UNIVERSITY of HAWAI'I®
HILO

Office of the Chancellor

December 22, 2014

Ms. Jessica Wooley, Director
Office of Environmental Quality Control
State of Hawai'i
235 South Beretania Street, Room 702
Honolulu, Hawai'i 96813

Subject: Environmental Impact Statement Preparation Notice for New Master Leases for the Mauna Kea Science Reserve and Related Facilities and Easements

Dear Director Wooley:

The University of Hawai'i (UH) has determined at the outset that it will prepare an Environmental Impact Statement (EIS) for its proposed new Master Leases for the Mauna Kea Science Reserve and related facilities and easements.

UH will prepare the EIS in accordance with the provisions and requirements of Hawai'i Revised Statutes (HRS), Chapter 343. Pursuant to HRS §343-5(c), an Applicant Action Publication Form and Environmental Impact Statement Preparation Notice (EISPN) are attached. The EISPN includes a description of the requested leases and a brief discussion of the kinds of potential environmental impacts which will be analyzed in the forthcoming EIS.

In accordance with Hawai'i Administrative Rules, Section 11-200 we respectfully request that you publish this notice in the next available edition of *The Environmental Notice* for the public to submit comments to UH during the statutory 30-day public consultation period. If you have any further questions about this letter or its attachments, please call me at (808) 922-7348.

Sincerely,

Donald O. Straney
Chancellor

Attachments:
1. OEQC Applicant Action Publication Form
2. EISPN for New Master Leases for the Mauna Kea Science Reserve and Related Facilities and Easements

200 W. Kāwili St.
Hilo, Hawai'i 96720-4091
Telephone: (808) 932-7348
Fax: (808) 932-7338
hilo.hawaii.edu

Tuiolosega, Herman

From: Donald Straney <dstraney@hawaii.edu>
Sent: Monday, January 05, 2015 4:03 PM
To: Tuiolosega, Herman
Cc: Stephanie Nagata; Marcia Heller
Subject: Master Leases: Mauna Kea Science Reserve

Aloha Mr. Tuiolosega,

Please note a correction to the cover letter sent to the DOH in December regarding the Master leeases for the Mauna Kea Science Reserve and Related Facilities and Easements:

In correction to the December 22, 2014 letter to Jessica Wooley, as director of the Office of Environmental Quality Control, the University of Hawai'i will prepare the EIS in accordance with the provisions and requirements of Hawai'i Revised Statutes (HRS), Chapter 343. Pursuant to HRS §343-5(b), an Agency Action Publication Form and Environmental Impact Statement Preparation Notice (EISPN) will be submitted.

Mahalo for your assistance in this matter.

Don Straney
Chancellor

AGENCY ACTIONS
SECTION 343-5(B), HRS
PUBLICATION FORM (FEBRUARY 2013 REVISION)

Project Name: New Master Lease for the Mauna Kea Science Reserve and Related Facilities and Easements

Island:	Hawaiʻi
District:	Hāmākua
TMK:	4-4-015:009 (Mauna Kea Science Reserve), 4-4-015:012 (Halepōhaku Mid-Level Facility), and 4-4-015:001 por. (Mauna Kea Access Road Easement)
Permits:	Issuance of New Leases for the Mauna Kea Science Reserve, or a portion of it, and Halepōhaku Mid-Level Facility and amendment of the Grant of Easement for the Mauna Kea Access Road.

Proposing/Determination Agency:
University of Hawaiʻi at Hilo
200 W. Kawili Street
Hilo, Hawaiʻi 96720
Donald Stranley (808) 932-7348

Accepting Authority:
Governor of the State of Hawaiʻi
415 South Beretania Street #5
Honolulu, Hawaii 96813
(808) 586-0034

Consultant:
Planning Solutions, Inc.
210 Ward Avenue, Suite 330
Honolulu, Hawaiʻi 96814

Status (check one only):

__DEA-AFNSI	Submit the proposing agency notice of determination/transmittal on agency letterhead, a hard copy of DEA, a completed OEQC publication form, along with an electronic word processing summary and a PDF copy (you may send both summary and PDF to oeqchawaii@doh.hawaii.gov); a 30-day comment period ensues upon publication in the periodic bulletin.
__FEA-FONSI	Submit the proposing agency notice of determination/transmittal on agency letterhead, a hard copy of the FEA, an OEQC publication form, along with an electronic word processing summary and a PDF copy (send both summary and PDF to oeqchawaii@doh.hawaii.gov); no comment period ensues upon publication in the periodic bulletin.
__FEA-EISPN	Submit the proposing agency notice of determination/transmittal on agency letterhead, a hard copy of the FEA, an OEQC publication form, along with an electronic word processing summary and PDF copy (you may send both summary and PDF to oeqchawaii@doh.hawaii.gov); a 30-day consultation period ensues upon publication in the periodic bulletin.
_✓Act 172-12 EISPN	Submit the proposing agency notice of determination on agency letterhead, an OEQC publication form, and an electronic word processing summary (you may send the summary to oeqchawaii@doh.hawaii.gov). NO environmental assessment is required and a 30-day consultation period upon publication in the periodic bulletin.
__DEIS	The proposing agency simultaneously transmits to both the OEQC and the accepting authority, a hard copy of the DEIS, a completed OEQC publication form, a distribution list, along with an electronic word processing summary and PDF copy of the DEIS (you may send both the summary and PDF to oeqchawaii@doh.hawaii.gov); a 45-day comment period ensues upon publication in the periodic bulletin.
__FEIS	The proposing agency simultaneously transmits to both the OEQC and the accepting authority, a hard copy of the FEIS, a completed OEQC publication form, a distribution list, along with an electronic word processing summary and PDF copy of the FEIS (you may send both the summary and PDF to oeqchawaii@doh.hawaii.gov); no comment period ensues upon publication in the periodic bulletin.

__ Section 11-200-23 Determination

The accepting authority simultaneously transmits its determination of acceptance or nonacceptance (pursuant to Section 11-200-23, HAR) of the FEIS to both OEQC and the proposing agency. No comment period ensues upon publication in the periodic bulletin.

__Section 11-200-27 Determination

The accepting authority simultaneously transmits its notice to both the proposing agency and the OEQC that it has reviewed (pursuant to Section 11-200-27, HAR) the previously accepted FEIS and determines that a supplemental EIS is not required. No EA is required and no comment period ensues upon publication in the periodic bulletin.

__Withdrawal (explain)

Summary:

The University of Hawaiʻi (UH) leases the 11,288-acre Mauna Kea Science Reserve (MKSR) under general lease S-4191, which expires on December 31, 2033, and the 19-acre Halepōhaku mid-level facility under general lease S-5529, which expires in 2041. In addition, UH holds non-exclusive Easement S-4697 for the Mauna Kea Access Road between the two leased properties, the leased area is roughly 71 acres and the easement expires on December 31, 2033. The two leased properties plus a 400-yard wide corridor on either side of the Mauna Kea Access Road, excluding areas within the adjacent Natural Area Reserve (NAR), make up the UH Management Area on Maunakea. UH is seeking to replace both of its existing leases with new leases well before they expire and to extend the term of the road easement.

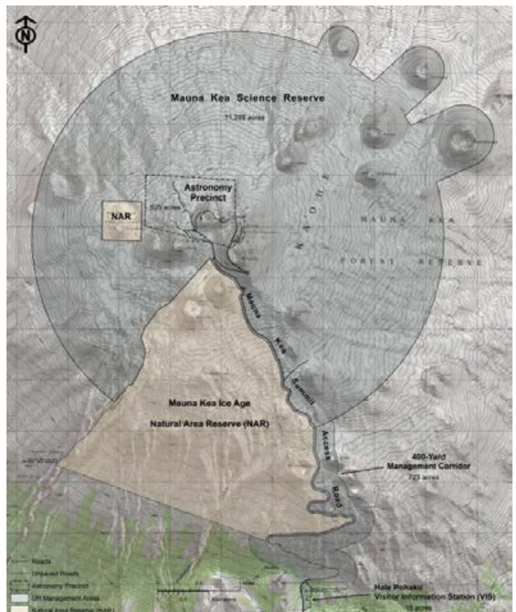
UH is seeking a new Master Lease for two principal reasons. The first is to incorporate into the Master Lease the new Comprehensive Management Plan (CMP) objectives. The second is to provide an adequate planning horizon for ongoing and future scientific activity, something that is increasingly difficult as the remaining term of the existing Master Lease becomes shorter.

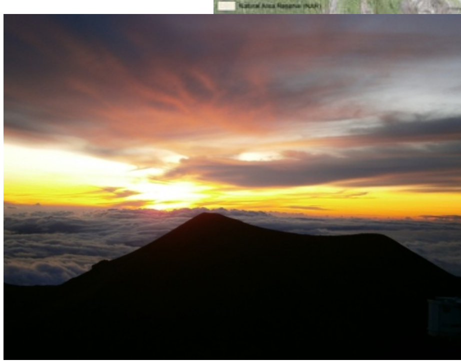
The Environmental Impact Statement Preparation Notice (EISPN) discusses a “No Action Alternative,” an action alternative under which UH leases the same areas it currently leases, and an action alternative under which UH leases a reduced land area. These three alternatives and potentially additional alternatives advanced by stakeholders during the EISPN review period will be evaluated in the Draft Environmental Impact Statement (DEIS).

The EISPN outlines the kinds of potential adverse and beneficial impacts that are likely to result from the alternatives being considered. These potential impacts and others identified by stakeholders during the review of the EISPN will be evaluated in the DEIS.

Environmental Assessment/Environmental Impact Statement Preparation Notice (EISPN)

NEW MASTER LEASES FOR MAUNA KEA SCIENCE RESERVE & RELATED FACILITIES & EASEMENTS





PROPOSING AGENCY:
UNIVERSITY OF HAWAI`I AT HILO

This Environmental Document was Prepared Pursuant to Chapter 343, Hawai`i Revised Statutes, and Chapter 200 of Title 11, Hawai`i Administrative Rules, Department of Health, Environmental Impact Statement Rules.

DECEMBER 2014

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ACRONYMS AND ABBREVIATIONS

Acronyms	Meaning
AO	Adaptive optics
ADT	Average Daily Traffic
ATV	All-Terrain Vehicles
BLNR	Board of Land and Natural Resources
BMP	Best Management Practice
BOR	Board of Regents
BTP	Burial Treatment Plan
Caltech	California Institute of Technology
CCC	Civilian Conservation Corps
CDUA	Conservation District Use Application
CDUP	Conservation District Use Permit
CFHT	Canada-France-Hawai`i Telescope
CFR	Code of Federal Regulations
CIA	Cultural Impact Assessment
CMP	Comprehensive Management Plan
CRMP	Cultural Resources Management Plan
CSO	Caltech Submillimeter Observatory
CWRM	Commission on Water Resource Management
dB	Decibels
DLNR	Department of Land and Natural Resources (State of Hawai`i)
DOE	Department of Education
DOE	Department of Energy
DOFAW	Division of Forestry and Wildlife
EA	Environmental Assessment
E-ELT	European Extremely Large Telescope
EIS	Environmental Impact Statement
EISPN	Environmental Impact Statement Preparation Notice
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-To-Know Act
ESA	Endangered Species Act
ESO	European Southern Observatory
GPS	Global Positioning System
HAR	Hawai`i Administrative Rules
HDOH	State of Hawai`i Department of Health
HDOT	State of Hawai`i Department of Transportation
HELCO	Hawaiian Electric and Light Company
HIBC	Hawai`i Island Burial Council
HPS	High Pressure Sodium
HRS	Hawai`i Revised Statutes
HVAC	Heating, Ventilating, and Air Conditioning
IfA	Institute for Astronomy
IRTF	Infrared Telescope Facility
JAC	Joint Astronomy Center
JCMT	James Clerk Maxwell Telescope
kV	Kilovolt
kW	Kilowatt
LLC	Limited Liability Company
LOS	Level-Of-Service
LUPAG	Land Use Pattern Allocation Guide
MKMB	Mauna Kea Management Board

MKSR	Mauna Kea Science Reserve
MKSS	Mauna Kea Observatories Support Services
MSL	Mean sea level
MW	Megawatt
NAAQS	National Ambient Air Quality Standards
NAR	Natural Area Reserve
NASA	National Aeronautics and Space Administration
NAOC	National Astronomical Observatories of the Chinese Academy of Sciences
NAOJ	National Astronomical Observatory of Japan
NPDES	National Pollutant Discharge Elimination System Permit
NRAO	National Radio Astronomy Observatory
NREL	National Renewable Energy Laboratory
NRHP	National Registry of Historic Places
NRMP	Natural Resources Management Plan
NSF	National Science Foundation
OCCL	Office of Conservation and Coastal Lands
OEQC	Office of Environmental Quality
OHA	Office of Hawaiian Affairs
OMKM	Office of Mauna Kea Management
PCSI	Pacific Consulting Services, Inc.
RCRA	Resource Conservation and Recovery Act
SIHP	State Inventory of Historic Places
SHPD	State Historic Preservation Division
SHPO	State Historic Preservation Officer
SMA	Submillimeter Array
SRHP	State Registry of Historic Places
TCP	Traditional Cultural Property
TMK	Tax Map Key
TMT	Thirty Meter Telescope
UH	University of Hawai`i
UKIRT	United Kingdom Infrared Telescope
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	Underground Storage Tanks
VLBA	Very Long Baseline Array
VLT	Very Large Telescope
VIS	Visitor Information Station
VOG	Volcanic smog

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1 PURPOSE AND NEED

1.1 INTRODUCTION AND OVERVIEW

1.1.1 EXISTING UNIVERSITY OF HAWAI`I PROPERTY ON MAUNAKEA

The University of Hawai`i (UH) currently leases (a) the 11,287.854-acre Mauna Kea Science Reserve (MKSR; TMK 4-4-015:009) under general lease S-4191[1], which expires December 31, 2033; and (b) the 19.261 acre Halepōhaku mid-level facility (TMK 4-4-015:012) under general lease S-5529 which expires in 2041. The Board of Land and Natural Resources (BLNR) established the MKSR in 1968 to be used as a scientific complex including a buffer area to protect astronomical research. These two properties together with a 70.798 acre roadway easement and associated buffer between the two properties make up the "UH Management Area" on Maunakea[2] (Figure 1.1).[3]

The first Maunakea observatories were built in the 1960s. Eight optical and/or infrared observatories are currently present in the MKSR's 525-acre "Astronomy Precinct". Each optical/infrared observatory consists of a single telescope, except the W.M. Keck observatory which houses two. The MKSR also hosts three submillimeter observatories and a radio antenna.

The Halepōhaku mid-level support facilities at roughly 9,200 feet on the southern slope of Maunakea include the Onizuka Center for International Astronomy, a visitor information center and comfort station, construction workers' cabins, and stone cabin facilities constructed by the Civilian Conservation Corps in the 1930s. The current Mauna Kea Access Road was improved in the late 1980's. The *Revised Management Plan for the UH Management Areas* approved by BLNR in 1995 added a 400-yard wide corridor on either side of the roadway. The total area of the Mauna Kea Access Road corridor is approximately 723 acres.

UH has expanded its management objectives for the UH Management Area over the years to include many factors in addition to astronomical research. The Maunakea *Comprehensive Management Plan*[4] (CMP), approved by the BLNR in April 2009, provides the management framework for the UH Management Area. The CMP addresses scientific (including astronomical), natural, and cultural resources.

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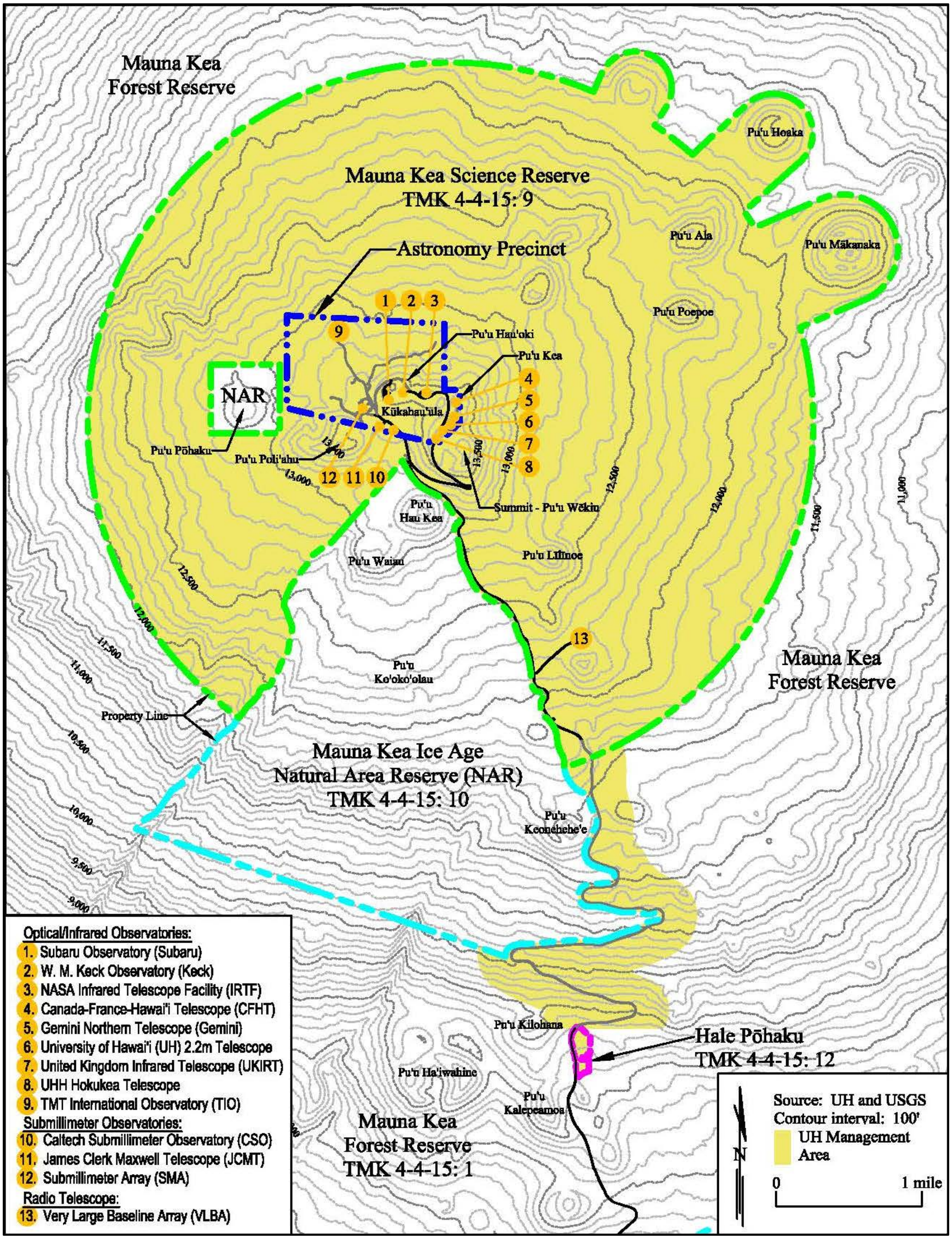
[1] This general lease is considered a "master lease" because UH has entered into subleases with various entities for the development, operation, and decommissioning of observatories within the MKSR with the approval of the BLNR.

[2] Maunakea is spelled as one word in this document because it is considered the traditional Hawaiian spelling (Ka Wai Ola, Vol. 25 No. 11). Maunakea is a proper noun, therefore spelled as one word in Hawaiian. This spelling is found in original Hawaiian language newspapers dating back to the late 1800s when the Hawaiian language was the medium of communication. In more recent years Maunakea has been spelled as two words, which literally mean "white mountain." Spelled as two words it is a common noun that could refer to any white mountain verses the proper name of this particular mountain on Hawai'i Island. The common "Mauna Kea" spelling is only used in this document where Mauna Kea is used in published or public documents, such as the "Mauna Kea Science Reserve."

[3] The entire UH Management Area is designated as part of the Conservation District, resource subzone.

[4] While ultimate authority over the management of the MKSR is retained by the Board of Land and Natural Resources (BLNR), certain responsibilities are performed by UH as provided in the BLNR-approved *Mauna Kea Comprehensive Management Plan (CMP)* and its subplans *(Cultural Resources Management Plan, Natural Resources Management Plan, Public Access Plan,* and *Decommissioning Plan.* These serve as the BLNR-approved management documents for land use and activities within the MKSR. In this document the "CMP" includes the CMP document and its four subplans.

Figure 1.1: Current "UH Management Area"



Source: University of Hawai`i

1.1.2 REQUEST FOR NEW MASTER LEASES AND RELATED EASEMENT

UH is seeking to replace both of its existing leases with new leases well before they expire and to extend the term of the road easement, which is presently due to expire at the same time as the existing master lease. More specifically, by letter dated August 22, 2013, the UH Board of Regents requested the mutual cancellation of the existing leases for MKSR (GL No. S-4191) and the Halepōhaku Mid-Level Facilities (GL No. S-5529), and the issuance of new 65-year leases for the premises. At the same time it asked that Grant of Easement No. S-4697 covering the Mauna Kea Access Road be amended so that it would be coterminous with the new general leases.

1.2 OBJECTIVES OF THE PROPOSED ACTION

The primary objective for requesting a new master lease for the UH Management Area is to maintain a physical and administrative environment that will allow the continuance of cutting edge astronomy research on Maunakea. While this would include continuing and upgrading some of the existing operations in the summit region of Maunakea and accommodate potential development of new facilities on previously disturbed sites over the next 65 years, it would also minimize the area disturbed by physical structures within the UH Management Area by requiring the re-use of existing facilities or sites, as well as the decommissioning of facilities and the restoration of impacted sites. The benefit anticipated by UH in requesting a new master lease is summarized in the August 22, 2013, letter from Mr. John Holzman, Chairman of the UH Board of Regents, to BLNR in which UH identified the following four purposes for its request:

(1) The need to address internal changes made by UH in how it manages lands on Maunakea;

(2) The need to reflect management actions and reporting requirements adopted by the BLNR;

(3) To assist in implementing legislation concerning the Maunakea lands managed by UH; and

(4) To provide the basis for developing sublease agreements with current and any potential future telescope projects.

These purposes are the objectives that UH is seeking to achieve through its request.

1.3 PURPOSE OF THIS DOCUMENT

Issuing a new master lease requires the BLNR to take an action that is subject to Chapter 343, Hawai`i Revised Statutes (HRS) and its implementing regulations Hawai`i Administrative Rules (HAR) §11-200. Chapter 343, HRS, establishes a system of environmental review intended to ensure that decision-makers consider environmental objectives in concert with the economic and technical objectives.

UH has decided that it will meet its Chapter 343 obligations by preparing an Environmental Impact Statement (EIS). HAR §11-200-15 describes the consultation that is appropriate prior to filing a Draft Environmental Impact Statement (DEIS). The purpose of this document is to facilitate the consultation that is called for in the regulations by providing a detailed description of the proposed action and the alternatives that UH is considering, identifying the <u>kinds</u> of environmental consequences which it believes each of these alternatives is likely to cause, and describing the specific analyses that it intends to conduct in order to be able to characterize the environmental effects of each alternative.

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2 ALTERNATIVES CONSIDERED

2.1 INTRODUCTION

2.1.1 BACKGROUND

Hawai`i Administrative Rules (HAR), §11-200-17 addresses the content requirements of draft and final environmental impact statements (EIS). Subsection §11-200-17(f) states:

> *(f) The draft EIS shall describe in a separate and distinct section alternatives which could attain the objectives of the action, regardless of cost, in sufficient detail to explain why they were rejected. The section shall include a rigorous exploration of the environmental impacts of all such alternative actions. Particular attention shall be given to alternatives that might enhance environmental quality or avoid, reduce, or minimize some or all of the adverse environmental effects, costs, or risks. Examples of alternatives include:*
>
> > *(1) The alternative of no action;*
> >
> > *(2) Alternatives requiring actions of a significantly different nature which could provide similar benefits with different environmental impacts;*
> >
> > *(3) Alternatives related to different designs or details of the proposed action which would present different environmental impacts;*
> >
> > *(4) The alternative of postponing action pending further study; and*
> >
> > *(5) Alternative locations for the proposed project.*

In order to achieve the objectives of the proposed action, the BLNR must grant a long-term master lease that will allow astronomical viewing and related activities in the summit region of Maunakea. UH believes that planning for the longest feasible duration will best provide for stable management and for secure funding supported by sublease commitments aligned with the useful life of observatory facilities. A 65-year lease term will align with the longest expected useful life of any current or planned observatory. For other observatories with shorter anticipated useful lives, shorter sublease terms may be appropriate and will be considered. However, UH believes that the kinds of investments needed to attain the action's objectives require the certainty that a 65-year lease term provides. Hence, UH does not believe that a shorter lease term is a viable alternative.

The original MKSR was established to allow management oversight of all the land where activities likely to affect astronomical activities might occur. UH believes that continued control of the current MKSR is the alternative that would best achieve the objectives stated above, but UH no longer considers control of the entire MKSR essential. UH believes that the majority of its goals and objectives could be achieved if it retained management control over a smaller area of the summit region.

2.1.2 OVERVIEW OF ALTERNATIVES THE EIS WILL ADDRESS

In view of the foregoing, UH has tentatively determined that the EIS will address the potential effects of two "action alternatives", one that entails a master lease of all of the area covered by the existing master lease and the other a master lease that reduces the portion of the summit under UH's control.

The EIS will also address the "No Action Alternative" — i.e., no granting of a new master lease. This alternative does not achieve the objectives that are laid out in Section 1.2, but HRS Chapter 343 and HAR §11-200 require that it be discussed in the same depth as the action alternatives that the proponent prefers. Furthermore, because UH feels it provides the clearest and most compelling explanation of the need for the proposed action, this description of the master lease alternatives begins with the "no action" alternative.

HAR §11-200-17 (F) also provides that for agency actions the discussion of alternatives include, where relevant, those alternatives not within the existing authority of the agency. No such alternatives have yet been identified for the present action. The rules require that in each case the analysis be sufficiently detailed to allow a comparative evaluation of the environmental benefits, costs, and risks of the proposed action and each reasonable alternative.

2.2 ALTERNATIVE 1: NO ACTION ALTERNATIVE

2.2.1 ASTRONOMICAL FACILITY OPERATIONS OVER REMAINDER OF EXISTING LEASES

Under Alternative 1, the No Action Alternative, the existing MKSR master lease (S-4191) would run its course and UH and its sublessees would terminate their uses no later than the end of 2033. Since all of the subleases that UH has issued (see Table 2.1) have the same termination date as the existing master lease and there is no provision for early termination of the master lease by the BLNR, none of the present uses would be forced to terminate prior to December 31, 2033.

UH's lease on Halepōhaku (S-5529) does not terminate until 2041. However, UH would have no further use for the facility if its activities within the MKSR were to cease, as would be the case by the end of 2033 under the No Action Alternative. Therefore, UH would continue to utilize Halepōhaku much as it does today until the astronomical facilities in the MKSR close and then likely take advantage of the early termination provisions in the Halepōhaku lease.

2.2.2 DECOMMISSIONING OF ASTRONOMICAL FACILITIES WITHIN THE MKSR

The manner in which observatories would close is governed by the CMP's Decommissioning Subplan (University of Hawai`i, January 2010). The CMP notes that the existing subleases specify terms for the disposition of observatory facilities in the event of termination or expiration of tenancy (Table 2.1). Unless and until existing observatories revise their subleases, they are obligated to comply with only their existing sublease terms. In general, the terms require sublessees either:

(1) Remove the facilities and restore the property at the expense of the sublessee;

(2) Sell the facilities to UH or a third party; or

(3) Surrender the facilities to UH upon approval of UH and the Chairman of BLNR.

The impact analysis presented in the EIS for Alternative 1, the No Action Alternative, will assume that all of the existing facilities would eventually be removed as described according to the terms of the lease or subleases.

Subleases are terminated upon conclusion of operation of a particular telescope by a sublessee, expiration of tenancy at the end of a lease, or revocation of a sublease by UH. Unless the facility is recycled, it must be deconstructed and the site restored per the terms of the sublease.[5] As described in the CMP's *Decommissioning Plan*, decommissioning entails the removal of the facility and restoration of the observatory site to either "even grade" or "original condition". The subleases do not state whether removal means complete removal of all facilities and infrastructure.

[5] Section 2.2.4 of the *Decommissioning Plan* addresses the actions that would be taken in the unlikely event that a sublessee was to abandon an observatory in place, without deconstructing and site restoration. It notes that if this happens, UH, as the lessee to DLNR, will ultimately be responsible for the site through the terms of their master lease.

Table 2.1: Existing Facilities and Decommissioning Terms

Facility	*Sublessee*	*Sublease Terms Regarding Decommissioning*
UHH Hokukea Telescope	UH owned no sublease,	Remove or dispose of by UH at the expiration or sooner termination of the lease, unless BLNR Chair approves that facilities may remain in place.
UH 2.2-m Telescope	UH owned, no sublease	Same as UHH Hokukea Telescope
United Kingdom Infrared Telescope (UKIRT)	UH owned, no sublease	Same as UHH Hokukea Telescope
NASA Infrared Telescope Facility (IRTF)	NASA	Surrender to UH subject to approval of UH and BLNR Chair or removal of facilities and restoration of property at expense of sub-lessee. The minimum period of advance notice for terminating sublease in writing by sublessee is not specified.
Canada-France-Hawai`i Telescope (CFHT)	Canada-France-Hawai`i Telescope Corporation	Same as NASA except that sublease has provision that allows termination by sublessee with six (6) months' notice.
W. M. Keck Observatory I	Caltech	(1) Removal of facilities and restoration of property at expense of Caltech; (2) sale to UH; (3) sale to a 3rd party, contingent upon the execution of a new Sublease and operating and site development agreement between the 3rd party and UH; (4) surrender in place. Options 2, 3, and 4 require approval of UH and DLNR. If none of these options are available, option 1 must be completed within 1 year of termination. Sublease has provision that allows termination by sublessee with two (2) years notice.
W. M. Keck Observatory II	Same as Keck 1	Same as Keck 1
Subaru Telescope	National Astronomical Observatory of Japan (NAOJ).	Same as Keck 1 except NAOJ is responsible.
Gemini North Telescope	US National Science Foundation (NSF)	Same as Keck 1 except NSF is responsible.
Caltech Submillimeter Observatory (CSO)	Caltech	Same as Keck 1.
James Clerk Maxwell Telescope (JCMT)	UK Science and Technologies Facilities Council (STFC) (see note)	Same as Keck 1 except STFC is responsible and period for removal is 6 months instead of 1 year.
Submillimeter Array (SMA)	Smithsonian Astrophysical Observatory/Taiwan	Same as Keck 1 except SAO is responsible
Very Long Baseline Array (VLBA)	US National Radio Astronomy Observatory (NRAO) and Associated Universities Inc.	Same as Keck 1 except NRAO is responsible and sublease provision for termination by sublessee has one-year notice (instead of 2).

Note: JCMT is expected to be a UH facility by the end of January, 2015.

Source: University of Hawai`i

While there is no legal mandate that will force observatories to close prior to 2033, the relatively short term remaining in the master lease is likely to forestall capital investment in entirely new facilities and discourage investment in the equipment needed to keep the existing facilities functional and competitive. As a result, the absence of a new master lease is likely to cause astronomical use of the mountain to begin to decline before master lease termination. The exact closure scenario that will be used for the purpose of the EIS in the absence of a new master lease is still being developed in coordination with the individual facility operators. However, in general it can be said that Caltech Submillimeter Telescope (CSO) is likely to be decommissioned no later than 2020, while the others would be decommissioned in the 2025-2033 time frame.

2.2.3 SUPPORT FACILITY OPERATIONS AND DECOMMISSIONING OVER REMAINDER OF EXISTING LEASES

UH is responsible for maintaining the infrastructure within the UH Management Area (i.e., the MKSR, Halepōhaku, and the Mauna Kea Access Road). Under the terms of the existing Halepōhaku lease, the property would either be returned to the BLNR with the then-existing facilities or BLNR could require UH to remove some or all the improvements prior to its return. The University will maintain the facilities until the point of lease termination so that they can be used by observatory staff and by workers involved in the decommissioning process. Consequently, they will be fully usable up until the time of surrender.

The Department of Land and Natural Resources (DLNR) Land Division has indicated that as the surrender date approaches, it would determine the remaining useful life of the property and the opportunities for alternate uses. If its study concludes that such uses are viable, the BLNR could accept the facilities. Should the Land Division conclude that no such alternate uses are likely to be viable, it would ask UH to remove the facilities in accord with the terms of the existing lease.

Infrastructure utilized by multiple parties within the UH Management Area, such as utilities, would be decommissioned once it was no longer needed. The analysis presented in this EIS assumes that under the No Action Alternative, this decommissioning would include the removal of all above ground utility infrastructure within the UH Management Area, such as switch gear and transformers. Infrastructure that is buried or flush with the ground surface, such as electric power lines and conduits, utility pull boxes, and roadway pavement, would not be removed.

2.2.4 UH MANAGEMENT ACTIVITIES OVER REMAINDER OF EXISTING LEASE

UH is required to comply with and implement the CMP throughout the life of its existing master lease. Generally, the components of the CMP will continue to be implemented in the order of their assigned priority.

Act 132 (SLH 2009) authorizes UH to adopt administrative rules pursuant to HRS Chapter 91 to regulate public and commercial activities in the UH Management Area. UH is in the process of developing administrative rules based on the principles and policies in the CMP (specifically the Public Access Plan). The initial steps are: (*i*) coordinating with DLNR to ensure the rules are consistent with those that govern state lands adjacent to the UH Management Area; and (*ii*) coordinating with the Office of Hawaiian Affairs (OHA) and DLNR regarding the rules. UH anticipates that the rules will be approved sometime in 2015 or 2016.

In this No Action Alternative, commercial tours will continue to operate under the current permit process managed by the Office of Mauna Kea Management (OMKM). Fees will be collected from the tour operators at a rate of $6/tour passenger or at whatever alternative rate is negotiated and approved, and these funds will be used toward managing the mountain including implementing the CMP, management programs, operating the Maunakea ranger program, the Visitor Information Station (VIS), and to maintain the road and facility infrastructure. Twenty percent of the fees collected will be provided to OHA.

As the end of the current master lease approaches, the decommissioning of facilities will place an increasing financial burden on UH in its effort to comply with the CMP. This will occur because: (*i*) the decommissioned observatories would no longer contribute to road maintenance and snow removal; and (*ii*) as observatories decommission, commercial tour demand may decrease resulting in reduced income from the per passenger fee collected. Reduced financial contributions would result in management activities scaled down to a maintenance level, rather than a proactive and dynamic management function. For instance, cost prohibitive management functions such as studies and surveys of the resources would be terminated, and resource monitoring would be reduced in scope and scale or eliminated. The ranger corps would also be trimmed, along with health and safety assistance, and monitoring as the number of workers and visitors to the summit region declines. Furthermore, capital investment in facilities related to CMP implementation would likely cease. Retaining qualified staff will also become a challenge as the end of the lease approaches because employees will look for positions elsewhere with long-term stability and opportunity.

2.2.5 POST-2033 DLNR MANAGEMENT OF SURRENDERED LAND

Under the No Action Alternative, land currently leased or under an easement by UH would be returned to DLNR for management at the end of 2033 when the current master lease expires. At that point UH's CMP would no longer apply to the land. The BLNR would decide a preferred management regime and/or use for the land. Based on discussions with DLNR, it appears most likely that the MKSR and Halepōhaku would be integrated into the Forest Reserve system, since that is where it resided prior to the creation of the MKSR. Alternatively, some or all of the land could be made part of the Mauna Kea Ice Age Natural Area Reserve (NAR). In either case, the DLNR would follow the requirements for the action of changing this land designation, which would include a public hearing.

Once the surrendered land is again part of the Forest Reserve system (or is assigned to the NAR), DLNR would manage the returned land similarly to the way it manages other lands within the Forest Reserve and NAR lands on Maunakea. DLNR's management of these lands is passive in nature, it does not have a comprehensive management plan for the Mauna Kea Forest Reserve or the Mauna Kea Ice Age NAR, or resources to implement such a management plan. Although uncertain, the analysis presented in the EIS will assume the following will occur, once UH returns the properties to DLNR:

- The County of Hawai`i would continue to maintain the portion of the Mauna Kea Access Road between the Saddle Road and Halepōhaku.
- DLNR would reduce the level of maintenance on the existing roadway between Halepōhaku and the summit to the level given to roads across other unimproved lands in Forest Reserves and other unencumbered State property. This means that it would immediately (i.e., beginning in January 2034) become unusable during the winter and would be reduced to 4-wheel drive-only use during all seasons very shortly thereafter.[6]
- The stargazing program and escorted public summit tours would terminate.
- DLNR would determine the remaining useful life of the VIS and other facilities at Halepōhaku property and evaluate the potential for alternate uses. DLNR would use the results of this study together with community input to determine the highest and best use of the facilities. If the results of this analysis and consultation indicate it is desirable, the VIS and other facilities at Halepōhaku would be turned over to DLNR; if not, UH would remove the facilities.
- Examples of the kinds of management activities DLNR is likely to undertake on land that reverts to its sole control include such things as: (*i*) feral ungulate eradication; (*ii*) invasive species control;

[6] The analysis makes an assumption that the DLNR would erect a gate and signage prohibiting vehicular use of this portion of the roadway soon after it reverts to its control.

(*iii*) trail maintenance; (*iv*) infrequent to no road maintenance; and (*v*) efforts to preserve threatened or endangered species, such as the Maunakea Silversword.

- Many of the existing recreational uses of the portion of Maunakea above Halepōhaku would cease or diminish greatly as a result of the reduced vehicular access. Skiing, for example, would almost certainly cease, and far fewer people would use the trails.
- Cultural uses of the summit region would almost certainly drop to a much lower level because so many of those who presently conduct activities there would not be able to continue to do so without vehicular access.
- DLNR would consider proposed land uses and activities within the former MKSR area per applicable Conservation District rules.

2.3 ALTERNATIVE 2: NEW MASTER LEASE FOR EXISTING LEASE AREA

Under Alternative 2, the BLNR would terminate the existing leases (leases S-4191 and S-5529) per UH's request and simultaneously award 65-year leases to UH for the following areas:

- The 11,287.854-acre MKSR, including the 525-acre Astronomy Precinct within which most of the existing observatories are located. This is the entirety of TMK 4-4-015:009 and is presently encumbered by General Lease S-4191 to UH. This would be the new master lease.
- The 19.261-acre Halepōhaku mid-level facility, which is located at an elevation of approximately 9,200 feet above sea level and contains the Onizuka Center for International Astronomy, the VIS, a construction laborer camp, which consists of two old buildings and four modern cabins; the common building and dorms, and maintenance facilities. This is the entirety of TMK 4-4-15:12 and is presently encumbered by General Lease S-5529 to UH.

The BLNR would also extend the term of Easement S-4697, which allows the non-exclusive use of the Mauna Kea Access Road from Halepōhaku to the boundary of the MKSR, at approximately 11,500 feet above sea level.[7] This easement is within the Mauna Kea Forest Reserve, TMK 4-4-015:001. UH and its sublessees would also continue to benefit from the use of the electrical and telecommunications facilities that have been installed within the utility easement that serves the improvements.

In addition, the road access rights would continue unchanged from Saddle Road to the point where they join the aforementioned Mauna Kea Access Road beginning at Halepōhaku.

Rent under the new master leases would be set by the Board of Land and Natural Resources (BLNR) in accordance with applicable law. UH would be responsible for maintaining the infrastructure for public access and for all costs associated with implementing the CMP. Because UH is a State agency, no performance bond would be required.

Under Alternative 2 the existing subleases (see Table 2.1) could continue through their existing term (i.e., December 31, 2033). The new master lease would enable UH to enter into new subleases with those currently holding subleases or with new parties. When negotiating the lease rent for the new subleases, UH will seek sublease rent based on the sublessees' share of the cost to manage the UH Management Area.

[7] Although the Grant of Easement (No. S-4697) includes only the Mauna Kea Access Road, the 1995 Revised Management Plan for the UH Management Areas on Mauna Kea (1995 Management Plan) added a 400-yard wide corridor on either side of the road, but excluded areas within the adjacent NAR on the western side of the road. The easement itself covers 70.798 acres, but the Mauna Kea CMP estimates that the total area of this portion of the Summit Access Road and associated corridor is approximately 723 acres.

