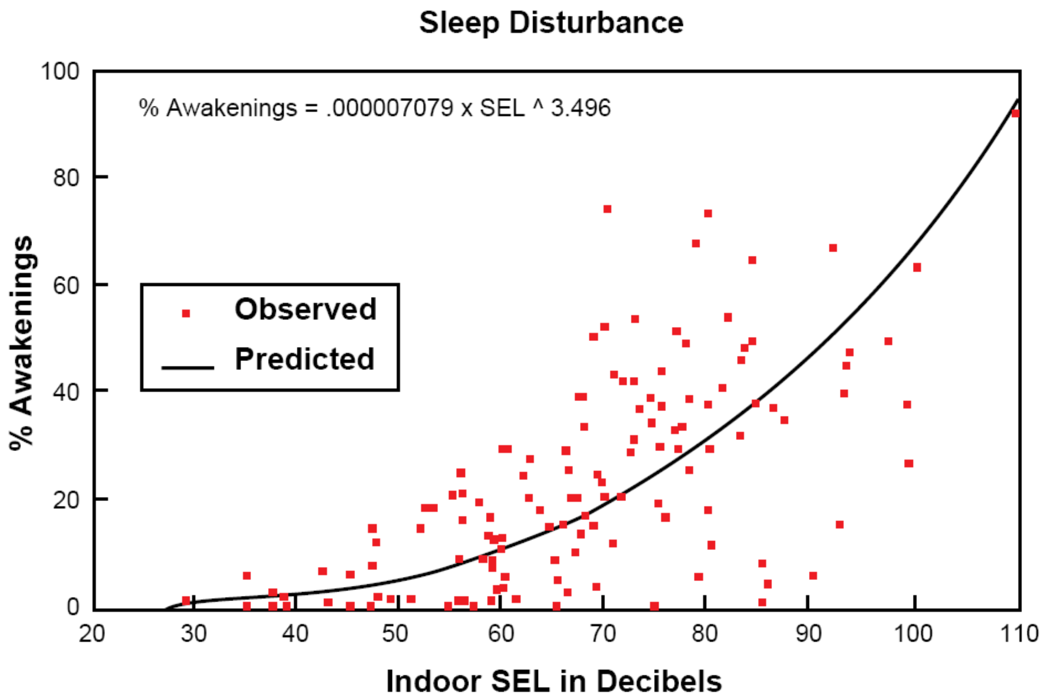

Figure 16. Percent of human awakenings at various dBA single event noise exposure levels (SEL) (Finegold *et al* 1993, Finegold *et al* 1994, Federal Interagency Committee on Aviation Noise 1997).

Road Noise Impacts to Incubating Adults: From April 20 through July 15, only two trucks, with maximum sound production of 83 dBA (measured at 50 feet, pursuant to EPA standards) will make one round trip each to the ATST site, per day throughout the construction period of the project. Approximately 11 Hawaiian petrel burrow entrances, located closer than 15 meters (50 feet) to the road may be exposed to sound levels higher than 83 dBA, resulting from ATST construction trucks, four times per day. Approximately 149 additional Hawaiian petrel burrow entrances are located within the road corridor of the Action Area, where they may be exposed to truck noise levels, at burrow entrances, of 65 dBA or greater. An estimated 600 to 900 vehicles, including buses and touring vans access the Haleakala National Park road per day (Bailey pers. comm. 2006c), in addition to the two trucks and seven to eight passenger vehicles scheduled to visit the ATST construction site during the Hawaiian petrel incubation period. Although Bailey's (pers. comm. 2006a) data analysis is not yet complete, preliminary reports suggest that egg neglect has not resulted in Hawaiian petrel mortality at Haleakala, due to noise disturbance or otherwise. The birds occupying burrows close to the road may be habituated to the vehicle noise. In 2002 and 2003, Bailey (NPS 2003) documented two egg mortalities which were both attributed to infertility.

Periods of egg neglect occur naturally and are usually associated with intermittent incubation resulting from asynchronous mate shift in inexperienced breeders, or in the general population during years of variable oceanic conditions which affect feeding success (Warham 1990). Therefore, eggs may be able to survive exposure for some period. In fork-tailed storm-petrels, chicks have been observed to hatch successfully from eggs that were left unattended for as long as seven consecutive days (Boersma *et al* 1980). Simons (1985) documented a Hawaiian petrel egg which was left unattended for three days during its incubation, and successfully hatched a healthy chick.

Summary of Noise Impacts to Incubating Petrels: Because construction is not expected to produce noise which is louder than ambient wind noise at the burrow entrance or at the nest chamber between April 20 and July 15, disturbance of incubating adult birds by construction site noise is not anticipated. Because birds occupying burrows adjacent to the Haleakala National Park road appear to be habituated to traffic noise caused by the 600 to 900 vehicles that access the Park each day, and because only two truck round trips will be associated with the ATST project during the incubation period, we believe that the ATST construction project is not likely to result in any Hawaiian petrel egg loss. The monitoring protocols developed to document egg neglect will yield additional information regarding petrel incubation behavior.

Summary of Vibration Impacts to Incubating Petrels: The incorporation of the noise standard between April 20 and July 15, limiting maximum equipment noise to 83 dBA (at five feet), will eliminate the use of any equipment at the construction site which would cause a vibration greater than 0.0019 in/sec at any of the closest burrows during this period. Fewer than 20 percent of people can perceive a vibration with a PPV of 0.0019 in/sec (Turunen-Rise *et al* 2003, Klaeboe *et al* 2003). The two round-trips taken by trucks per day during this period may produce noticeable vibration at the burrow sites along the road. Because the duration of the vibration would be limited, and because the birds are exposed to vibration from 600 to 900 vehicles, including buses, which produce vibration amplitudes which are identical to trucks (Jensen 1993), we do not believe that the effects of these two vehicles on the incubating birds will be measurable.

Nestling Period: Construction activities that will produce daily prolonged loud noises and vibration are scheduled to coincide with the nestling period (July 1 through the end of November). Hawaiian petrel nestlings have been observed on their nests, in their burrows, and near their burrow entrances during this period. Adults visit the burrows at night to feed the nestlings and would presumably be unaware of any noise disturbance. The noise generated by construction equipment and vehicles are expected to increase startle, alarm, and alert behavior and disturb the day time sleep of nestlings occupying burrows within 780 meters (2,560 feet) of the construction site and within 122 meters (400 feet) of the Haleakala Park Road. The closest burrow entrance is 12 meters (40 feet) from the outer edge of the construction site. The noise level at a point 12 meters (40 feet) away from an operating crane is 84 dBA when the crane is operating, and 101 dBA when the rock hammer is in use. Topographical shielding between the line of sight view of the construction site, and the burrow entrance, cuts 9 dBA off of the noise level (Fein, unpublished) so that the maximum noise level at any burrow entrance will be 92 dBA. Sound attenuation of 0.625 dBA per inch of burrow depth (Fein, unpublished) would result in a maximum noise level of 85 dBA within the nest chamber of the burrow closest to the construction site.

Potential consequences of construction noise and vibration could include increased metabolism, nest abandonment, and temporary damage to auditory cells. Juvenile Hawaiian petrels in close proximity to the construction site are expected to respond to loud noises and vibration with increased activity and decreased incidence of sleep, therefore their food demands are expected to increase. Rat pups exposed to 80 dBA and 100 dBA noises for 3 hours per day for 30 days were found to have increased incidence of grooming, play, locomotion behavior, and decreased incidence of sleep. No indication of a noise-induced stress reaction, such as changes in adrenal gland weight or stomach ulceration were found in the 15 to 45 day old rats, compared to the control groups (Smiley and Wilbanks 1982). Forty percent of people would be awakened by a sound of 85 dBA. The people who would not be awakened by such a loud sound are those who have habituated to the loud sound (Finegold *et al* 1994). Adult Hawaiian petrels feed chicks at night, when construction activity will not be occurring. Parents continue to feed chicks, driven primarily by the chick’s demands for food (Simons 1985). If a chick has an increased need for food resulting from increased daytime activity, it is not anticipated that this would result in reduced chick survival rates. A potential consequence of increased noise and vibration could be nest abandonment by juvenile Hawaiian petrels. No references to chick abandonment of their nests due to noise or vibration disturbance were found in a thorough literature review (CSAMultiSearch 2007). We do not expect Hawaiian petrel chicks to abandon their nest, where they are fed, due to the noise and vibration associated with the ATST construction activities. Hawaiian petrel chicks, exposed to noise and vibration associated with the Haleakala Park Road and past construction projects on Haleakala have not resulted in a documented decrease in chick survival or in chick nest abandonment. In 2001, excavation for a telescope began in September and continued through the months when the birds were absent from the colony. Although the closest petrel burrow to this telescope was 100 feet, the 2001 project did not appear to have a negative impact on the nestlings (NPS 2003). The monitoring protocols incorporated into the project description appear to be sufficient to capture new information which would indicate any risks to the chicks, associated with noise, which were not anticipated at the time of this analysis.

We were concerned the nestlings may be exposed to sound levels which are known to cause permanent hearing loss in mammals. Sound levels over 85 dB are considered harmful to inner ear hair cells, 95 dB is considered unsafe for prolonged periods (Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, unpublished). Nestlings may be outside the burrows closest to the loud construction equipment (66 feet) during the day and exposed to 101 dBA sounds which may be loud enough to damage ear hairs. A review of avian hearing loss was conducted and it was determined that hearing loss in birds is difficult to characterize because birds, unlike mammals, regenerate inner ear hair cells, even after substantial loss (Corwin and Cotanche 1988, Stone and Rubel 2000). Therefore, we do not expect permanent hearing loss in Hawaiian petrels to result from the proposed action.

Monitoring and research: Real-time monitoring of Hawaiian petrels, noise, and vibration will be continuously conducted at the Haleakala Observatories petrel colony in order to detect any effects of construction on the birds at this site. Motion-triggered digital infrared and visible spectrum cameras have been mounted at the entrances to the burrows in the Haleakala Observatories colony, adjacent to the ATST construction site. Most of the burrow cameras are mounted outside the burrow entrances so that the bird is visible only when it is at the burrow entrance. Several of the cameras are mounted in the burrows, so that the nesting activity of the birds can be monitored. Pre-construction data was gathered in 2006 and additional pre-construction data will be gathered and archived in 2007. A control site, with burrow cameras monitoring petrels which are not as directly impacted by construction activities, will be identified and monitored. During construction, a minimum of two noise sensors and two ground vibration sensors will be installed in the vicinity of the burrow(s) closest to the construction activity. Noise and ground vibration will be monitored and data will be archived for statistical comparisons with behavior data. NSF will fund a research biologist and, for less technical aspects of monitoring, a biological technician, to be based with a university, National Park Service, or private contractor, in order to ensure that any changes in behavior associated with the ATST construction project, and any petrel mortality associated with the project, are monitored and reported to the Service. Several university and contract research biologists are expressing interest in participating in the burrow camera noise disturbance study. NSF will select and fund a principal investigator to complete this work.

Construction site noise and vibration will be minimized to such a low level during the incubation period that the project is not expected to result in egg neglect or nest failure. Intensive real-time monitoring will be conducted during the incubation period to confirm that birds are not being disturbed. During the incubation period, a researcher will observe and document all burrow entry and exit events by the petrels occupying the 33 nest chambers within 80 meters of the ATST construction site. If a bird exits a burrow between April 20 and July 15 during any year of early construction, (when there has been any excavation or exterior construction work done on any ATST building between April 20 and July 15), and a bird does not enter that burrow within 24 hours, a burrow-scope would be used, (by a trained technician, within 36 hours of the bird's exit) to view the nest chamber of the burrow that was exited, to document the contents of the nest chamber. If an unattended egg is found, NSF would contact the Service by phone or email within six hours. A follow-up letter would be sent to the Service, documenting the egg neglect incident. The Service would review the incident to determine if initiation of formal consultation would be recommended. After June 1, daily burrow exit data for any burrows confirmed to be occupied by non-breeding pairs of birds, (with no egg) would no longer be tracked by the researcher in real time. Egg neglect incidences at the control site would be documented and studied, but would not be reported immediately to the Service.

During the year(s) of heavy excavation and external building construction, the fledglings will be monitored in real-time for mortality and fledging date. A monthly status report of all fledglings, including their most recent activity, and the date of the activity, will be provided to the Service. The behaviors of the chicks occupying burrows at the colony adjacent to the construction site will be compared to the behaviors of the birds from the control site. NSF will fund a researcher who would be expected to produce a Masters Thesis or peer-reviewed journal article summarizing the impacts of construction related noise and vibration on the behavior of the Hawaiian petrel adults and chicks.

The construction site and completed telescope structures will be systematically checked every week for downed birds from February 1 through November 30 of each year. Any dead bird found will be secured, labeled, placed in a freezer, and the Service will be contacted within 48 hours. NSF may utilize on-site personnel or local National Park Service personnel for this weekly monitoring work. The construction crew could be taught to look for downed birds during construction. NSF may also consider an agreement with the National Park Service to fund a petrel management and research intern position for 16 weeks/year, in exchange for a weekly downed petrel surveys by National Park Service staff. Weekly searches will begin when construction begins, and will run through the first year after the enclosure is completed, after which the timing of the searches may be modified, with the concurrence of the Service, based on the results obtained. The results of all weekly searches will be documented and submitted in an annual report to the Service.

A report summarizing the effects of the first year of construction disturbance on the Hawaiian petrels will be prepared and submitted to the Service. The report will summarize all behavioral events associated with construction. The report will provide any new information which will enable the Service to determine whether there is a need to modify the minimization measures for subsequent years. The report will include recommendations regarding revisions to monitoring protocols for future years. In subsequent years, if more or less intensive monitoring measures are agreed to by the Service and the NSF, monitoring could consist of a greater or reduced level of effort.

Predator Control

In order to contribute to the ongoing effort to control rat predation on Haleakala, the NSF proposes to install and maintain a permanent 24c State Conservation Label rat bait station grid around the Haleakala Observatories Hawaiian petrel colony. Forty-nine bait stations will be installed and maintained approximately 50 meters apart (Figure 17). Bait stations will be placed on previously disturbed areas along edges of buildings, roads, and trails, throughout the Haleakala Observatories petrel colony area. The rat bait station grid extends 200 meters around the petrel colony in all directions except to the southeast and directly to the west, where access would damage natural resources. In order to prevent predation of petrel eggs, rat bait stations will be stocked with fresh rodenticide as needed, in accordance with label requirements, from April 1 through July 15, during the 31 years of the ATST project. The ATST project would not result in any increase in rat population on the site. Sanitation practices would tightly control trash containment. In addition, thorough rat control would be maintained throughout all ATST structures.

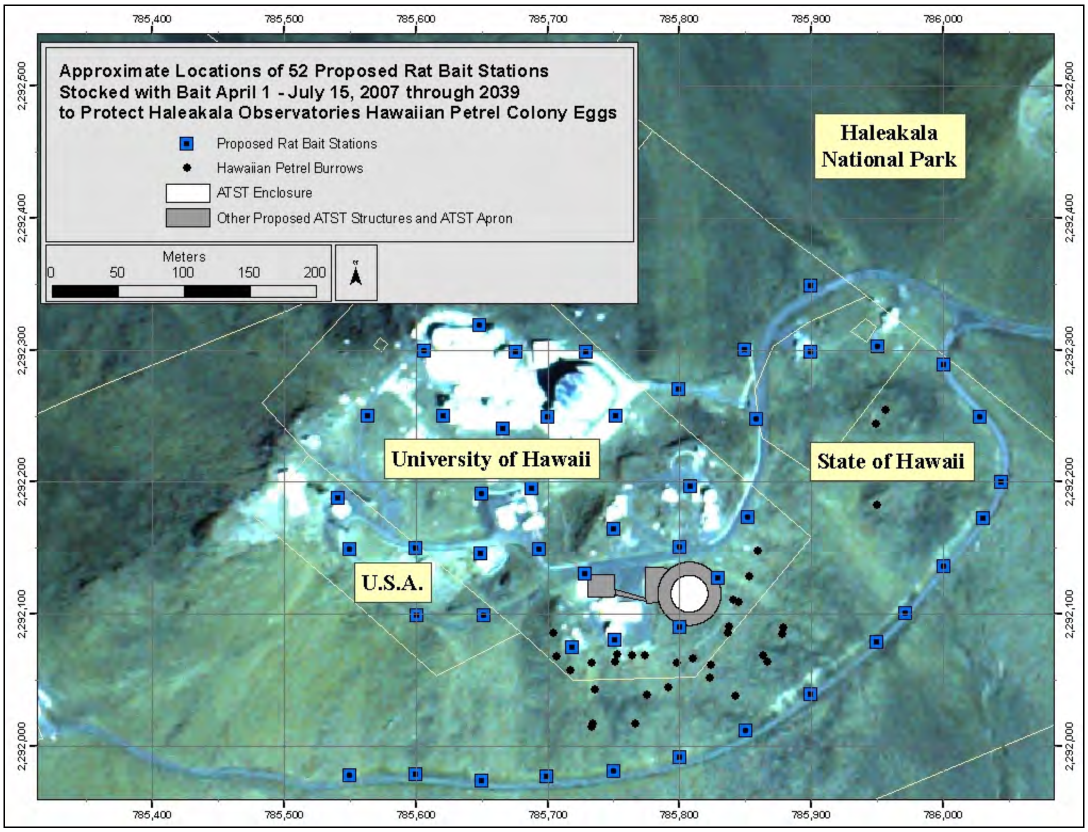

Figure 17. Approximate locations of rat bait stations to be maintained to protect the Haleakala Observatories Hawaiian petrel colony burrows.

We reviewed published data and unpublished sources of information to assess the effect the proposed rat control program would have on the Hawaiian petrel population at the Haleakala Observatories site (Simons and Hodges 1998, Hodges and Hagata 2001, Seto 1994, Seto and Conana 1996, Bailey pers. comm. 2006d, Fein pers. comm. 2006a). There are currently 33 known Hawaiian petrel nests which will benefit from rat baiting over the 31-year life of the ATST project. Although we do not expect complete control of rats because rat bait station placement will be limited to disturbed areas to minimize impacts to habitat, we do expect that the petrels at the Haleakala Observatories colony will benefit from the rat baiting program.

Invasive Species Interdiction and Control

To reduce the risk of transporting non-native species or seeds to the project site, NSF has proposed the following measures. The Haleakala Observatories Long Range Development Plan for the prevention of introduction of invasive exotic weed species will be followed during the construction, maintenance, and use of the ATST. In order to ensure that destructive, non-native species are not introduced to the Haleakala National Park or Haleakala High Altitude Observatories site, the Advanced Technology Solar Telescope Project Site Manager would 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 Institute for Astronomy supervision. All workers bringing vehicles into Haleakala Observatories would be required to complete the training and pass the test before beginning work on the site. In addition, all construction vehicles will be steam cleaned to remove all organic matter and insects before they are transported into Haleakala National Park. Any equipment, supplies, and containers with construction materials originating from outer islands, the mainland, or an international port, will be checked for infestation by unwanted species by a qualified biologist or agricultural inspector prior to departure from that port and again prior to unloading at Kahului Harbor or Airport (University of Hawaii 2005).

The following measures will also be taken to prevent introductions of invasive exotic species to the project area: Documentation of all inspections, including the name and contact information for the inspector will be maintained with each load. The Advanced Technology Solar Telescope Project Site Manager will ensure that the National Park Service is provided with advance notice about the arrival of each load in order to facilitate load inspections prior to vehicles reaching the park entrance. In addition, ATST facilities and grounds within 100 feet of the buildings will be thoroughly inspected on an annual basis for introduced species that may have eluded the cargo inspection processes. This annual inspection will be conducted by a qualified biologist. Any newly-discovered non-native, invasive plant or animal will be photo documented, mapped, and described. Any introduced species found inside or within 100 feet of the ATST buildings will be exterminated within six months of detection. Appropriate control methods include the use of available herbicides and pesticides, in accordance with the Long Range Development Plan (University of Hawaii 2005) and pursuant to label requirements.

Hawaiian Goose

NSF requested Service concurrence with their determination that the ATST project is not likely to adversely affect the Hawaiian goose. Based on vehicle use and Hawaiian goose fatality estimates provided by Bailey (pers. comm. 2006c), one Hawaiian goose is killed on the road at Haleakala National Park, for every 224,454 round-trips taken by vehicles through the Park. We calculated that during the 31-year life of the ATST project, a total of 66,294 vehicle round-trips will be taken to the project site (11,544 during construction and 54,750 during operation and use). By combining the average Hawaiian goose fatality rates due to vehicles driving the Haleakala National Park Road and the ATST vehicle use data, we calculated that there would be a collision with 0.3 Hawaiian goose during the 31-year live of the project. To further reduce the chance of a collision with a Hawaiian goose, all drivers accessing the ATST site during the life of the project will receive a Hawaiian goose briefing from the Institute for Astronomy. Drivers will receive a refresher briefing regarding the Hawaiian goose at the beginning of this species' breeding season approximately November 1 of each year. These measures will further reduce the probability of affecting this endangered species within the action area. Therefore, we concur with NSF's determination that the project is not likely to adversely affect the Hawaiian goose.

Hawaiian Hoary Bat

NSF requested that we review their determination that the ATST project would have no effect on the Hawaiian hoary bat. Hawaiian hoary bats are not likely to be in the vicinity of the construction site during the day because there are no roost trees in the vicinity of the site. At night, bats may transit the site, commuting through the area or foraging for local insects. Because the telescope buildings will not have external lighting, they will not attract insects which would attract foraging bats to the vicinity of the buildings. When they are commuting they navigate entirely by sight. However, the telescope buildings will be painted white and will therefore be more visible than their surroundings. Therefore a bat collision with the telescope structures is very unlikely. The Service does not have any information that would indicate that the Hawaiian hoary bat would be affected by the ATST project.

Endangered Plants and Plant Critical Habitats

There are a number of Haleakala silversword plants, 382 hectares (ha) (944 acres (ac)) of designated Haleakala silversword critical habitat, and one ha (2 ac) of *Geranium multiflorum* designated critical habitat, within the action area of the ATST project. NSF determined that the proposed project will have no effect on the Haleakala silversword, Haleakala silversword critical habitat, and *Geranium multiflorum* critical habitat, and requested that the Service review their determination. The Service does not have any information which would indicate that the Haleakala silversword plants or any of the Haleakala silversword and *Geranium multiflorum* critical habitat within the Action Area, would be affected by the proposed action. In providing for vehicle steam cleaning, invasive species inspections, and rapid response to on-site discoveries of introduced species, this project is providing the best available level of protection against habitat-modifying invasive insects, plants, and other pests.

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Bailey, C. pers. comm. 2006b. Gina Shultz, Patrice Ashfield, Holly Freifeld, Dawn Greenlee, from the Service met with NPS Hawaiian Petrel Biologist Cathleen Bailey to discuss various aspects of the proposed ATST project and measures which will minimize the impacts of the project to the Hawaiian petrel and Hawaiian goose. October 25, 2006.

Bailey, C. pers. comm. 2006c. NPS Hawaiian Petrel Biologist Cathleen Bailey Emailed Service Fish and Wildlife Biologist Dawn Greenlee with information regarding vehicle use of the Park and Hawaiian goose mortality on the road. November 21, 2006.

Bailey, C. pers. comm. 2006d. Bailey, C. pers. comm. 2006c. NPS Hawaiian Petrel Biologist Cathleen Bailey provided Service Fish and Wildlife Biologist Dawn Greenlee with information regarding the number of active Hawaiian petrel burrows on Haleakala. November 22, 2006.

Bailey, C. pers. comm. 2007. NPS Hawaiian Petrel Biologist Cathleen Bailey told Service Fish and Wildlife Biologist Dawn Greenlee that in her 20 years at Haleakala, she had not seen a Hawaiian petrel burrow collapse as a result of an earthquake. March 20, 2007.

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Fein, C. pers. comm. 2006b. Via email, Dr. Fein provided the Service with the results of video monitoring of burrows during the October 15, 2006, earthquake, which indicated that none of the burrows were damaged and none of the petrel chicks appeared to respond to the strong ground vibration. October 26, 2006.

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APPENDIX N

HALEAKALĀ ATST SURVEY REPORT

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HALEAKALĀ ADVANCED TECHNOLOGY SOLAR TELESCOPE (ATST) SURVEY REPORT

Prepared for:

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3i Marketing & Communications

Prepared by:
***SMS* Research & Marketing Services, Inc.**
Honolulu, Hawai'i
November, 2007

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EXECUTIVE SUMMARY

The current visitor experience at Haleakalā National Park is very positive

- Almost two-thirds of survey participants (64.8%) rated their experience at Haleakalā National Park as one of the best sightseeing experiences they have ever had
- Almost half of survey participants (48%) were very likely to return to the park and another 40 percent indicated they were somewhat likely to return

The current visitor experience includes the Haleakalā Observatories

- Haleakalā Observatories are clearly visible from the Puʻu ʻUlaʻula Outlook
- Close to one-fourth of respondents (22.3%) saw and read the observatory sign
- Over one-fifth of respondents (21.2%) took pictures of the observatory

There was very little negative reaction to an additional solar observatory

- A majority of respondents (60%) do not care if the new observatory is built
- Thirty-three percent of respondents are in favor of the observatory

Impact on visitor behavior is small but positive

- Over 75 percent of respondents indicated they would be somewhat to very likely to return to Haleakalā National Park to tour the telescope
- Seventy-three percent of respondents were likely to return to the park and likely to tour the telescope
- Three percent of respondents who initially indicated they were not going to return to the park, indicated they would return to tour the telescope

INTRODUCTION

HALEAKALĀ ATST SURVEY

In the Fall of 2007, KC Environmental, Inc. commissioned SMS Research & Marketing Services, Inc. (SMS) to conduct a study among visitors to Haleakalā National Park. The study was to evaluate visitor opinion on an Advanced Technology Solar Telescope (ATST) proposed for the Haleakalā High Altitude Observatory on Mount Haleakalā. The results of the study were intended to supplement the Draft Environmental Impact Statement previously submitted by KC Environmental, Inc.

OBJECTIVES

The overall goal of the project was to provide an unbiased estimate of the expected impact of the proposed ATST on the visitor experience at Haleakalā National Park based on the impressions of current park visitors. The specific objectives were:

- To measure current reaction to the park among a cross section of visitors;
- To measure visitor reaction to the addition of a large solar observatory in the adjacent High Altitude Observatory;
- To provide other information that may be useful in evaluating visitor reaction to the proposed ATST.

METHOD

The study was conducted from October 2, 2007 through October 8, 2007. Interviewers intercepted visitors after they exited the park and were asked to complete a self-administered survey that measured their experience of the park and the proposal for an ATST. Findings presented in this report are based on a sample of 543 Park visitors. Although intercept surveys are not based on rigorous probability samples, a sample of this size and type would have an associated margin of error of plus-or-minus 4.2 percentage points at the 95 percent confidence level.

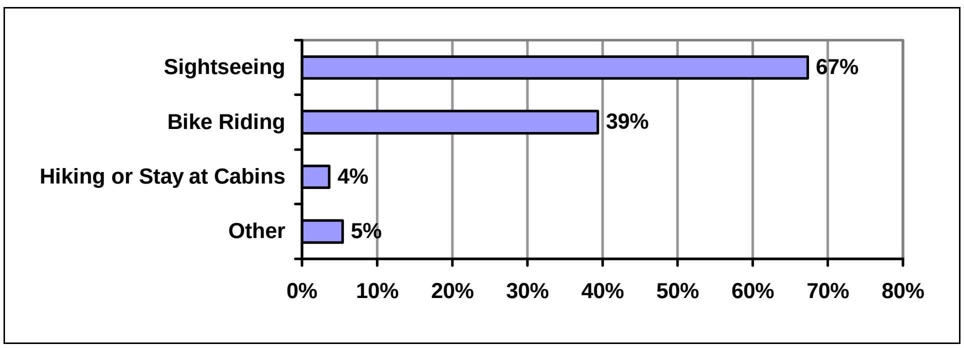
KEY FINDINGS

SURVEY RESPONDENTS

Judging from our sample, visitors to Haleakalā National Park are fairly new to the Park. Of the 543 visitors to Haleakalā National Park who comprise our respondent group, 11 percent were from Hawai'i and 89 percent were tourists or visitors to our State. Among the residents, half were Maui residents and the other half were from neighboring islands. Among the visitors, the great majority (71%) was visiting Maui for the first time, and among the whole group, only 20 percent had visited the Park before this time.

Most visitors came to the park either for sightseeing (67%) – especially to watch the sunrise from the summit; or to ride bicycles (39%) inside the park or to take the downhill run from the summit. About four percent were more active Park users. They came to hike or use the cabins. Finally, there was a group of people who gave other answers to the question, especially to the effect that whatever they were going to do, they were thwarted in that effort because of rain or bad weather.

Figure 1: Activities at Haleakalā National Park

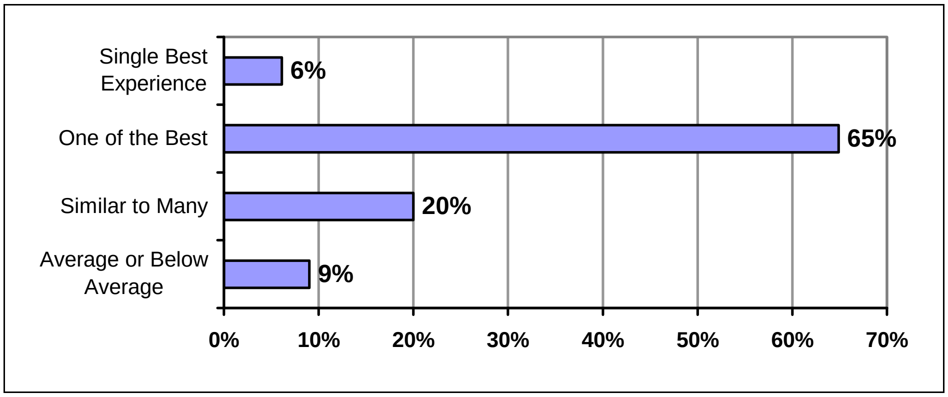


Responses sum to more than 100 percent because multiple responses were accepted.

CURRENT VISITOR EXPERIENCE

In general, Haleakalā National Park users' ratings of their on-site experience were very positive. Almost two-thirds of them (65%) rated their experience at the Park as one of the best sightseeing experiences they have ever had. Six percent indicated it was the single best sightseeing experience in their lifetime. A fifth (20%) of them said it was similar to many sightseeing experiences they had in the past (see Figure 2). And nine percent said the experience was average or below average.

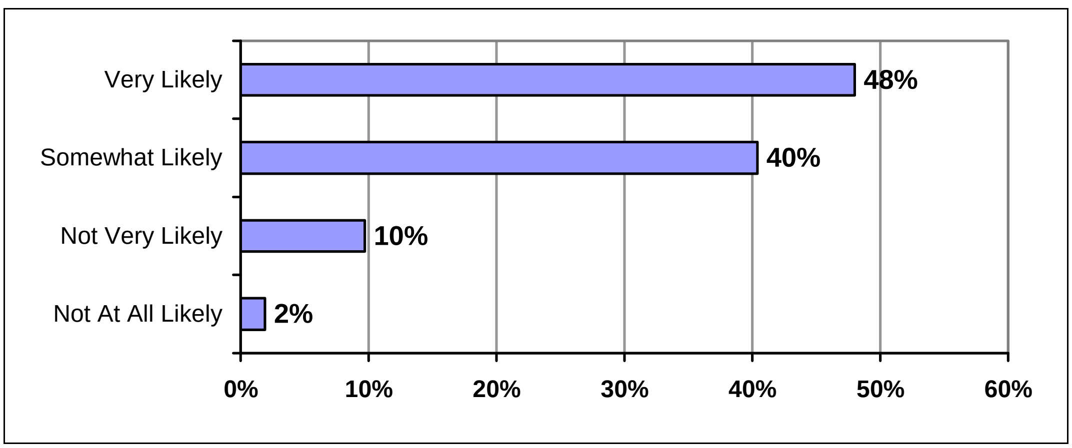
Figure 2: Haleakalā National Park Experience Rating



Return Visits

Nearly all of the survey respondents (93%) said they were likely to return to Maui someday. When we asked them if they wanted to come back to the Park, almost 90 percent said they were either somewhat or very likely to return (see Figure 3). Only two percent of the respondents said they would definitely not return to the Park.

Figure 3: Likelihood to Return to Haleakalā National Park



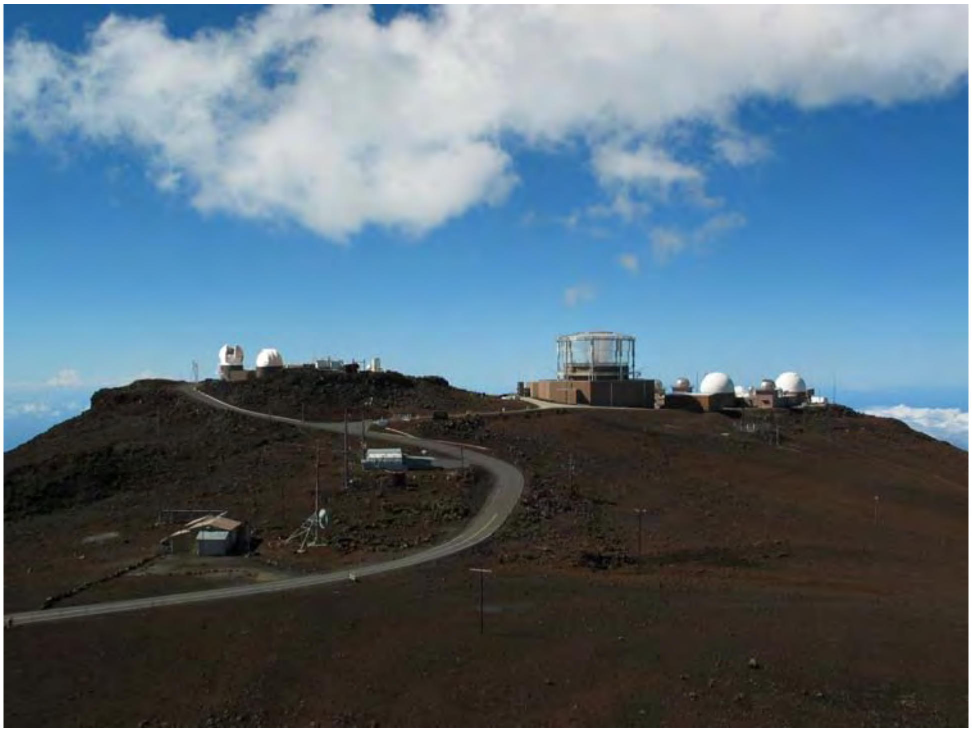
Most of those who said they would not likely return to the Park were those who did not think they would get back to Maui again. Only one person who said they would probably come back to Maui said they would not come back to the Park. Nearly half (45%) of those who said they might not get back to Maui said they'd like to visit Haleakalā National Park again.

In all, it was clear that the visitor experience at Haleakalā National Park was a very positive experience.

HALEAKALĀ OBSERVATORIES

The University of Hawai'i's Haleakalā Observatories, also known as Science City, is part of the visitor experience at Haleakalā National Park. Any visitor who travels into the park as far as the Pu'u 'Ula'ula Overlook, or Red Hill, will see the Observatories. Visitors who go up the mountain to see the sunrise usually view it from Red Hill. Figure 4 shows a view of Science City as it might appear to a visitor at Red Hill.

Figure 4: Existing Telescope Facilities without the Advanced Technology Solar Telescope (ATST)



Recently, the National Park erected an exhibit describing the Haleakalā Observatories and their work (Figure 5). About 38 percent of the survey respondents said they saw the exhibit, and 60 percent of those read the message on it.

Figure 5: Observatory Information Sign

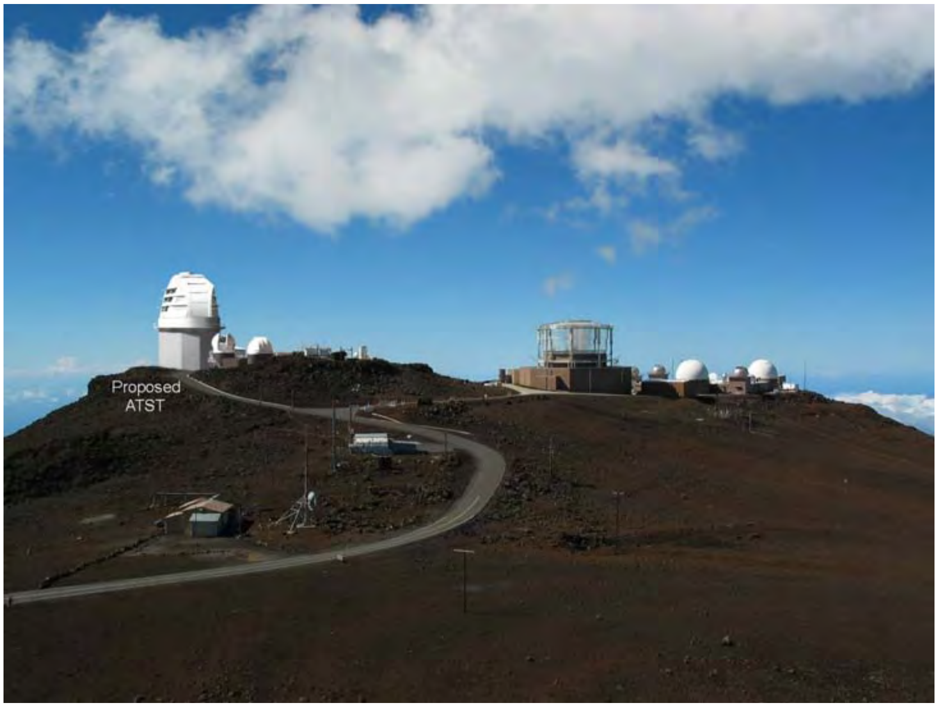
About 94 percent of all Park visitors we interviewed took pictures while they were at the park. Twenty-two percent took pictures of the Haleakalā Observatories while they were in the park. Visitors who actively include the Haleakalā Observatories in their park experience were a bit more likely to report higher ratings for the Park[1]. But overall, whether the Observatories were actively or passively included in their visit to Haleakalā National Park, ratings were very positive.

ATST IMPACT ON VISITOR EXPERIENCE AND VISITOR BEHAVIOR

All survey respondents were shown the pictures shown in Figures 4 and 5. In addition, they were shown the picture shown in Figure 6, in which the proposed ATST was inserted to scale, in the location proposed.

[1] Among those who took pictures of the observatories or read the sign, 76 percent rated the experience as either the best or one of the best experiences of their lifetime. The corresponding rating of other visitors was 68 percent.

Figure 6: Proposed Additional Facilities at Haleakalā

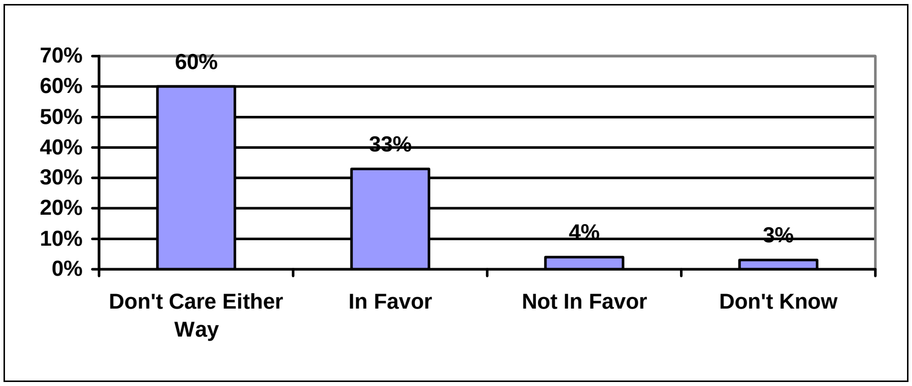


They were then given the following written description of the proposal to add an additional observatory at Science City:

> "There is a proposal to build another observatory in that same area to study the sun that would be 20-feet taller than the existing observatories (see accompanying renderings). The existing observatories cannot accommodate visitors, but the new one would be open for tours.
>
> Would you care if there is another telescope as described?"

About 70 percent of Park visitors responded that they didn't really care whether or not the ATST was added to the existing observatories. They had no objections. About five percent said they weren't sure or didn't answer the question. For the 25 percent who said they cared about the issue, we identified the nature of their concern by looking at their intention to return to the park to visit the new ATST facility. The results are presented in Figure 7.

Figure 7: Advanced Technology Solar Telescope (ATST) Support/Opposition

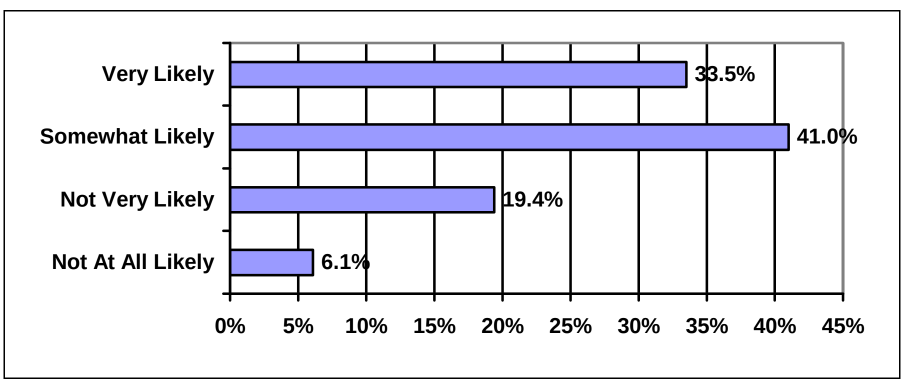


A majority of respondents (60%) had no objection to the ATST. A third of them (33%) were in favor of it being built. Four percent said they cared if the ATST was built, and would not return to the Park to visit the new facility. Three percent gave us no answer or said they were not sure about the whole issue.

ESTIMATING PARK VISITOR BEHAVIOR

The foregoing presentation shows that very few visitors to Haleakalā National Park have any objections to the proposed addition of the ATST to Haleakalā Observatories. Their attitudes are either neutral or positive. It is possible to estimate how ATST might influence first time and returning visitors' interest in coming to the Park. Figure 8 shows the likelihood that survey respondents would return to the Park to tour the new facility.

Figure 8: Likelihood to Return for Telescope Tour



Three-fourths (75%) of the respondents indicated they are somewhat to very likely to return to Haleakalā to tour the ATST.

By comparing respondents' initial intention to return to the park to their intention to return after evaluating the addition of the ATST, we can estimate the change in visitor behavior due to the new facility. The results of that analysis are shown in Figure 9.

Figure 9: Respondent Subgroups

		Intention to Return to Haleakalā National Park BEFORE evaluating ATST	
		Likely to Return to Haleakalā	**Not Likely To Return to Haleakalā**
Intention to Return to Haleakalā and Visit the ATST Facility	**Likely to Tour Observatory**	**Group A: Supporters of ATST** • Likely to return to Haleakalā • Likely to Tour the Observatory **73%**	**Group C: Converts** • Not likely to return to Haleakalā • Likely to return to tour ATST **3%**
	Not Likely to Tour Observatory	**Group B: Non-Supporters of ATST** • Likely to return to Haleakalā • Not likely to return to tour ATST **16%**	**Group D: Non-Returnees** • Not likely to return to Haleakalā • Not likely to return to tour ATST **8%**

Overall, the addition of the ATST to the existing observatories on Haleakalā would make only minor changes in visitor behavior. Nearly three-quarters (73%) of all Park visitors were very interested in returning to Haleakalā National Park before considering the new solar observatory and would be interested in touring the new facility when they return. Eight did not expect to return to Haleakalā and the prospect of touring a new solar observatory did not change that expectation. So over 80 percent of survey respondents would not change their behavior based on the proposed new observatory.

Sixteen percent of the group were initially interested in returning to Haleakalā, but said they would not return to tour the new observatory. All visitors in this group highly rated their experience at the park, and none were among those not in favor of the ATST. We have no reason to assume they would change their initial intention to return, but they would probably not tour the new observatory.

Finally, three percent of the Park visitors may change their behaviors. These people originally said they would be unlikely to return to Haleakalā National Park. After assessing the proposed new solar observatory, they reported that they would be likely to return to Haleakalā National Park to tour the new facility.

In the end, change in visitor behavior will be small and positive. At best the addition of the new solar observatory would increase park usage by about three percent.

CONCLUSION

The results of this research show that the current visitor experience at Haleakalā National Park is very positive. Most Park visitors appreciate their experience there and would like to return. Their experience includes the Haleakalā Observatories and those who mentioned the Observatories in their comments were no less likely to have valued their time at the park. Most visitors to Haleakalā National Park do not care whether the new observatory is built. Very few had any negative reaction to the idea and many will return to tour the telescope if it is built. The observatory may increase Park usage by about three percent.

APPENDIX

APPENDIX A: SURVEY INSTRUMENT

Haleakalā Survey	
Date: ____/____/____	Gender 1____Male 2____Female
Are you a visitor or resident? 1____Resident of Hawai'i 2____Visitor to Hawai'i	Zipcode: ____________________ (if visitor not from U.S., enter name of country)
Including this time, how many times have you been to Maui? _________times	Including this time, how many times have you been to Haleakalā National Park? _________times
If visitor, did you decide to come to Haleakalā National Park before or after you arrived in Hawai'i? 1____Before 2____After	What did you do at Haleakalā National Park today? 1___Sightseeing (Visitor's Center, look at the Crater, etc) 2___Go hiking or stay at the cabins 3___Other ________________
How likely are you to come back to Maui? 1____Very Likely 2____Somewhat Likely 3____Not Very Likely 4____Not At All Likely	How likely are you to come back to Haleakalā National Park? 1____Very Likely 2____Somewhat Likely 3____Not Very Likely 4____Not At All Likely
How would you rate your visit to Haleakalā National Park? 1____The single best sightseeing experience in my life 2____One of the best sightseeing experiences 3____Similar to many sightseeing experiences I have had in the past 4____An average or Below average sightseeing experience	

Haleakalā Survey (continued)	
Did you take photos of the telescope facilities today? 1____Yes 2____No 3____I did not take pictures	There is a proposal to build another observatory in that same area to study the sun that would be 20-feet taller than the existing observatories (see accompanying renderings). The existing observatories cannot accommodate visitors, but the new one would be open for tours. Would you care if there is another telescope as described? 1____Yes 2____No 3____Don't Care either way 4____Don't know
If they built a new telescope facility, how likely would you be to come back to the park to tour the telescope? 1____Very Likely 2____Somewhat Likely 3____Not Very Likely 4____Not At All Likely	Did you see and read the Haleakalā Observatories information sign? 1____Yes, read it 2____Saw it, but did not read it 3____No, did not see it 4____Don't know
What is your age? 1____18-24 2____25-34 3____35-44 4____45-54 5____55-64 6____65 or older	What is your ethnicity? 1____Caucasian 2____Chinese 3____Filipino 4____Hawaiian or Part Hawaiian 5____Japanese 6____Black or African American 7____Hispanic or Latino 8____Other

Thank you for completing this survey.

APPENDIX B: EXHIBITS ACCOMPANYING SURVEY INSTRUMENT

Exhibit S-1: Existing Telescope Facilities without the Advanced Technology Solar Telescope (ATST)

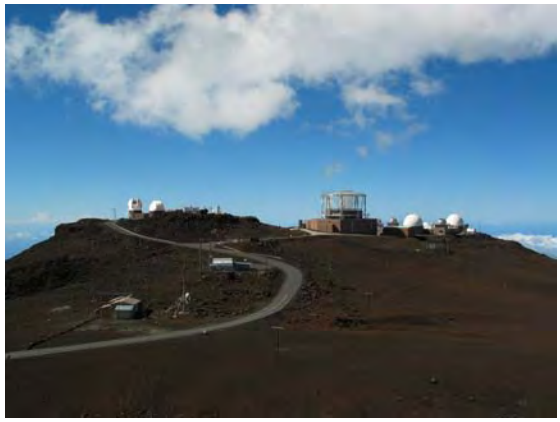


Exhibit S-2: Proposed Additional Facilities at Haleakalā

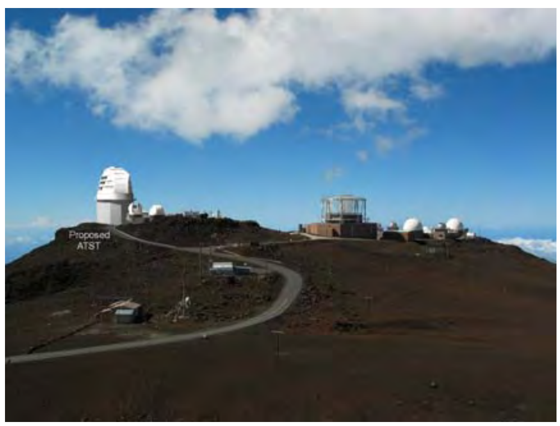


Exhibit S-3: Observatory Information Sign

APPENDIX C: FREQUENCIES

What is your gender?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
Gender	Male	Count	7	158	88	8	261
		% within SUPPORT	35.0%	50.0%	49.4%	42.1%	49.0%
	Female	Count	13	157	89	11	270
		% within SUPPORT	65.0%	49.7%	50.0%	57.9%	50.7%
	No answer	Count		1	1		2
		% within SUPPORT		.3%	.6%		.4%
Total		Count	20	316	178	19	533
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

Are you a visitor or resident of Maui?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
Are you a visitor or resident of Maui?	Visitor to Maui	Count	19	302	163	18	502
		% within SUPPORT	95.0%	95.6%	91.6%	94.7%	94.2%
	Resident of Maui	Count	1	14	15	1	31
		% within SUPPORT	5.0%	4.4%	8.4%	5.3%	5.8%
Total		Count	20	316	178	19	533
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

Including this time, how many times have you been to Maui?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
Including this time, how many times have you been to Maui?	first time	Count	16	208	117	17	358
		% within SUPPORT	80.0%	69.1%	70.9%	89.5%	70.9%
	second time	Count	2	52	19	1	74
		% within SUPPORT	10.0%	17.3%	11.5%	5.3%	14.7%
	third	Count		16	7	1	24
		% within SUPPORT		5.3%	4.2%	5.3%	4.8%
	fourth	Count	1	7	6		14
		% within SUPPORT	5.0%	2.3%	3.6%		2.8%
	5 or more times	Count	1	18	16		35
		% within SUPPORT	5.0%	6.0%	9.7%		6.9%
Total		Count	20	301	165	19	505
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

Including this time, how many times have you been to Haleakalā National Park?

		SUPPORT				Total
		Don't know	Don't care	Support telescope	Do not support telescope	
first time	Count	17	244	135	18	414
	% within SUPPORT	85.0%	78.2%	78.0%	94.7%	79.0%
second time	Count	2	33	15	1	51
	% within SUPPORT	10.0%	10.6%	8.7%	5.3%	9.7%
third	Count		9	6		15
	% within SUPPORT		2.9%	3.5%		2.9%
fourth	Count	1	12	4		17
	% within SUPPORT	5.0%	3.8%	2.3%		3.2%
5 or more times	Count		14	13		27
	% within SUPPORT		4.5%	7.5%		5.2%
Total	Count	20	312	173	19	524
	% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

If visitor, did you decide to come to Halakala National Park before or after you arrived in Hawaii?

		SUPPORT				Total
		Don't know	Don't care	Support telescope	Do not support telescope	
Before	Count	7	219	118	13	357
	% within SUPPORT	36.8%	76.8%	76.1%	72.2%	74.8%
After	Count	12	66	37	5	120
	% within SUPPORT	63.2%	23.2%	23.9%	27.8%	25.2%
Total	Count	19	285	155	18	477
	% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

What did you do at Haleakalā National Park today?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
What did you do at Haleakalā National Park today? - Response 1	Sightseeing (Visitor's Center, look at the Crater, etc.)	Count	9	203	124	8	344
		% within SUPPORT	47.4%	65.3%	71.3%	42.1%	65.8%
	Go hiking or stay at the cabins	Count	1	7	4		12
		% within SUPPORT	5.3%	2.3%	2.3%		2.3%
	Other	Count	1	13	5	4	23
		% within SUPPORT	5.3%	4.2%	2.9%	21.1%	4.4%
	Biking	Count	8	88	41	7	144
		% within SUPPORT	42.1%	28.3%	23.6%	36.8%	27.5%
Total		Count	19	311	174	19	523
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

How likely are you to come back to Maui?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
How likely are you to come back to Maui?if blank, enter 9	Very Likely	Count	10	180	113	5	308
		% within SUPPORT	52.6%	58.6%	67.7%	27.8%	60.3%
	Somewhat Likely	Count	6	101	54	7	168
		% within SUPPORT	31.6%	32.9%	32.3%	38.9%	32.9%
	Not Very Likely	Count	3	21		5	29
		% within SUPPORT	15.8%	6.8%		27.8%	5.7%
	Not At All Likely	Count		5		1	6
		% within SUPPORT		1.6%		5.6%	1.2%
Total		Count	19	307	167	18	511
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

How likely are you to come back to Haleakalā National Park?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
How likely are you to come back to Haleakalā National Park?if blank, enter 9	Very Likely	Count	8	143	100		251
		% within SUPPORT	40.0%	45.5%	56.5%		47.5%
	Somewhat Likely	Count	6	132	77		215
		% within SUPPORT	30.0%	42.0%	43.5%		40.7%
	Not Very Likely	Count	5	31		16	52
		% within SUPPORT	25.0%	9.9%		94.1%	9.8%
	Not At All Likely	Count	1	8		1	10
		% within SUPPORT	5.0%	2.5%		5.9%	1.9%
Total		Count	20	314	177	17	528
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

How would you rate your visit to Haleakalā National Park?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
How would you rate your visit to Haleakalā National Park?	The single best sightseeing experience in my life	Count	3	14	15		32
		% within SUPPORT	15.8%	4.5%	8.6%		6.1%
	One of the best sightseeing experiences	Count	8	208	118	6	340
		% within SUPPORT	42.1%	66.7%	67.4%	33.3%	64.9%
	Similar to many sightseeing experiences I have had in the pa	Count	4	61	32	8	105
		% within SUPPORT	21.1%	19.6%	18.3%	44.4%	20.0%
	An average or below average sightseeing experience	Count	4	29	10	4	47
		% within SUPPORT	21.1%	9.3%	5.7%	22.2%	9.0%
Total		Count	19	312	175	18	524
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

Did you take photos of the telescope facilities today?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
Did you take photos of the telescope facilities today?	Yes	Count		65	41	5	111
		% within SUPPORT		20.6%	23.3%	26.3%	21.6%
	No	Count	3	238	128	14	383
		% within SUPPORT	100.0%	75.3%	72.7%	73.7%	74.5%
	I did not take pictures	Count		13	7		20
		% within SUPPORT		4.1%	4.0%		3.9%
Total		Count	3	316	176	19	514
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

There is a proposal to build another observatory in that same area to study the sun that would be 20-feet taller than the existing observatories (see accompanying renderings). The existing observatories cannot accommodate visitors, but the new one would be open for tours. Would you care if there is another telescope as described?