2.3.1 POTENTIAL ASTRONOMY OPERATIONS UNDER NEW MASTER LEASE

UH sees a promising future for astronomy in the summit region of Maunakea. The long-term goal is to eventually have fewer observatories in the summit region, but maintain UH's and Maunakea's status as the Northern Hemisphere's pre-eminent center for ground-based astronomy research and education. Alternative 2 will encourage astronomical use on Maunakea to continue beyond the date at which the termination of the existing master lease would otherwise require it to end.

Observatory use during the life of the proposed master lease can be grouped into the categories below (which are those referred to in the CMP's Decommissioning Plan).

- *Continued Operation*. This category covers existing observatories that would continue to operate in their current configuration. Internal modifications could be made, such as installing new instrumentation, but there would be little or no changes to the size and external characteristics of the facility[8]. An existing observatory would be able to operate in this way until 2033 under its existing sublease and beyond 2033 if it enters a new sublease. Ultimately the operator would decommission the facility as appropriate.
- *Expansion/Modification*. This category includes the expansion or modification of an existing observatory in order to modernize or improve its capabilities, thus extending its useful life. The only current potential plans that fall into this category are the addition of two antennas and two pads to the Submillimeter Array (SMA) and modifications to the Canada-France-Hawai`i Telescope (CFHT) dome to accommodate the Maunakea Spectroscopic Explorer project (see below). Other observatories could make similar expansions or modifications throughout the term of their sublease. For the purposes of the analysis presented in this document the authors have assumed all ground disturbing activities would occur within the existing sublease areas and that the characteristics of the expanded or modified facilities would not be significantly different from those of the existing facilities. Each expansion or modification would be required to complete the BLNR-approved project development/review process and complete applicable environmental reviews, such as HRS Chapter 343.
- *Redevelopment/Recycling*. This category encompasses the removal of an existing facility and the construction of a new facility in its place, which would "recycle" the site. There are currently no plans that fall into this category. Such a redevelopment or recycling could be done by an existing observatory operator or a new operator that enters into a new sublease. For the purposes of the analysis presented in this document the authors have assumed that only those sites having a known or supposed potential for redevelopment or recycling would be subject to such actions during the term of the new master lease. Furthermore, it is assumed that any such uses that might occur would restrict ground disturbing activities to within the existing sublease areas and that the characteristics of the facilities would not be significantly different from those of the existing facilities. Each redevelopment or recycling would be required to complete the project development/review process and complete applicable environmental reviews, such as HRS Chapter 343.

Over the life of a new master lease it is not possible to know which observatories or observatory sites will fall into the three categories above. UH is committed to an overall reduction in astronomy

[8] The optical components, electro-mechanical components, and enclosure of an optical/infrared (O/IR) observatory can last for many decades and continue to perform up to their original specifications so long as routine maintenance is performed and components are replaced at the end of their service life. Rapidly changing technology, particularly in the area of detectors, can make the instrumentation that analyzes and records the light obsolete in a fraction of that time (as little as 10-20 years). However, old instruments can be replaced with new ones at relatively small cost. The result is that ground-based observatories can remain scientifically productive for many decades provided they receive proper maintenance and timely upgrades of their instrumentation and they continue to perform scientific research that can gain funding for their operation. Thus the continued operation category would be a viable one beyond 2033. The situation with radio telescopes is somewhat different because technological advances such as larger antennas and the use of interferometry can render older facilities scientifically obsolete.

facilities in the summit region; therefore, it is certain that not all sites will be redeveloped or recycled after an existing facility is decommissioned.

Additionally, it is not possible to guarantee that existing observatories would continue their activities on Maunakea beyond 2033 if they are given the opportunity to do so. A number have indicated that they would seriously consider and/or commit to extended operations should they be provided the opportunity. While it is not possible to precisely estimate the period of time that they, or their successors, would continue operating if the new master lease is issued, the Institute for Astronomy (IFA) has provided the following preliminary estimates that will be refined following consultation with existing and prospective sub-lessees for use in the EIS:

- TMT would remain in service through the end of the new master lease;
- CSO is expected to decommission on or about 2018;
- For the other two submillimeter facilities, James Clerk Maxwell Telescope (JCMT) and SMA, current plans foresee only one continuing after 2033;
- Current plans do not foresee either a major modification of the United Kingdom Infrared Telescope (UKIRT) or redevelopment of the UKIRT site. So, in view of its age, it seems quite possible that UKIRT will decommission within 20 years.
- Current plans assume that the Very Long Baseline Array (VLBA) Antenna will not continue beyond the end of its current sublease (2033).
- If the new master lease is approved, and the funding and necessary permits are secured, CFHT is likely to proceed with the Maunakea Spectroscopic Explorer (MSE) project, placing a 10-meter Keck-type telescope on the existing CFHT pier under a new dome. If this occurs, the facility would suspend operation sometime in the next 5-8 years and reopen about 3 years later, operating through the end of 2079.
- If the new master lease is approved, the UH Hilo Hokukea Telescope would be expected to continue more or less in its current concept for 30-40 years. The UH 2.2-m Telescope is likely to continue for that period as well, but there would be a concerted effort to recycle this site with a more modern telescope of approximately the same overall size. Whether or not the recycling can actually occur will depend upon whether UH is able to raise the necessary funds.
- Infrared Telescope Facility (IRTF) may continue for 10-20 years in its current form, but after that will either decommission or will have a major renovation to install a more modern telescope in a facility with similar characteristics. Whether this happens will depend on what priority National Aeronautics and Space Administration (NASA) gives to having a ground-based O/IR facility to support its space mission, particularly after Hubble is gone.
- Keck I and II, Gemini, and Subaru, which are now in the prime of life, have indicated a strong interest in extending their subleases if a new master lease is granted. In all likelihood they would continue operating without major change for 30-40 years. After that (i.e., in the latter part of the period covered by a new master lease) they could be modified or they might be decommissioned.

Under this and all other Alternatives, astronomical and related facilities on Maunakea would be restricted to existing sublease areas. No new sites would be developed.[9] All of the existing observatories will be consulted about their plans and aspirations for the future during preparation of the EIS, and the information that is obtained through that process will be used in preparing the EIS.

2.3.2 POTENTIAL HALEPŌHAKU USE UNDER NEW MASTER LEASE

Alternative 2 also includes continued use of Halepōhaku, with all of the activities that are now conducted and/or based at that location continuing. This includes the baseyard from which road

[9] Construction of the TMT Observatory is anticipated to start in 2015 would continue to completion.

maintenance equipment operates, the staff accommodations at Halepōhaku, the VIS, and other activities.

2.3.3 MANAGEMENT ACTIVITIES: ALTERNATIVE 2

If a new master lease is issued as requested, UH will continue to implement and enforce the CMP and any BLNR-approved amendments throughout the term of the lease. The Mauna Kea Access Road would continue to be maintained at roughly the same level it is today. Public access to the UH Management Area would continue as it is today and commercial tours would continue to operate under the permit program. Other facilities and services, such as the VIS and ranger program, would continue to operate similar to the way they do today.

Further, UH will continue to observe and comply with Act 132, which calls for any fees collected on the UH Management Area to be deposited into the Maunakea lands management special fund and used only for the management of the "Mauna Kea lands." CMP compliance assures any new or re-negotiated sublease will also require the sublessee to comply with the conditions of the CMP, including decommissioning requirements for funding the decommissioning process and site restoration. This will provide greater certainty that UH will not bear site restoration costs disproportionately. Following the example of the Thirty Meter Telescope sublease, all new and renegotiated subleases shall pay rent into the Maunakea lands management special fund. Those funds plus funds from the tour operator fees and any other sources would ensure the continued implementation of the CMP. However, similar to the No Action Alternative, management actions may taper off toward the end of the new lease term if funds available from the subleases and other sources diminish.

As described in Section 2.2.4, Act 132 (SLH 2009) authorizes UH to adopt administrative rules pursuant to HRS Chapter 91 to regulate public and commercial activities in the UH Management Area, and it is presently moving through the rule-making process. It presently anticipates that the rules will be approved sometime in late 2015 or early 2016.

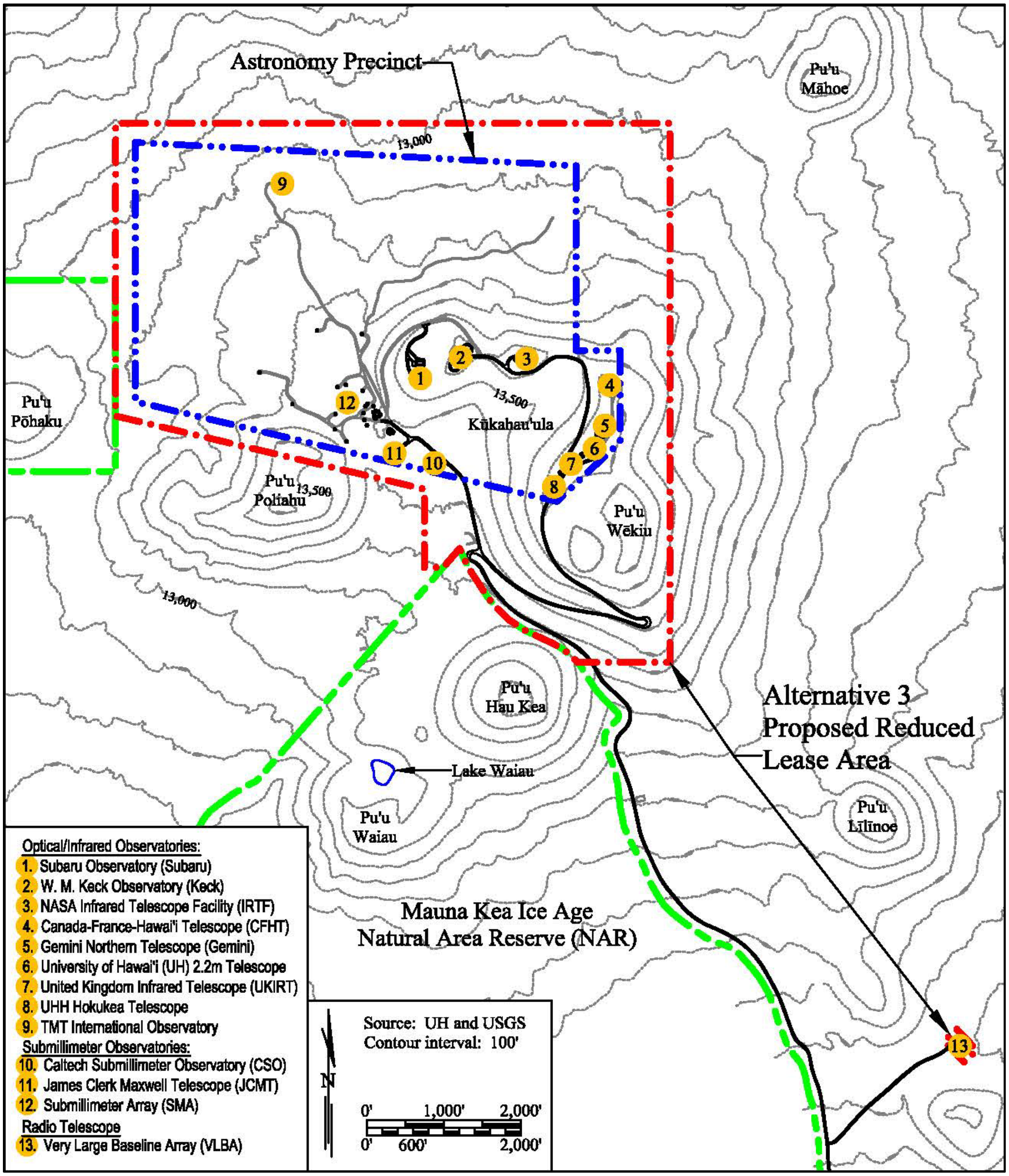
2.4 ALTERNATIVE 3: NEW MASTER LEASE FOR A REDUCED LEASE AREA

Under Alternative 3 the BLNR would terminate the existing master leases per UH's request and simultaneously award 65-year master leases to UH for the following areas:

- An area that includes the 525-acre Astronomy Precinct with approximately 353-acres of adjacent land plus the 2-acre VLBA sublease area. This area is a portion of the existing MKSR (TMK 4-4-015:009) and all together is 880 acres, or 7.8 percent of the current ~11,288 acre MKSR. The land adjacent to the existing Astronomy Precinct provides a 250-foot or greater buffer around the Astronomy Precinct, includes the switchback road up to the observatories, and captures the existing batch plant staging area. The approximate boundary of the area is shown in Figure 2.1 below.
- The 19.261-acre Halepōhaku mid-level facility as described in Alternative 2 (Figure 1.1).

Alternative 3 also provides for continued use of the Mauna Kea Access Road as described in Alternative 2 with the easement expanded to capture the entire roadway between the lease areas described above, including the road off the Mauna Kea Access Road to the VLBA site.

Figure 2.1: Alternative 3 Proposed Reduced Lease Area



Under Alternative 3 astronomical facilities would operate in the same way as described under Alternative 2 in Section 2.3.1. Also, support operations would continue as described under Alternative 2 in Section 2.3.2. When the VLBA site is decommissioned, UH would return that portion of the lease area back to DLNR. UH anticipates that it would ask the BLNR to limit uses on the Conservation District Lands that are no longer within the MKSR to those that would not degrade the value of the summit for astronomical research.[10]

2.4.1 UH MANAGEMENT AREA MANAGEMENT ACTIVITIES: ALTERNATIVE 3

The land area over which UH would have control is an order of magnitude smaller under this alternative than it is under Alternative 2. UH would undertake the same management activities for the land within the smaller UH Management Area under Alternative 3 as it would for the larger UH Management Area in Alternative 2 (Section 2.3.3). It would no longer undertake management activities in the remainder of the present MKSR.

2.4.2 DLNR MANAGEMENT OF LAND RETURNED TO DLNR UNDER ALTERNATIVE 3

Under Alternative 3 UH would no longer have control over or be responsible for the management of all of the land within the existing MKSR. Roughly 10,408 acres of the existing MKSR would be returned to DLNR when the current master lease is terminated. For the purposes of the analysis in this EIS, it is assumed that DLNR would designate and manage this land as outlined in the No Action Alternative in Section 2.2.5. An important distinction between the lands returned to DLNR under the No Action Alternative and the land returned to DLNR under Alternative 3 is that the latter consists only of undeveloped wilderness land. Under Alternative 3 there would continue to be access to the summit region via the access road because UH would continue to hold the non-exclusive easement for the roadway and maintain the roadway as it does today. UH anticipates further discussions with the Land Division to determine likely uses of the surrendered area.

2.5 ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL

UH considered and rejected other alternatives before it decided to submit its request to the BLNR. Those alternatives, and the reasons for their elimination, are summarized below.

2.5.1 DELAY REQUEST FOR NEW MASTER LEASE

As noted in Section 2.1.1, the EIS must evaluate the option to postpone the action as a means of avoiding or minimizing potential environmental impacts. For reasons noted above, delaying its request for a new master lease would make it impossible for UH to retain the organizations that operate the astronomical research facilities in the summit area over the long term. Hence, it is not a viable alternative to the proposed action.

2.5.2 ASTRONOMICAL FACILITIES IN A DIFFERENT LOCATION IN HAWAI`I

As described in Section 1.2, the primary objective for requesting a new master lease is to maintain a physical and administrative environment that facilitates the continuance of cutting edge astronomical research in Hawai`i. The summit area of Maunakea is uniquely well suited for ground-based astronomy. No other site within the State (in fact no other site in the entire Northern Hemisphere) provides the same combination of clear dark skies, low atmospheric turbulence (sharp images), low water vapor, and adequate land area. Hence, other locations in Hawai`i are not viable alternatives and are not being considered.

[10] Incompatible uses which the UH would hope to see limited include those with radio frequency or light emissions (such as cellular telephone towers, microwave relay stations, etc.) that are inimical to scientific observations.

2.5.3 ASTRONOMICAL FACILITIES IN A LOCATION OUTSIDE HAWAI`I

Few other places in the world offer observing conditions comparable to those available from within the MKSR. But competitors do exist. Conditions in the high mountains of northern Chile are also excellent. Those areas are far from big cities and associated light pollution. The arid climate prevents radio signals from being absorbed by water vapor. As a result, a number of important research groups have chosen it for their facilities. A consortium of fifteen European countries (the European Southern Observatory) already operates a number of large telescopes in Chile, and ESO is working to develop the European Extremely Large Telescope (E-ELT). Their present plans call for E-ELT to have a 39-meter (128-feet) diameter main mirror and to be the largest optical/IR telescope in the world.[11] If the project developers are able to adhere to their present schedule, the facility would begin operating early next decade. The E-ELT is only a few years behind Maunakea's TMT project.

The Chilean sites collectively can provide observing conditions comparable to those on Maunakea, but no single Chilean site provides both the superb conditions for optical/IR astronomy and also for submillimeter astronomy. Furthermore, Maunakea is unique in its ability to observe the entire Northern hemisphere of the sky; Chilean observatories cannot see a large portion of the Northern sky. Relocation of existing Maunakea facilities to Chile would be prohibitively expensive, so even if this alternative were viable scientifically (which it is not), it would apply only to new facilities. Most importantly, research conducted at other locations would not facilitate the continuance of cutting edge astronomy research in Hawai`i and is not, therefore, a viable means of achieving the project objectives.

[11] The telescope has a five-mirror design that includes advanced adaptive optics; it will provide images many times sharper than those from the Hubble Space Telescope.

3 OVERVIEW OF THE EXISTING ENVIRONMENT

The new leases and easement that UH is seeking are situated around the summit and southern face of Maunakea. This chapter provides an overview of the existing environment in those areas. The discussion is organized by potentially affected resources (e.g., topography, hydrology, sound levels, etc.). It is intended to orient readers to the general characteristics of the project area, familiarizing them with the kinds of resources that are present and that will be examined in the impact analysis. More detailed information will be provided in the EIS to identify and evaluate potential impacts.

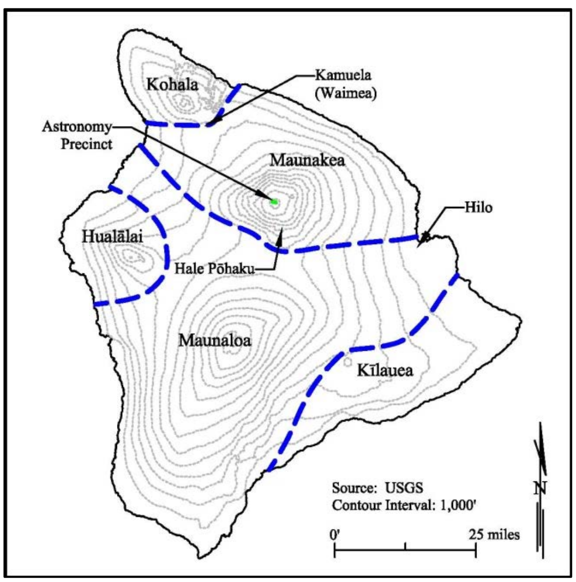
3.1 EXISTING PHYSIOGRAPHY, GEOLOGY, AND SOILS

3.1.1 GEOLOGICAL AND PHYSIOGRAPHIC OVERVIEW

3.1.1.1 Introduction

Rising to an elevation of 13,784 feet above sea level, Maunakea is the highest of the five shield volcanoes that have formed the Island of Hawai`i (see Figure 3.1 and Figure 3.2) and the highest insular volcano in the world. The dome of Maunakea measures 30 miles across and is studded with cinder cones in a pattern indicating that the volcano was built over rifts extending eastward, southward, and westward.

Figure 3.1: Volcanoes of the Island of Hawai`i

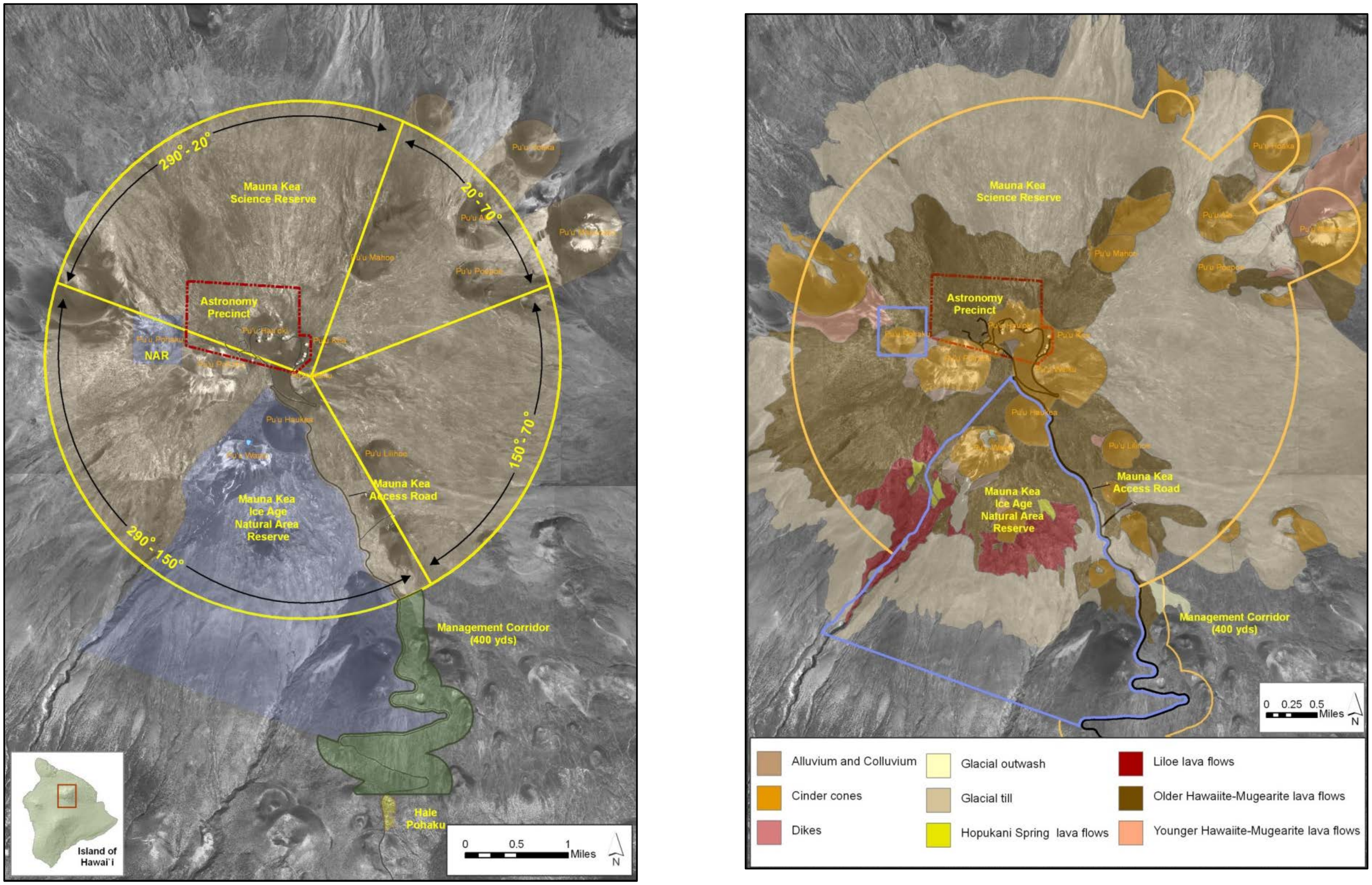


Approximate boundaries

Aerial photo showing cinder cones

The volcanic rocks of Maunakea are divided into two series. The older Hāmākua series, which originated during the shield-building stage of Maunakea's growth (the stage that Kilauea and Maunaloa are in today) is made up chiefly of primitive olivine basalts and forms the bulk of the mountain. The overlying Laupāhoehoe volcanic series consists predominantly of andesine andesites ("hawaiites") lava flows and cinder cones and forms a thin veneer over the upper part of the mountain. The Laupāhoehoe series is derived from post-shield eruptions from vents which are scattered across the mountain instead of along rift zones as occurred during the shield stage.

Figure 3.2: Maunakea Physiographic Segments and Geology



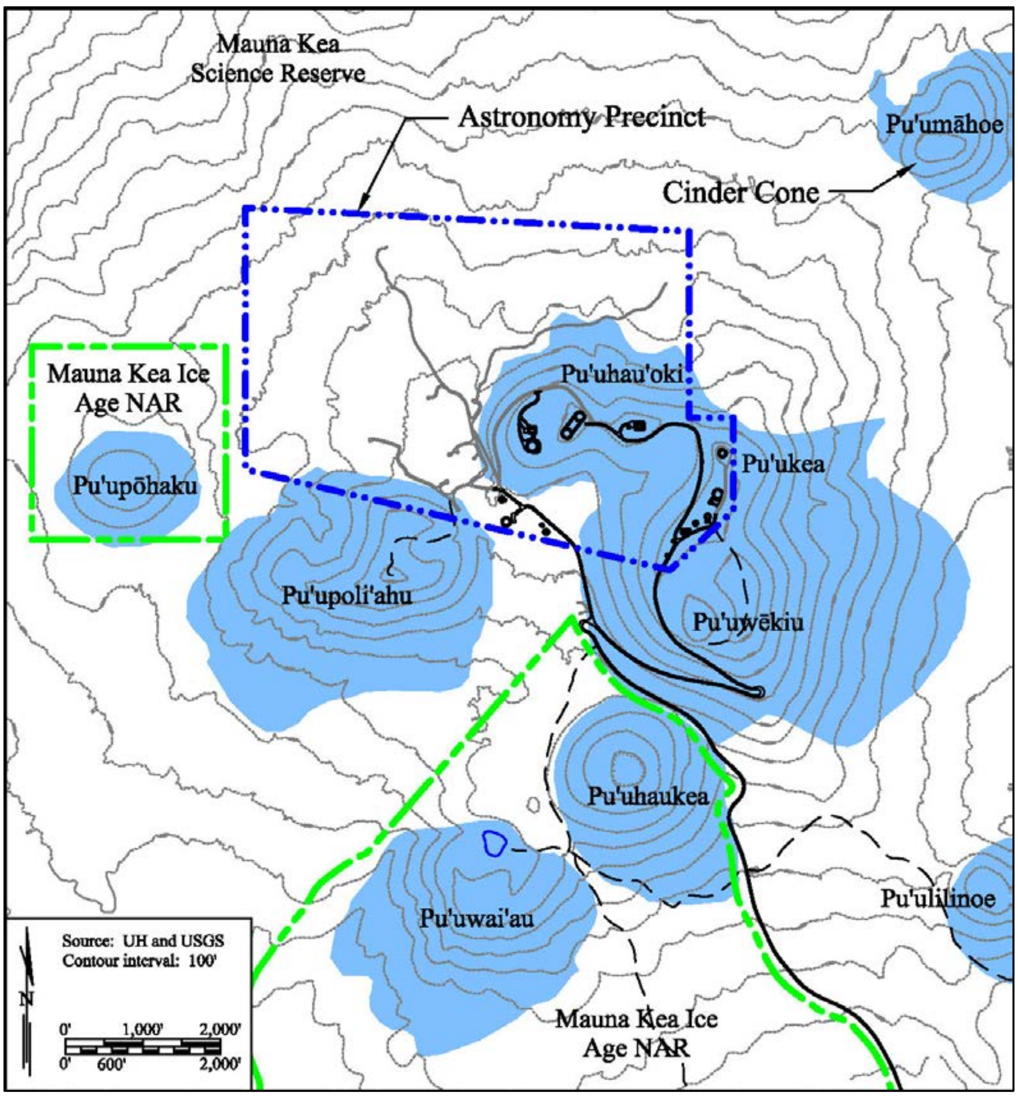
Source: University of Hawai`i 2009c Figures 2.1-7 and 2.1-2.

The Laupāhoehoe series cinder cones that are responsible for the "bumpy" appearance of Maunakea's surface formed over the last 60,000-4,000-years. The Laupāhoehoe series is the thickest in the Maunakea summit region where it filled in the summit caldera. This volcanic series is characterized by both short and long *`a`ā* [12] flows and bulky cinder cones (Stearns, 1966).

The most recent eruptive period, part of the Laupāhoehoe series, involved eight vents on the south flank of the volcano between Kalaieha cone (near Humu`ula) and Pu`ukole (east of Halepōhaku), while eruptions also took place on the northeast flank at Pu`ulehu and Pu`ukanakaleonui. Lava from Pu`ukanakaleonui flowed more than 20 kilometers (12 miles) northeastward, entering the sea to form Laupāhoehoe Point.

In the summit region the most prominent Laupāhoehoe series cinder cones are Pu`upoli`ahu, Pu`uhau`oki, Pu`ukea, Pu`uwēkiu, and Pu`uhaukea (Figure 3.3). Many other cinder cones are present within the MKSR, including Pu`ulilinoe, Pu`upoepoe, Pu`uala, Pu`umākanaka, and Pu`uhoaka.

Figure 3.3: Cinder Cones in Summit Region



[12] *`A`ā* is a type of lava flow that appears to be stony and rough.

Because it has been at least 4,600 years since Maunakea's last eruption, geologists classify it as "dormant". However, U.S. Geological Survey (USGS) scientists believe it has erupted a dozen times within the last 10,000 years and will erupt again sometime in the future.[13] The next eruption will likely produce a cinder cone and lava flow, because each eruption in the past 60,000 years has done so. The longest lava flows are expected to reach 15-25 km (9-15 miles) downslope. Most of the future lava flows will be *`a`ā*, but *pāhoehoe*[14] may form near vents. A prominent cinder cone would be expected to develop at each future vent.

3.1.1.2 Overall Physiography

The overall shape and mass of Maunakea is the result of lava from innumerable volcanic eruptions. As new flows covered older flows, the mountain grew higher and broader. The morphology of the upper flanks and summit area of Maunakea was subsequently altered by the Laupāhoehoe series post-shield eruptions, which produced the pu`u that dot the landscape. This period of volcanism coincided with the presence of glaciers on the upper mountain. When the erupted lava and ejected tephra met the glacial ice, they cooled quickly. The surfaces on which the ejecta were deposited were also affected, as were the rates of glacial melting and the amount of runoff. The combination of these factors resulted in the unique and varied geomorphic features of Maunakea.

The slope of the mountain from 9,000 to 12,900 feet ranges from 5 to 20 degrees, averaging approximately 15 degrees. The summit area, which includes the area from 12,900 feet to the tops of the highest cinder cones, encompasses a large, nearly flat plateau of remnant lava flows that were subsequently sculpted by glaciers. Due in part to minimal precipitation and the porous nature of much of its surface, the gulches that have eroded into the mountain slopes are largely the result of water from melting glaciers; fluvial processes are responsible for little surface erosion of the mountain. Wind has also played a small role in creating the topography both as an agent of erosion and as the carrier of smaller-sized volcanic ejecta.

Maunakea's late stage, post-shield eruptive activity, during both the Hāmākua Stage eruptions and the younger, Laupāhoehoe eruptions, resulted in the formation of more than 300 large cinder cones all across the volcano's summit and flanks (Porter 1972b). Wolfe and others (1997) mapped 23 cinder cones within the area of the MKSR, including three within the pie-shaped parcel and one in the square-shaped parcel of the Mauna Kea Ice Age NAR.[15] These include Pu`uhau`oki, Pu`ukea, Pu`uwēkiu, Pu`uhaukea, Pu`upoli`ahu, Pu`uwai`au, Pu`upōhaku, and Pu`ulilinoe all within the summit area of MKSR. Others, such as Pu`ukeonehehe`e, Pu`umākanaka, Pu`upoepoe, and Pu`umahoe, are at slightly lower elevations. The largest cone, Pu`umākanaka has a basal diameter greater than 4,000 feet and is more than 600 feet (183 m) high (Macdonald *et al.* 1983). Most of the cones are 100 to 300 feet high and typically have steep slopes, averaging approximately 25 degrees along both their outer and inner faces (Porter 1972b). Between the cinder cones are relatively gently sloped plateaus of primarily Laupāhoehoe *`a`ā* lavas. While it is clear that in some instances the lavas flowed from either the cone's base or around the cone, many of the cones appear to `sit' on top of these plateau flow units, having been deposited during later, explosive events. Glacial till, as well as both terminal and lateral moraines from the three glaciers that were present across the summit area are visible along Maunakea's flanks, delimiting the furthest extent of the glacial advances.[16] Lava

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[13] The USGS scientists who watch the mountain most closely believe that the next eruption of Maunakea is unlikely to occur in our lifetimes, but they do not rule that out as a possibility.

[14] *Pāhoehoe is a type of lava flow that appears to be smooth and/or ropey.*

[15] Porter (1979b) shows 25.

[16] *Till* is any deposit, transported via the glacier and placed along broad areas either adjacent to or at the toe of the glacier, but predominantly the latter. *Moraine* is any consolidated or unconsolidated deposit of material displaced by a glacier and deposited together within a fairly discrete area. Lateral moraines are parallel to the direction of the glacier's movement while terminal moraines represent material that is deposited or at the end of the glacier's movement. Till is usually a component of moraines.

tubes and caves are rare within the MKSR, and those that have been found have only small chambers (McCoy 2009).

The morphology of some of the cinder cones has been altered by development within the UH Management Area. The development of each existing observatory required localized site work that significantly modified the preexisting terrain, and modified the geologic structures and slope stability. Pu`uhau`oki and an unnamed cinder cone to the west (where Keck and Subaru observatories are located; Figure 3.3) have undergone the most significant alterations as connecting roads were built and the tops of the cones were flattened to serve as foundations for the facilities. Most of the material that was removed was transported away for use elsewhere or placed on the floor of the pu`u crater northwest of Keck, but some material was pushed over the sides of the cones. As a result, these areas have steeper slopes than would naturally occur, and because they consist of poorly consolidated material they are more susceptible to disturbance. A few other cinder cones in the UH Management Area have also been altered, but the changes to them have been less than those made to Pu`uhau`oki.

The NRMP conceptualizes Maunakea's summit landscape as four wedges or pie-shaped pieces that share a common apex located on Pu`uwēkiu, roughly at the center of the MKSR (see Figure 3.2).

- The segment between 290 degrees and 20 degrees along the arc of the MKSR boundary includes the area commonly referred to as the northern plateau. The plateau has fairly uniform slopes with only small topographic breaks and shallow gullies cut into its surface. Within this area, the elevation line of approximately 12,900 feet marks a division in surface materials, with primarily till below the line and lava flows and cinders above. The entire surface is rocky and rough, with the primary difference in the surface materials being the size and shape of the rocks.
- The segment from 20 degrees to 70 degrees is dominated by cinder cones aligned from the northeast to southwest. Slopes are steep on the cones and moderately sloped between them. Between the cones, the surface is predominately till, with some larger lava pieces around the bases of the cones. As on the northern plateau area, there is only minor incision of gullies into the land surface.
- The segment from 70 degrees to 150 degrees has relatively uniform slopes and ground cover, with the latter being dominated by till. There are only moderate gullies cut into the surface, and gulches that become well defined are further downslope, below the MKSR boundary. Several of these downslope gulches fall within the large Wailuku watershed, which extends to the coast near Hilo.
- The final segment (between 150 degrees and 290 degrees) includes both NAR parcels. Cinder cones fall along margins of this area, and as a result, slopes are steep on the cones with surfaces dominated by cinder and lava flows around the bases. The western portions of this arc are dominated by lava flows, with rough *`a`ā* covering most of the surface. Surfaces range from rough, broken areas with large debris to smooth areas with small particles, due in part to glaciers scraping over the lava. The area is unique, in part because of the presence of glacial moraines that were deposited along the sides and at the terminal positions of the glaciers. This piece contains the most defined drainage network in the summit area, Pōhakuloa Gulch. The wedge-shaped Mauna Kea Ice Age NAR parcel contains hundreds of scattered outcrops of hawaiite formed by the interaction of glacial ice and hot volcanic ejecta.

3.1.1.3 Glacial Features

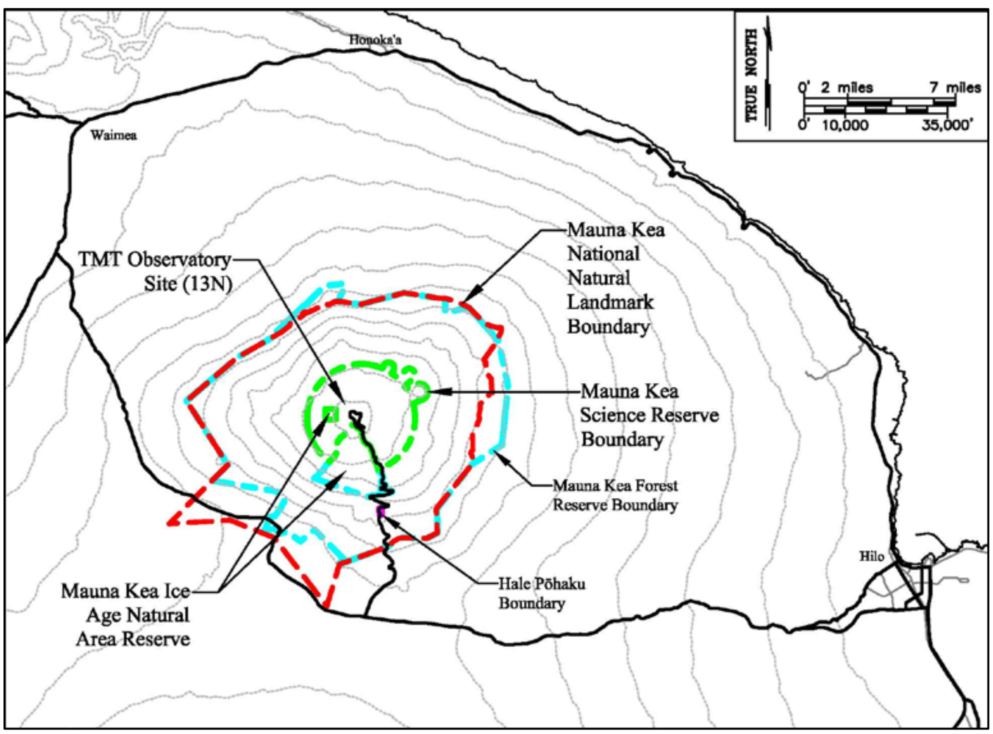
As reported in Macdonald and Abbott (1983: 258), Porter (1979) estimated that during the last glaciation of the Pleistocene epoch, an ice cap covered approximately 27 square miles of the summit area of Maunakea. The estimated average ice thickness in the summit region during the most recent period of glaciation was 200 feet, and the ice is believed to have been up to 350 feet thick in places. Within the limits of this glacier, which reached down to the 11,000 and even the 10,500-foot elevation, many areas were scraped bare of ash and cinder. Areas of buried ground ice in the craters of two of the summit cinder cones were documented by Woodcock (1974); the study indicated that permafrost existed near the summit at that time when the mean annual temperature was below freezing.

The glacial features found on Maunakea are unique to glaciated terrains, and are found at no other oceanic volcano in the Pacific. However, those few that are in the Astronomy Precinct are not unique on Maunakea, and better examples are widely distributed in other parts of the summit. The degree of glacial polishing is related to the thickness of the overlying ice that was present; because the glacial ice cap in the Astronomy Precinct was less thick than at lower elevations southeast of the summit, glacial polishing and striations are poorly developed there. The last glaciers melted in the area 10,000-13,000 years ago, leaving boulders once being transported in the ice standing on high places as the ice melted. Such glacial erratics[17] and other debris form extensive deposits of glacial till about a mile downslope from the Astronomy Precinct, but the glaciers were never extensive enough to form the kinds of widespread glacial moraines that are preserved on the south flank of Maunakea.

3.1.1.4 National Natural Landmark Designation

The U.S. Department of Interior, National Park Service administers the National Natural Landmarks Program and designated a portion of Maunakea as a National Natural Landmark (NNL) in November 1972. NNLs are natural areas that the Secretary of the U.S. Department of the Interior has determined to be one of the best examples of a type of biotic community or geologic feature in its biophysiographic providence in the nation. In making the NNL designation, the Department of the Interior referred specifically to its status as the highest insular mountain in the United States, standing more than 30,000 feet above its submerged base at the bottom of the Pacific Ocean, the presence of the highest lake in the United States (Lake Wai`au), and the indisputable evidence of glaciation above the 11,000-foot level.