		SUPPORT				Total
		Don't know	Don't care	Support telescope	Do not support telescope	
Yes	Count	1		139	12	152
	% within SUPPORT	33.3%		79.9%	70.6%	29.8%
No	Count		164			164
	% within SUPPORT		51.9%			32.2%
Don't Care either way	Count		152			152
	% within SUPPORT		48.1%			29.8%
Don't Know	Count	2		35	5	42
	% within SUPPORT	66.7%		20.1%	29.4%	8.2%
Total	Count	3	316	174	17	510
	% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

If they built a new telescope facility, how likely would you be to come back to the park to tour the telescope?

		SUPPORT			Total
		Don't care	Support telescope	Do not support telescope	
Very Likely	Count	88	82	1	171
	% within SUPPORT	28.0%	46.1%	5.3%	33.5%
Somewhat Likely	Count	126	76	8	210
	% within SUPPORT	40.1%	42.7%	42.1%	41.1%
Not Very Likely	Count	75	15	9	99
	% within SUPPORT	23.9%	8.4%	47.4%	19.4%
Not At All Likely	Count	25	5	1	31
	% within SUPPORT	8.0%	2.8%	5.3%	6.1%
Total	Count	314	178	19	511
	% within SUPPORT	100.0%	100.0%	100.0%	100.0%

Did you see and read the Haleakalā Observatories information sign?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
Did you see and read the Haleakalā Observatories information sign?	Yes, read it	Count	1	59	51	1	112
		% within SUPPORT	25.0%	18.8%	29.3%	5.3%	21.9%
	Saw it, but did not read it	Count		53	30	2	85
		% within SUPPORT		16.9%	17.2%	10.5%	16.6%
	No, did not see it	Count	2	194	88	15	299
		% within SUPPORT	50.0%	61.8%	50.6%	78.9%	58.5%
	Don't Know	Count	1	8	5	1	15
		% within SUPPORT	25.0%	2.5%	2.9%	5.3%	2.9%
Total		Count	4	314	174	19	511
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

What is your age?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
What is your age?	18-24	Count		17	9	1	27
		% within SUPPORT		5.4%	5.1%	5.3%	5.2%
	25-34	Count	1	109	75	5	190
		% within SUPPORT	33.3%	34.5%	42.1%	26.3%	36.8%
	35-44	Count		71	42	5	118
		% within SUPPORT		22.5%	23.6%	26.3%	22.9%
	45-54	Count		69	30	5	104
		% within SUPPORT		21.8%	16.9%	26.3%	20.2%
	55-64	Count	1	37	19	3	60
		% within SUPPORT	33.3%	11.7%	10.7%	15.8%	11.6%
	65 or older	Count	1	13	3		17
		% within SUPPORT	33.3%	4.1%	1.7%		3.3%
Total		Count	3	316	178	19	516
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

What is your ethnicity?

			SUPPORT				Total
			Don't know	Don't care	Support telescope	Do not support telescope	
What is your ethnicity? - Response 1	Caucasian	Count	5	263	121	13	402
		% within SUPPORT	100.0%	84.6%	69.5%	72.2%	79.1%
	Chinese	Count		3	7		10
		% within SUPPORT		1.0%	4.0%		2.0%
	Filipino	Count		9	5		14
		% within SUPPORT		2.9%	2.9%		2.8%
	Hawaiian or Part Hawaiian	Count		5			5
		% within SUPPORT		1.6%			1.0%
	Japanese	Count		6	13		19
		% within SUPPORT		1.9%	7.5%		3.7%
	Black or African American	Count		1	3		4
		% within SUPPORT		.3%	1.7%		.8%
	Hispanic or Latino	Count		13	9	3	25
		% within SUPPORT		4.2%	5.2%	16.7%	4.9%
	Other	Count		11	16	2	29
		% within SUPPORT		3.5%	9.2%	11.1%	5.7%
Total		Count	5	311	174	18	508
		% within SUPPORT	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX O

ATST SITE SURVEY WORKING GROUP FINAL REPORT

Project Documentation
Report #0021
Revision A

ATST Site Survey Working Group Final Report

Site Survey Working Group

Oct. 6, 2004

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   Changes: Original release

2. Date:
   Revision:
   Changes:

3. Date:
   Revision:
   Changes:

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Table Of Contents

1. EXECUTIVE SUMMARY

This report contains the final results of the ATST site survey, initiated in 2000 to determine the location of the Advanced Technology Solar Telescope. This report supersedes ATST RPT-0016, *ATST Site Survey Working Group Interim Report.* The interim report contained results from analyses that are now known to be incomplete. Note that even with this extensive survey, there are still caveats. The data presented here were collected over too short a period to reflect long-term temporal variations. Also, the tests were limited to only six promising sites.

The results of this report come from a measurement and analysis technique that uses an array of scintillometers to estimate the seeing as a function of height above the ground. A considerable amount of effort has gone into testing and verifying the method, and the Working Group is of the opinion that the method gives an acceptable estimate up to a height of 50 m above the ground. This report contains the results of the verification tests, as well as two independent approaches to the analysis to allow the reader to judge the level of uncertainty in the results.

The ATST Site Survey Working Group (SSWG) has overseen the development and construction of instrumentation to measure daytime solar seeing, sky brightness, clear time fraction, dust levels, and water vapor content. These quantities have been measured at six candidate sites:

- Big Bear Solar Observatory, California
- Mees Solar Observatory, Haleakala, Hawaii
- Observatorio Roque de los Muchachos, La Palma, Canary Islands, Spain
- Panguitch Lake, Utah
- Sacramento Peak Observatory, Sunspot, NM
- Observatorio Astronomico Nacional, San Pedro Martir, Baja California, Mexico

These six sites were selected from an initial list of 72 candidates. The list was culled down primarily by considerations of feasibility and observing conditions. In a few cases, site visits eliminated candidates on the basis of changing environmental conditions, particularly drought. The six tested sites represent a cross-section of geographical locales: continental mountain (Sac Peak), continental mountain lake (Panguitch), peninsula mountain (San Pedro), coastal mountain lake (Big Bear), Atlantic island mountain (La Palma), and Pacific island mountain (Haleakala).

With the release of the interim report it became clear that the six sites could be grouped into two classes based on the observing conditions. A meeting of the ATST Science Working Group in November 2003 resulted in the recommendation that testing be continued only at the top group of sites (Big Bear, Haleakala, and La Palma). Thus those sites have an additional year of data included in this report, and are the main subject of the final report. Note that the overall classification of the sites into two groups remained unchanged when the improved seeing analysis was applied to all six sites.

As of August 31, 2004 data have been collected over various time periods at the six sites ranging in length from 0.5 to 2.1 years (1.9 to 2.1 years for the top group of sites) to determine which sites fulfill the scientific site requirement goals for the ATST. Those goals are:

- Clear daytime fraction of 70%, 3000 hours annual sunshine.
- 1800 annual hours with r_0 (500 nm) > 7 cm (measured at the telescope aperture), including at least 100 continuous 2-hr periods.
- 200 annual hours with r_0 (500 nm) > 12 cm (measured at the telescope aperture) including at least 10 continuous 4-hr periods.

- Large isoplanatic angle, i.e., good atmospheric conditions at high altitudes.
- 480 annual hours with a sky brightness less than or equal to 25 ± 10 millionths at 1.1 radii at 1 micron with a radial profile equal to or steeper than $R^{-0.8}$, including at least 40 continuous 4 hour periods.
- 600 annual hours with the precipitible water vapor below 5 mm, including at least 40 continuous 4-hour periods.

The instrumentation used for the survey comprised two major pieces – a seeing monitor, and a sky brightness monitor. The seeing monitor included two components: a solar differential image motion monitor (S-DIMM), and an array of six scintillometers known as the shadow band ranger (SHABAR). Both seeing monitor components were designed and developed by Jacques Beckers and constructed at Sac Peak Observatory. The S-DIMM measures the total value of r_0 integrated from the observing height to the top of the atmosphere with no height weighting of $C_n^2(h)$. The SHABAR measures the steady and fluctuating intensity of sunlight in six detectors giving the clear time fraction and a measure of the seeing with $C_n^2(h)$ weighted towards lower heights h by a factor $h^{-1/3}$. The SHABAR also measures the cross-covariance of scintillation between the 15 possible pairs of detectors which are arranged in a non-redundant array. These covariances are used to estimate $C_n^2(h)$ and hence r_0 as a function of height above the 8-m height at which the seeing monitor entrance aperture is mounted. Since the height of the ATST primary mirror is expected to be around 25 m, the inferred $r_0(h)$ is a vital piece of information. The seeing monitor is mounted on a substantial 6-m tall test stand that is designed such that the dominant motion of the instrument platform is a horizontal translation without tilting. The additional height of the telescope pier and telescope itself places the entrance aperture of the seeing monitor at 8 m above the ground. The sampling time and cadence of the seeing monitor is 10 sec.

The sky brightness monitor (SBM) comprises a miniature coronagraph that compares the sky brightness in three wavelength bands (450, 530, and 890 nm) to the solar disk intensity. The SBM was designed and developed by Haosheng Lin and constructed at the Institute for Astronomy in Hawaii. It is sensitive to sky brightness below 1×10^{-6} of disk center intensity with a field of view of 4 to 8 solar radii. It also provides an intensity measurement in the 940-nm water vapor absorption band. In addition to the SBM, a commercial dust counter was installed to count particulates in five size ranges (0.3, 0.5, 1, 2, and 3 microns). The dust counter was mounted at the 6-m height of the top of the seeing monitor test stand, while the SBM was located at ground level.

In addition to the seeing monitor and SBM, a weather station recorded wind speed, wind velocity, pressure, relative humidity, and temperature at two locations (top and bottom of the test stand).

Calibration of the S-DIMM instrument consisted of measuring the plate scale of the detector using observations of double stars. The SHABAR detectors were tested using generated laboratory signals as inputs and standard electronic measuring devices and techniques for the outputs. In addition, all field units were run for a brief period co-located with a constant “standard” unit at Sac Peak. Similar tests were performed for the SBM in Hawaii before shipment.

The data analysis to estimate $r_0(h)$ proved to be challenging. It essentially comprises the fitting of the observed cross-covariances as a function of detector separation with a model of the structure function, $C_n^2(h)$, composed of weighting functions derived from the theory of atmospheric turbulence. In addition, the integral of the model over the atmosphere is required to fit the observed S-DIMM value of r_0,, and the total observed scintillation. This requires the inclusion of an estimate of high-altitude seeing. Several tests of the analysis have been performed -- simulations, comparisons between simultaneous SHABAR/S-DIMM r_0 estimates at different heights, and comparison with in-situ measurements of C_n^2. In all cases the analysis appears to provide a reasonable estimate of $r_0(h)$. This report contains the results of the verification tests as well as two independent inversions of the seeing data so that the reader can judge the reliability of the results.

The SBM analysis to obtain sky brightness measurements involves the extraction of portions of the recorded images, averaging, correction for extinction and air mass, and fitting for radial and wavelength power laws. These power-law exponents are then used to extrapolate the sky brightness at the location and wavelength specified in the science requirements. This analysis also was challenging, primarily due to instrumental difficulties.

The clear time fraction (CTF) is estimated from the steady intensity level of the scintillometers in the SHABAR. The estimated CTF is sensitive to how certain instrumental data flags are interpreted: either as clouds, or as instrumental outages. When the flags are designated as instrumental outages, we find very good agreement between the CTF estimated here and those estimated by the earlier GONG site survey. Since the two methods of treating the flags represent the upper and lower limits of the CTF, we report the results from both treatments of the data.

An effort was made to reduce the impact of site-specific observing habits, equipment outages, and bad weather on the extrapolation of the measured seeing statistics to estimates of annualized hours of quality observing conditions. Once the relevant measurements are estimated for each sample, corrections are applied to the data to obtain the summary quantities that are shown in the following figures and table. The figures in this executive summary show a few of the seeing (Figures ES.1 and ES.2) and sky brightness (Figures ES.3 and ES.4) characteristics of the sites, as summarized in the captions. The summary tables contain the statistical outline of the seeing (Table 1) and sky brightness (Table 2) results. In addition to these overall summaries, this report contains detailed information on the statistical dependence of seeing as a function of time of day, time of year, wind speed and wind direction.

A striking result of the seeing analysis is the qualitative difference between the Big Bear site and the sites on Haleakala and La Plama (or more generically, between lake sites and island mountain sites). Many seeing properties, including the distributions of near-ground-level turbulence and the contribution from high-altitude scintillation, are systematically different between the two kinds of site. Based on the studies described in this report, the SSWG is satisfied that these differences are real, and result from the absence of a near-surface layer of solar-heated air at Big Bear. Earlier studies have suggested such a difference between lake sites and mountain sites, and the current work confirms this distinction.

The ATST site survey is one of the few comparative studies of solar site characteristics, and has been done with new instrumental and analysis techniques that can provide new details about the height dependence of the atmospheric turbulence. The reader should keep in mind the limitations of this work: the short observational time span, and the limited number of sites that have been tested.

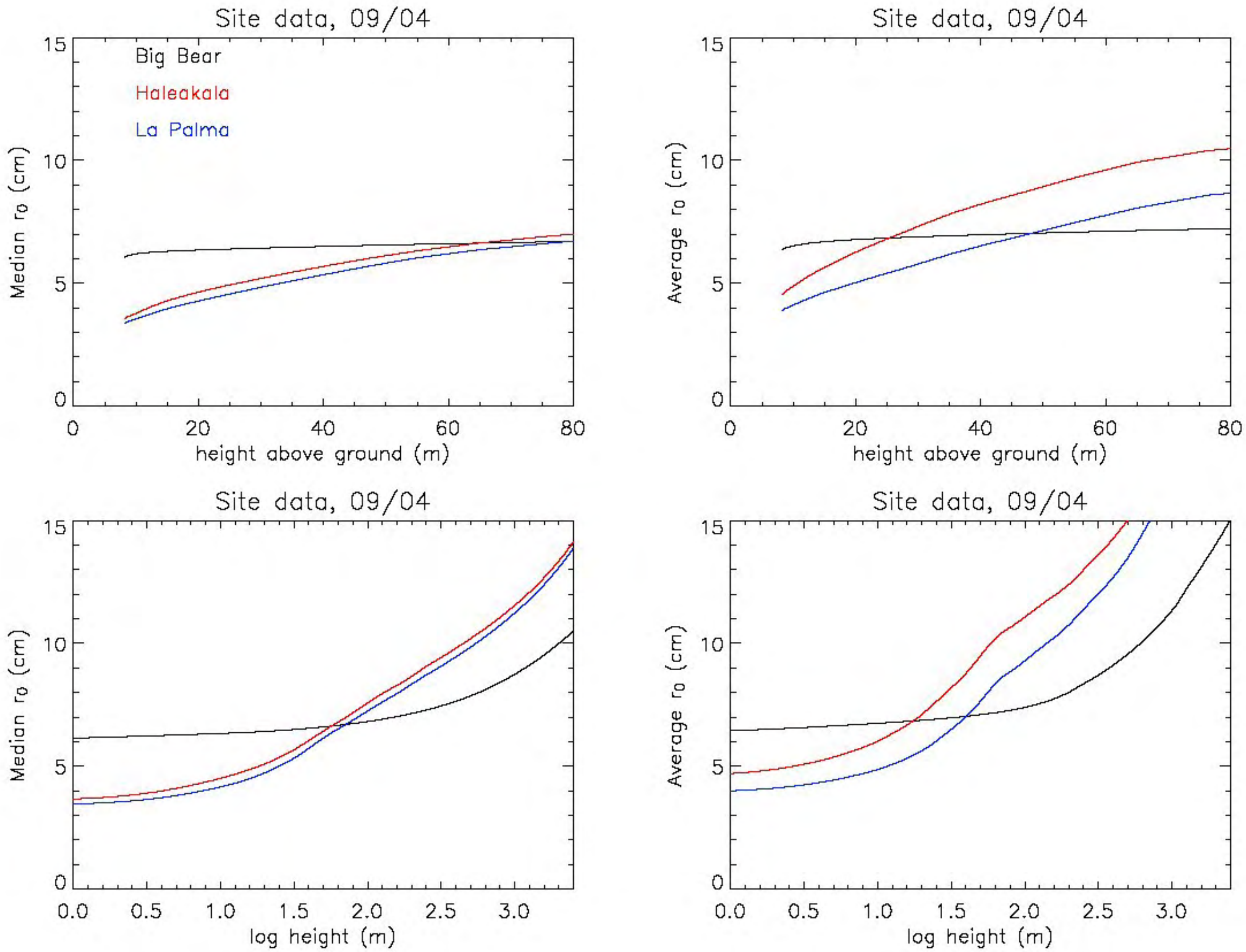


Figure ES.1 – These plots show the behavior of r_0 as a function of height as derived from the SHABAR and S-DIMM analysis. The left column shows the median values for each site; the right column shows the average r_0. The bottom row is on a logarithmic height scale to show high-altitude seeing, and the top row is on a linear scale to show the low-level seeing.

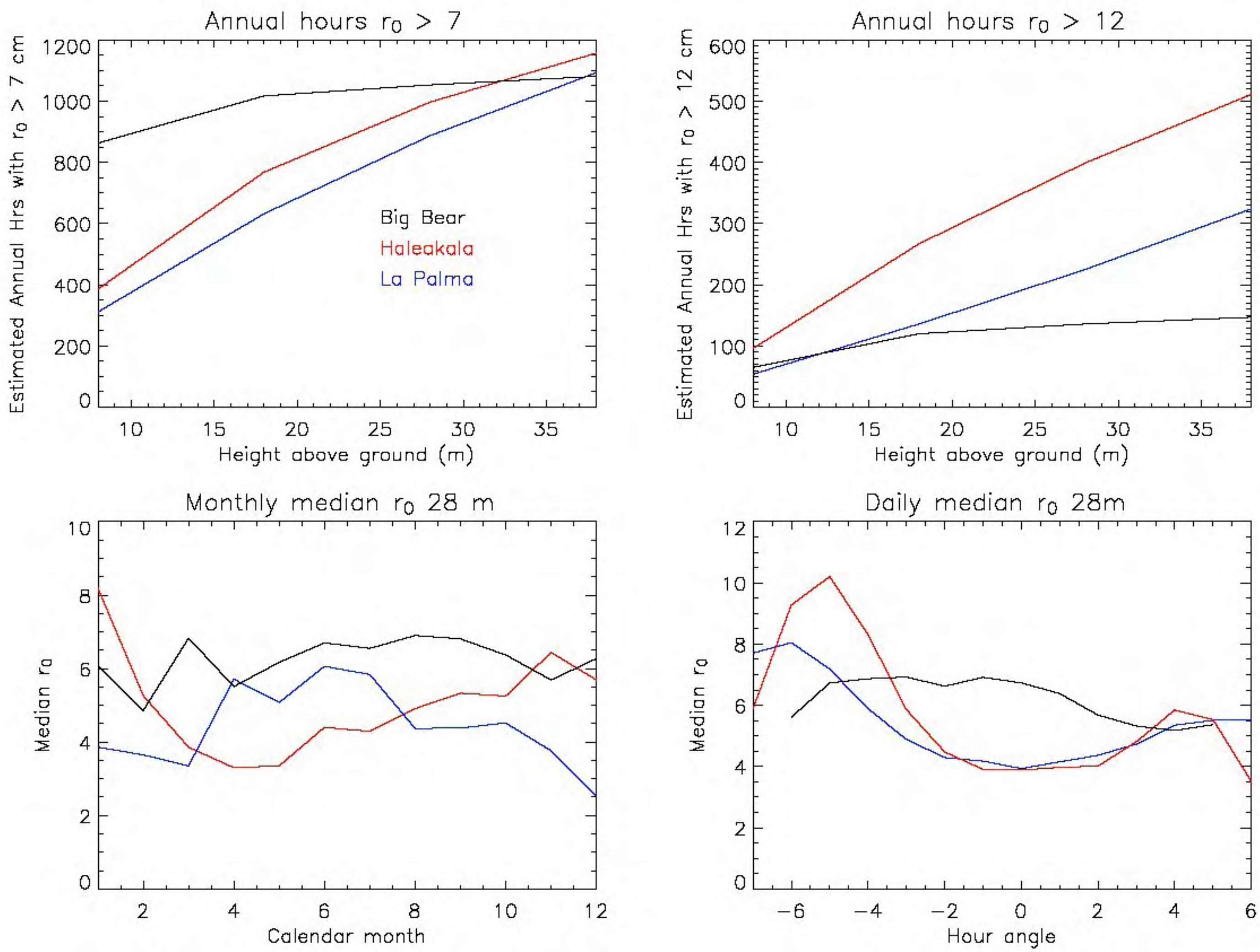


Figure ES.2 – These plots show some temporal characteristics of r_0 at the sites. The top row shows the corrected estimated annual number of hours during which r_0 was greater than 7 cm (upper left panel) or 12 cm upper right (right panel) as a function of height above the ground. The qualitative difference between the lake site (Big Bear) and the mountain sites (Haleakala and La Palma) is likely due to the absence of a surface layer at the lake. The lower row shows the median values of r_0 as a function of calendar month (lower left) and hour angle (lower right).

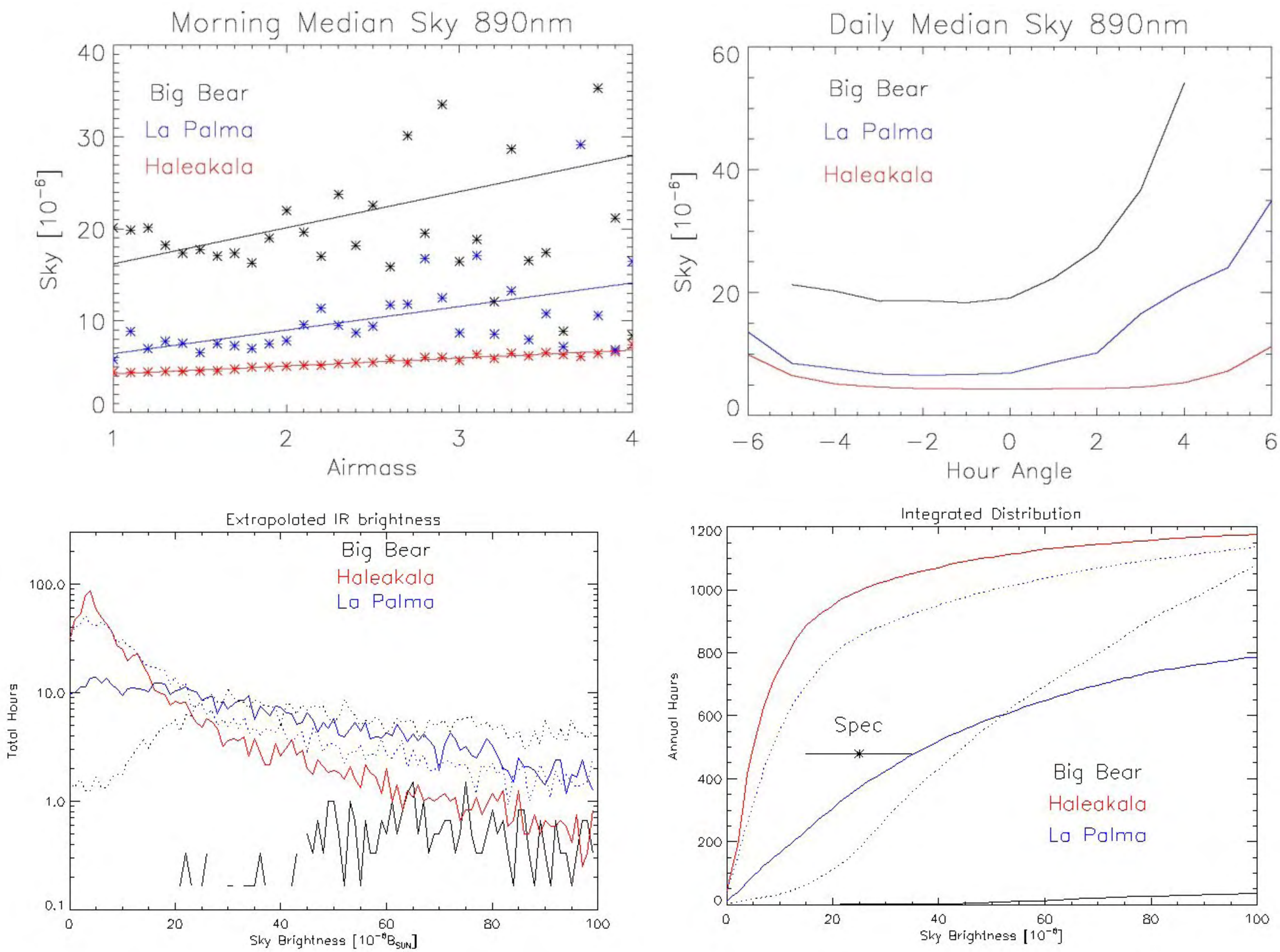


Figure ES.3: These plots show some of the Sky brightness results. Upper left: The median sky brightness at 890 nm as a function of morning air mass. Upper right: The median 890-nm sky as a function of hour angle. Lower left: a histogram of the sky brightness extrapolated to 1000 nm and 1.1 radii. Lower right: The cumulative histogram of the extrapolated sky brightness. See Figure 10.21 for further details.

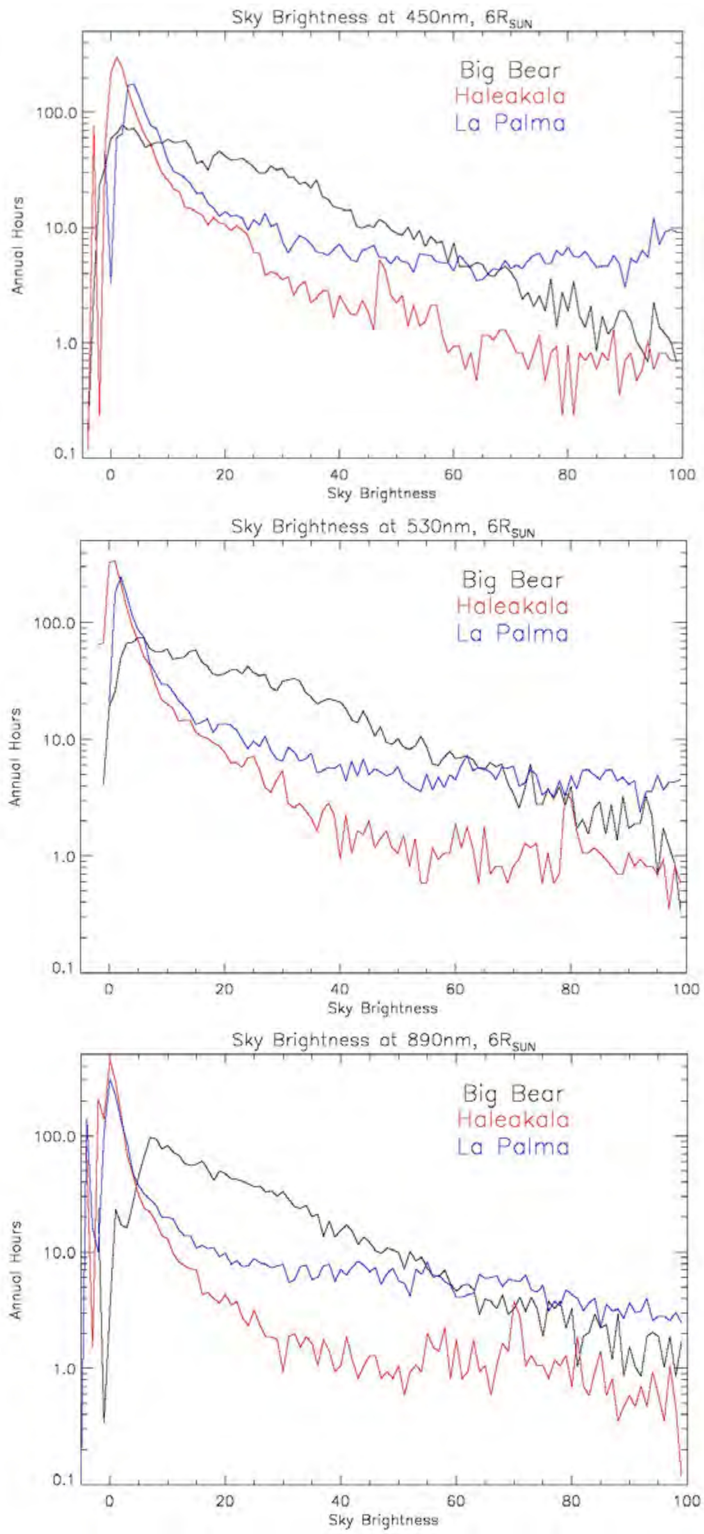


Figure ES.4 – These plots show histograms of the sky brightness measurements for the three sites.

Seeing	Big Bear	Haleakala	La Palma
Time Period Start	18-Jul-2002	6-Aug-2002	28-Sep-2002
Time Period End	30-Aug-2004	30-Aug-2004	30-Aug-2004
N days observed	774	755	702
N valid seeing measurements	820434	713678	718370
Smoothed S-DIMM r0 Median (5-min running mean)	6.04	3.53	3.42
S-DIMM Corrected Annual hours r0 >7 cm	856	389	313
S-DIMM Corrected Annual hours r0 > 12 cm	64	96	53
S-DIMM Corrected Annual N 2-hr blocks r0 > 7 cm	62	15	14
S-DIMM Corrected Annual N 2-hr blocks r0 > 12 cm	1	2	0
Results from IAC analysis -- CASE 2 Clear time fraction			
S-DIMM/SHABAR r0 18 m Median, cm	6.33	4.42	4.15
S-DIMM/SHABAR r0 28 m Median, cm	6.42	4.99	4.73
S-DIMM/SHABAR r0 38 m Median, cm	6.49	5.48	5.25
S-DIMM/SHABAR 8 m Corrected Annual hours r0 >7 cm	863	386	311
S-DIMM/SHABAR 18 m Corrected Annual hours r0 >7 cm	1017	768	632
S-DIMM/SHABAR 28 m Corrected Annual hours r0 >7 cm	1053	997	887
S-DIMM/SHABAR 38 m Corrected Annual hours r0 >7 cm	1081	1157	1093
S-DIMM/SHABAR 8 m Corrected Annual hours r0 > 12 cm	65	96	54
S-DIMM/SHABAR 18 m Corrected Annual hours r0 > 12 cm	120	267	136
S-DIMM/SHABAR 28 m Corrected Annual hours r0 > 12 cm	136	399	225
S-DIMM/SHABAR 38 m Corrected Annual hours r0 > 12 cm	147	511	324
S-DIMM/SHABAR 8 m Corrected Annual N 2-hr blocks r0 > 7 cm	49	15	17
S-DIMM/SHABAR 18 m Corrected Annual N 2-hr blocks r0 > 7 cm	71	47	43
S-DIMM/SHABAR 28 m Corrected Annual N 2-hr blocks r0 > 7 cm	83	82	60
S-DIMM/SHABAR 38 m Corrected Annual N 2-hr blocks r0 > 7 cm	84	106	80
S-DIMM/SHABAR 8 m Corrected Annual N 2-hr blocks r0 > 12 cm	0	2	0
S-DIMM/SHABAR 18 m Corrected Annual N 2-hr blocks r0 > 12 cm	1	3	2
S-DIMM/SHABAR 28 m Corrected Annual N 2-hr blocks r0 > 12 cm	1	10	4
S-DIMM/SHABAR 38 m Corrected Annual N 2-hr blocks r0 > 12 cm	1	18	4

Summary Table 1: Seeing results from the S-DIMM and for one of the inversion methods at heights of 8, 18, 28, and 38 m above the ground.

Weather			
Clear Time fraction Case 1: Flags are clouds	0.465	0.574	0.475
Corrected annual clear hours Case 1	1684	2725	2403
Clear Time fraction Case 2: Flags are down	0.712	0.619	0.639
Corrected annual clear hours Case 2	2579	2931	3197
Clear Time fraction GONG (Teide for La Palma)	0.714	0.647	0.708
Wind Speed median m/s	4.7	4.5	3.6
Sky Brightness			
Time Period Start	25-Feb-03	3-Jan-03	23-Apr-03
Time Period End	31-Aug-04	31-Aug-04	31-Aug-04
N days observed	216	189	186
N valid measurements	51036	62188	80432
Sky brightness median, 1.e-6 extrap to 1.1 r, 1 micron	96 to 800	5.8	31 to 114
Sky brightness median, 1.e-6 at 6 r and 890 nm	20	1.1	5.4
Sky brightness median, 1.e-6 at 6 r and 530 nm	21	2.4	11
Sky brightness median, 1.e-6 at 6 r and 450 nm	19	3.1	14
Radial exponent median at 890 nm	2.20	1.03	1.92
Wavelength exponent median at 4 r	0.32	0.53	0.51
Water vapor absorption median at 950 nm	0.12	0.10	0.09
Corrected annual hours satisfying sky brt req	2 to 198	1004.0	384 to 861
Corretced Annual N 4-hour blocks satisfying sky brt req	0 to 4	212	62 to 107
0.3 Dust Median	721197	27909	654435
0.5 Dust Median	36783	5229	10845
1.0 Dust Median	7938	927	5355
2.0 Dust Median	1728	216	450
5.0 Dust Median	234	45	81
N measurements	10292 to 10340	1217 to 2343	2654 to 3073

Summary Table 2: Weather and sky brightness quantities.

2. GOALS

The Advanced Technology Solar Telescope (ATST) Site Survey Working Group (SSWG) was formed to test probable sites for the ATST. This goal is summarized in the charge to the SSWG:

SSWG charge:
The main objective of the ATST site survey is to ensure that the ATST is located at the best feasible site. The task of the Site Survey Working Group (SSWG) is to advise the ATST project scientist on how to perform the ATST site test campaign. The goal of the site survey is to ensure that the ATST is located at a site that allows the ATST to meet its science requirements. The SSWG is composed of solar physics community members with a range of expertise that includes site testing and solar observing. The SSWG reports to the Project Scientist on a regular basis.

The SSWG will:
- Develop, review and evolve a site-testing plan
- Specify site requirements based on science requirements stated in the ATST proposal
- Consult with the Project Scientist and ASWG on site requirement specification
- Recommend the initial sites to be tested
- Recommend site test procedures and equipment
- Review the data reduction methods
- Periodically monitor the results
- Prepare a report on the site survey results

This report fulfills the obligation of the last item in the charge. It contains descriptions of the instrumentation; discussions of the data analysis including the limitations of the methods, and presents the results to date.

In addition to selecting the ATST site, there were two goals:
- Provide ATST engineering input
- Study daytime seeing

The ATST engineering effort requires information about the meteorological conditions at the site. These are provided by the weather station component of the site survey instrumentation. In addition, the engineering studies are modeling the performance of the telescope which requires actual observed statistical distributions of the site characteristics.

The final goal of the survey was perhaps the most interesting to the SSWG. The SSWG is aware of only two useful earlier comparative studies of daytime seeing at multiple sites with consistent instrumentation and methods. The CalTech survey that selected Big Bear examined some 38 sites in southern California (Zirin and Mosher 1985) using visual observations and trained observers. The JOSO site survey that selected two sites on the Canary Islands (Brandt & Wöhl 1982) studied nearly 40 sites in southern Europe with a variety of atmospheric sounding methods. With the ATST site survey, the details of the height and temporal variations of C_n^2 have been recorded over a wide range of meteorological and geographical conditions. This information might eventually lead to a method of identifying new potential solar observing sites.

3. SCIENTIFIC REQUIREMENT GOALS

This section duplicates ATST Project Document Specification #0006 Revision #A

3.1 SEEING

The highest ATST scientific priority is high-resolution studies of solar fine structure, such as magnetic field generation, evolution, and flux-tubes. This, in turn requires high spatial resolution; the ATST 4-m aperture has a diffraction limit of 0.03 arcsec at a wavelength of 500 nm. This can only be achieved if r_0 is 4m, which will never occur. Thus, adaptive optics is required, and the limitations of these systems must be considered in deriving the site requirements. In addition, the key scientific requirement is the S/N ratio of the intensity measured by the ATST, since I(lambda, x, y, t) is the fundamental measurement from which all other physical parameters are derived.

The Strehl ratio is a key determinant of the S/N ratio. Experience with A/O suggests a minimum Strehl of 0.2-0.3 is needed (see ATST Science Requirements Document (SRD)). Examining Fig. 3.1 shows that a Strehl of 0.2 can be reached with a 400-element A/O system at an r_0 of 7 cm. However, since r_0 typically varies over a wide range during the day, it is better to have more elements to reduce the Strehl ratio variation. A/O systems with 1000 elements are available now; such a system would provide a Strehl greater than 0.4 at an r_0 of 7 cm. A 7-cm r_0 is also the minimum aperture at which granulation can be resolved in the visible, which sets the fundamental lower limit of the A/O wavefront sensor subaperture size. In addition, the number of elements required to correct over an aperture D at a given r_0 is (D/r_0)^2, so for 1000 elements. I.e., the cost, complexity and performance of the AO system are strong functions of r_0. For a 4-m aperture and an AO system with 1000 elements (largest system operational to date; Starfire), r_0 must be at least 12.7 cm in order to achieve the high Strehl A/O performance called for in the SRD.

Putting all this together suggests that r_0 must be greater than 7 cm for substantial periods of time, and preferably should be at least 12-13 cm as much as possible, assuming an A/O system with on the order of 1000 elements.

AO corrected FOV: For flux tube studies, a FOV of 10 arcsec should be sufficient, but for active regions an FOV of 2-5 arcmin is needed, requiring MCAO. A site with large isoplanatic patch is therefore highly desirable. In addition to r_0, the isoplanatic patch, theta, plays an important role in determining the performance of an A/O system. The wavefront sensor noise decreases as the FOV of the correlating Shack-Hartmann sensor increases. A typical minimum FOV for effectively tracking granulation is 8-10 arcsec. However, the field of view of the A/O subapertures that is used to determine the wavefront errors should not be larger than the isoplanatic patch. If the wavefront sensor FOV contains several isoplanatic patches only turbulence close to the telescope aperture is corrected. The site requirement is: large isoplanatic angle (theta > 10 arcsec is desirable) for substantial periods of time.

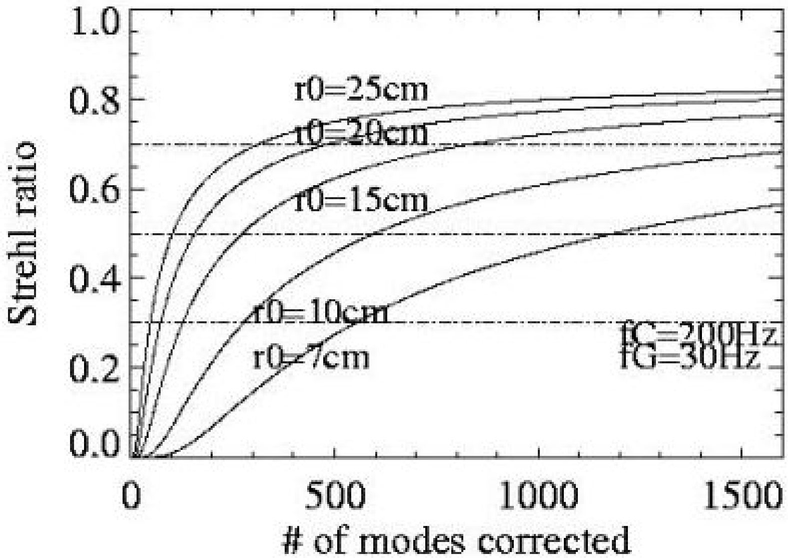


Figure 3.1: Plot of achievable Strehl ratio as a function of number of modes or elements in an A/O system for selected values of r_0. Plot courtesy of T. Rimmele.

To provide a requirement on the temporal distribution of r_0, flux tube studies can be done with 1-hour time series, but active region evolution occurs over many hours. A reasonable compromise might be 4 hours for $r_0 > 7$ cm, 2 hours for $r_0 > 12$ cm. The other major input for the temporal distribution is the overall fraction of clear time. In order to ensure sufficient productivity, the clear time fraction during the day should be at least 70% (i.e. 3000 annual sunshine hours). Given the ATST science priorities, 60% of the clear time (i.e. 1800 hours annually) would be a reasonable allocation for high-resolution work, with the remaining 40% split equally between coronal and IR studies.

Since there may be no tested site that fulfills all requirements, the desired site characteristics are described as goals. In practice, sites coming close to these goals will be highly ranked.

Summarizing, the draft ATST site requirement goals for high-resolution conditions are:

- Clear daytime fraction of 70%, 3000 hours annual sunshine.
- 1800 annual hours with r_0 (500 nm) > 7 cm (measured at the telescope aperture), including at least 100 continuous 2-hr periods.
- 200 annual hours with r_0 (500 nm) > 12 cm (measured at the telescope aperture) including at least 10 continuous 4-hr periods.
- Large isoplanatic angle, i.e., good atmospheric conditions at high altitudes.

3.2 SKY BRIGHTNESS AND IR

The second-level science priority for the ATST is coronography and IR studies. During the remaining 40% of the clear time (i.e. 1200 annual hours), the site should supply conditions that allow this science to be performed. The corona has a very low intensity compared to the solar disk and the coronal intensity falls off very rapidly with distance from the solar limb, as shown by the classical Baumbach expression:

$$I_c = I_{disk} * 10^{-6} * (0.0523\,\rho^{-2.5} + 1.425\,\rho^{-7} + 2.565\,\rho^{-17})$$

where I_c is the coronal intensity, I_disk is the intensity of the solar disk, and rho is the distance from the limb in units of solar radii. Figure 3.2 shows a plot of this function, along with two examples of the K corona intensity profile.

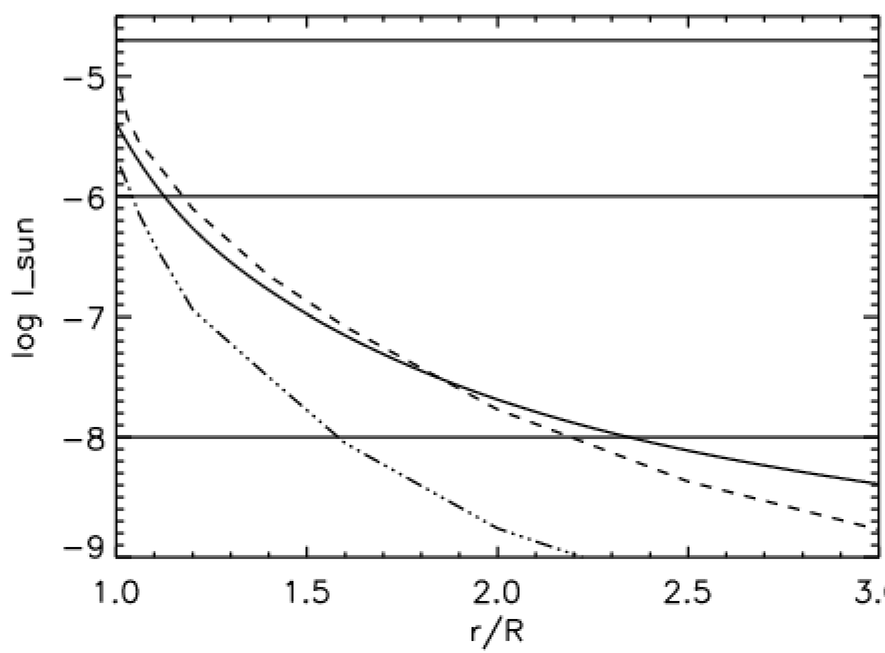


Figure 3.2: Coronal intensity relative to solar disk as a function of distance from the solar limb. Solid line: Baumbach expression, dashed line: K corona at maximum, dot-dash line: polar K corona at minimum. Horizontal lines at 20 millionths, 1 millionth, and 0.01 millionth (upper limit to sky brightness during an eclipse)

According to Golub & Pasachoff, the best coronal sites often have a sky brightness less than 20 millionths of the solar disk center, and sometimes as low as 1 millionth. These levels are indicated in figure 3.2, along with the upper limit to the sky brightness during a total eclipse. It is obvious that even the best coronal site cannot compete with an eclipse for sky brightness. However, the brightest coronal emission lines can exceed 100 millionths at line center. It is thus desirable for the ATST site to provide useful coronal spectroscopic conditions. A draft requirement is that 16% of the clear time provides a sky brightness less than or equal to 25 +/- 10 millionths at a distance of 1.1 radii from the limb at 1 micron, with a radial slope equal to or steeper than $R^{-0.8}$.

The impact of water vapor on infrared solar observations is somewhat controversial. For broad-band photometry, the precipitable water vapor (PWV) content can strongly influence the observations, particularly during the night. On the other hand, spectroscopic solar observations may not be severely affected particularly if the solar lines are unblended with water vapor. In addition, techniques for correcting water/solar blends have been developed. To minimize any adverse effects on IR observations with the ATST, it is prudent to set a site requirement that 20% of the clear time occur with a PWV less than 5 mm over several hours. This needs to be translated into a requirement on the strength of the water vapor bands around 9400 A.

Summarizing, the draft ATST site requirement goals for sky brightness and water vapor are:

- 480 annual hours with a sky brightness less than or equal to 25 +/- 10 millionths at 1.1 radii at 1 micron with a radial profile equal to or steeper than R -0.8, including at least 40 continuous 4 hour periods.
- 600 annual hours with the precipitible water vapor below 5 mm, including at least 40 continuous 4-hour periods.

4. BRIEF HISTORY OF THE SSWG

The SSWG was initially formed at the 2000 SPD meeting at South Lake Tahoe. During the course of a community meeting on the ATST, a call for SSWG volunteers was made. A number of community members agreed to serve on this group. The membership has gone through some changes during its existence for various reasons. The following list shows the current and past members of the group.

Current Members:

- Jacques Beckers, U. Chicago
- Timothy Brown, High Altitude Observatory (Chair)
- Manuel Collados, Instituto de Astrofisica de Canarias
- Carsten Denker, New Jersey Institute of Technology
- Frank Hill, National Solar Observatory
- Jeff Kuhn, U. Hawaii - Institute of Astronomy
- Matt Penn, National Solar Observatory
- Hector Socas-Navarro, High Altitude Observatory
- Dirk Soltau, Kiepenheuer-Institut fuer Sonnenphysik
- Kim Streander, High Altitude Observatory

Past Members:

- K.S. Balasubramaniam, National Solar Observatory
- Peter Brandt, Kiepenheuer-Institut fuer Sonnenphysik
- Mark Giampapa, National Solar Observatory
- Harrison Jones, NASA/Goddard
- Haosheng Lin, U. Hawaii - Institute of Astronomy
- Sara Martin, Helio Research Corp.
- Matthew Penn, National Solar Observatory
- Richard Radick, Air Force Cambridge Research Labs
- Richard Shine, Lockheed-Martin Solar & Astrophysics Lab

The SSWG has had a number of telecons. In 2001, there were a total of eight telecons during which the list of 72 candidate sites was discussed along with the process to reduce it to the small number of sites that were testable within the resource constraints of the survey. That task was accomplished in October 2001. There then ensued a long interval until the next telecon in December 2002. During the hiatus, the seeing instruments were being built and tested and there was a reduced need for SSWG interaction. Once the instruments were deployed and the data began to be collected, the telecons became more frequent. Six were held in 2003 and 16 in 2004 as of the time of this report.

5. PRELIMINARY SELECTION PROCESS

The site selection process began with the making of a list of potential sites with the only constraint being that the candidates had to be reasonably sunny. The list was inserted into a spread sheet, along with some basic geographic and climate data. The spread sheet is shown in Table 1. There are 72 sites in the list, but only six could be tested given the resources of the survey. The problem was how to cull the list down from 72 to 6 sites.

Site Name	ID	Elevation (ft)	Lake area (Acres)	Shortest Distance to Ocean (miles)	Annual Sunshine hours	Number of ocean sides (<100 miles away)	score
Normalization		5,000	1000	25	3000	4	
Power		1.0	0.5	1.0	2.0	1.0	
Abiquiu Lake, NM	20	6309	6811.4	655	2800	0	0.18
Bear Lake, UT	52	5922	82003.2	670	2400	0	0.41
Big Bear, CA	30	6781	2725.8	70	2800	0	1.39
Caballo Reservoir, NM	1	4190	8115.2	535	3000	0	0.22
Castaic Lake, CA	40	1561	3705.6	30	2400	1	2.61
Cerro Tololo, Chile	46	7267	0.0	37	3100	1	1.87
Cone Peak, Monterey, CA	60	4920	0.0	3	1200	1	11.62
El Vado Lake, NM	8	6919	3206.9	650	2800	0	0.16
Elephant Butte, NM	4	4360	27027.2	525	3000	0	0.34
Great Salt Lake, UT - Carrington Island	69	4708	1280000.0	575	3000	0	1.64
Guillermo Haro Obs, MX	55	8136	0.0	285	3200	0	0.24
Haleakala, HI	43	10020	0.0	7	2800	4	13.84
Heron Lake, NM	37	7165	4761.6	650	2800	0	0.17
Isabella Lake, CA - Rocky Point Peninsula	16	2856	7539.2	110	2400	0	0.90
Jelm Mountain, WY	53	9593	0.0	900	2200	0	0.07
Jungfrau, SW	25	11729	0.0	460	1700	0	0.14
Junipero Serra Peak, CA	71	5837	0.0	11	1600	2	4.44
Kitt Peak, AZ	36	6955	0.0	275	2600	0	0.19
La Crescenta, CA	48	2060	0.0	21	3000	2	2.28
La Palma, Canaries	3	7631	0.0	5	2600	4	16.39
Laguna Verde, BO	62	13970	5600.0	215	3000	0	0.72
Lahontan Reservoir, NV	19	4167	6575.8	215	3200	0	0.53
Lake Arrowhead, CA	50	5121	742.4	60	2800	0	1.15
Lake Cachuma, CA	63	758	3129.6	9	2400	2	8.50
Lake Casitas, CA - Island	68	835	2075.0	6	2600	2	11.91
Lake Elsinore, CA	21	1247	4243.2	23	2800	2	4.00
Lake Havasu, AZ	31	456	11148.8	195	3600	0	0.62
Lake Henshaw, CA - Monkey Hill Island	51	2803	5420.8	35	2800	1	2.86
Lake Mathews, CA	22	1398	2499.1	29	2800	2	2.79
Lake Mead, AZ	57	1220	148448.0	260	3200	0	1.30
Lake Mohave, AZ	47	650	4780.8	215	3600	0	0.44
Lake Pleasent, AZ	61	1561	2176.0	290	3200	0	0.25
Lake Powell, AZ	28	3707	66412.8	435	2800	0	0.56
Lake Tahoe, CA	10	6240	117856.0	160	2400	0	1.99
Lake Titicata, Peru/Bolivia	32	12506	2240000.0	178	2500	0	7.10
Lowell Obs, AZ	12	7222	0.0	360	2400	0	0.14
Lyman Lake, AZ	45	5984	1295.4	455	2800	0	0.18
Manashtash Ridge, WA	64	3187	0.0	175	2000	0	0.15
Mauna Kea, HI	17	13828	0.0	17	2800	4	6.82
Mauna Loa, HI	33	11000	0.0	24	2800	4	4.24
Mono Lake, CA - Paoha Island	70	6595	41184.0	172	2400	0	1.22
Mount Locke, TX	24	6766	0.0	460	2800	0	0.12
Mt. Graham, AZ	56	10683	0.0	380	2400	0	0.18
Mt. Hamilton, CA	26	4188	0.0	30	2000	1	1.28
Mt. Hopkins, AZ	2	8349	0.0	290	2400	0	0.20
Mt. Laguna, CA	42	6285	0.0	46	2800	1	1.29
Mt. Lemmon, AZ	35	9025	0.0	325	2400	0	0.19
Mt. Wilson, CA	38	5715	0.0	29	3000	1	2.06
Nacimiento Reservoir, CA	9	807	5740.8	16	2000	2	5.47
Navajo Lake, NM	58	6093	10112.0	605	2800	0	0.22
Panguitch Lake, UT	65	8222	1139.2	410	3200	0	0.23
Paranal, Chile	14	8908	0.0	7	3800	1	12.99
Pathfinder Reservoir, WY	67	5860	21145.6	875	2200	0	0.18
Perris Reservoir, CA - Island	27	1769	2393.6	41	2800	2	2.00
Pic Du Midi, FR	5	9386	0.0	130	2500	0	0.49
Pine Flat Reservoir, CA	15	958	5600.0	130	2800	0	0.66
Pyramid Lake, NV - island	54	4139	109830.4	215	3200	0	1.45
San Antonio Reservoir, CA	39	787	5273.6	18	2000	2	4.72
San Carlos lake, AZ	29	2503	9670.4	370	2600	0	0.29
San Pedro Martir, MX	7	9284	0.0	37	2600	2	2.10
San Vicente Reservoir, CA - island	59	656	1203.2	20	2800	1	2.94
Santa Rosa Lake, NM	49	4726	11622.4	725	2800	0	0.18
Seminoe Reservoir, WY	41	6371	16678.4	880	2200	0	0.17
Sierra La Laguna, Baja	72	7500	0.0	18	2500	3	4.09
Silverwood Lake, CA	11	3383	889.6	58	2800	1	1.18
Strawberry Reservoir, UT - Island	44	7657	13280.0	620	3000	0	0.25
Sunspot, NM	18	9223	0.0	570	2200	0	0.10
Teide, Canaries	23	7858	0.0	8	2600	4	10.38
Theodore Roosevelt Lake, AZ	66	2100	12450.5	350	3200	0	0.36
Utah Lake, UT	13	4488	84294.4	580	3000	0	0.48
Walker Lake, NV	34	3970	35532.8	210	3200	0	0.94
White Mountain, CA	6	11327	0.0	160	2000	0	0.42

An attempt was made to determine a “quality score” based on the elevation, lake area, distance to ocean, annual sunshine hours, and number of ocean sides (defined as the number of cardinal directions in which the ocean was less than 100 miles distant). Drawing from the collective experience of the SSWG, this formula was weighted to increase the score if the site was high in elevation, had a large lake, was close to the ocean, sunny, and had several ocean sides. The formula used was

$$S = \left(\frac{Elevation}{N_{el}}\right)^{P_{el}} + \left(\frac{LakeArea}{N_{la}}\right)^{P_{la}} + \left(\frac{Sunshine}{N_{sh}}\right)^{P_{sh}} + \left(\frac{OceanSides}{N_{os}}\right)^{P_{os}} \times \left(\frac{N_{od}}{OceanDist}\right)^{P_{od}}$$

where the quantities of the type N are the normalizations and the quantities P are the powers shown in Table 1, which also shows the scores computed in this way. The various values of N and P could be adjusted and the scores easily recomputed. A similar analysis was used to test common assumptions about the environmental influences on seeing.

Since this approach proved unable to reproduce the results obtained by the Big Bear site survey (Zirin & Mosher 1985), it was eventually discarded in favor of simple debate amongst the SSWG members. This debate quickly led to the conclusion that Big Bear, La Palma and Sac Peak should be tested since they are well-established productive solar observatories. It was also agreed that Hawaii should be tested, but there was vigorous discussion as to which one of the three established sites (Haleakala, Mauna Kea, Mauna Loa) would be a candidate. After looking at feasibility issues, the SSWG selected Haleakala as the Hawaiian candidate. This left two open slots to fill.

The process to fill the last two slots generated more discussions. It was felt that the set of candidates should have at least one additional lake site since there is ample evidence that lakes are very beneficial for solar observing. It was also felt that the inclusion of another non-US site could be advantageous in the search for international partners for the project. Further discussions pared the list for the two final sites down to:

- Abiquiu Lake, NM
- Lake Henshaw, CA
- Navajo Lake, NM
- Panguitch Lake, UT
- San Pedro Martir, Mexico
- Strawberry Reservoir, UT
- Lake Tahoe, NV/CA

After discussing the pros and cons of these sites and conducting a visit to Abiquiu Lake (which has a very low water level due to the prolonged drought in the southwest US), the SSWG took a vote and selected Panguitch and San Pedro Martir as the last two candidate sites.

6. DESCRIPTION OF THE SITES

6.1 BIG BEAR LAKE, CALIFORNIA

Location: 34° 14' 31" N 116° 58' 34" W
Elevation: 6717 feet (2067 m)
Lake Area: 82,000 acres
Distance to ocean: ~70 miles
Estimated sunshine: 2800 hrs/year

Big Bear Lake is the site of the Big Bear Solar Observatory operated by the New Jersey Institute of Technology. The lake is situated in the San Bernardino Mountains east of Los Angeles, and can be classified as a costal mountain lake. The observatory was constructed at the lake as the result of the extensive CalTech survey of sites in southern California (Zirin & Mosher 1985). Figures 6.1 and 6.2 show views of the observatory dome located at the end of a man-made causeway on the north side of the lake. The location of the site and the terrain around the lake are shown in Figure 6.3.

Figure 6.1: A view of the dome at Big Bear Solar Observatory

Figure 6.2: The Big Bear dome viewed from the lake

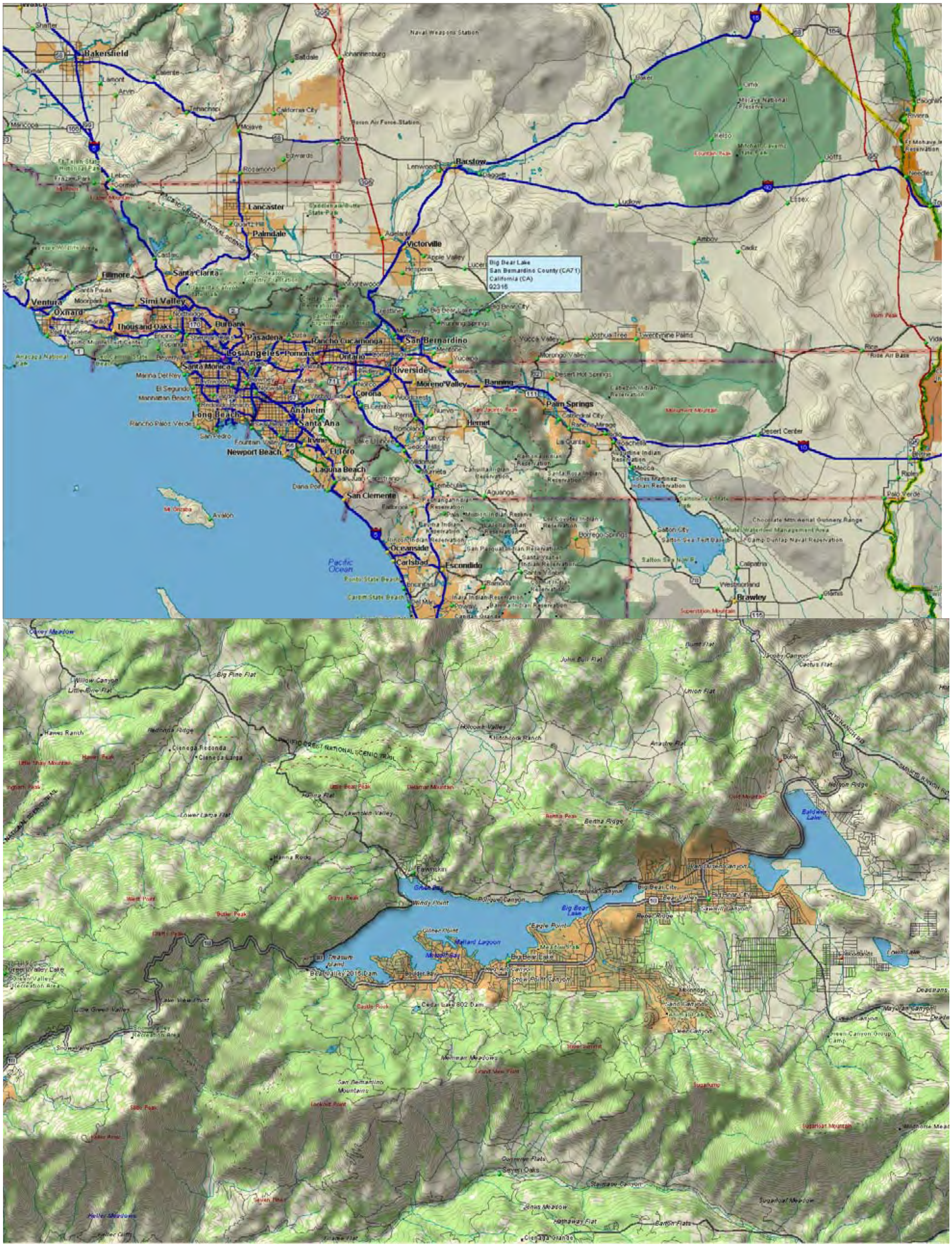


Figure 6.3: The location and terrain of Big Bear Lake. North is up.

6.2 HALEAKALA, HAWAII

Location: 20° 42' 17" N, 156° 10' 36" W
Elevation: 10,023 feet (3084 m)
Lake Area: None
Distance to ocean: 7 miles
Estimated sunshine: 2800 hrs/year

Haleakala is the site of the Mees Solar Observatory, operated by the Institute for Astronomy of the University of Hawaii. Haleakala is the mountain that mainly forms the island of Maui in the Pacific Ocean, and is classified as a Pacific Ocean island mountain. Figure 6.4 shows a general view of the top of the mountain. Figure 6.5 shows location and terrain maps

Figure 6.4 – An aerial view of the top of Haleakala

Figure 6.5: The location and terrain of Haleakala. North is up.

6.3 La Palma, Canary Islands, Spain

Location: 28° 45' 33" N, 17° 52' 33" W
Elevation: 7800 feet (2400 m)
Lake Area: None
Distance to ocean: 5 miles
Estimated sunshine: 2600 hrs/year

La Palma is the site of the Observatorio del Roque de los Muchachos, operated by the Instituto de Astrofísica de Canarias. La Palma is one of the Canary Islands, Spain in the Atlantic Ocean, and is classified as an Atlantic Ocean island mountain. Figure 6.6 shows an aerial view of the observatory. Figure 6.7 shows location and terrain maps

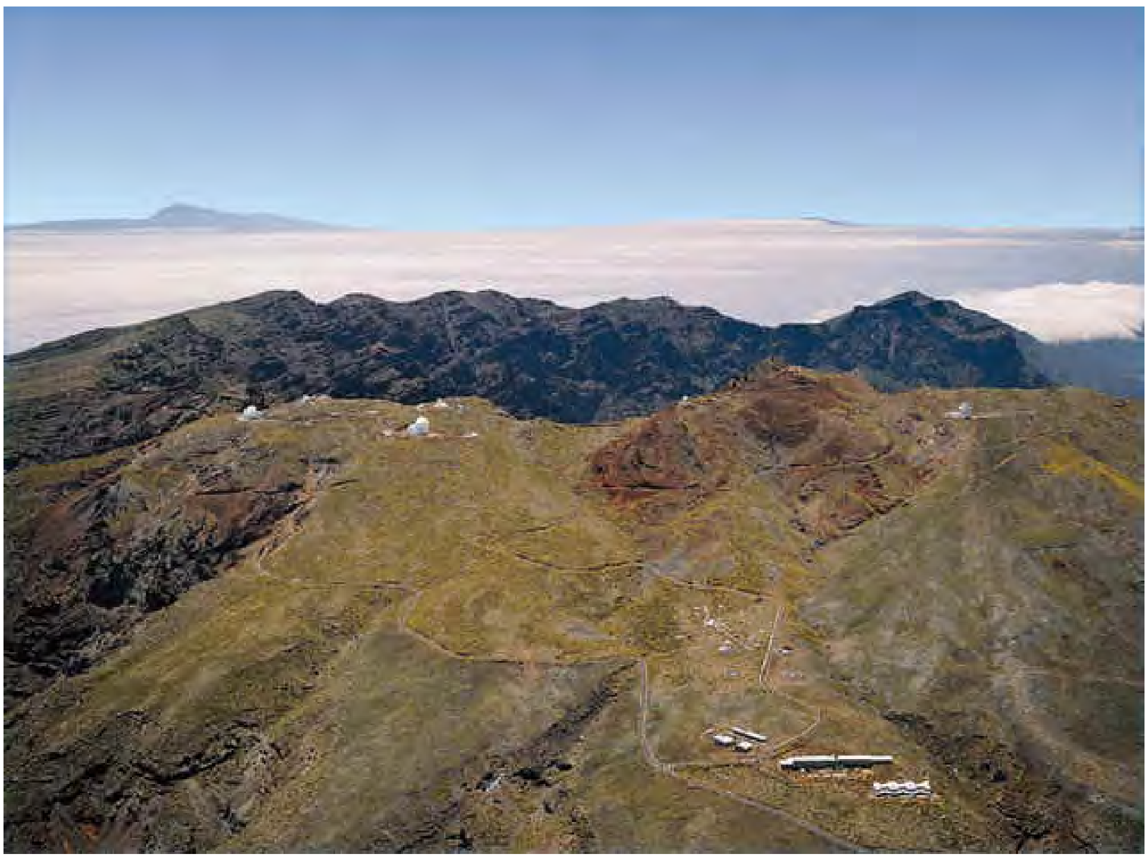


Figure 6.6 – An aerial view of the Observatorio del Roque de los Muchachos, La Palma, Canary Islands, Spain

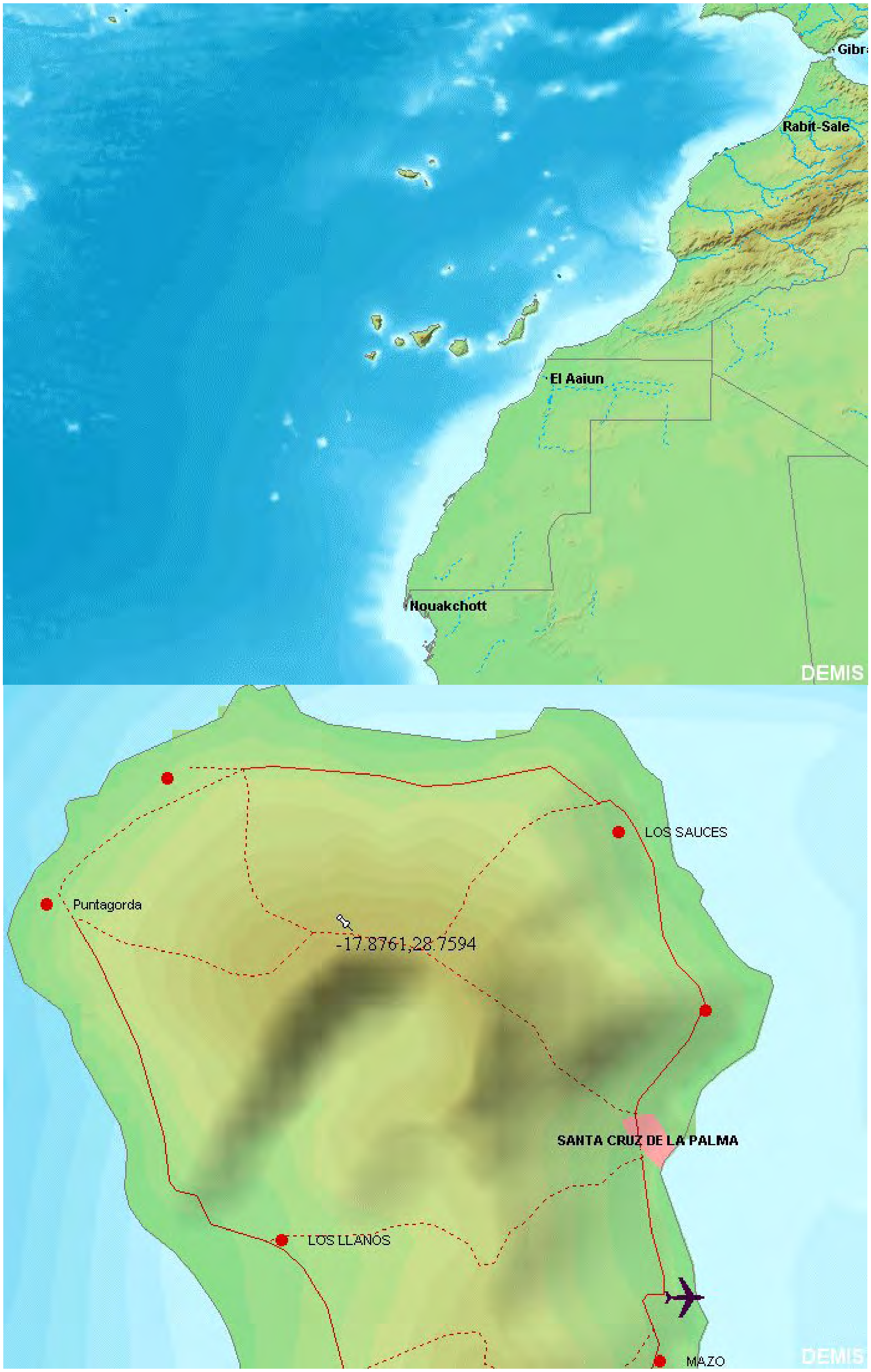


Figure 6.7 – location and terrain of La Palma

6.4 PANGUITCH LAKE, UTAH

Location: N 37 42.942', W 112 38.530'
Elevation: 8222 feet (2506 m)
Lake Area: 1139.2 Acres (4.6 sq km, 1.25 km NS, 3.25 km EW)
Distance to ocean: 410 miles to the west
Estimated sunshine: 3200 hrs/year

Panguitch Lake is in the Dixie National Forest. There is no observatory located at Panguitch Lake. There are a number of summer cabins and resorts, and a general store around the lake which is noted for its fishing. Panguitch can be classified as a continental mountain lake. Figure 6.8 shows a view of Panguitch in winter, and Figure 6.9 shows the location and terrain of the site.

Figure 6.8 **--** A view of Panguitch Lake in the winter when the lake is frozen. The view is from the south shore, looking across the lake to the north shore where the site survey is being conducted.

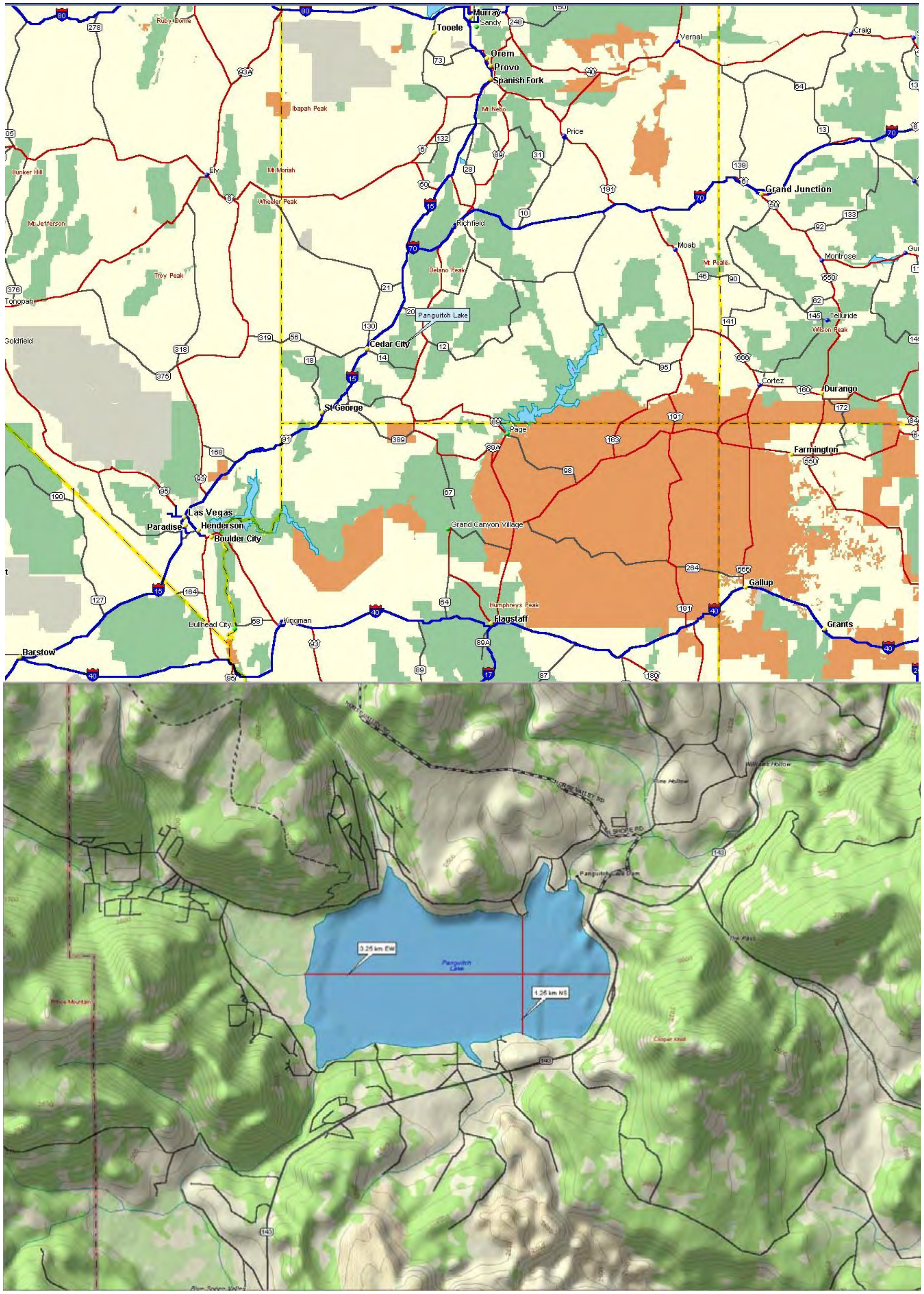


Figure 6.9 – Location and terrain of Panguitch Lake. The location being tested for the ATST is at the top of the vertical line across the lake in the terrain map. North is up.

6.5 SACRAMENTO PEAK, NEW MEXICO

Location: 32° 47' 16" N, 105° 49' 13" W
Elevation: 9255 feet (2847 m)
Lake Area: None
Distance to ocean: 570 miles to the west
Estimated sunshine: 2200 hrs/year

Sacramento Peak is the location of one of the two sites of the National Solar Observatory. The site is classified as a continental mountain. Figure 6.10 shows an aerial view of the observatory. Figure 6.11 shows location and terrain maps.

Figure 6.10 – An aerial view of Sacramento Peak Observatory, NSO.

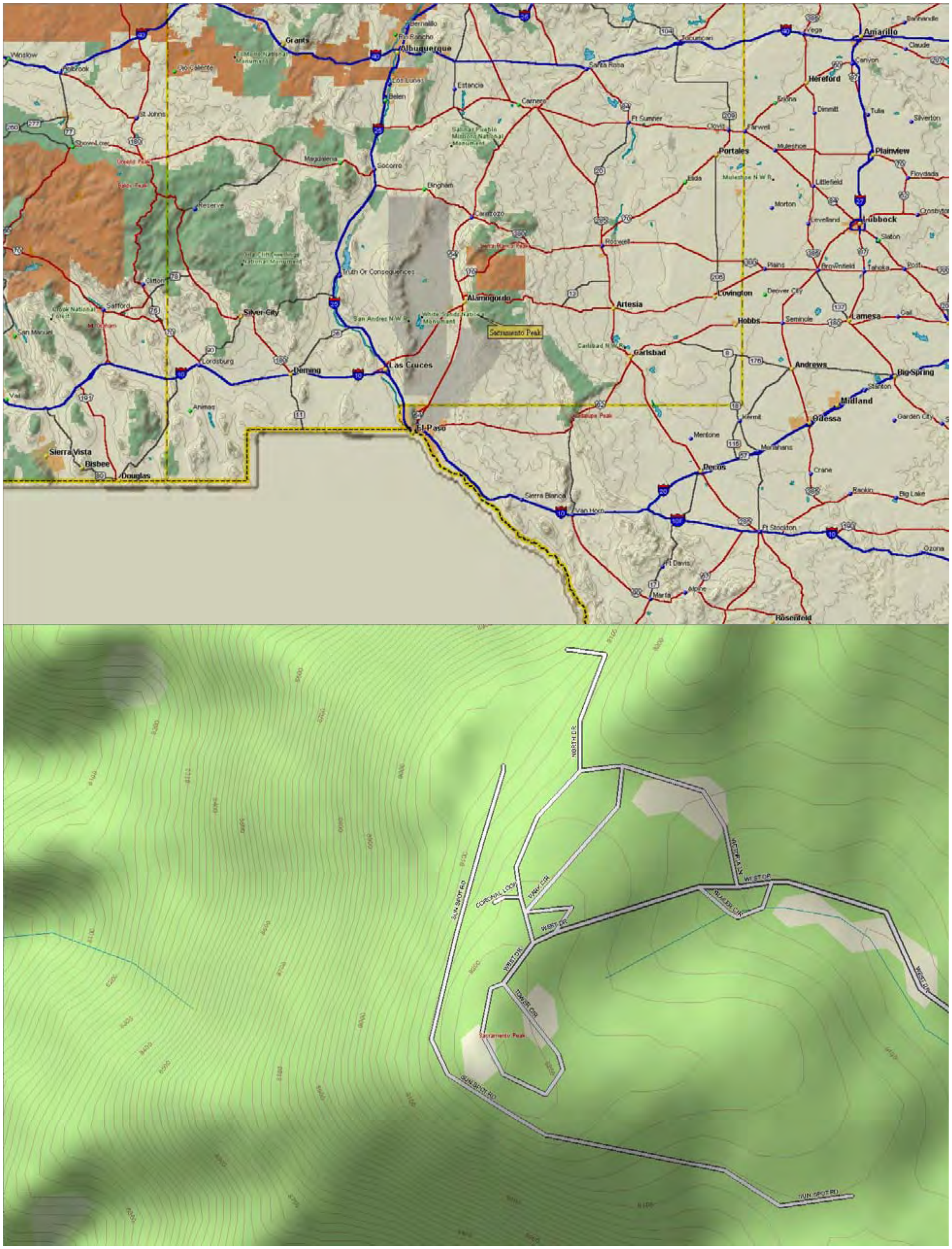


Figure 6.11 – Location and terrain for Sacramento Peak. North is up.

6.6 SAN PEDRO MARTIR, BAJA CALIFORNIA, MEXICO

Location: 31° 02.65' W 115 27.82'
Elevation: 9186 feet (2800 m)
Lake Area: None
Distance to ocean: 61 km to the west (Pacific Ocean), 61 km to the east (Gulf of California)
Estimated sunshine: 2600 hrs/year

San Pedro Martir is located in Baja California Norte, Mexico. It is the site of the Observatorio Astronomico Nacional, operated by the Universidad Nacional Autonoma de Mexico (UNAM). The site is classified as a peninsula. Figure 6.12 shows an aerial view of the observatory, and Figure 6.13 shows location and terrain for the site.

Figure 6.12 – An aerial view of the Observatorio Astronomico Nacional at San Pedro Martir, Mexico

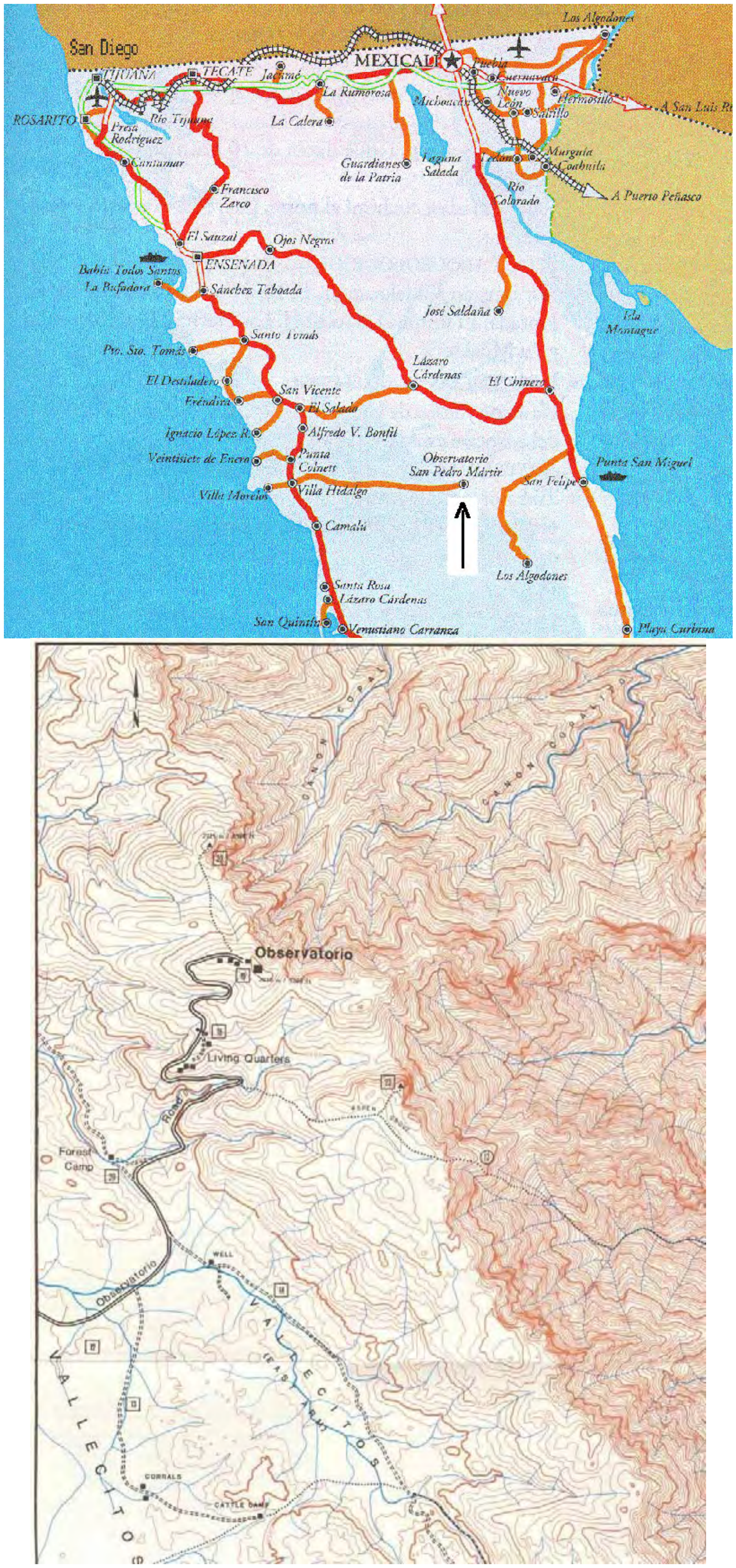


Figure 6.13 – Location and terrain of San Pedro Martir. North is up.

7. HISTORICAL DATA AND LONG TERM TRENDS

Since this survey has only covered a maximum of 2.1 years at any site, it is useful to consider historical data to get a feel for the validity of the short-term results reported here. A thorough analysis of existing data sets remains to be done. As an example of the information in the long-term data sets, Figure 7.1 shows about 15 years of sky brightness data from Haleakala and Sac Peak, obtained with the Evans Sky Photometers. The Sac Peak data shows a strong annual variation, which the ATST survey has not sampled adequately. The Haleakala data does not show a prominent annual variation, but does show the effect of the Mt. Pinatubo eruption with the sky brightness decreasing from 1991 to 1995. Labonte (2003) has published the long-term sky brightness variations. Any long-term trends in the parameters discussed in this report will not be apparent.

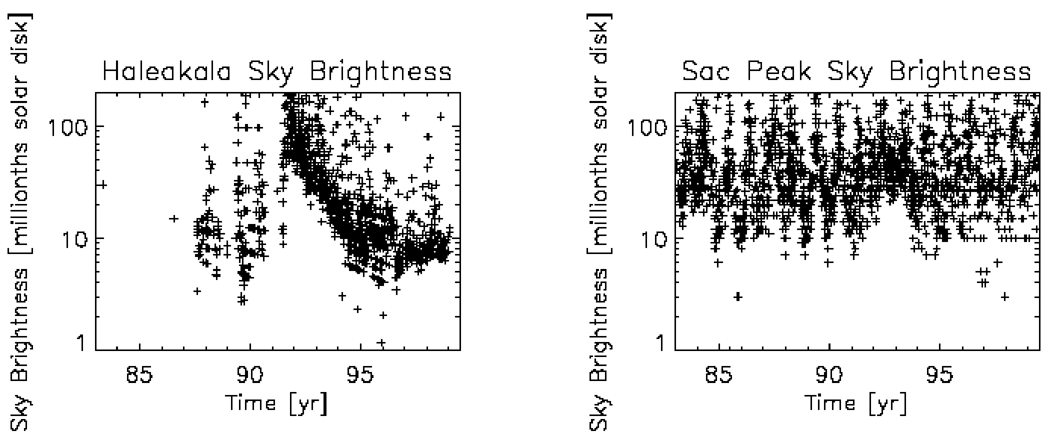


Figure 7.1 – Long-term sky brightness measurements at Haleakla and Sac Peak. The effects of the Mt. Pinatubo eruption are evident in the Haleakala data starting in 1991. From Kuhn et al. (2002)

Other long-term climate patterns of concern are the extended drought in the southwest US, and fluctuations in cloud cover and precipitation associated with El Niño. The current so-called mega drought in the US eliminated Abuquiu Lake from the list of potential sites due to the extremely low level of water in the lake at the start of the survey. Since most lakes in the southwest US are used as reservoirs, keeping the water level up for solar astronomy is not a high priority. Information about annual fluctuations in cloud cover can be found in the GONG site survey results (Hill et al. 1994)

In addition to historical trends in the past, some attempt should be made to anticipate long-term future changes. An example of this is shown in Figure 7.2 which shows two maps of jet aircraft contrails in 1992, and predicted in 2050. This figure shows a marked increase in the coverage of the world by contrails, particularly in the southwest US. The amount of particulates and pollution in the atmosphere cannot be substantially reduced with technology. On the other hand, there is a hope that the continued development of adaptive optics technology will improve the ability to correct for seeing. Thus, clear air may be the most precious resource for solar astronomy.

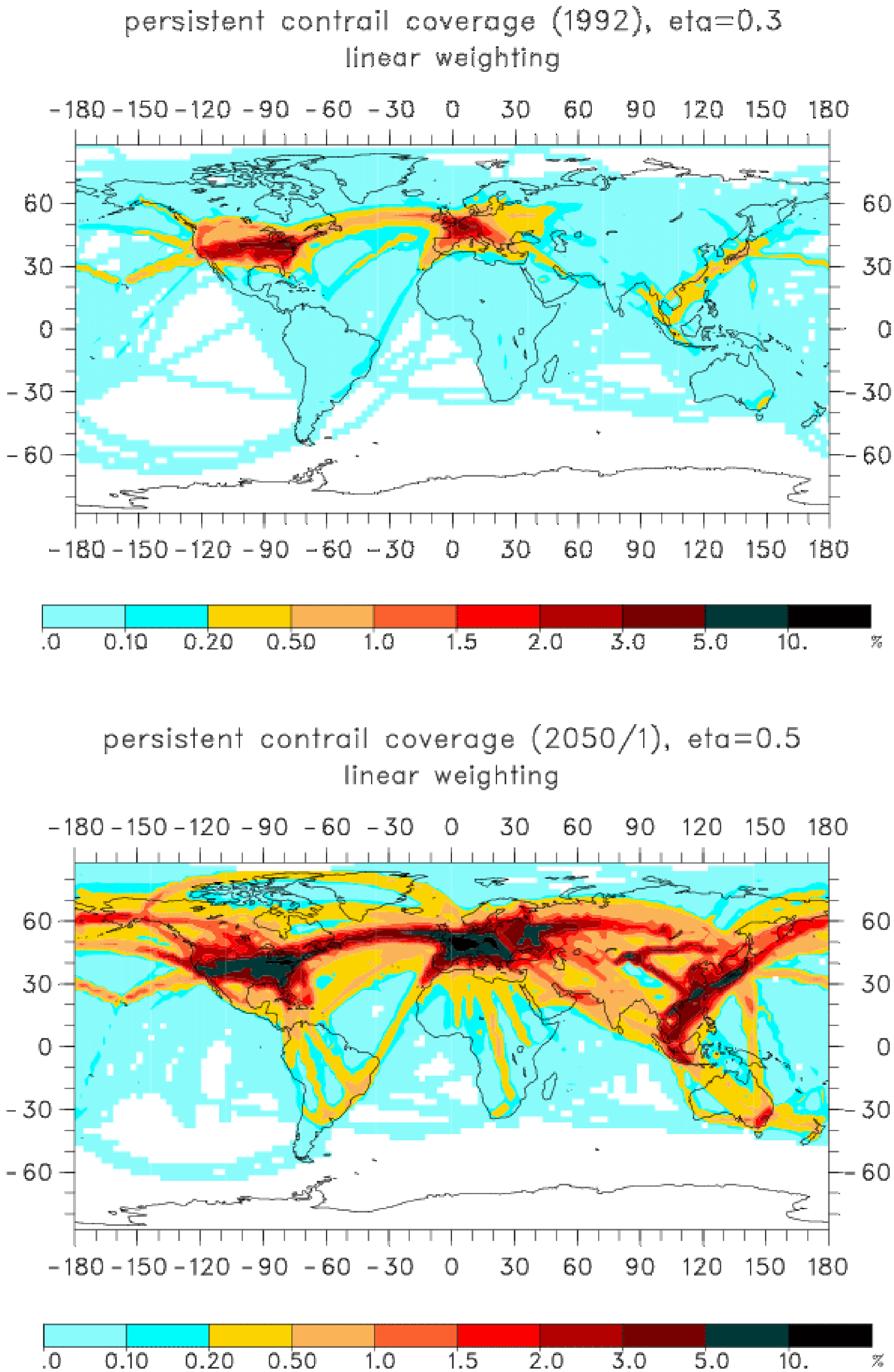


Figure 7.2 – World map of jet aircraft contrails in 1992 (top), and predicted for 2050 (bottom)

8. INSTRUMENTATION AND OPERATIONS

8.1 S-DIMM AND SHABAR

The Solar Differential Image Motion Monitor (S-DIMM) is based on the well-established night time DIMM with the exception that a slit image of the solar limb is used as the target instead of a stellar point source. The instrument was developed by Jacques Beckers, and full details can be found in Appendix 13.01.

The SHABAR (a contraction of the phrase Shadow Band Ranging), is a new instrument developed by Jacques Beckers. It is based on the well-known fact that the localized variations of the index of refraction in the atmosphere produce fluctuations in the intensity of stars. This was extended to the Sun by Seykora (1993), who used a single scintillometer to estimate daytime seeing. Beckers (see Appendix 13.01) realized that an array of scintillometers could be used to estimate the daytime seeing as a function of height. The method has also been applied to night-time observations, using the moon as a source, by Hickson & Lanzetta. Figure 8.1 shows the S-DIMM and the SHABAR detector head mounted on the Meade telescope during a test at Sac Peak.

Figure 8.2 shows the computer screen displayed during the operation of the seeing monitor. On the left is an image of the S-DIMM slits. The relative motion of the ends of the slits is related to the value of the Fried parameter, r_0 integrated over the entire atmosphere. The instantaneous value of r_0 over 10-s intervals is shown as the yellow curve in the upper panel on the right side of the screen. The middle panel on the right side of the screen shows the average intensity as the red curve, and the scintillation as the green curve. The anti-correlation between r_0 and the scintillation can be clearly seen. Finally, the lower panel on the right shows three of the 15 cross-correlation curves between pairs of scintillometers. It is these curves that contain information on the height variation of the seeing.

Figure 8.1 – The ATST seeing monitor. Visible are the two circular apertures for the S-DIMM, the linear array of six scintillometers for the SHABAR, and the Meade telescope.

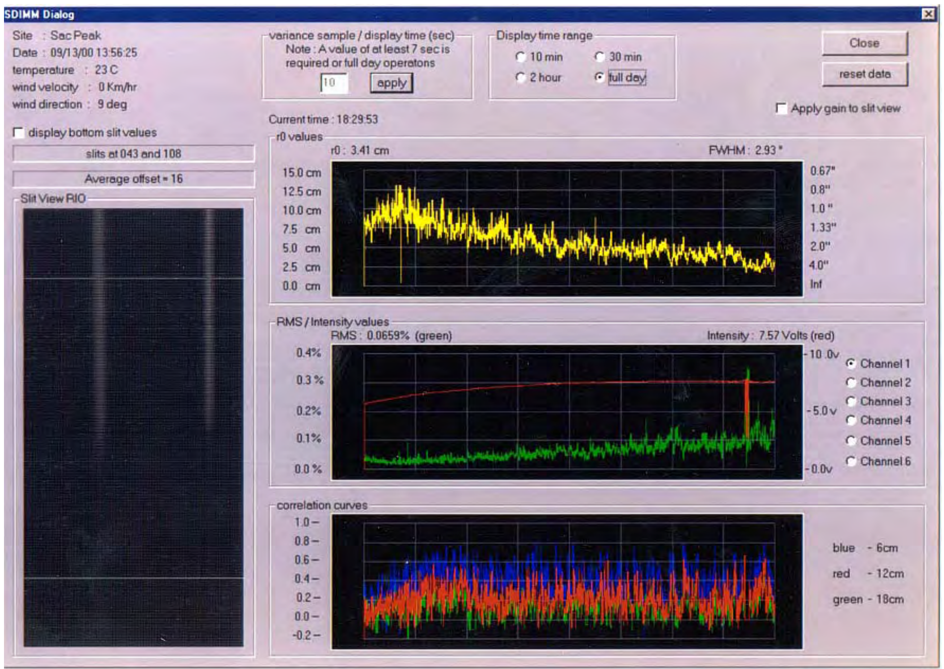


Figure 8.2 – The real-time operations screen of the seeing monitor. Left: images of the S-DIMM slit. Right top: yellow curve shows measurements of r_0 from the S-DIMM. Right center: red curve shows average intensity; green curve shows scintillation. Right bottom: three of the 15 cross-correlation curves.

8.2 SKY BRIGHTNESS MONITOR

The sky brightness monitor was designed by Haosheng Lin at the University of Hawaii, and is described in detail in Appendix 13.6. It essentially is a miniature coronagraph, with a field of view of 2 to 6 solar radii, a CCD, and a filter wheel with bandpasses of 450, 530, 890, and 940 nm. Figure 8.3 shows the instrument under development at Haleakala.

Figure 8.3 – The sky brightness monitor.

8.3 Dust Counter

The dust counter is a Met One model GT-321 handheld aerosol particulate monitor with a sample time of one minute. It counts the particles with a vacuum system to collect 0.1 cubic ft of air, and a laser optical system to count and size the particles as they enter the vacuum orifice. The device is polled by the computer every ten minutes. The device is mounted on the top of the test stand, at a height of 6 m. This places the instrument above the ground where normal daily activities can stir up dust and affect the measurements. A picture of the device is shown in Figure 8.4

In practice, this instrument suffered from severe battery problems. Continual charging of the batteries resulted in their early demise. A strategy of frequent battery replacement instead of charging was adopted, but only a relatively small number of particulate samples were actually obtained.

Figure 8.4 – The Met One GT-321 aerosol particulate monitor

8.4 Weather Station

The weather station provides measurements of wind speed in mph, wind direction in one of 16 directions, maximum wind gust during a sample, relative humidity, barometric pressure, and two temperatures. One of the temperature sensors is placed at the top of the test stand, and the other at the base. This gives a rough measure of the near-ground temperature gradient.

8.5 Test Stand

In order to lift the seeing monitor above the ground boundary layer, the equipment was mounted on a test stand. The height of the test stand platform was specified at 6 m as a compromise between construction costs and the desire to place the monitor at a height that the ATST entrance aperture could be at. With the height of the Meade telescope pier and the telescope itself, the resulting effective height of the seeing measurement is 8 m.

The test stand was designed by John Briggs based on the ideas of Robert Hammerschlag, the designer of the Dutch Open Telescope tower. The ATST site survey test stand is designed such that the movement of the platform at the top of the stand is restricted to be translational in the horizontal plane without any tilting. This allows the S-DIMM to operate in winds up to 23 mph before the slit images do not remain in the measurement area. Figure 8.5 shows the top of the test stand with the seeing monitor. Figure 8.6 shows the test stand installation at each of the six sites.

Figure 8.5 – The top of the test stand with the seeing monitor (right), weather station anemometer (left), and mobile SHABAR unit (center)

Figure 8.6 – The test stand installation at the six sites. Top row, left to right: La Palma, Big Bear, San Pedro. Lower row, left to right: Haleakala, Panguitch, Sacramento Peak

8.6 Technical Staff

- Steve Hegwer – Project manager
- John Briggs – Project engineer
- Larry Wilkins – Electronics engineer
- Mark Komsa – Electrical Engineer
- Ed Leon – Electronics
- Scott Gregory – mechanical design & fabrication
- Robert Rentschler – Civil engineering
- Steve Fletcher – Programmer
- Tony Spence – Electrical Engineer
- Dylan Sexton – Electronics technician

- Panguitch Observer -- Jim Mason, Terry Bender
- La Palma Observer -- Noel D. Torres Taño, Eberhard Besenfelder
- BB observers – Randy Fear, Bill Marquette
- HA observers – Les Hieda, Garry Nitta, Dan Ogara
- SPM observers – Dave Hiriart, Raul Michael
- Sac Peak Observers – John Cornett, Tim Henry

8.7 Deployment and Maintenance History

This section contains a list of the instrument configurations and a list of the major maintenance events during the course of the survey.

8.7.1 Instrument configurations

Local Standard system:
Computer: SDIMM3
SDIMM head: SM2
Meade telescope: 126165
SHABAR amplifier box: #3

Sunspot system on "Menzel Test Stand" (MTS).
Computer: SDIMM2
SDIMM head: SM1
Meade telescope: 126539
SHABAR amplifier box: #6 (later changed)

Panguitch system.
Computer: SDIMM6 (later changed)
SDIMM head: SM6
Meade telescope: 1219
SHABAR amplifier box: #0

Baja system.
Computer: AURA1
SDIMM head: SM3
Meade telescope: 129319
SHABAR amplifier box: #1 (later changed to #7)

Big Bear system (BBSO).
Computer: AURA4
SDIMM head: SM4
Meade telescope: 129320
SHABAR amplifier box: #4

La Palma system.
Computer: SDIMM1
SDIMM head: SM7
Meade telescope: 129317
SHABAR amplifier box: #5

Hawaii system (MSO).
Computer: SDIMM4
SDIMM head: SM5
Meade telescope: 129318
SHABAR amplifier box: #9

8.7.2 Major Instrument Events

March 9, 2002: SDIMM wedge tests at Big Bear; also SDIMM stellar scale observations the evening of March 9-10.

April 4-5, 2002: SDIMM stellar scale observations for the Hawaii system after installation in Hawaii

April 5, 2002: Wedge tests at Hawaii.

July 14, 2002: Simultaneous run with Panguitch system and Local Standard at Evans.

August 28, 2002: Stellar scale measurements conducted after installation at Panguitch.

September 30, 2002: Two runs of stellar scale measurements after installation at La Palma.

October 30, 2002: Hawaii's SDIMM science camera (#366111) dies; unit is serviced at Sunspot using replacement camera #366112.

November 14, 2002: The hard disk crashed on computer AURA1 of the Baja system.

November 16, 2002: Baja system and Local Standard ran together at Evans on this day and also November 19, 20, and 21.

November 21, 2002: Repeat SDIMM stellar scale measurements for the Baja system.

January 14, 2003: SDIMM head returned broken from La Palma. At Sunspot, replaced broken science camera with one recently refurbished by the manufacturer.

January 15, 2003: Afternoon run of La Palma's rebuilt SDIMM unit "SM7" using the Local Standard telescope (#126165) and computer at Evans. Similar runs on Jan. 17 and 21.

January 20, 2003: The computer at Panguitch was changed from SDIMM6 to SDIMM5. SDIMM6, repaired, becomes spare at Sunspot.

February 6, 2003: First data after installation at Baja. SDIMM wedge tests Feb. 7th. Visit cut short by bad weather.

March 21, 2003: Lightning strike at Sunspot killed the photodiode array and SHABAR amplifier box #6. Temporarily moved the diode array from Local Standard to the Sunspot system and began using SHABAR box #8 on the Bridge. Began building a replacement diode array named "MTS2."

April 8, 2003: Recently shielded the ground-level T2 temperature sensor at Sunspot from direct sunlight, to match installations at other sites (except Big Bear, for which the T2 sensor is near the lake water line, but is nonetheless usually exposed).

April 11, 2003: Final tests of the new MTS2 photodiode array at Evans; installation in the Sunspot system was shortly afterwards. The array original to Local Standard was returned to Local Standard at this time.

August 26, 2003: Jim Mason reports camera failure at Panguitch. His SDIMM unit "SM6" is returned to Sunspot. The dead science camera #366899 was replaced with #229117. Mason did SDIMM wedge tests after JWB's reassembly at Panguitch.

October 20, 2003: The Baja SHABAR has been inoperative for some time, likely because of a lightning strike. The SDIMM and Meade were repaired and functional briefly recently, but the Meade has failed in a new way. JWB returns to Baja and replaces the SHABAR and Meade components.

November 2003 The SDIMM, SBM and Shabar instrument operations were terminated at Sac Peak, Panguitch Lake and San Pedro Martir. Most of thehe instruments were returned to Sac Peak. The Panguitch Lake SBM was sent to Haleakala.

Jan 2004 An SDIMM was setup at Erie, Colorado for a cross calibration check with the ATD Sonic Anemometers mounted on the 300 meter tower

March 2004 The Evans Visual Sky Photometers were sent to Big Bear, Haleakala and La Palma to provide a sanity check for the SBM measurements

April 20, 2004 Replaced Wx station at BBSO

April 21, 2004 Replaced La Palma SBM camera and controller

April 21, 2004 Replaced La Palma SDIMM computer

April 27, 2004 Replaced Haleakala Meade controller board

April 2004 The new 2.0 reflective ND filters are installed on the SBMs to replace those with pinhole problems

April 2004 The sonic anemometer/hygrometer/scintillometer system was deployed on a crane at Big Bear for 30 days

June 2004 The sonic anemometer/hygrometer/scintillometer system was deployed on a crane at Haleakala for 30 days

July 8, 2004 Replaced BBSO weather station

July 15, 2004 Replaced La Palma SDIMM computer

August 6, 2004 Replaced Haleakala Meade controller board

8.8 CALIBRATION AND TESTING

8.8.1 Validation tests, Assembly level

8.8.1.1 SHABAR

- Electrical gain measurements for all DC and AC channels; AC bandpass measurement (lower limit), all channels.
- Electrical response tests (2), diagnostic data mode. One sequence with DC input only (output at ~8 v), another with both DC (output at ~8 v) plus AC (output at ~ 10 mv, 50 hz(?)). Same input presented to all channels, at diode end of cable. (LW & RR)
- Correlation test, normal data mode, 2-sec cadence. Inject DC (~8v) and AC (~10mv)into all channels at diode end of cable. Step AC through 50, 100, 250, 500, 750, 1000, 1500, 2000 hz, dwelling about 3 minutes per step. Takes about 1 hour. (JB or LW)
- Optical response tests, diagnostic data mode (10-sec bursts), to characterize pickup, dark current, crosstalk, etc. One sequence with micro-telescopes covered (dark), a second with all micro-telescopes open to sunlight, finally, a series of six, each with only one of the micro-telescopes open, in sequence. Requires clear sky. (JB)
- Common input test. Output from one reference diode, exposed to sunlight, distributed through all inputs of unit under test. (LW & JB)
- Transit scan tests, normal data mode, 2-sec cadence. One scan with bar oriented E-W, another N-S Requires clear sky. (JB)

- Raster scan test, normal data mode, 2-sec cadence E-W & W-E scan pairs, spaced about 1/2 degree in declination, sampling the entire FOV of the microtelescopes. Takes 2-3 hours on Meade mount, labor-intensive, requires clear sky. (JB)
- Cable check. (LW)

8.8.1.2 SDIMM

- Wedge tests.
- Double star separation measurements to determine plate scale.

8.8.2 Validation tests, end-to-end system level

Clear sky throughout.

- Optical response tests, diagnostic data mode (10-sec bursts). One sequence with micro-telescopes covered (dark), a second with all microtelescopes open to sunlight, finally a series of six, each with only one of the telescopes open, in sequence.
- Software tests. Exercise various SOH (state of health) conditions.
- Exercise observing procedure & scripts, including SHABAR and SDIMM diagnostic modes and normal observing mode.

8.8.3 Certification tests

8.8.3.1 DAILY

- SHABAR optical response test, diagnostic data mode. One sequence with all micro-telescopes open to sunlight.
- SDIMM response, diagnostic data mode. One sequence after setup, focus adjustment, etc, completed.

8.8.3.2 MONTHLY (OR AS SPECIFIED)

- Optical response tests (8), diagnostic data mode (10-sec bursts). One sequence with micro-telescopes covered (dark), a second with all micro-telescopes open to sunlight, finally a series of six, each with only one of the telescopes open, in sequence.
- Transit scan test, normal data mode, 2-sec cadence. One scan with bar oriented E-W on the Meade mount.
- Wedge tests.

8.8.4 Results of SHABAR assembly tests and calibration

8.8.4.1 TEST A1

R. Radick & L. Wilkins 30 Nov 01

Summary of SHABAR assembly level test A1: Electrical gain measurements for all DC and AC channels; AC bandpass measurement (lower limit), all channels.

Electrical gain measurements were made on SHABAR boxes #'s 0-9 by L. Wilkins, using a digital meter, and compared with previous measurements made by E. Leon. Box #3 was remeasured three times, and two digital diagnostic files were also recorded by computer for that box. One of these two files (… 011116 165637) was compared in detail to its corresponding manual file.

1. The four manual measurements for box #3 show very high repeatability (rms distance 8.7 ppm, or about 0.1%) in the DC/AC gain ratios. The comparison between the digital and manual measurements showed differences that averaged less than 0.03% (!).

2. The Wilkins and Leon measurements were compared by computing percentage differences, rms distances and correlation coefficients. In general, the agreement was poorer than for the repeat measurements on the same box (#3) by a factor of 5x or so, even in the best cases. Some of the discrepancies may have arisen when some of the amplifiers were changed, which happened at some point between the two sets of gain measurements. Overall, the agreement seems satisfactory for box #'s 0,1,2,4,5,6,and 8 It appears that boxes 3 and 7 may have been interchanged at some time between the two sets of gain measurements

3. Recommend updating gain ratios as shown in Table 8.1. The values are those measured by Wilkins except for box #3, which is the average of the four manual measurements plus the one diagnostic file analyzed.

Table 8.1 – Preliminary AC/DC gain ratios for the SHABAR arrays

	Chan 0	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5
Box 0	0.009313	0.009625	0.009775	0.009985	0.009104	0.009958
Box 1	0.009453	0.009947	0.009479	0.009751	0.009401	0.009541
Box 2	0.009784	0.009373	0.009965	0.009656	0.009305	0.009588
Box 3	0.009562	0.009445	0.009431	0.009387	0.009382	0.009453
Box 4	0.009682	0.010151	0.009568	0.009484	0.009511	0.009548
Box 5	0.009307	0.009343	0.009477	0.009443	0.009149	0.009487
Box 6	0.009332	0.009555	0.009196	0.009417	0.009410	0.009316
Box 7	0.009957	0.009788	0.009518	0.009174	0.009582	0.009316
Box 8	0.009340	0.009429	0.009564	0.009468	0.009404	0.009435
Box 9	0.009632	0.009435	0.009121	0.009621	0.009502	0.009658

4. Bandpass measurements showed no anomalies.

Addendum - R. Radick & L. Wilkins - 03 Jan 02

After modification of unit #8, as described in test report A2, the gains for that unit were re-measured. The updated gain table is shown below (new values for Box 8 highlighted in **boldface)**:

Table 8.2 – Final AC/DC gain ratios for the SHABAR arrays

	Chan 0	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5
Box 0	0.009313	0.009625	0.009775	0.009985	0.009104	0.009958
Box 1	0.009453	0.009947	0.009479	0.009751	0.009401	0.009541
Box 2	0.009784	0.009373	0.009965	0.009656	0.009305	0.009588
Box 3	0.009562	0.009445	0.009431	0.009387	0.009382	0.009453
Box 4	0.009682	0.010151	0.009568	0.009484	0.009511	0.009548
Box 5	0.009307	0.009343	0.009477	0.009443	0.009149	0.009487
Box 6	0.009332	0.009555	0.009196	0.009417	0.009410	0.009316
Box 7	0.009957	0.009788	0.009518	0.009174	0.009582	0.009316
Box 8	**0.009616**	**0.009418**	**0.009117**	**0.009620**	**0.009487**	**0.009654**
Box 9	0.009632	0.009435	0.009121	0.009621	0.009502	0.009658

8.8.4.2 TEST A2

R. Radick & L. Wilkins -- 18 Dec 01

Summary of SHABAR assembly level test A2: Electrical response tests (2), diagnostic data mode. One sequence with DC input only (input set to create a ~8 to 9 V output on the DC outputs), another with both

DC input (input again set to create a ~8 to 9 V output on the DC outputs) plus AC (input set to create ~ ± 8 to 9 V, or roughly 6 V rms, on the AC outputs, at ~50 hz). With the gain setting we have chosen, and with the resistor values we are using to split up the signal, this requires 7 VDC and .040 VAC rms. Same input presented to all channels, at diode end of cable.