Figure 3.4: Maunakea National Natural Landmark



Source: Final EIS for the Thirty-Meter Telescope Project

[17] "Glacial erratics" are stones and rocks that were transported by a glacier and then left behind after it melted. They can range in size from pebbles to large boulders.

3.1.2 SOILS

3.1.2.1 Soils in the Mauna Kea Science Reserve

As described in the NRMP, from 9,000 feet upward Maunakea is a dry environment with much of its surface covered with rock that has been moderately altered by biogeochemical reactions. Due primarily to low rates of precipitation and a cool temperature regime, biogeochemical weathering of rocks is very slow and predominately mechanical in nature. This environmental setting is the primary reason why so much of the area does not contain soils and why disturbances to surface features remain visible for long periods.

The Natural Resources Conservation Service has classified higher elevations of the MKSR as Very Stony Land or Cinder Land composed entirely of post-shield volcanic material (see Figure 3.5).[18] A combination of coarse gravel to cobble-sized pieces of cinder and lava covers the ground surface of most of the summit area. Cinder is the dominant component of the cinder cones forming the summit and it is this debris that makes up the outer slopes of the cones (Porter 1972b; Wood 1980; Wolfe et al. 1997). Areas that were capped by lava flows at the summit plateau are relatively flat and dark grey to black in color, with a low albedo (surface reflectivity); *`a`ā* flows deposited before glaciers covered the summit area later lost their original craggy surfaces when glaciers slid over them. Exposed outcrops of moraine and till from these glacial icecaps are composed of poorly sorted cobbles, rocks, and boulders (Wolfe et al. 1997). Rills and small gullies incising the flanks of Pu`upoli`ahu, Pu`uwai`au, and other cones are indicative of a naturally altered layer that is less porous and more prone to erosion than cones that contain more porous layers of ash or other material (Wolfe et al. 1997).

Lava flow outcrops are scattered throughout the MKSR, poking out from layers of cinder, till, and a slowly increasing coating of finer particles as one descends the mountain. Many of these outcrop formations are the result of lava erupting under the icecaps of the glacial periods.

3.1.2.2 Soils at Halepōhaku and Mauna Kea Access Road

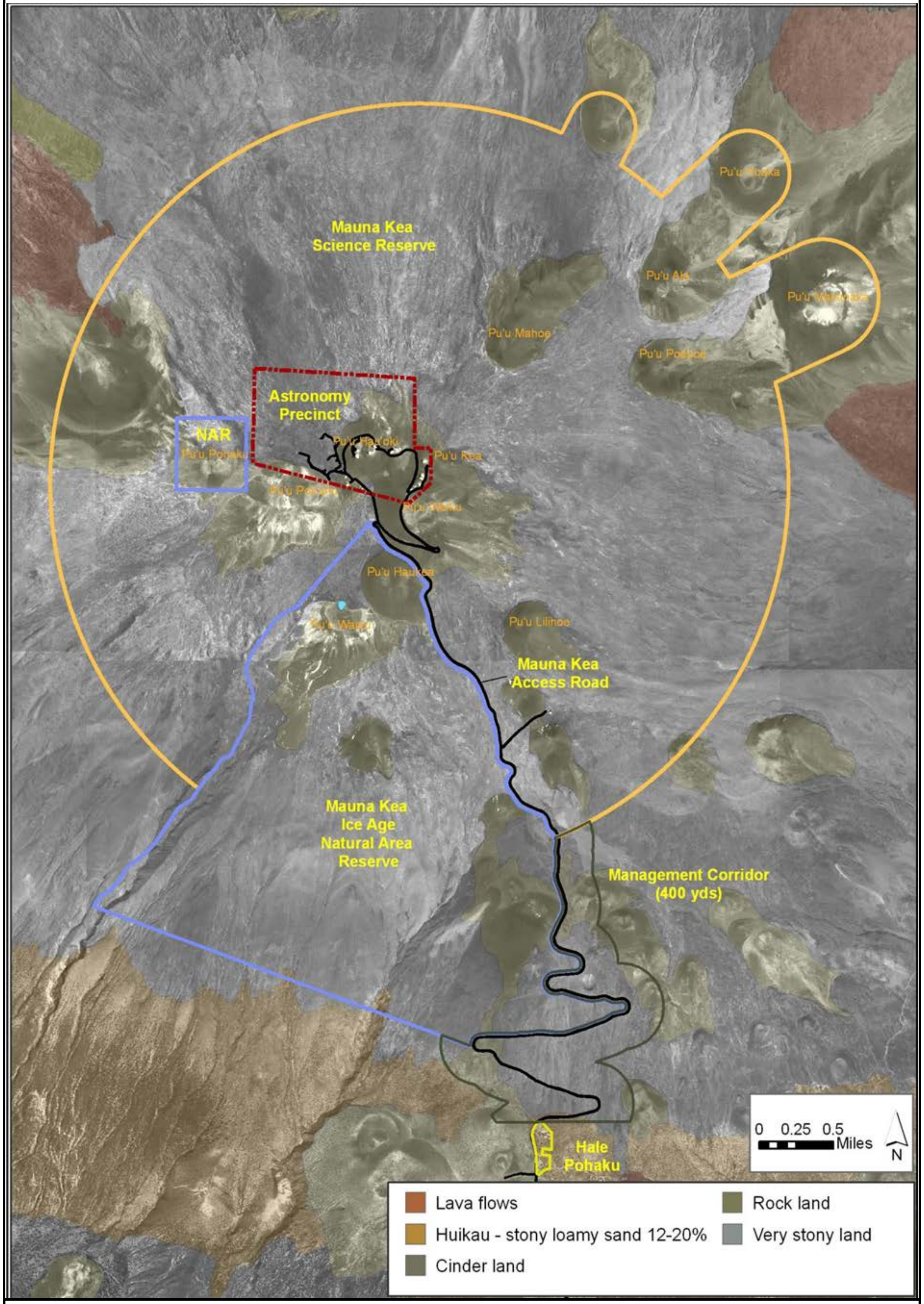
The NRMP reports that the ground surface of the lower-elevation Halepōhaku facilities is covered with small particles that are several centimeters deep in some locations. The slopes of cinder cones in the vicinity of Halepōhaku are comprised of larger fragments than those of the summit and have been dusted with fine-grained particles. The lowest lying areas are littered with cinder and small lava rocks. The area around the existing Halepōhaku facilities has been extensively modified by construction around buildings, and is impacted by minor gullying, especially in the upper portions where water runoff is concentrated from parking areas and roof drainage. The undisturbed surfaces are covered with loose volcanic blocks overlying fine grained sand of volcanic origin; clumps of vegetation have trapped high mounds of wind-blown sand.

Following the construction of the Mauna Kea Access Road, erosion of materials next to the roadway has been an issue during heavy rainfall or rapid snow erosion. Past episodes have transported loose material as much as 300 feet downslope from the road, but the construction of settling basins along the roadway has largely mitigated this occurrence.

The Hawai`i Electric Light Company transformer substation is located in a natural saddle, or dip, between Pu`ukalepeamoa to the south and a cinder cone and crater associated with Kilohana to the north. The Hawai`i Electric Light Company enclosure is mostly sited on a thick layer of imported gravel fill, and has had no impact on surrounding geologic structures. The surface underlying this fill consists of unconsolidated sand and gravel that has been unaffected by surface water runoff. The adjoining cinder cone slopes are covered with debris from volcanic eruptions, consisting mostly of broken volcanic bombs.

[18] See information on soils from the Natural Resources Conservation Service at: http://www.hi.nrcs.usda.gov/soils.html.

Figure 3.5 Soils of Maunakea



Source: University of Hawaii 2009c Figure 2.1-13

3.2 CLIMATE AND AIR QUALITY

3.2.1 INTRODUCTION

As discussed in the NRMP, at the upper elevations of Maunakea the prevailing conditions are dry, windy, and cool, with high visibility and low surface albedo. Ugolini (1974) classified it as semi-arid, barren alpine desert tundra. The atmospheric feature that most strongly influences its climatic regime is the North Pacific Anticyclone.[19] The anticyclone is formed as warm air from the equatorial zones rises and moves north toward latitude 30º North, where the air cools and sinks back toward the earth's surface. A result of the sinking air is the trade winds that blow outward from the center of the cell, and in this case, toward the Hawaiian Islands.

As the warm air sinks and blows from the northeast, it encounters rising air from the ocean surface that cools as it rises, and at the point of contact between the two air parcels the layer of warm air overlies the cool air. This atmospheric feature is termed an inversion; in Hawai`i it is commonly called the trade wind inversion. In vertical profile, the air column around Hawai`i under this climatic regime can be described as comprising three layers: from sea level to 2,000 feet is the marine layer, where evaporation from the ocean lifts water upwards; from 2,000 feet to 7,000 feet is the cloud layer, where water in the air parcel condenses, forming clouds; and from 7,000 feet to approximately 20,000 feet is the dry inversion zone, where the atmosphere is dry and stable. The photograph to the right illustrates a typical inversion capping of the clouds at approximately 7,500 feet.

The NRMP identifies just two meteorological seasons in Hawai`i – summer (May – September) and winter (October –April), with the trade winds blowing approximately 80 percent of the time in the summer and 50 percent of the time in the winter. Pre-contact Hawaiians recognized these two seasons as the warm (summer) season (*Ka`ū)* and the cool (winter) season (*ho`oilo*). Rainfall associated with the trade winds occurs when the moist air encounters the mountain slopes and is forced upwards; the lower temperature that prevails at higher elevations causes the moisture in the air to condense and form clouds which often generate rain.

The past and existing uses and activities on Maunakea have not changed the climate on the island. While emissions from internal combustion engines used in vehicles and other equipment operating on Maunakea have incrementally contributed greenhouse gases that affect global climate, their contribution is tiny relative to other sources in Hawai`i and elsewhere.

3.2.2 TEMPERATURE

The NRMP reports that annual temperatures on Maunakea vary only slightly over the course of the year. According to (da Silva 2006), the mean daily temperature difference is only 7.5°F at the summit of Maunakea between the coldest month and the warmest month. During winter, the mean daily minimum temperature is 32.5°F; during the summer, the mean daily maximum is 40°F.

Mean monthly temperatures above the inversion layer generally range between 25°F and 33°F in January and between 38°F and 43°F in September (da Silva 2006). Even though variability between annual mean lows and highs is minimal, temperature ranges recorded at the summit area are quite large, ranging from 2°F to 61°F. Average temperatures at Halepōhaku, at 9,000 feet, range between 30°F and 40°F throughout the year (Group 70 International 1999).

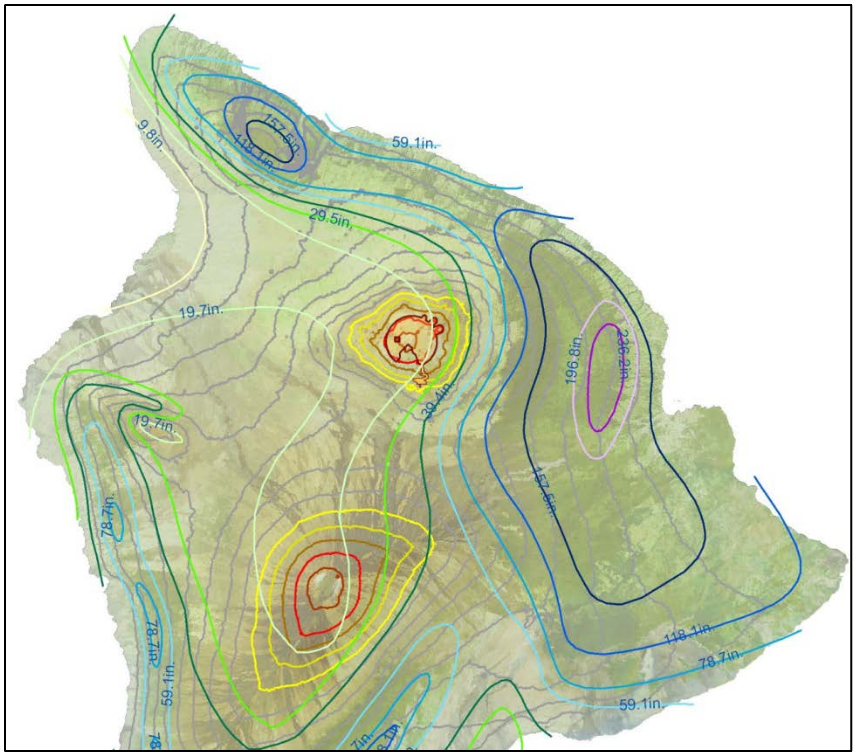
[19] This semi-permanent high pressure ridge is located some 2,000 miles north and east of the Hawaiian Islands, shifting its center from lat 30º N, long 130º W, in the winter, to lat 40º N, long 150 W, in the summer.

3.2.3 PRECIPITATION AND HUMIDITY

3.2.3.1 Precipitation

The highest trade wind rainfall rates occur on the windward sides of the islands, in an elevation band of 2,500 to 7,000 feet. The trade wind inversion caps upward migration of the clouds at 7,000 feet; as a result, Maunakea remains dry from that elevation upwards when the trade wind inversion is present (da Silva 2006). As shown by the rainfall isohyetal lines depicted on Figure 3.6, average annual rainfall totals show a significant decrease from 7,000 feet to the summit. The average annual rainfall map reproduced in the NRMP indicates that precipitation within the MKSR averages less than 20 inches per year on the upper reaches of Maunakea and between 25 and 30 inches per year at Halepōhaku. However, other data reported within the report demonstrate that there is a good deal of variability.

Figure 3.6: Average Annual Rainfall.



Source: University of Hawai`i 2009 Figure 2.1-16

The longest period of record for statistical data representative of the summit area climate is from the National Weather Service (NWS) station "Mauna Kea Observatory 1", at an elevation of 13,780 feet. The data set represents a 31-year-long period, from 1969–2000. For this period, average annual precipitation is reported as 7.41 inches. The Subaru Telescope recorded precipitation data for a period of seven years from 1999 to 2005. Mean annual precipitation during that period was estimated at 15.5 inches by interpolating annual precipitation from a cumulative plot for 1999–2003 (Miyashita et al. 2004).[20] Ehlmann et al. (2005) reports annual precipitation as a range of 4.7 to 17.7 inches recorded at the Very Long Baseline Array (VLBA), located below the summit area. It is obvious from these numbers that the mean precipitation is variable year to year.

The amount and duration of snow and ice covering the summit during the months of November – March is variable (Laws and Woodcock 1981). Da Silva (2006) reports that snowpack volumes fluctuate from year to year as does, most likely, the formation of ice. The authors of the NRMP were unable to locate data on average snowfall, snowpack volumes, or patterns of ice formation for the MKSR in the literature. However, based upon precipitation occurrence, associated relative humidity, and average temperatures, da Silva (2006) calculated that snowfall was more likely to occur at the MKSR in January than in any other month.

[20] This value includes the contribution from snowfall, although the efficiency of snow capture by the recording instrument is unknown.

3.2.3.2 Humidity

Data summarized in the NRMP indicate that average monthly relative humidity on Maunakea is relatively constant. The highest average monthly value occurs during November (41 percent) and the lowest during April (30 percent). Over the course of the year, the average is approximately 36 percent (da Silva 2006). The same source reports that the dew point is also relatively consistent, having an annual mean value of 4.1º F.

3.2.3.3 Wind

No long-term wind records are available for the summit of Maunakea. However, data are available from the NOAA observatory located at an elevation of 11,000 feet on nearby Maunaloa, although these values are not anticipated to be representative of Maunakea due to terrain influences and the mass of the respective mountains. These show that winds are most often from the southeast and exceed 22 miles per hour (10 meters per second) a substantial proportion of the time (see Figure 3.7 and Figure 3.8).

3.2.4 AIR QUALITY

3.2.4.1 Applicable Air Quality Standards

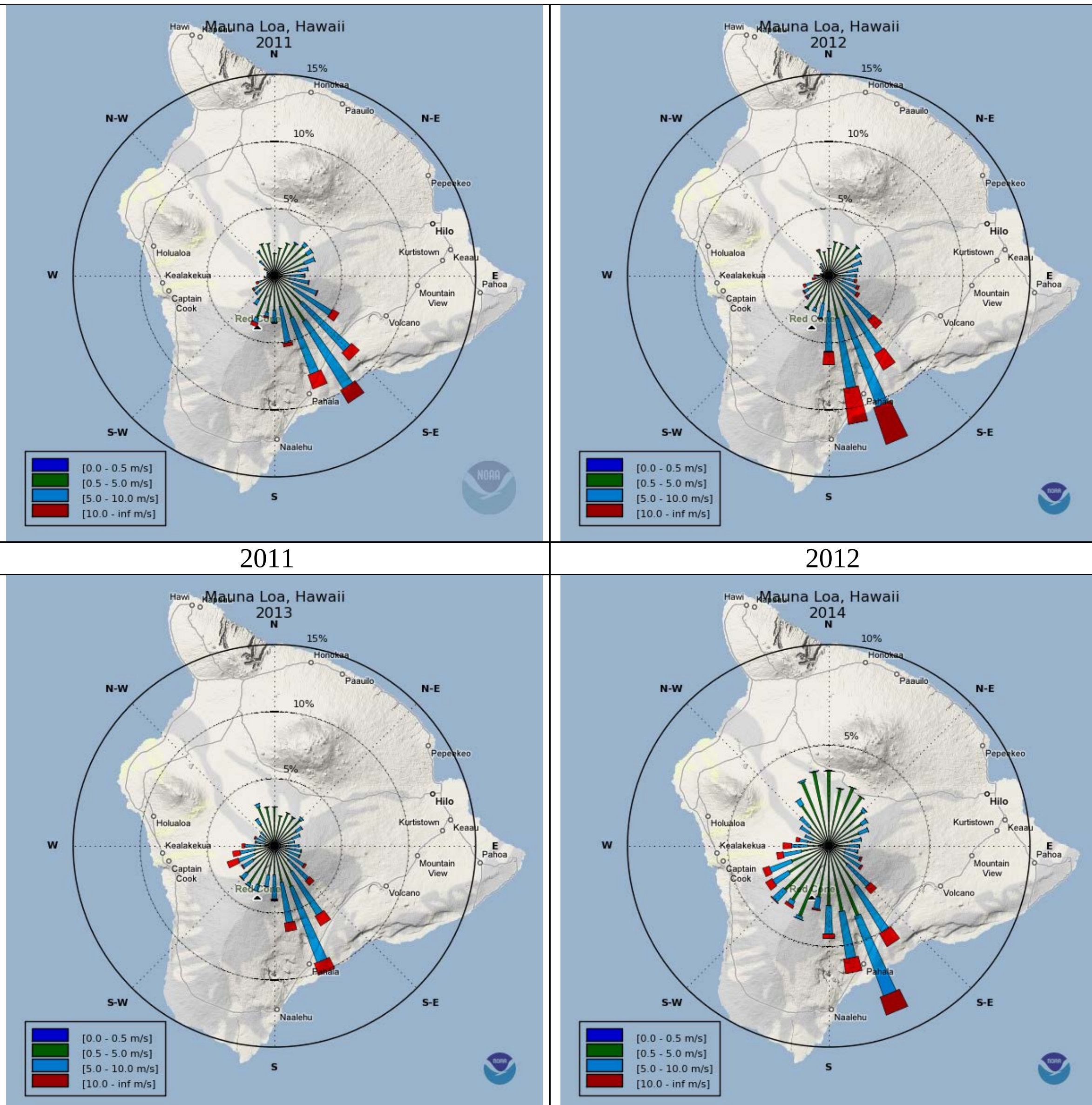
The U.S. Environmental Protection Agency has set national ambient air quality standards (NAAQS) for ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, 2.5-micron and 10-micron particulate matter ($PM_{2.5}$ and PM_{10}), and airborne lead. These standards establish the maximum concentrations of pollution considered acceptable, with an adequate margin of safety, to protect the public health and welfare. The State of Hawai`i has its own ambient air quality standards, and in some cases, they are more stringent than the federal standards.

Both state and national air quality standards consist of two parts: (*i*) an allowable concentration of a pollutant, and (*ii*) an averaging time over which the concentration is measured. The allowable concentrations are based on the results of studies of the effects of the pollutants on human health, crops, and vegetation, and, in some cases, damage to paint and other materials. The averaging times are based on whether the damage caused by the pollutant is more likely to occur during exposure to a high concentration for a short time (one hour, for instance), or to a lower average concentration over a longer period (8 hours, 24 hours, or one month). For some pollutants there is more than one air quality standard, reflecting both its short-term and long-term effects. Table 3.1 presents the state and national ambient air quality standards for selected pollutants.

3.2.4.2 Existing Air Quality

The quality of the air at the summit of Maunakea is known throughout the astronomy community to be excellent for viewing. Less is known about other aspects of air quality at the summit because no regular air quality monitoring is performed there. Five DOH monitoring stations do exist at other locations on the island, including Hilo, Kona, and three locations in the Puna District; however, all of these monitor air quality below the trade-wind inversion layer and the data from them are not representative of conditions in the project area. Potential sources of air pollutant emissions at the summit include vehicle exhaust and fugitive dust from road grading, construction, and other activities conducted on unpaved surfaces. The volume of this activity is low, however, and scientists do not believe that the resulting emissions are sufficient to have a measurable effect on air quality.

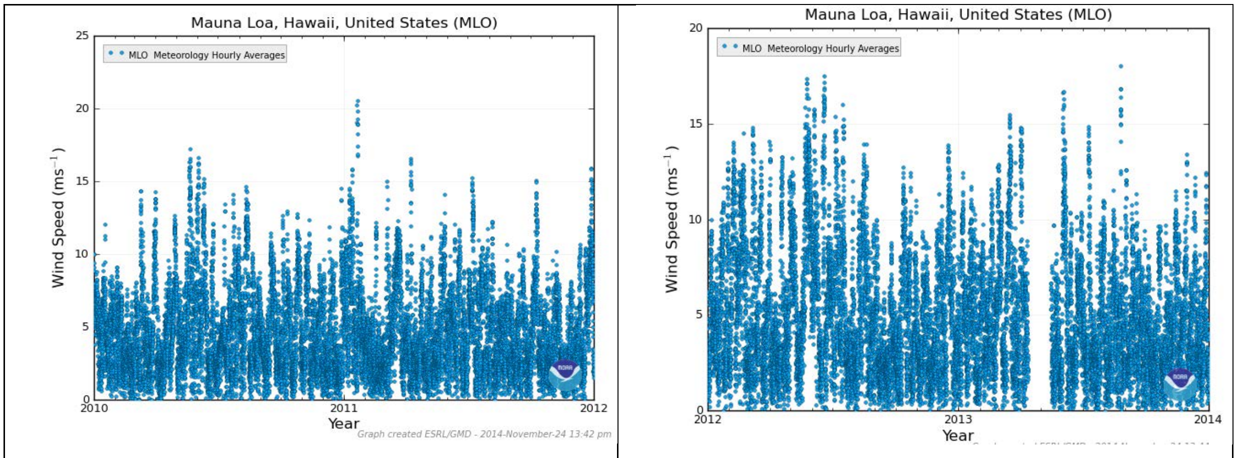
Figure 3.7: Annual Wind Roses for Maunaloa



2011	2012
2013	2014

Source: U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division, Meteorology 2014, Mauna Loa, Hawaii, United States, Wind Rose.

Figure 3.8: Mauna Loa Observatory: Hourly Wind Speed Data, 2010-2014



Source: Source: U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division, Meteorology 2014, Mauna Loa, Hawaii, United States, MLO Hourly Wind Averages

Table 3.1: State and National Ambient Air Quality Standards

Pollutant/Averaging Period	***Standards***		
	Hawai`i State Standard	***Federal Primary Standard*** [1]	***Federal Secondary Standard*** [2]
Nitrogen Dioxide (NO_2): Annual	0.04 ppm	0.053 ppm	0.053 ppm
Sulfur Dioxide (SO_2):			
1-hour	None	75 ppb	None
3-hour	0.5 ppm	---	0.5 ppm
24-hour	0.14 ppm	0.14 ppm	None
Annual	0.03 ppm	0.03 ppm	None
Carbon Monoxide (CO)			
1-hour	9 ppm	35 ppm	None
8-hour	4.4 ppm	9 ppm	None
2.5-micron Particulate Matter ($PM_{2.5}$)			
24-hour	None	35 $\mu g/m^3$	35 $\mu g/m^3$
Annual	None	12 $\mu g/m^3$	15 $\mu g/m^3$
10-micron Particulate Matter (PM_{10})			
24-hour	150 $\mu g/m^3$	150 $\mu g/m^3$	150 $\mu g/m^3$
Annual	50 $\mu g/m^3$	None	None
Ozone: 8-hour	0.08 ppm	0.075 ppm	0.075 ppm
Hydrogen Sulfide (H_2S): 1-hour	25 ppb	None	None
Lead: 3 months	1.5 $\mu g/m^3$	0.15 $\mu g/m^3$	0.15 $\mu g/m^3$

[1] Designated to set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly.

[2] Designated to set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

Source: State of Hawai`i Department of Health, January 17, 2013.

Although there is no active monitoring for air quality at the Maunakea summit, the NRMP reports that the National Oceanic and Atmospheric Administration (NOAA) Mauna Loa Observatory has collected air quality data for the summit of Maunaloa since its construction in 1956 (Juvik and Juvik 1998; Barnes 2008). These indicate that for the air pollutants considered by DOH to be of greatest concern (ozone, carbon monoxide, and sulfur dioxide), the air quality at Maunaloa is excellent. Given the similarities between the two locations, the overall air quality at Maunakea is believed to be excellent as well (NASA 2005; Barnes 2008).

Early 2008 volcanic activity from Halema`uma`u Crater at Kīlauea Volcano released record amounts of sulfur dioxide, as much as 4.4 million pounds/day (2,000 tonnes/day), and ambient air concentrations were found to exceed 40 ppm along the road neighboring the Kīlauea crater's rim (U.S. Geological Survey 2008b). This far exceeds the DOH and federal air quality standards for this pollutant, which limits sulfur dioxide concentrations to 0.14 ppm based on a 24-hour averaging period (State of Hawaii Department of Health January 17, 2013). Because of the presence of such a major source less than 40 miles to the southeast of the Maunakea summit, the possibility that ongoing eruptions from Kīlauea volcano might contribute airborne particulates and/or sulfur dioxide to the Maunakea summit area was also evaluated during preparation of the NRMP. Using data from the NOAA Mauna Loa Observatory and elsewhere, researchers concluded that gas and ash debris emitted from Kīlauea are most likely kept below the inversion layer when it is present and that even when it is not there are no significant observable increases in high-altitude air-borne particulates that can be directly associated with the new vent (Barnes 2008).

The current development and activities within the UH Management Area on Maunakea has not significantly affected air quality in the region. The activity with the greatest affect is vehicle travel in the area, particularly on unpaved roadways. Vehicle emissions include some of the pollutants listed in Table 3.1; however, the number of vehicles in the region is small and the trade winds quickly move any pollutants out of the region. Travel on unpaved roads generates dust. The visible dust is not $PM_{2.5}$ or PM_{10}, it is primarily of much larger particle size and generally settles back to the ground quickly after being kicked up. The dust is not a significant air quality human health concern but may affect certain biological resources, which is discussed in Section 3.4.

3.3 HYDROLOGY

3.3.1 SURFACE WATER

3.3.1.1 Streams and Surface Water Runoff

There are no regularly flowing or perennial streams in the Mauna Kea Science Reserve or in the vicinity of Halepōhaku. The Wailuku River is the only river whose numerous gulches extend along the upper flanks of Maunakea, and stream flow is considered to be perennial where the gulches come together, downslope near the elevation of 10,000 feet. The only surface water regularly present in the summit region is Lake Wai`au within the adjacent Mauna Kea Ice Age Natural Area Reserve (NAR).

Drainage at the summit occurs by percolation of rainfall through the cinder and broken rock substrates. Runoff from paved surfaces is directed to lined channels that conduct the water to collection basins or dry wells, where it then percolates. This system assists in the prevention of surface erosion.

Only during times of heavy rainfall will a few of the normally dry channels nearby have flowing water. The drainage patterns in the UH Management Area have been minimally impacted by the development. On the cinder cones, the introduction of impervious surfaces has not resulted in surface runoff, as the cinder is so pervious that the capacity to absorb water has always been greater than the rate of precipitation. The Mauna Kea Access Road does create surface runoff and slightly alters the path of natural surface runoff. Because there are numerous points of discharge along the road and the rates of discharge at each are fairly small, the resulting erosion and deposition of materials are minor. Past rainfall events have been known to transport loose material as far as 300 feet downslope from the road, but the construction of settling basins along the roadway has largely mitigated this occurrence. Even on those infrequent occasions when surface runoff does occur, it generally does not extend below an elevation of 6,000 feet, which means that the majority of the water ultimately ends up percolating and becoming groundwater recharge with only a small amount lost to evaporation.

3.3.1.2 Lakes

Lake Wai`au is located at the bottom of Pu`uwai`au and is one of Hawai`i's few confined surface water bodies and one of the highest alpine lakes in the Unites States. Lake Wai`au is believed to have formed approximately 15,000 years ago following the last glacial retreat. The lake, when full, is heart-shaped, 300 feet in diameter, has a maximum depth of roughly 7.5 feet, and sits at an elevation of 13,020 feet on the southern flank of Maunakea. Its water is derived from snow melt and precipitation within the watershed; it is not nourished by relic layers of ice or permafrost within the ground. The lake freezes almost entirely during colder times of the year.

The presence of Lake Wai`au is attributable to an impermeable layer within Pu`uwai`au that creates a perched[21] aquifer, which is a limited aquifer that occurs above the regional aquifer. In the absence of this impermeable layer, the rainwater and snowmelt would continue its downward migration to the regional aquifer. Topography limits the lake's watershed to about 35 acres and does not include any portion of the UH Management Area.

Researchers (Woodcock A.H., 1980) have long thought that Lake Wai`au is sensitive to precipitation levels, and the ongoing drought conditions that affected the summit area from roughly 2011 to 2013 are believed to have caused the declining water levels observed during that time (Patrick and Delparte, 2014). In December 2013, scientists visiting the lake observed an unprecedented sight; . Lake Wai`au measured a mere 1,240 square feet and was less than a half-foot deep (Patrick and Delparte, 2014) (see Figure 3.9 below). While the lake size was known to fluctuate over time, this dramatic reduction caused concern, given the possibility of losing a specialized ecosystem as well as a prominent feature of Hawaiian ethnogeography. USGS scientists at HVO as well as collaborators, including Idaho State University, continued to study the conditions at Lake Wai`au after the December 2013 observation. As of November 2014, precipitation over the last year had mostly restored the lake, providing strong evidence that the previous multi-year shrinkage was due to drought as opposed to changes in the volcanic system.

Figure 3.9 Effect of Draught on Water Levels in Lake Wai`au

Prior to 2010, the lake area was typically 1.25-1.75 acres, with the maximum size outlined in yellow in the top left image (depth was ~10 feet). By late 2013, the lake was just 1,000-2,000 square feet (<0.05 acre) in area. Based on the National Drought Mitigation Center's data, since 2008 precipitation has been sparse at the summit of Maunakea during this period.

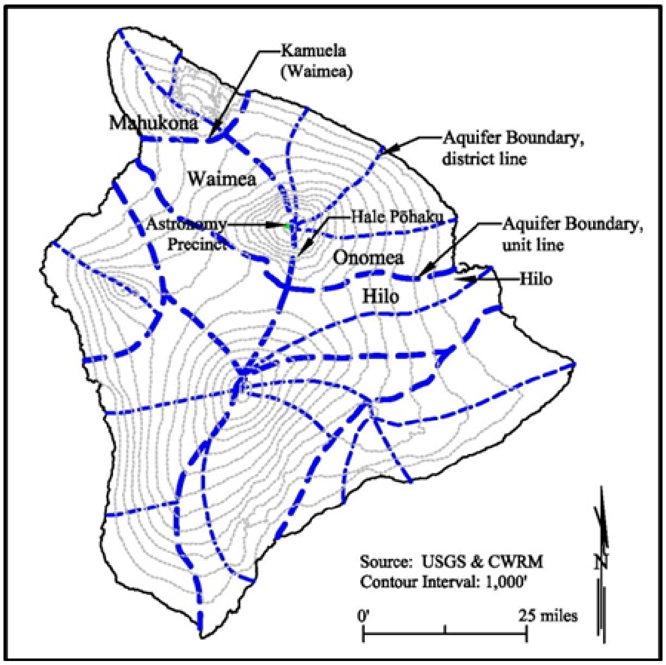
Source: Photographs courtesy of OMKM, modified from Patrick and Delparte (2014).

[21] A perched aquifer is an aquifer that occurs above the regional water table, in the unsaturated zone. This occurs when there is an impermeable layer of rock or sediment (known as an aquiclude) or relatively impermeable layer (known as an aquitard) above the main aquifer but below the surface of the land.

3.3.2 GROUNDWATER

The occurrence of groundwater beneath the summit area is what is referred to in Hawai`i as "high-level," which means that the groundwater is impounded by subsurface geologic structures, such as intrusive dikes, which compartmentalize the groundwater. Although groundwater is the primary source of drinking water in Hawai`i, there are no wells extracting groundwater near the summit, since it is considered uneconomical to drill a well deep enough to reach the groundwater and pump it to the surface. The nearest well is located approximately 12 miles away in Waiki`i Ranch along Saddle Road; the ground elevation at the well is 4,260 feet above mean sea level (MSL) and the static water level in the well was measured at 1,280 feet above MSL in 1988. Pierce and Thomas (September 22, 2009) report resistivity data and models that suggest that high level groundwater is present in the Pōhakuloa Training Area (PTA) as much as 3,300 feet above MSL. The Astronomy Precinct is located entirely above the Waimea Aquifer (Figure 3.10), which has a sustainable yield of 24 million gallons a day.

Figure 3.10: Groundwater Aquifers on the Island of Hawai`i



As evidenced by modest spring and seeps, shallow groundwater does exist in the mountain's flanks below the summit area. The most prominent of these springs and seeps are the series of springs found near Pōhakuloa and Waikahalulu Gulches. The gulches are on Maunakea's south flank at a distance of approximately 3.25 and 1.25 miles west of Halepōhaku, respectively. Scientific dating tests of the springs' water indicate that it is recent, meaning that the water is not from the melting of ancient subsurface ice or permafrost, and analyses of the water shows it to be identical to rainfall at the summit. This indicates that at least some of the rainfall and snow melt at the summit percolates downward to a perching layer to ultimately discharge at the ground surface as a spring or seep.

Halepōhaku is located above the Onomea Aquifer system (Figure 3.10). There are no wells in the vicinity of Halepōhaku, because, similar to the summit area, the groundwater is at such a great depth that it is not considered economical to use it. As evidenced by modest spring and seeps, shallow groundwater does exist in the mountain's flanks below the summit area. The most prominent of these springs and seeps are the series of springs found near Pōhakuloa and Waikahalulu Gulches. The gulches are on Maunakea's south flank at a distance of approximately 3.25 and 1.25 miles west of Halepōhaku, respectively. Scientific dating tests of the spring's water indicate that it is recent, meaning that the water is not from the melting of ancient subsurface ice or permafrost, and analyses of the water shows it to be identical to rainfall at the summit. This indicates that at least some of the rainfall and snow melt at the summit percolates downward to a perching layer to ultimately discharge at the ground surface as a spring or seep.

All of the areas for which UH is seeking a lease or easement covered by proposed facilities are situated *mauka* of the Underground Injection Control line established by DOH and regulated under Hawai`i Administrative Rules Title 11, Chapter 23 (§11-23). The designation, which stems from the fact that the total dissolved solids (TDS) concentration of the groundwater is less than five thousand parts per thousand, means that the aquifer is an existing or potential source of drinking water.

The existing wastewater systems at Halepōhaku, and the individual wastewater systems operated by each observatory on Maunakea have all been designed to meet the HDOH permit requirements for sanitary waste systems. Domestic type wastewater is discharged into these approved systems, and there is no direct discharge into the ground. The collected solids are pumped out of the systems on a regular basis, hauled off the mountain, and disposed of in approved facilities. The natural nutrient removal that takes place over the decades-long travel time from the summit, to the groundwater aquifer, and ultimately discharged or extracted from a swell (the nearest wells are the Waiki`i wells) results in no impact to the discharge due to the introduction of the domestic wastewater. The wastewater generated during mirror washing is no longer directed into any of these systems and instead, is fully containerized and hauled down the mountain for disposal. It has been shown that the past disposal practices of mirror washing wastewater have not had a significant impact on water quality. Developments and activities within the UH Management Area have a negligible effect on natural water quality.

3.4 BIOTIC ENVIRONMENT[22]

Ecosystems on Maunakea range from highly modified fertile lowlands to an alpine stone desert. For the NRMP, the ecosystems under consideration are those found above approximately 9,000 feet, beginning at Halepōhaku. High elevation ecosystems on Maunakea can be divided into two basic types: (i) the subalpine ecosystem (from approximately 5,600 feet to 9,800 feet elevation), and (ii) the alpine ecosystem, which occurs above 9,800 feet. The shift from subalpine to alpine ecosystems is determined by the elevation of the nocturnal ground frost line (Mueller-Dombois and Fosberg 1998). The subalpine and alpine ecosystems can be further subdivided by vegetation community, as described in Section 3.4.1.

The following sections (Sections 3.4.1 through 3.4.4) discuss the plant, invertebrate, bird, and mammal species found in the subalpine and alpine ecosystems of Maunakea, with the focus being on the MKSR and Halepōhaku. Each section also reviews previous research for each group (especially biological surveys) done at Halepōhaku and the MKSR, as well as information gaps, and threats to native populations of plants and animals. The remainder of this section is divided into the following parts:

- Section 3.4.1 discusses the botanical resources present in and around the MKSR and related areas.
- Section 3.4.2 discusses invertebrate resources.
- Section 3.4.3 describes the avian biota that are present.
- Section 3.4.4 describes the mammals that occur in the area.

3.4.1 BOTANICAL RESOURCES

Section 2.2.1 of the NRMP contains detailed information concerning the botanical resources of the upper slopes of Maunakea, focusing on conditions at Halepōhaku (and surrounding areas), the Mauna Kea Access Road (from Halepōhaku to the summit), and the MKSR.[23] This section summarizes that

[22] Discussion is extracted/modified from the 2009 NRMP.

[23] Information on the plants found in these areas was gathered primarily from botanical accounts of high elevation habitats on Mauna Kea (Hartt and Neal 1940; Smith et al. 1982; Char 1985, 1990, 1999b, a; Group 70 International 2000; Pacific Analytics 2004), two review reports (Conant et al. 2004; Aldrich 2005), general accounts on high elevation flora in the Hawaiian Islands (Gagné and Cuddihy 1990; Wagner et al. 1990; Mueller-Dombois and Fosberg 1998); and a variety of other scientific publications that provided additional information on the area. The NRMP notes that the great majority of the survey work in the MKSR has been qualitative rather than quantitative vegetation surveys and has been focused on areas considered for future telescope construction. There have been no studies of vegetation communities on Maunakea between the upper edge of Halepōhaku (9,340 feet) and 11,800 feet.

information.[24] Subsequent to publication of the NRMP, a botanical baseline survey was performed in 2011 and the results were published in 2013 (Gerrish 2013). The need for a baseline inventory was stated in the NRMP, noting that there had never been a comprehensive quantitative study of the plant communities of the UH Management Areas on Maunakea. Information from this survey is also included in this section, updating information found in the NRMP as appropriate.[25]

As discussed in Aldrich (2005), the makeup of the high elevation plant communities differs depending on whether they are located in the subalpine or alpine ecosystems. Some plant species are found in both ecosystem types, but most flowering plants are limited to the subalpine ecosystem, which is found below the nocturnal ground frost line.[26] Halepōhaku and the lower portions of the Mauna Kea Access Road fall into the subalpine community, which can be further divided into māmane woodlands and subalpine shrublands. The MKSR and upper portions of the Mauna Kea Access Road fall within the alpine community. The NRMP further divided the alpine community into alpine shrublands, alpine grasslands and alpine stone desert (see Figure 3.11).[27] Although they are not plants, fungi and lichens are also addressed in this section, as they are often treated as plants by land managers, and many have close associations with plant communities.