Electrical response measurements were made on SHABAR units 0-9 by L. Wilkins, using signal generators to supply the inputs and recording the digitized data using the SHABAR diagnostic data application (acdc data file …). Evaluation of test data was performed by R. Radick

1. The first series of tests indicated the presence of spiky pickup at the level of about 100 mv pk to pk (~0.5%) in all AC outputs of all units. Further analysis indicated that this was not 60 Hz pickup - the indicated frequency was, if anything, around 20 Hz. Further investigation showed that the sensor cable shield, attached to chassis ground, was coupling power supply noise to the AC outputs, which were referenced to a separate ground. To correct this, the two grounds were made common at the SHABAR box.

2. Retest indicated that the pickup problem had been eliminated – no artifacts were observed at a level exceeding 0.1%, except for unit #8, which showed 90-100 Hz noise present in several AC output channels, ranging up to 200 mv pk to pk (~1%) in one channel. Investigation showed that capacitors involving the input amplifier, which had been changed for the other units, had not been changed for this unit.

3. After modification, retest of unit #8 showed no DC or AC output anomalies.

4. At present, none of the units show DC or AC output anomalies at levels exceeding 0.1%, and units 8 and 9 appear to be particularly well-behaved. Gain measurements (test A1) will be repeated for the modified unit #8.

8.8.4.3 TEST A3

R. Radick & L. Wilkins -- 04 Jan 01

Summary of SHABAR assembly level test A3: Correlation test, normal data mode, 10-sec cadence. Inject DC and AC into all channels at diode end of cable, with inputs set to create 8-9 V outputs, both DC and AC. Step through 50, 100, 250, 500, 750, 1000, 1500, 2000 Hz, dwelling about 3 minutes per step.

Measurements were made on SHABAR boxes #'s 0-9 by L. Wilkins. Evaluation of the test data was performed by R. Radick.

1. Background: Last summer, test measurements performed by P. Jibbons showed that the AC correlation between SHABAR output channel pairs, when driven by nominally identical electrical inputs, was significantly less than the expected value of unity. Further test measurements showed that the degradation increased with the frequency of the input and with the time interval between the A/D samples, ranging from as much as 1% at 100 Hz to as much as 20% at 500 Hz. The worst pairs showed anticorrelation above about 1200 Hz. This behavior was attributed to delays associated with polling the A/D, which was done in an interrupt-driven mode, roughly 330 times per second with about 26 μsec between sequential A/D channel reads. To remedy this, the software was rewritten to poll the A/D in burst mode, which captures 14x10000 samples over 10 seconds, with about 4 μsec between sequential A/D channel reads. This alleviated the problem substantially – retest of one unit showed the degradation had been reduced to about 0.1%, at worst, at 100 Hz, and about 0.3%, at worst, at 500 Hz.

2. Subsequent modifications to the circuitry to reduce settle time appear to have alleviated the problem even further, especially at the low frequencies that are of greatest concern for measuring solar scintillation. The degradation now appears to be 0.01% or less, at worst, at 100 Hz, and 0.2% or less, at worst, at 500 Hz. It was discovered, however, that the progression of the degradation does not always follow the expected sequence, in the sense that the correlation between two channels (0 and 4, say) might be closer to the expected value of unity than that for two channels (0 and 3, say) sampled more closely in temporal sequence. This behavior was found in units 0, 2, 4, 6, 7, and 8, but not the others. We suspect it may have to do with variations in the lag intrinsic to the circuit, but also conclude that it does not merit further attention at this time.

3. The following table list representative results of the measurements for 100, 250, and 2000 Hz. Degradation is the reduction of the correlation coefficient below the expected value of unity, in percent, for the worst pair of channels, generally (0,5). Order is the progression of the degradation in channel pairs (0,1), (0,2), (0,3), (0,4), and (0,5) = (1,2,3,4,5) – the expected sequence is 12345. An “x” indicates presence of at least one deviation from the expected order.

8.8.5 S-DIMM Plate Scale Measurements

In order to calibrate the S-DIMM measurements from limb displacements to r_0 in cm, it is necessary to know the plate scale of the S-DIMM in arcsec per pixel. This was done by repeatedly observing double stars with well-known separations through the S-DIMM optical system. The analysis of this data provides table 8.3 of S-DIMM plate scales.

Table 8.3 – S-DIMM Plate Scale Measurements

Site	System (Telescope + SDIMM Head)	Measurement 1 (Arcsec/pixel)	Measurement 2 (Arcsec/pixel)	Measurement 3 (Arcsec/pixel)	Measurement 4 (Arcsec/pixel)
Local Standard	165+SM2	0.428 ± 0.022	0.445 ± 0.003	0.435 ± 0.003	0.441 ± 0.003
Haleakala	318+SM5	0.422 ± 0.003	0.445 ± 0.003	---	---
San Pedro	319+SM3	0.447 ± 0.004	0.433 ± 0.005	0.439 ± 0.003	---
Big Bear	320+SM4	0.458 ± 0.004	0.458 ± 0.003	0.426 ± 0.003	0.442 ± 0.003
Sac Peak	539+SM1	0.421 ± 0.004	---	---	---
La Palma	317+SM7	0.407 ± 0.004	0.453 ± 0.005	---	---
Panguitch	994+SM6	0.429 ± 0.004	---	---	---

The mean and standard deviation of all measurements is 0.437 ± 0.014, with a peak-to-peak variation of 12.5% and an expected variation of 3.2%. The peak-to-peak variations and scatter in the measurements are probably due primarily to temperature variations during the nights when the observations were obtained. However, the overall variation between instruments is better estimated by the expected variation of 3.2%.

9. DATA REDUCTION

9.1 INGEST

The data arrives in Tucson on a CD which typically contains 1 to 8 weeks of seeing data. SBM data also arrives on CDs which are usually separate from the seeing CDs. The seeing CDs are copied onto a Sun workstation and file name problems resulting from Windows naming conventions are resolved by opening every file and constructing a new file name from information in the header. Quick-look plots which display every quantity are generated. An example of one of these plots is shown in Appendix 13.9.

9.2 DATA CULLING AND FLAGS

The data files contain a state of health flag whose bits are set to indicate various problems with the instrument as listed in Table 9.1.

Table 9.1 – Data flags

Flag Value	Event
0	Good data
1	Failed video
2	Failed Meade
4	Failed Weather station
8	Failed SHABAR
16	Non-zero rail count (high wind)
32	Observing log entry

Simultaneous events add numerically, i.e. If the weather station and the SHABAR have both failed, then the flag value is 12. Of these flags, the most commonly occurring in the data are 2 and 8. The 2 flag (FAILED MEADE) is associated with a timeout condition when the S-DIMM software is attempting to read the Meade's right ascension position during Meade communication port initialization or if the read of the Mead's right ascension was not completed during normal operations. The intent of the flag is to identify periods of possible RA drift. If this flag is set just once it remains set throughout the data run. Data obtained with only the flag 2 set is still valid since a read of the RA position of the telescope will not affect the data. The 8 flag (FAILED SHABAR) indicates that the average value of a DC channel over a 10 second sample period differs by greater than 30% from the average value of any other DC channel over the same 10 second sample. This condition occurs almost exclusively when there is no light reaching the SHABAR detectors. In virtually all cases this means that the seeing instrument is stowed but still powered on to collect weather data. The 16 flag (NONZERO RAIL COUNT) indicates that the slit images of the S-DIMM have moved outside the designated measurement area. This happens when a high wind occurs, typically greater than 10 m/s. The existence of these flags is checked in the course of the processing and data is discarded on the basis of these values. In particular, the presence of the 8 or 10 flag, as well as a zero reading from the S-DIMM, is commonly present when the S-DIMM/SHABAR is shut down but the weather station is running.

9.3 SHABAR/S-DIMM ANALYSIS

The data analysis to estimate $r_0(h)$ proved to be challenging. It essentially comprises the fitting of the observed scintillation cross-covariances as a function of detector separation with a model of the structure function, $C_n^2(h)$, composed of weighting functions derived from the theory of atmospheric turbulence. In addition, the integral of the model over the atmosphere is required to fit the observed S-DIMM value of r_0. Since the release of the interim report, a considerable amount of effort has gone into understanding and improving this analysis. Several verification tests have been performed -- simulations, comparisons between simultaneous SHABAR/S-DIMM r_0 estimates at different heights, comparison between completely different methods of estimating r_0 and, most recently, comparison with in-situ measurements of $C_n^2(h)$. In all cases the analysis provides a reasonable estimate of $r_0(h)$ up to 50 m in height.

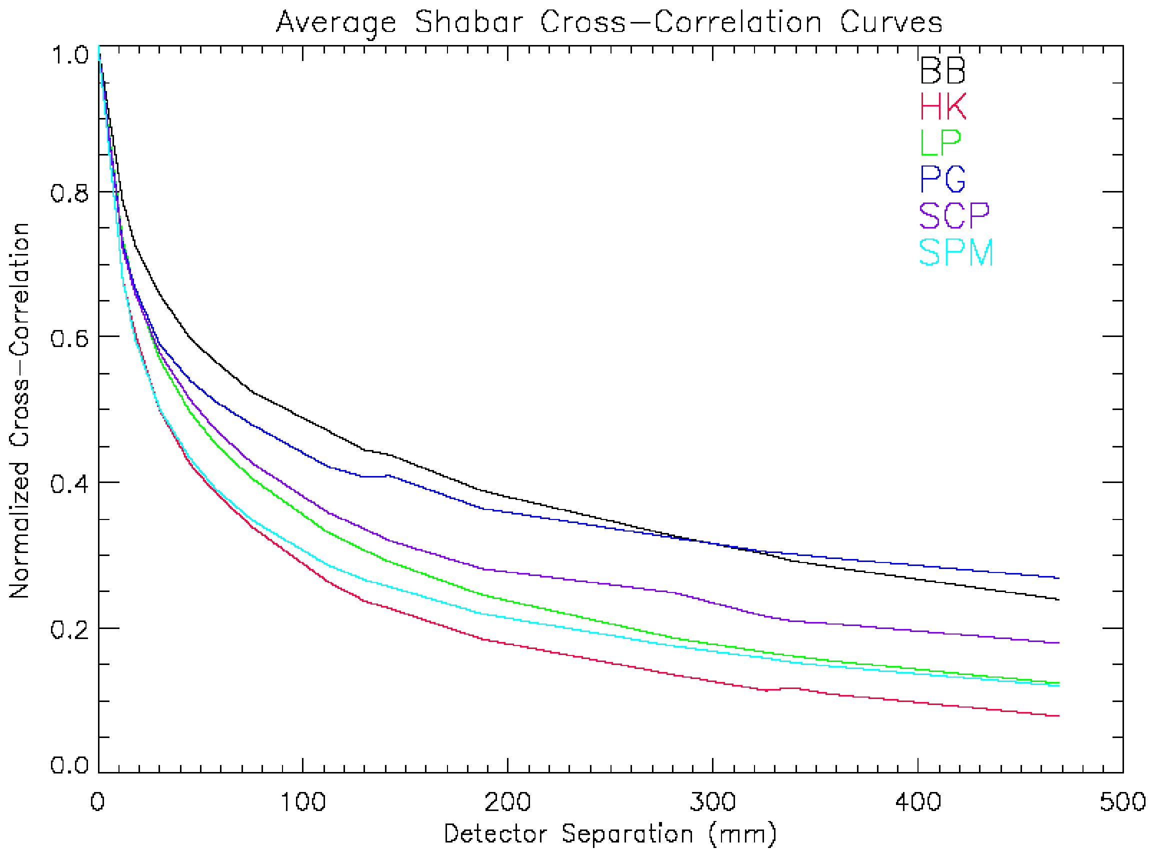


Figure 9.1 – The average cross-correlation curves for the sites as of October 2003. The two lake sites, Big Bear (BB) and Panguitch (PG), have relatively shallow curves as a function of detector separation which indicates that the seeing arises from a region far above the instrument. The four non-lake sites have a relatively steeper cross-correlation as a function of separation, indicating a boundary layer near the telescope.

As an illustration of the method, Figure 9.1 shows the average observed normalized cross-correlation (not cross-covariance) for each of the six sites. The cross-correlation, normalized by the observed scintillation, ranges in value from +1 (complete correlation, achieved with the correlation of a detector with itself), to -1 (complete anticorrelation). The theory shows that cross-correlation curves are more sharply curved when the seeing is close to the detector, and less so when the seeing is far away. This behavior can be seen in Figure 9.1.

To estimate the physical magnitude of $C_n^2(h)$, the cross-covariances with the scintillation measurements must be used. Thus, the observed cross-correlation functions must be rescaled by the observed scintillation to produce the cross-covariance functions that are then fitted by the model. Ideally, all of the detectors would be exactly similar in their response to intensity fluctuations and the rescaling factor for each detector pair would be the square root of the product of the scintillation measured by each detector in the pair. In practice there are gain variations as discussed in section 8.8.4. Thus, the rescaling factor is the average scintillation observed by all six detectors during the sample interval.

The details of the theoretical foundations and some tests of the method are contained in the appendices (13.2, 13.3, and 13.10). Since the interim report, we have implemented two independent algorithms to perform the analysis. Here we present the details of the two methods, discuss some of the caveats of the method and illustrate some additional tests of the reliability of the results.

9.3.1 The Inversion Methods

The two methods were developed by Manuel Collados (the IAC method), and Hector Socas-Navarro (the HAO method.) They both perform a fit of a model $C_n^2(h)$ to the observed cross-covariances $B_I(d)$, which are the cross-correlations seen in Fig. 9.1 normalized by the observed scintillation and *d* is one of the 15 possible detector separations. In addition to these values, the models must also fit r_0 (or $r_0^{-5/3}$) as measured by the S-DIMM, and the observed total scintillation *s*. The methods differ in the details of the fitting procedure, pre-treatment of the data, and the inclusion of the high-altitude seeing which is not sampled by the SHABAR but substantially affects the S-DIMM measurement.

9.3.1.1 IAC METHOD

Before proceeding with the inversion, the data is processed thusly:

1. The median of the six measured scintillation values is taken as *s* at each sample. The median is used, instead of the mean, as sometimes individual detectors show anomalously large values due to flying dust or insects during the integration time.
2. A 31-point running mean is applied to the temporal variation of each parameter, corresponding to a five-minute average. This reduces the larger fluctuations in the parameters caused by turbulence. Note that the output number of points is the same as the input, except for the first and last 2.5 minutes. These two intervals are discarded and not used in the analysis. All points with an instantaneous S-DIMM r_0 = 0, or a SHABAR flag equal to 8 or 10 are not included in the average. A minimum of five points in every five-minute interval is required. Otherwise, the interval is rejected and not analyzed.
3. The zenith angle *z* of the sun at each moment is computed. The only input required here is the Universal Time and geographical coordinates of the site. The zenith angle is needed to compute the kernel functions for a particular time

The cross-covariance $B_I(d)$ between the normalized intensity fluctuations measured by two detectors separated by a distance *d* and observing the entire solar disk is given by the equation

$$B_I(d) = \int_0^\infty W(h,d) C_n^2(h) dh. \qquad (9.1)$$

The scintillation *s* follows the same equation with *d*=0. Figure 9.2 shows the weighting functions or kernels *W(h,d)* for the scintillation and the 15 baselines between the six SHABAR detectors as a function of height up to 10 km. Details of the calculation of *W(h,d)* can be found in Appendix 13.2.

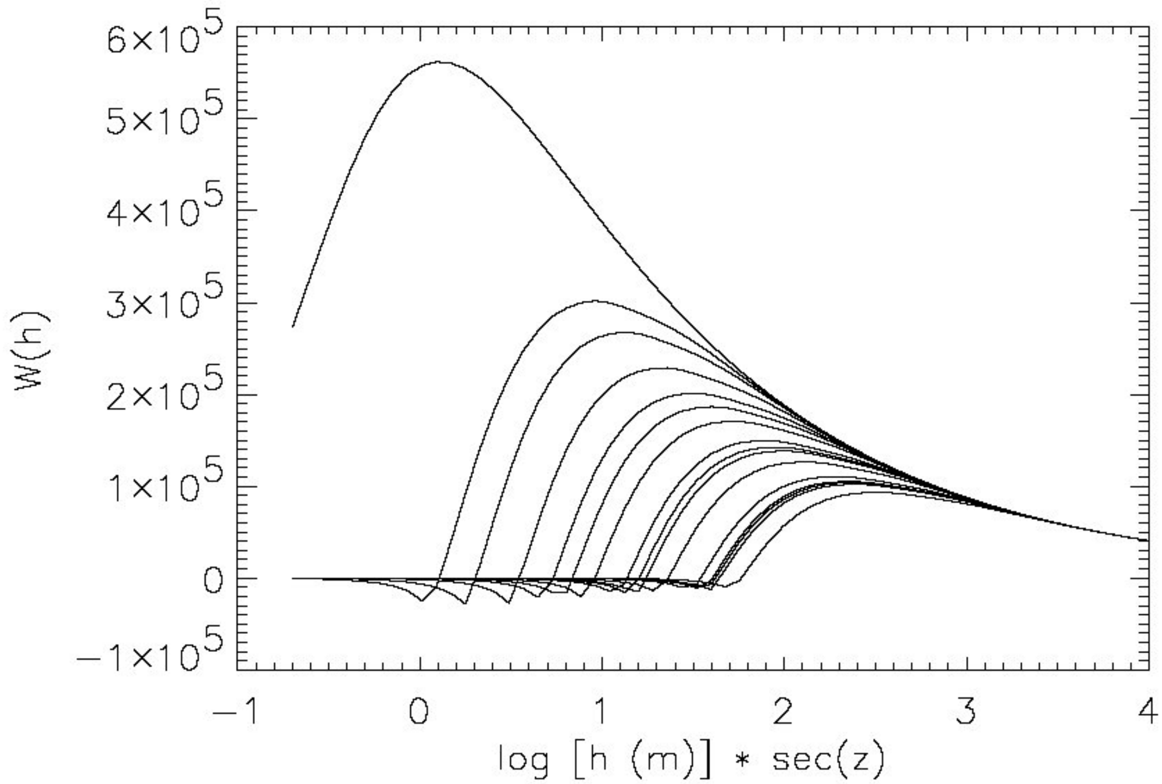


Figure 9.2 – Height dependence of the weighting function *W(h,d)* for the scintillation and the fifteen values of *d* available in the SHABAR. The upper and lower curves correspond, respectively, to the smallest and largest separations (0 and 468 mm). *z* is the solar zenith angle.

The Fried parameter is given by

$$r_0^{-5/3} = C \sec(z) \int_0^{\infty} C_n^2(h) dh, \tag{9.2}$$

where C is a constant.

The procedure for determining $C_n^2(h)$ is as follows:

1) Define N reference heights (nodes) h_i , $i = 1, \ldots, N$ at which C_n^2 will be estimated. The first node is located 20 cm above the instrument, the second 1 meter, and the remaining are equidistant in the logarithm of the height up to a maximum value defined by the user. For the ATST site survey, N=68 and the maximum height is 40 km. This location of the nodes proved to be efficient during the testing of the method.

2) Evaluate the interpolation coefficients that allow the determination of $C_n^2(h)$ at any height h from the values at the nodes. A linear interpolation in a (log(h), C_n^2) grid is used.

3) Compute the weighting functions $W_{node}(h_i, d_j)$ for nodes $i = 1, \ldots, N$ and detector separations r_j, $j = 1, \ldots, 16$. Then the equations relating the observables and $C_n^2(h)$ can be written as

$$B_I(d_j) = \sum_{i=1}^{N} W_{node}(h_i, r_j) C_n^2(h_i), \tag{9.3}$$

and

$$r_0^{-5/3} = \sum_{i=1}^{N} W_{node}^{r_0}(h_i) C_n^2(h_i). \tag{9.4}$$

Here, the weighting function W for r_0 is simply the constant C sec z [MANOLO – is this right?]

4) To ensure that $C_n^2(h_i)$ is always positive, it is replaced by exp [$y(h_i)$]. Then any positive or negative value of y will produce a positive value of $C_n^2(h_i)$.

5) A standard non-linear least-squares technique is used to obtain the values of $C_n^2(h_i)$ that minimize the χ^2 of the fit, with

$$\chi^2 = \sum_{i=1}^{17} \left(\frac{x_i^{obs} - x_i^{synth}}{\sigma_i} \right)^2, \tag{9.5}$$

where the vectors x_i^{obs} and x_i^{synth} , i = 1, …, 17, are constructed from the observed and modeled values of the 15 cross-covariances plus the scintillation and r_0. The values σ_i are the standard deviations of the observed quantities during the time interval being considered.

In practice, it turned out that a significant number of points could not be successfully inverted because the observed scintillation and cross-covariances were too small to be consistent with the observed r_0. To account for this "missing scintillation", a new parameter, Δs, was added to the observed scintillation and cross-covariances. This changes Eq. 9.3 to

$$B_I(d_j) + \Delta s = \sum_{i=1}^{N} W_{node}(h_i, r_j) C_n^2(h_i). \tag{9.6}$$

Equation 9.4 is unchanged.

With this addition, the minimization procedure is the same as before, with a constant value of Δs. Starting with Δs = 0, the stratification of $C_n^2(h)$ and the corresponding values of r_0 , s, and $B_I(d)$ are computed. If the modeled value of r_0 is larger than the observed value by more than one percent, then the value of Δs is increased by a given value and the procedure repeated until convergence between the model and observed values of r_0 is reached. The value of Δs is not allowed to be negative. If the modeled value of r_0 is less than the observed value for $\Delta s = 0$, the result is considered to be valid. The maximum allowed value of Δs is three times the observed scintillation. If this maximum is reached during the iteration, the point is rejected as invalid.

The fact that Δs is a constant added to both the observed scintillation and all of the cross-covariances implies that it somehow arises from high-altitude layers. This is evident from Figure 9.2, which shows that all of the kernels are identical above a height of about 1 km. However, the physical meaning of Δs is still obscure. Its presence implies that a source of image degradation, not producing scintillation, is required. One possible explanation is the existence of a finite outer turbulence scale. Turbulence can be thought of as being composed of cells of all sizes. Large eddies will produce corresponding large-scale wavefront distortions, while small eddies will produce small-scale distortions. The S-DIMM will respond to large-scale distortions with high values of r_0, and small-scale distortions with low r_0 values. In addition, the S-DIMM is most sensitive to small eddies due to the -5/3 exponent in Equation 9.2. On the other hand, scintillometers average phase fluctuations over a large area that increases with altitude. This spatial averaging will decrease the effects of small eddies and increase the sensitivity of the scintllometers to large-scale turbulence. With this scenario, the missing scintillation arises from a lack of large-scale eddies, i.e. a finite outer scale. The lack of the large eddies will not affect the S-DIMM measurements. The inclusion of Δs in the analysis produces a $C_n^2(h)$ profile consistent with the observed r_0 and a scintillation value that would have been measured if all scales of turbulence (up to infinitely large) had been present.

An alternative explanation for the need to include a missing scintillation term is as follows. The scintillation s is related to $C_n^2(h)$ by $s \propto \int h^{-1/3} C_n^2(h) dh$ and r_0 is related by $r_0 \propto \left[\int C_n^2(h) dh\right]^{3/5}$. Thus, the value of s is weighted towards low-altitude seeing and is less sensitive to high-altitude seeing, while r_0 is an unweighted integral. Thus, if the turbulence is located primarily at high elevations, then the value of s could be apparently inconsistent with r_0. If this is the case, then more missing scintillation should be needed for successful fits at sites where there is little or no near-ground turbulent boundary layer. Figure 9.3 shows the distribution of the missing scintillation at the three sites. This plot clearly shows that the site with the most "missing scintillation" is Big Bear. This site is at a lake, which presumably substantially reduces the turbulence at low altitudes.

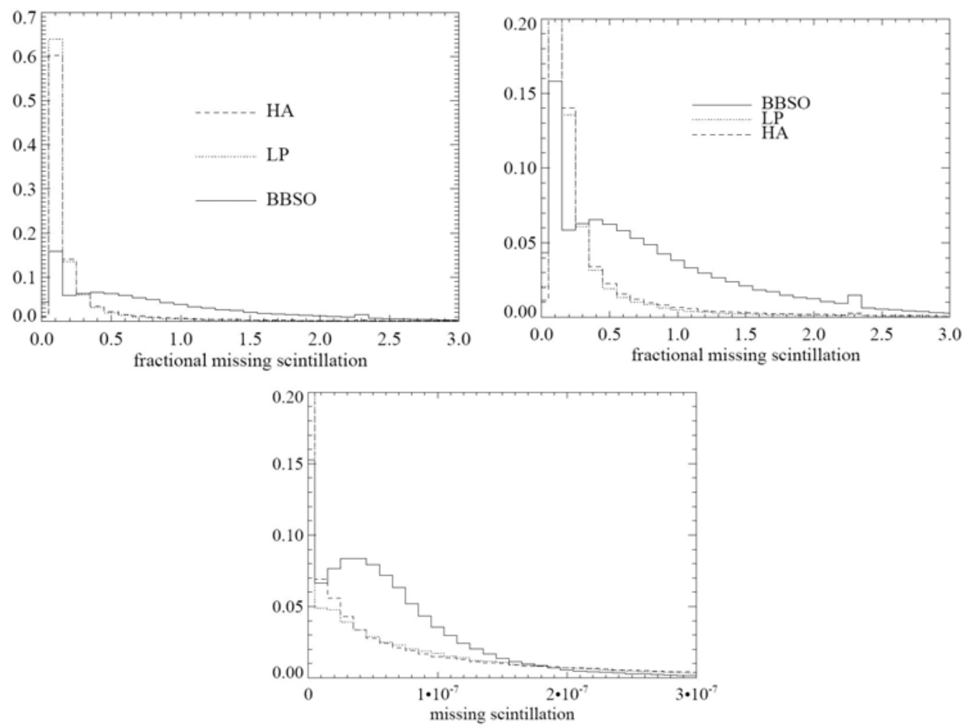


Figure 9.3: Histograms of the relative frequency of occurrence of "missing scintillation" Δs values at the three sites. Top two panels: relative occurrence of Δs as a fraction of the observed scintillation; left: entire distribution; right: zoom of lower portion. Bottom panel: relative occurrence of Δs as an absolute scintillation measure. Solid line: Big Bear; Dashed line: Haleakala; Dotted line; La Palma. Note that the two mountain sites (La Palma and Haleakala) typically require 10-20% fractional Δs while the lake site (Big Bear) frequently needs a substantially larger value.

9.3.1.2 HAO METHOD

This inversion code performs an iterative least-squares fit to the measured B_I. The fitting procedure is based on the Levenberg-Marquardt algorithm combined with Singular Value Decomposition (Press et al 1986) of the covariance matrix.

The SHABAR data are block-averaged in 5-minute intervals before the inversion. The SDIMM r_0 values are averaged in the same way, but taking into account the -5/3 exponent (see Eq. 9.9). During this step the presence of thin clouds is identified by looking for sign changes in the derivative of the intensity measured by the instrument. When this derivative changes sign two or more times within a 5-minute period, the entire block is flagged as cloudy. These points are considered as bad weather and the inferred r_0 *(h)* is set to zero for all heights.

The set of free parameters is a vector containing the values of C_n^2 at each height plus two other parameters, B_I^{high} and α, that account for high-altitude seeing. We start with a guess model that has 49 points equi-spaced in log*(h)* from -0.7 to 3.1. The values of C_n^2 in this model are used to compute synthetic B_I according to Eq. 9.7. The integral in that equation is only evaluated from the model C_n^2 up to its maximum height H_m (approximately 1000 meters). The rest of the integral represents the high-altitude turbulence, and is retrieved by the inversion as a free parameter B_I^{high}:

$$B_I(d) = \int_0^{H_m} W(h,d) C_n^2(h) dh + B_I^{high} \qquad (9.7)$$

with

$$B_I^{high} = \int_{H_m}^{\infty} W(h,d) C_n^2(h) dh \qquad (9.8)$$

Notice that the high altitude contribution to r_0 has an important difference with respect to Eq. 9.8, namely the absence of the kernel function *W(h,d)*. Since the kernel is height dependent, it is not possible to convert B_I^{high} to an equivalent contribution to r_0 *(h)*. We thus introduced an additional free parameter α so that:

$$r_0^{-5/3} = C \sec z \left(\int_0^{H_m} C_n^2(h) dh + \alpha B_I^{high} \right) \qquad (9.9)$$

The integrals from h = 0 to $h = H_m$ that appear in Eqs. 9.7 and 9.9 are solved with parabolic accuracy using the following scheme. Let x_1, x_2, and x_3 represent log*(h)* at three successive grid-points. We assume that the kernel varies as a parabola: $W = w_1 x^2 + w_2 x + w_3$ for $x_1 \le x \le x_3$.

The function C_n^2, on the other hand, exhibits an exponential variation with log*(h)*: $C_n^2 = 10^{(ax^2+bx+c)}$. This scheme requires some tedious algebra (details are provided in Appendix 13.3), but has the advantage of improved accuracy for a given height discretization.

The derivatives of B_I with respect to C_n^2 that enter the minimization algorithm are computed numerically by perturbing slightly the model atmosphere at each grid point. A standard regularization method is applied so that the algorithm has a preference for smooth models whenever possible. Several tests were carried out with a small subsample (May 2003 for the three candidate sites) varying the regularization parameter. We picked the largest value that yielded a satisfactory fit to the data.

In order to ensure that the inversion algorithm is robust and avoids secondary minima we use a multiple initialization strategy. For each observation we perform at least 5 different inversions with different initializations. The solution corresponding to the best fit (lowest χ^2) is selected. If the fits obtained from the best solution are still not satisfactory, the code attempts up to 10 different inversions with random initializations.

9.3.2 Verification Tests

A number of tests have been performed to verify the technique. These tests are comparison of the two inversion methods, and comparison of the inversion results with in-situ measurements of C_n^2 at a number of sites. These tests supplement the simulations and multiple height comparisons that were described in the interim report.

The results of the comparison between the two inversion methods are summarized in Figure 9.4. This figure shows the cumulative distribution of the estimated r_0 at the three sites and at five heights, as derived from the HAO method (solid line) and the IAC method (dashed line). The agreement is quite good. There are discrepancies that appear at higher heights, where the SHABAR sensitivity is decreasing. This effect is also seen in the ATST/in-situ comparison.

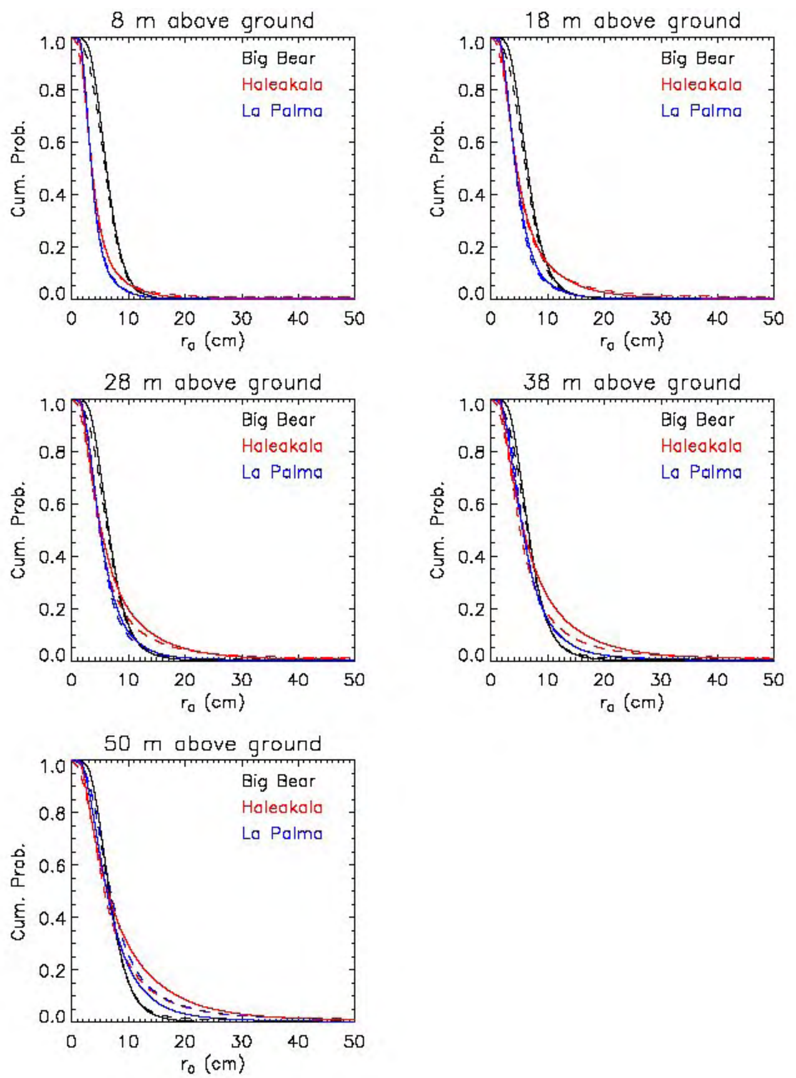


Figure 9.4: A comparison between the two inversion methods. Here we show the cumulative distribution of the estimated r_0 at the three sites and at five heights, as derived from the HAO method (dashed line) and the IAC method (solid line).

For a more detailed look at the inversion method comparison, Figure 9.5 shows $C_n^2(h)$ and $r_0(h)$ average curves for the month of May 2003 at the three sites.

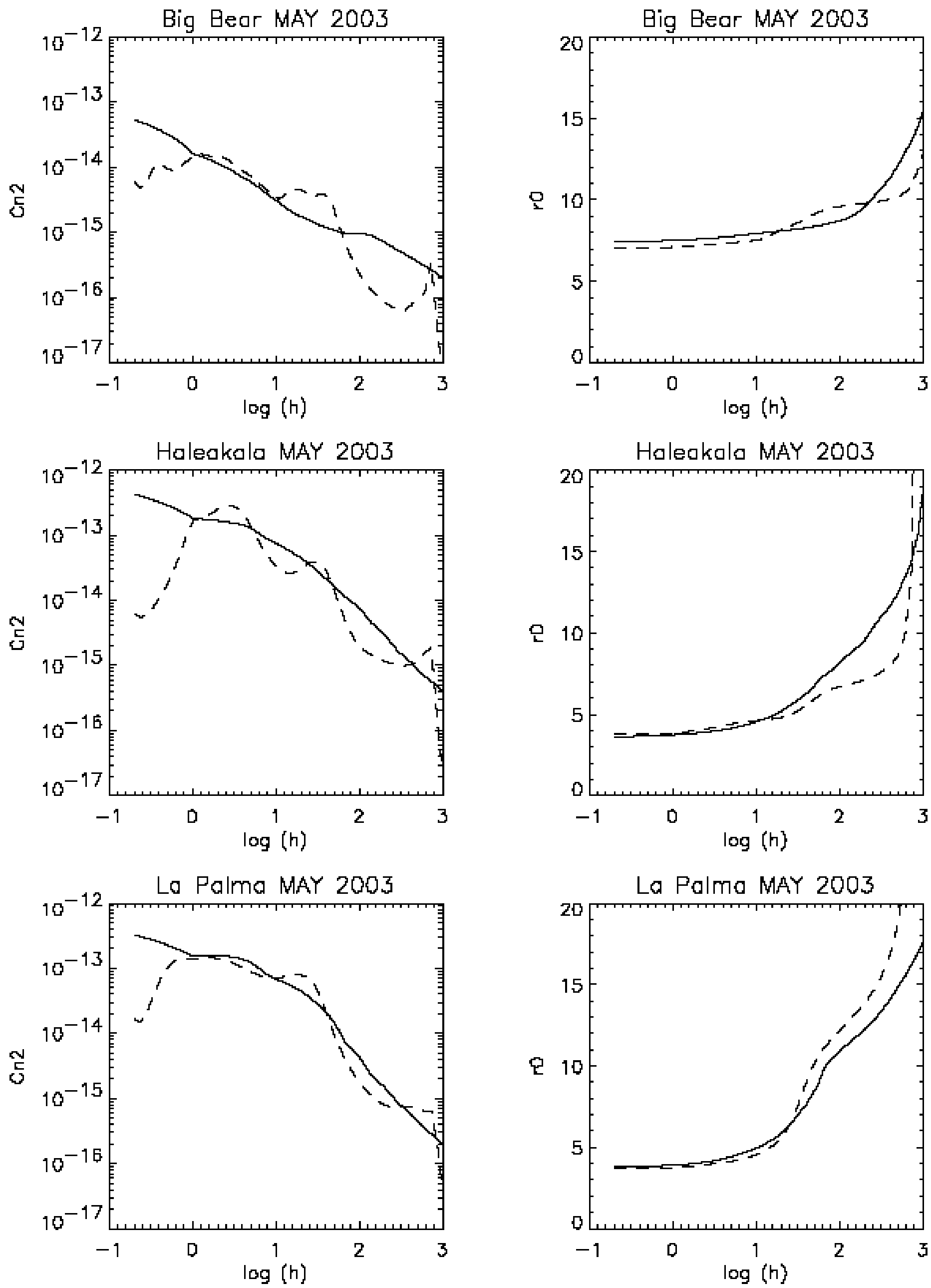


Figure 9.5: The estimated curves of $C_n^2(h)$ and $r_0(h)$ averaged over May 2003 for Big Bear, Haleakala, and La Palma. The two sets of lines are for the two inversion methods -- Dashed: HAO method, Solid: IAC.

Arguably the best verification of the method is to compare completely independent estimates of $C_n^2(h)$. To this end, an ATST seeing monitor was installed in Erie, Colorado, at the base of a tower that carried hygrometers, sonic anemometers, and other instruments (Hill et al. 2004, Figure 9.6) that could make in-situ measurements (Oncley and Horst 2004) of C_n^2 (derived from C_T^2 and C_q^2) at specific heights.

Temperature (*T*) and humidity (*q*) fluctuations were monitored at a 30 Hz rate; higher data rates were not warranted due to path averaging of the sonic anemometer. This data was then used to produce C_T^2 and C_q^2 (and thus C_n^2).

Figure 9.6: Sensors (hygrometers and sonic anemometers) mounted on a tower in Erie, Colorado for in-situ measurements of C_n^2. These estimates are used to verify the ATST seeing analysis.

The results of this comparison are shown in Figure 9.7 which shows scatter plots of the ATST estimates verses those of the in-situ measurements for heights 5, 10, 22, 50, and 100 m. The Pearson correlation coefficient is shown on the plot, along with a line that indicates strict equality. This plot shows good agreement between the two measurements up to a height between 22 and 50 meters, verifying the measurements at heights relevant to the ATST. It should be noted that agreement between the two measurements is expected to drop off at a linear distance greater than 50 meters because the largest separation of the SHABAR solar irradiance scintillometers is 47 cm. This drop-off is more severe for the Erie measurements than is expected for measurements at the candidate ATST sites, because of the low sun angle (sec(z) always larger than 2.0) that prevailed during these mid-winter tests.

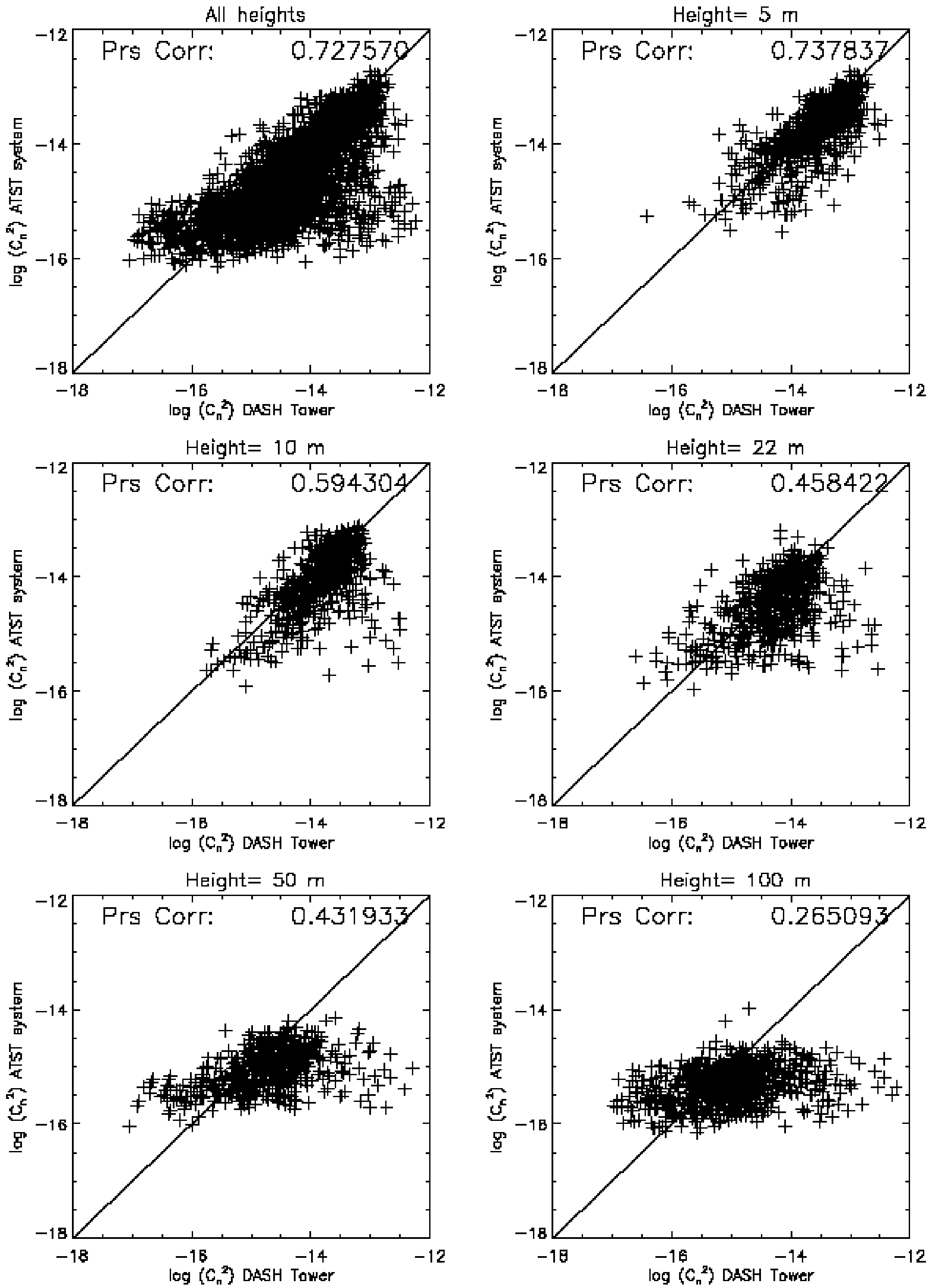


Figure 9.7: Results of the comparison of C_n^2 from the ATST system with in-situ measurements in Colorado.

To represent a lake and mountain environment the experiment was then repeated for three heights using a crane at Big Bear and Haleakala. Figure 9.8 shows the crane test at Big Bear and Haleakala; Figure 9.9 illustrates the spacing of the sensors. Additional details of the crane setup and experimental procedure can be found in Appendix 13.4.

Figure 9.8: The in-situ C_n^2 measurements underway at Big Bear (left) and Haleakala (right).

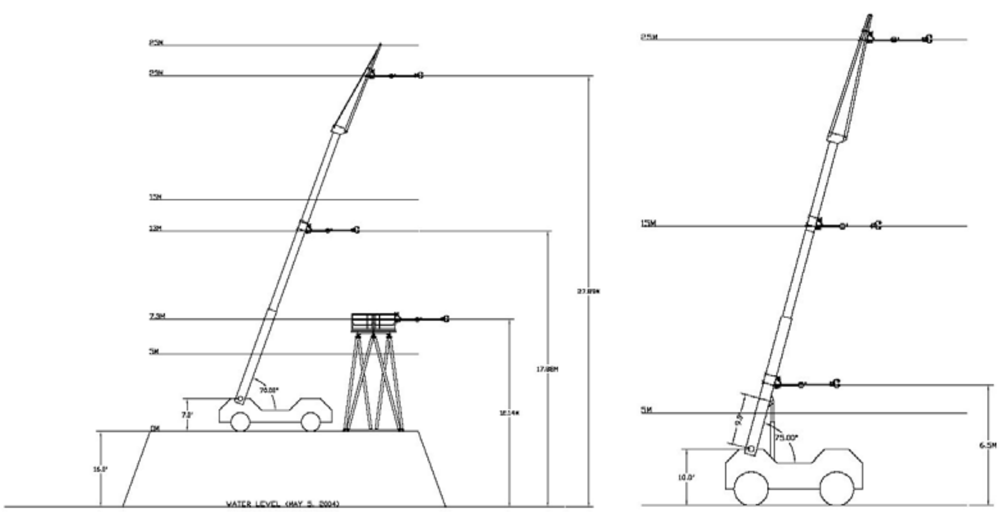


Figure 9.9: The crane at Big Bear (left) and Haleakala (right) with the in-situ probes, showing the heights of the sensors.

Figure 9.10 shows scatter plots of the ATST estimates verses those of the in-situ measurements for various heights at the two sites. Note that Pearson correlation coefficient shows good agreement (~ 0.87) between the two measurement techniques for the Haleakala data but only moderate agreement (~0.23) for the Big Bear data. The obvious differences between the two sites are: a significant difference in the level of humidity; the local topography and environment; and the probable lack of a near-ground boundary layer at Big Bear.

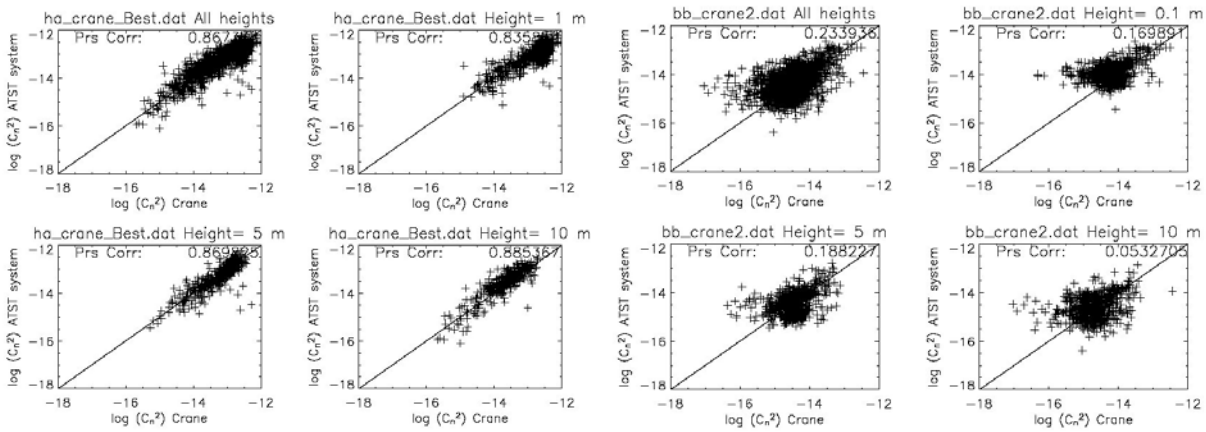


Figure 9.10: Scatter plot comparisons between the ATST estimates and the in-situ measurements of C_n^2 at Haleakala (left four panels) and Big Bear (right four panels). In each four-panel set the comparison is for the three heights of the in-situ measurements, plus all of the points combined. The straight line is strict equality, and each plot is labeled with the Pearson correlation coefficient (Prs Corr) of the data.

The presence of humidity does complicate in-situ measurements of C_n^2 as the correction to sonic temperature for humidity is of the same magnitude as the correction of C_T^2 to obtain C_n^2. The corrections for humidity have been determined in terms of the Bowen ratio (Wesely 1976), so measurements of sensible heat flux and water vapor flux should have been adequate to correct both sonic temperature and $C_T^2$for humidity.

The data set from crane measurements at Big Bear did however show a higher level of noise than that obtained from Haleakala. It is possible that the discrepancy with the Big Bear data could have been due to contamination of the temperature spectra by velocity spectra, which is caused by the finite time difference between successive sonic pulses. This is particularly important for small values of C_T^2 and hence C_n^2. It is also possible that the lack of a boundary layer at Big Bear has reduced the scintillation signal to the point that the SHABAR measurements are dominated by noise. This is consistent with the site-dependent behavior of the "missing scintillation" discussed in Section 9.3.1.1. The Pearson correlation coefficient increases to ~0.58 if outlying data points (~> 2 σ), as well as points that may have been contaminated by clouds, are removed. This is shown in Figure 9.10

Of particular note for Big Bear data is May 12th 2004, which demonstrated the data's dependence on wind speed and direction (Figure 9.11). On that day the typical westerly winds of 8 to 10 m/s changed to variable directions with velocities of 5 m/s or less. The resulting Pearson correlation coefficient for that data set was ~0.77. This increased correlation may result from the presence of a ground boundary layer when the winds are not out of the west.

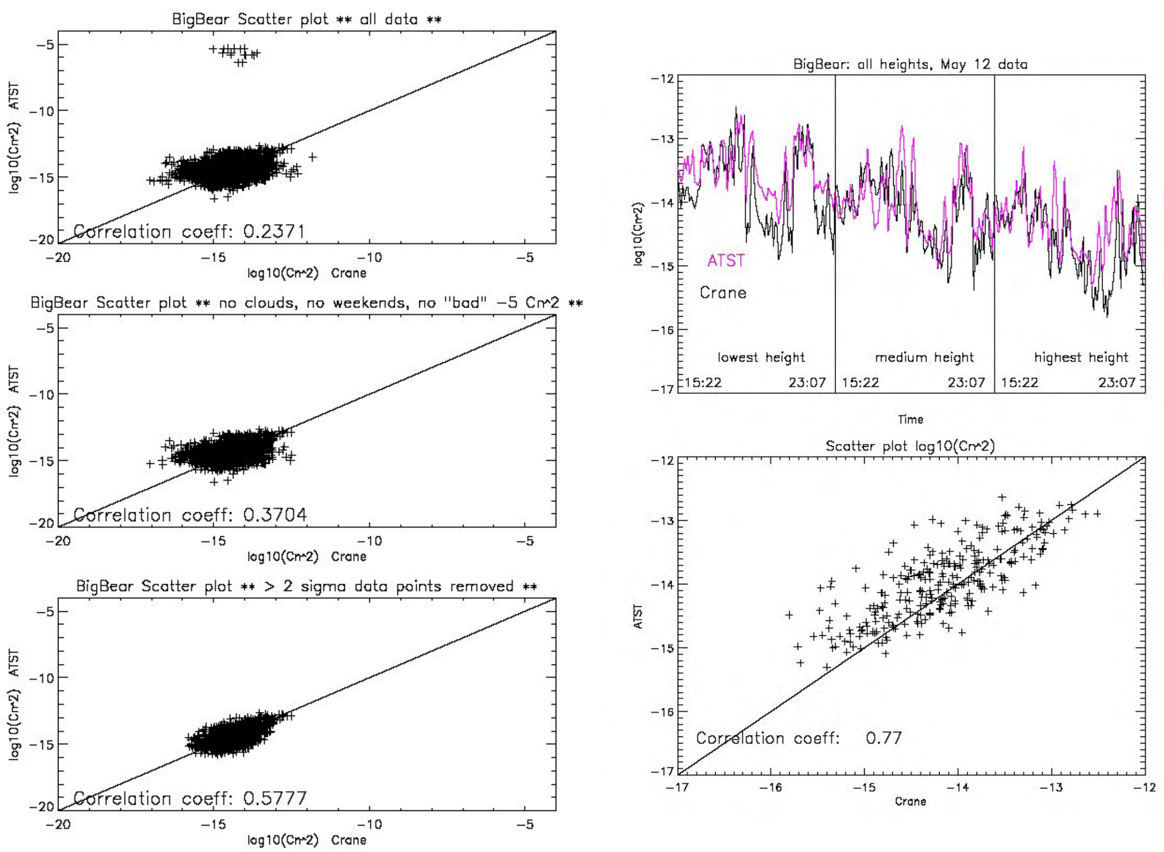


Figure 9.11: Left panels: The influence of noise on the correlation between the ATST and in-situ measurements of C_n^2. Top Left: all data; middle: excluding possibly cloudy points; bottom: excluding points more than 2 σ from the mean. Right panels: The correlations for Big Bear on May 12, 2004 when the winds were atypically variable. Top right: the time series for the three heights; bottom: the correlation for this day.

As a result of the comparisons between the ATST system and the in-situ measurements of C_n^2 we conclude that the SHABAR/S-DIMM analysis gives reliable results up to a linear distance of about 50 m from the instrument as long as there is sufficient near-ground turbulence to provide a significant scintillation signal.

9.4 SBM Analysis

9.4.1 Overview of Data Analysis

A detailed treatment of the data analysis is discussed in Appendix 13.7, where one day from Sunspot and one day from Haleakala are analyzed.

The SBM images from all sites were examined to determine regions of valid sky measurements. In several sites the edge of the telescope tube is visible at the outer image edge; this defines the outer edge of the valid field-of-view. In all sites the diffraction from the occulter edge is visible which determines the inner edge of the valid FOV. Also the azimuth angles must be limited to avoid the shadow of (and diffraction from) the occulter support arms. A set of pixels with outer radial, inner radial and azimuthal limits was determined which avoided these problems in all images (i.e. from all sites and at all wavelengths). The same set of pixels is used for the images from all sites for all wavelengths. Figure 9.12 shows the valid sky pixels overlaid on a sample image from each site in the 890 nm wavelength channel.

Within these valid sky pixels several measurements are made. They include the mean sky brightness, sky brightness as a function of radial distance (γ), and the wavelength dependence of the mean sky brightness (β).