3.4.1.1 Subalpine Plant Communities (Halepōhaku and Lower Mauna Kea Access Road)

Three major types of subalpine communities are present on Maunakea: (*i*) open dry forest (or woodlands), (*ii*) tussock grassland, and (*iii*) subalpine dry shrublands.[28] Each is described below.

3.4.1.1.1 Subalpine Plant Communities

Subalpine woodlands are dry most the year, with rainfall ranging from 15 to 39 inches/year most of which falls between December and March. Fog drip from clouds that form in the afternoons is an important source of moisture in this zone, and understory plants tend to be concentrated under māmane trees, where they receive fog drip. Māmane occurs in almost pure stands on the eastern, northern, and western slopes of Maunakea, and in a narrow band at tree line on the southern slope. Other tree species, such as pilo (*Coprosma montana*) are scarce, and naio (*Myoporum sandwicense*) is absent in these areas. However, naio trees are co-dominant with māmane on the southwestern slopes of the mountain. The lower elevation for the māmane-naio forest type is currently approximately 6,000 feet.

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[24] Complete listing of vascular plants occurring at Halepōhaku and the MKSR is presented in Table 2.2-3 of the NRMP. Lichen species are presented in Table 2.2-4 of the NRMP, and mosses in are listed in Table 2.2-5 of the NRMP. Threats to the subalpine and alpine plant communities of Maunakea are discussed in NRMP Section 2.2.1.3. Photos of common native species found in the subalpine and alpine zones are presented in Figure 2.2-2 of the NRMP. The NRMP presents photos of rare plants (Threatened, Endangered, Candidate, Species of Concern) in Figure 2.2-3 of the NRMP and photos of common invasive species are presented in Figure 2.2-4 of the NRMP.

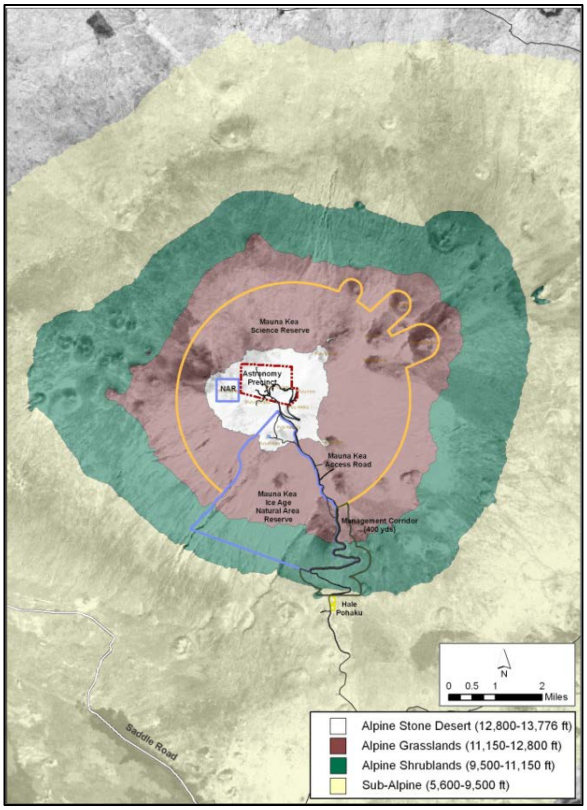
[25] Gerrish's 2011 survey findings differ somewhat from the zonation described in the NRMP, in part due to his survey being specific to the UH Management Areas rather than based on a treatment of Maunakea as a whole; this document uses the same zonation as the NRMP. Also, there are some species that were not necessarily observed during the 2011 survey but have been known to be present and were included in the discussions in the NRMP so they have remained in this discussion.

[26] The nocturnal ground frost line is the elevation (approximately 9,800' above sea level) above which frost often forms at night.

[27] The botanical baseline survey performed in 2011 indicated that the alpine shrublands differ from the upper elevations, but found no important distinction between the alpine grasslands and the alpine stone desert in terms of plant distribution.

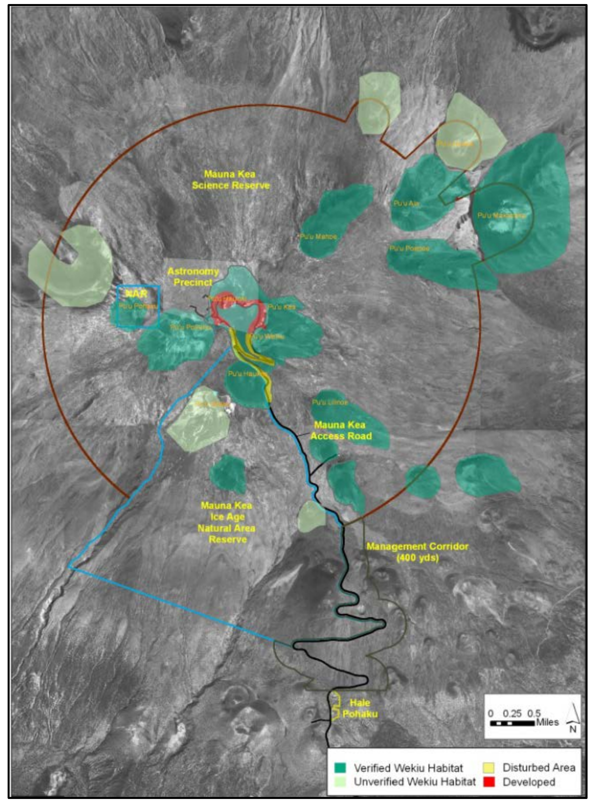
[28] Tussock grasslands were once an important, vegetation community on Maunakea, but overgrazing by feral and domesticated sheep and goats, and establishment of invasive weed species, has virtually eliminated these grasslands (Mueller-Dombois and Fosberg 1998).

Figure 3.11: High Elevation Ecosystems



Source: University of Hawaii 2009c, Figure 2.2-1.

Figure 3.12: Wēkiu bug potential habitat



Source: University of Hawaii 2009c, Figure 2.2-20.

Although feral grazer abundance was greatly reduced in the area in the 1980s, and is currently low, the forest has not fully recovered, due to continued browsing and the presence of invasive plant species that inhibit māmane regeneration.[29] As a result, the understories of most māmane forests are now dominated by invasive grasses such as orchardgrass (*Dactylis glomerata*), common velvetgrass (*Holcus lanatus*), sweet vernalgrass (*Anthoxanthum odoratum*), Kentucky bluegrass (*Poa pratensis*) (Hess et al. 1996), as well as *Nassella*, *Bromus* spp., and *Rytidosperma*, and herbs, especially fireweed and mullein (Gerrish 2013), although native grasses can still be found in some areas (see below). The heavy growth of the invasive grasses suppresses germination of māmane seeds and increases the likelihood of fires in the dry woodland (Hess et al. 1996).

The māmane woodland supports a larger number (39) of introduced species than is found in the entire alpine ecosystem. Thirty-seven of the thirty-nine introduced plants of the UH Management Area occur in the māmane woodland (and many of them in alpine communities, as well) (Gerrish 2013). Māmane regeneration in these degraded woodlands is highest in the higher elevation areas (such as at Halepōhaku), where grass densities are low (Hess et al. 1996).

The māmane woodlands at Halepōhaku consist of clumps of māmane trees interspersed with open areas of bare soil or rocky outcroppings. Understory plants at Halepōhaku tend to be denser under and around the clumps of māmane, with groundcover plants being primarily mixed bunch grasses forming upright tussocks. The most abundant native grasses found during the 2011 survey were pili uka (*Trisetum glomeratum)* and Hawai`i bentgrass *(Agrostis sandwicensis)*. The most abundant invasive grasses were needlegrass, (*Nassella cernua)* and wallaby grass *(Rhytidosperma*

[29] Sheep, and evidence of browsing, continues to be observed in the subalpine and alpine zones of Maunakea. A flock of approximately 60 sheep was observed in February 2008 in Pōhakuloa Gulch within the Ice Age Natural Area Reserve (Hadway 2008).

semiannulare). Common non-native grasses and herbaceous species found at Halepōhaku include ripgut grass (*Bromus diandrus*), orchard grass (*Dactylis glomerata*), hairy cats-ear or gosmore (*Hypochoeris radicata*), alfilaria or pin clover (*Erodium cicutarium*), sheep sorrel (*Rumex acetosella*), common groundsel (*Senecio vulgaris*), and common mullein (*Verbascum thapsus*). Char (1999a) found patches of non-native California poppy (*Eschscholzia californica*) to be locally common near the cabins, but does not mention the high density of common mullein or fireweed (*Senecio madagascariensis*) currently found at Halepōhaku, suggesting that species is a relatively recent introduction. A small grove of Eucalyptus trees is above the information station parking lot at Halepōhaku, as are a few shrubs of non-native tagasaste, or broom (*Cytisus palmensis*).

<u>Native Grasses, Sedges, and Ferns in Māmane Woodlands</u>. Native grasses and sedges found in māmane woodlands include Hawai`i bentgrass (*Agrostis sandwicensis*), alpine hairgrass (*Deschampsia nubigena*), lovegrass (Eragrostis sp.), mau`u la`ili or Hawaii blue-eyed grass (*Sisyrinchium acre*), pili uka (*Trisetum glomeratum*), two sedge species (*Carex macloviana* and *C. wahuensis*), and Hawai`i wood rush (*Luzula hawaiiensis*). The 2011 survey noted all of these species except lovegrass and mau`u la`ili, and according to the survey pili uka and Hawai`i bentgrass are the two most common grasses in this community. Native herbs found in the māmane woodlands include Hawai`i stinging nettle (*Hesperocnide sandwicensis*), `ena`ena (*Pseudognaphalium sandwicensium*), makou (*Ranunculus hawaiiensis*), and Hawai`i black snakeroot (*Sanicula sandwicensis*). The 2011 survey noted the native herbs in this community as `ena`ena, yellow wood sorell (*Oxalis corniculata*), and pua kala (*Argemon glauca*).

In 1985 Char observed numerous indigenous ferns kalamoho (*Pellaea ternifolia),* `iwa`iwa *(Asplenium adiantum-nigrum),* and olali`i *(Asplenium trichomanes)* among the rocks in the area immediately adjacent to and above the Mid-Level Facilities maintenance area, along with Hawai'i catchfly (*Silene hawaiiensis),* a federally listed Threatened Species. All three of these fern species were observed during the 2011 survey, along with a very small population of bracken (*Pteridium aquilinum*).

<u>Native Shrubs and Trees in Māmane Woodlands</u>. Native shrubs and trees found in māmane woodlands include `akoko (*Chamaesyce olowaluana*), `aheahea (*Chenopodium oahuense*), `aiakendnd (*Coprosma ernodeoides*); alpine mirror plant (*Coprosma montana),* `a`ali`i (*Dodonaea viscosa*), three species of na`ena`e (*Dubautia arborea, D. ciliolata ciliolate,* and *D. scabra*), nohoanu *(Geranium cuneatum hololeucum),* pukiawe (*Leptecophylla tameiameiae*), `ulei (*Osteomeles anthyllidifolia*), `akala (*Rubus hawaiensis*), alpine catchfly (*Silene struthioloides*), alpine tetramolopium (*Tetramolopium humile humile*), and `Ōhelo (*Vaccinium reticulatum*). Of these, pukiawe is the most common in the higher elevation reaches of the subalpine community. Shrub species recorded at Halepōhaku include `āheahea (*Chenopodium oahuense*), pūkiawe (*Leptecophylla tameiameiae*) and nohoanu (*Geranium cuneatum*). The latter two are associated with rocky areas.

Native vines and lianas commonly found in māmane woodlands include two species from the mint family (Lamiaceae). They are littleleaf Stenogyne (*Stenogyne microphylla*) and mā `ohi`ohi (*Stenogyne rugosa*). There is also a large climbing liana or sprawling shrub, pāwale (*Rumex giganteus*). At Halepōhaku both native vines are found climbing into the canopy of some māmane trees (Char 1999a); these same vine species were noted as being present during the 2011 survey.

Non-native species commonly found in the māmane woodlands include the invasive grass species discussed above and several herbs and shrubs including telegraph plant (*Heterotheca grandiflora*), hairy cat's ear or gosmore (*Hypochoeris radicata*), peppergrass (*Lepidium spp.*), and common mullein (*Verbascum thapsus*). Common mullein is an invasive species and is listed as a Hawai`i State Noxious Weed. Other state and federal noxious weeds found in the subalpine community include the federally listed Kikuyu grass (*Pennisetum clandestinum*), and the state listed fountain grass (*Pennisetum setaceum*) and the herb fireweed (*Senecio madagascariensis*). Common mullein and telegraph plants were very abundant in the vicinity of Halepōhaku in October 2007. In the 2011 survey the most common invasive species in the vicinity of Halepōhaku were fireweed, common mullein, and wallaby grass (*Rhytidosperma semiannulare*).

3.4.1.1.2 Subalpine Fungal Communities

Section 2.2.1.1 of the NRMP describes the wide variety of fungal species that inhabit the mountain's subalpine and alpine habitats. A survey of higher fungi in the māmane-naio forests between 6,000 and 9,000 feet on Maunakea found 71 species of Ascomycetes (cup fungi such as yeast, mildew, morels and truffles) and Basidiomycetes (club fungi such as mushrooms, toadstools, earthstars, stinkhorns, brackens, rusts, and smuts) (Gilbertson et al. 2001).[30] Desert stalked puffballs and earthstars are characteristic fungi found in higher elevation areas on Maunakea and commonly appear after rains. Some of the more common ground-dwelling species that occur in māmane-naio woodlands include the salt-and-pepper shaker earthstar (*Myriostoma coliforme*), partially-buried puffballs (such as *Disciseda anomala* and *Disciseda verrucosa*, fornicate earthstars (*Geastrum fornicatum*), hygroscopic earthstars (*Geastrum corollinum and G. campestre*), desert stalked puffballs (*Battarraea phalloides*), and stalked puffball (*Tulostoma fimbriata* var. *campestre*). *Tulostoma fimbriata* var. *campestre* grow above the treeline, often in association with plants such as the silversword (*Argyroxiphium sandwicense* ssp. *sandwicense*). Some of the more common fungi that appear on trees and downed tree-branches include *Heliocybe sulcata* and *Hypoxylon submonticulosum*, conks such as *Phellinus robustus*, and bracket fungi such as *Gloeophyllum trabeum*. Other fungal species present include witch-broom-forming fungus (*Botryosphaeria mamane*) discovered growing on māmane trees (generally causing death of the branches it infects), and four white-rot associated fungi (*Hyphodermella maunakeaensis*, *Phanerochaete crescentispora*, and *Radulomyces kama`aina*, and *Radulomyces poni*).

Mycorrhizal fungi found in most Hawaiian soils form symbiotic associations with the roots of plants and are important for the functioning of many native Hawaiian ecosystems, even in high altitude areas and on young lava flows. The plants provide the fungi with carbohydrates (from photosynthesis). In return, the fungi greatly increase the surface area of the roots for better absorption of water and mineral nutrients such as phosphates, and they may also improve plant resistance to disease. Mycorrhizae are especially important to plant growth in phosphorous-poor soils, such as those on Maunakea. Many native plants in the subalpine māmane woodlands and shrublands that have been tested were found to form associations with fungi.

3.4.1.1.3 Threatened and Endangered Subalpine Plant Species[31]

Section 2.2.1.1.1 of the NRMP describes the threatened and endangered plant species (federal and state) found (historically and/or currently) in the subalpine community. Endangered species include the Maunakea silversword (*Argyroxiphium sandwicense* subspecies *sandwicense*), diamond spleenwort (*Asplenium fragile* var. *insulare*), kiponapona (*Phyllostegia racemosa* var. *racemosa*), and Hawaiian vetch (*Vicia menziesii*); the 2011 survey notes the presence of the Maunakea silversword but none of the others. The only threatened plant species found in the subalpine community is Hawaiian catchfly (*Silene hawaiiensis*); the 2011 survey observed the alpine catchfly (*Silene struthioloides*), which is not a listed species. The Maunakea silversword is found in a Department of Land and Natural Resources (DLNR)-maintained enclosure near Halepōhaku and in the MKSR. Diamond spleenwort, a fern, was previously found as high as 9,600 feet on Maunakea, but has not been observed at Halepōhaku or along the Maunakea access road. Māmane woodlands are critical habitat for the endangered Palila (*Loxioides bailleui*), a bird now found only in māmane woodlands on Maunakea.

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[30] Higher fungi are those that produce complex fruiting bodies and release spores (for example, mushrooms). Lower fungi include the Zygomycotina and the Chytridiomycotina. Chytrid fungi are important saprophytes and parasites in both aquatic and terrestrial habitats and are biodegraders of materials such as chitin, keratin and cellulose. They also play a role in nutrient recycling. Chytrid fungi have been implicated in the global reduction of frog populations. Zygomycetes are mostly terrestrial fungi and live in decaying plant or animal matter. Bread mold (*Rhizopus stolonifer)* is an example of zygomycotinid fungi.

[31] Table 3.2 and Table 3.3 contain information on all listed plant and animal species and species of concern.

Table 3.2: Number of Federal and State Listed Species, Candidate Species, and Species of Concern found or potentially found at Halepōhaku and MKSR

Legal Status	***Plants***	***Arthropods & Snails***	***Birds***	***Mammals***
Federally Endangered	4	0	5	1
Federally Threatened	1	0	0	0
Federal Candidate for Listing	1	1	0	0
Federal Species of Concern	0	6	6	0
State Endangered	4	0	5	1
State Threatened	1	0	0	0
State Candidate for Listing	1	0	0	0
State Species of Concern	4	3	0	0
Source: NRMP				

Table 3.3: Potentially Present Threatened, Endangered, Candidate, and Species of Concern

Group	***Scientific Name***	***Common Name***	***Status[1]***
Endangered Species			
Plant	*Argyroxiphium sandwicense sandwicense*	\`Ahinahina, Mauna kea silversword	FE, SE
Plant	*Asplenium fragile* var. *insulare*	Diamond spleenwort	FE, SE
Plant	*Phyllostegia racemosa* var. *racemosa*	Kiponapona	FE, SE
Plant	*Vicia menziesii*	Hawaiian vetch	FE, SE
Bird	*Branta sandvicensis*	Nēnē (Hawaiian goose)	FE, SE
Bird	*Buteo solitarius*	\`Io	FE, SE
Bird	*Hemignathus munroi*	\`Akiapola\`au	FE, SE
Bird	*Loxioides bailleui*	Palila	FE, SE
Bird	*Pterodroma sandwichensis*	\`Ua\`u (Hawaiian petrel)	FE, SE
Mammal	*Lasiurus cinereus semotus*	\`Ope\`ape\`a (Hawaiian hoary bat)	FE, SE
Threatened Species			
Plant	*Silene hawaiiensis*	Hawai\`i catchfly	FT, ST
Candidate Species			
Plant	*Ranunculus hawaiiensis*	Makou	FC, SC
Species of Concern			
Plant	*Chamaesyce olowaluana*	\`Akoko	HSOC
Plant	*Cystopteris douglasii*	Douglas' bladderfern	HSOC
Plant	*Dubautia arborea*	Mauna Kea dubautia, na\`ena\`e	HSOC
Plant	*Sanicula sandwicensis*	Hawaii black snakeroot	HSOC
Arthropod	*Agrotis melanoneura*	Black-veined agrotis noctuid moth	FSOC, HSOC
Arthropod	*Coleotichus blackburniae*	Koa bug	FSOC
Arthropod	*Hylaeus difficilis*	Difficult yellow-faced bee	HSOC
Arthropod	*Hylaeus flavipes*	Yellow-footed yellow-faced bee	FSOC, HSOC
Arthropod	*Micromus usingeri*	Flightless brown lacewing	FSOC
Snail[2]	*Succinea konaensis*	Succineid snail	FSOC
Snail	*Vitrina tenella*	Zonitid snail	FSOC
Bird	*Asio flammeus sandwichensis*	Pueo	FSOC, SE[3]
Bird	*Chasiempis sandwichensis*	\`Elepaio	FSOC
Bird	*Hemignathus virens virens*	\`Amakihi	FSOC
Bird	*Himatione sanquinea*	\`Apapane	FSOC
Bird	*Pluvialis fulva*	Kolea (Pacific golden plover)	FSOC
Bird	*Vestiaria coccinea*	\`I\`iwi	FSOC, SE[4]
Note 1: Key to Legal Status: FE = Federally Endangered, FEET= Federally Threatened, FC = Federal Candidate for listing, FSOC = Federal Species of Concern, SE = State Endangered, SC = State Candidate for Listing, HSOC = Hawaii State Species of Concern, ST = State Threatened. Note 2: It is unknown whether snails are present at Halepōhaku – no surveys for snails have been completed at this elevation. Note 3: State Endangered on O\`ahu only. Note 4: O\`ahu, Lāna\`i, and Mōloka\`i only.			
Source: University of Hawaii 2009c, Table 2.2-2.			

3.4.1.1.4 Subalpine Plant Candidate Species and Species of Concern

According to Section 2.2.1.1.2 of the NRMP, the only federal and state Candidate species found in the subalpine community on Maunakea is makou (*Ranunculus hawaiensis*). Makou, an endemic buttercup, was once very plentiful in subalpine and alpine communities, but populations have decreased due to predation by slugs and feral animals and competition with invasive plant species.

State Species of Concern in the subalpine community include `akoko (*Chamaesyce olowaluana*), Douglas' bladderfern (*Cystopteris douglasii*), Maunakea dubautia or na`ena`e (*Dubautia arborea*), and Hawai`i black snakeroot (*Sanicula sandwicensis*); `akoko and Hawai`i black snakeroot were not noted in the 2011 survey. `Akoko, a small tree in the family Euphorbiaceae, was once common in the subalpine forest, but has been reduced in abundance, primarily due to fire and grazing of small trees and saplings by feral ungulates (which also girdle larger trees by stripping bark from their trunks. Douglas' bladderfern is an endemic fern found in low densities in both subalpine and alpine communities. While not recorded at Halepōhaku, Smith et al. (1982) recorded it in the alpine zone, and it is discussed later. The Maunakea dubautia is a large shrub or small tree closely related to silverswords found in subalpine and alpine communities on Maunakea. Hawai`i black snakeroot is an herb in the Apiaceae family. It is restricted to subalpine woodland and shrublands on Maui and Hawai`i (Wagner et al. 1990). Little information is available about this species. Most of these species have been greatly reduced in abundance due to grazing by feral animals, habitat alteration, and competition with introduced plants.

3.4.1.2 Alpine Plant Communities (Mauna Kea Access Road and MKSR)

As discussed in Section 2.2.1.2 of the NRMP, the three basic types of alpine plant communities on Maunakea (shrublands, grasslands, and stone desert) begin at approximately 9,500 feet, and rise to the summit. There are no sharp lines of delineation between the types; they grade into one another, beginning with the alpine shrubland at the treeline, which grades into the alpine grasslands, and culminates with the alpine stone desert at the summit. The three community types are all characterized by sparse vegetation situated on barren rock and cinder. Plant density decreases with increasing elevation, with the result that there are only scattered plants at the higher elevations. The alpine shrublands are inhabited mainly by low-lying shrubby species, while the upper elevations are inhabited by grasses and herbaceous species. All were decimated by heavy grazing by feral ungulates, and invasive plant species now compete with native plants for limited resources such as water and sheltered growing locations. The three plant communities are described in further detail in Sections 3.4.1.2.1, 3.4.1.2.3, and 3.4.1.2.4 .

3.4.1.2.1 Alpine Shrubland

The alpine shrublands on Maunakea (also referred to as Leptecophylla shrublands or just shrubland) are dominated by pukiawe (*Leptecophylla tameiameiae*). Section 2.2.1.2.1 of the NRMP identifies it as the dominant plant community from the treeline at 9,500 feet to around 11,150 feet. As mentioned earlier, these shrublands are also found in the subalpine zone. The density and diversity of plant species in the Leptecophylla shrublands decreases with increasing altitude. At the upper end of its elevation range, the Leptecophylla shrublands consist mainly of scattered pukiawe shrubs and tufts of native grasses.

Native herbs and shrubs commonly found in Leptecophylla shrublands include ōhelo (*Vaccinium reticulatum*), alpine catchfly (*Silene struthioloides*), and Maunakea dubautia (*Dubautia arborea*). The 2011 survey also noted a prevalence of alpine tetramolopium (*Tetramolopium humile*). Native ferns found in this community include Douglas' bladderfern (*Cystopteris douglasii*), kalamoho (*Pellaea ternifolia*), `olali`i (*Asplenium trichomanes*), and `iwa`iwa (bird's nest ferns, *Asplenium adiantum-nigrum*). Native grasses found in Leptecophylla shrublands include Hawaiian bentgrass (*Agrostis sandwicensis*), and pili uka (*Trisetum glomeratum*). Species historically common, but now uncommon, found in this community include `Āhinahina (the Maunakea silversword, *Argyroxiphium sandwicense* ssp. *sandwicense*), lava dubautia (*Dubautia ciliolata* ssp. *ciliolata*), `ōhelo papa

(Hawaiian strawberry, *Fragraria chiloensis*), `ena `ena (*Pseudognaphalium sanwicensium*), and nohoanu (*Geranium cuneatum* ssp. *hololeucum*).

Several non-native plant species have taken hold in the alpine shrublands on Maunakea. These include hairy cat's ear or gosmore (*Hypochoeris radicata*), sheep sorrel (*Rumex acetosella*), common mullein (*Yerbascum thapsus*), fireweed (*Senecio madagascariensis*), and the common dandelion (*Taraxacum officinale*). Historically recorded non-native herbs include big chickweed (*Cerastium fontanum*), bull thistle (*Cirsium vulgare*), hairy horseweed (*Conyza bonariensis*), and woodland groundsel (*Senecio sylvaticus*). Char (1999) did not record these during her survey of the upper slopes of the mountain, but she did not look below 12,000 feet, and it is thought that these species are likely still found in the alpine shrubland community on Maunakea. The 2011 survey didn't observe any of these species either. Non-native grasses found in the Leptecophylla shrublands include Kentucky bluegrass (*Poa pratensis*), and historically, annual bluegrass (*Poa annua*), and velvet grass (*Holcus lanatus*); the 2011 survey did not note the presence of annual bluegrass in this community but found small numbers of the other two species. Common mullein (*Yerbascum thapsus*) and sheep sorrel (*Rumex acetosella*) were observed to be abundant along the Mauna Kea Access Road in the lower regions of the alpine shrubland plant community in October 2007 and again during the 2011 survey. They have also been found at the summit near the observatories though that is not reflected in the results of the 2011 survey.

3.4.1.2.2 Alpine Fungal Communities

The NRMP notes that only limited information is available regarding the fungal communities in the alpine regions on Maunakea. It reports that the stalked puff-ball *(Tulostoma fimbriata* var. *campestre)* can be found growing above the treeline, often in association with plants such as the silversword.

3.4.1.2.3 Alpine Grassland

Section 2.2.1.2.2 of the NRMP describes the alpine grasslands that replace the *Leptecophylla* shrublands around 11,000 feet in elevation (although *Leptecophylla*, pūkiawe, shrubs can be found in all habitats, clear to the summit). These grasslands, which occur up to 12,800 feet, are dominated by two native grasses, Hawai`i bentgrass (*Agrostis sandwicensis*) and pili uka (*Trisetum glomeratum*). Char (1999b) recorded that the Hawaiian bentgrass was more abundant than pili uka, although the densities of both are very low. During the 2011 survey pili uka was more abundant along the Access Road but Hawai`i bentgrass was more prevalent in the Astronomy Precinct area. The alpine grassland community includes other native species that are present in in the alpine shrubland communities, although at much lower densities.

3.4.1.2.4 Alpine Stone Desert

The alpine stone desert plant community is found above 12,800 feet on Maunakea. As described in Section 2.2.1.2.3 of the NRMP, it consists of several species of mosses and lichens, an unknown number of species of algae, and a limited number of vascular plants, predominantly the same species found in the alpine shrublands and grasslands. Most of the species of plants found in the region are endemic or indigenous. A few non-native plant species have also become established here, even at the summit.

High wind speeds, high solar radiation, regular freezing and thawing cycles, low precipitation, high rates of evaporation, and the porosity of the substrate all limit the development of the plant and animal communities in this zone (Aldrich 2005). Plant density is extremely low in this high elevation climate, and plant distribution is determined primarily by substrate type. Cinder cones do not provide suitable growing habitat for most plants because of the instability of the surface material, which is destructive to plant root systems, and the inability of the granular soil to hold water and nutrients. Some mosses and lichens are found in protected areas on andesite (Hawaiite-mugearite) lava flows, in pits, fissures, small caves, overhangs and shaded pockets and crevices (Char 1999b). Vascular plants are found mainly at the base of rock outcrops where there is an accumulation of soil and moisture, and some protection from wind. The aeolian and colluvial material found scattered throughout the lava flows in low-lying swale areas provide poor habitat for plants.

Algae, Lichens, and Mosses in the Alpine Stone Desert. Algae species have not been extensively surveyed in the alpine stone desert on Maunakea. Massey (1978) reported several species of algae and diatoms in Lake Wai`au, one species of algae (*Haematococcus* sp.) is known to occur on snow banks, staining the snow red, and Smith et al. (1982) thought there are undoubtedly species of algae present in the soils.

Lichens in the Alpine Stone Desert. Lichens are a symbiotic relationship between a fungus (generally an Ascomycete) and a green alga, a blue green bacterium, or both. Smith et al. (1982) identified 21 species of lichens and five possible other species that could not be collected because they were crustose species imbedded in the andesite flows. Twenty-six species of lichens were recorded within the portion of the Astronomy Precinct surveyed by Smith and Berryman in 2011. Two species, *Lecidea baileyi* and *L. maunakeansis*, are endemic to the Hawaiian Islands. The remaining species are indigenous to Hawaii. Around half of the lichen species found on Maunakea are endemic, two of which (*Pseudephebe pubescens* and *Umbilicaria pacifica*) are limited to Maunakea alone. *Pseudephebe pubescens,* a species primarily found in high altitude and alpine regions of the world, has not been recorded anywhere else in Hawai`i or on any other tropical island. The remaining species are indigenous to Hawai`i. *Lecanora polytropa* is the most abundant and is found throughout the summit on all substrate types, including cinders and colluvial material on the cinder cones up to the summit of Pu`uwēkiu. Other common species on the summit are *Lecidea skottsbergii* and *Candelariella vitellina*, though *Lecidea skottsbergii* wasn't observed during the 2011 survey. The highest densities and diversity of lichens tends to be found on andesite rocks, in north- and west-facing protected locations, away from direct exposure to the sun. Areas to the west of the major cinder cones have a low density and diversity of lichens; Smith et al. (1982) thought this was most likely due to a rain shadow effect created by the cinder cones. The two areas of highest lichen concentration and unique assemblages identified by Smith et al. were the southern slope of Pu`uwēkiu, just below the Switchback Road, and the lava flows north of Pu`upoli`ahu. The southern slope of Pu`uwēkiu has many large rocks, and Smith et al. (1982) opined that it supports the "highest substantial colony of lichens in the state".

Based on species composition, substrate, and orientation (north-south), Char (1999b) identified four lichen communities on the summit:

(1) Nearly vertical north-facing andesite rocks characterized by an association of *Umbilicaria hawaiiensis, Pseudephebe pubescens,* and *Lecanora muralis*.

(2) Vertical west-facing andesite rocks characterized by a mixed association of *Acarospora depressa, Candelariella vitellina, Lecanora muralis, Lecidea skottsbergii, Lecidea vulcanica, Physcia dubia, Rhizocarpon geographicum,* and *Umbilicaria hawaiiensis*.

(3) South-facing rocks characterized by an association of *Umbilicaria pacifica, Physcia dubia, Lecanora muralis, Candelariella vitellina,* and *Lecidea skottsbergii*.

(4) Cinder cones, deposits of aeolian or colluvial material on lava flows, and scattered rocks and cobbles. Diversity of species was low on cinder cones and on aeolian and colluvial materials on lava flows, with only the most common lichen species present, such as *Lecanora muralis. Candelariella vitellina* and *Lecidea skottsbergii* are found on small rocks or cobbles scattered throughout the cinder and colluvial material.

In addition, there are numerous small caves throughout the summit region that are colonized by *Lepraria* species, which can tolerate deep shade and can be found up to three meters deep in some of the larger caves.

Mosses in the Alpine Stone Desert. Mosses in the alpine stone desert occur in protected places where water is more consistently available, such as under overhanging rocks and in shaded crevices or caves where snow melts slowly. Smith et al. (1982) conducted a survey of the area above 13,000 feet and found approximately a dozen species (some could not be identified with certainty to the species level), most of which are indigenous to the Hawaiian Islands. Two species, *Bryum hawaiicum* and *Pohlia mauiensis* are endemic. The most common species of moss were a previously undescribed species of

Grimmia and *Pohlia cruda*, which are most prevalent on the north-northeast and south-southeast facing sides of rocky mounds, generally in association with runoff channels from snow melt.[32] Moss cover appears to be much lower in the rain-shadow region west of the summit cone, probably due to the more arid conditions, and are believed to be absent in loose cinders or on the aeolian or colluvial fields. Table 2.2-5 in the NRMP lists all of the mosses observed on the summit of Maunakea.

Vascular Plants in the Alpine Stone Desert. Section 2.2.1.2.3.2 of the NRMP reports very few species of vascular plants within the summit area. The most abundant native vascular plant species reported are two grass species, Hawai`i bentgrass (*Agrostis sandwicensis*) and pili uka (*Trisetum glomeratum*), and two fern species, `iwa`iwa (*Asplenium adiantum-nigrum*) and Douglas' bladderfern (*Cystopteris douglasii*). Of these four species, the two grasses are the most common. The grasses tend to be found at the bases of large rock outcroppings where fine substrate and moisture accumulate. The native fern, `iwa`iwa, is found on cinder plains and lava flows from the summit down to approximately 2,000 feet. Douglas' bladderfern grows on weathered rocks up to 13,400 feet elevation. Historically, the Maunakea silversword (*Argyroxiphium sandwicense* ssp. *sandwicense*), pūkiawe (*Leptecophylla tameiameiae*), ōhelo (*Vaccinium reticulatum*), and alpine catchfly (*Silene struthioloides*) have also been observed at or near the summit. Hence, while none have been seen recently, some may still be present in more remote, unsurveyed areas.

Non-native species found in the alpine stone desert include Hairy cat's ear or gosmore *(Hypochoeris radicata)* and common dandelion (*Taraxacum officinale*), both of which are temperate weed species with a world-wide distribution. Other non-native species historically observed in the alpine stone desert include annual bluegrass (*Poa annua*), Kentucky bluegrass (*Poa pratensis*), big chickweed (*Cerastium fontanum* ssp. *vulgare*), bull thistle (*Cirsium vulgare*), hairy horseweed (*Conyza bonariensis*), sheep sorrel (*Rumex acetosella*), and common chickweed (*Stella media*). Individuals or populations of these species may still be present. Wind-borne seeds and plant fragments from lower elevations may act as sources for invasive plant species to the alpine zone, but most lowland species will not be able to grow there due to the harsh conditions.

3.4.1.2.5 Threatened and Endangered Alpine Plant Species

`Āhinahina (the Maunakea silversword, *Argyroxiphium sandwicense* ssp. *sandwicense*) is the only federally Endangered species found in the alpine vegetation communities on Maunakea. The Maunakea silversword is a subspecies of silversword found only on Maunakea, and historically occurred at least from 8,500 feet to 12,300. Recovery efforts for the Maunakea silversword are underway and consist principally of an outcrossing program in the field, greenhouse propagation of seeds, and outplanting seedlings into five fenced outplanting exclosures in the alpine shrubland and grassland areas on Maunakea and into one naturally occurring population at Waipāhoehoe gulch. Recently, a small population of Maunakea silverswords was discovered in the MKSR.

The NRMP contains an extensive discussion of the problems that must be overcome in order to recover the species. These include overcoming the genetic bottleneck that resulted from the drastic reduction in population size, the continuing presence of feral ungulates, and the Silversword's own biology.[33]

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[32] *Grimmia* are silvery-gray mosses that form clumps in run-off channels and semi-exposed rock faces; members of this genus are the mosses most often seen at the summit. *Pohlia cruda* is a bright green moss found in well-protected, deeply shady locations. Pohlia species are so well hidden they are unlikely to be seen by the casual observer. The remaining moss species are not as abundant and tend to occur in habitats intermediate between the somewhat exposed *Grimmia* habitats and the protected *Pohlia* habitats.

[33](1) Silverswords only flower once in their lifetime, and then die. (2) It takes from three to fifty years for the plant to reach maturity and flower. (3) If the flower bud is eaten or destroyed prior to seed dispersal, the plant dies and does not produce another flowering stalk. the silversword cannot pollinate itself, and must rely on insect pollination. (4) The abundance and diversity of pollinating insects in high elevation areas on Mauna Kea is limited; hence pollinator activity may not be sufficient to allow for enough pollen exchange to produce viable seeds. Moreover, native insect populations may be being impacted by introduced ants and yellowjackets, further reducing pollinator movement between plants.

3.4.1.2.6 Candidate Species and Species of Concern

There are no federal or state Candidate species found in the alpine regions of Maunakea. There are two state Species of Concern found in this region, Maunakea dubautia or na`ena`e (*Dubautia arborea*) and Douglas' bladderfern (*Cystopteris douglasii*). *Dubautia arborea*, or na`ena`e, is a small tree or shrub found in subalpine and alpine communities on Maunakea. Dubautia are closely related to silverswords (*Argyroxiphium* spp.), and often form hybrids with other Dubautia species and with species of *Argyroxiphium*. It has been adversely affected by grazing, habitat alteration, and competition with introduced plants. *Cystopteris douglasii* is a small, endemic bladderfern that grows on weathered rocks exposed to trade winds. It is threatened by habitat alteration, invasive species, and grazing animals.

3.4.1.3 Botanical Habitat Alteration

For Halepōhaku and the MKSR, most habitat alteration has occurred through development such as building of new telescopes and associated facilities, use of unpaved areas for parking lots, off-road vehicle use, and most importantly grazing by feral ungulates and the spread of invasive plants. The NRMP calls out several species that are of particular concern.

- *Common mullein*. Common mullein (*Verbascum thapsus*) is a Hawai`i State Noxious Weed that is native to the temperate zone of Europe, and is adapted to disturbed dry and rocky sites (Juvik and Juvik 1992). Mullein is currently abundant at Halepōhaku and is present on roadsides and remote upland areas on Maunakea along the Mauna Kea Access Road, up to 12,460 feet, suggesting that vehicles using the roadways are an important vector. Removing the entire plant before it flowers, or cutting the taproot appear to be the most effective means of control.
- *Telegraph weed*. Telegraph weed (*Heterotheca grandiflora*) is a weed of dry, disturbed areas that is native to California and the southwestern United States and Mexico. Telegraph weed, which was not recorded in plant surveys at Halepōhaku until 1990, is now fairly abundant at Halepōhaku and can be found along the roadside of the Mauna Kea Access Road. This suggests that its spread was facilitated by the presence and use of the Mauna Kea Access Road.
- Fireweed. Fireweed (*Senecio madagascariensis)* is a Hawai`i State Noxious Weed that originates from South Africa and was accidentally introduced to Hawai`i in the 1980s, possibly in contaminated fodder imported from Australia. Fireweed competes with other plants for limiting resources such as nutrients and water, and is a heavy invader of pasturelands, where it is poisonous to livestock. It is now common at Halepōhaku and can be found along the Mauna Kea Access Road The Hawai`i Department of Agriculture is working on a biological control program for this weed, but no effective means of control has yet been confirmed.
- *Hairy cat's ear*. Hairy cat's ear (*Hypochoeris radicata),* which is similar in appearance to the common dandelion, is a widely distributed weed originating from Eurasia. The taproot is a popular food item for feral pigs, which may dig up large areas looking for them, and a preferred forage item for grazing animals. It is found both at Halepōhaku and in the MKSR. Because it attracts foraging feral ungulates and competes with other species for water and nutrients, it thought to have a negative impact on native plant communities, but the magnitude of the effect has not been documented.
- *Common dandelion*. Common dandelion (*Taraxacum officinale*) is a cosmopolitan weed of temperate climates, that is generally found in higher elevation, wet, disturbed areas in Hawai`i. It was observed in 1982 above 13,000 feet and was observed growing on the shores of Lake Wai`au in 1940.

3.4.2 INVERTEBRATES

Invertebrates, which are animals lacking a backbone, constitute approximately 97% of all known species on earth. This group includes a wide range of terrestrial forms such as the arthropods (insects, spiders, crustaceans), mollusks (snails, bivalves, squid, octopus), and many phyla of worms (priapulid worms, flatworms, roundworms, nematodes, horsehair worms, velvet worms, and acorn worms). Invertebrate species known from the subalpine and alpine regions of Maunakea are listed in Table 2.2-

6 of the NRMP, which was compiled from a variety of sources, including the review of invertebrate species found in high elevation areas of Maunakea presented in Aldrich (2005) and searches of scientific literature and databases.[34]

Because of this diversity and complexity, this plan focuses primarily on the arthropods (primarily insects and spiders) found in the upper elevations of Maunakea. A second important group of invertebrates, the land snails, are also discussed. Arthropods comprise more than 75% of the native Hawaiian biota, and include some of the world's best known species radiations (Roderick and Gillespie 1998). Discoveries about this group of animals are still being made on Maunakea (Brown 2008; Medeiros 2008). For example, the wēkiu bug, found at the summit of Maunakea, was only discovered in 1979 (Howarth and Montgomery 1980), and is still being studied. Photos of selected native invertebrates are presented in Figure 2.2-10 and photos of common invasive invertebrates are presented in Figure 2.2-11.

3.4.2.1 <u>Subalpine Invertebrate Communities (Halepōhaku and Lower Mauna Kea Access Road)</u>

As discussed in Section 2.2.2.1 of the NRMP, the māmane forests on Maunakea have high arthropod diversity—more than 200 species have been collected there—and many more are likely present. The more important are described in the following subsections.

3.4.2.1.1 <u>Lepidoptera (Moths and Butterflies)</u>

Lepidoptera (moths and butterflies) are an important group of arthropods found in the subalpine māmane forests, including several moth species that feed on māmane (*Sophora chrysophylla*) seeds. One species of moth found in the subalpine and alpine areas is a flightless *Thyrocopa* moth that was discovered above the treeline on *Dubautia ciliolata* near Halepōhaku. This species is diurnal (most moths are nocturnal), appears to forage on dead leaves of shrubs and clumps of grass, and has lost the ability to fly. It moves around by jumping, and could easily be mistaken for a grasshopper by the casual observer. So far, it appears that this species is limited to Maunakea, but more research is needed. Other *Thyrocopa* species that can be found in the subalpine zone at Halepōhaku include *Thyrocopa indecora* and *T. adumbrata*. Other moth species found the subalpine area includes moths in the genus *Mestolobes*. These small brown moths are thought to be endemic to the Hawaiian Islands, though not much is known about them.

The māmane-feeding Lepidoptera include moths from the genus *Cydia* (of which there are at least seven species on Maunakea), *Peridroma*, and *Scotorythra*. These moths are the most important prey items for the endangered Palila (*Loxioides bailleui*), and are likely an important protein source for developing Palila chicks. It is thought that parasitic wasps may be reducing moth abundance in the māmane woodlands. Other moth species with larva that feed on māmane seeds include *Peridroma albiorbis* and an undescribed species of *Scotorythra* (Banko et al. 2002). These moths, too, are vulnerable to attacks from predatory wasps and ants and by parasitic wasps and flies.

Another native moth species, *Uresephita polygonalis virescens*, was previously reported to be a common prey item for the Palila, but is no longer observed to be part of the Palila diet. Banko et al. (2002) suggest that this species has been reduced in abundance by parasitism. Finally, the black-veined *Agrotis* noctuid moth (*Agrotis melanoneura*) has been observed at light traps at Halepōhaku in recent years, and is uncommon but widespread on Maunakea.

3.4.2.1.2 <u>Hymenoptera (Bees, Wasps, and Ants)</u>

There are no native ants (or social insects of any kind) in the Hawaiian Islands, but other members of the hymenoptera are present. The NRMP reports that native bees, such as those found in the family Colletidae, are important pollinators, while most of the native wasps are arthropod parasites, often helping to keep herbivorous insect populations in check. The yellow-legged yellow-faced bee

[34] While the listing in the table is extensive, the NRMP authors make it clear that it does not represent a complete list of species that may be present. Because of the sheer number of species and wide diversity of forms, compiling such an inventory of invertebrates on Mauna Kea was not possible.

(*Hylaeus flavipes*) is the only *Hylaeus* observed at high elevations on Maunakea, where it is found associated with māmane. It is also thought to be a potential pollinator of the Maunakea Silversword. Other native bees that may be found in the subalpine zone (but which have not been confirmed for Halepōhaku) include *H. ombrias, H. difficilis* and *H. volcanicus*. Invasive hymenoptera found in the subalpine zone on Maunakea include many parasitoid wasp species, ants, honeybees (*Apis mellifera*) and yellowjackets (*Yespula pensylvanica*).

3.4.2.1.3 True bugs (Heteroptera) and other Arthropods

A new species of plant bug, *Orthotylus sophorae*, was recently discovered in association with māmane woodlands. It is often found in association with other māmane-associated Heteroptera species, including the endemic nabid *Nabis kahavalu* and endemic lygaeid *Nesius (Icteronysius) ochriasis*. Other lygaeid bugs (relatives of the wēkiu bug) found in the subalpine region include *Neseis nitida comitans, Nysius coenosulus, Nysius palor, Nysius lichenicola,* and *Nysius terrestris.* Other arthropod species of interest found in the subalpine region include the Hawai`i long-horned beetle (*Plagithmysus montgomeryi*), koa bug (*Coleotichus blackburniae*), various *Nesosydne* leafhoppers, *Micromus* brown lacewings, and wolf spiders (*Lycosa* species).

3.4.2.1.4 Snails

The NRMP reports that close to 800 species of land snails are present in the Hawaiian Islands, many of which are endemic. The highest diversity of land snails is found in wetter forests below the subalpine zone on the Island of Hawai`i, but several species of land snail occur, or once occurred, in the subalpine māmane woodlands on Maunakea. Land snail abundance and diversity has been greatly impacted (up to 90% of the species once here are now thought to be extinct) by human-introduced predators, including rats (*Rattus rattus*), rosy wolfsnail (*Euglandina rosea*), garlic snail (*Oxychilus alliarius*), and the predatory flatworm *Platydemus manokwari*.

No surveys for snails have been conducted in the subalpine regions as high as Halepōhaku, but a survey for snails at Pu`u Lā`au Forest Reserve from 6,200 to 8,600 feet found four species of snails: two endemic (*Succinea konaensis* and *Vitrina tenella*), one of unknown origin, and one invasive species. The snail of unknown origin was an unidentified species in the genus *Striatura*. The non-native snail found was the garlic snail, *Oxychilus* alliarius. Historically, *Partulina confusa*, a tree-dwelling snail endemic to the Island of Hawai`i, was found in māmane-naio forests, but none were seen during the Pu`u Lā`au Forest Reserve survey, and it is possible that this species is now extinct. As discussed below, *Succinea konaensis* and *Vitrina tenella* are federal Species of Concern.

3.4.2.1.5 Threatened and Endangered Invertebrate Species, Candidate Species and Species of Concern

There are no federal or state listed Threatened or Endangered Species of invertebrates known to be present at Halepōhaku or in the subalpine zone of Maunakea. The NRMP reports that Federal Species of Concern include the koa bug (*Coleotichus blackburniae*), the flightless brown lacewing (*Micromus usingeri*), the black-veined Agrotis noctuid moth (*Agrotis melanoneura*), several species of native *Hylaeus* bees including *H. flavipes, H. difficilis,* and *H. ombrias*, and two species of snails (*Succinea konaensis* and *Vitrina tenella)*. The black-veined *Agrotis* noctuid moth and the *Hylaeus* bees are also listed as Hawai`i state Species of Concern.

The koa bug, the only native herbivorous *Scutelleridae* stink bug in Hawai`i, was quite common until the 1960s, when several parasites were released in Hawai`i to control *Nezara viridula*, a pest stinkbug. These parasites have decimated koa bug populations, and it is now rare in the wild, though higher elevation areas such as Maunakea may provide a refuge for koa bug from introduced biological control agents. The flightless brown lacewing has recently been collected on *Dubautia arborea* and Mamane on Maunakea, and the black-veined *Agrotis* noctuid is uncommon but widespread on Maunakea, including at Halepōhaku. The current status of the native bee populations at high elevation areas on Maunakea is unknown, as no formal surveys have been conducted there. *Hylaeus flavipes* has been observed foraging on māmane (*Sophora chrysophylla*) trees at Halepōhaku, while the other species of bees listed above are thought to be found in dry forests and shrublands, but have not been studied at Halepōhaku or the vicinity.

Succinea konaensis and *Vitrina tenella,* both listed as federal Species of Concern, are ground-dwelling snails. In the aforementioned survey conducted at Pu`ulā`au, both of these species were found beneath rocks at approximately 8,500 feet. Predators of these high elevation snails include ground foraging birds such as Ring-necked pheasants and rodents, primarily. Little is known about the life history of Hawai`i's endemic terrestrial snails, and little information is available regarding *Succinea konaensis* and *Vitrina tenella.*

3.4.2.1.6 <u>Invasive Invertebrate Species</u>

Section 2.2.2.1.2 of the NRMP cites invasive invertebrates as a serious threat to Hawai`i.[35] Invasive arthropods found in the subalpine region of Maunakea include (at a minimum) the five parasitoid wasp species and one parasitoid fly species, European earwig (*Forficula auricularia*), ants, honeybees (*Apis mellifera*) and yellowjackets (*Vespula pensylvanica*). Both ants and yellowjackets are known to have detrimental effects on native arthropod populations, which in turn can affect the native plant and bird communities.

Honeybees (*Apis mellifera*) are thought to compete with native nectarivorous insects such as native bees, but their impact on native pollinators in Hawai`i has not been fully studied. However, in areas where native pollinators are few or missing, honeybees may provide pollination services to some native plant species. Yellowjackets are known to seriously impact native arthropod communities, and they could pose a threat in the subalpine woodlands and shrublands if their densities increase above what are believed to be their currently low levels.

Five species of invasive non-native ants have been found on Maunakea: *Linepithema humile, Cardiocondyla venustula, Pheidole megacephala, Tetramorium bicarinatum,* and *Monomorium pharaonis*. The species with the highest elevational range and highest densities are *Cardiocondyla venustula* (~8,000 feet) and *Linepithema humile* (~9,200 feet). *Pheidol megacephala, Tetramorium bicarinatum,* and *Monomorium pharaonis* were found in fewer locations and at lower densities (<6,000 and <6,400 feet, respectively). A study of invasive invertebrates present at Halepōhaku and the MKSR conducted in 2007-2008 by Bishop Museum entomologists indicate that ants were present at Halepōhaku or in the MKSR.

Linepithema humile, or the Argentine ant, has not yet been found at Halepōhaku, but it is known to occur at similar elevations on other parts of Maunakea (~9,200 feet) and is able to colonize dry upland areas. It is a serious threat to native flora and fauna because of its appetite for arthropods, seeds, and nectar. It is a predator of many endemic arthropods, including noctuid moths and *Hylaeus* bees, which are the pollinators of rare subalpine plants such as the Haleakalā silversword, *Argyroxiphium sandwicense macrocephalum*, and Cole et al. (1992) reported that many invertebrate populations on Haleakalā were smaller in areas infested with Argentine ants than in areas not infested. As Maunakea silverswords (*Argyroxiphium sandwicense sandwicense*) are thought to be pollinated by *Hylaeus* bees, the establishment of a colony of Argentine ants in the subalpine zone on Maunakea could further inhibit recovery of the small population of silverswords found there.

In 2007-2008, Bishop Museum scientists observed European earwigs (*Forficula auricularia*) in high numbers around the VIS at Halepōhaku, but it appears to be restricted in elevation and had not become established above the VIS in 2009. This species is predatory, and could potentially impact native invertebrate species in the subalpine zone (Englund et al. 2009). The NRMP recommends further research on the distribution and impact of this species on native invertebrates.

The garlic snail, *Oxychilus alliarius*, is an introduced terrestrial snail that was first recorded in the Hawaiian Islands in the 1930s and can be very abundant, especially in moist ground in forested areas. It is an omnivore and opportunistic predator that Howarth (1985) judged to negatively impact native

[35] New arrivals to Hawai`i include the little fire ant, which has a very painful sting; the Erythrina gall wasp, which is destroying native wiliwili trees; and the Varroa mite, which is harming Hawai`i's queen bee, honey, and pollination industries.

snail populations. It has been found at 8,600 feet elevation on Maunakea, but its true elevational limit is unknown.

3.4.2.2 Alpine Invertebrate Communities (MKSR and Upper Mauna Kea Access Road)

Alpine invertebrate communities are discussed in Section 2.2.2.2 of the NRMP. Because little information regarding invertebrate communities in the alpine shrublands and grasslands of Maunakea was available to the authors of that report, they focused on the invertebrate community found on the summit area, where invertebrate communities in the alpine stone desert have received a fair amount of attention since 1980, when the wēkiu bug and other resident species were discovered.

The arthropod community on the summit of Maunakea consists of two parts: those species that are blown up the mountain by the wind and die there in the cold (referred to as aeolian drift), and those cold-adapted species that are permanent residents and that feed on the dead and dying arthropods found in the aeolian drift or on one-another. In total, 21 resident species and 21 species of undetermined status (unknown if they are resident or aeolian) have been recorded as occurring in the alpine stone desert. The 21 resident species include 12 native species, five species of unknown origin, and four non-native species. Of the 21 species with unknown status (whether they are resident or aeolian), four are native species, seven are unknown, and ten are non-native species. These numbers are approximate because of the uncertainty of many species identifications. An additional 67 species (47 non-native, 12 native, and eight of unknown origin) have been recorded in the aeolian drift.[36]

Native resident (and potential resident) species include the wēkiu bugs (*Nysius wekiuicola*), two noctuid moth species (*Agrotis* sp.), hide beetles (*Dermestes maculates* and *Dermestes frischii*), a large wolf spider (*Lycosa* sp.), two sheet web spiders (*Erigone* species), an unidentified Linyphiid sheet web spider (Family Linyphiidae), two unknown Entomobryid springtails (Family Entomobryidae), a Collembola springtail (Class Collembola, family and species unknown), two species of mites (Families Anystidae and Eupodidae), a bark louse (*Palistreptus inconstans*) and a centipede (*Lithobius* sp.). The wēkiu bug (*Nysius wekiuicola*) is the best-studied invertebrate at the summit – there is little information available regarding the habits of most of the other summit species.

The wēkiu bug is a true bug in the family *Lygaeidae* (order *Heteroptera*), and is approximately the size of a grain of rice. Wēkiu bugs reside under rocks and cinders on the summit of Maunakea, where they feed diurnally (during the day) on dead and dying insects blown up the mountain from lower elevations, using their strawlike beaks to suck the hemolymph (a fluid comparable to blood) from other insects, but do not appear to feed on healthy, living individuals of the other resident arthropod species. The wēkiu bug and its sister species, *Nysius aa*, which resides on the summit of Maunaloa, differ from other species in the genus *Nysius* in being scavengers and predators of dead and dying arthropods; all other known species in the genus are seed and/or plant consumers. Food resources alone probably do not greatly influence the distribution of wēkiu bugs, as arthropod diversity and abundance in the aeolian drift was found to be similar in areas where wēkiu bugs are found and those where they are not, although it is possible that abundance of flies and other weak-flying aeolian waifs is higher along ridge crests and in areas where wind eddies drop their particulate loads. Snowfields may chill and store insects for consumption by resident scavengers such as the wēkiu bug, and the bugs can often be seen foraging on the edge of snow banks. Permafrost was once thought to be an important source of moisture for the wēkiu bug, but recent evidence suggests that this is unlikely to be the case.

Wēkiu bugs are often abundant above about 13,450 feet on undisturbed areas on Pu`uwēkiu and Pu`uhao`oki, on stable accumulations of loose cinders and tephra rocks, where the interstitial spaces are large enough to allow the bug to migrate downwards to moisture and shelter. These habitat types are found on the ridges and craters of the cinder cones. Areas that had accumulated aeolian dust and silt, such as Pu`upoli`ahu, had fewer wēkiu bugs. Studies suggest that observatory construction and

[36] Although the aeolian-drift species provide an important food source for the resident species, they are not of critical importance, because their exact species composition is probably not important to the survival of the residents so long as they continue to blow up the mountain in large numbers.

other human activities have not impacted wēkiu bug distributions at the summit outside of the immediate vicinity of paved and covered areas. Porter and Englund's 2006 report found that wēkiu bugs mainly reside on or near the crater rims of cinder cones that formed nunataks (ice free areas rising above the surrounding glacier) or that lay at the glacier limit during the last glaciation, and that the bug is most abundant on the north- and east-facing slopes (and on slopes shaded by local topography), where seasonal snow remains the longest. Crests of glacially overridden cones and inter-cone expanses of glacial till appear to lack suitable wēkiu bug habitat. Wēkiu bugs appear to be restricted to non-glaciated habitats. Jesse Eiben, a PhD graduate from UH, has been researching wēkiu bug genetics and natural history since Fall 2005 and has discovered that wēkiu bugs are found not only on the summits of the pu`u, but also on the flanks and at the bases of the cones where cinders have accumulated to sufficient depths (Eiben 2008). Figure 3.12 shows the potential and known wēkiu bug habitat in the MKSR, as determined by Eiben. Eiben and Rubinoff (2014) have recently published a comprehensive life table of the Wēkiu bug, describing growth, reproduction, and population increase modeling which will be useful in the future for understanding any potential impacts to the species. The developmental parameters they quantified were used to determine the species would not be listed as endangered or threatened.

Invertebrate surveys at the summit discovered a large (up to 2 cm body length), black wolf spider (*Lycosa* sp.). This wolf spider is thought to be endemic to the Hawaiian Islands, although its distribution elsewhere is not known; many lycosid species are capable of `hang gliding, ballooning' or long-distance dispersal by wind, and that is the most likely means of its arrival in the summit area. The wolf spider is an ambush predator, hiding under large rocks until an active prey comes within range that likely preys on any actively moving arthropod including the wēkiu bug. It is found in low but regular densities across the summit in a wider variety of areas than the wēkiu bug.

Three presumably native Linyphiid spiders (*Erigone* sp.) were collected in 1982, but were not seen in 1997–1998 surveys. One is described as being a "small, brown, sheet web spider which builds its sheet-like web across vesicles and other indentations on the undersides of rocks in the summit area; another was a single distinctive male located near 13,000 feet on the northwest slope of the surveyed area; and the third species belonged to an unknown genus in the *Linyphiidae* family, and had similar range and habitats.

A small black centipede in the genus *Lithobius*, presumed to be endemic, occurs primarily on lava flows with large outcrops of andesitic rock. The centipede burrows in the silt and aeolian debris in cracks and under rocks at the base of lava cliffs. Like many of the other species encountered on the summit, the centipede is thought to feed on aeolian drift, but few individuals of this species have been collected or observed, and little is known of its ecology.

Howarth (1999) reported finding a species of black Agrotis moth (originally identified as an *Archanarta* species) whose larvae feed on foliose lichens, dead arthropod remains, and even the remains of larger animals (including the skin of dehydrated sheep). These were observed from approximately 10,000 feet to the summit, but little is known of their ecology.

Resident (and possible resident) species of uncertain origin include an unidentified rove beetle (*Staphylinidae*), an unidentified *Hydrophilid* beetle (family *Hydrophilidae*), a moth fly (*Psychoda* species), an unidentified scuttle fly (family *Phoridae*), a fungus gnat (*Sciara* sp.), an unidentified ichneumonid wasp (family *Ichneumonidae*), unidentified micro-hymenoptera, and several unknown species of mites (Families *Bdellidae*, *Laelapidae*, *Phytoseidae*, and one unknown family). No information is available regarding the distribution of these species, their abundance, or behavior at the summit.

Non-native resident (and potential resident) species include: a book louse (*Liposcelis divinatorius*), big-eyed bug (*Geocoris pallens*), a hunting spider (*Meriola arcifera*), a sheet web spider (*Lepthyphantes tenuis*), and an unidentified jumping spider (family *Salticidae*). One non-native species of fly, the blue bottle fly (*Calliphora vomitoria*), two predatory carabid beetle (*Agonum muelleri* and *Trechus obtusus*), and two species of diving water beetle *(Rhantus pacificus*, which is endemic to the Hawaiian Islands, and an undetermined *Hydrophilid* of unknown origin), were recorded as occurring in Lake Wai`au. .

3.4.2.2.1 Invertebrate Threatened and Endangered, Candidate, and Species of Concern in the Alpine Zone

There are no Species of Concern, Candidate, Threatened or Endangered species known to reside in the MKSR.

3.4.2.2.2 Invasive Species

Two spiders, *Lepthyphantes tenuis* and *Meriola arcifera* have invaded the Science Reserve since 1982. The first (*L. tenuis*) is a sheet web spider from Europe that may compete with the native sheet web spiders; the second (*M. arcifera*) is a non-web-building, ground-hunting spider native to Argentina, Bolivia, and Chile. This species was first collected in Hawai`i in 1995 and is limited to upper elevations on the Saddle Road to the summit of Maunakea. Howarth et al. (1999) thought it possible this species may prey on or compete with the wēkiu bug and other arthropods at the summit.

Hippodamia convergens, a non-native beetle introduced in 1896 as a biological control agent of aphids, has been seen at Pu`upōhaku in the Ice Age NAR. This species is tolerant of alpine conditions and in addition to feeding on aphids can feed on dead insects; hence it may compete directly with the wēkiu bug for food. Several other non-native beetle species known to eat dead invertebrates have been seen in the area as well, including *Aleochara verna*, *Creophilus maxillosus*, *Tachyporus nitidulus*, *Sphaeridium scarabaeoides*, *Necrobia rufipes*, and *Dermestes frischii*), and these may also compete with wēkiu bug for food, although there remains some question as to whether these species feed on isolated dead insects in a similar way to wēkiu bugs.

A study of invasive invertebrates conducted by the Bishop Museum in 2007-2008, found a non-native species of predatory carabid beetle, *Agonum muelleri*, around Lake Wai`au. A subsequent investigation by Englund *et al*. (2009) concluded that it is probably restricted to the region immediately around the lake. As this is not favorable wēkiu bug habitat, it is unlikely this species is currently impacting the wēkiu bug, though it could be feeding on other native invertebrates found in the area.

3.4.2.3 Invertebrate Habitat Alteration

Section 2.2.2.3.1 of the NRMP identifies a number of habitat changes that have affected native invertebrate communities by directly removing habitat (through development) or changing it to the extent that the invertebrates are no longer able to live there (for example, by changing host-plant abundances). At both Halepōhaku and the MKSR, habitat alteration has occurred through development of astronomy facilities and support structures (such as parking lots), everyday use, and (primarily in the subalpine zone) introduction of invasive species. A prime example of habitat loss through development has been the loss of wēkiu bug habitat on the summit through construction of telescope facilities. The NRMP estimates that since 1963, approximately 62 acres of potential arthropod habitat have been lost to astronomy-related development on the summit.[37] The true level of impact from dust is unknown at this time, as it has not been studied.

Grazing by introduced mammals has heavily altered habitats in the subalpine woodlands, by changing the composition of plant species in favor of invasive weed species. Native plants previously used by native invertebrates, such as Hylaeus bees, have been reduced in abundance to the point that the small and widely dispersed native plant populations are no longer able to support pollinator populations. Thus, habitat alteration through removal of plant species can seriously impact populations of pollinators and other animals that rely on the plants as source of food or shelter. The destruction of their pollinators can, in turn, can make it difficult or even impossible for these plant species to repopulate the area.

[37] Wēkiu bug habitat may also be altered by dust blown up from road grading and other construction activities. This dust can reduce surface porosity and fill pockets between cinders, inhibiting movement by arthropods and perhaps affecting wēkiu bug food sources by decreasing the accumulation of aeolian drift.

Other invasive animals, such as rats and non-native birds, can impact arthropod populations directly through predation. However, the NRMP judges invasive invertebrates as perhaps the greatest threat to native invertebrates in Hawai`i through competition, predation, habitat alteration, and parasitism. Invasive parasitoid wasps and flies are likely reducing Cydia moths and other moth species that live in the subalpine māmane woodlands; thus the parasitoid wasps not only directly affect the moths they attack but also indirectly affect predators of the moths such as the Palila.

3.4.3 BIRDS

Section 2.2.3 of the NRMP describes the birds on Maunakea (see Table 3.4). It notes that Hawai`i has an incredible diversity of birds, a great number of which are endemic species, and that these evolved from a few different species of birds that managed to colonize the islands. It also discusses the great changes that have occurred in the bird population since the arrival of humans and their associated animal species, with perhaps no more than a third of the bird species that were present before the first human settlement still surviving. A large percentage of extant native bird species are endangered due to habitat loss, non-native predators (cats, rats, and mongoose), disease (avian malaria and pox), hunting and over-collection (historically for feathers, meat, or specimens), and competition with non-native birds and insects for food.

3.4.3.1 <u>Subalpine Bird Communities (Halepōhaku and Lower Mauna Kea Access Road)</u>

As described in Section 2.2.3.1 of the NRMP, the māmane woodlands have a fairly diverse bird community, including frugivores, nectarivores, insectivores, and two raptor species. The māmane trees themselves are the primary food source for birds in the region, providing nectar and seeds on a seasonal basis; several bird species also prey in the insects that utilize the māmane trees. Thus, the severe degradation of the māmane woodlands by non-native browsing animals (cattle, sheep, and goats) has led to a steep decline in the native bird populations that depend upon this forest type.

<u>*Native Bird Species*</u>. Native bird species found in māmane woodlands on Maunakea include the Palila (*Loxioides bailleui*), `Amakihi (*Hemignathus virens*), `Apapane (*Himatione sanguinea*), `Elepaio (*Chasiempis sandwichensis sandwichensis*), `Akiapola`au (*Hemignathus munroi*), `I`iwi (*Vestiaria coccinea*), `Io (*Buteo solitarius*), Kolea (*Pluvialis fulva*) and Pueo (*Asio flammeus sandwichensis*) (Scott et al. 1986). The Hawaiian petrel or `Ua`u (*Pterodroma sandwichensis*), has been observed in subalpine lava flows on Maunaloa, at 8,000–9,200, and occasionally in subalpine and alpine habitats on Maunakea. Of the above species only the Palila, `Amakihi, `Apapane and `I`iwi have been observed at Halepōhaku in recent times.

<u>*Non-Native Bird Species*</u>. Non-native birds found in māmane and māmane-naio woodlands on Maunakea include Black Francolin (*Francolinus francolinus*), Erckel's Francolin (*Francolinus erckelii*), Chukar (*Alectoris chukar*), Japanese Quail (*Coturnix japonica*), Ring-necked Pheasant (*Phasianus colchicus*), Wild Turkey (*Meleagris gallopavo*), California Quail (*Callipepla californica*), Eurasian Skylark (*Alauda arvensis*), Melodious Laughing-thrush (*Garrulax canorus*), Red-billed Leiothrix (*Leiothrix lutea*), Northern Mockingbird (*Mimus polyglottos*), Common Myna (*Acridotheres tristis*), Japanese White-eye (*Zosterops japonicus*), Northern Cardinal (*Cardinalis cardinalis*), House Finch (*Carpodacus mexicanus*), House Sparrow (*Passer domesticus*), Warbling Silverbill (*Lonchura malabarica*), Nutmeg Mannikin (*Lonchura punctulata*), and Yellow-fronted Canary (*Serinus mozambicus*). Of these, only eight species (Erckel's Francolin, California Quail, Eurasian Skylark, Red-billed Leiothrix, Japanese White-eye, House Finch, House Sparrow, and Yellow-fronted Canary) have been recorded as occurring at Halepōhaku during limited survey work conducted there. However, it seems likely that the most of the non-native species listed above can be found at or near that area, at least seasonally.

Table 3.4: Bird species potentially found at Halepōhaku and MKSR

Community	*Elev. (m)*	*Scientific Name*	*Common name*	*Origin*	*Status2*	*MKSR*	*HP*	*Refs*
Subalpine Dry Forest	1800-2900	*Asio flammeus sandwichensis*	Pueo	E	FSOC		??	5
Subalpine Dry Forest	1800-2900	*Branta sandvicensis*	Nēnē (Hawaiian goose)	E	FE, SE		??	2
Subalpine Dry Forest	1800-2900	*Buteo solitarius*	'Io	E	FE, SE		??	5
Subalpine Dry Forest	1800-2900	*Chasiempis sandwichensis*	Hawai'i 'Elepaio	E	FSOC		??	5
Subalpine Dry Forest	1800-2900	*Hemignathus munroi*	'Akiapola'au	E	FE, SE		??	5
Subalpine Dry Forest	1800-2900	*Hemignathus virens virens*	'Amakihi	E	FSOC		~	1,2
Subalpine Dry Forest	1800-2900	*Himatione sanquinea*	'Apapane	E	FSOC		~	1,2
Subalpine Dry Forest	1800-2900	*Loxioides bailleui*	Palila	E	FE, SE		~	1,3
Subalpine & Alpine	1800-3780	*Pterodroma sandwichensis*	\`Ua\`u (Hawn. petrel)	E	FE, SE	??	??	2
Subalpine Dry Forest	1800-2900	*Vestiaria coccinea*	'I'iwi	E	FSOC		~	6
Subalpine Dry Forest	1800-2900	*Pluvialis fulva*	Kolea (Pac. golden plover)	I	FSOC		??	5
Subalpine Dry Forest	1800-2900	*Acridotheres tristis*	Common myna	X			??	5
Subalpine Dry Forest	1800-2900	*Alauda arvensis*	Sky lark	X			~	2
Subalpine Dry Forest	1800-2900	*Alectoris chukar*	Chukar	X			??	5
Subalpine Dry Forest	1800-2900	*Callipepla californica*	California quail	X			~	1,2
Subalpine Dry Forest	1800-2900	*Cardinalis cardinalis*	Northern cardinal	X			??	5
Subalpine Dry Forest	1800-2900	*Carpodacus mexicanus*	House finch	X			~	1,2
Subalpine Dry Forest	1800-2900	*Coturnix japonica*	Japanese quail	X			??	5
Subalpine Dry Forest	1800-2900	*Francolinus erckelii*	Erckel's francolin	X			~	1
Subalpine Dry Forest	1800-2900	*Francolinus francolinus*	Black francolin	X			??	5
Subalpine Dry Forest	1800-2900	*Garrulax canorus*	Melodious laughing-thrush	X			??	5
Subalpine Dry Forest	1800-2900	*Leiothrix lutea*	Red-billed leiothrix	X			√	1
Subalpine Dry Forest	1800-2900	*Lonchura malabarica*	Warbling silverbill	X			??	5
Subalpine Dry Forest	1800-2900	*Lonchura punctulata*	Nutmeg mannikin	X			??	5
Subalpine Dry Forest	1800-2900	*Meleagris gallopavo*	Wild turkey	X			??	5
Subalpine Dry Forest	1800-2900	*Mimus polyglottos*	Northern mockingbird	X			??	5
Subalpine Dry Forest	1800-2900	*Passer domesticus*	House sparrow	X			√	1,2
Subalpine Dry Forest	1800-2900	*Phasianus colchicus*	Ring-necked pheasant	X			??	5
Subalpine Dry Forest	1800-2900	*Serinus mozambicus*	Yellow-fronted canary	X			√	4
Subalpine Dry Forest	1800-2900	*Zosterops japonicus*	Japanese white-eye	X			√	1,2

Notes: Origin: E = endemic, I = indigenous, X = introduced/alien.

Legal Status: FC = Federal Candidate for listing, FE = Federally Endangered, FT= Federally Threatened, FSOC = Federal Species of Concern, SC = State Candidate for Listing, SE = State Endangered, SSOC = Hawaii State Species of Concern, ST = State Threatened

Location: MKSR = Mauna Kea Science Reserve (12,000+ ft), HP = Hale Pōhaku. √ = present (recorded through surveys). ?? = Known to reside in that habitat type on Maunakea, but not recorded during bird surveys.

Source: University of Hawaii 2009c, Table 2.2-7.

Federally listed Endangered species that occur in māmane woodlands on Maunakea include the Palila (*Loxioides bailleui*), \`Akiapola\`au (*Hemignathus munroi*), \`Io (*Buteo solitarius*) and Nana (*Branta sandvicensis*). The latter three species have not been recorded at Halepōhaku. There are no federally listed Threatened species known to be found at Halepōhaku. Brief descriptions of these species are presented in Table 3.5. The latter three species have not been recorded at Halepōhaku. There are no federal Candidate species of birds found at Halepōhaku.

Federal Species of Concern found at Halepōhaku include the Hawai\`i \`Amakihi (*Hemignathus virens*), \`Apapane (*Himatione sanguinea*) and \`I\`iwi (*Vestiaria coccinea*). Other federal Species of Concern that may occur at Halepōhaku (but have not been recorded there) include the Hawai\`i \`Elepaio (*Chasiempis sandwichensis sandwichensis*), Kolea (*Pluvialis fulva*), and Pueo (*Asio flammeus sandwichensis*). Brief descriptions of these species are presented in Table 3.6.

3.4.3.2 Alpine Bird Communities (MKSR and Upper Mauna Kea Access Road)

Section 2.2.3.2 of the NRMP reports that no birds are known to currently inhabit or regularly use the summit area or the alpine shrubland and grasslands, though an occasional bird may be observed flying through the area, and sometimes birds are blown up the mountain during strong winds and die there. Several dehydrated Red-billed Leiothrix have been found at or near the summit, documented occasionally in OMKM Ranger Reports.

3.4.3.3 Birds: Threatened and Endangered Species, Candidate Species, and Species of Concern

As noted above, federally listed endangered species that occur in māmane woodlands on Maunakea include the Palila (*Loxioides bailleui*), `Akiapola`au (*Hemignathus munroi*), `Io (*Buteo solitarius*) and Nana (*Branta sandvicensis*). The latter three species have not been recorded at Halepōhaku. There are no federally listed Threatened species known to be found at Halepōhaku.

There are no federal Threatened Species, Candidate Species, or Species of Concern known to inhabit the alpine community on Maunakea. There is one federal Endangered species, the Hawaiian Petrel (*Pterodroma sandwichensis*)[38] or `Ua`u (Banks et al. 2002), which may have historically utilized lower portions of the alpine zone on Maunakea. The `Ua`u is a pelagic seabird that historically nested in the mountains of all main Hawaiian Islands. `Ua`u nest in underground burrows and feed at sea. Prior to human contact the `Ua`u was abundant on the saddle area between Maunaloa and Maunakea. A breeding colony of `Ua`u is known from Hawai`i Volcanoes National Park from 8,000 feet to 9,200 feet. Skeletal remains of `Ua`u have been found on Maunakea at elevations up to 12,400 feet, possibly indicating presence of the birds in the alpine zone. In 1954, Richardson and Woodside found five freshly dug `Ua`u burrows at Pu`ukole, east of Halepōhaku, and in the 1960s and 1970s there were observations of `Ua`u from Pu`ukole around the eastern flank of Maunakea to Pu`ukanakaleonui. Currently they are thought to be located on Maunaloa along the summit trail, and on Maunakea above 9,850 feet near Pu`ukanakaleonui. Conant et al. (2004) point out that Hawaiian petrels were used as food by the ancient Hawaiians, and the presence of the bones at these high elevations could represent either petrel activity or the remains of an ancient Hawaiian meal. No `Ua`u were observed during bird surveys conducted (in a rather limited area) on the summit of Maunakea in 1988.

[38] Although it is listed as the Dark-rumped Petrel (*Pterodroma phaeopygia sandwichensis*) under the Endangered Species Act, this species has recently undergone a name change and is referred to as the Hawaiian Petrel (*Pterodroma sandwichensis*) in recent literature.