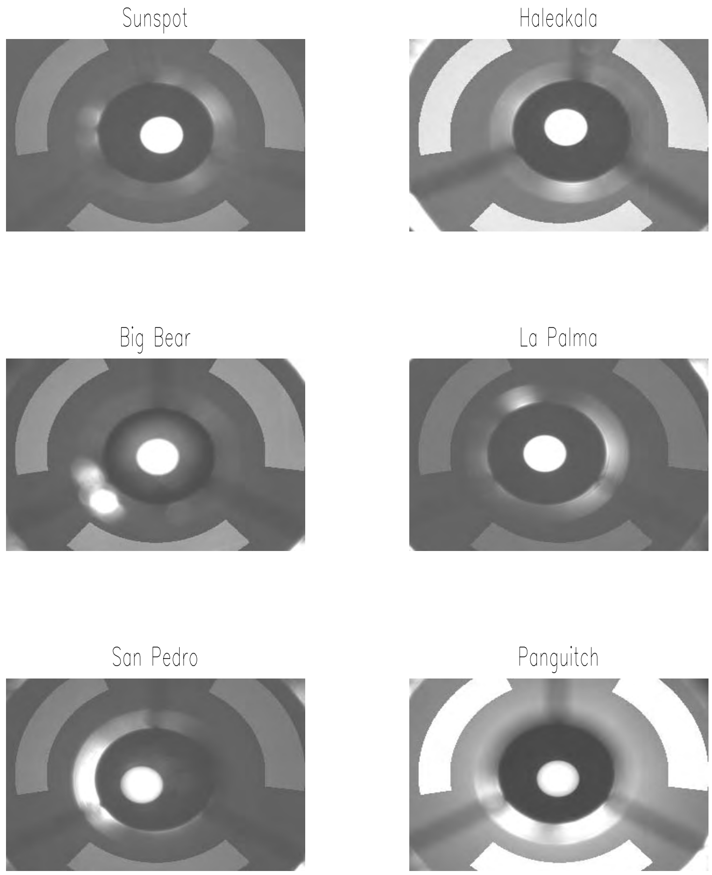


Figure 9.12: Sample images at 890 nm from all six sites, showing the valid sky pixel regions as three highlighted arcs. These pixel locations are identical in all images and are used for all wavelength channels as well. The inner, outer and azimuthal boundaries of these arcs were selected to avoid diffraction from the occulter edge, telescope tube front and the occulter support arm shadows. These obstacles are avoided at all wavelengths.

The SBM occulters developed problems with pinhole damage at each of the sites after they were originally deployed in 2003. The original occulter contained a single ND4 filter, and as it degraded this filter developed holes and transmitted significantly more light than 10^{-4} of the solar disk. At the three sites a first fix was made by replacing the ND4 filter with an absorptive filter from manufactured by CVI. This filter had a large transmission variation from 450nm to 940nm, and provided less than optimal data. The second replacement used a set of 2 ND2 filters, tilted to prevent reflection images, to replace the CVI filters. If one of these filters developed a pinhole it would result in only a 1% change in the transmitted solar disk intensity. The only true failure mode would be if both of the filters happened to develop pinholes which were precisely aligned; so far this problem has not been seen in the data.

The SBM instrument was designed to capture the solar disk image simultaneously with an image of the surrounding sky, by using these filters as occulters rather than an opaque occulting disk. This design allowed a “local calibration” on each image, where the sky brightness was normalized to the central solar disk brightness. In this way changing sky conditions or changing instrumental properties would not affect the sky measurement, since the Sun and sky were measured simultaneously. This design was meant to mimic the successful visible sky photometer built by Evans and used at many observatories.

With the advent of the pinhole problem, it was determined that the local calibration technique could not be used, and that a “global calibration” technique should be used. Because the image of the sky taken by the SBM does not pass through the ND filters which suffered degradation, the sky images should be relatively unaffected by the pinhole problem. (A caveat is that the pinholes do introduce more stray light into the SBM, but this is found to be a minimal problem.) This global calibration technique relies on knowledge of the atmospheric extinction at each wavelength at the sites, the instrumental count rate at each wavelength, and it relies upon the assumption that the extinction and the instrumental gain do not vary significantly during the observing periods. Through examining the data with various tests these are found to be valid assumptions, within the error bars that are quoted. Thus this technique is used to reduce all of the SBM data from the three sites.

9.4.2 Details of the “Global Calibration” Technique

The idea is simple: use a mean extinction value and a constant instrumental response to predict the solar intensity for each image, instead of trying to measure the solar intensity from the central FOV which is corrupted with pinholes. If the solar disk center intensity at a particular time t and a particular wavelength is given by $I_\lambda(t) = I_{0,\lambda} e^{-\tau_\lambda(t)}$ then we can compute this value if we know τ_λ and $I_{0,\lambda}$ for a particular image. Since the optical depth τ_λ is given by the product of the extinction κ and the air mass M, we could compute the optical depth exactly if we knew both quantities. We can compute M for any given image, and if we assume that the extinction is equal to some median value measured with valid ND4 or 2ND2 data, then we would know enough to compute the optical depth.

The second assumption involves the zero air mass measured intensity $I_{0,\lambda}$. This can be represented as the product of the solar intensity, the filter (and optics) transmission, and the gain of the detector $I_{0,\lambda} = I_{Sun,\lambda} T_\lambda g_\lambda$. The solar intensity should vary only slightly as the Earth-Sun distance changes throughout the year; here we assume it is constant. If we assume that the instrumental parameters (the transmission and detector gain) are constant, then we can compute this quantity using the zero-intercept of the log(I) vs M relationship and use it to analyze the entire data set.

9.4.2.1 VALUES FOR EXTINCTION AND INSTRUMENTAL COUNT RATE

Figure 9.13 plots histograms of the instantaneous extinction measured in the May 2003 data ND4 data and also from all 2ND2 data the three test sites. Table 9.2 lists the median values taken from these distributions, with exception of the 2ND2 data from La Palma at 890nm. Here the computed median extinction is negative, due to problems with image drift and vignetting in the central FOV, and also due to the fact that only 20 days of 2ND2 data were collected at La Palma. The modal value of the extinction is listed in Table 9.2 in this case.

Table 9.2 – Measured median extinction (κ) values

Site	Date	450nm	530nm	890nm
Big Bear	May 2003	0.25	0.19	0.11
	May-Aug 2004	0.20	0.14	0.04
Haleakala	May 2003	0.17	0.12	0.04
	Mar-Aug 2004	0.17	0.11	0.04
La Palma	May 2003	0.20	0.14	0.05
	Jun-Aug 2004	0.16	0.09	0.06*

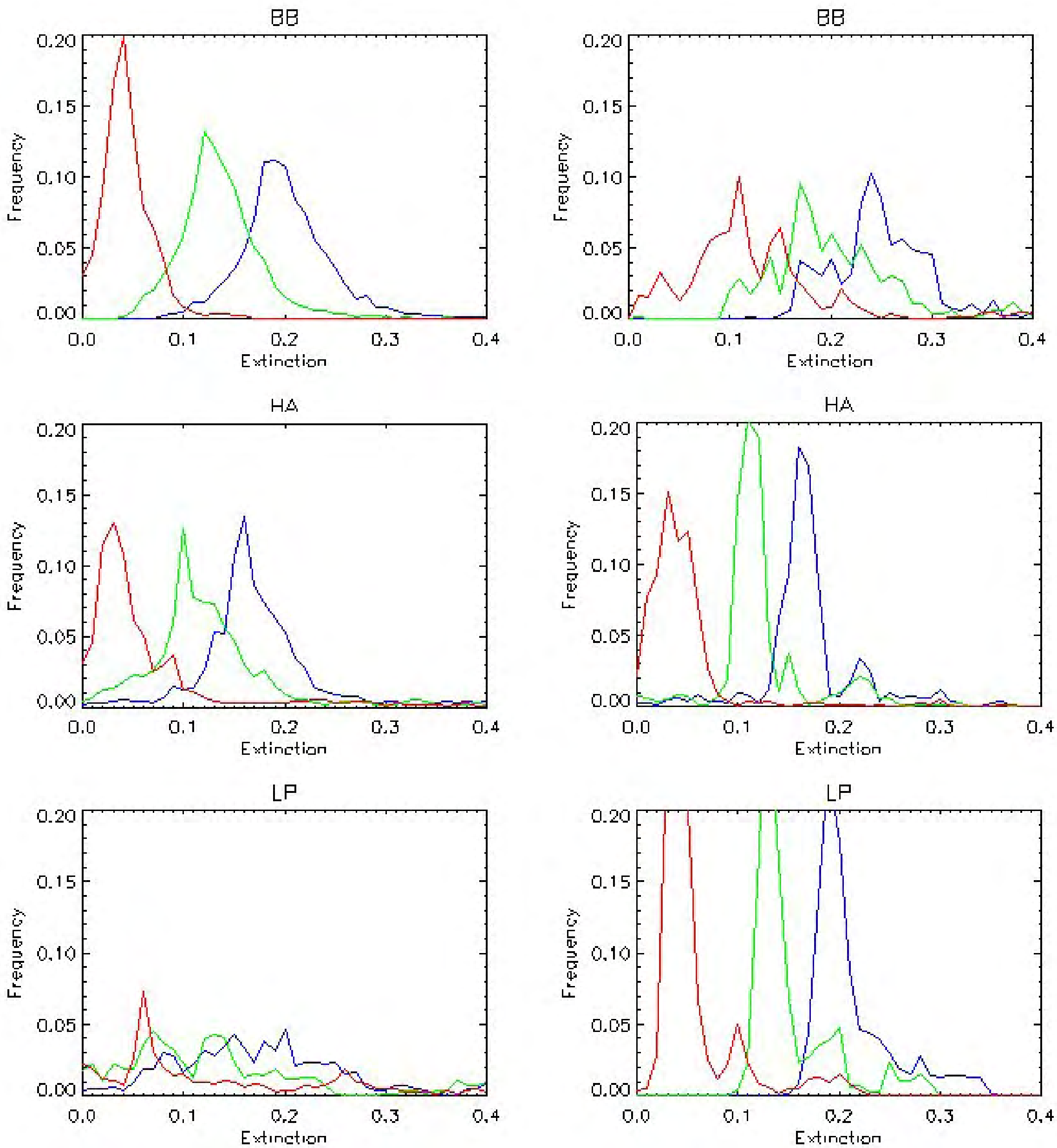


Figure 9.13. – Plotted are histograms of the measured extinctions at all three sites at three wavelengths for the May 2003 data with the ND4 filter (right column) and for all data taken from the site with the 2ND2 filter (left column). The medians of these distributions are listed in Table 9.2.

There is little variation seen between the 2003 and the 2004 extinction medians, and widths of about +/- 0.05 are seen in the distributions for the extinction. The values used in the data analysis, and the associated measurement errors used in the error analysis are listed in Table 9.3.

Table 9.3. Values of extinction (κ) used in analysis

Site	450nm	530nm	890nm
Big Bear	0.23+/-0.05	0.17 +/- 0.05	0.07 +/- 0.05
Haleakala	0.17 +/- 0.05	0.12 +/- 0.05	0.04 +/- 0.05
La Palma	0.20+/- 0.05	0.14 +/- 0.05	0.05 +/- 0.05

Table 9.4 shows the measured counts per second of the solar disk center for zero air mass at each wavelength for dates in May 2003 and for dates in 2004 when the 2ND2 was used. This is the coefficient $I_{0,\lambda}$ discussed earlier. In each case a linear fit is made to the observed log(solar intensity) as a function of air mass during the morning hours using air mass values between 1.0 and 4.0.

Table 9.4 – Measured instrumental count rate (ADU per sec / 10^8)

Site - Date	450nm	530nm	890nm
BBSO 15 May 2003	4.12	11.74	6.04
19 May 2003	3.83	10.14	5.75
24 May 2004	3.18	8.73	2.78
22 July 2004	3.27	9.05	2.79
04 Aug 2004	3.26	8.98	2.74
Haleakala 8 May 2003	5.32	13.1	3.69
15 May 2003	5.17	12.8	3.70
19 Mar 2004	3.54	8.81	2.38
08 Jun 2004	3.40	8.60	2.53
10 Aug 2004	3.48	8.99	2.69
La Palma 05 May 2003	6.20	12.85	3.58
26 May 2003	5.9	12.29	3.48
07 Jul 2004	3.19	6.50	1.43
03 Aug 2004	3.15	6.84	1.68
20 Aug 2004	3.15	7.40	2.20

The variations seen here are more troubling. It is most likely that they arise from an improper value for the transmission of the ND filter used in the occulter in each case. If the variation was due to a linear instrumental drift, then the measurements using the 2ND2 filter from Big Bear and Haleakala would show more variation during the 3 and 5 month periods over which they were collected. The measurements using a single occulter are internally consistent with no systematic time variability, so this points to the incorrect transmission value of the ND filter as the likely source of the variations.

The medians and standard deviations of these values were used in the data analysis; the values are listed in Table 9.5.

Table 9.5 – Instrumental count rate used in analysis (ADU per sec / 10^8)

Site	450nm	530nm	890nm
Big Bear	3.27+/-0.42	9.05+/-1.25	2.79+/-1.71
Haleakala	3.54 +/-0.97	8.99+/-2.28	2.69+/-0.65
La Palma	3.19+/-1.58	7.40+/-3.12	2.20+/-1.00

9.4.2.2 INTERNAL CONSISTENCY CHECK FOR GLOBAL CALIBRATION METHOD

How do these approximations affect the data? We can compare the sky brightness using these two techniques for the May 2003 data, where presumably the local calibration method is not affected by pinholes, and gives the “right” answer. Histograms for all three sites for all wavelengths are shown in Figure 9.14. The agreement with the BBSO data is very good, with no systematic differences between the local and global calibration methods. The Haleakala and La Palma data do show some systematic variations at low sky brightness, when the global calibration method appears to systematically increase the measured sky brightness from the value obtained with the local calibration method. This only seems important at sky brightness values less than about 10 millionths. This must reflect some correlation between changing sky brightness and changing atmospheric extinction during excellent sky conditions that is not accounted for in the global calibration technique.

Apart from this deviation at the very best sky conditions, the differences between the two techniques are small, and the global calibration technique was used for the data analysis.

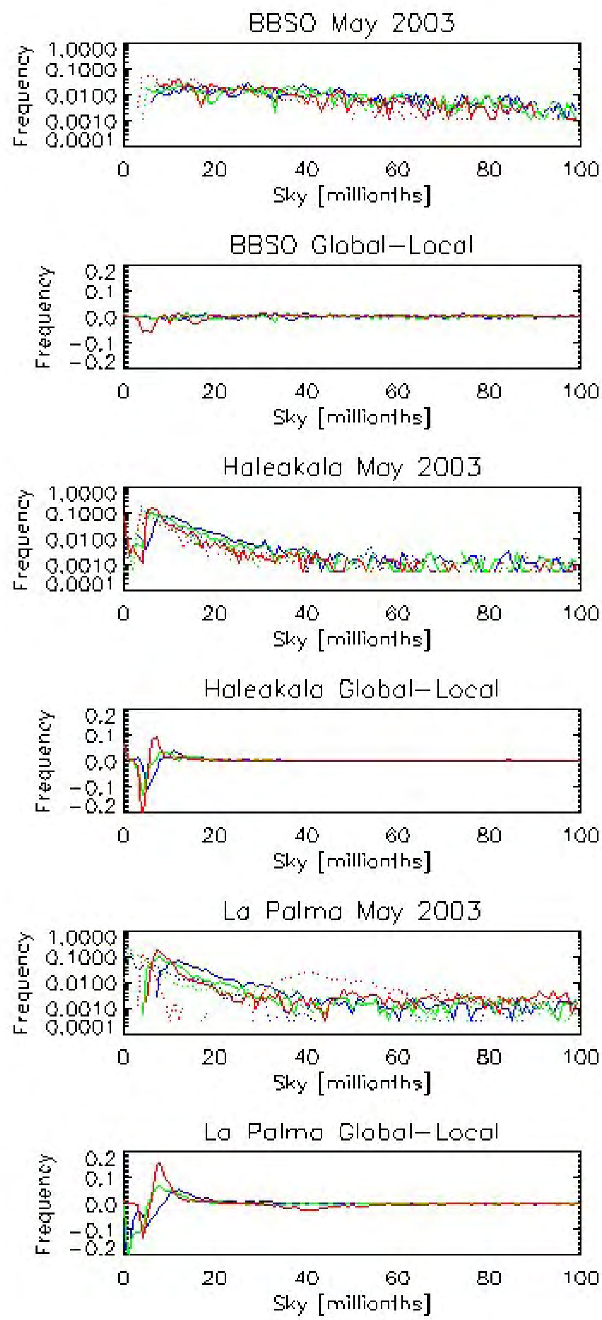


Figure 9.14: Histograms of the global (solid) and local (dashed) calibration technique sky brightness data for May 2003 from each site at all wavelengths. The second plot shows the difference, with the global-local histograms showing the differences between the techniques.

9.4.2.3 INSTRUMENTAL SCATTERED LIGHT

Measuring the instrumental scatter has proven to be the most difficult task involved in the data analysis of the SBM observations. The techniques for making this measurement require stable sky conditions; at Haleakala there seem to be several days of stable skies and the instrumental scattered light measurements taken there show the least scatter. At the other two sites however, sky conditions stable enough to make this measurement seem are difficult to find. It is likely that the instrumental scattered light changes with the use of different occulters, and this is suggested by the Haleakala data, but the measurements from the other sites have such a large inherent scatter that no systematic behavior is seen as the SBM occulters are changed.

The instrumental scatter for the SBM was derived by assuming that the sky brightness for any given wavelength (normalized by the solar intensity) follows $I_{sky}/I_{sun} = \Phi\ \kappa\ M + B$, where Φ is the atmospheric scattering function, κ is the extinction, M is the air mass and B is the instrumental scattered light. Knowing the air mass for each observation, a plot of normalized sky brightness versus air mass was made, the slope of which gives the sky brightness per air mass (see later discussion) but the intercept gives the instrumental scattered light. This value is calculated for several dates when ND4 and 2ND2 data was taken and the values are listed in Table 9.6 below.

The instrumental stray light must always be positive to have physical meaning, and so the negative values in Table 9.6 reflect the difficulty in making this measurement from the data. The color dependence of the instrumental stray light probably mostly depends on the wavelength properties of the internal paint used inside the SBM telescope tube and on the internal baffles.

Table 9.6. Values in millionths for the instrumental stray light for various dates

Site – Date	450nm	530nm	890nm
Big Bear 15 May 03	-3.45	-4.11	0.04
19 May 03	11.64	12.41	9.17
24 May 04	1.83	2.19	5.39
22 Jul 04	5.29	5.55	8.71
04 Aug 04	6.97	6.96	9.54
Haleakala 8 May 03	5.15	4.39	4.57
15 May 03	3.65	3.00	3.79
19 Mar 04	1.95	2.33	3.21
8 Jun 04	1.04	1.25	2.49
10 Aug 04	1.57	1.58	2.50
La Palma 5 May 03	-0.25	0.18	2.61
26 May 03	2.07	1.74	3.54
7 Jul 04	0.46	0.67	-0.09
3 Aug 04	-38	-25.5	-4.06
20 Aug 04	1.18	1.27	-0.20

The median values plus and minus the standard deviation of the measurements is shown in Table 9.7. In the discussion of the median sky conditions we describe another method to estimate the instrumental scattered light.

Table 9.7. – Median of instrumental scattered light values.

Site	450nm	530nm	890nm
Big Bear	5.29+/-5.66	5.55+/-3.87	8.71+/-4.01
Haleakala	1.95+/-1.70	2.33+/-1.25	3.21+/-0.89
La Palma	0.46+/-17.40	0.67+/-11.85	-0.06+/-2.97

Another approach to compute the instrumental scatter values has proved to be more successful; basically it takes the median of the many sky brightness measurements and then computes the fit, rather than taking the median of the fit coefficients. First, a set of days with good sky conditions are identified for each site, based on the daily minimum sky brightness values in the 890nm channel. Next, the sky brightness in the morning at each site from only those days is binned in air mass, in intervals of 0.1 air masses from 1.0 to 4.0. The median sky brightness in each bin is computed, and a linear fit is made to the median sky brightness as a function of air mass.

The results are shown in Table 9.8 below, where the values for the linear fit intercept are shown, along with the number of days used to compute the median sky brightness. All of the values lie within the large error bars listed in Table 9.7. The values computed for Haleakala all lie within 0.5 millionths of the values listed in Table 9.7. But unlike the values listed in Table 9.7, the instrumental scatter values computed with this technique are all positive, and when compared to the daily minimum sky brightness measured at the sites (see Figure 4 below) these instrumental scatter values lie below the majority of the sky brightness measurements as one would expect.

The instrumental scatter values at Big Bear are larger than the instrumental values at the other sites, except for the scatter at 890nm. This is the strangest result from this technique, and suggests a possible problem with the calculation of the instrumental scatter at Big Bear at this wavelength. The instrument scatter at La Palma at 450nm seems a little low, although it is within 1.5 millionths of the scatter at Haleakala.

Table 9.8. – Instrumental scatter values computed from median of dark sky morning data

Site	Days	450nm	530nm	890nm
Big Bear	86	6.27	3.00	1.27
Haleakala	104	2.28	1.90	3.61
La Palma	75	0.97	1.09	3.44

9.4.2.4 ERROR ANALYSIS

Each measurement of sky brightness includes the mean value of the sky within the valid observation window and a value of the standard deviation of the sky brightness within that window. This is treated as the error in the sky brightness measurement and referred to as σ_{SB}. Using standard error propagation techniques we can derive the error in the sky brightness measurement using the global calibration technique. The error depends on the error in the sky brightness measurement, σ_{SB}, the error in the extinction value for each site (taken as the width of the observed extinction distributions) σ_{κ}, and the error in the instrumental count rate (taken as the standard deviation of five count rate measurements) σ_I.

9.4.3 Extrapolation to compute IRspec

The ATST Site Requirements document describes the goal sky brightness at a wavelength of 1075 nm and a radial height of 1.1 solar radii. This goal is stated as a sky brightness of less than 25 ± 10 millionths at a distance of 1.1 radii, with a radial coefficient less than 1.0. This goal is referred to as the "IRspec" for the sky brightness. Since the SBM instrument does not observe at 1075 nm or at 1.1 solar radii, the SBM data must be extrapolated using the radial and wavelength coefficients γ and β and the measured sky brightness at 890nm.

Since the average distance for the SBM mean sky brightness is about 6 R_{SUN}, the sky brightness at $1.1R_{SUN}$ can be computed with $B_{1.1}=(5.45)^{\gamma}B_6$ where γ is the radial coefficient. Since the wavelength coefficient is computed as β the sky brightness at 1000 nm can be computed from the 890 nm brightness with $B_{1000}= (0.89)^{\beta} B_{890}$ and so the sky brightness at 1.1 R_{SUN} and 1000 nm can be computed as:

$$B_{1.1,1000} = (0.89)^{\beta} (5.45)^{\gamma} B_{6,890}$$

9.5 Clear Time Fraction

The fraction of time that the sky is clear at the sites is determined from the DC scintillometer data. This data, shown in Figure 9.15, displays the usual intensity variation that results from the varying atmospheric thickness as a function of zenith angle.

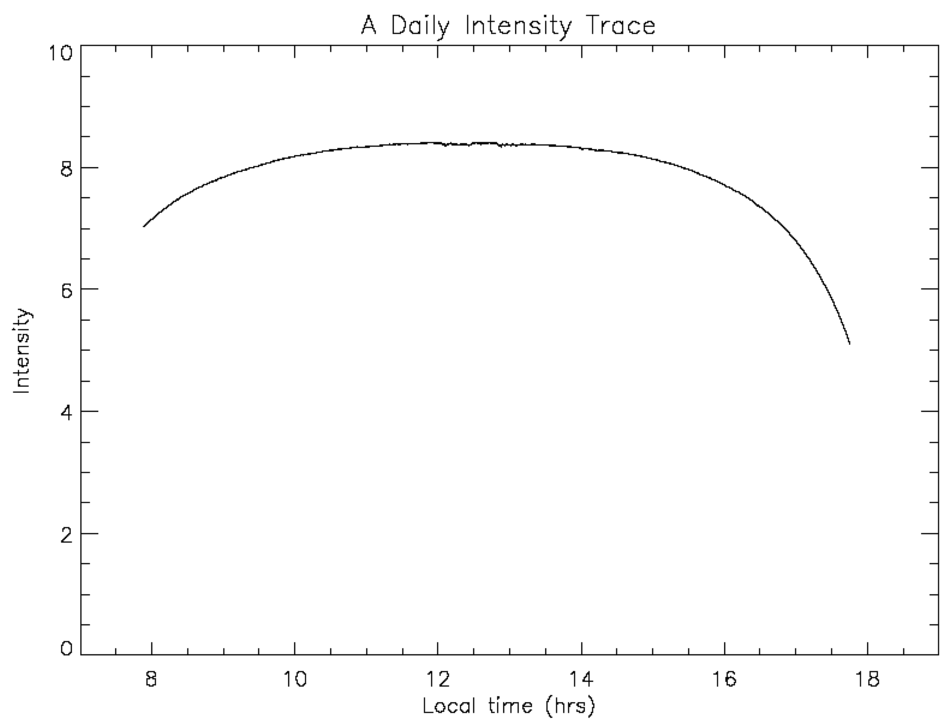


Figure 9.15: A trace of the intensity recorded during a clear day at Haleakala.

The existence of a cloud at a given observational time was operationally defined by the following steps:

- Within a five-minute period centered on the observation time, compute the temporal derivative of the intensity, *dI/dt*.
- Count the number of times that *dI/dt* changed sign within the five minute period.
- If the number of sign changes is greater than or equal to 2, define the observation as cloudy, otherwise it is clear.
- Move to the adjacent time sample and repeat

The clear time fraction was then computed as (the number of clear points) divided by (the number of clear plus the number of cloudy points). The results of this computation were found to be sensitive to the choice of treatment of the SHABAR 8 and 10 flags discussed in section 9.2. Thus, we performed the analysis in two ways: designating all of the flags as cloudy, or designating all of the flags as instrumental down time. Assignment of the flagged points as cloudy significantly reduces the estimated clear time fraction, and impacts the results of the analysis discussed in section 9.8.

9.6 STATISTICS

The statistics of the various measured quantities were computed using standard techniques. The quantities are the mean, median, standard deviation, 10^{th} percentile and 90^{th} percentile values. Both relative and cumulative frequency distributions were obtained on a monthly and complete data set basis.

9.7 TIME BLOCK DISTRIBUTION

The distribution of time blocks was determined by applying a threshold to the data, locating all points above the threshold, and then essentially taking a derivative of the index of the surviving points. A jump in this derivative by a value greater than 1 indicates the end points of a contiguous block of time. The difference in these indices gives the length of the block. This data set can then be statistically analyzed.

9.8 CORRECTION FOR OBSERVING SCHEDULE AND WEATHER

A difficulty with our site-survey program is that the survey instruments measure the site quality with incomplete time coverage. Thus, the expectation value of the number of hours per day satisfying some condition (excellent seeing, for example) must be extrapolated from the number of hours actually observed. In the simplest case, one performs this extrapolation by writing

$$\langle G_a \rangle = G_{tot} / N u_{tot}$$

where G_a is the estimated actual good hours per day, the angle brackets indicate expectation value, G_{tot} is the total number of good hours observed during the survey, N is the total number of days spanned by the survey, and u_{tot} is the survey instrument's fractional "up" time, that is, the hours that it was capable of taking observations, divided by the total possible hours of observations within the survey span. Here "capable of taking observations" means that the Sun was up (which for this purpose will be taken to mean that the local time is less than 7 hours before or after local solar noon), that the hardware was functional, and that the operators were present or otherwise able to take observations. Hardware failures and times when the instrument was shut for reasons other than bad weather count as "down" time. Times when the instrument was capable of observing, but because of bad weather it did not, count as "up" time and as "bad" conditions. Finally, one finds occasional observations yielding invalid results, for reasons that often are unknown. These invalid observations count as "down" time. For easier comparison with later results, it is helpful to define the total number of "up" hours in the survey as H_{tot}, with (by virtue of the definitions above)

$$H_{tot} \equiv 14 N u_{tot}$$

Then

$$\langle G_a \rangle = 14 \frac{G_{tot}}{H_{tot}} \qquad (9.8.1)$$

This procedure is justifiable if there is no correlation between the times when conditions are good and the times when the survey instrument operates. In practice, we find (possibly) significant variations from site to site in the number of hours per day that the survey instruments have been operated, and also in the distribution of observations during the day. Since all sites show variation in the quality of observing conditions during the day, it is possible that a simple correction for fractional "up" time may give significantly incorrect results.

There follows a derivation of a simple correction to the extrapolation procedure in Eq. 9.8.1, taking into account the daily variation of seeing quality and of instrumental up time (averaged over the entire interval studied in the survey) . This discussion will be described in terms of seeing quality, but the technique applies equally to other interesting observing conditions, such as coronal sky conditions.

First, some more definitions:
Let *t* be the hour angle of the Sun as seen from the site in question.

Let *g(t)* be the probability that seeing at a particular site is "good" (whatever one chooses that to mean) at time *t.* Clouds and bad weather count as bad seeing. For purposes that follow, we will assume that, within a normalizing factor *z*, this function can be estimated by forming the following ratio, with the data binned by solar hour angle: (hours of observations with good seeing) divided by (hours of valid observations). Thus,

$$g(t)z \cong G_{tot}(t) / H_{val}(t), \qquad (9.8.2)$$

where $G_{tot}(t)$ is as before, except binned according to *t*, and $H_{val}(t)$ is the total time during which valid observations were obtained, also binned by *t.* Eq. 9.8.2 amounts to assuming that the existing observations provide an adequate estimate of the shape of the daily variation of the probability of good seeing, but that the magnitude of *g* is uncertain within a factor *z* because the time sampling is incomplete on a day-to-day basis. Both G_{tot} and H_{val} must be smaller for a real system than for a perfect one. For a well-run survey, *z* will therefore be roughly unity, but it might be either larger or smaller.

Let *u* be the probability that the site is "up" at any time during a given day. Note that this not a function of time of day. An operational way to estimate *u* is to form the ratio (number of days on which some observations were obtained, plus number of days lost to bad weather) divided by (total days spanned in the survey). Alternatively, one might compute (number of days on which some observations were obtained) divided by (number of days on which the weather allowed some observations). In either case, the estimate of days that were or were not ruined by bad weather should be determined from some independent, e.g. GONG, data set.

Let *j(t)* be the probability that, if the site was "up" on a given day, it is actually "up" at time *t* on that day. Thus, the total probability that the site is observing the Sun at any given time is $u_{tot}=uj(t)$. We estimate *j(t)* by forming, for each bin of solar hour angle, the ratio (total number of observations in the data set, plus number of possible observations on bad-weather days) divided by (*u* times the number of possible observations in the time span covered by the data set).

What we want to know is: how many hours of good seeing are available per day (on average). Given the definitions, this is

$$\langle G_a \rangle = \int_{-7}^{+7} g(t)dt \equiv 14\overline{g}. \qquad (9.8.3)$$

Notice that we cannot immediately evaluate $<G_a>$ by simply integrating our operational estimate of *g(t)z*, because the latter differs from the true *g(t)* by the unknown normalizing factor *z.*

What we have measured is the actual number of good seeing hours per day during the times when the site was "up":

$$G_{tot} = Nu\int_{-7}^{+7} g(t)\, j(t)dt \qquad (9.8.4)$$

We can also measure the average number of "up" hours per day:

$$H_{tot} = Nu\int_{-7}^{+7} j(t)dt \equiv 14Nu\overline{j}. \qquad (9.8.5)$$

Now write

$$g = \overline{g} + g'(t), \qquad (9.8.6)$$

where $\int_{-7}^{+7} g'(t)dt = 0,$ and in a similar fashion,

$$j = \overline{j} + j'(t). \qquad (9.8.7)$$

That is, we break *g* and *j* into the sum of their mean vaules and the variation around the mean. Then expand out Eq. 9.8.4 to get

$$\begin{aligned} G_{tot} &= Nu\int_{-7}^{+7}\left[\overline{g} + g'(t)\right]\left[\overline{j} + j'(t)\right]dt \\ &= 14Nu\left(\overline{g}\,\overline{j} + \langle g'j'\rangle\right), \qquad (9.8.8) \end{aligned}$$

where $\langle g'j'\rangle = \frac{1}{14}\int_{-7}^{7} g'(t)\,j'(t)dt$ and the cross-terms vanish because g' and j' give zero when integrated onto a constant.

The number of good-seeing hours is then

$$\begin{aligned} 14\frac{G_{tot}}{H_{tot}} &= 14(1/\,j')\left(\overline{g}\,\overline{j} + \langle g'j'\rangle\right) \\ &= 14\overline{g}\left(1 + \frac{\langle g'j'\rangle}{\overline{g}\,\overline{j}}\right) \qquad (9.8.9) \end{aligned}$$

So, by comparison with Eq. 9.8.3,

$$\langle G_a\rangle = 14\frac{G_{tot}}{H_{tot}}\left(1 + \frac{\langle g'j'\rangle}{\overline{g}\,\overline{j}}\right)^{-1}. \qquad (9.8.10)$$

Now notice that if we replace *g(t)* in Eq. 9.8.6 with our operationally defined *g(t)z*, then

$$g(t)z = \overline{g}z + g'z \qquad (9.8.11)$$

If we use the operationally defined *g(t)z* in Eq. 9.8.10, the unknown factor *z* then cancels in the correction term $\langle g'j'\rangle/(\overline{g}\,\overline{j})$. Notice that u (the site fractional up time also drops out. This is so because we have implicitly assumed that the days when the site is "up" are uncorrelated with the days when the seeing is good. Thus, all of the things on the right hand side of Eq, 9.8.10 can be estimated from the seeing and site operation statistics that are available. We use $<G_a>$, estimated in this fashion, as our measure of the likely amount of good seeing at each site.

10. RESULTS

10.1 DATA COVERAGE

Table 10.1 summarizes the seeing data included in this report.

Table 10.1 – Data coverage

Site	Start Date	End Date	Days Spanned	Days Closed for Weather	Valid Data points
Big Bear	18 Jul 2002	30 Aug 2004	774	40	820434
Haleakala	6 Aug 2002	30 Aug 2004	755	60	713678
La Palma	28 Sep 2002	30 Aug 2004	702	60	718370

10.2 SEEING

We present here the current results for the analysis that combines the SHABAR and S-DIMM data. Figure 10.1 shows the median and average value of r_0 as a function of height above the ground for the sites. All valid estimates of r_0 have been included in these curves.

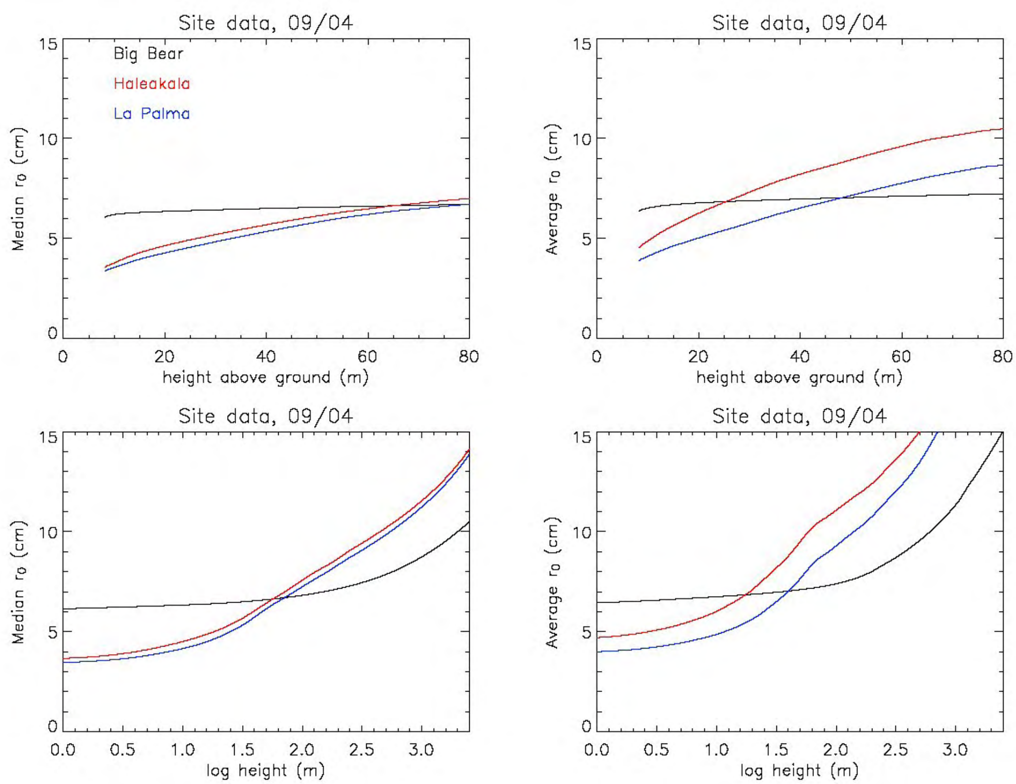


Figure 10.1 – The median and average values of r_0 as a function of height above the grpound estimated from the fit to the combined SHABAR/S-DIMM data. These curves include all valid estimates for each site. The curves are shown with a logarithmic height scale in the bottom panels, and on a linear height scale near the ground in the top panels. Results are from the IAC analysis.

The detailed seeing results for all six sites are contained in Appendix 3.11. These appendices show the variation of r_0 with season, time of day, wind speed and wind direction. Some of the features of these plots for the top group of sites are:

- Big Bear: The seeing is better in the summer and fall, and in the early morning It is poor when the wind blows from the north, the landward side of the site. It is best when the wind is onshore, from the south or from the west. The seeing deteriorates when the wind speed is large.
- Haleakala: The seeing is best in the winter months, and early in the morning. It is best when the wind is from the south or blowing strongly.

- La Palma: The seeing is best in the summer and early in the morning. It is best when the wind comes from the north, but there is little dependence of the seeing on wind speed.

One of the strengths of the SHABAR+S-DIMM analysis is that it provides an estimate of the structure function, $C_n^2(h)$. Figure 10.2 shows the median and average values of log $C_n^2(h)$ for all valid estimates,.

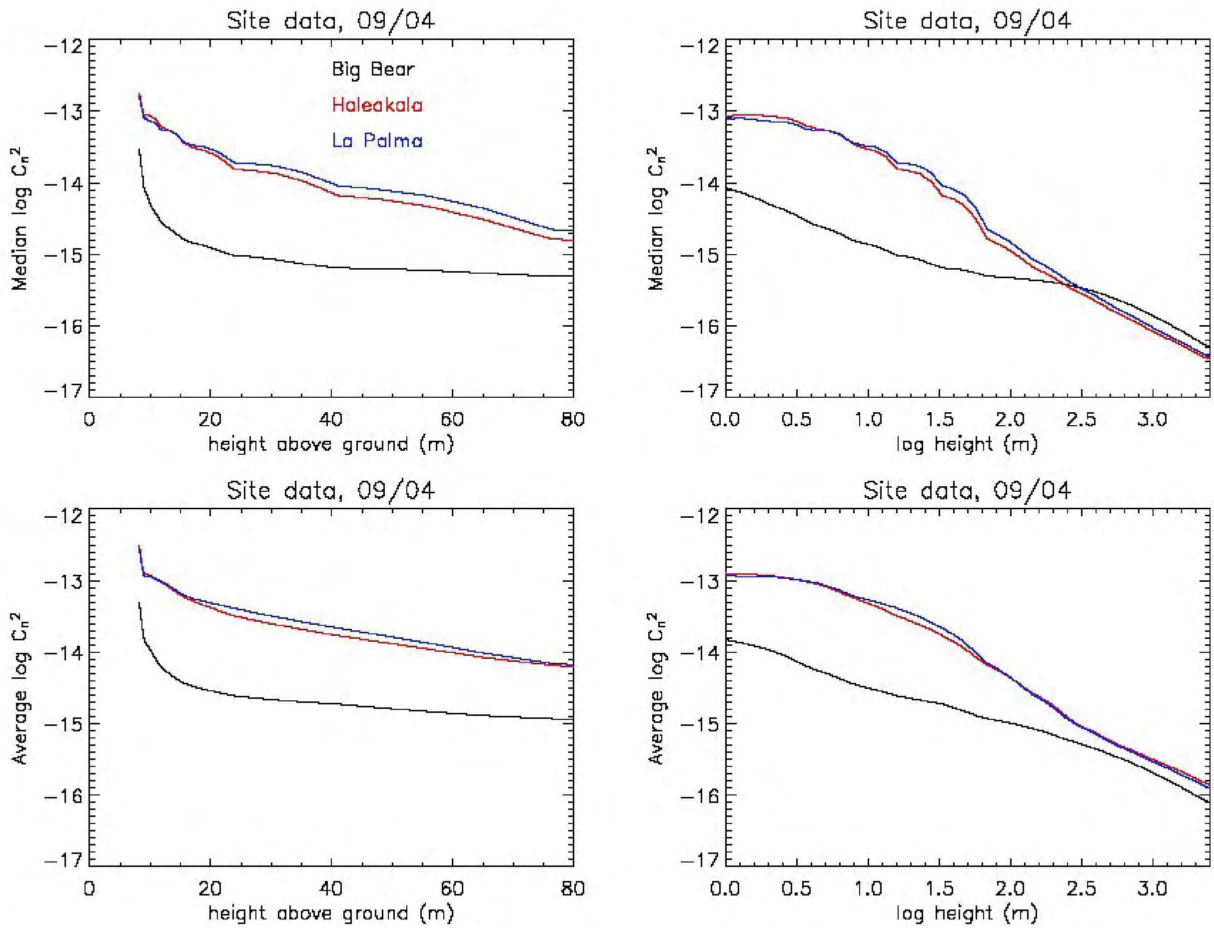


Figure 10.2 – The median and average log $C_n^2(h)$ for all valid estimates from the IAC method.

Figure 10.2 shows the absence of a ground layer at the lake site (Big Bear), which is present at the other two sites without lakes. It also suggests that the high altitude seeing is better for the two ocean islands than for the continental lake. Results are from the IAC analysis.

Figures 10.3 and 10.4 show the cumulative distribution of the measurements of r_0 obtained from the S-DIMM (Figure 10.3), and from the IAC analysis of the combined S-DIMM and SHABAR measurements at four heights (Figure 10.4). A comparison of these distributions determined from the two analyses (IAC and HAO) is shown in Figure 9.3.

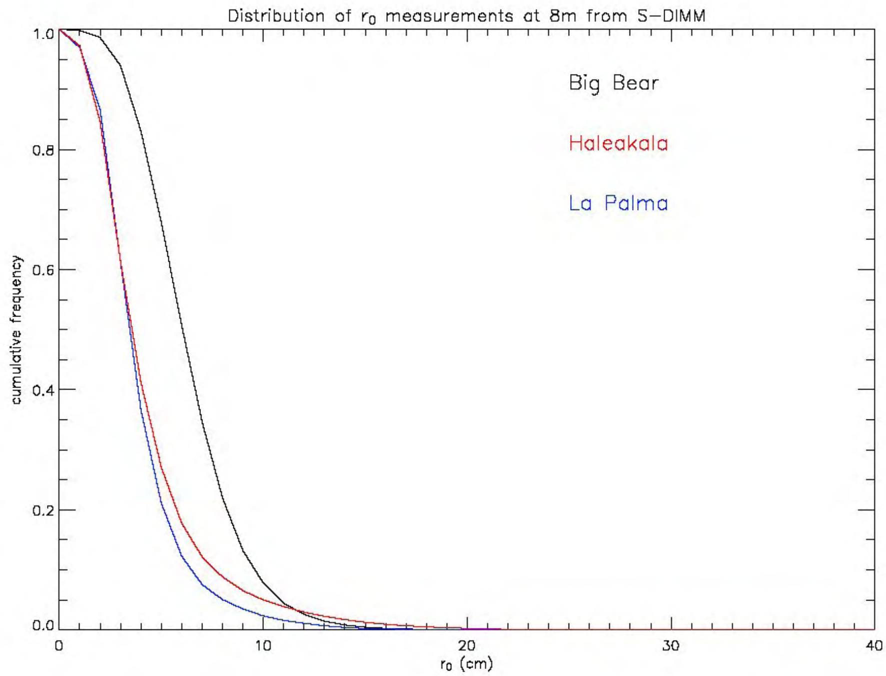


Figure 10.3: The cumulative frequency distribution of the r_0 measurements from the S-DIMM at a height of 8 m above the ground at the three sites.

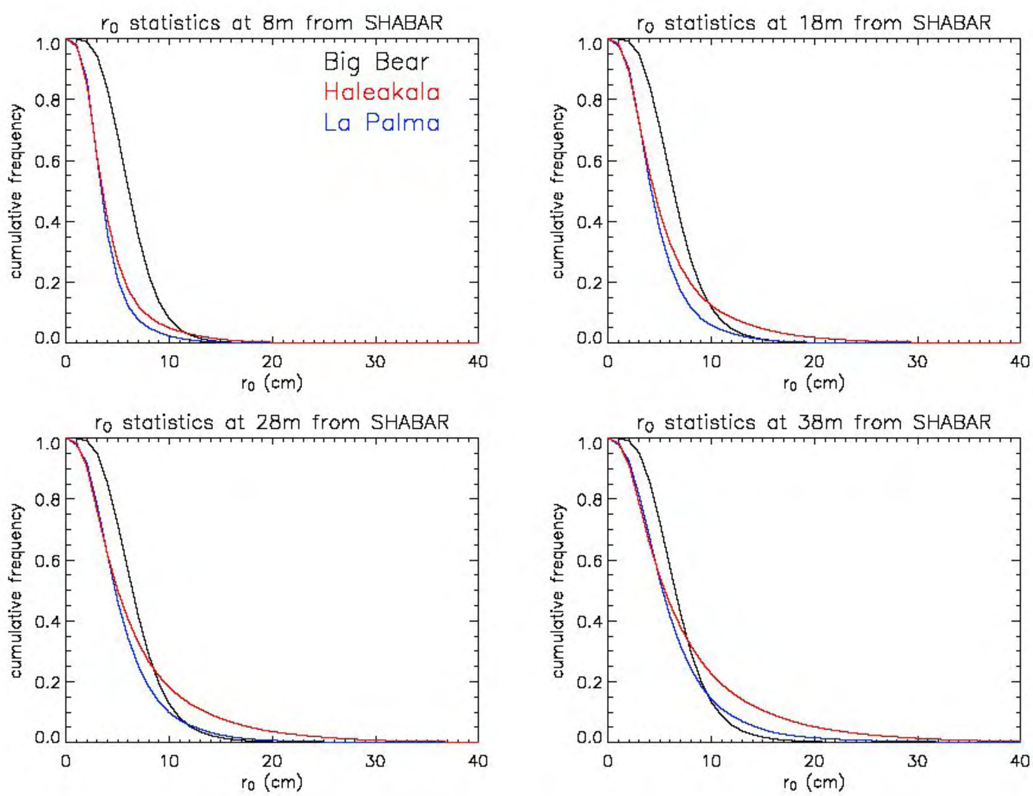


Figure 10.4: The cumulative frequency distributions of r_0 obtained from the IAC analysis of the combined S-DIMM and SHABAR data at four heights of 8, 18, 28, and 38 m above the ground.

10.2.1 Seeing Time Distribution

We have applied the correction for observing practices discussed in section 9.8 to the results of the seeing analysis. The results of the analysis are dependent on the way the clear time fraction is computed. Thus, we present in this section the results of two choices of approaches:

- Case 1: With instrumental flags considered as cloudy points
- Case 2: With instrumental flags considered as down time points

The two cases produce different observational coverage patterns for the sites. These are shown in Figures 10.6 to 10.8. The observing probability function *j(t)*, discussed in Section 9.8, is shown in Figure 10.5. The seeing probability functions, *g(t)*, are shown in Figures 10.9 and 10.10 for the good (r_0>7 cm) and the excellent (r_0>12 cm) cases. Note that these functions treat bad weather as observations with r_0=0 and, for Big Bear, go to zero at high absolute hour angles. This is due to the small number of observations taken during those times, which then produces a probability dominated by the days closed but marked cloudy on the log sheets. In addition, the latitude of the site affects these plots and Figure 10.5 since the higher-latitude sites sample the extreme hour angles less frequently during the year. Figure 10.11 shows an example of the probability of observing r_0 above a threshold of 5 cm, ignoring clouds.

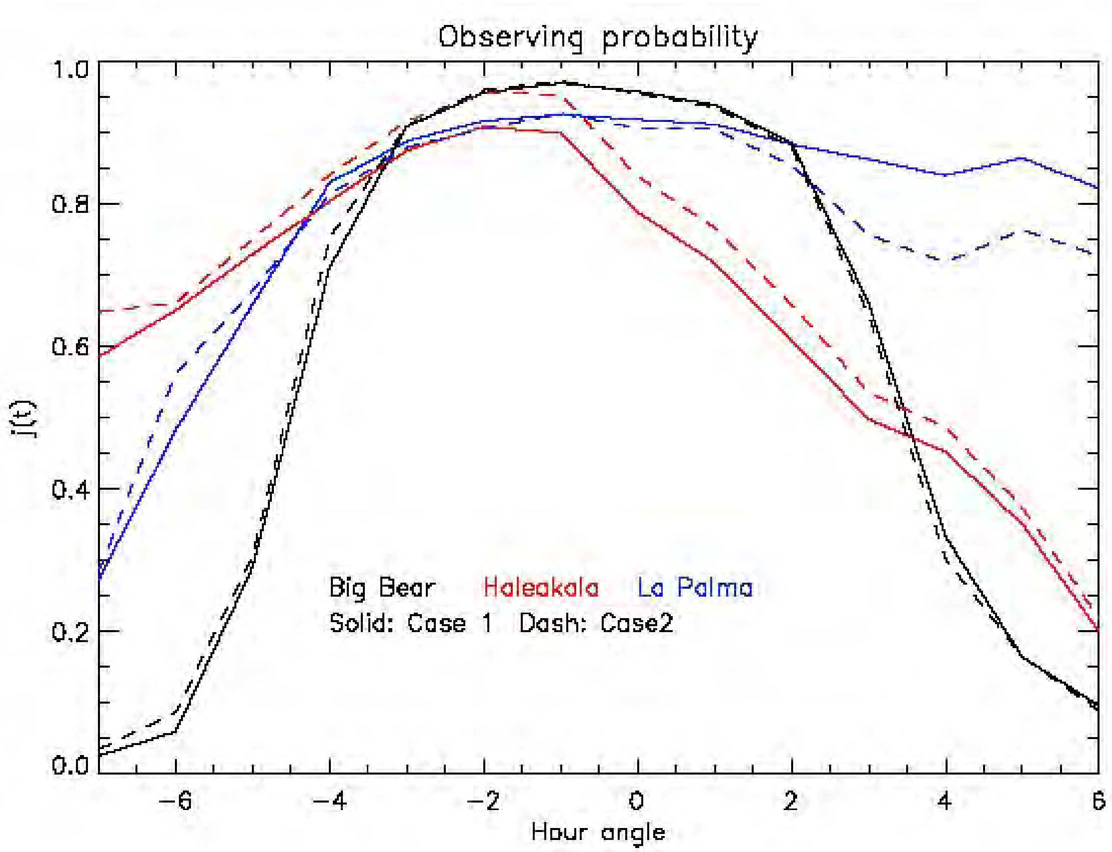


Figure 10.5: The observing probability, *j(t)*, as a function of hour angle for the three sites and the two cases of clear time fraction computation.

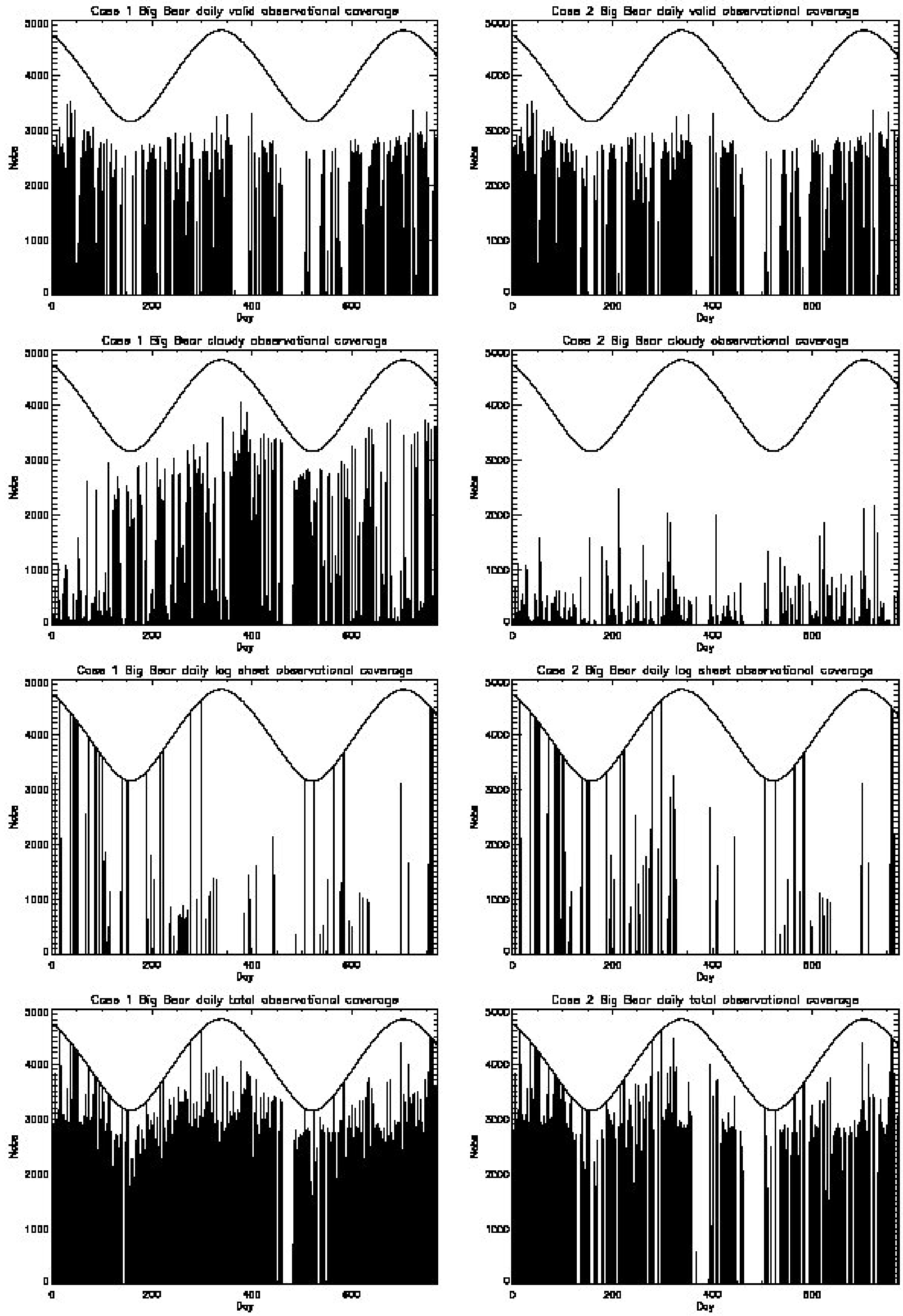


Figure 10.6: The observational coverage at Big Bear. Top Row: Daily number of valid seeing observations. Second row: Daily number of cloudy observations. Third row: Daily number of observations when instrument was closed and the log sheets indicated bad weather. Bottom row: total of the other three rows. Left column: Case 1 (flagged points indicate clouds), right column: Case 2 (flagged points indicate instrument down).