Table 3.5: Summary Descriptions of Federally Listed Endangered Bird Species

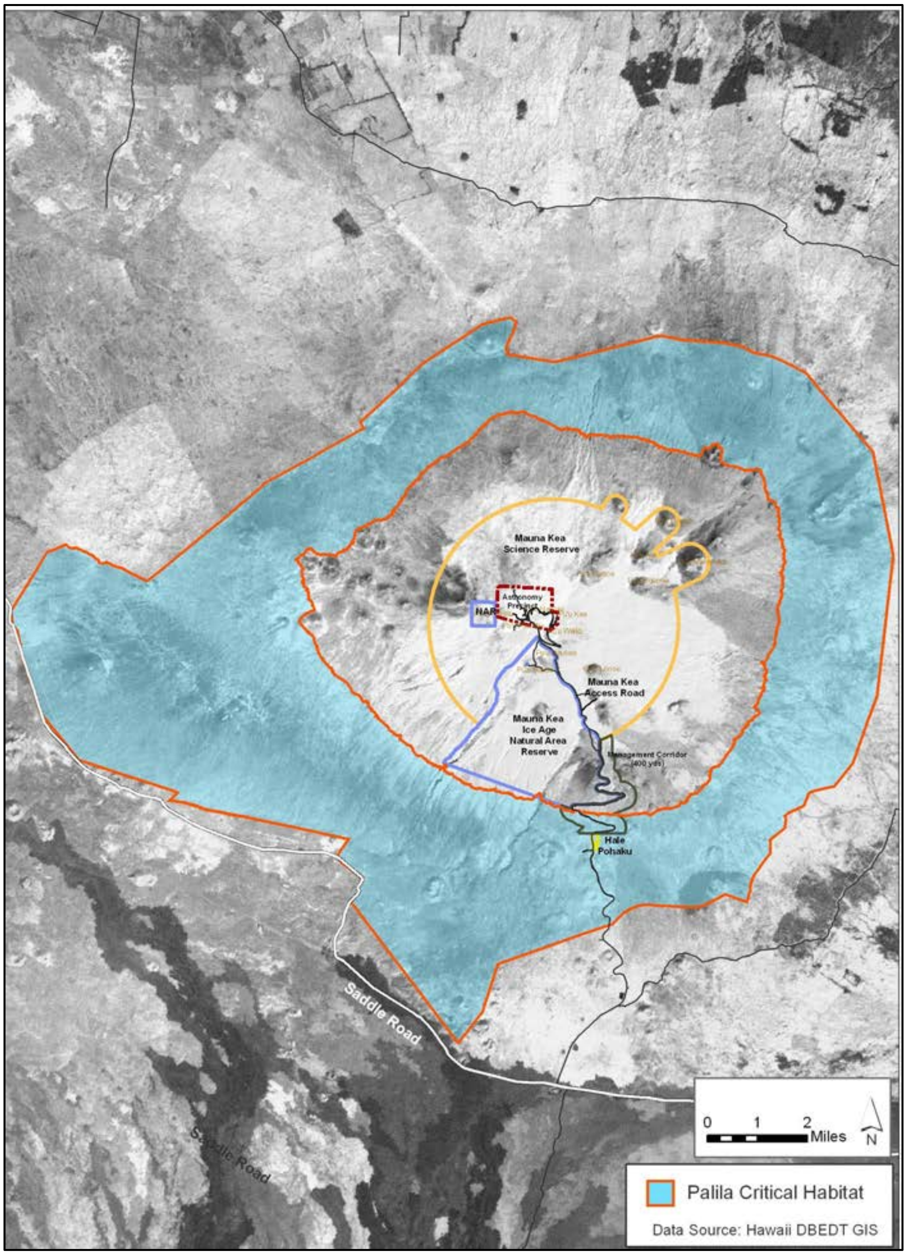
Name	***Summary***
Palila	Palila (*Loxioides bailleui*) are seed-eating finches with stout beaks and a yellow head and breast. The Palila is one of three remaining seed-eating honeycreepers in the Hawaiian archipelago, and the only one left on the main islands. They are also the only remaining species of Hawaiian bird that relies solely on dry forest for habitat. Palila feed on the green seedpods of māmane trees, eating the seeds inside and preying on caterpillars of *Cydia* and other moth species that also feed on the seeds. Palila also eat naio fruits as well as māmane flowers, buds, and young leaves. Once common in lowland dry forests on several of the Hawaiian Islands, habitat alteration, first by humans, and subsequently by grazing mammals, has decreased the Palila's range to a small band around Maunakea, in the last remaining stands of māmane woodlands. Most Palila are now found in the southwestern portion of the mountain. Given their reliance on māmane, the main threat to current Palila populations is habitat degradation and loss, caused by grazing of māmane seedlings by non-native mammals; smothering by invasive plant species (such as grasses); increased frequency and intensity of fires; and development. Availability of māmane seeds is an important limiting factor, and Palila may not breed during drought years when fewer māmane seedpods are produced. Predation by non-native mammals is also a threat to Palila, although predators are not as abundant in the subalpine zone on Maunakea as they are in lowland areas. Invasive parasitoid wasps are also thought to impact the moth species upon whose caterpillars Palila feed, thus reducing an important food source for Palila adults and chicks. An additional threat to the Palila is the presence of avian malaria at lower elevations. Halepōhaku falls within the critical habitat of the Palila, which extends to 10,000 feet on Maunakea.
`Akiapola`au	*`Akiapola`au* (*Hemignathus munroi*) are honeycreepers with a strongly decurved upper bill and a stout, woodpecker-like lower bill that can be used to drill holes in trees and loosen bark. The `Akiapola`au then uses its upper bill as a tool to pick out insects (primarily moth larvae and beetles) from under the bark. `Akiapola`au are primarily insectivorous, but also supplement their diet with sap from `ōhi'a trees. Prior to disturbance by man and deforestation by introduced grazing mammals, mesic and dry forest cover was nearly continuous from eastern Maunakea to Hamakua. During that time, `Akiapola`au were most likely common and widespread, and in the 1970s, `Akiapola`au were still found in low numbers in māmane and māmane-naio woodlands on Maunakea from 6,200 to 9,500 feet (1,900 to 2,900 m) elevation. They are now very rare in (and perhaps even extirpated from) the subalpine communities on Maunakea, and are primarily found in koa-`ōhi'a forests.
`Io	*`Io (Buteo solitarius), or Hawaiian hawk*, are territorial, monogamous raptors that feeds on birds, mammals, insects, and spiders. They occur from sea level to approximately 8,500 feet on the Island of Hawai`i and are known to utilize a broad range of forest habitats. `Io avoid unforested areas and are most abundant in native forests. They have been observed in subalpine māmane-naio woodlands in the past, but recent survey work suggests that `Io do not utilize māmane-naio forests much, if at all. There is no evidence that avian malaria, introduced predators, or environmental contaminants are seriously affecting the `Io population. Survey work indicates that `Io populations are stable, and it is currently thought that the species may be a candidate for down-listing from Endangered to Threatened, or removal from the Endangered Species list altogether.
Nēnē	Nēnē (*Branta sandvicensis*) is the only remaining species of goose in the Hawaiian Islands from the seven or more species that existed prior to the arrival of Polynesians (Olson and James 1982). Nēnē historically inhabited grasslands, grassy shrublands, and dryland forest, from sea level to the subalpine and alpine zones. They likely inhabited high-elevation sites such as the māmane woodlands in the subalpine zone on Maunakea during the non-breeding season. Nēnē feed on leaves, buds, flowers and seeds of grasses and herbs, and the fruits of `ōhelo (*Vaccinium reticulatum*), `aiakenana (*Coprosma ernodeoides*), and other plants. Nēnē are ground-nesting birds and their numbers have been greatly reduced by non-native mammalian predators. Until recently, their populations remained small/sustained by a captive breeding program, and their present distribution reflects locations of release sites of captive-bred birds. On the Island of Hawai`i, Nēnē are currently found from sea level to 7,900 feet with a number of population centers in the wild. The nearest being the Pōhakuloa area. They have not been observed at Halepōhaku or above, and no evidence suggests they are currently using those areas.
Source: University of Hawaii 2009c	

Table 3.6: Summary Descriptions of Federal Bird Species of Concern

Name	***Summary***
`Amakihi	*Hawai`i `Amakihi* (*Hemignathus virens virens*) are yellowish-green honeycreepers with a thin, slightly decurved beak that feed on insects, nectar, and fruit (Hawaii Audubon Society 1997). They are the most common native birds remaining, ranging from 2,100 feet to 9,850 feet, and have a strong association with dry and mesic forests, including māmane and māmane-naio woodlands. `Amakihi in subalpine woodlands nest primarily in māmane trees, generally preferring trees that are taller than average. Because of their varied diets, `Amakihi populations in subalpine woodlands do not fluctuate as greatly on a seasonal (or daily) basis as do `Apapane and `I`iwi populations. However, `Amakihi are highly dependent on nectar availability, especially during the breeding season, and will not breed in areas that do not have sufficient densities of māmane flowers. `Amakihi retain mates for more than one season, are territorial, and breed from November through July, with the most nesting occurring in March through May. Generally two to three eggs are laid during a breeding attempt. Overall reproductive success of the `Amakihi is average for open-nesting passerines (around 35%, with the greatest causes of failure being nest desertion and failure of the eggs to hatch). High survival rates and relatively long life of adult birds may aid in population stability, but they are susceptible to avian malaria, and low elevation populations have fairly high infection rates. Despite this, `Amakihi populations have recently been increasing in lowland areas on Hawai`i. It is currently unknown whether these populations are being supplemented by movement of `Amakihi from higher elevation populations, or if the `Amakihi is developing some level of resistance to avian malaria and is thus able to reproduce and maintain stable populations despite high infection rates.
`Apapane	*`Apapane* (*Himatione sanguinea*) are bright crimson honeycreepers with black wings and tail. They have a long decurved bluish-black bill, and feed primarily on nectar, but also take insects and spiders; they also make a whirring noise during flight. `Apapane breed in mesic and wet `ōhi'a forests, making seasonal and daily movements from wet forest to subalpine woodland and leeward dry woodlands when nectar is available there. In the breeding season, `Apapane maintain small breeding territories, are monogamous, and lay clutches of one to four eggs (three on average). Breeding activity begins October-November and peaks in February through June. During the non-breeding season, `Apapane forage together in small flocks, or in mixed flocks with other species of honeycreeper. `Apapane are susceptible to avian pox and malaria, and have the highest prevalence of malaria (*Plasmodium*) parasites of any native or alien bird species in the Hawaiian Islands. Other factors that likely impact `Apapane populations are habitat loss and degradation (including habitat alteration by invasive plants) and predation by non-native mammalian predators. It is unknown whether competition with non-native birds and insects is affecting `Apapane populations.
`I`iwi	*`I`iwi* (*Vestiaria coccinea*), are bright vermillion (red with a touch of orange) honeycreepers with a long, strongly curved salmon-colored bill and black wings, and have a squeaky call that sounds like "a rusty hinge" and whose wings produce a distinctive whirring noise in. They feed primarily on nectar and secondarily on insects (especially butterflies and moths). They were once one of the most common forest birds in the islands, present in forests from sea level to the tree line. The breeding season coincides with peak `ōhi'a flowering, with most breeding occurring between February and June. During the non-breeding season, they can be found foraging in flocks, or may defend a territory in areas of intermediate flower density. `I`iwi abundance in subalpine forests is tied to nectar availability, as measured by māmane flower abundance (Hess et al. 2001). Hess et al. (2001) found that while there is a small resident population of `I`iwi in the subalpine māmane woodlands most `I`iwi move between māmane woodlands and their primary habitats, mesic to wet koa and `ōhi`a forests. `I`iwi are mostly likely uncommon visitors to Halepōhaku, and are most likely to be observed there while māmane are flowering. `I`iwi are highly susceptible to avian malaria and viable populations of these birds persist only in high elevation areas where mosquitoes are rare or absent. Japanese white-eyes compete with `I`iwi for food, and studies have found a negative relationship between the abundance of `I`iwi and Japanese white-eyes; non-native mammalian predators (rats and cats) are also thought to impact `I`iwi populations.

Name	***Summary***
`Elepaio	`Elepaio (*Chasiempis sandwichensis*) are insectivores that often catch their prey in the air. Once very abundant in forested areas of O`ahu, Ka`ūa`i, and Hawai`i, they are still widespread, but not abundant. They are found primarily in koa-`ōhi'a forests. Some authorities recognize the Maunakea subalpine `Elepaio as a separate subspecies, *Chasiempis sandwichensis bryani* (Pratt 1980). Habitat degradation has reduced their densities in māmane woodlands, and they are most abundant in this habitat type on the southwestern slope of Maunakea, with highest densities near Pu`ulā`au. In subalpine environments, `Elepaio nest primarily in māmane trees, preferring taller trees than average. Nest predation by feral cats and rats is less common in `Elepaio nesting on Maunakea than in `Elepaio that nest in other habitats, due to the low density of predators in this habitat type. They are territorial and monogamous, and stay in their territories year-round; nesting occurs from February to August. Maunakea `Elepaio eggs reportedly have unusually high hatching failure, but 80% of nests fledge at least one young, suggesting that `Elepaio populations in subalpine māmane forest on Maunakea may be limited primarily by lack of adequate habitat. `Elepaio are also negatively affected by the presence of invasive birds such as the Japanese white-eye.
Kolea	Kolea, or Pacific Golden Plovers (*Pluvialis fulva*), are migratory shorebirds that spend the winter in Hawai`i and the summer in the arctic, where they breed (though some non-breeding birds will stay for the summer). Generally Kolea arrive in August or September and leave by early May. While they are in Hawai`i they maintain foraging territories, which most birds return to year after year. Kolea forage on lawns, fields, and grassy mountain slopes for invertebrates and occasionally eat leaves and flowers. They are found up to approximately 10,000 feet elevation, and utilize open areas in the subalpine zone on Maunakea.
Pueo	Pueo, or Hawaiian Owls (*Asio flammeus sandwichensis*), are ground-nesting owls found on all the major Hawaiian Islands, in shrublands, grasslands, and montane parklands. Pueo hunt at dawn and dusk (and sometimes during the day) and feed on small mammals (mostly rodents), birds (native and non-native), and insects. Breeding occurs throughout the year and three to six eggs are laid. Because Pueo build their nests on the ground, they are susceptible to predation by non-native mammals such as cats and mongoose, and habitat alteration (development, agriculture). Non-native barn owls and feral cats may also compete with Pueo for food (primarily small rodents and birds). Pueo nests have been observed at 9,000 feet on eastern Maunakea, in māmane woodlands at Kanakaleonui and above Pu`ulā`au Cabin, on the western slope, at the bases of māmane trees.
Source: University of Hawaii 2009c	

Figure 3.13 Palila Critical Habitat



Source: NRMP

3.4.3.4 <u>Invasive Bird Species</u>

A number of introduced bird species are present in sub-alpine regions on Maunakea. They include Black Francolin (*Francolinus francolinus*), Erckel's Francolin (*Francolinus erckelii*), Chukar (*Alectoris chukar*), Japanese Quail (*Coturnix japonica*), Ring-necked Pheasant (*Phasianus colchicus*), Wild Turkey (*Meleagris gallopavo*), and California Quail (*Callipepla californica*). All are game birds that were introduced and managed for hunting in grasslands, shrublands, and open woodlands. Most of the game birds are generalists and feed on plants, invertebrates (especially insects), fruits, and seeds. As discussed in Section 2.2.3.1.3 of the NRMP, these non-native birds have both positive and negative effects on native species.

On the positive side, Chukar and Ring-necked Pheasants can at least partially fill the ecological role of extinct and rare native birds as the primary dispersers of seeds of native plants such as pukiawe

(*Leptecophylla tameiameiae*), `ōhelo (*Vaccinium reticulatum*), nohoanu *(Geranium cuneatum*), `aiakendnd (*Coprosma ernodeoides*), pilo (*Coprosma montana*), and a native sedge, *Carex wahuensis*. All these species are found at Halepōhaku or in the subalpine zone on Maunakea. Pukiawe seeds are notoriously difficult to germinate without treatment, yet those found in game bird droppings had high germination rates, suggesting that these birds may play an important role in maintaining pukiawe populations in upland areas. Although māmane seeds are eaten by introduced game birds, seeds in their droppings typically do not germinate, suggesting that the birds do not aid in the regeneration of māmane through seed dispersal, and in fact, may reduce māmane regeneration if enough seeds are consumed. In addition, invasive plant parts in Chukar and Ring-necked Pheasant diets consisted mainly of flowers and leaves rather than fruits and seeds. Arthropods (primarily non-native species such as ladybugs) made up a relatively small portion of the game bird diets.

On the negative side, these birds did disperse some seeds of invasive species, including common velvetgrass (*Holcus lanatus*), hairy cats-ear (*Hypochoeris radicata*), mouse ear chickweed (*Cerastium vulgatum*), common catchfly (*Silene gallica*), and common evening primrose (*Oenothera biennis*). All these plant species, or closely related ones, are found at Halepōhaku. However, native seed germinations from Chukar and Ring-necked pheasant droppings outnumbered invasive species five to one in a study conducted on Haleakalā. Introduced game birds may well be spreading both native and invasive species at Halepōhaku, and the extent of their impacts there is unknown. Studies conducted in other locations have found that non-native birds are often the vectors of invasive plant seeds.

Other than the mummified remains of several Red-billed leiothrix found near Lake Wai`au and at the summit, no invasive bird species have been found at or near the summit (Montgomery and Howarth 1980; Nagata 2007).

3.4.3.5 Avian Habitat Alteration

Habitat alteration is one of the primary causes of extinction of native birds in Hawai`i and is primarily responsible for the current endangered status of the Palila (*Loxioides bailleui*), and the reduced population sizes of several other Hawaiian honeycreepers. Habitat alteration has occurred through the activities of man (e.g. clearing of land for ranching and limited development, such as the Halepōhaku Mid-Level Facility); grazing by introduced ungulates on māmane seedlings, saplings, and mature trees (thus preventing forest regeneration); and invasion by non-native/invasive weeds and grasses (which compete with native plants for resources, smother native seedlings, and increase the risk of fire), plants, microbes, invertebrates, and vertebrates (including predators such as rats and cats).

Invertebrates and Disease Organisms. Invasive invertebrates that can affect native bird populations include parasitic worms; parasitic and blood feeding species such as mosquitoes, mites, fleas, and flies; and nectarivorous and insectivorous species that compete with birds for food, such as honeybees, yellowjackets and ants. Parasitic and blood feeding species (such as mosquitoes) not only affect the host through the taking of blood or flesh, but also by spreading diseases.

Currently there are two avian diseases that are impacting native bird populations: avian poxvirus (*Poxvirus avium*) and avian malaria (*Plasmodium relictum*). Avian pox is a virus that causes skin lesions, and in more serious cases necrotic lesions in mucous membranes of the mouth and upper respiratory tract; in most cases avian pox does not kill the bird. High-elevation dry forests such as māmane woodlands may provide native birds a refuge from the avian pox virus. Avian malaria is a disease caused by protozoan in the genus *Plasmodium*. Malaria cannot be transmitted directly between birds and requires a vector (mosquitoes) to move between hosts. The parasite uses the mosquito to reproduce and its offspring then infect a new bird host when it is bitten by the mosquito. Native forest birds are extremely susceptible to infection with *P. relictum*, and in lab experiments, 65–90% of birds die after being bitten by a single infective mosquito. In Hawai`i, malaria has historically been spread mainly by the southern house mosquito (*Culex quinquefasciatus*), which is limited in elevation because of cold intolerance, but recent evidence indicates that the mosquitoes are moving up the mountain, perhaps in response to a warming climate.

The vectors for avian malaria and pox are not found in the subalpine or alpine zones on Maunakea, and avian malaria (*P. relictum*) has a threshold temperature of around 59° F, below which it is not transmitted to birds. However, birds such as `I`iwi and `Apapane that frequently travel between lower elevation forests and the subalpine zone can be infected while in the lower elevation habitats. Protection and restoration of high elevation forests, including māmane woodlands, may allow individuals of these species to persist without being exposed to malaria, and in the face of global warming may provide the only disease free habitat for forest birds.

Invasive invertebrates with the potential to impact native bird populations include honeybees, yellowjackets, parasitoid wasps and ants. The latter three could impact bird populations by reducing native arthropod populations upon which the birds feed. Honeybees, and some ant species, may compete with native birds for nectar. Honeybees are present up to the treeline, but pollinator interactions have not been studied in māmane forests.

Invasive Plants. Invasive plants such as grasses and vines can impact native bird populations on Maunakea through displacement of native subalpine forest and shrublands. Invasive grasses and weeds can prevent forest recovery by smothering the seedlings of māmane and other native plants. Invasive grasses can also change the fire regime, and a large wildfire in the māmane forest would seriously reduce available habitat for the endangered Palila.

Invasive Predators. Invasive predators such as cats, rats, barn owls, and mongoose have a direct impact on native bird populations. Cats and mongoose eat both adult birds and chicks, while rats primarily consume eggs (and sometimes chicks). Although rats, cats, and mongoose are not abundant in māmane woodlands, they still impact Palila populations. Feral cats (*Felis catus*) are thought to be the most serious predator of Palila, particularly at their nests. Mongooses (*Herpestes auropunctatus*) are thought to have less of an impact on Palila, because they do not climb trees (Banko et al. 2002). Although rats (*Rattus rattus*) are rare in māmane woodlands, they do depredate Palila nests, possibly out of proportion to their numbers. Barn Owls (*Tyto alba*) prey primarily on rodents, but do consume a small number of native birds and insects; their status in the māmane woodlands near Halepōhaku is unknown. Mice (*Mus musculus*) are present in māmane woodlands; they do not appear to depredate Palila nests, but they do eat seeds and seedlings of native plants and can therefore indirectly impact native bird populations by changing plant communities. Because of their toxic seed coat, māmane seeds do not seem to be a preferred food of mice (Banko et al. 2002).

Invasive Birds. Non-native birds can compete directly with native birds for resources such as food. Japanese White-eyes are likely to compete directly with insectivorous and nectarivorous honeycreepers for limited resources in māmane woodlands. Non-native birds also can act as a food base for predators, which will take native birds as prey in addition to the non-natives.

3.4.3.5.1 Effects of Human Activities on Protected Bird Species on Maunakea

There are several human uses at Maunakea that impact native bird species. The introduction and maintenance of populations of non-native mammals for hunting and ranching activities have impacted native bird species that utilize māmane forest (such as the Palila) through habitat degradation by grazing feral and domestic ungulates. Sheep, cattle, and goats damage māmane trees and prevent regeneration of the forest, while at the same time enhancing the spread and establishment of non-native plant species. Hunting and ranching do not occur at Halepōhaku, proper, but both occur close by. Because Halepōhaku is not fenced, feral ungulates may still use the site. Access to hunting and hiking areas via trails and roads passing through Halepōhaku by both vehicles and hikers can also lead to introduction of invasive species and erosion. Other human uses, such as tourism and scientific research also have impacts, such as introduction of invasive plants and animals, providing food sources to invasive arthropods, mammals and birds, and (limited) trampling of forest habitat. Improperly disposed food items and water used in landscaping and cleaning activities may help sustain larger populations of invasive species than would otherwise occur in the subalpine environment.

Because birds do not occupy the summit regions, human uses in the astronomy district have not directly impact bird populations. However, astronomy support facilities at mid-elevation areas do impact bird habitat through habitat loss, limited contamination (small spills associated with such activities as vehicle maintenance), unintentional provision of food and water for invasive species, and general wear and tear. At Halepōhaku these impacts are present, but they are generally limited in scope due to the small size of the developed area.

3.4.4 MAMMALS

Hawai`i has very few native species of mammals, and most native mammals that are found in the Hawaiian Islands are marine mammals. The `Ōpe`ape`a, or Hawaiian hoary bat (*Lasiurus cinereus semotus*) is the only native land mammal in Hawai`i. Hawai`i has many non-native species of animals that were brought to the islands by humans, beginning with the arrival of the first Polynesians. Some of these were accidental introductions, but most were purposeful, either for food, pets, or biological control.

3.4.4.1 Subalpine Mammal Communities (Halepōhaku and Lower Mauna Kea Access Road)

Mammals found in the subalpine zone on Maunakea include the Hawaiian hoary bat (*Lasiurus cinereus semotus*), feral cats (*Felis catus*), black rats (*Rattus rattus*), mice (*Mus musculus* and *Mus domesticus*), domesticated sheep (*Ovis aries*), mouflon sheep (*Ovis musimon*), feral sheep/mouflon sheep hybrids, goats (*Capra hircus*), cattle (*Bos taurus*), feral pigs (*Sus scrofa*), and mongoose (*Herpestes auropunctatus*). Table 3.7 lists mammal species known to occur in subalpine and alpine habitats on Maunakea, including Halepōhaku and the MKSR.

Table 3.7: Mammal Species Potentially Found at Halepōhaku and MKSR

Community	*Scientific Name*	*Common name*	*Origin*	*Legal Status*	*MKSR*	*HP*	*Refs.*
Subalpine & Alpine	*Lasiurus cinereus semotus*	`Ope`ape`a (Haw. Hoary bat)	E	FE	??	??	
Subalpine & Alpine	*Rattus rattus*	Black rat	X	??		~	5
Subalpine & Alpine	*Mus domesticus*	House mouse	X	~		~	1,4
Subalpine & Alpine	*Ovis aries* (also *Ovis ovis*)	Feral sheep	X	~		~	2,3
Subalpine & Alpine	*Ovis musimon*	Mouflon sheep	X	~		~	3
Subalpine & Alpine	*Capra hircus*	Feral goat	X	~		~	1
Subalpine & Alpine	*Bos taurus*	Cattle	X	H		H	5
Subalpine Dry Forest	*Sus scrofa*	Pig	X	??		??	
Subalpine Dry Forest	*Felis catus*	Feral cat	X	??		??	5
Subalpine & Alpine	*Mus musculus*	Mouse	X	~		~	1,4
Subalpine Dry Forest	*Herpestes auropunctatus*	Mongoose	X			??	
Notes: All mammals present are found are found at elevations ranging from 5,900 feet to 9,500 feet except the Hawaiian hoary bat, whose range extends to the summit.							
Source: University of Hawaii 2009c, Table 2.2-8.							

3.4.4.1.1 Threatened and Endangered Species, Candidate Species & Species of Concern: Subalpine Zone

The federally listed Endangered `Ōpe`ape`a (*Lasiurus cinereus semotus*) was once found on all the main Hawaiian Islands, but now is thought to be limited to Hawai`i, Ka`ūa`i, and Maui. It was listed as a federally Endangered Species in 1970. `Ōpe`ape`a have been observed up to 13,500 feet on Maunaloa, and use a variety of both native and non-native vegetation types. While the Hawaiian hoary bat typically roosts alone in foliage (as opposed to roosting in large colonies as many bats do), it has also been observed in lava tubes, manmade structures, and rock crevices. `Ōpe`ape`a are known to migrate, and their densities in high elevation areas are thought to be highest during the winter (December through March). `Ōpe`ape`a have been observed in the māmane woodlands on Maunakea, but the status of the bat at Halepōhaku and environs is unknown.

3.4.4.1.2 Invasive Mammal Species: Subalpine Zone

Non-native mammals found at Halepōhaku include feral cats (*Felis catus*), black rats (*Rattus rattus*), mice (*Mus musculus* and *Mus domesticus*), mongoose (*Herpestes auropunctatus*), domesticated sheep (*Ovis aries*), mouflon sheep (*Ovis musimon*), goats (*Capra hircus*), cattle (*Bos taurus*), and feral pigs (*Sus scrofa*). Each of these has had a role in the degradation of māmane woodlands and/or their associated animal communities on Maunakea.

Invasive mammalian predators include cats, dogs, rats, mongoose, feral pigs, and mice. Cats, rats, and mongooses all prey on bird species found in the māmane woodlands. Rats and mice eat insects, and may especially impact flightless species (of which there are several in the subalpine and alpine zones on Maunakea).

Domestic livestock were introduced to the Hawaiian Islands late in the 18th century, and feral populations of cattle, sheep, and goats (*Bos taurus*, *Ovis aries*, *Capra hircus*) soon became established in forests. Feral sheep had established in Maunakea's subalpine woodland by 1825; lacking natural predators except for wild dogs, the sheep population reached about 40,000 animals by the early 1930s. Sheep suppressed māmane and other tree reproduction over large areas, stripped bark from tree stems, and consumed herbaceous vegetation, thereby leaving the soil exposed to accelerated erosion. Because damage to the ecosystem was severe and because feral sheep competed with commercial flocks foresters subsequently built a stock-proof fence around the Maunakea Forest Reserve and reduced the population through sheep drives and hunter-guide programs. By 1950 fewer than 500 feral sheep were left; control efforts were then relaxed and unsurprisingly feral sheep populations increased. Sustained yield management for public hunting was started in 1955, with the population kept below 5,000 animals. During the 1970s, the population averaged 1,500 animals. Even at this relatively low level, vegetation continued to deteriorate where sheep concentrated, especially at tree line.

Ecosystem damage has also been caused by mouflon sheep (*Ovis musimon*), which were released in the Mauna Kea Forest Reserve starting in 1962. Food preferences, grazing and browsing behavior, and herding habits are similar to those of feral sheep, and native plants are particularly susceptible to damage by mouflon. In 1986, the largest concentrations of mouflon were on the southeastern and northwestern flanks of the mountain, and animals were moving into areas formerly occupied by feral sheep. The mouflon population in 1986 was estimated at 500 animals.

Because of continued habitat degradation and the attendant threat to the Palila, the State was ordered to remove feral sheep and feral goats completely and permanently from those portions of the māmane forest designated as critical Palila habitat. The status of mouflon sheep was not affected by the court order. The feral sheep and goat "eradication" effort was completed in 1981.

By the early 1990s it was evident that some feral sheep and goats had escaped, and small flocks (perhaps 20 animals each) of sheep can now be seen at tree line on the western side of Maunakea. There are fewer feral goats present, with only 26 observed (and shot) during semi-annual helicopter hunting efforts conducted by DOFAW in the ten years ending in 2005.

The protective fence that was built around Maunakea to protect the forest reserve is inadequately maintained, and it now has many holes that allow feral animals to continue to move across the fence line, into and out of Mauna Kea Forest Reserve. DLNR is seeking funding to build and maintain a perimeter fence to protect the Mauna Kea Forest Reserve. The presence of a new (or repaired) fence, combined with funds for proper upkeep, would help prevent migration of feral ungulates from lower elevations, and allow for more successful control, and eventually, eradication of feral ungulates found in the upper elevations of Maunakea (provided that sufficient effort is made to eradicate the animals). Currently efforts are being made to fence important areas of Palila habitat, rather than the entire Forest Reserve.

3.4.4.2 Alpine Mammal Communities (MKSR and Upper Mauna Kea Access Road)

Sheep, goats, cattle, cats and mice have all been recorded in the alpine zone of Maunakea. However, the density of mammals in the alpine zone on Maunakea is low due to limited food resources.

3.4.4.2.1 Alpine Zone Threatened/ Endangered Mammal Species, Candidate Species & Species of Concern

No Endangered, Threatened, or Candidate Species, or Species of Concern are known to reside in the alpine zone on Maunakea. It is possible that the federally listed endangered `Ōpe`ape`a (*Lasiurus cinereus semotus*) may occasionally use the area, although no records regarding this are available. It seems unlikely that this species would roost here given the cold climate and lack of trees.

3.4.4.2.2 Invasive Mammal Species: Alpine Zone

Sheep, goats and cattle have been documented all the way up to the summit of Maunakea. Grazing ungulates will feed on almost any palatable plant not protected by rocky crevices or impassable topography on the summit. Prior to ungulate control efforts, feral ungulates decimated the once thriving silversword population in the subalpine and alpine zones on Maunakea and reduced abundances of other palatable native species. In 2008 a flock of 60 feral sheep was observed in Pōhakuloa Gulch, and scat was seen at Lake Wai`au in the Ice Age Natural Areas Reserve. Feral goats are likely to be rare or absent from MKSR, but feral sheep and mouflon are probably present.

Although densities of feral ungulates in the alpine zone on Maunakea are currently low, even a few animals can exert serious grazing pressure on the plants found in this community, and feral ungulates continue to threaten native plant communities. For example, in 2007 an isolated population of Maunakea silversword (*Argyroxiphium sandwicense sandwicense*) at approximately 12,200 feet elevation in MKSR showed signs of grazing by feral ungulates. Feral ungulates in the alpine zone are also responsible for soil/cinder compaction, addition of nutrients to nutrient poor soils, and seed dispersal.

Feral cats and rats may be present in the lower reaches of the alpine zone, at very low densities. If Hawaiian petrels utilize the alpine areas on Maunakea, mammalian predators may prey on eggs, nestlings and adult petrel. Mice have been observed within the observatories and along the road above 12,000 feet.

3.5 SPECIAL HAZARDS

The UH Management Area is not susceptible to flooding or tsunami inundation. Its exposure to volcanic activity, earthquakes, and weather-related hazards is summarized below.

3.5.1 VOLCANISM

The potential for renewed volcanic activity in this region is extremely remote and is discussed in Section 3.1.1. Maunakea last erupted about 4,600 years ago, and the volcano is considered to be dormant. In 1997, Wolfe and others mapped a dozen separate post-glacial (post-10,000 year old) eruptive vents on Maunakea's middle flanks, but none younger than 40,000 years were found in the summit area. Maunakea's summit region lies within Zone 7 of the USGS lava flow hazard map (U.S. Geological Survey 1997b). This zone is considered to have a low probability of coverage by lava flows outside of localized upwelling events, and there has been no recent evidence to support an eruption at Maunakea within the near future.

3.5.2 SEISMIC ACTIVITY

The most significant geologic hazard within the MKSR is seismic activity. Hawai`i Island is one of the most seismically active areas on Earth. Probabilistic seismic hazard maps for the Island of Hawai`i have been developed and indicate that the highest hazard is for the southeast coast with the second highest hazard location being the west/southwest Kona coast (Klein et al. 2000).

About two dozen earthquakes with magnitude 6 or greater have been documented on Hawai`i since the devastating earthquakes of 1868; those that caused damage are listed in Table 3.8. The approximate epicenter of those earthquakes and the predicted Modified Mercalli Intensity Scale seismic intensities are illustrated on Figure 3.14. The earthquake in 2006 caused minor damage to the

Keck, Subaru, UH 2.2-meter, and CFHT observatories. Some auxiliary equipment was damaged, but the telescopes' mirrors and overall facility structural integrity were not affected.

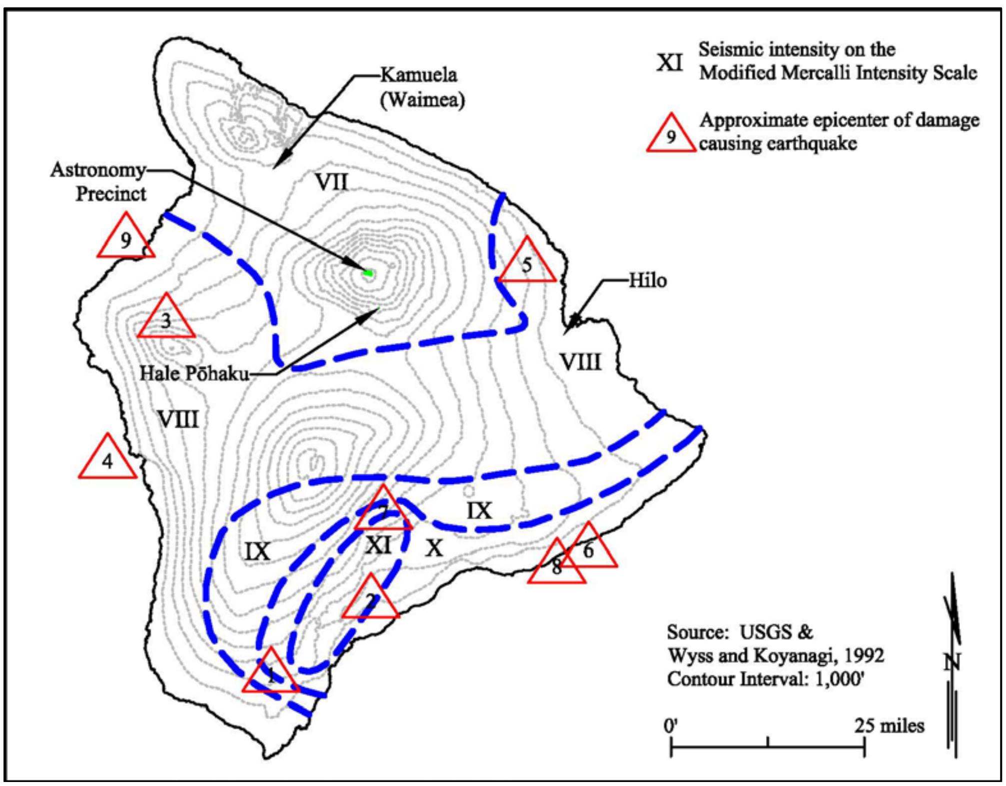
Table 3.8: Summary of Damage Causing Earthquakes

#	*Date*	*Epicenter Location*	*Intensity*		*No. of Deaths*	*Damage*	*Repair Cost*
			Modified Mercalli	*Magnitude*			
1	03-28-1868	Southern Hawai`i	IX	7.0	0	Extensive-S. Hawai`i	Unknown
2	04-02-1868	Southern Hawai`i	XII	7.9	81	>100 houses destroyed in tsunami	Unknown
3	10-05-1929	Hualālai	VIII	6.5	0	Extensive-Kona	Unknown
4	08-21-1951	Kona	VIII	6.9	0	Extensive-Kona	Unknown
5	04-26-1973	North of Hilo	VIII	6.2	0	Extensive-Hilo	$5.6M
6	11-29-1975	Kalapana	VIII	7.2	2	Extensive-Hilo	$4.1M
7	11-16-1983	Ka`oiki	IX	6.7	0	Extensive-S. Hawai`i	>$6M
8	06-25-1989	Kalapana	VII	6.2	0	Southeast Hawai`i	almost $1M
9	10-15-2006	Kīholo Bay	VIII	6.7&6.0	0	NW Hawai`i	>$100M

Note: The approximate epicenter location is illustrated on Figure 3.11.

Source: U.S. Geological Survey Earthquakes Hazards Program. Accessed December 12, 2014. http://earthquake.usgs.gov/earthquakes/states/historical_state.php#hawaii

Figure 3.14: Seismic Intensities and Estimated Epicenters of Damage Causing Earthquake (1868 to present)



Potential hazards related to earthquakes within the MKSR include pu`u slope-failure and landsliding, fracturing of the confining layers of Lake Wai`au, and potential damage to manmade structures within the UH Management Area. Similar to the summit area, earthquakes have and will continue to impact Halepōhaku. The area is susceptible to seismic intensities of up to VII on the Modified Mercalli Intensity Scale.

3.5.3 HIGH WINDS, SNOW, AND OTHER HAZARDS

The summit area of Maunakea is subject to high winds, and high wind warnings are posted for the summit area a number of times per year. Weather can change very rapidly, resulting in severe conditions including winds in excess of 100 miles per hour, sub-zero temperatures, and snow and ice. "White-outs" caused by blowing snow and fog block all visibility. Road conditions can become hazardous due to deep snow drifts, freezing fog, and ice preventing vehicular passage. Severe weather conditions can last up to a week preventing immediate rescue.

The high altitude of the MKSR carries with it a number of risks. The oxygen level is greatly reduced, and this can lead to shortness of breath and/or impaired judgment. Reduced atmospheric pressure at high altitudes may cause altitude sickness or result in the development of other life threatening conditions such as pulmonary edema (fluid in the lungs) and cerebral edema (fluid on the brain). Also, because the summit is above much of the atmosphere that blocks the sun's damaging ultraviolet rays, there is an increased risk of serious sunburn and eye damage, especially if there is snow on the ground.

3.6 SOUND

3.6.1 NOISE METRICS

Sound levels are fluctuating air pressure waves expressed on a logarithmic scale in decibels (abbreviated as dB). A change of 10 units on a decibel scale reflects a 10-fold increase in sound energy. A 10-fold increase in sound energy roughly translates to a doubling of perceived loudness. In general, humans can rarely detect a change of 1 decibel, can usually hear a change of 3 decibels, and can easily hear a change of 5 decibels.

In evaluating human response to noise, acousticians compensate for people's varying abilities to discern frequency or pitch components of sound. While a healthy young ear may be able to hear sounds over the frequency range of 20 hertz[39] (Hz) to 20,000 Hz, the human ear is most sensitive to sounds in the middle frequency range used for human speech, and less sensitive to lower- and higher-pitched sounds. The "A" weighting scale is used to account for this varying sensitivity. Thus, most community noise standards are expressed in decibels on the A-weighted scale, abbreviated dBA. Zero on the decibel scale corresponds to the threshold of human hearing, while sound levels of 120 dBA and higher can be painful and cause hearing damage. For reference, human speech at 10 feet is about 60-70 dBA. Noise-sensitive uses include residences, hospitals, schools, and parks, but could also be a sensitive issue for cultural practices and nature-watching activities.

Noise levels fluctuate over time so they are often evaluated using statistical metrics. The L_{max} and L_{min} levels are the loudest and quietest instantaneous levels, respectively, measured during some time period. The L_{eq} level, or equivalent sound level, is the energy-averaged noise level over some period of time. Fluctuating noise levels can also be described by their percentile levels, abbreviated L_n. For example, the L_{10} noise level represents a less common noise level exceeded only ten percent of the time, while the L_{90} level represents more steady background noise occurring 90 percent of the time.

3.6.2 APPLICABLE NOISE LIMITS

Hawai`i Administrative Rules Title 11, Chapter 46, Section 4 (HAR §11-46-4) defines the maximum permissible community sound levels in dBA. These differ according to the kind of land uses that are involved (as defined by the zoning district) and time of day (daytime or nighttime). These limits are shown in Table 3.9 below. Definitions of two technical terms used in this discussion are as follows:

[39] Hertz is a unit of frequency, and is defined as the number of complete cycles per second. Hertz is the high or low pitch, while decibels are the volume.

- *A-Weighted Sound Level (dBA).* The sound level, in decibels, read from a standard sound-level meter using the "A-weighted network". The human ear is not equally sensitive in all octave bands. The A-weighting network discriminates against the lower frequencies according to a relationship approximating the auditory sensitivity of the human ear.
- *Decibel (dB).* This is the unit that is used to measure the volume of a sound.[40] The decibel scale is logarithmic, which means that the combined sound level of 10 sources, each producing 70 dB will be 80 dB, not 700 dB. It also means that reducing the sound level from 100 dB to 97 dB requires a 50 percent reduction in the sound energy, not a 3 percent reduction. Perceptually, a source that is 10 dB louder than another source sounds about twice as loud. Most people find it difficult to perceive a change of less than 3 dB.

Table 3.9: Hawai`i Administrative Rules §11-46 Noise Limits

Zoning District	*Noise Limit (in dBA)*	
	Daytime (7:00 a.m. to 10:00 p.m.)	*Nighttime (10:00 p.m. to 7:00 a.m.)*
Class A: Areas equivalent to lands zoned residential, conservation, preservation, public space, open space, or similar type.	55	45
Class B: All areas equivalent to lands zoned for multi-family dwellings, apartment, business, commercial, hotel, resort, or similar type.	60	50
Class C: All areas equivalent to lands zoned agriculture, country, industrial, or similar type.	70	70
Source: Hawai`i Administrative Rules §11-46 *Community Noise Control*		

The maximum permissible sound levels specified in HAR §11-46-4(b) apply to any excessive noise source emanating from within the specified zoning district. The sound levels are as measured at or beyond the property line of the premises from which the noise emanates. Mobile noise sources, such as construction equipment or motor vehicles are not required to meet the 70 dBA noise limit. Instead, construction noise levels above these limits are regulated using a curfew system whereby noisy construction activities are not normally permitted during the nighttime periods, on Sundays, and on holidays. Construction activities (which could typically exceed the limits established for fixed machinery) are normally allowed during the normal daytime work hours on weekdays and on Saturdays using a system involving the issuance of construction noise permit. It is also possible to seek a noise variance that allows noise in excess of the levels that would otherwise be permissible.

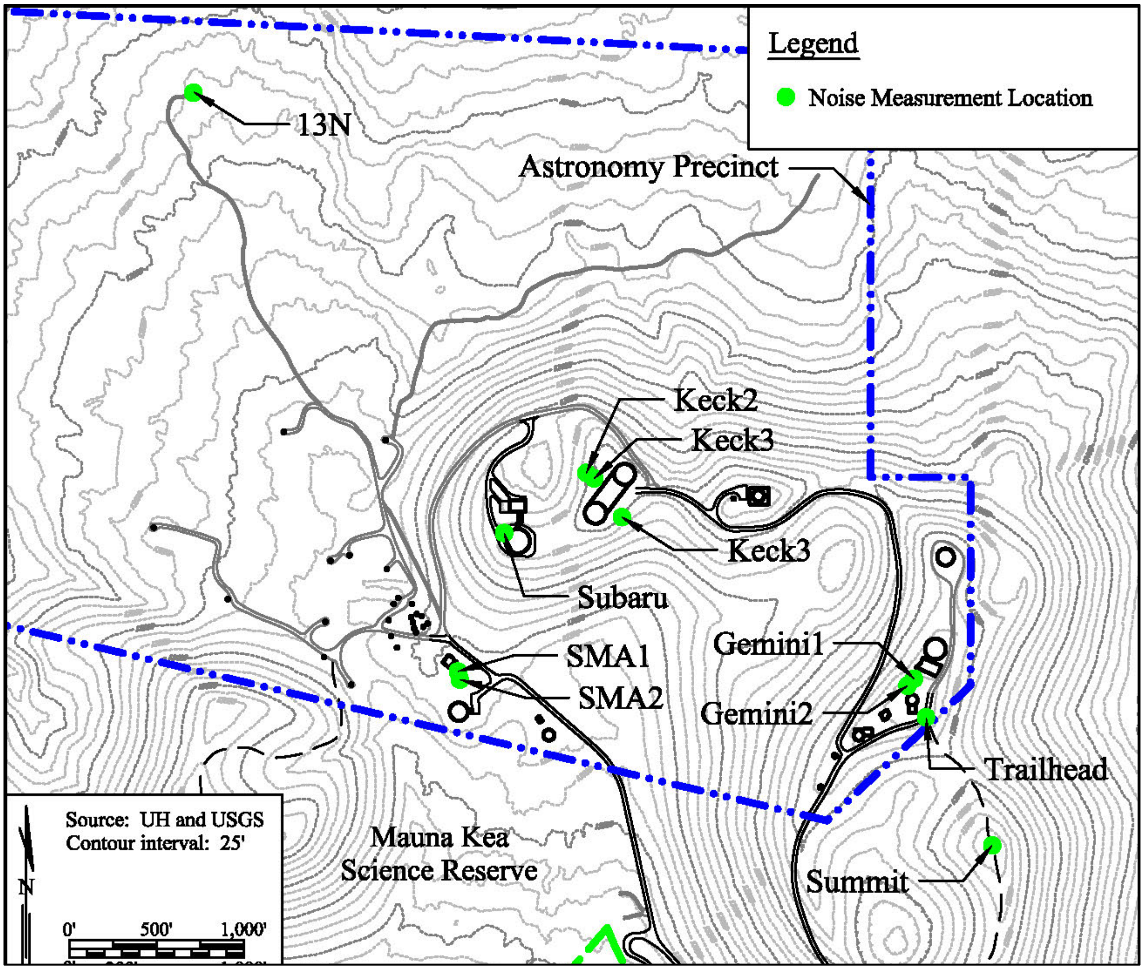
The MKSR and Halepōhaku are within a Conservation District and are, therefore, classified as a Class A district for the purpose of determining compliance with HAR §11-46. A maximum L_{10} noise level of 55 dBA during daytime hours (7 a.m. to 10 p.m.) and 45 dBA during nighttime hours (10 p.m. to 7 a.m.) is allowed as measured at the property lines of a parcel in a Class A district. Noise levels may not exceed these maximum permissible L_{10} levels within any twenty-minute period, except by permit or variance.

3.6.3 EXISTING AMBIENT SOUND LEVELS: MAUNAKEA SUMMIT AND HALEPŌHAKU

The most recent ambient sound levels were measured at various locations on Maunakea on October 21, 2009, from 10 a.m. to 3 p.m. for the Thirty-Meter Telescope Project. Ambient noise levels were measured for 15-minute periods at twelve locations (Figure 3.15).

[40] The sound pressure in decibels is equal to twenty times the logarithm to the base ten of the ration of the pressure of the sound measured to a reference pressure of 20 micropascals, or 0.0002 dynes per square centimeter.

Figure 3.15: Noise Measurement Sites



Measurements were collected to describe the existing noise environment, quantify HVAC system noise levels at existing observatories, and to characterize the background environmental noise levels; results are presented in **Error! Not a valid bookmark self-reference.** below. Noise measurements were collected during favorable meteorological conditions; specifically, the winds were generally light with gusts less than 5 miles per hour (mph) except at the Pu`uwēkiu/Kūkahau`ula Summit and Trailhead measurement locations, where wind speeds reached up to 14 mph. Measurement locations were selected to represent specific distances from observatory HVAC exhaust systems. Existing noise levels were measured at four existing observatories to characterize typical HVAC noise levels and multiple measurements were taken at three of these facilities, resulting in a total of eight readings related to existing facilities. All measurements were collected in areas facing HVAC system exhaust outputs where noise levels from the systems are loudest.

The Pu`uwēkiu/Kūkahau`ula Summit and Trailhead measurement locations experienced measured noise levels of 47 and 49 dBA L_{eq}, and 50 and 53 dBA L_{10}. The dominant noise source for sound levels measured at both these recreational use sites was due to a steady wind of 5 to 14 mph moving from the direction of the nearby observatories toward the measurement locations. Winds in this range are typical for this area and generally dominate the ambient noise levels.

Table 3.10: Noise Measurement Results

Noise Measurement Location	***Approximate Distance from nearest observatory HVAC exhaust (feet)***	***Noise Level L_{eq}(h) (dBA)***	***Noise Level L_{10} (dBA)***
Halepōhaku VIS	N/A, Parking Lot Area	52	56
13N[1]	N/A, Ambient	36	40
SMA1	15	77	78
SMA2	50	60	61
Pu`uwēkiu/Kūkahau`ula Summit[2]	400	49	53
Pu`uwēkiu/Kūkahau`ula Trailhead[2]	50	47	50
Gemini1	50	60	60
Gemini2	80	59	60
Subaru	50	48	49
Keck1	15	68	69
Keck2	20	51	54
Keck3	50	38	40

Notes: Leq (h) = Leq is the Equivalent Sound Level, or the steady A-weighted sound level over a specified period of time, in this case an hour, that has the same acoustic energy as the fluctuating noise during that period; it is a measure of the cumulative acoustical energy.

Instrumentation. The noise measurement instrument used in this study was a Larson Davis Model 820 Sound Level Meter (LD 820). The LD 820 meets or exceeds accuracy requirements as defined by the American National Standards Institute Standard S1.4 for Type I Instrumentation.

Calibration. The meter was calibrated for use beforehand using a Larson Davis LD 200 portable acoustic calibrator. The LD 820 was configured to measure and record A-weighted sound pressure levels over a period of 15 minutes, and the noise data recorded by the LD 820 included Lmax, Lmin, L_{eq}, L_{10}, L_{50} and L_{90} levels. A three-inch foam windscreen was used to cover the microphone during data sampling in order to reduce wind interference.

[1] TMT Observatory Site.

[2] Recreational use area.

Source: University of Hawaii 2010.

The observatories are generally quiet with all operations occurring indoors during the day. However, most of the existing observatories utilize heating, ventilation, and cooling (HVAC) systems to keep the interior of the observatory domes in equilibrium with the outside temperature when they open in the evening, and the HVAC systems exhaust vents are the primary sources of noise from the observatories. Nothing has been documented in literature to suggest that military-related noise from the U.S. Army's Pōhakuloa Training Area or Bradshaw Army Airfield, or from local and tourist-related air travel, is an issue at the MKSR or Halepōhaku. Noise levels in the vicinities of the existing observatories were at or below 60 dBA L_{eq} beyond a distance of 50 feet from HVAC exhausts.

Ambient sound levels at Maunakea are low, with vehicle traffic and wind providing the dominant background. Observatory operations generate minimal noise, primarily related to their HVAC systems. Noise associated with a relatively small numbers of visitors (estimates by rangers indicate an average of about 28 non-commercial visitor vehicle trips a day to the summit, most of them staying less than 30 minutes) and observatory vehicle trips (the existing observatories average about 30 vehicle trips a day) is relatively limited.

While people's sensitivity to noise vary, no one is habitually exposed to noise at the summit; the scientists and observatory staff use the Halepōhaku dormitories, and tourists and other visitors leave the summit before nightfall. While construction activities create intermittent, though sometimes significant disruptions, the existing ambient noise levels remain low and fully within the applicable noise standards of 55 dBA during daytime hours and 45 dBA during nighttime hours, except within the immediate area of certain observatory HVAC systems and/or their exhaust. Noise measurements at various locations in the summit region indicate that although the applicable noise standards are sometimes exceeded in the vicinity of observatory HVAC systems and/or their exhaust, noise levels are unlikely to exceed the noise standards at identified noise sensitive locations.

The NRMP notes that the U.S. Army Pōhakuloa Training Area (PTA) abuts the Mauna Kea Forest Reserve at approximately 7,400 feet, along the mountain's south-southwest flank and that live fire is permitted at this installation; it also notes that navigable airspace above neighboring Bradshaw Army Airfield extends vertically to 8,700 feet. No noise from either of these sources was audible at the time of the aforementioned survey, and the authors of the NRMP found nothing in the literature to suggest that military-related noise is an issue at the MKSR or Halepōhaku.

3.7 VISUAL AND AESTHETIC RESOURCES

3.7.1 ISLANDWIDE

The Island of Hawai`i's landscape and visual resources are varied. On the northern tip, the coast is rugged, covered in dense vegetation and dotted with waterfalls and rivers. Inland, around the town of Waimea, at an elevation of 4,000 feet, the landscape is comprised of rolling pastures used for cattle ranching. The western side of the island consists of popular resorts and beaches, but lacks vegetation. The southern and southeastern portions of the island experience high rainfall and are covered with lush vegetation; Volcanoes National Park is located in this area. The eastern portion of the island consists of steep terrain with dramatic views of the rainforest and cliffs along the coast.

The Hawai`i County General Plan (County of Hawai`i, 2005) includes a chapter on Natural Beauty that recognizes the importance of preserving the island's natural and scenic beauty. The chapter includes goals, policies and standards to identify and protect scenic vistas and viewplanes. One goal is to "Protect scenic vistas and view planes from becoming obstructed." The General Plan also provides guidelines for designating sites and vistas of extraordinary natural beauty to be protected, and includes the standard "Distinctive and identifiable landforms distinguished as landmarks, e.g. Maunakea, Waipi`o Valley." Around the island of Hawai`i the following natural beauty sites have been identified that include Maunakea:

- View of Maunakea and Maunaloa from Pāhoa-Kea`au, Volcano-Kea`au Roads, and various Puna subdivisions.
- Viewpoint of Hilo Bay with Maunakea in background.
- Mauna Kea State Park area.

In addition, the South Kohala Community Development Plan (County of Hawai`i, 2008) includes a policy to preserve Waimea's sense of place. To do this, the plan recommends the strategy to "protect the pu`u of Waimea that have cultural, historical and visual importance" and which have "grand views of Mauna Kea."

3.7.2 MAUNAKEA SUMMIT REGION

In contrast to the lush coastal areas, the summit of Maunakea is an alpine ecosystem. Above the tree line, at roughly 9,500 feet, there is little more than low shrubs and above 12,800 feet vegetation consists of little more than lichens, moss, and small ferns. A small alpine lake, Lake Wai`au, is situated on the upper southern flank of the mountain. The summit of Maunakea is often obscured by vog, a volcanic smog formed when sulfur dioxide and other volcanic gases emitted by Kīlauea mix with oxygen, moisture, and sunlight. The vog has been especially thick since February 2008 when gas emissions from Kīlauea dramatically increased.

3.7.3 VISIBILITY OF EXISTING FACILITIES

3.7.3.1 MKSR Facilities That are Visible

There are a dozen observatories on Maunakea within the Astronomy Precinct with an additional observatory approved for construction. These observatories and the attributes that affect their visibility are listed in Table 3.11. Some of these observatories are visible or will be from locations around the island such as Hilo, Honoka`a, and Waimea; the viewshed of each observatory, the percent of the island's land area from which the observatory is potentially visible, is listed in Table 3.11. On the west coast of the island, the existing observatories appear most visible at sunset, when they are lit by the setting sun; on the east coast they appear most visible at sunrise.[41] Considering all existing observatories together, at least one observatory is visible from roughly 43 percent of the island's land area.

Table 3.11: Existing Observatory Visual and Aesthetic Attributes

Observatory	*Ground Elevation (feet)*	*Dome Height (feet)*	*Dome Color*	*Viewshed (% of Island)*
Subaru	13,578	141	Metallic	20
Keck	13,603	111	White	17
IRTF	13,652	53	Aluminum	14
CFHT	13,726	125	White	35
Gemini	13,764	151	Aluminum	39
UH 2.2 m	13,784	80	White	36
UKIRT	13,762	61	White	26
UHH 0.9 m	13,727	20.25	White	15
CSO	13,362	63	Metallic	5
JCMT	13,390	100	White	7
SMA	13,279 – 13,400	45	NA	2
TMT	13,100	~180	Metallic	14
Source: University of Hawaii 2010, Table 3-4 and 3-8.				

The astronomical observatories are prominent visual elements on the summit of Maunakea. All optical/infrared observatory structures are or will be colored white or silver to minimize the difference in temperature between day and night and the associated cooling needs as much as possible. Most of the structures are rounded, but the Subaru observatory has a cylindrical paneled structure. The cylindrical panels of the Subaru observatory make it less visible during most of the day; however, at sunset, it appears bright due to the reflection of sunlight from its flat surfaces. After conducting a viewshed analysis based on topography, at least one of the existing observatories is visible from roughly 44 percent of the island. Roughly 72 percent of the County's population resides within that viewshed area. At the summit, the existing observatories obscure portions of the 360-degree panoramic view from the summit area.

Maunakea is often veiled by clouds formed by the inversion layer and obscured by vog; this shrouds the summit from view from low elevation areas around the island, as well as the views from the summit to the island below. On a cloud-free day, some of these existing observatories are visible from locations around the island such as Hilo, Honoka`a, and Waimea. On the west coast of the island, the observatories appear most visible at sunset, when they are lit by the setting sun; on the east coast they appear most visible at sunrise.

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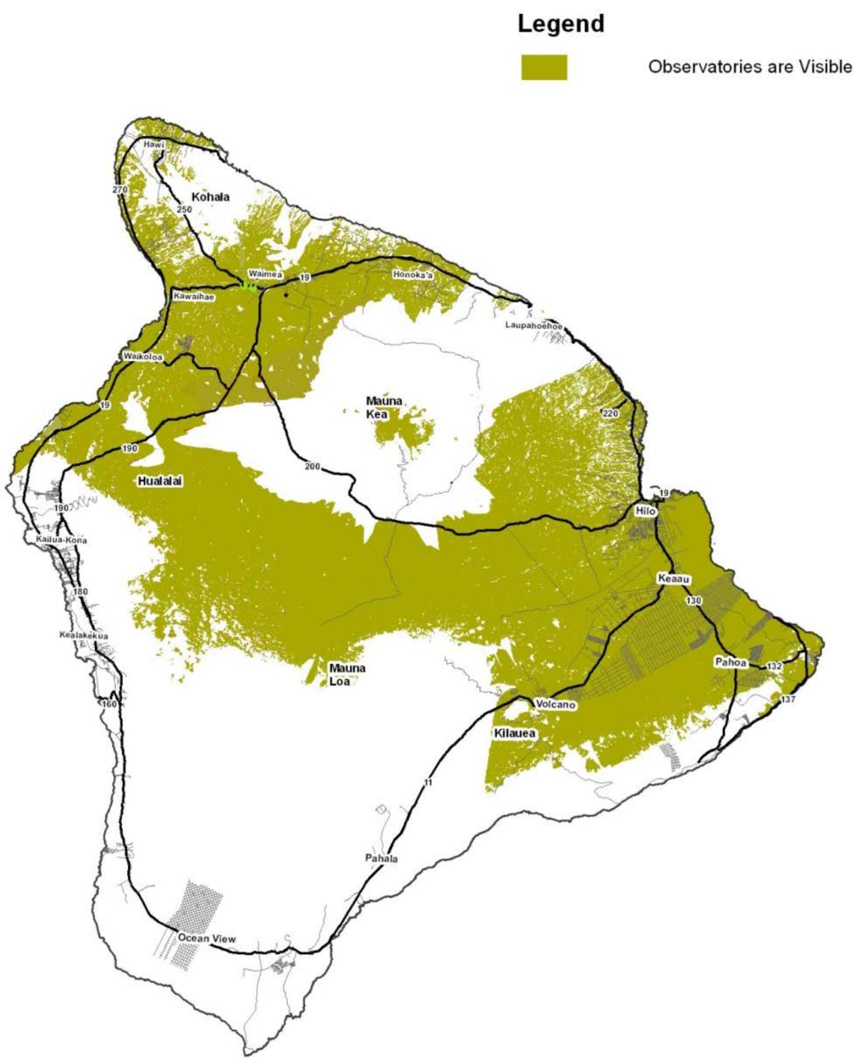
[41] Some of these observatories also use laser guide stars as part of their AO system. The laser guide stars may be visible within some portions of the MKSR.

The existing observatories on Maunakea do not block or obstruct any of the identified views in the County of Hawai`i General Plan or the South Kohala Development Plan. They are, however, visible within the viewplanes from Hilo, Waimea, and the summit.

Figure 3.16 illustrates the combined viewshed of the existing 11 observatories near the summit within the Astronomy Precinct, where the top of at least one of the existing observatories is visible. From approximately 43 percent of the island area a viewer is able to potentially see at least one existing observatory. According to 2000 U.S. Census data, 72 percent of the population of the Island of Hawai`i, or about 107,000 people reside within the viewshed of the existing observatories.

Figure 3.16: Viewshed of Existing Observatories on Maunakea



Source: Parsons Brinckerhoff.

3.7.4 HALEPŌHAKU

The existing support facilities at Halepōhaku are not visible from other locations on the island. The 2000 Master Plan provides a number of design guidelines to maintain the visual aesthetics of Halepōhaku. These guidelines aim at maintaining the proportions of developments in Halepōhaku and help them blend into the physical landscape.

3.8 CULTURAL RESOURCES

This section describes the traditional and contemporary cultural resources, beliefs, and practices associated with the project area. The separate, but closely related, subject of archaeological sites, historic properties and the overall cultural landscape of Maunakea is presented in Section 3.9. The discussion is drawn largely from information contained in the *Cultural Resources Management Plan for the University of Hawai`i Management Areas on Mauna Kea*.

3.8.1 OVERVIEW

Distinguishing between traditional and customary cultural practices and contemporary practices is of critical importance, as the Constitution of the State of Hawai`i affords special protections to some practices. Article XII, Section 7 of the Hawai`i Constitution states:

> *The State reaffirms and shall protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by ahupua`a tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778, subject to the right of the State to regulate such rights.*

The Hawai`i Supreme Court has provided guidance in determining if a cultural practice is traditional or customary:

> *To establish the existence of a traditional or customary native Hawaiian practice, we hold that there must be an adequate foundation in the record connecting the claimed right to a firmly rooted traditional or customary native Hawaiian practice* (State v. Hanapi, 1974).

Although contemporary cultural practices are not afforded special protection under the Hawai`i constitution, HRS §343-2 requires the evaluation of the environmental effects of a proposed action on cultural practices, without distinguishing between traditional and customary practices and contemporary practices. In addition, guidelines for assessing cultural impacts of proposed actions adopted by the Hawai`i Environmental Council recommend that Cultural Impact Assessments (CIA) also include the identification of cultural beliefs associated with an area, along with an assessment of the effects of the proposed action on those beliefs.

Given the constitutional protection afforded traditional and customary cultural practices, the discussion that follows seeks to distinguish those practices that can be considered traditional and customary from other contemporary cultural practices.

Cultural practices and beliefs involving Maunakea have been changing since the arrival of the earliest Polynesian settlers, an evolutionary process that continues today. Absent a written language, Hawaiian practices and beliefs were originally recorded in chants and oral histories that were passed on from generation to generation for 1,000 years or more. The earliest written records of native Hawaiian beliefs and practices were created by European explorers and settlers in the late 18th century.

The arrival of European and Asian settlers also marked the beginning of wide-spread changes in cultural practices and beliefs throughout much of the Hawaiian Islands. Because of the evolutionary nature of cultures and beliefs, current cultural practices and beliefs involving Maunakea are diverse. Over the last 200 years, many practices have been modified or abandoned altogether as non-Hawaiian religious and cultural practices were introduced to the islands.

Traditional and customary cultural practices are defined as "those beliefs, customs, and practices of a living community of people that have been passed down through generations, usually orally or through practice" (Parker and King 1998:1, PHRI 1999:1). Traditional and customary practices and beliefs contribute to the maintenance of a community`s cultural identity and demonstrate historical continuity through the present. This is established through practice or historical documentation of a practice or belief, including both written and oral historical sources (Parker and King 1998:1; PHRI 1999:2).

3.8.2 RELIGIOUS BELIEFS AND PRACTICES

At the time of contact, Hawaiian cultural and religious practices were inseparably intertwined, as were many other activities. When describing the organization, structure, and lifeways of traditional societies, it is important to remember that the terms used today, such as religion, economics, and politics, are modern analytical constructs. Another factor which can complicate the discussion is the change over time in the meaning and usage of Hawaiian words. *Kapu* and *noa*, for example, are commonly translated as sacred and profane, but according to Bradd Shore these terms refer more precisely to the relations possible between the divine and the human, with *kapu* "being a state of contact with the divine" and *noa*, "an unbounded state of separation from the divine (Shore 1989:164-165).

Ranging from Euro-American explorers' and missionaries' journal accounts to early native Hawaiian historians like David Malo, Kepelino, and S.M. KamaKa`ū, and to later 19th and 20th century ethnologists, there is rich documentation of religious ceremonial and ritual life throughout the islands (Valeri 1985:37-44). Indeed, prior to and following significant undertakings, such as battles, voyaging, and the planting and harvesting of crops and fish, rites marked by offerings or sacrifices occurred. Offerings of appeasement were made to *`aumakua* and *akua* to avert disasters like famines, volcanic eruptions, and disease, or to ensure the coming of rain, success in crop fertility, bountiful fish harvests, or victory in battle.

Following European contact, increasing numbers of Hawaiians converted to Christianity, while restrictions were placed upon traditional religious observances. As a result, traditional oral histories and written documentation of historic religious practices and any associated beliefs regarding Maunakea remain virtually non-existent. Because Queen Regent Ka`ahumanu abolished the *kapu* system in 1819 and imposed restrictions on certain traditional Hawaiian religious practices in the post-contact period (KamaKa`ū 1961:307, 322), it is likely that the voices of those practitioners was silenced, or at least muted, with traditional knowledge being passed on covertly. It is possible that close proximity to missionary settlements and Christian-converted chiefs may have, to a greater degree, influenced decline in traditional practice. In areas further removed from Christian centers, where new religious teachings had less appeal, traditional religious practices may have continued (Barrere et al. 1980:34).

Aside from Ka`ahumanu's restrictions, it has also been suggested that it may be culturally inappropriate for practitioners to speak aloud of their ceremonial or ritual practices and beliefs. As Jess Hannah points out when asked about the presence of heiau or burials upon Maunakea:

> "*those days...if they know about them....they don't talk about `em. Even Alex [Bell], he knew `em all, they had something here and there, but they would never pin `em down. You couldn't pin point it. Something about how they were brought up or raised, it was bad luck or hard luck to talk"* (Maly and Maly 2006:A-437, 438).

Likewise, when Johnny Ah San was asked about burial locations on Maunakea, he observed that "you take those Hawaiians, they were superstitious, and they hardly want to talk about that" (Maly 1999:A-75).

Nevertheless, modern day oral history interviewees explain their knowledge, as well as an unfortunate lack thereof, concerning the cultural practices and beliefs associated with Maunakea, including (*i*) pilgrimage, offerings and prayer; *(ii)* erecting *kūahu* or family shrines; (*iii*) human burials and the scattering of cremated remains; (*iv*) *piko* deposition in Waiau; *(v)* collecting water; *(vi)* adze manufacturing; *(vii)* navigation and astronomical observation; and *(viii)* hunting.

3.8.3 PILGRIMAGE, PRAYER, OFFERINGS, AND SPIRITUAL SIGNIFICANCE OF MAUNAKEA

In public testimony before the Mauna Kea Advisory Committee, Ed Stevens ascribed Maunakea's spiritual significance to the fact that it is the highest point in Polynesia. Stevens states that the mountain is significant "because it was considered to be the gateway to heaven. When the ancient *kāula* [priest, prophets] made their treks to the summit, it was to be nearest to *akua* where prayers could be offered in the highest reverence” (Maly 1999:C-10).

Instances of the cultural importance attached to Maunakea are related in several pilgrimages made to the mountains by royalty to partake in ceremonial practices in the post-contact period. During the reign of Kamehameha I, fearing dissension amongst some of his chiefs, in the company of Kekuhaupi`o, the king is reported to have traveled to Maunakea to make a ceremonial offering close to Lake Wai`au (Desha 2000:94 in Maly and Maly 2005:50). In 1881 or 1882, Queen Emma ascended Maunakea and at Lake Wai`au, she swam across the lake, riding on the back of Waiaulima (de Silva and de Silva 2006; McCoy and Nees 2008; Maly and Maly 2005:158; Maly 1999:A-4, -5, -387). Queen Emma’s swim across Lake Wai`au was a cleansing ceremony initiated in an effort to prove her genealogical connection to Wākea and Papa (Kanahele and Kanahele 1997:9 in Maly 1999:D-21).

In addition, some oral history interviewees have noted seeing offerings left on Maunakea in recent times. Libert Landgraf recalls seeing a *pu`olo* (offerings) left at Lake Wai`au and on the summit of Maunakea, which he describes as a gift or something wrapped in *ti* leaves. “My feeling of that is it has cultural, I don’t want to go out on a limb and say religious, but it has a significant cultural significance...someone is taking a gift or presentation to a particular area” (Orr 2004:51). Other interviewees, including Rally Greenwell, Hisao Kimura, Coco Vredenburg-Hind, and Daniel Kaniho Sr., testify that they either saw or had heard that *`opihi* shells were present in the Maunakea adze quarry (Maly and Maly 2006:A-37, -215; Maly 1999:A-118, -260). Archaeologists theorize that because these *`opihi* shells are too few to be interpreted as the remains of food consumption activities, it is more like that they were offerings to *akua* (McCoy 1990:108).

Other oral history interviews demonstrate the spiritual resonance of Maunakea in the following statements in Table 3.12.

Table 3.12: Testimony on the Spiritual Significance of Maunakea

Interviewee	***Statement***
Libert Landgraf	“*I looked at sites, the area, as the church...In this instance maybe the summit of Mauna Kea represents to us what the church is, and the individual sites or the individual platforms is the altar*.” (Orr 2004:49)
Kealoha Pisciotta	“*This is a really hard issue for Hawaiian people, because the Hawaiian people have really no temples. [They’re] in the state or national parks...So Mauna Kea represents one of the last kind of places where the practice can continue...But for Mauna Kea, it’s not a temple built by man. It’s built by Akua...*” (Orr 2004:49)
Pualani Kanaka`ole Kanahele	“*If you want to reach mana, that [the summit] is where you go*.” (Maly 1999:A-372)
Pualani Kanaka`ole Kanahele	“*Mauna Kea was always kupuna [an elder, ancestor] to us...And there was no wanting to on top. You know, just to know that they were there...was just satisfying to us. And so it was kind of a hallowed place that you know it is there, and you don’t need to go there. You don’t need to bother it...and it was always reassuring because it was the foundation for our island*.” (Maly 199:A-366)
Florence La`i-ke-aloha-o-Kamāmalu `Coco’ Vredenburg-Hind	“*I don’t think I could live anywhere else. I feel like it’s right, I belong to the dirt, the soil...It just like they protect all of us. These mountains protect us*.” (Maly 1999:A-117, 120)
Alexander Kanani`alika Lancaster	“*My grandmother...she said, `When you go up there, you going feel the spirit.’ And you do feel the spirit.*” (Maly 1999:A-234)
Tita Elizabeth Ka`ūikeōlani Ruddle-Spielman	“*Yes the mana is there. There is no question.*” (Maly 1999:A-286)
Source: Mauna Kea Cultural Resources Management Plan (2009)	

From these statements it is clear that Maunakea continues to be viewed as a place of spiritual significance and cultural importance, a belief which is rooted in Hawaiian tradition. With the ready access to the summit afforded by the development of astronomical facilities, the frequency of visitations to Maunakea by cultural practitioners is believed to have increased significantly. Many of these visits are by individuals, small groups or families, while some are larger organized events, such as observations of annual solstice and equinox events.

3.8.4 AHU, KŪAHU AND MODERN SHRINES

Although the archaeologically-documented presence of ancient *ahu* and *kūahu* (shrines) within the summit region of Maunakea indicates religious observances of various kinds in the Hawaiian past, no knowledge regarding the traditional practices and beliefs associated with these ancient features exists today, or if it exists, has not been shared with archaeologists and anthropologists. In the early post-contact era the existence of *ahu* on Maunakea are reported; however, information is unavailable concerning their traditional function, be it ritual, ceremonial, or otherwise. In the 1880s – 1890s, two surveyors, J.S. Emerson and E.D. Baldwin, independently noted various *ahu* on *pu`u* in the lowlands surrounding Maunakea and the presence of a "pile of stones on the highest point of Maunakea" (Maly and Maly, 2005:494-502, 505). During the past 35 years, numerous new *ahu*, interpreted as modern shrines, have been observed in the summit region.

It is interesting to note that the Hawaiian word *kūahu*, a more obscure and presumably older term for one kind of shrine (the *ko`a*, or fisherman's shrine being another), does not appear in any of the early accounts. By the post-contact era, it appears that *kūahu* was no longer in common use, as opposed to *ahu*, a word with many meanings. Morphologically, *ahu* are a pile or mound of stones, yet in the functional sense, *ahu* may have served historically as altars or shrines, or as markers signifying burial locales, *ahupua`a* boundaries, or trail routes. When Thomas Thrum visited Haleakalā on Maui in the 1920s, he reports that *ahu* served as trail and waymarks, memorials of traveling parties, land boundaries, burial markers, or tributes to deities (Thurm 1921:259). While Emerson and Baldwin certainly confirm the presence of *ahu* as they are defined morphologically, the surveyors do not specifically speak to the functions of the *ahu* on Maunakea.

While oral history interviewees reveal that they have heard of, or have seen, the presence of *ahu* on the summit plateau and Maunakea's summit, there is little information available about the particularities of traditional religious observances practiced in association with these features (Orr 2004:47; Maly 1999:A-134; Maly and Maly 2006:A-183, -335, -349, -565). Libert Landgraf states that he was unsure of whether they were trail markers, grave sites, or something else (Orr 2004:47). Pualani Kanaka`ole Kanahele discloses that she does not know if *ahu* "represent these *ahupua`a* markers, or whether they are actually *kūahu* [altar] or *ahu* for different families that lived in that mountainous area...or if it had to do with *konohiki* [land overseers] that were in charge of a particular *ahupua`a* and so this family went there to mark the upper regions...they could also be new ones" (Maly 1999:A-372). On the other hand, Kealoha Pisciotta offers up the following explanation of the significance of *ahu*—"some of the shrines mark the birth stars of certain *ali`i*...and also birth and death" (Orr 2004:47).

Extensive archaeological surveys of the MKSR have documented over 300 modern *ahu* constructed within the past 35 years. The majority of the modern *ahu*, often classified as "find spots" by archaeologists, are interpreted to be modern shrines. The surveys and ongoing archeological monitoring by OMKM reveal that the construction of modern shrines is an ongoing practice on Maunakea, although not all modern *ahu* can be verified to have been constructed by Native Hawaiian or intended to serve as traditional shrines. Modern structures (i.e., those less than 50 years old) are not afforded protection as historic properties under federal or State laws. In addition, Conservation District rules prohibit the erection of any structure that remains more than 30 days without a permit (HAR §13-209-4).

3.8.5 PIKO BELIEFS AND PRACTICES

The cultural weight that Maunakea carries within the Hawaiian community is evident in the phrase, "*piko Ka`ūlana o ka `āina*," which translates as "the famous summit of the land" and is used as a term of endearment (Maly 1999:A-3). However, the phrase also expresses the belief that the mountain is a *piko* (the navel, the umbilical cord) of the island, and for this reason it is sacred (Maly 1999:D-20). In this context, the significance of the cultural practice of transporting and depositing a baby's *piko* on Maunakea may be better understood. Pualani Kanaka`ole Kanahele explains the symbolic importance of this practice, saying that:

> *...the piko is that part of the child that connected the child back to the past. Connect the child back to the mama. And the mama's piko is connected back to her mama and so on. So it takes it back, not only to the wā kahiko [ancient times], but all the way back to Kumu Lipo...So it's not only the piko, but it is the extension of the whole family that is taken and put up in a particular place, that again connects to the whole family line. And it not only gives mana or like to that piko and that child, but life again to the whole family* (Maly 1999:A-376).

According to some native Hawaiian cultural practitioners there are families who have a long history of taking *piko* to the top of Maunakea. According to Kaleohano Kalihi, in 1956 his grandfather had taken a gourd container filled with 40 *piko* "from all the people that had been born into this family" to "the piko of Mauna Kea. The place of the *punawai* [spring]..." (Maly 1999:A-1). Kahili also mentioned that until he took the *piko* to Waiau, his grandfather had "taken care of" those *piko*.

Another cultural practitioner, Elizabeth `Tita' Lindsey Kimura, describes being a *piko* caretaker for her family, "I still have some of her *piko* that she [her mother] collected. Not collected, but when she goes to my sisters that have babies and the *piko hā`ule* [a piko that has fallen off], she'd pick it up and bring it home...yes, I still have it in the *`ōmole* [bottle]...and I'm waiting for somebody to go up to Mauna Kea with it" (Maly and Maly 2006:A-217). One of Kimura's relatives, Irene Loeyland Lindsey-Fergerstrom, also confirmed that she took her children's *piko* and the *piko* of one of her relatives up to Maunakea (Maly 1999:390).

Cultural practitioners also provide insight into the proper means of placing the *piko*. Irene Loeyland Lindsey-Fergerstrom recalls that "we put the *piko* in a little cotton and put `em in a bottle. And sometimes it's hard to come out, so *kūkū* [grandmother] Laika said all you do is take the cover off and place it on the ground and it will just deteriorate" (Maly 1999:A-392). Also, when Lindsey-Fergerstrom took *piko* to Maunakea, her husband "dug a little hole and put the *piko* in...the summit" (Maly 1999:A-391). Elizabeth `Tita' Lindsey Kimura relates that her mother "was very particular...you don't just *hana kapulu* [to act carelessly or slovenly]...you got to treat it with respect" (Maly and Maly 2006:A-217). Kimura also says that the reason for taking the piko up to Maunakea is that the mountain is "neat" and "clean," practitioners don't want any *kapulu*...in the discarding of the *piko*" (Maly and Maly 2006:A-217). It is clear that maintaining cleanliness and purity is an important component in this cultural practice. Kealoha Pisciotta explains that in light of some practitioners belief that Lake Wai`au has become polluted, she fears that people won't put the *piko* of the baby there if it's polluted" (Orr 2004:45).

Hawaiians often hid the *piko* of newborn babies in the belief that it would ensure a long life. Another belief was that, by hiding the *piko*, one could prevent the child from growing up to be an irresponsible adult. A well-known Hawaiian proverb related to this belief is, "*He piko pau `iole,*" which translates as, "an umbilical cord taken by a rat." Pukui interprets this proverb in the following way:

> *A chronic thief. The umbilical cords of infants were taken to special places where the cords of other family members were kept for many generations. If a rat took a cord before it was hidden away safely, the child became a thief* (Pukui 1983:96).

3.8.6 MORTUARY PRACTICES

There are numerous references to human burials on the high-elevation northern and eastern slopes of Maunakea (McEldowney 1982). The practice of burying the dead in remote, high elevation areas may have been a common practice, based on the information collected by Thomas Thrum for Haleakalā on Maui:

> *The use of the craters within Haleakalā as burial places, far removed from places of habitation, is quite in keeping with ancient Hawaiian practice. Distances and difficulties were no bar to the faithful execution in carrying out the instruction of a dying relative or friend* (Thrum 1921:258).

One reason, but undoubtedly not the only one, for taking the dead to remote areas was fear that the bones might be used to make fishhooks. A person named Nainoa gave such an explanation in testimony before the Land Commission:

> *In old times, if anyone died, could not wait, but people come and steal shin bones for fishhooks, so used to carry body secretly and bury in mountains* (quoted in McEldowney 1982:1.0).

There are early accounts of burials having been found in the general vicinity of Pu`ulilinoe. E.D. Preston's account of his work at Lake Wai`au, in 1892, noted that "At an elevation of nearly 13,000 feet, near Lilinoe, a burying ground was found where ancient chiefs were laid to rest in the red volcanic sand" (Preston 1895:601). W.D. Alexander's surveying party saw what they interpreted as graves on the top of Pu`ulilinoe, also in 1892:

> *The same afternoon [July 25, 1892] the surveyors occupied the summit of Lilinoe, a high rocky crater, a mile southeast of the central hills [the `summit'] and a little over 13,000 feet in elevation. Here, as at other places on the plateau, ancient graves are to be found. In olden times, it was a common practice of the natives in the surrounding region to carry up the bones of their deceased relatives to the summit plateau for burial* (Alexander 1892).

Kamaka`ū indicated that Queen Ka`ahumanu, who like Fornander also considered Lilinoe to be named after an actual person buried there, made an unsuccessful attempt to recover her bones on Maunakea in 1828. Kamaka`ū added that the body of Lilinoe "was said to have lain for more than a thousand years in a well-preserved condition, not even the hair having fallen out" (Kamaka`ū 1961:285). Kamaka`ū's description of Lilinoe's body is probably the source of modern stories about a mummified body having been found on Maunakea and removed to some unknown location.

Of the many locations with confirmed and possible burial sites, Pu`umākanaka is perhaps the best known, with the 1925-1926 USGS survey team having found human remains on its summit:

> *To set up Camp Four at 12,400 feet near [Pu`umākanaka], we had difficulty finding a small flat area for the tents. Mākanaka is the largest and most perfectly formed cone in the summit area. 1,500 feet in diameter at the rim and 300 feet deep, while the base is more than 600 feet below the rim at one point. On the rim I found a partially uncovered grave, eroded by high winds, with an incomplete human skeleton. This was unknown, as far as I could discover, to anyone familiar with the area. The name Puu Mākanaka means "Hill crowded with many people" and the grave must have been ancient* (Killmartin 1974:15).

Other accounts suggest the placement of upper-elevation burials ensured the safekeeping of high-ranking members of the *ali`i* class. Ed Stevens maintains that "oral history and traditions tell us that...the bones of very special personages were placed in the *pu`u* at or near the summit for safekeeping...they were the special ones" (Maly 1999:C-10, 13). Daniel Kaniho Sr. suggests that "they were all *ali`i*...they were kind of high-ranked people." (Maly 1999:A-169).

Today numerous oral history interviewees reveal that they have knowledge of burials located at a number of *pu`u* dotting Maunakea's western and eastern slopes, including Ahumoa, Kemole, Papalekoki, Mākanaka, Kihe, Kanakaleonui, Ka`ūpo, and Pu`uo`o (Maly 1999:A-22, -48, -75, -165, -250, -279, -351, -395, -397).

Some cultural practitioners explain practices that relate to ancient family burials atop the mountain. Alexander Kanani`alika Lancaster reveals that he and his family members went up to Maunakea "for ceremonial. They go up there bless the whole mountains for all our ancestors who's buried up there...the old folks always said, `Our family is up there'" (Maly 1999:240). As no documentation exists on traditional cultural practices relating to ancient Maunakea burials, it is unknown whether blessing ceremonies would be considered a traditional cultural practice or a contemporary cultural practice.