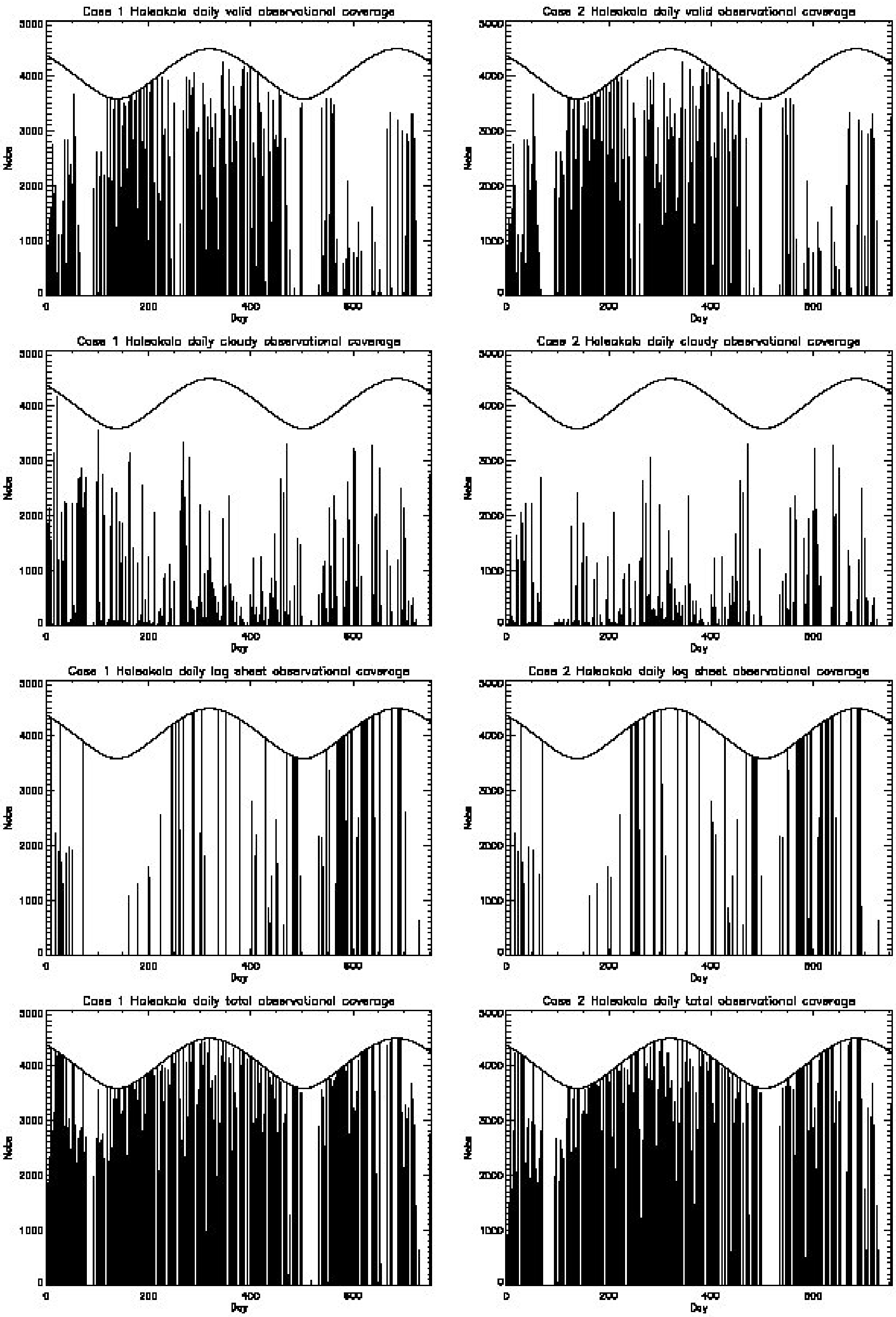


Figure 10.7: As Figure 10.6, but for Haleakala

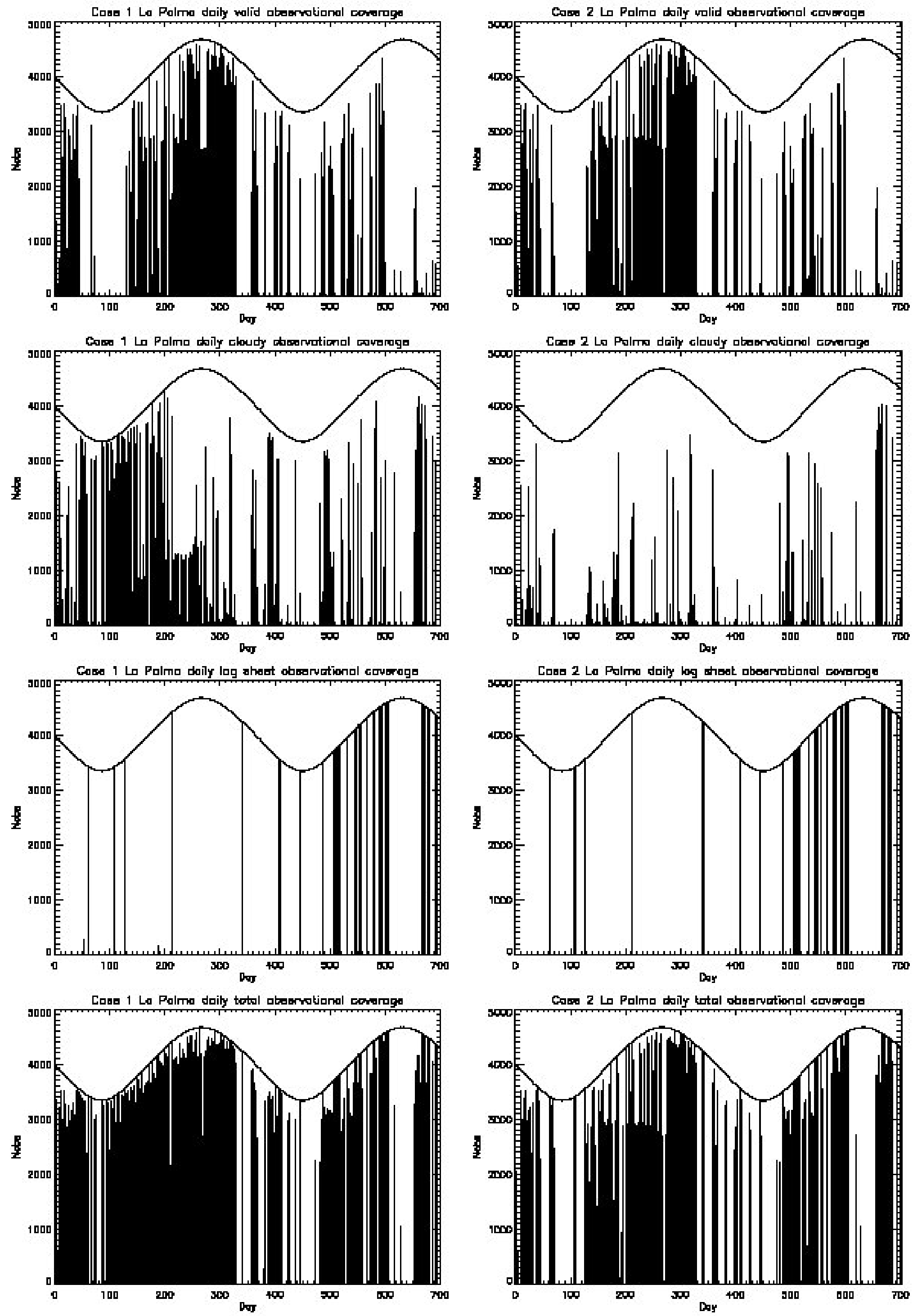


Figure 10.8: As Figure 10.6, but for La Palma

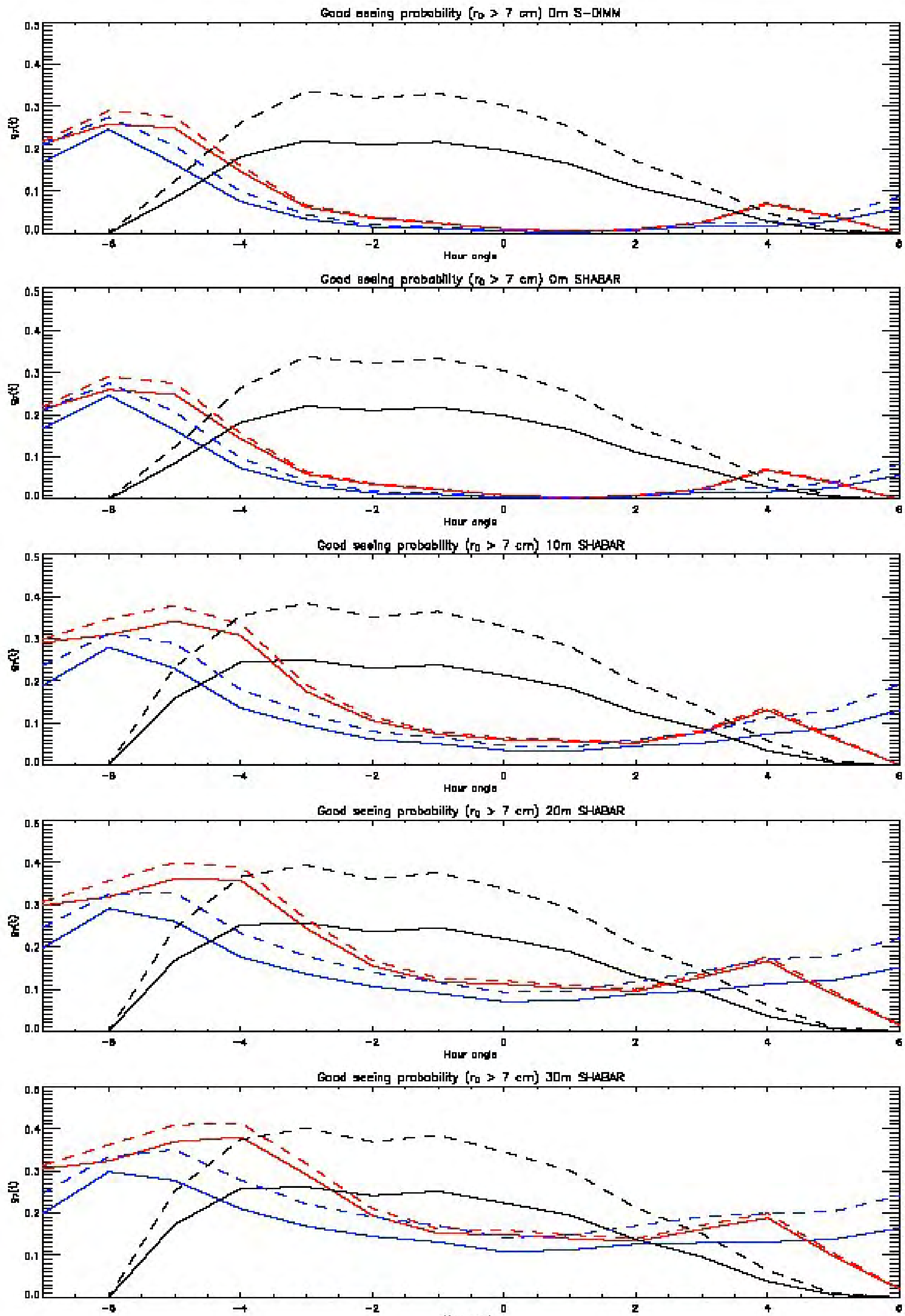


Figure 10.9: The probability *g(t)* of obtaining good seeing (r_0> 7 cm) as a function of hour angle. Black: Big Bear; red: Haleakala; blue: La Palma. Solid line: Case 1; dashed line: Case2. Top to bottom: S-DIMM data; SHABAR at 8 m above the ground; 18 m; 28; and 38 m. These plots count bad weather as r_0=0. The apparent decrease of *g(t)* at Big Bear at the extreme hour angles is due to the small number of observations at those times which results in the statistics being dominated by cloudy days on which the instrument was shut down.

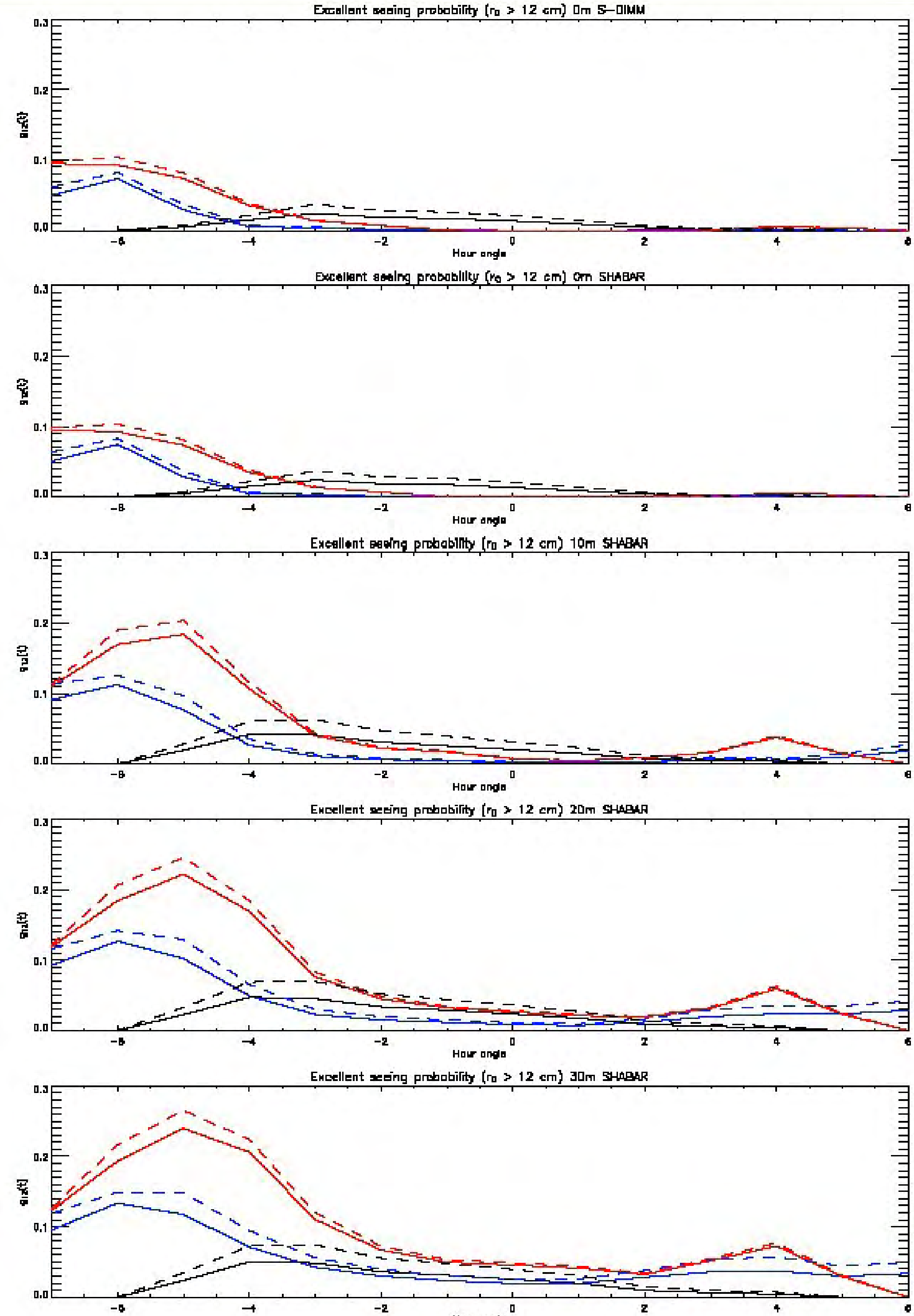


Figure 10.10: As figure 10.9, but for excellent seeing (r_0>12 cm).

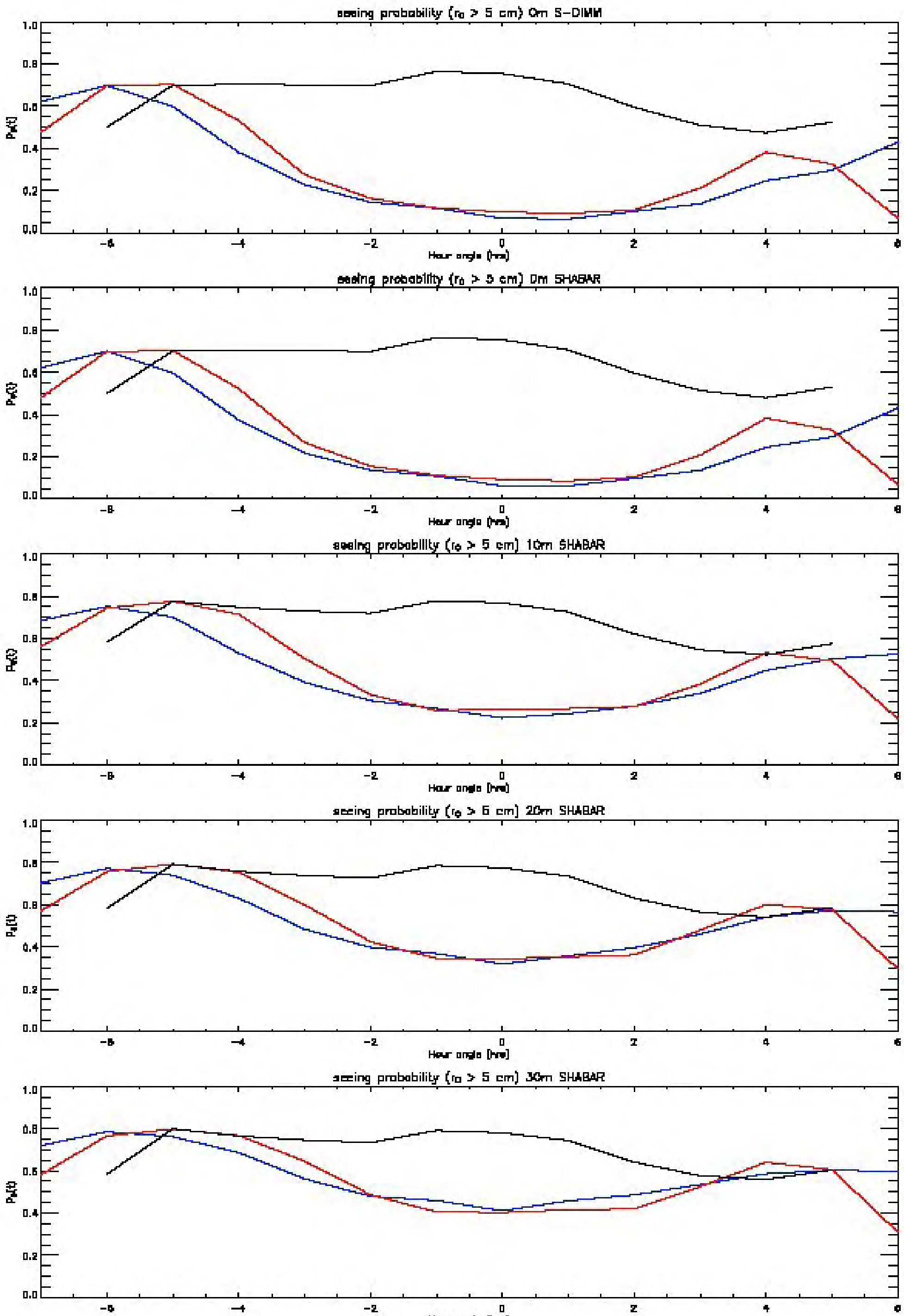


Figure 10.11: The probability functions for r_0> 5 cm as a function of hour angle and height at the sites. These functions, unlike the functions *g(t)* shown in figures 10.9 and 10.10, do not include bad weather and so do not exhibit end effects at Big Bear.

Tables 10.2 through 10.4 show the results for Case 1, with instrumental flags considered as cloudy points. These tables show the raw observed and corrected annual hours for good seeing (r_0> 7 cm) and excellent seeing (r_0>12 cm) as derived from the S-DIMM observations, and the IAC analysis of the combined S-DIMM/SHABAR measurements at heights of 8, 18, 28, and 38 m above the ground. The table also contains the derived correction factor as defined by Eq. 9.8.10. Lastly, the table contains the observed and corrected annual values of the number of 2-hour time blocks of good and excellent seeing. These numbers are corrected by the same factors used for the individual hour counts. Tables 10.5 through 10.7 show the results for Case 2, with the flags treated as instrumental down time.

Table 10.2 CASE 1 Results for Big Bear

Total Hours Observed: 4903 Clear Weather Fraction: 0.465							
Good Seeing (r_0>7cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	802	836	1.493	560	59	61	40
SHABAR 8m	808	842	1.493	564	47	49	32
SHABAR 18m	926	965	1.447	666	65	68	47
SHABAR 28m	957	997	1.444	690	75	78	54
SHABAR 38m	982	1023	1.443	708	76	79	55
Excellent Seeing (r_0>12cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	61	63	1.522	42	1	1	1
SHABAR 8m	62	64	1.520	42	0	0	0
SHABAR 18m	109	114	1.440	79	1	1	1
SHABAR 28m	123	129	1.435	90	1	1	1
SHABAR 38m	134	139	1.438	97	1	1	1

Table 10.3 CASE 1 Results for Haleakala

Total Hours Observed: 3451 Clear Weather Fraction: 0.574							
Good Seeing (r_0>7cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	253	374	1.044	358	10	15	14
SHABAR 8m	250	370	1.043	355	10	15	14
SHABAR 18m	514	762	1.075	709	31	46	43
SHABAR 28m	670	992	1.077	921	55	81	75
SHABAR 38m	782	1158	1.082	1071	72	107	97
Excellent Seeing (r0>12cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	62	92	1.042	88	1	1	1
SHABAR 8m	62	92	1.041	88	1	1	1
SHABAR 18m	176	261	1.066	245	2	3	3
SHABAR 28m	269	398	1.084	367	7	10	10
SHABAR 38m	348	515	1.094	471	12	18	16

Table 10.4 CASE 1 Results for La Palma

Total Hours Observed: 4196 Clear Weather Fraction: 0.475							
Good Seeing (r_0>7cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	153	186	0.747	249	6	7	12
SHABAR 8m	152	185	0.745	249	7	9	14
SHABAR 18m	348	423	0.868	487	20	24	34
SHABAR 28m	509	620	0.916	677	31	38	47
SHABAR 38m	645	785	0.945	831	44	54	62
Excellent Seeing (r0>12cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	22	26	0.604	44	0	0	0
SHABAR 8m	22	27	0.601	45	0	0	0
SHABAR 18m	64	78	0.709	110	1	1	2
SHABAR 28m	116	141	0.802	176	2	2	3
SHABAR 38m	178	217	0.864	251	2	2	3

Table 10.5 CASE 2 Results for Big Bear

Total Hours Observed: 3201 Clear Weather Fraction: 0.712							
Good Seeing (r_0>7cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	802	1281	1.496	856	59	94	62
SHABAR 8m	808	1290	1.496	863	47	75	49
SHABAR 18m	926	1478	1.454	1017	65	104	71
SHABAR 28m	957	1528	1.451	1053	75	120	83
SHABAR 38m	982	1567	1.450	1081	76	121	84
Excellent Seeing (r_0>12cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	61	97	1.527	64	1	2	1
SHABAR 8m	62	99	1.525	65	0	0	0
SHABAR 18m	109	174	1.454	120	1	2	1
SHABAR 28m	123	197	1.449	136	1	2	1
SHABAR 38m	134	213	1.452	147	1	2	1

Table 10.6 CASE 2 Results for Haleakala

Total Hours Observed: 3203 Clear Weather Fraction: 0.619							
Good Seeing (r_0>7cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	253	403	1.035	389	10	16	15
SHABAR 8m	250	399	1.034	386	10	16	15
SHABAR 18m	514	820	1.068	768	31	49	47
SHABAR 28m	670	1069	1.073	997	55	88	82
SHABAR 38m	782	1247	1.978	1157	72	115	106
Excellent Seeing (r_0>12cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	62	99	1.033	96	1	2	2
SHABAR 8m	62	99	1.033	96	1	2	2
SHABAR 18m	176	281	1.053	267	2	3	3
SHABAR 28m	269	428	1.073	399	7	11	10
SHABAR 38m	348	555	1.085	511	12	19	18

Table 10.7 CASE 2 Results for La Palma

Total Hours Observed: 3123 Clear Weather Fraction: 0.639							
Good Seeing (r_0>7cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	153	250	0.801	313	6	10	14
SHABAR 8m	152	249	0.799	311	7	11	17
SHABAR 18m	348	569	0.900	632	20	33	43
SHABAR 28m	509	833	0.940	887	31	51	60
SHABAR 38m	645	1055	0.965	1093	44	72	80
Excellent Seeing (r_0>12cm)	Raw observed hours	Naïve annual hours	Correction factor	Corrected Annual hours	Raw N 2-hr blocks	Naïve annual N 2-hr blocks	Corrected Annual N 2-hr blocks
S-DIMM 8m	22	36	0.679	53	0	0	0
SHABAR 8m	22	36	0.676	54	0	0	0
SHABAR 18m	64	104	0.767	136	1	2	2
SHABAR 28m	116	190	0.845	225	2	3	4
SHABAR 38m	178	292	0.899	324	2	3	4

Figures 10.12 and 10.13 show the average and median values of r_0 as a function of hour angle, site, and height above the ground. These values do not depend on the choice of clear time fraction computation. In addition, since these numbers are derived from the valid seeing observations alone, they are free of the end effects seen in Figures 10.9 and 10.10.

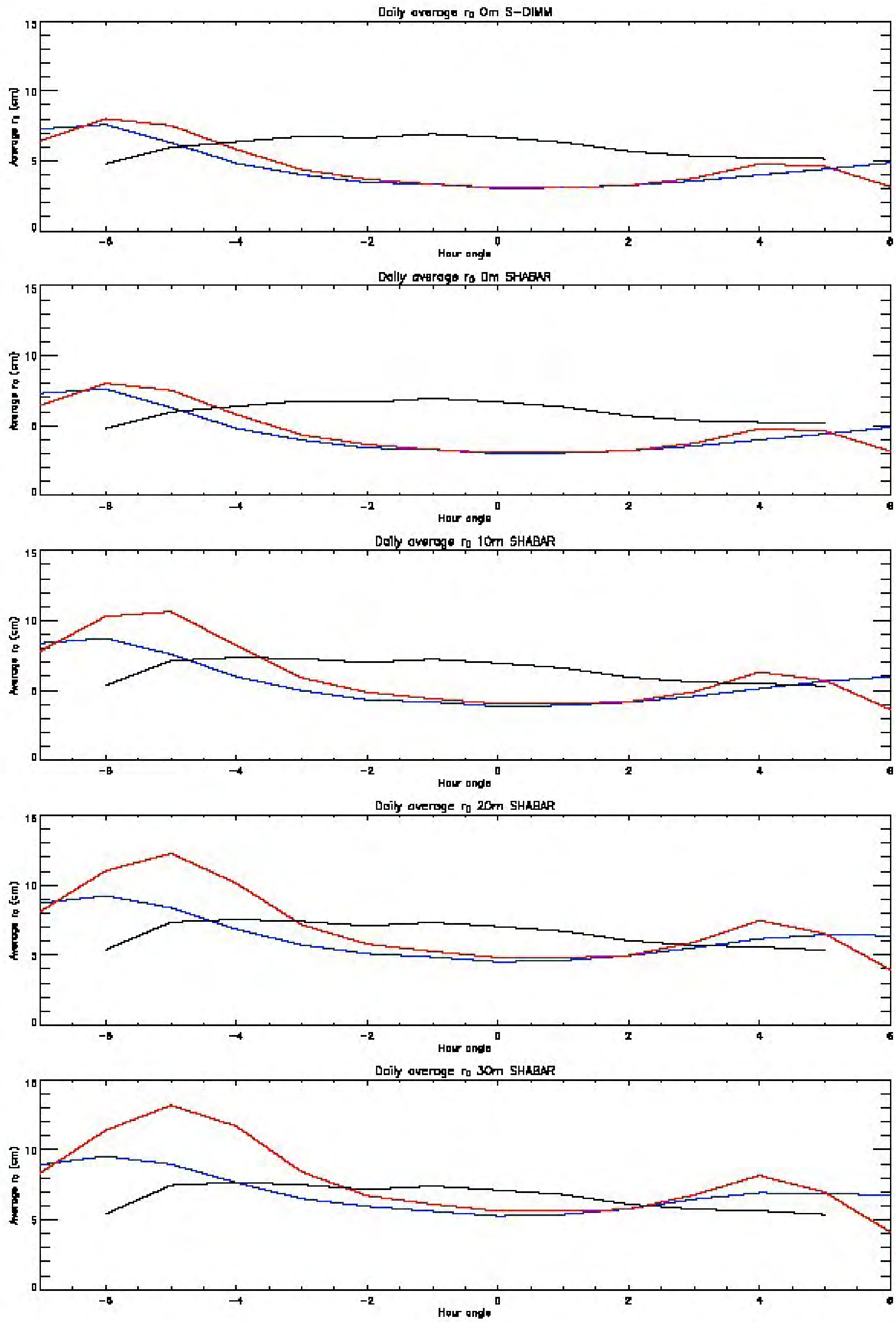


Figure 10.12: The average value of the valid measurements of r_0 as a function of hour angle. Black: Big Bear; red: Haleakala, blue: La Palma. Top to bottom: S-DIMM data; SHABAR at 8 m above the ground; 18 m; 28; and 38 m.

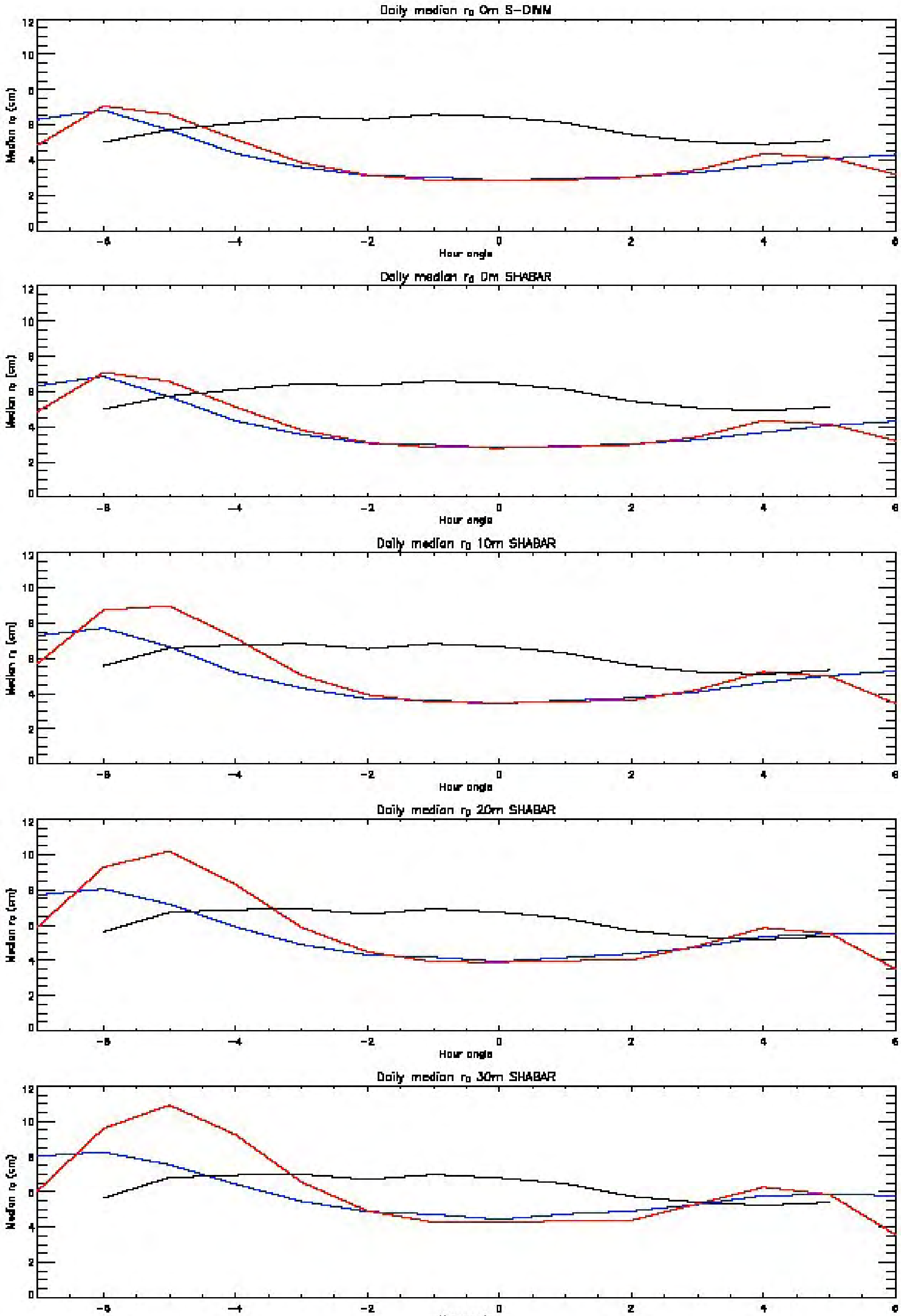


Figure 10.13: As figure 10.12, but showing the median value of r_0.

10.3 CLEAR TIME

The clear time fraction (CTF) estimated for the three sites is shown in table 10.8, using the two cases of treating the instrument flags:

- Case 1: With instrumental flags considered as cloudy points
- Case 2: With instrumental flags considered as down time points

Also shown are the results of the GONG site survey (Hill et al. 1994) for Big Bear, Haleakala, and Teide (as a proxy for La Palma). The results for Case 2 agree well with the GONG measurements, while the Case 1 estimates are substantially lower. Note that Case 2 is the same approach that was used in the GONG analysis. In reality, it is likely that at least some of the flagged points were indeed cloudy, so the values from the two cases provide lower and upper limits.

Table 10.8: Clear Time Fractions

	Big Bear	Haleakala	La Palma
CTF, ATST, Case 1	0.465	0.574	0.475
CTF, ATST, Case 2	0.712	0.619	0.639
CTF, GONG	0.714	0.647	0.708

These fractions can be used to estimate the total annual number of clear hours at the sites. These can be corrected using the method of section 9.8. Table 10.9 shows the results.

Table 10.9: Estimated Annual Clear Time Hours

	Big Bear	Haleakala	La Palma
Case 1 Raw Hours	2375	2935	2427
Correction Factor	1.411	1.077	1.010
Corrected hours	1684	2725	2402
Case 2 Raw Hours	3638	3162	3265
Correction Factor	1.411	1.079	1.021
Corrected hours	2579	2931	3197

Figure 10.14 shows the average daily dependence of the clear time fraction at the sites.

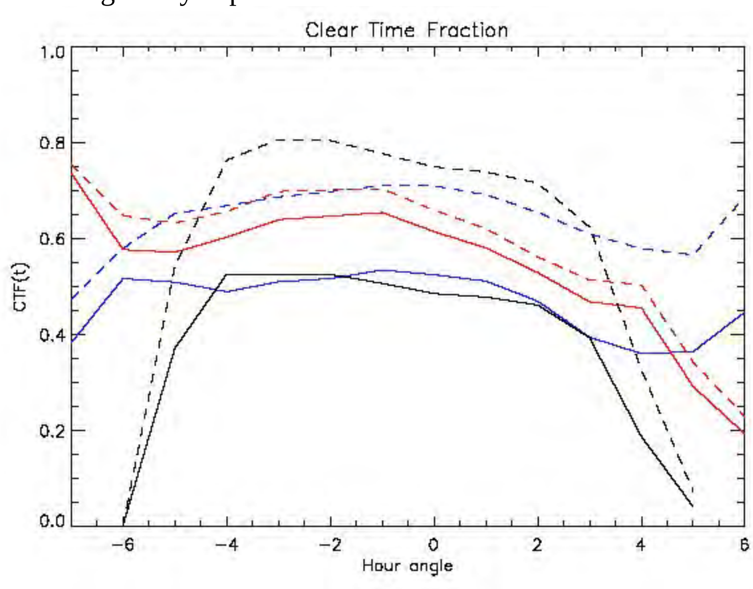


Figure 10.14: The daily variations of the clear time fraction, corrected for cloudy days from the log sheets. Black: Big Bear, red: Haleakala, blue: La Palma. Solid: Case 1, dashed: Case2.

10.4 SKY BRIGHTNESS

10.4.1 Results of the Global Calibration Analysis

The global calibration technique was applied on all the data that was taken from the three sites up through observation on 31 August 2004. The data from Haleakala spanned the largest number of calendar days since the SBM operated there the longest.

10.4.1.1 DISTRIBUTION OF SKY BRIGHTNESS AT EACH SITE

Shown in Figure 10.15 are the distributions of the sky brightness at each site for each wavelength. The scale is logarithmic, and the y-axis is simply the sum of the total number of hours from each site. This is not corrected by the number of days observed nor by any annual sunlight illumination factor. Because the total number of days from each site which is used in this plot is about 200 days, the plots from the three different sites can be compared in a general way.

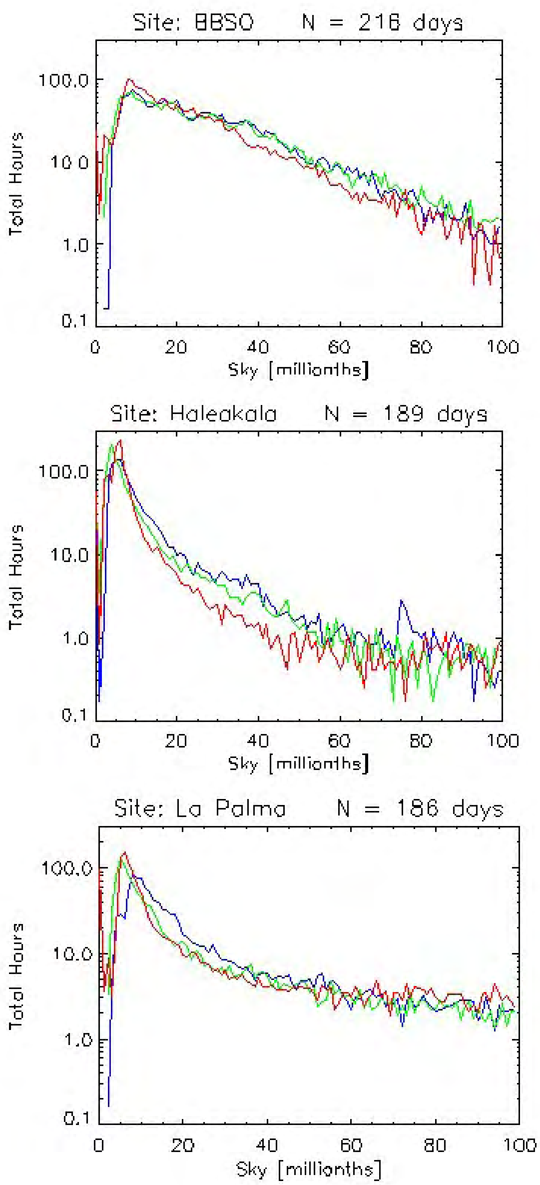


Figure 10.15: Distribution of sky brightness measurements for each site for each wavelength. Blue: 430 nm, green: 530 nm, red: 890 nm.

The distributions of sky brightness at Haleakala and at La Palma are similar, and both are different from the distribution observed at Big Bear. The source of the long tail of bright sky values at Big Bear is not exactly known, but it is consistent with the fact that the atmospheric extinction measured at Big Bear is the largest of the three sites.

10.4.1.2 SAMPLES OF THE BEST SKY AT EACH SITE

Shown in Figure 10.16 are plots of the lowest sky brightness seen at each site during each day of SBM observations. The range of possible instrumental scattered light values is also shown on this plot. The Figure shows that Big Bear has the largest range of best daily sky conditions while Haleakala shows the most consistent best sky conditions during the SBM observing period.

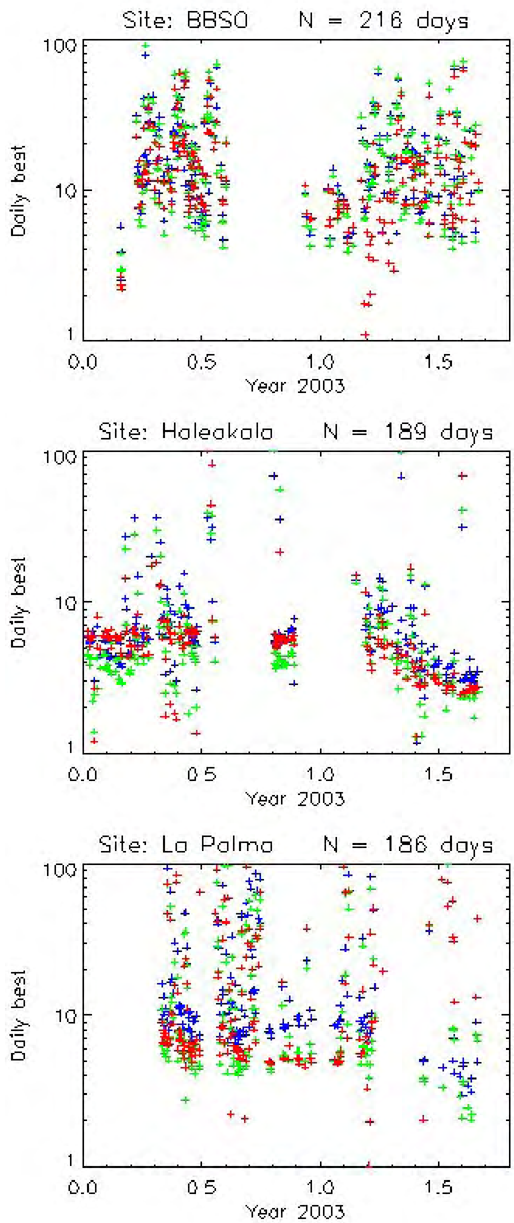


Figure 10.16: The lowest sky brightness value in each wavelength on each day of SBM observations at the three sites.

This plot is also useful to examine to detect any trends which might exist in the instrumental parameters which could affect the global calibration analysis. For example, if the SBM CCD gain degraded over time, or if the transmission of the sky light to the CCD were hindered by dust collecting on the filter, this figure would show a linear trend toward lower sky brightness as a function of time. Such a trend is seen in the Haleakala data taken in the year 2004. The best sky conditions seem to drop from about five millionths in early 2004 to about three millionths later in the year. This suggests that the assumption about constant SBM instrumental response may be incorrect at this level. The data from the other two sites has too much inherent scatter to see if this effect is present with those instruments.

The linear fits from the best coronal days selected for the instrumental scatter determination can also be used to measure the sky brightness, in this case the produce of the atmospheric scatter and the extinction (Φ κ) is measured, which represents the increase in the sky brightness in millionths per unit air mass. The values from these fits are shown in Table 10.10 listed as "N = x median".

Another way to examine the best sky conditions present at the sites is to compare the slope of the sky brightness versus air mass plots which were produced for the instrumental scattered light analysis. Shown in Table 10.10 are the values for this slope, equal to the produce of $\Phi\kappa$ in the previous equation. It shows that while a large range in values exists, the two mountain sites have darker sky (particularly at 890nm) than found at the Big Bear site, during the best days.

Table 10.10: Morning sky brightness per air mass (in millionths) for sample best days

Site – Date	450nm	530nm	890nm
Big Bear 15 May 03	13.97	12.71	5.06
19 May 03	10.47	8.49	1.39
24 May 04	8.17	6.05	2.35
22 Jul 04	0.91	-0.31	-1.65
04 Aug 04	10.45	8.97	5.34
N=86 median	9.65	10.56	8.95
Haleakala 8 May 03	3.79	2.87	1.24
15 May 03	2.43	1.75	0.78
19 Mar 04	3.37	2.38	0.82
8 Jun 04	2.23	1.40	0.33
10 Aug 04	1.65	0.99	0.19
N=104 median	2.06	1.54	0.81
La Palma 5 May 03	5.64	3.82	1.67
26 May 03	3.17	2.09	0.78
7 Jul 04	3.62	2.43	0.23
3 Aug 04	22.55	15.2	2.42
20 Aug 04	2.48	1.57	0.24
N=75 median	4.35	2.84	1.09

10.4.1.3 THE MEDIAN SKY AT EACH SITE

The entire SBM data set from each site in each wavelength was grouped into bins of 0.1 air mass, from an air mass of 1.0 to 4.0, and the median of each bin was taken. This can be used to examine the typical conditions at the site. If the daily variation in the sky brightness dominates the variation seen at the site, then we should see a linear trend in the sky brightness as a function of air mass as mentioned above. However, if the day-to-day variations dominate the daily variation, we may not see any trend with the sky brightness as a function of air mass.

Shown in Figure 10.17 is the median sky brightness as a function of air mass for the three sites for each wavelength. A linear fit is made to each set of points, and the fit coefficients are listed in Table 10.11. From these coefficients we can determine a value for the instrumental scatter (intercept) as well as the median sky brightness per air mass (slope). For the Big Bear data, the intercept values for the fits do not correspond well with the values previously computed for the instrumental scatter, and the sky brightness at 450nm seems to decrease slightly with air mass. It is likely that the temporal variations dominate the air mass variation in the data, and that we should not expect a simple relationship for this site. This is supported by the fact that when just the morning observations from Big Bear are analyzed in a similar method, the fit is much better; perhaps changing atmospheric conditions in the afternoon dominate the variations. The data from the other two sites does show linear trends in the sky brightness as a function of air mass, and intercept values that roughly agree with the expected instrumental scatter. It is likely that the slopes in these values then represent the median sky brightness conditions during the SBM observations at these sites.

Table 10.11: Fits to the median sky brightness versus air mass (intercept, slope)

Site	450nm	530nm	890nm
Big Bear	26.27, -0.78	22.44, 0.84	7.89, 6.55
Haleakala	1.83, 2.17	1.47, 1.64	3.39, 0.83
La Palma	-1.90, 10.34	-3.36, 9.58	1.84, 5.39

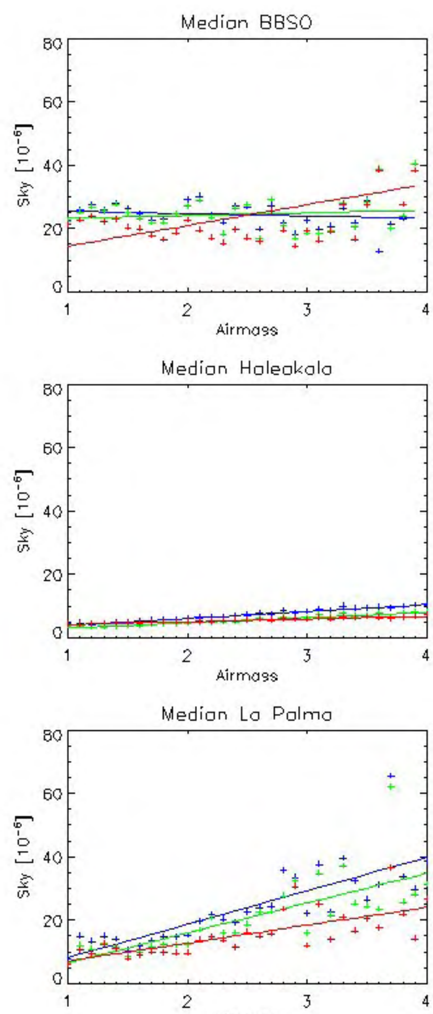


Figure 10.17: Fits to the median sky brightness binned in increments of 0.1 air masses.

10.4.2 Extrapolation from the IR requirement to measured values

10.4.2.1 MEASURED VALUES OF RADIAL SLOPE AND COLOR

In observations with good central neutral densities when the solar disk position can be determined the radial slope of the sky brightness can be measured. Here the sky brightness is fit with a power law in radial distance, $I_{sky} = I_0 (R/R_{sun})^{-\gamma}$. Shown in Figure 10.18 are the distributions of the measured radial sky brightness exponent from 2ND2 data from 2004 and from ND4 data in May 2003. The 2004 data from La Palma suffers from low counts and the power law fits are not very good.

The color of the sky brightness can be measured using a power law in wavelength as discussed before where $I_{sky}=I_0\lambda^{-\beta}$. This is probably more accurate when the local calibration technique is used, but is in theory possible for all the observations. The color power law exponent was calculated only for 2ND2 and early ND4 observations during the same periods as the radial slope calculations. The distributions of values are shown in Figure 10.19, and again the 2ND2 data from La Palma suffer from low counts due to a short instrumental exposure time. (Note: there are just 20 days during that time period).

Median values were computed from the distributions shown in Figures 10.18 and 10.19, and the values for these medians and an estimate of the error based on the width of the distributions is shown in Table 10.12. These values are used to compute the infrared sky brightness; this process of course assumes constant sky color and radial intensity behavior throughout the year.

Table 10.12: Sky radial and color power law exponents and scale factor

Site	Radial (γ)	Color (β)	$(5.45)^{\gamma}(.89)^{\beta}$
Big Bear	2.20+/-0.17	0.32 +/-0.4	40 +/- 9.0
Haleakala	1.03 +/-0.17	0.53 +/-0.4	5.4 +/- 1.2
La Palma	1.92 +/-0.57	0.51 +/-0.4	21 +/- 16

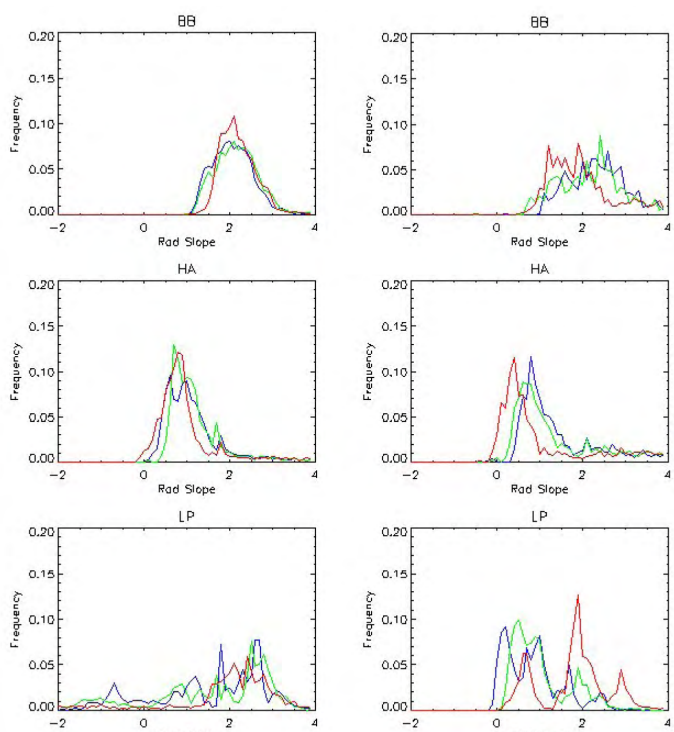


Figure 10.18: Distribution of the radial gradient for the sky brightness measured in 2004 (left column) with the 2ND2 occulter and in May 2003 (right column) with the ND4 occulter.

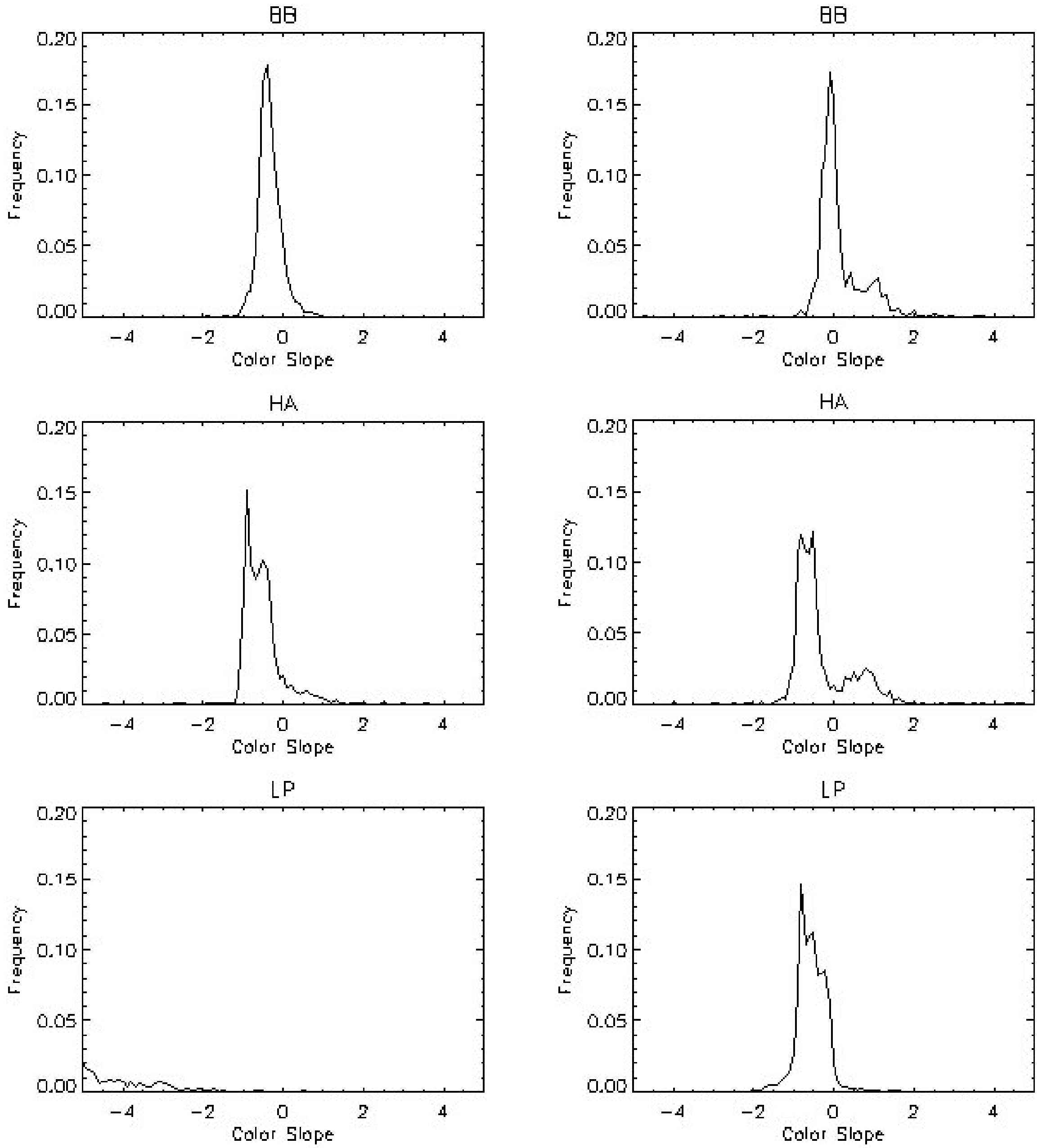


Figure 10.19: Distributions of the exponent of the color power law for the mean sky brightness for the 2ND2 2004 data (left column) and the May 2003 ND4 data (right column). The sky brightness values in 2004 at La Palma with the 2ND2 filter suffered from very short exposure times at 890 nm and give spurious power law fits.

10.4.2.2 THE INFRARED SKY BRIGHTNESS EXTRAPOLATED TO 1.1R_{SUN}

Shown in Figure 10.20 is the integrated distribution of the computed sky brightness at 1.1 solar radii at 1000 nm. As can be predicted from Table 10.12, the largest changes are seen in the Big Bear and La Palma distributions, whereas the Haleakala distribution is altered less, compared to the 890 nm data. The two dashed lines are produced by assuming that the Haleakala scale factor should be applied to the Big

Bear and La Palma data sets (rather than the scale factor computed in Table 10.12) and that the instrumental stray light at Big Bear at 890 nm is equal to the Haleakala instrument value and the La Palma stray light is 3.1 millionths at 890 nm. Both of these dashed lines then represent a best-case scenario for the extrapolation of the La Palma and Big Bear 890 nm sky brightness measurements.

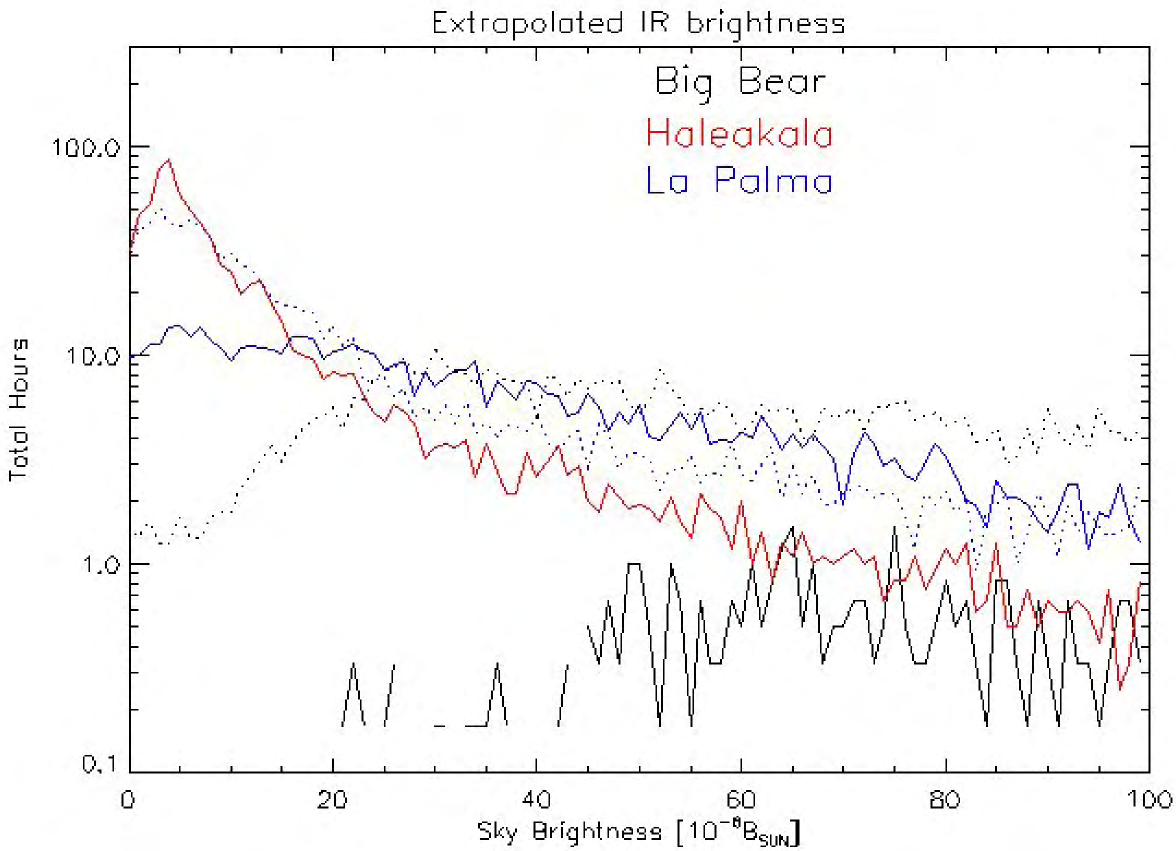


Figure 10.20: Sky brightness measurements from each site extrapolated from 890 nm to 1000 nm, and from about 6 solar radii to 1.1 solar radii. The units are in total hours from each site and are not corrected for instrumental down time or different durations of SBM observations at the sites. The solid lines represent the data scaled by the factors listed in Table 10.12. The dashed lines for Big Bear and La Palma represent "best case" extrapolation scenarios, where the Haleakala scale factor is used.

10.4.3 Comparison with Sky Brightness Goals

Only a simple correction for instrumental down time is applied here. Referring to Section 9.8, if the instrumental down-time is computed on a daily basis rather than by hour, the factor Nu_{tot} simplifies to just the total number of days that the instrument was up. To compute the annual hours at each sky brightness, we simply multiply the total number of hours by $(365./N_{up})$ where N is the number of days the SBM instrument was operational (including cloudy days) at each site.

In Table 10.13 the number of days where the instrument was operational at each site is shown, and the correction factor is computed.

Table 10.13: Annualizing facts for SBM observations

	Big Bear	Haleakala	La Palma
Span	03/2/25-04/8/31	03/1/3-04/8/31	03/4/23-04/8/31
Total Days N	554	607	497
SBM up N_{up}	356	260	283
SBM down N_{down}	198	347	214
Scale Factor ($365/N_{up}$)	1.025	1.404	1.290

Table 10.14 shows information about the number of images and the total observing time at each site. Note for most of the SBM observations, the SBM image cadence at Big Bear was 10 minutes, while at the other two sites it was 5 minutes.

Table 10.14: Other facts about SBM observations

	Big Bear	Haleakala	La Palma
N_{days}	216	189	186
N_{best}	86	104	75
N_{scans}	12759	15547	20108
N_{images}	51036	62188	80432
N_{hrs}	2126.5	1295.6	1675.7

A total of 193656 images were taken which comprised 29.75 Gbytes of raw data.

Figure 10.21 shows the integrated histograms for the annually corrected extrapolated infrared sky brightness at all sites. The dashed lines show the “best-case” scenarios for Big Bear and La Palma where the radial power law measured with the Haleakala SBM is used instead of the radial power law measured at those two sites. The point at sky brightness of 25 millionths and 480 annual hours represents the ATST requirements goal value, and the horizontal bar represents the error bar stated in the ATST requirements document.

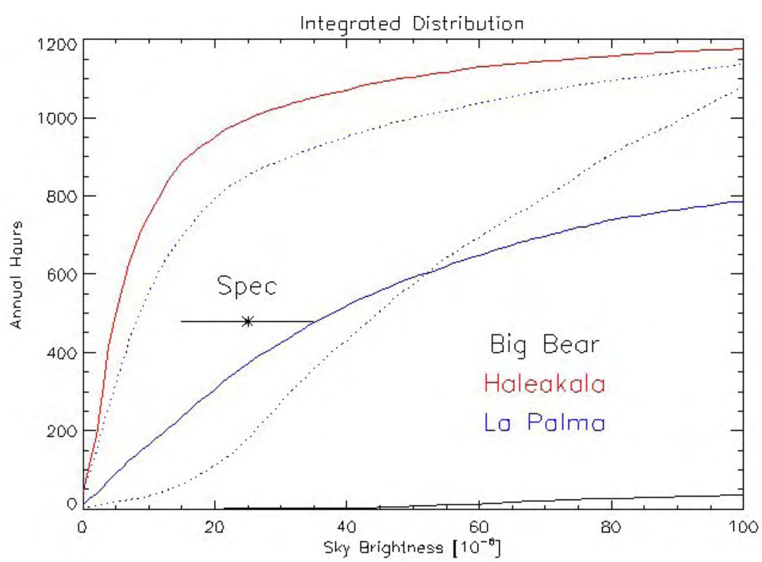


Figure 10.21: Integrated sky brightness distribution for each site after correcting for the instrumental down times. The number of annual hours at or below a given sky brightness is plotted for the extrapolated sky brightness at 1.1 solar radii at 1000 nm. For Big Bear and La Palma two lines are shown; each solid line extrapolates to the IR value using the sky brightness radial power law measured using the SBM at the site and the dashed line extrapolates using the power law measured at Haleakala. The dashed lines are considered a best-case scenario for these two sites.

The figure shows that the Haleakala site exceeds this spec; the La Palma site meets the spec or exceeds the spec depending on the radial exponent which is used, and the Big Bear site does not meet the spec even with the most optimistic radial extrapolation.

Table 10.12 lists the median values for the measured radial slope from each site. Each site meets the ATST spec of 0.8 for the radial slope power law.

The number of continuous four hour blocks was estimated as simply the number of days with one four hour block of sky brightness at or below the level of 25 millionths at 1000nm at 1.1 Rsun. The actual criterion was that the sky brightness for 95% of the time samples within the four hour block were below the threshold value, so if 3 points were actually above the threshold the block would still be counted. It is possible that one day would contain two four-hour blocks, but this is unlikely given the strong dependence of the sky brightness on hour angle. The range of values shown for La Palma and Big Bear are computed based upon the two types of radial extrapolation which were used. Finally the number of blocks observed with the SBM was multiplied by the factors for each site to compute the annual number of blocks. Both Haleakala and La Palma meet the goal of having 40 continuous 4-hour blocks annually, and Big Bear does not meet this goal.

Table 10.15 shows some median values for each site.

Table 10.15: Median values

	Big Bear	Haleakala	La Palma
Time Start	03/2/25	03/1/3	03/3/23
Time End	04/8/31	04/8/31	04/8/31
N days	216	189	186
N valid pts	51036	62188	80432
Median, 1000nm, 1.1Rsun	96-800	5.8	31-114
Median, 890nm, 6Rsun	20	1.1	5.4
Median, 530nm, 6Rsun	21	2.4	11
Median, 450nm, 6Rsun	19	3.1	14
Median β	2.20	1.03	1.92
Median γ	0.32	0.53	0.51
Median 940nm κ	0.12	0.10	0.09
Corrected Annual Spec Hrs	2 – 198	1004	384 – 861
Number Annual 4hr blocks	0 – 4	212	62 – 107

10.4.4 Caveats and Future Work

Several more items could be investigated using this data if given enough time.

10.4.4.1 COMPARISON WITH VISUAL PHOTOMETER DATA

The visual sky photometers (VSP) built by Evans were shipped to the three sites and data was taken during SBM observations. The idea was to directly compare the visual observations (taken in the green) with the 530nm channel SBM observations taken at the same time. The original idea was to verify that no blunders were being made in the SBM sky brightness measurements, and that "coronal" conditions as measured with the SBM corresponded to "coronal" conditions measured with the Evans VSP.

While being shipped to the various sites the VSP instruments suffered misalignments, and although a cross-calibration was performed before the instruments were shipped, the shipping misalignments probably undid the calibration efforts. Data taken at Haleakala and BBSO shows that the VSP instruments measure different sky values than the SBM, but that the sky intensities are correlated. Data taken from La Palma does not show such a correlation, and it is thought that the VSP shipped to La Palma has become seriously misaligned.

While the sky brightness measurements with the SBM and VSP are correlated, unfortunately they show different slopes. Figure 10.22 shows that when the SBM measures an increase in the sky brightness, the VSP only measures half of that increase. Figure 10.23 shows that during the calibration of the SBM instrument at Haleakala, the relationship was inverted.

The current conclusion is that the VSP measurements have trouble from possible misalignment of the instrument, and from the visual nature of the measurement. It is felt that the SBM data is much more reliable and certainly more linear in its response to the true sky brightness. The comparison between the VSP and SBM doesn't show any blunders, and for a detailed comparison linking the SBM data with historical VSP records at these sites, a much more detailed cross-calibration of the two instruments is required.

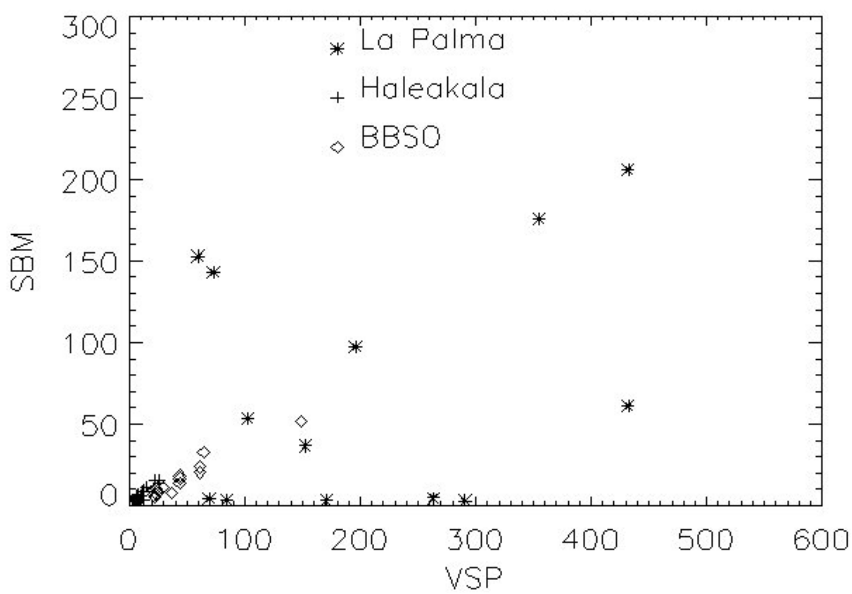
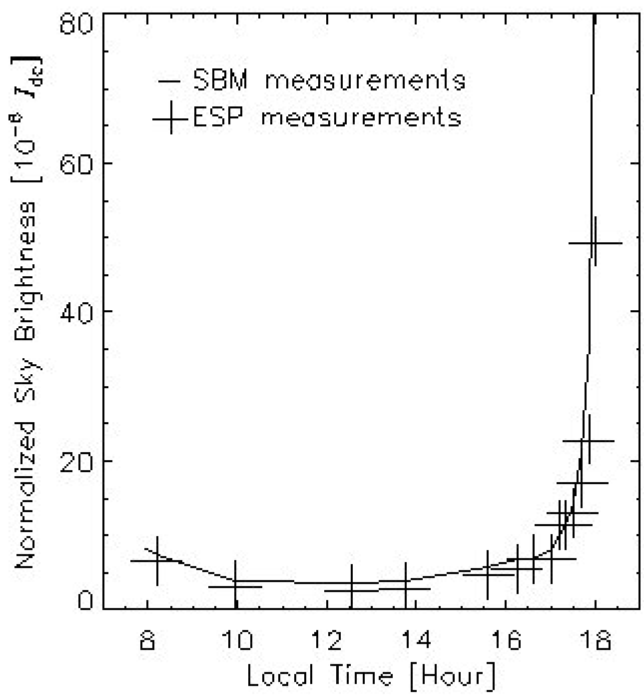


Figure 10.22: Comparison between the VSP and SBM sky brightness measurements at the three sites.



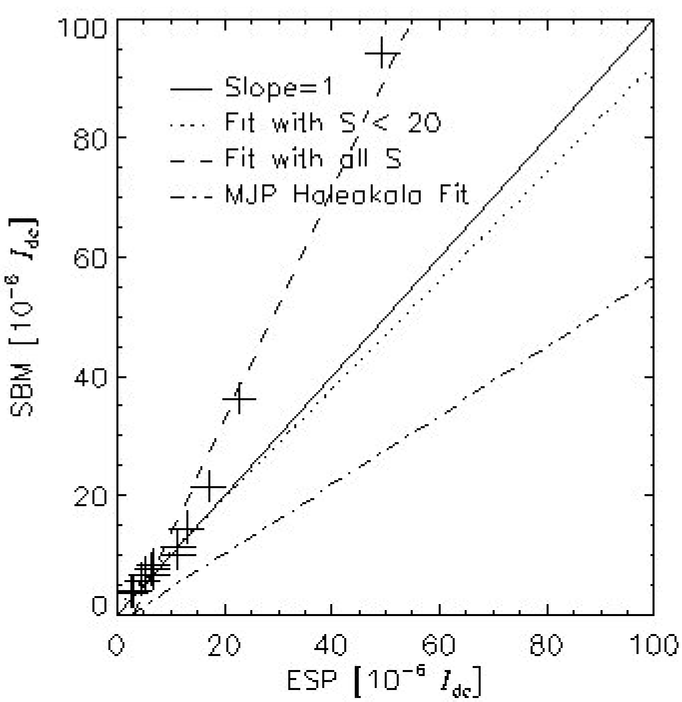


Figure 10.23: Original calibration data from SBM and VSP (listed as ESP on the x-axis) during early tests at Haleakala. The relationship shows a slope=2 value, whereas data taken in 2004 shows a slope=1/2 value. It is thought that the VSP measurements are very sensitive to instrument alignment and observer bias.

10.4.4.2 SBM INSTRUMENTAL SCATTERED LIGHT: POST EXPERIMENT TESTING AT HALEAKALA

A study of the instrumental scattered light after the experiment is complete at one site would help to confirm the stray light values. The instruments should be shipped to Haleakala, where apparently the most consistent sky conditions are found, in order to make a side-by-side test of the SBMs.

The radial variation of the instrumental scattered light has not been accounted for when computing the radial power law values. Although this was originally done in the SBM data analysis paper, the value obtained for Haleakala at that time was about 0.2, as compared with a value near 1.1 for this study. This value has a large bearing on the extrapolated, near sun IR sky brightness which is computed. An addendum to this report is in preparation discussing this issue. A cross-comparison test would help to solve this problem.

The color power law obtained in this study is also not corrected for instrumental stray light. While this has a much smaller influence on the extrapolated near sun IR sky brightness, it would be good to understand this parameter more fully. Again, cross-calibrations at a site with consistent sky brightness conditions would help.

10.4.4.3 SECOND ORDER ANNUAL CORRECTION

The ATST site survey seeing data has been corrected with a second order annualization routine that is more detailed than the values used herein. The sky brightness measured at the sites is a very strong function of air mass, and therefore time of day, so there may be correlations between the observing window at each site and the sky brightness there. A second order correction would hope to remove that correlation from the prediction of the annual hours of sky brightness.

Figure 10.24 shows plots of the measured sky brightness as a function of hour angle at each site, and also the number of observations from each site at each hour angle (the data is binned in hour angle bins of width 1.0). A more detailed analysis of this data using this relationship would help.

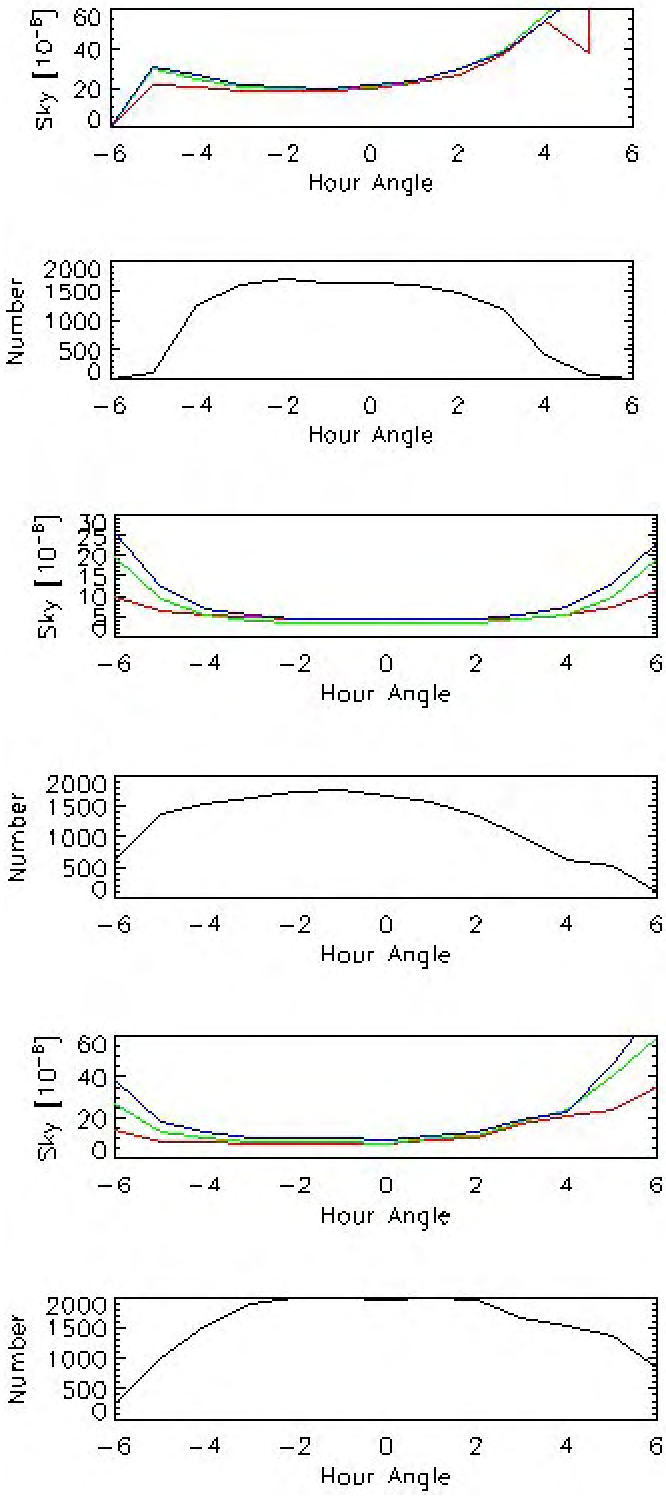


Figure 10.24: Presentation of the sky brightness as a function of hour angle from each site shown for all three wavelengths. The measured sky brightness is a strong function of hour angle (due to changing air mass). Below the colored graph in each case is the number of observations in each hour angle bin from the sites. From the top the sites are BBSO, Haleakala and La Palma.

10.5 WATER VAPOR

A simple proxy for the water vapor absorption is computed for the May 2003 and the 2004 2ND2 filter data. The extinction at 890nm was simply subtracted from the extinction value at 940 nm; this procedure differs slightly from the previous procedure used for the six-site study by the small factor of 1.054^{α} where α is the power law exponent for the extinction versus wavelength behavior.

The distributions of this extinction difference are shown in Figure 10.25. As with the sky brightness color power law exponent, the 2004 2ND2 distribution for the La Palma water absorption significantly varies from the 2003 La Palma distribution. It is ignored due to the fact that there are low counts in the 890 and 940 nm 2ND2 La Palma data, and that there are only 20 days of observations. Only the May 2003 data is used for the La Palma median calculation, which is shown in Table 10.15 along with the median values for the other sites.

It is not a simple feat to compute the atmospheric precipitable water vapor from this water absorption factor. There is a non-linear relationship between the two values, and this must be modeled with atmospheric absorption spectra and the SBM 940 nm filter profiles. This task has not yet been done.

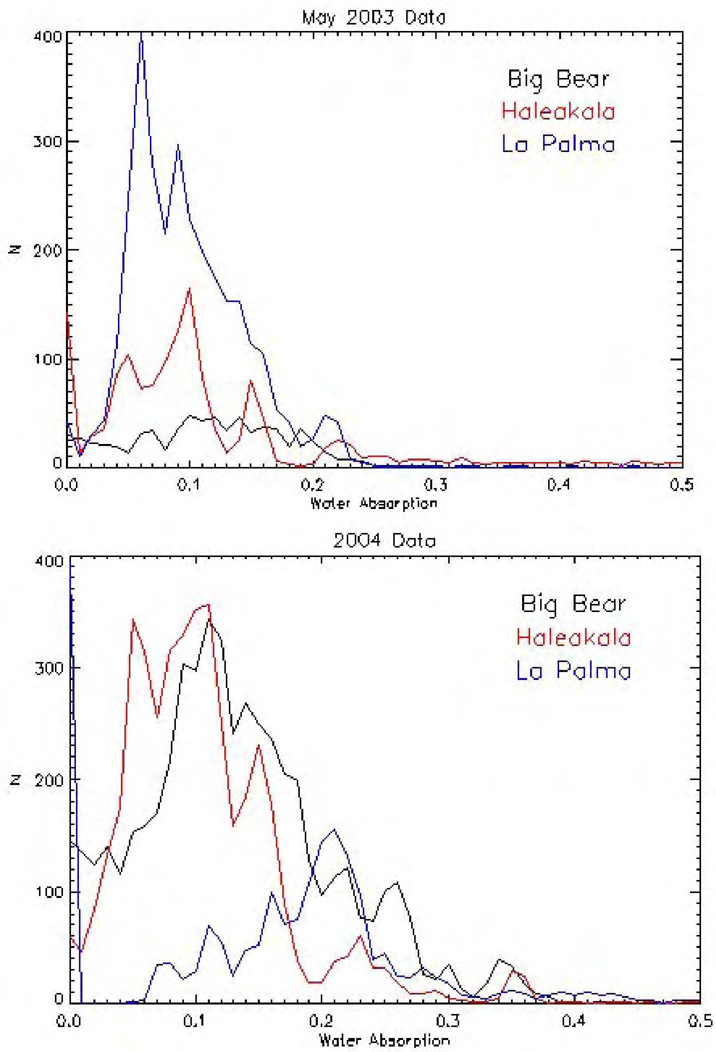


Figure 10.25: The distribution of water absorption coefficients at the three sites for the ND4 2003 data and the 2ND2 2004 data. The low counts in the La Palma 2ND2 data likely explain the strange distribution for that data.

10.6 DUST

The dust counter obtains a sample every 10 minutes. These numbers have been analyzed to provide the statistical distribution for each of the five particle sizes at all six sites. The detailed distributions are provided in Appendix 13.14. The medians are contained in table 2 in the Executive Summary. Figure 10.26 provides an example of the temporal behavior of dust during August 2003 at Big Bear.

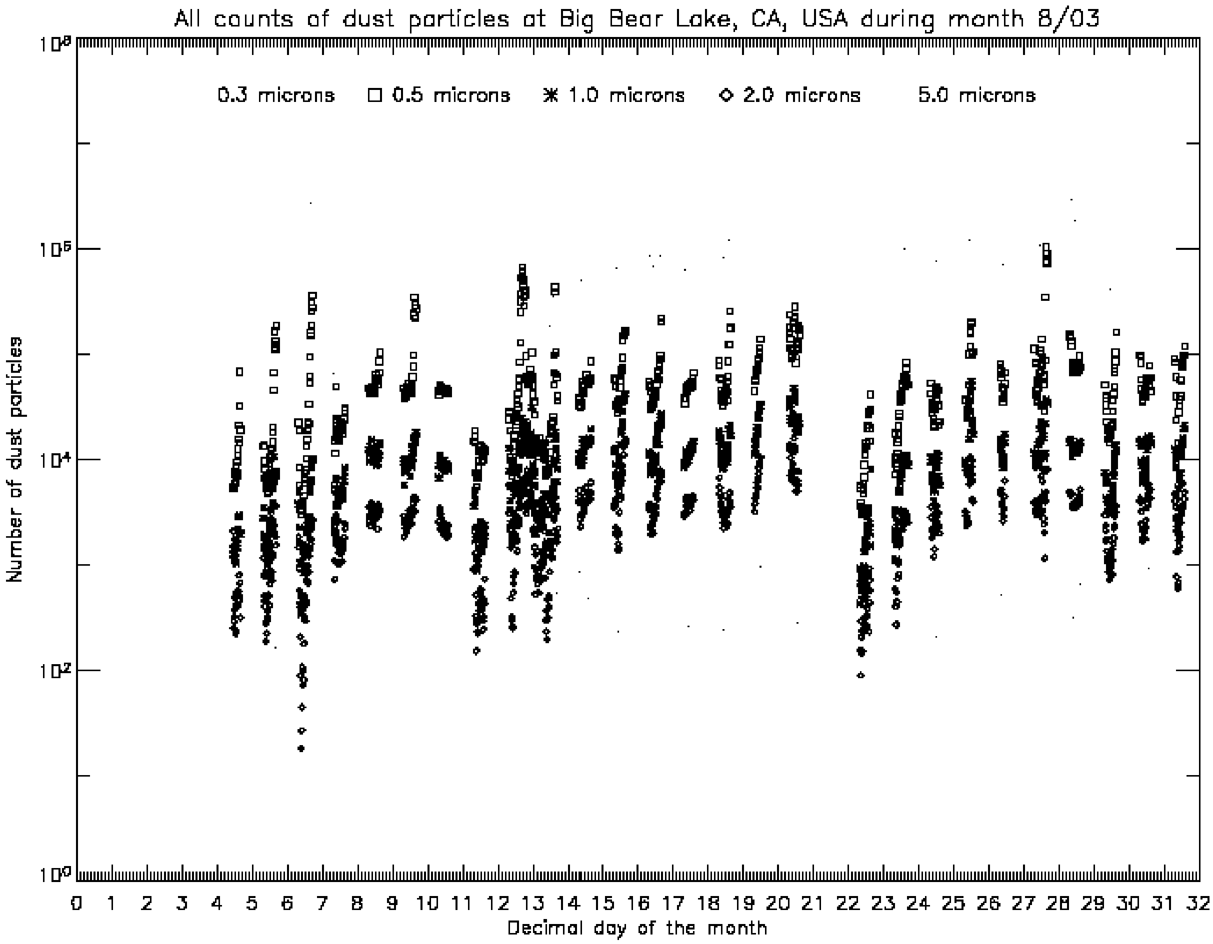


Figure 10.26: An example plot of the dust counts during August 2003 at Big Bear.

10.7 METEOROLOGY

Detailed weather results can be found in Appendices 13.12 and 13.13. Here we present an overview summary of the median quantities.

	Big Bear	**Haleakala**	**La Palma**
Median wind Speed (m/s)	4.7	4.5	3.6
Maximum wind gust (m/s)	26	53	25
Median wind direction azimuth (0: N, 90: E)	247	292	247
Median ground temperature (F)	62	57	51
Median tower temperature (F)	57	52	51
Median temperature gradient (top-base) (F)	-5	-4	0

10.8 CONCLUSIONS

The ATST site survey is one of the few comparative studies of solar site characteristics to be carried out with consistent instrumentation and analysis methods. It incorporates a new technique of combined differential image motion and scintillation measurements to estimate the seeing and the structure function over a range of heights. The survey also includes a multi-band miniature coronagraph to estimate sky brightness and water vapor content.

This effort has produced a considerable data base of information on the six sites tested. While some issues remain concerning the reliability of the seeing analysis method and the length of time spanned by the survey, the ATST Site Survey Working Group believes that the information in this report will provide useful input to the ATST site selection process

11. ACKNOWLEDGMENTS

This survey is a substantial undertaking, involving approximately 50 people. Their names are mentioned in the list of contributors, the Site Survey Working Group section, and the technical staff sections. In addition to those dedicated people, the ATST SSWG would like to thank the Big Bear Water District Board, the Dixie National Forest Service, Dan Weedman, Gloria Koningsberger, Ed Seykora,, Goran Scharmer, and Rob Rutten.

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13. APPENDICES

13.1 SEEING INSTRUMENTATION PAPER (EXP. ASTRON,)

13.2 CN2 ANALYSIS REPORT (RPT-0014)

13.3 HECTOR'S INTEGRAL

13.4 CRANE TEST DETAILS

13.5 HALEAKALA STELLAR DIMM DATA

13.6 SBM INSTRUMENTATION PAPER

13.7 SBM ANALYSIS PAPER

13.8 VSP CALIBRATION

13.9 QUICK-LOOK PLOT EXAMPLE

13.10 LA PALMA HEIGHT COMPARISON

13.11 DEPENDENCE OF SEEING ON SEASON, TIME OF DAY, WIND SPEED, WIND DIRECTION

13.12 WEATHER STATISTICS

13.13 HIGH-ALTITUDE WINDS

13.14 DUST STATISTICS

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APPENDIX P

Federal Highway Administration
Haleakalā National Park
Road Report

HALEAKALA HIGHWAY
HALEAKALA NATIONAL PARK
MAUI, HAWAI'I

PAVEMENT/DRAINAGE CONDITION INVESTIGATION, DISTRESS IDENTIFICATION AND RECOMENDATIONS

Report # HALA 3-2-2009

March 2, 2009(Revised April 2009)

Prepared by: H. R. Marquez, Quality Assurance Specialist

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1.0 INTRODUCTION

This report documents the follow-up comprehensive investigation to a previous pavement condition investigation report for the Haleakala Highway within the park boundary of Haleakala National Park. That report was entitled, *Pavement Condition Investigation, Distress Identification and Recommendations, dated May 01, 2006 prepared by* H. R. Marquez, Quality Assurance Specialist, FHWA/PWT. Some information contained in this report as needed, has been duplicated and updated from the 2006 report based on the information gathered during this investigation.

The purpose of this investigation was to:

- Perform a visual evaluation of the existing pavement condition
- Perform drainage structures evaluation as it pertains to exisiting damage and condition of existing structures including "cover" over existing drainage structures.
- Perform physical sampling and testing of existing pavement and underlying materials
- Determine thickness and strength of existing pavement structural section
- Assess the potential damage that could result from planned construction of the Advanced Technology Solar Telescope (ATST) with respect to associated construction traffic on the Haleakala Highway within the park Boundary as described in subpart **1.2 Advanced Technology Solar Telescope(ATST) project**
- Evaluate and assess the cause for present pavement failures and distresses---water pumping and water bleeding at numerous locations
- Review available information from previous roadway work

1.1 Haleakala National Park

Haleakala, originally part of Hawaii Volcanoes National Park, was re-designated as a separate entity in 01 July 1961. Haleakala National Park was designated an International Biosphere Reserve in 1980. As of 9/30/2008, Haleakala NP consists of 33,230.53 acres: 33,222.45 acres of Federal Land and 8.08 acres of Non-Federal Land.

Access to Haleakala National Park is via State Highway 377 and 378 also denoted on route maps as the Haleakala highway. The Haleakala Highway originates approximately 1.5 mile southeast of Kahului, Hawaii off of state highway 36, Hana highway. The Haleakala highway designation at this point is highway 37. The route traverses south to southeast to the junction of SH 37 and SH 377. At this point the route traverses north to south and is designated as state highway 377 to the junction of SH 377 and SH 378. Then the route traverses southeast to Haleakala National Park. The route within the park is sometimes referred to as the Haleakala Crater Road.

The roadway within the park is a two-lane highway approximately 22-foot wide with steep grades (5%-7%) and nine (9) switchbacks. The road was originally constructed between 1933-1935 and has under gone numerous reconstruction phases since then consisting of roadway widening, installation of metal and concrete box culvert extensions, pulverization and overlay of existing bituminous surfaces with Hot Asphalt Concrete Pavement and chip seals. A chronologonical history of roadway construction is summarized in **Table 1.**

For the purposes of this report, the mile posts (MP) are in reference to the junction of State Hwys. 377 and 378 as MP 0.00.

The MP designation at the north entrance to Haleakala National Park is at MP 10.3, and an elevation of approximately 6852 feet above sea level. The south boundary at the Haleakala Observatories is at MP 21.2, and an elevation of approximately 9970 feet, see attached map **Appendix A**

An effort has been made to denote the MPs in this report to previous reports and roadway reconstruction. The MP may deviate slightly.

1.2 Advanced Technology Solar Telescope (ATST) project

The proposed project is the development and associated construction by the National Science Foundation(NSF) of an ATST project within the 18.166-acre University of Hawaii' Institute for Astronomy(IfA) Haleakala High Altitude Observatories(HO) site at the summit of Haleakala, County of Maui, Hawaii.

The proposed construction would include the construction of an observatory facility including a telescope, its piers and rotating platforms, telescope enclosures, support building, parking facilities and modifications to the existing facility. The entire facility would include approximately 40,500 square feet of new building space.

The earliest possible construction start would be during fiscal year 2009. Excavation and construction of the foundations and piers would take place in the first year of construction(2009) and erection of the enclosure and building structures would follow in the second, third and fourth years (2010 to 2013). Once the enclosure is in position the telescope mounts would be installed and the majority of the remaining work would progress toward the end of construction. The site would be fully operational by 2015. The dates as noted are best estimates at the time of this report furnished by NSF. The estimated construction schedule will be approximately 7 years.

1.3 Chronology of Roadway and Structures.

During this investigation a historical records review was performed to document the age of highway construction phases and features on the route.

The 10.6-miles of highway within the park boundary were designed by the Bureau of Public Roads (BPR) between 1925 and 1933. Road construction began on October 13, 1933 and was completed in December of 1935. The contractor was E. E.Black, Ltd. Of Honolulu, Hawaii at a cost of $367,068.32.

In 1999 the 10.6-mile section of the Haleakala Highway located within the park boundary was documented by the Historic American Engineering Record (HAER) program in the report titled “Haleakala Highway, HAER No. Hi-52”. The period of significance for the historic district extends from 1933 to 1966. The proposed historic district includes roads, bridge, trails, walkways, retaining walls, culverts and other roadway features from1933 to 1966.

As noted in the following **Table 1** the route has undergone widening, rehabilitations and numerous overlays of various types over its 74 year use period.

Historical records describe rehab work as follows:

In 1979/80 road reconstruction involved a pavement consisting of 1-1/2" of Hot Asphalt Concrete Pavement (HACP) over 2-3/4" of Asphalt Stabilized Base.

Beginning in the early 90's NPS observed that the 12 year or so old pavement rapidly deteriorating, and implemented a series of repair projects.

1. Between the entrance boundary and park HQ, NPS pulverized existing road 4+ inches deep, recompacted and paved with 3" HACP, then a couple of years later added another 1-1/2". From park HQ ahead, NPS excavated failed areas of the road 12" deep, then filled the excavations with Asphalt treated base (HDOT spec) and then overlaid the entire road with 1-1/2" HACP. That treatment was used to the White Hill parking area.

2. There were areas (miles long around Halemau Trailhead) were the failed areas were so extensive that NPS did not excavate, patch and overlay, but instead pulverized 4" deep and resurfaced with 3" AC.

3. The pulverizing and resurfacing was also used on the Red Hill spur.

Review of the historical data for the Haleakala Highway is summarized in the following **Table 1**. The dates may deviate slightly from the time the project was designed to when it was actually constructed.

TABLE 1…..CHRONOLOGY HISTORY OF ROADWAY CONSTRUCTION						
YEAR	**DESCRIPTION**		**STATION TO STATION**	**Length (mi.)**	**MP TO MP**	**Thickness**
1933-1935	Began October 13, 1933, completed December 1935	• Grading, drainage, surfacing • Concrete Boxes constructed, 11 each • Metal culverts • Stone Retaining walls	0+00(Park. Bdry) – 115+16.5Bk 123+28.5Ah-569+70.6	10.643	10.3 to 20.93	4-inches Loose measured bituminous surface treatment
1934	Bridge constructed	Completed August 1934.	85+15 to 85+50	35 feet	11.9	-----
1952	-----	Seal Coat	-----	-----	-----	-----
1979-1980	------	1 ½”-Overlay	0+00 – 490+83	9.296	10.3 to 19.60	2 ¾” Asphalt Stabilized Base(AS) overlay
1979-1980	-----	1 ½”-Overlay	49+50 – 490+83	8.359	11.2 to 19.60	1 ½ “ Hot Asphalt Concrete(HACP) overlay
1993-1994	-----	Overlay	0+00 -49+50	0.938	10.3 to 11.24	3.0” Hot Asphalt Concrete(HACP) overly
1993-1994	-----	Overlay	49+50 – 465+00	7.869	11.24 to 19.10	1 ½” Hot Asphalt Concrete(HACP) overlay
1999-2000	-----	Overlay	Park Brdy to Red Hill	9.296	10.3 to 20.9	1 ½” Hot Asphalt Concrete(HACP) overlay
1999-2000	-----	Chip Seal	-----	-----	10.3 to 18.5	Application of chips
2007	-----	Lava Tube Bridge work	235+00	0.055	14.8	-----
2009	-----	Chip Seal(PLANNED)	-----	-----	18.5 to 20.9	Application of chips

1.4 Weather

The weather condition on this route within the park varies significantly over the short 10.6 mile section. At the summit of Haleakala temperatures are unpredictable and commonly range between 40°F and 65°F, but can drop below freezing at anytime of year with the wind chill factor. During this investigation ice was noted at numerous locations above MP 12.5 where water was present.

The vegetative zone that the road traverses through is subalpine scrublands dominated by pukiawe, mamane, pilo, ‘ohelo and ‘a’ali’i with alien grasses mixed in with the native shrubs. Annual rainfall ranges from 120 inches to 400 inches or more.

The following **Table 2** is a summary of monthly high/low temperatures and average precipitation for each month including annual average temperatures and total precipitation. The weather station readings are from on the NOAA website near the summit of Haleakala at 9538 ft (0.71°N 156.24°W).

TABLE 2…..WEATHER DATA													
Descr.	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Avg High - °F	59.8	59.0	59.4	60.6	62.3	65.7 High	65.5	66.1	65.0	64.3	62.8	60.7	62.6
Avg Low - °F	41.9	41.4 Low	41.6	42.6	43.9	46.5	47.2	47.5	46.3	46.0	45.3	43.4	44.5
Avgas Précis (in)	8.85	6.78	7.15	4.92	2.10	1.20	2.42	2.79	1.87	2.72	5.67	7.32	53.79

2.0 INVESTIGATION

This investigation was performed between January 05, 2009 and January 12, 2009 by H. Rick Marquez, Quality Assurance Specialist, Pacific Western Technology (PWT). The investigation consisted of visual and physical condition assessment of the existing pavement structure and visual inspection of the drainage structures.

2.1 Visual Pavement Condition Assessment

As was outlined in the previous report four distinct sections of pavement conditions were evident during the visual inspection of this route. The following **Table 3** summarizes those distinct sections and conditions, each focusing on the type and severity of surface distress observed. Note that the MP have been adjusted slightly from the previous report to more closely reflect the limits of the four sections as was determined by the current investigation.

TABLE 3…..VISUAL INSPECTION		
Section	**Mile Point(MP)**	**Comments**
1	**10.3 to 11.2** ***(0.9 miles)***	• With the exception of the area on the mainline directly in front of Park Headquarters very little pavement distress was noted in this section. The severity of fatigue and longitudinal cracking is very low. Very little transverse cracking was noted. A review of project historical records indicates that the area from station 49+50 to station 55+00 has experienced severe distress in the past and numerous locations have been sub excavated and patched prior to overlay. • The riding surface through this section is a chip seal on a Hot Asphalt Concrete Pavement.
2	**11.2 to 14.8** ***(3.6 miles)***	• This section exhibits water pumping and water bleeding at numerous locations of pavement fatigue cracking. The level of fatigue cracking is moderate to high at numerous locations throughout this section. The severity levels for water bleeding and pumping can not be defined because the amount and degree of water bleeding/pumping changes with varying moisture conditions and these conditions are random throughout this section. Water was visibly seeping or ejecting from beneath the pavement through cracks in the pavement at the time of this investigation. In most case, detectable deposits of fine material from the underlying support layers have been pumped up through the cracking and have stained the surface of the pavement and are clearly visible on the surface of the road**. (see attached photos).** • Transverse cracking was noted beginning at MP 13.0 to MP 18.5. • The riding surface through this section is also a chip seal on a Hot Asphalt Concrete Pavement.
3	**14.8 to 18.5** ***(4.3 miles)***	• Pavement distress through this section consisted mostly of minor longitudinal and transverse cracking and was quantified as low to moderate **(see attached photos).** . No pumping or water bleeding through the pavement was noticed through this section. • The riding surface through this section is also a chip seal on a Hot Asphalt Concrete Pavement
4	**18.5 to 21.2** ***(2.7 miles)***	• No pavement distress was evident. • This section of road was recently overlaid with new 1.5 to 2.0-inches HACP.

It is evident that the existing roadway does not have adequate drainage particularly in the area from MP 11.2 to 14.8 and this is contributing to the numerous failures that are occurring in this section. The roadway ditch flowline elevation in many instances is at or very near to the same elevation as the roadway pavement allowing water to enter the underlying materials very easily. The soils throughout the route are highly permeable allowing water to freely flow into the subgrade. In addition to poor drainage this section of roadway appears to receive more precipitation than the rest of the route. It is recommended that future rehabilitation work on this route address improved drainage measures particularly in this section.

2.2 Physical Pavement Investigation

Roadway physical investigations were performed as proposed between MP 10.3 to 21.2 in both the uphill and downhill lanes of the route.

The physical investigation consisted of:

1. Auguring through the existing pavement surface to determine thickness of pavement and base layer.
2. Obtain samples of underlying materials for testing to determine soil strengths using California Bearing Ratio test method--Soaked
3. Perform Falling weight deflectmeter analysis

The Falling Weight Deflectometer (FWD) survey was performed on January 5 & 6, 2009 by HDOT using their Dynatest machine. Auguring through the existing surface for thickness measurements and sampling was performed by Island Geotechnical, Maui.
Testing of soil samples was performed by Geolabs, Maui

2.2.1 Pavement and base layer thickness

Pavement thicknesses are summarized in **Table 4**. The thickness indicated in this table indicates **<u>total thickness</u>** of bituminous treated materials measured at each hole location.

Table notations:

- Site = numerical numbering of MP locations
- Location, (MP = mile point),
- Elevation,
- Lane, (U = uphill, D = downhill),
- Asphalt Cement Thickness(AC),
- California Bearing Ratio(CBR),
- Plasticity Index(PI),
- S = indicates a soil sample was taken at this location.

Soil classifications were performed on the soil sample and classified based on the American Association of State Highway Testing Officials (AASHTO) and the Unified Soil Classification System (USCS) soil classification methodology. A copy of the AASHTO and USCS classifications tables are included in **Appendix D.** Sites noted in the table with an astric (*) denotes sample locations and test results from previous investigations.

The values indicated in the AC-Thickness column of table 4 are an accumulation of bituminous materials that have been placed on this route since the original highway construction was completed in1935. Historical records indicate that the original bituminous materials were placed on native subgrade material and referred to in historical records as **"surfacing with treated crusher-run base course".**

During initial construction in 1933 a crusher was placed onsite at station 160+00 to produce finishing and surfacing material. All surfacing material was produced from rock quarried on site by widening rock cuts uniformly along the roadway. This was verified during the auguring performed on this investigation, no evidence of base course was encountered; however there did appear to be varying amounts of screened material under the bituminous layer. It is assumed this material was produced for finishing subgrade prior to placing bituminous layer.

During the auguring operation the majority of the sample holes encountered either bedrock or in fill areas encountered large rock at a depth of 15 to 24 inches.

TABLE 4…..SUMMARY OF THICKNESS, CBR & SOIL CLASSIFICATIONS										
Site	**MP**	**Elevation (feet)**	**Lane**		**Thickness (inches)**	**CBR**	**PI**	**Classifications**		
			U	**D**	**AC**			**AASHTO**	**USCS**	
1*	10.33	6746				45	36	A-2-7(0)	GP-GM	**SECTION 1, MP 10.2 TO 11.2**
1	10.5		U		8					
2	10.5			D	8					
2*	10.58	6816							SP	
3	10.6		U		8					
4	10.8			D	7					
5	11.0(S2)		U		8	6.7				
6	11.2		U		5					**SECTION 2, MP 11.2 TO 14.8 SECTION WITH HIGHEST LEVEL OF PAVEMENT DISTRESS**
13*	11.26	7035							SM	
7	11.3			D	7					
8	11.4		U		5.5					
3*	11.47	7078					15		SP	
4*	11.77	7159							SM	
9	11.8(S3)		U		5.5	51.5				
10	11.9(S4)			D	6.5	8.0				
5*	11.95	7199				25	NP	A-1-a(0)	SP	
11	12.1		U		5.5					
33*	12.19	7264							SM	
12	12.2			D	6.5					
13	12.4(S5)		U		5.5	4.7				
6*	12.46	7338							SM	
14	12.5			D	6.5					
15	12.7		U		5.5					
16	12.8			D	6					
17	13.0		U		5.5					
7*	13.15	7488					11		SP-SM	
18	13.4			D	6.5					
19	13.5		U		6.5					
20	14.0(S6)			D	6					
21	14.0(S6)		U		6.0	5.9				
10*	14.13	7801				45	8	A-2-5(0)	GM	
8*	14.27	7846							GP	
22	14.5			D	8					
23	14.5		U		7.5					
9*	14.77	7963							SM	
24	15.0			D	7					**SECTION 3, MP 14.8 TO 18.5**
25	15.0		U		8					
12*	15.20	8104							GP	
32*	15.38	8155							SM	
11*	15.49	8191							GP	
14*	15.83	8304							SP	
26	16.0		U		6.5					
27	16.0			D	7					
15*	16.65	8539					13		SP	
28	17.0(S7)		U		8					
29	17.0(S7)			D	8					
16*	17.13	8671				35		A-2-4(0)	SM	
17*	17.32	8738							SM	

18*	17.50	8783							SP	
20*	17.70	8829							GP	
19*	17.86	8876							SP	
30	18.0(S7)		U		8	87				
31	18.0			D	8					
31*	18.09	8947				20		A-1-a(0)	SP	
21*	18.35	9031						A-1-a(0)	GP-GM	
32	18.6		U		8					**SECTION 4, MP 18.5 TO 21.2**
22*	18.65	9120							SP	
24*	18.88	9182							SP	
33	19.0			D	7.5					
34	19.0		U		8					
23*	19.33	9310					NP	A-1-a(0)	GP	
30*	19.45	9352							GP	
35	19.5(S8)		U		7.5	31				
25*	19.75	9442						A-1-a(0)	SP-SM	
36	19.8			D	8					
37	20.0(S8)		U		7.5					
38	20.3(S8)		U		7	38.4				
39	20.4			D	8					
29*	20.59	9663							SP	
40	20.6		U		7.5					
41	20.7			D	8					
42	20.8		U		8					
43	20.8			D	7					
26*	4+60	9751							SP	**SPUR RD.**
27*	18+65	9883					NP		SP	
28*	30+15	9985				70		A-1-a(0)	GP-GM	

2.2.2 Falling-weight Deflectometer (FWD) Analysis

An FWD is a device designed to measure the deflection response of a pavement structure given an imposed load, see **Photo 20, Appendix B.** This deflection response can be used to analyze and estimate a variety of items including the structural capacity of a pavement and pavement layer elastic moduli (i.e. the strength of pavement layers).

The load pulse of an FWD is intended to simulate the load pulse generated by a moving vehicle, and in the case for this study, a relatively heavy vehicle such as a loaded dump truck is simulated. See **Figure 1** below for a schematic of an FWD test.

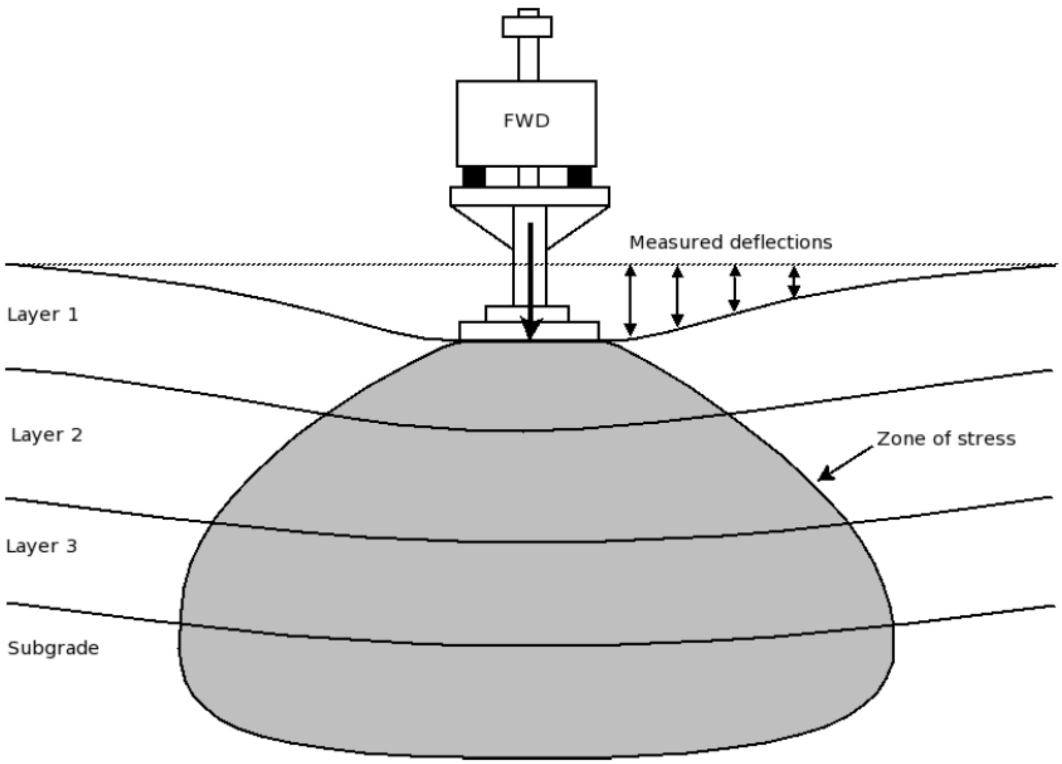


Figure 1. Schematic of FWD Test - Deflection Basin and Zone of Stress

For this investigation, FWD testing was completed at 291 locations with an approximate spacing of 500 feet between tests (alternating lanes). Between mileposts 11.2 and 14.8, the interval spacing for testing was decreased to 250 feet. Based on the coring data and cumulative differences of deflection, the route was broken into 3 sections for modeling purposes. See the **Table 5** below.

The MODTAG software program was used to analyze the FWD data. MODTAG allows the user to evaluate the deflection basins using both the empirical AASHTO process (1993 AASHTO DARWin) and mechanistic-empirical processes (MODCOMP).

<table>
<tr><th colspan="3">TABLE 5----- FWD ANALYSIS SEGMENTS – FOR MODELING</th></tr>
<tr><th>Segments</th><th>Pavement Thickness</th><th>Comments</th></tr>
<tr><td>MP 10.3 – 11.0</td><td>8 inches</td><td rowspan="3">▪No base layers were modeled.
▪Either one or two granular subgrade layers were modeled ranging in thickness from 24 to 60 inches.
▪Depth to bedrock was highly variable and complicated the analysis.</td></tr>
<tr><td>MP 11.0 – 14.2</td><td>6-7 inches</td></tr>
<tr><td>MP 14.2 – 20.8</td><td>7-8 inches</td></tr>
</table>

It is important to note that the depth to bedrock can have a significant impact on the deflection data and resulting analysis. Whether bedrock (or some hard bottom) is at 10 inches or 100 inches or 10 feet will influence the FWD data and analysis. For this route all of these cases existed. When abnormally high layer moduli were estimated from the software program, these data points were thrown out and were considered to have either collection/analysis errors or near-surface bedrock.

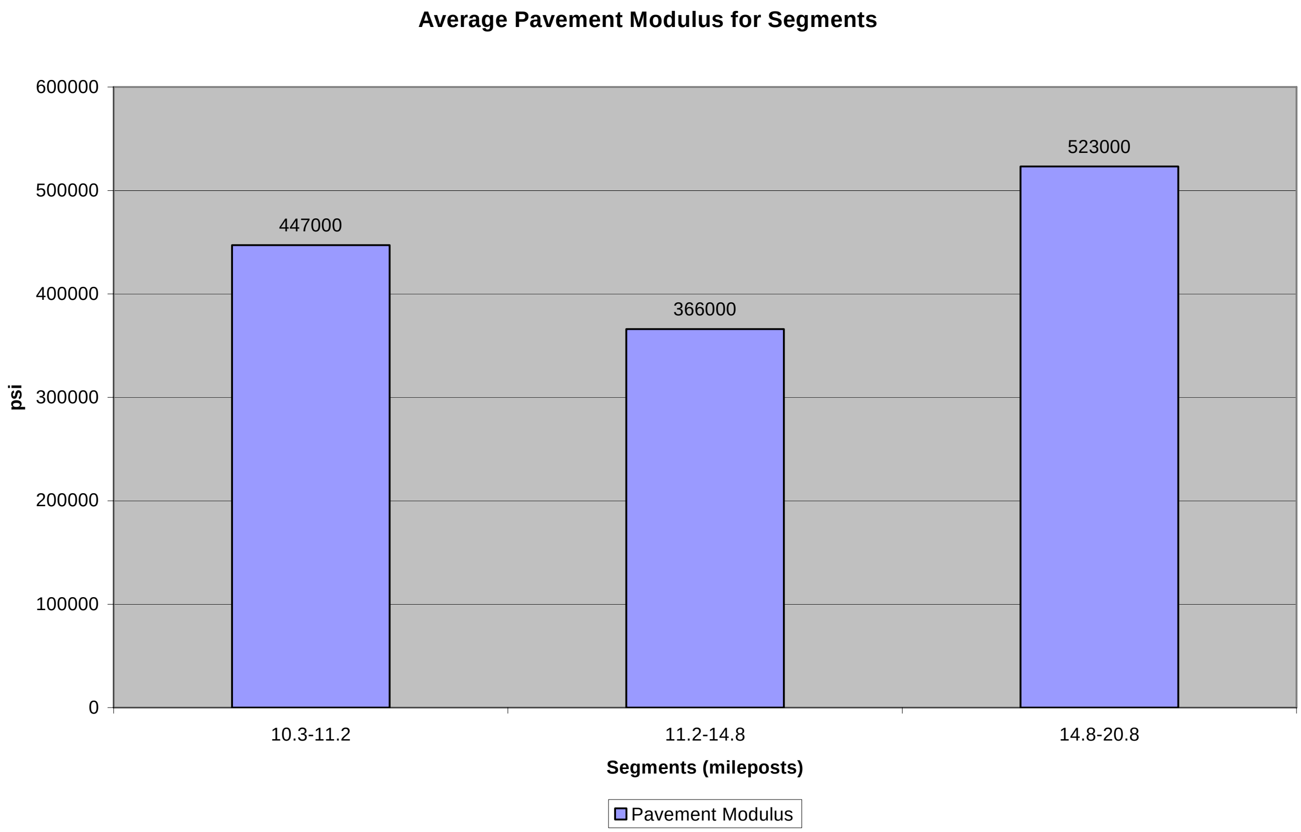
The results of the FWD data analysis indicate that the route can generally be segmented into 3 lengths that represent similar condition and future performance. *However, it is very important to note that while in general the pavement within each segment is expected to perform similarly there will be specific locations that will perform better or worse than the average*. Some of the areas that may have lower performance are denoted in **Table 7.**

Table 6 below summarizes the estimated remaining service life of the 3 segments (based on 18-kip equivalent single axle loads or ESAL). The segments in **Table 6** are slightly different than **Table 5**, because they are based on condition and service life as opposed to the existing pavement structure.

TABLE 6----- ESTIMATED REMAINING SERVICE LIFE			
Segment	**Milepost**	**ESAL**	**Action Needed**
1	10.3 – 11.2	190,000 ~15 years	This segment has good subgrade and pavement modulus values. Future action on this segment should include cyclical preservation treatments (i.e. crack sealing and/or chip sealing) and possibly some spot repairs. No major structural rehabilitation for this segment is expected.
2	11.2 – 14.8	0 (begin planning for rehabilitation)	Although the average remaining service life for this section was about 50,000 ESAL, there are many areas throughout the length that are highly distressed and have reached terminal serviceability. So for practical purposes this section has little to no remaining serviceability and should be rehabilitated within 3 to 5 years. The rehabilitation may include full-depth reclamation with an asphalt overlay, addition of edge/trench drains, and ditch clean-out/reshaping.
3	14.8 – 20.8	100,000 (7-8 years)	This segment had the highest pavement modulus values. However, the subgrade strengths were lower than segment 1 which resulted in lower remaining service life. Future action on this segment would follow the same actions as segment 1 (preservation).

The above estimates of remaining service life assume that the Park will be proactive about maintaining and preserving the route. Without regular maintenance the estimated remaining service life will not be achieved. The above estimates are also based on average daily traffic values of 517 with less than 6% buses (or heavier vehicles), and the fact that oxidation, aging, and other environmental factors may lead to pavement degradation quicker than the relatively light traffic load.

The two charts below show the average modulus values for the 3 segments and **Table 7** indicates locations where particularly low modulus values were estimated and may be currently exhibiting distress or will in the near future. In Table 7, E_P is the pavement modulus and M_R is the subgrade modulus. For this project we believe that E_P values less than 200,000 psi and M_R values less than 15,000 psi are of concern. **Table 7** clearly indicates that most of the areas of low modulus values are in segment 2.


Average Pavement Modulus for Segments
psi
600000
500000
400000
300000
200000
100000
0
447000
366000
523000
10.3-11.2
11.2-14.8
14.8-20.8
Segments (mileposts)
Pavement Modulus

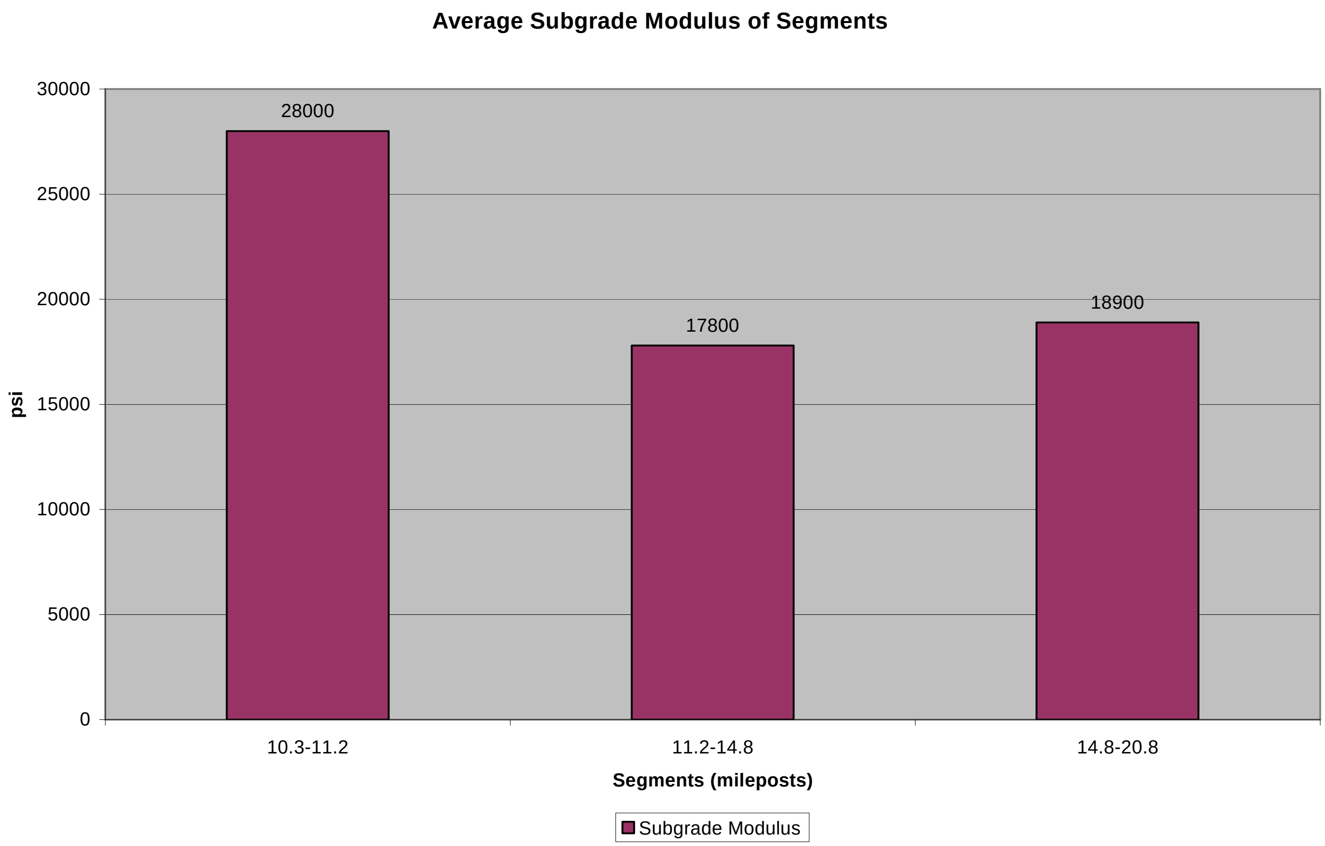

Average Subgrade Modulus of Segments
30000
25000
20000
15000
10000
5000
0
psi
28000
17800
18900
10.3-11.2
11.2-14.8
14.8-20.8
Segments (mileposts)
Subgrade Modulus

TABLE 7: Stations with Low Modulus Values
BOLDED text = E_P < 200k and M_R < 15k and
Not Bolded = M_R < 15k only

Segment 1 Milepost 10.3-11.2	Segment 2 Milepost 11.2-14.8	Segment 3 Milepost 14.3-20.8
20+00	45+00	267+50
29+99	47+50	272+50
	55+00	277+50
	67+50	282+50
	70+00	285+00
	72+50	**302+50**
	77+30	310+00
	80+00	335+00
	82+50	342+51
	83+75	347+51
	87+50	350+00
	88+75	352+50
	91+25	357+50
	92+50	375+01
	93+75	377+51
	98+75	382+50
	100+01	387+49
	106+24	397+51
	113+75	**402+51**
	115+01	467+51
	116+25	482+50
	125+00	497+50
	127+50	522+50
	128+75	532+50
	129+99	542+50
	137=50	**552+50**
	140+01	
	146+25	
	148+75	
	150+00	
	152+50	
	153+75	
	158+76	
	168+75	
	172+51	
	175+00	
	180+01	
	182+51	
	197+50	
	200+00	
	202+51	
	212+50	
	215+00	
	242+50	

2.2.3 Drainage structure investigation analysis and summary

The drainage structures inventory performed for the route included:

- Identify location, diameter, and amount of cover over all metal culverts**(C)**
- Identify location, size and amount of cover over all concrete box culverts**(B)**
- Identify existing damage(if any) to drainage structures

Most of drainage structures were installed/constructed during the original construction of the route in 1933-1935 including the bridge at MP 11.9 and the 11 concrete box culverts at various locations. The metal culverts and some of the concrete box culverts have been extended 2 to 6 feet overtime to accommodate widening of the roadway from the original 16-foot width roadway to the current 20-22 foot width roadway. Most of this work occurred between 1976 to early 1980.

Many of the culverts as well as the concrete boxes and the bridge have masonry headwall end treatments, abutments and parapet walls. With the exception of those structures that were extended during subsequent projects for widening the roadway much of the masonry stone work dates back to the original 1933-1935 era. The condition of the masonry stone work was not specifically evaluated at each location. The masonry stone at most locations is intact and functional. Some loose cap and corner stone were evident but were not recorded. Mortar at some locations over time has eroded from between the stones.

The following **Table 8** is a summary of the findings of that investigation. As noted in the table the following culverts were documented as having existing damage or a condition as noted: sites, 1, 4, 26, 59, 68, 79 & 80 and noted with an *. The damage noted does not appear to be affecting the performance of the structure. Cause of damage is unknown.

The “cover” column in the table indicates the difference between the surface of pavement and top of the culvert at its minimum cover. That minimum cover is usually at the inlet and usually in the uphill lane. The minimum cover as specified for metal culverts with a metal thickness of 0.052 inches for an H-20 loading is 12-inches. This value is recommended by the Handbook of Steel Drainage and Highway Construction Products handbook.

TABLE 8…..SUMMARY---DRAINAGE STRUCTURE INVENTORY					
Site #	**MP**	**TYPE OF DRAINAGE**	**SIZE (dia.)**	**COVER (feet)**	**REMARKS (S=denotes span, R=denotes rise)**
1*	10.6	C	24”	2	Damage-dent—4” to 6”dent @ approx. centerline of rdwy.
2	10.65	C	24”	2	
3	10.75	C	24”	2	
4*	10.85	C	24”	1.5	Damage-dent—4” to 6” dent @ approx. centerline of the rdwy.
5	11.0	C	24”	3	
6	11.1	C	24”	5	
7	11.25	C	24”	2	Park Headquarters
8	11.3	C	24”	1.5	
9	11.4	C	24”	1.5	
10	11.5	C	24”	1.5	
11	11.52	C	24”	2.5	
12	11.72	BRDG.	-----	-----	Station 85+15 to 85+50, see Bridge inspection report dated 2005
13	11.73	C	24”	2.5	
14	11.81	C	24”	1.5	
15	11.90	C	24”	5	
16	12.01	C	24”	4	
17	12.10	B	-----	2	Concrete Box Culvert, open bottom, S=7.5’ X R= 7.5’
18	12.16	C	24”	3	
19	12.22	C	24”	2	
20	12.40	C	24”	1.5	
21	12.43	C	24”	1.5	
22	12.52	C	24”	1.5	
23	12.63	C	24”	1.5	
24	12.72	B	-----	5	Concrete Box Culvert, open bottom S=7.0’ R= 6.0’
25	12.75	C	36	2	
26	12.90	C	24”	1	Very little cover at inlet
27	13.01	C	24”	5	
28	13.08	C	24”	3	
29	13.09	B	-----	6	Concrete Box Culvert, open Bottom S=8’, R=7.5’
30	13.11	B	-----	4	Concrete Box Culvert, open bottom, S=10’, R= 10’
31	13.40	C	24”	2	
32	15.50	C	24”	12	
33	13.57	C	24”	8	
34	13.61	C	30”	5	

35	13.71	C	24”	1.5	
36	13.85	C	24”	3	
37	13.91	B	-----	2	Concrete Box Culvert, open bottom, S=9, R=9
38	14.00	C	24”	1.5	MP 14.0
39	14.10	B	-----	3	Concrete Box Culvert, open bottom, S=6, R=6
40	14.20	C	36”	5	
41	14.38	C	36”	1	
42	14.48	C	24”	4	
43	14.53	C	24”	3	
44	14.95	C	24”	2	
45	15.10	C	36”	2	
46	15.17	C	24”	4	
47	15.20	B	-----	3	Concrete Box Culvert, S=6, R=6
48	15.38	B	-----		Concrete Box Culvert, open bottom, S=6, R=6
49	15.60	C	24”	2	
50	15.70	C	36”	2	
51	15.81	C	24”	2	
52	15.83	B	-----	3	Concrete Box Culvert, S=6, R=6
53	15.98	B	-----	3	Concrete Box Culvert, open bottom, S=6, R=6
54	16.01	B	-----	5	Concrete Box Culvert, S=6, R=6, MP 16.0
55	16.02	C	24”	3	
56	16.08	C	24”	5	
57	16.16	C	24”	2	
58	16.27	C	24”	2	No day light visible through culvert; damaged, silted, or alignment.
59	16.31	C	24”	10	
60	16.58	C	36”	3	
61	16.59	C	36”	1.5	
62	16.61	C	36”	4	
63	16.70	C	36”	15	
64	16.78	C	24”	1.5	
65	16.81	C	24”	6	
66	17.08	C	24”	2	
67	17.13	C	24”	2.5	
68	17.18	C	24”	1	Very little cover at inlet
69	17.31	C	36”	1.5	
70	17.44	C	24”	2	
71	17.63	C	24”	2	Plugged with silt and debris
72	17.83	C	24”	1.5	

73	17.88	C	24"	2.5	
74	17.93	C	24"	2	
75	18.02	C	24"	3	
76	18.13	C	24"	3.5	
77	18.28	C	24"	1.5	
78*	18.43	C	24"	2.0	Damage-dent @ uphill shld.
79*	18.69	C	24"	2.0	Damage-dent @ approx. centerline of the rdwy.
80	18.84	C	24"	1.5	
81	19.44	C	24"	1.5	
82	19.49	C	24"	1.5	
83	19.83	C	24"	1.5	
84	19.92	C	24"	1.0	w/grate, inlet
85	19.34	C	24"	1.5	w/grate, inlet—silted
86	20.0	C	24"	1.5	
87	20.1	C	24"	2.0	
88		C	16"	1.5	Access road to telescope site
89		C	12"	2.0	Access road to telescope site

Future maintenance or rehab of this route should include:

- Grouting or sealing of all culvert extension.
- Cleaning of overgrowth from drainage structure inlets and outlets
- As noted in the **Table 8** some culverts are in need of cleaning as silt has decreased the potential capacity of the drainage.

3.0 TRAFFIC

3.1 Traffic, NPS

The traffic data shown in the following **Table 9** summarizes the traffic data as noted and supplied by Haleakala National Park for the year indicated using the park's procedures and methodology for collection and reporting traffic at Haleakala National Park. Complete procedures for collecting, reporting, extrapolations and adjustments can be found at the following web site: http://www.nature.nps.gov.stats/.

TABLE 9-----SUMMARY OF PARK TRAFFIC					
Year	**Total vehicles entering/year (one-way)**	**Park Visitor ADT (one-way)**	**Buses, ADT (one-way)**	**Other Vehicles, ADT (one-way)**	**Total ADT (one-way)**
2004	184,809	426	36	44	506
2005	185,872	429	35	44	508
2006	190,160	441	36	44	521
2007	200,320	480	25	44	549
2008	182,906	439	18	44	501
AVERAGE>>>>>>>>>>>>		443	30	44	517

3.1.1 Traffic ESALS

The following **Table 10** is a summary of traffic volumes and resulting ESALs calculated from table 9 data for the period from 2004 to 2008.

TABLE 10…..2004 to 2008 AVERAGE TRAFFIC ESALS					
Vehicle Class	**Vehicle Types**	**Daily**	**Yearly**	**Factor**	**ESALS**
2	Passenger car	443	161,695	0.0004	65
2	Other Vehicles	44	16,060	0.0004	6
4	Buses(coaches)	30	10,950	1.0	10,950
Total ESALS/YEAR					11,021

3.2 Anticipated ATST construction traffic

The following **Table 11 and 11A** are summaries of anticipated construction related traffic volume increase as a result of the ATST constructions project based on information provided by ATST Project Architect. Table 11 is the original traffic data submitted by ATST and table 11A is additional traffic data (mostly FHWA Class 3 vehicles) not included in the original submittal (Table 11). The tables have been edited to include number of loads and class of vehicle based on the Federal Highway Administration and Hawaii Department of Transportation classification description/classes per the description provided by ATST. A copy of the FHWA and HDOT class charts are included in **Appendix C.**

TABLE 11…..SUMMARY OF ACTIVITES, RELATED LOADS AND VEHICLE CLASSIFICATIONS					
Duration	ATST Construction Activities	Large Vehicle Use of Haleakalā Highway	Number of loads	CLASS OF VEHICLE	
				FHWA	HDOT
3 months	Contract start-up, mobilization, demolition and clearing	Delivery of trailers and excavation equip. – 8 flatbed trucks Test tower, cesspool, and other items removed – 4 truckloads.	8 4	9 5	3S-2 2D
3 months	[1] Major earthwork and leveling, utility trenching, testing as required	Exchange of equipment, approximately – 6 large loads. Water for dust control – 30 tank trucks. Soil testing support – 3 trucks. Soil remediation support – 3 trucks.	6 30 6	9 6 5	3S-2 3X 2D
3 months	[1] Foundation excavation, drilling/pouring caissons, drilling for shafts, utility install.	Drill rig and specialized equipment to site – 4 truckloads. Concrete for caissons, approximately – 15 truckloads. Utility/electrical equipment pipe, cable – 5 truckloads.	4 15 5	6 7 3	3X ----- 2S
3 months	Pouring foundations, placement of utilities	[2] Concrete delivery – 100 truckloads. Concrete waste removal – 3 truckloads. Rebar & embedded steel items 5. Utility materials – 6 truckloads.	100 3 5 6	7 6 5 6	----- 3X 2D 3X
5 months	Pouring of telescope pier	Concrete delivery – 170 truckloads 160-ton crane delivered and erected, 2 large trucks. Concrete pump and support – 6 trucks. Concrete waste removal – 5 truckloads. Rebar & embedded steel items 10. Scaffolding and concrete formwork – 30 truckloads	170 2 6 5 10 30	7 10 7 7 5 7	----- 3-3 ----- ----- 2D -----
3 months	Completing slabs, pits and other building concrete	Approximately 50 truckloads of concrete Concrete waste removal – 2 truckloads. Rebar & embedded steel items – 5 truckloads.	50 2 5	7 7 5	----- ----- 2D
5 months	Steel erection	Delivery of steel for building and lower enclosure – 10 flatbeds. [3] Ancillary materials and equipment – 10 truckloads.	10 10	5 5	2D 2D
3 months	Roof and wall panel installation	Approximately 20 truckloads of materials. Ancillary materials and equipment – 20 truckloads.	20 20	6 7	3X -----
6 months	Dome framing, major utility equipment installation, S&O, building interior construction	Dome contractors trailers and containers – 4 truckloads Delivery of upper enclosure structure – 10 large, heavy, possibly wide loads on flatbeds. Delivery of platform lift and elevator – 4 large loads. Delivery of building fixtures and materials. – 20 truckloads. Ancillary materials and equipment – 10 truckloads	4 10 4 20 10	9 12 4 9 7	3S-2 2S-1-3 B 3S-2 -----
9 months	Enclosure work: cladding mechanical fit-up, testing	Delivery of enclosure cladding panels, plate-coil, and mechanical equipment – 20 large, heavy, flatbed loads. Ancillary materials and equipment – 10 truckloads	20 10	9 7	3S-2 -----
12 months	Telescope and coudé rotator installation.	Telescope contractors trailers and containers – 4 truckloads Delivery of telescope assemblies to site – 20 large, heavy, often wide loads on flatbed trucks. Construction crane and other equipment disassembled and trucked away from site. – 6 truckloads. Ancillary materials and equipment – 10 truckloads	4 20 6 10	9 12 7 7	3S-2 2S-1-3 ----- -----
3 months	Finish site work: Paving of apron and service yard. Concrete walks, finish utilities.	Concrete delivery – 50 truckloads. Concrete waste removal – 3 truckloads. Rebar & embedded steel items – 5 truckloads. Asphalt paving materials and equipment – 10 truckloads. Water for dust control – 10 tank trucks	50 3 5 10 10	7 7 9 9 6	----- ----- 3S-2 3S-2 3X
6 months	Primary mirror and other optics coated and installed.	Delivery of primary mirror – 1 heavy, wide, slow moving flatbed. Delivery of coating chamber – 1 heavy, wide, slow, flatbed. Ancillary materials and equipment – 10 truckloads.	1 1 10	12 10 9	2S-1-3 3-3 3S-2

TABLE 11A…..”ADDITIONAL”SUMMARY OF ACTIVITES, RELATED LOADS AND VEHICLE CLASSIFICATIONS					
				CLASS OF VEHICLE	
Duration	**ATST Construction Activities**	**Large Vehicle Use of Haleakalā Highway**	**Number of loads (one-way)**	**FHWA**	**HDOT**
3 months	Contract start-up, mobilization, demolition and clearing	Pickup trucks, vans Passenger vehicles	360 360	3 2	2P P
3 months	[1] Major earthwork and leveling, utility trenching, testing as required	Pickup trucks, vans Passenger vehicles	360 360	3 2	2P P
3 months	[1] Foundation excavation, drilling/pouring caissons, drilling for shafts, utility install.	Pickup trucks, vans Passenger vehicles	360 360	3 2	2P P
3 months	Pouring foundations, placement of utilities	Pickup trucks, vans Passenger vehicles	360 360	3 2	2P P
5 months	Pouring of telescope pier	Pickup trucks, vans Passenger vehicles	600 600	3 2	2P P
3 months	Completing slabs, pits and other building concrete	Pickup trucks, vans Passenger vehicles	360 360	3 2	2P P
5 months	Steel erection	Pickup trucks, vans Passenger vehicles	600 600	3 2	2P P
3 months	Roof and wall panel installation	Pickup trucks, vans Passenger vehicles	360 360	3 2	2P P
6 months	Dome framing, major utility equipment installation, S&O, building interior construction	Pickup trucks, vans Passenger vehicles	720 720	3 2	2P P
9 months	Enclosure work: cladding mechanical fit-up, testing	Pickup trucks, vans Passenger vehicles	1080 1080	3 2	2P P
12 months	Telescope and coudé rotator installation.	Pickup trucks, vans Passenger vehicles	1440 1440	3 2	2P P
3 months	Finish site work: Paving of apron and service yard. Concrete walks, finish utilities.	Pickup trucks, vans Passenger vehicles	360 360	3 2	2P P
6 months	Primary mirror and other optics coated and installed.	Pickup trucks, vans Passenger vehicles	720 720	3 2	2P P
2 years	Integration Testing & Commissioning	Deliveries Pickup trucks, vans Passenger vehicles	204 2920 2920	6 3 2	3X 2P P
Annually	Operational life of ATST	Deliveries Pickup trucks, vans Passenger vehicles	15 1095 1095	6 3 2	3X 2P P

Class Summary for Table 11A: Class 2=11,695,
Class 3=11,695,
Class 6 =219

3.2.1 ATST Construction Traffic ESALS

The following **Table 12** is a summary of resulting ESALs calculated from table 11 and 11A for the ATST construction traffic volumes anticipated and submitted by the NSF.

TABLE 12…..ESTIMATED ESALS FOR ATST CONSTRUCTION PROJECT			
Vehicle Class(FHWA)	**Number of Trips**	**Factor**	**ESALS**
2	11,695	.0004	5
3	11,700	0.004	47
4	4	1.25	5
5	50	0.5	25
6	292	1.0	292
7(concrete trucks)	487	1.5	731
9	87	2.1	183
10	3	2.2	7
12	31	3.3	102
Total expected ESALS			1397

As noted in **Table 12** the total expected ESALS based on the ATST's 60 month construction schedule is approximately 1397 with the largest contributor to ESALs being the 487 loads of concrete that are expected to be delivered to the project site. This amount of traffic (1397 ESALS) over the 84 month construction time schedule including the 2-year integration testing and commissioning and annually over the operational life of the ATST project is considered relatively small. It amounts to approximately 13 %(1397/11021) of the current ESALS applied to the road in one year or a 1.8% increase in ESALs over the estimated 7-year construction period.

A method of reducing the number concrete trucks and related ESALS by an estimated 40% would be to place an on site batch plant to produce concrete.

The advantages would be:

- Reduced ESALs by an estimated 200 ESALS
- Be able to produce concrete on site, on demand
- The quality characteristics of the concrete would not be an issue if produced on site
- Eliminate the 2-hour haul from town to the job site
- Reduced fuel consumption

4.0 DISCUSSIONS AND RECOMMENDATIONS

4.1 Pavement section

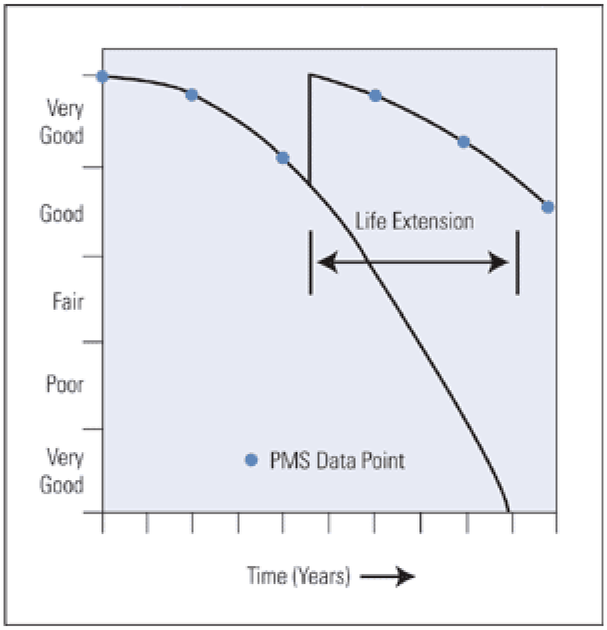
As indicated previously the existing 10.6-mile section of Haleakela Highway was constructed between 1932 and 1935 and since then has undergone numerous reconstruction, rehabilitation, subexcavation and maintenance work consisting of widening, overlays, pulverization w/overlay and surface course (chip seal) construction. Some of the rehabilitation has included corrective rework of the subgrade. The corrective work consisted of sub excavation and patching at numerous locations.

From MP 10.3 to MP 11.2 and MP 14.8 to MP 21.2 the roadway appears to be performing adequately without any noted severe structural problems or distresses and should continue to perform well with a continued maintenance program. The remaining service life for MP 10.3 to 11.2 is estimated at 15 years or more and for MP 14.8 to 21.2 the estimated service life is estimated at 7-8 years. This remaining service life however could be reduced with increased traffic volumes and larger than expected traffic loadings.

The pavement section from MP 11.2 to MP 14.8 has also received numerous overlays but has not performed as well due to the unstable underlying materials and water issues. This section exhibits severe fatigue cracking and associated water bleeding/pumping and loss of underlying materials as is evident from the presence of fines on the surface of the road and pavement staining. This section will continue to deteriorate at a much faster rate due to water intrusion into the underlying structural layers, continued loadings and loss of fines. The water source is continued precipitation and accumulation of water in the roadway ditches that eventually flows through the highly permeably material into the subgrade under the pavement. This condition was evident during the first investigation as well as this investigation. This section of road appears to have higher moisture/water accumulations on the surrounding slopes and roadway cut/fill slopes and ditches. The surrounding fauna is also more prevalent through this section. Many areas of roadway within this segment are at or very near the end of their service life.

Based on the investigation performed and the data gathered the pavement form MP 10.3 -11.2 and MP 14.8 to 21.2 should continue to perform well with a regular maintenance program. However the pavement from MP 11.2 – 14.8 is at or near the end of its service life and will continue to deteriorate at a faster rate over time.

The following graph is included to indicate as roads approach the end of their service life they deteriorate at a more rapid rate. While the following graph is intended to show the benefits of a good preventive maintenance treatment and resulting increase in the service life it also depicts the rapid decrease of service life during the later years of the intended design.



Life-extending benefits of preventive maintenance treatment.

As defined in the *1993 AASHTO Guide for Design of Pavement Structures*, the serviceability of a pavement is its ability to serve the type of traffic (trucks, buses, and automobiles) which use the facility. Serviceability is measured using a 0 to 5 index. A roadway with a serviceability of 0 would be impassable and a roadway with an index of 5 would be perfect. A new asphalt roadway is typically given a serviceability index value of 4.2. Terminal serviceability is defined as the lowest index value that will be tolerated before rehabilitation, resurfacing or reconstruction is necessary. For this route a terminal serviceability would be reached when an index value of 2.5 is reached. The time it takes a roadway to go from a serviceability index of 4.2 to 2.5 is defined as the roadway's pavement service life (typically 20 years). As a general guideline, when a roadway has a serviceability level of 2.5, 55% of people will state that the road is unacceptable from a ride and cracking standpoint. Once the serviceability level drops to 2.0, about 85% of people will state that the road is unacceptable.

As discussed previously in this report, the section of pavement from MP 11.2 to 14.8 is at or very near the end of its service life (i.e. at terminal serviceability) and failure at various locations will begin to occur more often. This is why it is recommended that preparations begin for the rehabilitation of this section of roadway.

The projected construction traffic volumes submitted by the ATST was their best estimate of anticipated traffic volumes and loading to construct this project. Note that a comparison of NPS traffic ESAL loading, **Table 10** and ATST project construction traffic over the 7-year period **Table 12,** will result in an increase of approximately 2% additional ESAL loadings on this route—1397/[11,021 X 7] = 1.8%. It should also be pointed out that the increased ATST construction ESALs of 1397 are equivalent to approximately 47 days or 1 ½ months(1397/30) of normal tour bus traffic on this route. This amount of traffic is considered relatively small.

The factors that will most significantly impact the roadway and result in damage will be if the estimated ATST construction traffic is much higher than anticipated and the construction vehicle loadings exceed the legal load limits.

Prior to start of work it is recommended that the ATST prepare and submit diagrams showing vehicle configuration (axle spacings and width), weight per axle, and overall vehicle widths and lengths to the NPS for compliance with legal load requirements and conformance with current load rated capacity. With the anticipated heavy and "wide" loads that will be necessary for the construction of this project it is recommended that the contract include a clause for notification to the NPS prior to large and heavy vehicles entering the park. Periodic monitoring during the construction project should be employed to verify that legal loads limits are not being exceeded. Photo logging of the route is recommended to document the condition of road before an after the ATST project is completed.

The following **Table 13** is provided to provide estimated costs over the next 5 years to perform regular maintenance (crack sealing) and complete rehabilitation of MP-11.2 to 14.8. The unit costs are best estimates on current (March 2009) market and the prices will change over time.

TABLE 13 …..SUMMARY OF COSTS FOR PULVERIZING AND CRACK SEALING					
Pulverize, 8-10 inch depth	Width(ft)	Length(ft)	Quantity(sy)	Unit Cost	Cost
	26	19,008	54,912	$9.00	$494,208.00
Overlay, 3-inch depth	Width(ft)	Length(ft)	Quantity(tons)	Unit Cost	Cost
	24	19,008	9000	$350.00	$3,150,000.00
Pulverize and overlay					**$3,644,208.00**
Estimating notes: For estimating purposes a unit weight of 155 pounds per cubic foot was used to estimate tons of mix for overlay. Unit cost for overlay includes: binder, traffic control, stripping, mobilization, testing, and surveying. Does not include cost of curb and drainage correction costs.					
Crack Seal	Estimated 1500 LF per mile of road way in segment 2 @ $5.00/LF = 7.0 X 1500 X $5.00=**$52,500.00**				

4.2 Metal and Concrete Box Culverts

All metal and concrete box culverts inspected have the minimum specified cover to withstand an H-20 loading. The culverts with the least amount of cover and should be monitored during construction are the culverts at sites #26 and #68, see **Table 8**.

It is also recommended that the masonry stone work at all structures including box culverts and retaining walls be photographed prior to start of ATST project work. Unless a construction vehicle comes in direct contact with a structure it is not anticipated that the minimal construction traffic would damage the stone masonry. Pre construction photos of all structures are recommended as this may eliminate any issues after the project is completed to address whether any resulting damage was ATST construction related.

4.3 Bridge

Based on conversation with ATST representatives and as noted in their table for duration and number of loads it is our understanding that the possibility of heavier than legal loads may be necessary to cross the Haleakala Bridge during the construction of the proposed project. As this bridge is composed of concrete, issues with the number of cycles (fatigue) will not be of concern as much as the actual weight of the loadings themselves. Although constructed in 1934, the bridge has a favorable load rating as was noted in the 2005 inspection report. Nevertheless it would be prudent to require written notification within 30 days of each anticipated occurrence of vehicle loadings above legal limits crossing the structure. Diagrams showing vehicle configuration (axle spacings and width), weight per axle, and overall vehicle widths and lengths should be presented to the NPS for verification by the Federal Lands Highway Bridge Office, for conformance with current load rated capacity. With the anticipated heavy and “wide” loads that will be necessary for the construction, the probability of accidental damage to the bridge will also proportionally increase. It is recommended that prior to the construction notice to proceed that the bridge be photographed, inspected, and documented to existing condition. Periodic monitoring during the construction project may be employed if actual construction traffic deviates from those presented herein or if concerns arise, to verify that the bridge is not being impacted due to construction activities resulting from the project.

4.4 Other Structures

UNDERGROUND UTILITIES:

Under ground utilities exist under the road in the uphill lane beginning at MP 20.3 and they exist under the mainline roadway into the Haleakala Visitor Center. The utility line, according to construction records is approximately 24-inches below the existing pavement. The line is inside a 6-inch schedule 40 PVC casing and the casing is in enclosed in a 12-inch concrete jacket**.** There are a total of 4 manhole covers in the roadway approximately 3.5 feet wide by 5.5-feet long in this run of utility line. Precautions should be taken to ensure no damage to the covers is done during the haul of the heavier loads to the project site.

Recommended precautions are:

- Avoid direct axle loading on the covers
- Replace the existing covers with heavier gage steel
- Reinforce the existing covers with additional steel bracing

BITUMINOUS CURB:

There are numerous sections of bituminous curb throughout the route. The curb in the upper portion of the route is in tack and functional. The curb in the lower section of the road, below MP 16.0 does not have a fully exposed face as the numerous overlays have decreased the height and thus the water carry capacity. Tires from over sized loads (length) could potentially damage the curb if run over.

5.0 SUMMARY

When compared to normal daily traffic using Haleakala Highway (passenger and bus traffic), the low stress/volume of traffic, 1397 ESALs, related to the ATST project is expected to have little effect on the roadway sections from MP 10.3 to 11.2 and 14.8 to 21.2 assuming the traffic axle loadings are legal and the volume of traffic as estimated by the ATST staff is correct. From MP 11.2 to 14.8, the deterioration of this section will continue at relatively rapid pace with or without ATST traffic. There are numerous areas within this section that have failed and are at terminal serviceability. It is recommended that the Park begin planning for a rehabilitation project in this section. While the rehabilitation my not have to occur in the next 3 to 5 years, it is expected that reactive and routine maintenance (small patches & pothole repairs) will increase until rehabilitation is completed.

The analysis and information contained is this report is based on measured physical characteristics of the roadway materials and visual evaluation of the roadway. Given the high variability of the nature of soils at varying moisture contents and varying stages of remaining service life it is difficult to ascertain with confidence how a particular structural roadway section will perform.

For question or comments concerning this report contact Mike Voth (720-963-3505) or Rick Marquez (720-963-3398).

APPENDIX A

SITE MAP


Station 0+00, MP-10.3
Approx. location of segment 2, pavement distress and water bleeding
Pu'u Nianiau
378
To Kahului
Hosmer Grove
MP 11.2
SB #1
SB #2
Supply
SB #3
Trail
Park Headquarters Visitor Center
7000ft
2134m
MP 14.8
SB #4
SB #5
Halemau'u Trailhead
7990ft
2436m
SB #6
Leleiwi Overlook
8840ft
2694m
Hōlua
Cabin and campsite
6940ft
2115m
SB # 7
SB #9
Kalahaku Overlook
9324ft
2842m
SB #8
No left turn travelling uphill
Station 470+00
MP-20.3
Sliding Sands Trailhead
Haleakalā Visitor Center
9740ft
2969m
Pu'u o Māui
Kamoali'i
Ka Lu'u o ka 'Ō'ō
Pu'u'ula'ula Summit
10023ft
3055m
Pā Ka'oao
WILDERNESS
Station 570+00, MP-21.2
Pu'u o Pele
Magnetic Peak
10008ft
3050m
Haleakalā Observatories (closed to public)
Haupa'akea
9159ft
2792m

APPENDIX B

PHOTOS

Photo #1---Segment 2, Typical pavement distress in wheel path, close-up of photo #2**.**

Photo #2---Segment 2, Pavement distress adjacent to water in the roadway ditch line

Photo #4---Segment 2 MP 11.9, Typical pavement distress, note water in paved water way

Photo #5 & 6---Segment 2, MP 14.2 & 12.1, Typical pavement distress along centerline of roadway, Note: water flowing through cracks and pavement staining due to migration of fines.

Photo #7---Water seepage from what appears to be a patched area in Section 1

Photo #8---Section 2, Water seepage from fatigued roadway section

Photo #9---Close-up of water in fatigued pavement, note fine on the surface of the pvt.

Photo #10---Segment 4, Auguring at MP 20.3, Note: Start of Utility line in Rdwy**.**

Photo #11---Close-up auguring at MP 19, uphill lane

Photo #12---Very wet subgrade material at MP-14

Photo #13---Auger hole, Uphill lane- note water flowing through the pavement.

Photo 13A---Water flowing through pavement layer cracking

Photos 14, 15 & 16-----Typical open bottom Concrete Box Culverts with Masonry hdwls.

Photo 15---

Photo 16---

Photo #17-----Typical Metal Culvert with Stone Masonry Hdwls.

Photo #18---Typical metal culvert with masonry headwall and note minimum cover

Photo 19---MP 20.3, start of under ground utility line in uphill lane, typical bituminous curb shown on the right.

Photo 20---MP- 20.4, FWD testing in the uphill lane

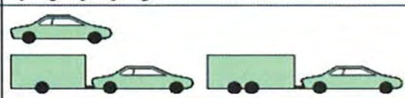
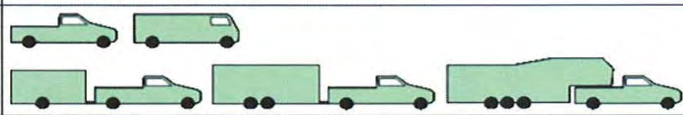
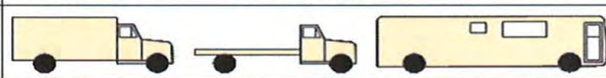
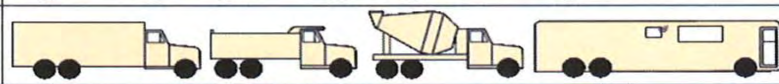
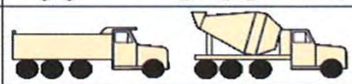
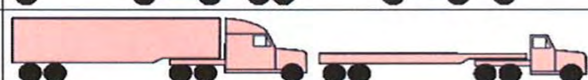
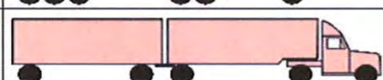
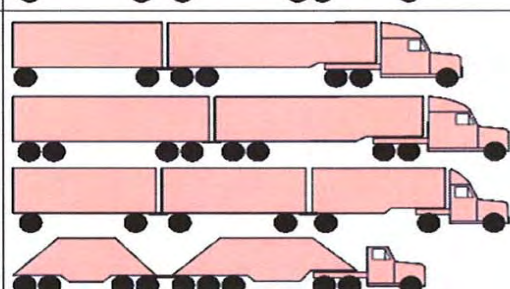
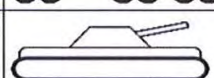
Photo #21-----Section 3, low to moderate transverse and longitudinal cracking

Photo #22-----Section 4, newer roadway surface. Not yet chipped with low to moderate transverse and longitudinal cracking.

APPENDIX C

VEHICLE SCHEMA

FHWA VEHICLE CLASS

	Class	Schema	Description
Light-weight Vehicles	1		all motorcycles plus two wheel axles
	2		all cars plus one/two axle trailers
	3		all pickups and vans single/dual wheels plus one/two/three axle trailers
Single Unit Vehicles	4		buses single/dual wheels
	5		two axle, single unit single/dual wheels
	6		three axle, single unit
	7		four axle, single unit
Combination Unit Vehicles	8		four or less axles, single trailers
	9		five axles, single trailers
	10		six or more axles, single trailers
	11		five or less axles, multi-trailers
	12		six axles, multi-trailers
	13		seven or more axles, multi-trailers
Unclassified Vehicles	14		Unclassifiable vehicle
	15		Not used

HDOT VECHICLE CLASS

			FHWA TYPE
1	P	Passenger Cars	2
2	B	Buses	4
3	2P	2 Axle Panel or Pickup less than 1.5 Ton Capacity	3
4	2S	2 Axle, 4 Tires other than Panel or Pickup	3
5	2D	2 Axle, Six Tires	5
6	3x	3 Axle	6
7	2S–1	2 Axle Tractor 1 Axle Semi–Trailer	8
8	2S–2	2 Axle Tractor 2 Axle Semi–Trailer	8
9	3S–1	3 Axle Tractor 1 Axle Semi–Trailer	8
10	3S–2	3 Axle Tractor 2 Axle Semi–Trailer	9
11	2S–1–2	2 Axle Tractor,1 Axle Semi–Trailer, 2 Axle Trailer	11
12	2S–1–3	2 Axle Tractor, 1 Axle Semi–Trailer, 3 Axle Trailer	12
13	2S–2–2	2 Axle Tractor, 2 Axle Semi–Trailer, 2 Axle Trailer	12
14	2S–2–3	2 Axle Tractor, 2 Axle Semi–Trailer, 3 Axle Trailer	13
15	3S–1–2	3 Axle Tractor, 1 Axle Semi–Trailer, 2 Axle Trailer	12
16	3S–1–3	3 Axle Tractor, 1 Axle Semi–Trailer, 3 Axle Trailer	13
17	3S–2–2	3 Axle Tractor, 2 Axle Semi–Trailer, 2 Axle Trailer	13
18	3S–2–3	3 Axle Tractor, 2 Axle Semi–Trailer, 3 Axle Trailer	13
19	2–2	2 Axle Truck 2 Axle Trailer	8
20	2–3	2 Axle Truck 3 Axle Trailer	9
21	3–2	3 Axle Truck 2 Axle Trailer	9
22	3–3	3 Axle Truck 3 Axle Trailer	10
23	Others	not used or unclassified	14 15

HALEAKALA HIGHWAY BRIDGE,
STRUCTURE LOAD RATING

STRUCTURE NO. 8290-001P
INSPECTION DATE: 6/16/05

TRUCK TYPE	INVENTORY RATING (NORMAL TRAFFIC)		OPERATING RATING (MAXIMUM LOAD)	
	TONS	METRIC TONS	TONS	METRIC TONS
H	18	16	27	24
HS	33	30	49	44
TYPE 3	31	28	45	41
TYPE 3S2	47	43	72	65
TYPE 3-3	55	50	88	80

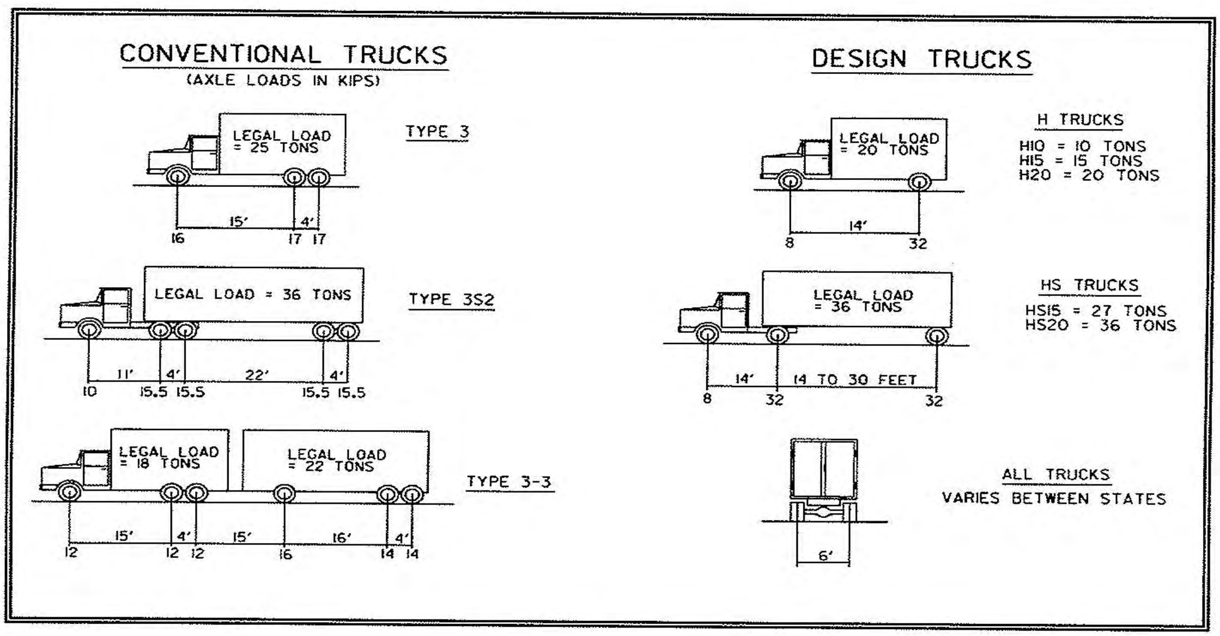
DESIGN LOADING: H15 (M13.5)

X	CAPACITY MEETS OR EXCEEDS DESIGN LOAD
	CAPACITY IS LESS THAN DESIGN LOAD
X	ORIGINAL LOAD RATING CALCULATION APPLICABLE
	ORIGINAL LOAD RATING CALCULATION REVISED

DATE OF LOAD RATING CALCULATION: 5/91

LOAD RATING CONTROLLED BY: MOMENT CAPACITY OF BEAMS

REMARKS:



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APPENDIX D

SOIL CLASSIFICATION CHARTS

AASHTO CLASSIFICATION

Table 1—Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35 Percent or Less Passing 75 µm)			Silt-Clay Materials (More Than 35 Percent Passing 75 µm)			
Group Classification	A-1	A-3[a]	A-2	A-4	A-5	A-6	A-7
Sieve analysis, percent passing:							
2.00 mm (No. 10)	—	—	—	—	—	—	—
0.425 mm (No. 40)	50 max	51 min	—	—	—	—	—
75 µm (No. 200)	25 max	10 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)							
Liquid limit	—			40 max	41 min	40 max	41 min
Plasticity index	6 max	NP	[b]	10 max	10 max	11 min	11 min
General rating as subgrade	Excellent to Good			Fair to Poor			

[a] The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.
[b] See Table 2 for values.

Table 2—Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35 Percent or Less Passing 75 µm)							Silt-Clay Materials (More Than 35 Percent Passing 75 µm)			
Group Classification	A-1			A-2							A-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5, A-7-6
Sieve analysis, percent passing:											
2.00 mm (No. 10)	50 max	—	—	—	—	—	—	—	—	—	—
0.425 mm (No. 40)	30 max	50 max	51 min	—	—	—	—	—	—	—	—
75 µm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)											
Liquid limit	—		—	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max		NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min[a]
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to Good							Fair to Poor			

[a] Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30. (See Figure 2.)

USCS CLASSIFICATIONS

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	FIELD INDENTIFICATION PROCEDURES (excluding particles larger than 3 inches and basing fractions on estimated weights)			INFORMATION REQUIRED FOR DESCRIBING SOILS
1	2		3	4	5			6
Coarse-grained Soils More than half of material is larger than No. 200 sieve size. (The No. 200 sieve size is about the smallest particle visible to the naked eye.)	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the ¼-in. size may be used as equivalent to the No. 4 sieve)	(Clean Gravels Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics. Give typical name: Indicate approximate percentage of sand and gravel, maximum size, angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information, and symbol in parentheses. Example: Silty sand gravelly; about 20% hard, angular gravel particles 1/2in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% non plastic fines with low dry strength; well compacted and moist in place; alluvial sand (SM).
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines	Predominatly one size or a range of sizes with some intermediate sizes missing			
		(Gravels with Fines Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures	Nonplastic fines or fines with low plasticity (for identification procedures see ML below)			
			GC	Clayey gravels, gravel-sand-clay mixtures	Plastic fines (for identification see CL below)			
	Sands More than half of coarse fraction is smaller than No. 4 sieve size	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines	Wide range in grain sizes and substantial amounts of all intermediate sizes missing			
			SP	Poorly graded sands or gravelly sands, little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing			
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures	Nonplastic fines or fines with low plasticity (for identification			
			SC	Clayey sands, sand-clay mixtures	Plastic fines (for identification procedures see CL below)			
					Identification Procedures on Fraction smaller than No. 40 Sieve Size			
					Dry Strength (Crushing Characteristics)	*Dilatancy (Reaction to Shaking)*	*Toughness (Consistency near PL)*	
Fine-grained Soils More than half of material is smaller than No. 200 sieve size.	Silts and Clays Liquid limit is less than 50.		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	None to slight	Quick to slow	None	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Give typical name, indicate degree and character or plasticity, amount and maximum size of coarse grains, color in wet conditions, odor (if any), local or geologic name, and other pertinent descriptive information, and symbol in parentheses. Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry and place; loess (ML).
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Medium to high	None to very slow	Medium	
			OL	Organic silts and organic silty clays of low plasticity	Slight to medium	Slow	Slight	
	Soils and Clays Liquid limit is greater than 50.		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Slight to medium	Slow to none	Slight to medium	
			CH	Inorganic clays of high plasticity, fat clays	High to very high	None	High	
			OH	Organic clays and silts of medium to high plasticity	Medium to high	None to very slow	Slight to medium	
Highly Organic Soils			Pt	Peat and other highly organic soils	Readily identified by color, odor, spongy feel and frequently by fibrous texture			

APPENDIX E

SUMMARY OF SOIL TESTS

SUMMARY OF LABORATORY TEST RESULTS

Haleakala Crater Road
Haleakala National Park, Island of Maui, Hawaii

SAMPLE NO.	Sample Cinder 1	Sample Comb. 19.5 – 20.0 – 20.3	Sample Comb. 18 – 17 - 17	Sample MM 11.0U
DESCRIPTION	Dark gray cinder GRAVEL with sand and trace silt.	Reddish brown silty SAND with some gravel.	Dark gray cinder GRAVEL with sand.	Dark gray-brown cinder SAND with silt.
CBR TEST (ASTM D 1883) (Surcharge – 51 psf)				
Molding Moisture Content, %	17.9	13.9	15.2	14.8
Molding Dry Density, pcf	85.0	112.2	115.3	123.2
Swell Upon Saturation, %	0.00	0.02	0.00	0.00
CBR at 0.1" Penetration	31.0	38.4	87.0	6.7

SAMPLE NO.	Sample MM 11.8U	Sample MM 11.9D	Sample MM 12.4U	Sample MM 14.0U
DESCRIPTION	Gray silty SAND with some gravel.	Dark gray-brown cinder SAND with silt.	Dark gray-brown SILT with trace sand.	Brown cinder GRAVEL with silt & sand.
CBR TEST (ASTM D 1883) (Surcharge – 51 psf)				
Molding Moisture Content, %	13.8	12.5	33.5	17.7
Molding Dry Density, pcf	99.7	124.6	85.3	112.9
Swell Upon Saturation, %	0.02	0.00	0.00	0.00
CBR at 0.1" Penetration	51.5	8.0	4.7	5.9