Other cultural practitioners reveal that they have participated in the practice of scattering the cremated remains of loved ones from atop Maunakea. It is noteworthy that cremation was not a common practice to traditional Hawaiian culture, and when it was done it was a punishment and meant to defile the dead person. Writing in the 1830s, native Hawaiian historian David Malo stated that "the punishment inflicted on those who violated the tabu of the chiefs was to be burned with fire until their bodies were reduced to ashes" and that cremation was practiced on "the body of anyone who had made himself an outlaw beyond the protection of the tabu" (Malo 1951:57, 20). Noted native Hawaiian historian and ethnologist Mary Kawena Pukui explains why cremation was a form of defilement: "if the bones were destroyed, the spirit would never be able to join its *`aumakua*."

There are several cultural practitioners who have taken cremated remains to Maunakea, including Toshi Imoto, Tita Elizabeth Ka`ūikeōlani Ruddle-Spielman, and Kealoha Pisciotta. Imoto explained that in 1954, he and six others ascended Maunakea's summit, where *paniolo* Eben Low's ashes were scattered from an *ahu*, which is described as an old survey marker. It is also noteworthy that at the time Low's ashes were scattered, a commemorative cement plaque was placed at Lake Wai`au in Low's honor (Maly 1999:25-26). Ruddle-Spielman, who happens to be the granddaughter of Eben Low, explained that in 1969, she and her family members scattered her parents' cremation ashes from the Maunakea summit (Maly 1999:273-274). Kealoha Pisciotta also revealed that she brought her aunties' ashes to Maunakea (Orr 2004:52). Finally, Theodore "Teddy" Bell says that he wants his ashes to be scattered from the mountain (Maly and Maly 2006:A-293).

Undoubtedly, the scattering of cremation ashes today is a contemporary cultural practice that has taken the place of traditional interment practices. But debate continues over whether this practice evolved from traditional practices and beliefs or whether it is a new practice based on modern customs and beliefs. Pualani Kanaka`ole Kanahele explains that while the scattering of cremation remains on Maunakea may be viewed by some as non-traditional, she counters that view, saying: "it may not be the *iwi* [bones] itself, but the ashes are the essence of what is left of the *iwi*. It doesn't matter, it's going back" (Maly 1999:A-377).

Contrary to that, in 1970, a woman identified solely as Kolokea C. testified before the Hawaiian Culture Committee of the Queen Liliuokalani Children's Center that when her brother died, she had intended to have his body cremated. However, she was told by her 73-year old great-great-grandaunt that "cremation was *puhi i ka iwi* [bone burning]" and that cremation was expressly prohibited by Kolokea's great-great-grandfather. The auntie recommended burial in the ground or at sea instead, as with a cremation "the body will be without peace." Ms. Kanahele explains that cremation is an evolutionary development of a contemporary practice from an earlier traditional practice, whereas Kolokea C. concluded that cremation was non-traditional, having learned from her family the traditional prohibitions on the practice.

3.8.7 WATER COLLECTION

Little documentation exists that Hawaiians sought to collect water or snow in ancient times, yet Lloyd Case says that "they went there because that mountain has the power to heal and it still does...I've heard of the old ones getting water from Waiau to use for healing..." (Maly 1999:A-353). Presently, cultural practitioners engage in water and snow collection for ceremonial and/or medicinal purposes.

Regarding the waters on the mountain, Anita Leilani Kamaka`ala Lancaster and Alexander Kanani`alika Lancaster explain that their family uses the "sacred water" of Waiau for baptisms (Maly 1999:A-246). And Kealoha Pisciotta states that "it's for medicine...all of these waters" (Orr 2004:45). However, concern surrounding the purity of Lake Wai`au is also a factor influencing the contemporary practices of Lake Wai`au water collection and snow collection on Maunakea. Some cultural practitioners believe that effluent from the observatories enters the aquifer and has caused the green coloration of Lake Wai`au's water. Although scientific studies disprove the theory that effluent has in fact leached into the aquifer, Kealoha Pisciotta stated that "we are not really trusting to take the water for the medicine anymore" (Orr 2004:45). Pisciotta states that because she is unsure about the purity of the Waiau waters, she gathers snow instead. In her words, "the snow along this ridge here and by the lake, is what I was told is the snow to collect. It's powerful snow..." (Orr 2004:51).

3.8.8 ADZE MANUFACTURING

The manufacture of stone adzes made from discarded preforms left by ancient Hawaiian adze makers or from unmodified pieces of raw material in the Maunakea adze quarry is a practice occurring today, about which relatively little is known, however. One reason is that the collection of material from the quarry, a large part of which is located in the NAR, is not a permitted activity under the NAR rules. The collection and use of material from the quarry thus tends to be clandestine.

Cultural practitioners also have different beliefs concerning the appropriateness of using material from the quarry for adze manufacture and whether this activity should be taking place at all. For instance, Lloyd Case expressed his disapproval for the contemporary practice of adze collection as follows:

> *"I think that whatever is there should stay there. Because not only would it be a resource that people can go and see, what the old Hawaiians did and how things were. But if you take everything off of that mountain, and people keep taking things, you have nothing to show for our past."* (Maly 1999:A-352)

On the other hand, Hannah Springer believes that if it can be demonstrated that the quarried lack potential for archaeological analysis, adze quarrying could be permitted. She expresses that she does not know how access could or should be regulated, but expects that if it were stipulated that practice be done in a traditional manner, not many individuals would engage in quarrying. Springer states:

> *"Should there be fresh mining? I don't know if there's information that can still be extracted from the fragments that remain from past work there. If already there has been tremendous removal of material, how valid is the data that remains? What sort of picture would we get from analysis of it? I cannot answer that. If it has relatively low value maybe we would want people to continue to mine an already tapped source. Hundred and eighty degrees away from that, I can't imagine how many people would make the effort if they had to kālai [carve or cut] the pōhaku [stone]. So that might be self regulation, right there. To identify and designate an area where people could go. And again I don't know how you determine who's authentic to go up there." (Maly 1999:A-310)*

Pualani Kanaka`ole Kanahele believes that adze quarrying should be permitted, but only if those quarrying can demonstrate a genealogical tradition of adze quarrying. She states:

> *I have two mana`o [opinion, thought] for that. One is, an old site should be approached...it depends on what you are taking it for. I can only say, `Yes, take it if I see that you bring down the ko`i [adze] and you use it for something.' It has to be functional for you, and not just a show piece or something that you want to use commercially...So I am thinking that if you would go to an old place to mine the ko`i, then you need to show some kind of genealogy where your kūpuna also had that kind of function. So if your kūpuna were some kind of a kālai ki`i [carvers of images] or kālai wa`a [canoe makers] or had some kind of a function with the ko`i, if you have that...because then it would make us stronger to know that you still*

> *have that and that you still continue this in some form...So it's not like saying, `Oh you cannot, first you have to show us your genealogy.' No. `Show us what your genealogy is because that makes you stronger, that makes us stronger, that brings mana into the place.' That it is still be continued by the mo`opuna kuakāhi, kualua, kuakolu [the great; great great; and great great great grandchildren] of this kūpuna (Maly 1999:A-373, -374)*

Modern-day adze collection and quarrying can be considered a traditional cultural practice that has been modified to include the use of contemporary methods and tools (e.g., steel rock hammers).

3.8.9 NAVIGATION AND ASTRONOMICAL OBSERVATION

Kepā Maly notes in his collection of archival documentation on traditional practices that no specific references to *kilo hōkū* (observing and discerning the nature of the stars) being practiced upon Maunakea are present (Maly and Maly 2005:95). Maly speculates it is likely that *kilo hōkū* was practiced upon the mountain, as the gods and deities associated with the mountain are also embodied in the heavens, but such accounts are absent from the historical literature. Libert Landgraf also says that he has "no personal knowledge of it," but he suspects "that it probably was a very good observation [point]" (Orr 2004:55). Lloyd Case says that he thinks a platform, which he believes to have been a "navigational *heiau*", was present on the Maunakea summit. He states that "before the observatories were there, they had one when all the stones were piled up, kind of similar to some of the heiau of Māhukona" (Maly 1999:A-349).

In contrast to Maly's statement that there is an absence of evidence of traditional Hawaiian astronomical observations, cultural practitioner Kealoha Pisciotta believes that "the lake [Wai`au] is like the navigation gourd," a concept which she learned from her auntie (Orr 2004:45). According to Pisciotta, her auntie also instructed her to go to the lake and when she did, Kealoha says "I could see clearly why she wanted to look into the lake. Because when you look into the lake, the whole heavens are reflected in it and it's just like the gourd that they carry on the canoe with the water and the *ane ane*" (Orr 2004:45).

Pisciotta states that the mo`olelo passed down from her auntie describe solstice alignments with Maunakea, thus she believes that the solstices were marked from the Maunakea summit. Pisciotta emphasized that she does not doubt the validity of the mo`olelo, but that she is interested in understanding how the solstice alignments work. Thus, she has concerns that the view plane from Maunakea has been diminished and obstructed by leveling of *pu`u* and and the erection of observatory domes (Orr 2004:54-55). Pisciotta reveals the importance of the solstice alignments by stating that "if you do not measure the solstice and the equinox, you cannot keep track of the sacred time. And if you don't know where you're at, you don't know part of the *wā* or epic period you're in, so you don't know where you are in the prophesy either" (Orr 2004:58-59).

On a similar note, Tita Elizabeth Ka`ūikeōlani Ruddle-Spielman conveys the significance of the Maunakea view plane, but as a landscape viewed from the sea. She says:

> *It was so important when we used to go fishing with Uncle Francis, I used to go with him. From Keawaiki. When we started out, he'd say `Now watch the pu`u on the mountain.' And we'd go out, and that was my job to watch the pu`u as we went along. And as soon as a cloud came down to that certain pu`u we'd turn around and go right home again, because he know that the ocean would change. It was anywhere that we went, whether we were going towards Kona or coming this side towards Kohala. He said `You watch that pu`u and as soon as you see the clouds hug it, or heading towards it, let me know, because we are turning around and going home.' And he never failed...No, it was on the side, the slopes [not the pu`u near the summit, but on the slopes]. But he knew, and sure enough, by the time we got home, that wind would change, but we had gotten home safely...that is very important, this whole idea of line of sight, cultural landscape. So not only is it important close up on top, but as viewed from afar (Maly 1999:A-282).*

3.8.10 HUNTING

There is no evidence that hunting in the summit region was a traditional cultural practice. Available information indicates that it was not until the late 19th century and throughout the 20th century, following the introduction of numerous non-native ungulate species (such as cattle, goats, and sheep), that hunting for subsistence and sport began on Maunakea. Following the Māhele, livestock was deemed the property of the king and the government, although private parties could apply for license to own and brand livestock (Maly and Maly 2005:270). Interestingly, government correspondence dating from 1850 to 1856 shows that illegal hunting activity by individuals was becoming problematic (Maly and Maly 2005:270-273).

In 1861, a legal dispute over hunting rights led to the decision that no hunting activities could take place on Maunakea, except for individuals who had acquired leasehold interests in the mountain lands or who gained special permission to hunt (Maly and Maly 2005:274-277). In the years that the forested slopes of Maunakea were controlled by cattle ranching operations, Jess Hannah contends that one benefit of being employed as a ranch hand lay in one's ability to practice subsistence hunting. He said, "If you go hunting that was the main benefit because guys could go hunt pig, sheep, and all that. You could always eat" (Maly and Maly 2006:A-428).

David Woodside, a former government naturalist, concurs and explains that it was only after World War II that public hunting on Maunakea lands was permitted. This managed-hunting policy was developed in part because non-native goats and sheep were adversely impacting the forests and in part because individuals interested in sport and subsistence hunting organized to gain the right to hunt (Maly and Maly 2006:A-323-326). Indeed, Lloyd Case explains the importance of subsistence hunting to many ranch families, "a lot of my brothers and the old timers like David Hogan Ka`ūwē, when they went out hunting, it was basically a hunt where each family took home so much of the meat so that everybody had meat: (Maly 1999:A-345).

Based on all available evidence subsistence hunting within the UH management area on Maunakea is a contemporary cultural practice that has evolved from non-Hawaiian traditions.

3.9 ARCHAEOLOGICAL RESOURCES

The number, variety, and significance of the historic properties located in the UH Management Area on Maunakea is unusual and perhaps unparalleled elsewhere in Hawai`i. To help protect these resources, much of the locational data which has been accumulated by specialists has been left out of this section, to discourage theft, vandalism, or inappropriate visitation. An overview of the number and types of archaeological and historic properties is presented below, together with a chronologically organized history of the archaeological investigations which have been conducted on the mountain over the years. The cultural significance of specific sites and of the mountain itself is addressed above in Section 3.8.

Prior to contact with Europeans, Hawaiians engaged in a number of activities in the summit region. Except for the activities at the adze quarry, those activities were generally small in scale, without long-lasting adverse effects, and resulted in a minimal impact to the mountain landscape.

After the initial contact with Europeans it is reported that visits by Native Hawaiian to the summit greatly decreased; few foreigners are documented as visiting the summit area during that time as well. In the later 19th century and early 20th century the number of visitors to the summit area increased due to the popularity of horseback excursions to the summit area. Native Hawaiians, kama`āina, and visitors are reported to have visited the summit in this way. Trails worn by the horses and visitors had a minimal impact on the mountain and apparently followed the two primary trails, the Maunakea – Humu`ula Trail and the Maunakea – `Umikoa Trail.

Access to the summit was made easier over the years with the paving of Saddle Road and the road to Hale Pōhaku following World War II. In 1964, the first road to the summit was cut, making the construction of the observatories possible and also providing a relatively easy means of access to the general public. The increased number of visitors increased the potential for disturbance to cultural, archaeological, and historic resources. The road also facilitated access by cultural practitioners and allowed Native Hawaiians and scientists easier access to identify, record, and propose measures to protect cultural resources and culturally important natural resources.

The number of visitors and workers and the fact they have largely been unaware of the cultural significance of Maunakea increased the potential for impact to cultural resources. For example, in the past some engaged in off-road driving in the summit area; this has largely been curtailed by road improvements and OMKM rangers. Others have unknowingly impacted archaeological resources or disrupted the ambiance necessary for Native Hawaiian religious observances.

Prior to 1982, few archaeological surveys were conducted, so it is not known whether development on the mountain damaged subsurface resources. There is no indication that any archaeological sites in the summit region were destroyed during the construction of the Mauna Kea Access Road or the early observatories. Since 1982 the number and thoroughness of archaeological surveys undertaken prior to the construction of new observatory facilities has increased. Surface sites found in the vicinity of development projects have been flagged and protected during construction; monitoring during construction to identify possible subsurface cultural deposits or human burials was not undertaken in most cases.

Some of the historic shrines have been altered in the recent past. Some have been defaced with modern writing and symbols, while portions of others have been repositioned. Consultations conducted during the development of the CMP indicate that some cultural practitioners believe they have the right to modify the historic shrines, while others disagree. The accumulation of offerings have reportedly become obtrusive and distracting to the point that they have an adverse effect on historic properties in some cases.

Traditional accounts suggest that some ancient trails were present in the summit region. In some instances in other areas of Hawai`i Island, Hawaiian trails have been preserved and are archaeological features. It is unknown if the current trails in the summit region follow the same route as the ancient trails. In general, over the years the trails have been improved to accommodate visitors to the region, including realignment of certain trails. In some cases, roads have also been built that intersect or replace short sections of trails. These activities may have impacted the ancient trails; alternatively the ancient trails followed different routes and have been impacted by natural erosive processes. In either case, there is no remaining physical evidence of ancient Hawaiian trails in the region.

3.9.1 OVERVIEW OF ARCHAEOLOGICAL RESEARCH IN THE UH MANAGEMENT AREA

Archaeological surveys have been conducted in all three of the UH Management Area subparts (i.e., the MKSR, Hale Pōhaku, and the Mauna Kea Access Road easement). An intensive survey of the MKSR was conducted between 2005 and 2009. The Mauna Kea Access Road inventory survey was completed in 2010 and the three historic stone buildings at Hale Pōhaku were recorded and assigned state site numbers in 2010. A brief overview of the archaeological investigations undertaken in each area follows.

3.9.1.1 Mauna Kea Science Reserve (MKSR)

Table 3.14 below summarizes the archaeological surveys that have occurred in the MKSR. The first systematic archaeological investigations in the Mauna Kea Science Reserve were carried out in 1975-76 in the context of a National Science Foundation funded research project on the Mauna Kea Adze Quarry (McCoy 1977, 1990; Cleghorn 1982; Allen 1981; Williams 1989). The primary research objectives of the 1975-76 Mauna Kea Adze Quarry Project as originally conceived were to: (i) develop a technological model of adze manufacture based on a characterization of techniques, stages, and activity pattern variability within and between sites in the quarry complex; (ii) provide new data on chronological changes in Hawaiian adze types, and (iii) determine the relationship of this particular quarry industry to other forms of economic specialization and the development of socio-political complexity (McCoy 1976, 1986:7).

Table 3.13: Summary of Archaeological Surveys and Fieldwork in the MKSR

Year	*Project/Area*	*Survey Type*	*New Sites*	*Reference*
1975-76	*Mauna Kea Adze Quarry*	*Reconnaissance and inventory*	*3*	*McCoy 1976, 1977; Cleghorn 1982*
1981	*Kitt Peak National Observatory*	*Reconnaissance*	*0*	*McCoy 1981*
1982	*Institute for Astronomy (IfA) / 1,000 acres of the summit and north slope*	*Reconnaissance*	*21*	*McCoy 1982a and McEldowney 1982*
1982	*CSO*	*Reconnaissance*	*0*	*McCoy 1982b*
1983	*Maunakea Observatory Power Line*	*Reconnaissance*	*0*	*Kam and Ota 1983*
1984	*NSF Grant-in-Aid Survey*	*Reconnaissance*	*19*	*McCoy 1984*
1987	*Summit Road Improvement*	*Reconnaissance*	*0*	*Williams 1987; McCoy 1999*
1988	*VLBA Observatory / 115 acres for VLBA*	*Reconnaissance*	*2*	*Hammatt and Borthwick 1990*
1990	*Subaru Observatory / 5.1 acres on pu‘u*	*Reconnaissance*	*0*	*Robins and Hammatt 1990*
1990	*Gemini Observatory / 2 acres on Pu‘u Kea*	*Reconnaissance*	*0*	*Borthwick and Hammatt 1990*
1991	*Pu‘u Mākanaka*	*Reconnaissance*	*1*	*McCoy 1999a*
1995	*SHPD site relocation and GPS recording*	*Reconnaissance*	*17*	*McCoy 1999a*
1997	*SHPD transect survey*	*Reconnaissance*	*31*	*McCoy 1999a*
1999	*SHPD survey of Pu‘u Wēkiu*	*Reconnaissance*	*1*	*McCoy 1999a*
2010	*TMT / 36 acre Area E*	*Inventory*	*0*	*Hammatt 2010*
2010	*OMKM survey of the Science Reserve*	*Inventory*	*166*	*McCoy and Nees 2010*

Source: McCoy and Nees 2010

As seen in Table 3.14, archaeological surveys undertaken between 1975 and 1999 identified a total of 95 sites (McCoy 1975, 1977, 1982a, 1982b, 1984, 1990, 1999a; Hammatt and Borthwick 1988, 1990) in an area encompassing some 3,711 acres, which represents roughly 33% of the 11,288 acre Science Reserve. With the exception of a survey undertaken as part of a research project on the Mauna Kea Adze Quarry Complex, all of these surveys were reconnaissance level studies, which by definition are limited in terms of coverage and completeness.

Table 3.14: Historic Property Types Recorded in the MKSR between 1975-1999

Site Type	***Number***	***Percent of Total***
Shrines	77	81.05
Isolated Adze Quarry-Workshop	1	1.05
Workshop	1	1.05
Adze Quarry Ritual Complex	1	1.05
Burials and Possible Burials	5	5.26
Stone Markers/Memorials	5	5.26
Unknown Function	5	5.26
TOTAL	***95***	***100%***

Source: McCoy and Nees 2010.

Five of the 95 sites recorded between 1975 and 1999 are of unknown function. The other 90 sites include: (1) 77 shrines; (2) 1 isolated adze quarry-workshop; (3) 1 adze manufacturing workshops; (3) 1 positively identified burial site and 4 possible burial sites with an unknown number of interments at each site, and (4) 5 cairns that appear to be markers built either by surveyors or visitors to commemorate a visit.

Of the original 95 sites identified in the Science Reserve, 77 or 81% were classified as shrines. An additional 8 shrines are associated with adze manufacturing by-products, one each on Sites 11079, 16203, and 21211 and five on Site 16204. These four sites have been previously interpreted as a different kind of workshop, but the functions are not readily clear. The total number of shrines recorded in the MKSR through 1999 is thus 85.

An intensive archaeological inventory survey of the MKSR was undertaken between 2005 and 2009. The primary objective the inventory survey was to identify, record, and evaluate the significance of all of the historic properties in the Science Reserve, and to make recommendations regarding their preservation and continued protection. A total of 263 sites were identified in the survey, including the 95 previously recorded sites (documented between 1975 and 1999) and two traditional cultural properties (Kūkahau`ula and Pu`ulilinoe) that were given Statewide Inventory of Historic Places (SIHP) site designations by SHPD in 1999 (McCoy and Nees 2010).

The following summary information on site types is drawn from McCoy and Nees (2010). Shrines are the most common site type in the Science Reserve, but the relative number of sites has little meaning because of differential site complexity. The next most common site type is a complex of adze quarries/workshops found in the Pōhakuloa Gulch area. This site complex is part of the larger Mauna Kea Adze Quarry Complex, which was placed on the National Register of Historic Places in 1962 as a National Historic Landmark. The Mauna Kea Adze Quarry Complex consists of: (1) the quarry proper, which is defined as the source areas of tool-quality basalt, and (2) diverse activity remains located outside of the quarry proper as just defined, but an integral part of the quarry industry because of the activities that took place. These include isolated adze manufacturing by-products (e.g., cores, flakes), hammerstones and unfinished adzes in various stages of completion; shrines with associated lithic scatters of uncertain function and/or offerings; a ritual complex and two possible burials with lithic artifacts that suggest the possibility of adze maker interments. Burials and possible burials are another fairly common site type, but they are localized to just a few places. The remainder of the historic property inventory is represented by small numbers of diverse site types, such as markers/memorials, temporary shelters, one and possibly two of the camps occupied by the 1926 USGS survey party, and an isolated horseshoe located along what is believed to have been the `Umi Koa Trail. The function of a few sites could not be determined.

The survey included test excavations at two sites and probes at several overhangs to determine the presence/absence of buried cultural deposits. A single radiocarbon date of AD 1420-1480 was obtained on a piece of wood charcoal from a thin cultural layer in a rockshelter located in the Pōhakuloa Gulch area. This is currently the only dated site in the Science Reserve other than some of the historic sites. Table 3.15 presents summary statistics on the number of historic property types in the Science Reserve, as documented by McCoy and Nees (2010).

Table 3.15: Functional Site Types in the MKSR

Functional Site Type	***Number***	***Percent of Total***
Traditional Cultural Properties	2	0.76
Shrines	141	53.61
Mauna Kea Adze Quarry Complex Sites	67	25.47
Burials and Possible Burials	29	11.03
Stone Markers/Memorials	15	5.70
Temporary Shelters	3	1.14
Historic Campsites	2	0.76
Historic Transportation Route	1	0.38
Unknown Function	3	1.14
TOTAL	***263***	***99.99***
Source: McCoy and Nees (2010)		

3.9.1.2 Mid-Level Facility Parcel at Hale Pōhaku

A number of archaeological investigations have been conducted at Hale Pōhaku (see Table 3.16), beginning with a one-day reconnaissance survey by the Bishop Museum in 1979 for the *Hale Pōhaku Mid-Level Complex Development Plan.* No sites were found at that time (McCoy 1979). Three more surveys were conducted by the Bishop Museum between July 1984 and June 1985 as part of the preparation of a supplemental EIS for a permit to build a new construction laborer camp. Two shrines and five lithic scatters comprised of adze-manufacturing by-products and octopus sinker manufacturing by-products were recorded in the surveys, which encompassed roughly 40 acres on the west and east sides of the Mauna Kea Access Road between 9,080 and 9,200 feet in elevation. The lithic scatters and shrines, one of which has octopus sinker manufacturing by-products on it that have been interpreted as offerings, were designated the Pu`ukalepeamoa Site, after the name of one of the large cinder cones at Hale Pōhaku (McCoy 1985). This cone, through which the Mauna Kea Access Road passes, is the source of the stone (primarily dunite and gabbro) used in the manufacture of the sinkers. The two shrines and some of the lithic scatters found in the 1984-85 work are located outside of the Mid-Level facility parcel.

The discovery of lithic artifact in the vicinity of the Hawai`i Electric Light substation led to a reconnaissance survey of the substation and surrounding area (Sinoto 1987) and a data recovery project in 1987 (McCoy 1991). The data recovery project involved a more intensive survey, including surface collections at 11 different lithic scatters and limited test excavations of two of the scatters (McCoy 1991). SHPD arbitrarily assigned SIHP numbers to two of the shrines and 12 lithic scatters found in the 1984-85 and 1987 projects (Cordy 1994).

Table 3.16: Summary of Archaeological Investigations at Hale Pōhaku

Year	*Project*	*Investigation*	*Reference*
1979	Hale Pōhaku Mid-Level Facilities Complex Development Plan	Reconnaissance Survey	McCoy 1979
1984-85	Supplemental EIS for Construction Laborer Camp	Reconnaissance Survey	McCoy 1979
1986	HELCO Transmission Line and Substation	Reconnaissance Survey	Bonk 1986
1987	HELCO Transmission Line and Substation	Reconnaissance Survey	Sinoto 1987
1987	HELCO Transmission Line and Substation	Data Recovery	McCoy 1991
1990	Japan National Large Telescope Dormitories	Reconnaissance Survey	Robins and Hammatt 1990
1993	Japan National Large Telescope Dormitories	Data Recovery	Hammatt and Shideler 2002
2005	Septic Tank Excavations	Monitoring	McCoy 2005
2009	Architectural Inventory of Rest Houses and Comfort Station	Architectural Inventory Survey	PCSI 2010
Source: Mauna Kea Cultural Resources Management Plan (2009)			

A total of 2,364 artifacts and 129 faunal remains were collected in the data recovery project. In addition to the debris related to adze and octopus sinker manufacture some 20 special purpose bird cooking stones called *pōhaku `eho* were found. Three radiocarbon dates from charcoal recovered in fire pits indicate that the site, which has been interpreted as a temporary camp occupied on the ascent to, and descent from, the Maunakea adze quarry, is of late pre-contact age (ca. AD 1600-1700).

Cultural Surveys Hawai`i, Inc. conducted another reconnaissance survey at Halepōhaku on August 9, 1990. The survey, which was done in conjunction with the proposed construction of dormitories for the Japan National Large Telescope (now called the Subaru Telescope), covered the entire

Halepōhaku parcel. No new sites or features were found in the survey. Two of the lithic scatters located in the area of the proposed dormitories that had been recorded in the 1984-85 Bishop Museum survey were relocated, mapped in more detail, and recommended data recovery investigations prior to construction of the dormitories (Robins and Hammatt 1990). The data recovery work was conducted October 19-20, 1993 by Cultural Surveys Hawai`i, Inc. Two radiocarbon dates were obtained that support the idea of a late prehistoric camp site (Hammat and Shideler 2002).

In March 2005, archaeological monitoring was conducted at Halepōhaku during the excavation of four new septic tank pits (McCoy 2005). The monitoring report noted that while all of the known surface features in the lease area have undergone data recovery and no longer exist, there is possibility that buried cultural deposits might exist in some undisturbed areas (McCoy 2005).

There are also three historic buildings located at Halepōhaku: two stone cabins and one stone comfort station. The cabins were constructed by the Civilian Conservation Corps (CCC) in the 1930s, while the comfort station was built in 1950 by the Territory of Hawaii Division of Forestry. Architectural inventory surveys of the structures were completed in 2010 (PCSI 2010). In all, a total of six historic properties have been documented in the Halepōhaku area; three archaeological sites and three architectural properties.

3.9.1.3 Maunakea Access Road

In 1987 the Bishop Museum was contracted by the Facilities Planning and Development Office of UH to undertake an archaeological reconnaissance survey of the access road above Halepōhaku as part of the planning process for road improvements and new parking areas. The survey covered a 100-foot wide corridor on both sides of the road, from Halepōhaku to the location of an old, abandoned batch plant and stockpile area located below Pu`uhaukea in the NAR. A post-fieldwork letter report dated July 7, 1987 (Williams 1987) indicates that no new sites were found during this survey. New data on SIHP No. -16204 (see below), located close to the road, was obtained during the project (McCoy 1999b). In 2009, PCSI conducted an inventory survey of the 400-yard wide management corridor along the roadway. That survey identified one previously recorded site (a lithic scatter associated with adze production) and three new sites, interpreted as possible burials (McCoy, Nees and Mintmier 2010).

3.9.2 HISTORIC PROPERTY TYPES

A total of 275 historic properties have been identified and recorded in the UH Management Area with the completion of the archaeological inventory surveys (McCoy and Nees 2010). The spatial distribution of the known sites has been withheld from this document in order to limit access and misappropriation of sites and artifacts.

Four categories of sites were recognized in the early surveys of the MKSR. They were shrines; adze manufacturing “workshops”; burials; and probable Survey Markers. The archaeological inventory survey (AIS) conducted by PCSI between 2005 and 2009 identified several additional site types (McCoy and Nees 2010, McCoy, Nees and Mintmier 2010) and the initiation of annual monitoring of historic properties (Nees and Gosser 2013). Each class of sites is briefly described below in terms of its defining characteristics. Functional inferences are based on formal attributes, locational context, and comparative data (ethnographic and archaeological) from Hawai`i and other areas of East Polynesia. One specific site that is known to exist from historic accounts and maps, but which has not been identified on the ground, is the `Umikoa Trail. While the trail is believed to date to the 19th century, there is archaeological evidence, including cairns and other isolated lithic scatters that indicate Hawaiian adze makers and perhaps other people were following a similar route to the alignment of the `Umikoa Trail in the pre-contact period.

While the majority of the sites consist of just a single feature, there are a fair number of multi-feature sites. These include a number of sites located outside the adze quarry but which contain adze manufacturing by-products (e.g., cores, flakes, hammerstones, and unfinished adzes in various stages of completion) and in some cases associated shrines and/or enclosures. How to classify and interpret such sites presents some problems, which are addressed more thoroughly in the AIS report (McCoy and Nees, 2010). The site types listed below in Table 3.17 represent just one possible way of classifying and presenting the data.

Table 3.17: Historic Property Types in the UH Management Area

Site Type	***Number***	***Percent of Total***
Traditional Cultural Properties	*2*	*0.7*
Shrines	*143*	*52*
Burials and Possible Burials	*34*	*12.4*
Mauna Kea Adze Quarry Complex Sites	*69*	*25.1*
Stone Markers/Memorials	*15*	*5.5*
Temporary Shelters	*3*	*1.1*
Historic Campsites	*2*	*0.7*
Historic Transportation Route	*1*	*0.4*
Historic Buildings and Structures	*3*	*1.1*
Unknown Function	*3*	*1.1*
TOTAL	***275***	***100.1***
Source: McCoy and Nees (2010), McCoy Nees and Mintmier (2010) and Nees and Gosser (2013)		

3.9.2.1 Traditional Cultural Properties

A Traditional Cultural Property (TCP) is a type of historic property that was formally defined for the first time in 1998 by Patricia Parker and Thomas King, in National Register Bulletin 38 *Guidelines for Evaluating and Documenting Traditional Cultural Properties*. TCPs were defined with Parker and King as follows:

> *A traditional cultural property, then, can be defined generally as one that is eligible for inclusion in the National Register because of its association with cultural practices or beliefs of a living community that (a) are rooted in the community's history, and (b) are important in maintaining the continuing cultural identity of the community (National Register Bulletin 38 1998:1)*

King further elaborates in a recent book devoted to TCPs that he and Parker invented the term as a "way of saying places that count to ordinary people, are held dear by them, whatever significance they may have for professional scholars." (King 2003:1). Such a broad definition poses some obvious problems, especially in the case of large mountains, where some people regard the whole mountain as culturally significant while others of the same group may hold that only the summit or specific sites are culturally significant.

During the preparation of previous documents in 1999 and 2000, SHPD determined that three areas on Maunakea met the criteria for designation as TCPs because of their association with legendary figures and on-going cultural practices. Each of these three TCPs was given a state site number and all three are listed in the State Inventory of Historic Places. The TCPs are identified in Table 3.18.

Table 3.18: Traditional Cultural Places on Maunakea

SIHP no.	***Traditional Cultural Place***	***Notes***
50-10-23-21438	Kūkahau`ula	The summit, which is comprised of a series of overlapping cinder cones, including Pu`uwēkiu, Pu`ukea, Pu`uhau`oki and at least one other unnamed cone.
50-1-23-21439	Pu`ulilinoe	
50-1-23-21440	Pu`uwai`au	Located outside the UH Management Area, in the Mauna Kea Ice Age NAR.
Source: Mauna Kea Cultural Resources Management Plan (2009)		

Studies conducted for improvements to the Hawaii Defense Access Road and Saddle Road (1996) included a TCP assessment for Maunakea written by Dr. Charles Langlas of the University of Hawaii at Hilo (Langlas et al. 1997). A letter written in March 1999 that accompanied the submittal of a supplement to the main study, prepared in 1998 which indicated that “the author intended to conclude that although the whole upper zone of Mauna Kea should be considered eligible as a traditional cultural property for the National Register of Historic Sites (as a historic district), he cannot recommend that the summit peak be considered eligible as a specific site, because he cannot make public the information he collected by Kupuna X” (Langlas 1999).

Tom King, in the declaration he submitted as part of the contested case hearing for the Keck Outrigger project (King 2003:6-7), stated his opinion that the landscape on the upper slopes of Maunakea meets the eligibility criteria for inclusion in the National Register as a TCP. While King did not set a boundary, there are individuals who believe that all of the lands above the 6,000 foot elevation should be recognized as a TCP (NASA 2005:xv).

3.9.2.2 Shrines

Shrines are by far the most common site-type in the UH Management Area (see Table 3.17). Approximately one-half (143 of the 275 historic properties identified as of 2013) are shrines. This number includes a couple of possible shrines, where some doubt exists about the presence of uprights because none were found in a standing position. As described below, shrines are also found in association with isolated lithic scatters comprised of adze manufacturing by-products transported from the adze quarry, so the total number of shrines in the MKSR is actually larger.

The quintessential characteristic of all remains identified as shrines is the presence of one or more upright stones. A number of shrines consist of just a single upright, while others are characterized by multiple uprights arranged in different patterns on a variety of different kinds of foundations. Kenneth Emory, who was the first one to describe the shrines on Maunakea and note their East Polynesian affinities, was of the opinion that the uprights represented or symbolized the gods. Emory made the following comments about the shrines he saw in the nearby adze quarry, during the brief reconnaissance of the main quarry area in 1937:

> *The adze makers, clinging to the ancient form of shrine at which to approach their patron gods, have preserved a most important link with their ancestral home. Each upright stone at a shrine probably stood for a separate god. The Hawaiian dictionary describes `eho as “a collection of stone gods” and this is the term which the Tuamotans, the neighbors of the Tahitians, used to designate the alignment of upright stones on the low and narrow platforms at their maraes, or sacred places (Emory 1938:22).*

On current evidence there are at the minimum two functional classes of shrines: (*i*) occupational specialist shrines related to adze manufacture; and (*ii*) all other types, which on current evidence appear to be “non-occupational.” Morphologically, there is nothing to distinguish between these two classes, each of which exhibits considerable variability in ground plan, number of uprights, etc. The Maunakea shrines are, in this regard, no different from Hawaiian shrines in general. According to Buck, “Shrines varied considerably in construction, and similar forms were distinguished merely by their function” (Buck 1957:528).

The sole factor which distinguishes the occupational shrines from all others are associated lithic scatters found either on the shrine itself or in close enough proximity to be considered part of a single site. The artifacts found on shrines are interpreted as offerings, while those some distance away are interpreted as some kind of specialized “workshop”.

3.9.2.3 Burials and Possible Burials

Prior to the beginning of the archaeological inventory survey in 2005, the only positively identified human remains that were known to exist in the MKSR were located near the summit of Pu`umākanaka, although as noted previously, there are also references to human remains having been seen on Pu`ulilinoe in 1882. Jerome Kilmartin, a surveyor with the USGS, noted the presence of human remains on Pu`umākanaka in 1925. In a popular account of his experiences on the mountain, written many years later, Kilmartin noted that the name Pu`umākanaka means "Hill crowded with many people" and the grave must have been ancient (Kilmartin 1974:15).

A total of 34 burial and possible burial sites containing a total of 60 component features were identified during the archaeological inventory surveys of the MKSR and Mauna Kea Access Road Corridor (MKARC) (McCoy and Nees 2010; McCoy et al. 2010; Collins and McCoy 2014) and during annual monitoring being conducted by OMKM (Nees and Gosser 2013). For the sites classified as possible burials there are compelling reasons, such as the topographic location and morphological characteristics of the structures, to believe that these sites are indeed burials, but because human remains were not seen at the time they were recorded they are classified as possible burials. Because of the extreme sensitivity of these sites, the locations of known and possible burial sites are not provided.

A burial treatment plan (BTP), prepared in accordance with Hawaii Administrative Rule (HAR) 13-300-33, was reviewed and approved by the DLNR and the Hawai`i Island Burial Council (HIBC) (Collins and McCoy 2014). The BTP covers all 34 burial and possible burial sites, provides recommended short-term and long-term preservation measures, including some recommended by SHPD and recognized cultural descendants. While no lineal descendents of burials in the MKSR and MKARC have been identified to date, the HIBC, at its November 2013 meeting, voted to recognize 20 individuals as cultural descendants; notification letters were sent out to these individuals in December 2013.

3.9.2.4 Stone Tool Quarry and Workshop Complexes

Two stone tool quarry/workshop complexes have been found in the UH Management Area, one in the MKSR and one at Halepōhaku. The complex in the MKSR is part of the Maunakea adze quarry complex and consists of a large number of quarries, workshops, shrines, and at least two habitation rock shelters. As described above, the Pu`ukalepeamoa site at Halepōhaku is a multi-functional site complex, consisting of several temporary campsites where the manufacture of adzes and octopus lure sinkers took place. Two shrines, both related to sinker manufacture, are a part of this unusual site complex, which is the only one of its kind known at the present time.

3.9.2.5 Adze Quarry Ritual Complex

SIHP Site No. 50-10-23-16204, first recorded in 1975 during research on the Maunakea adze quarry (McCoy 1977, 1999b), is one of the most complex and significant sites within the MKSR. The site, which is located on a prominent whaleback ridge on the east side of the access road, between an approximate elevation of 12,250 and 12,330 feet, consists of 5 shrines, 26 open-air enclosures, and a diffuse scatter of adze manufacturing byproducts. McCoy (1999b) has interpreted the site, which is located outside of the quarry proper where there is no local source of stone-tool quality basalt, as the locus of initiation rites for apprentice adze makers.

3.9.2.6 Isolated Adze Manufacturing "Workshops"

There are currently 17 sites in the MKSR that have been tentatively interpreted as adze manufacturing "workshops" based on the presence of one or more of the following artifacts—flakes, cores, unfinished adzes, and hammerstones (see Table 3.17). These are "workshops" of a different kind than those found in the adze quarry. First, there is no naturally occurring source of raw material of the same quality as that found in the adze quarry in the environs of these sites. With one or two possible exceptions, there is little question that the artifacts in these sites were transported from the quarry, even though a geochemical analysis has not yet been conducted to determine this. Second, there appears to be a considerable amount of inter-site variability in the number and frequency of different artifact classes found on these sites, unlike the usual workshop.

In some cases there appears to be a disproportionate number of unfinished adzes compared to the number of flakes, thus pointing to the high probability that some of the adzes were flaked elsewhere and/or transported to these sites at a later stage of the manufacturing process. At other sites the predominant artifact type is flakes. These characteristics, combined with the small size of most of the artifact assemblages, indicate that these were no ordinary workshops. Indeed, the evidence for *in situ* manufacture, as opposed to a place where offerings were made, is in many instances ambiguous. If manufacture did take place it would appear to have been an essentially symbolic act.

Associated with several of these workshops are one or more shrine. Unfinished adzes, flakes and occasionally other manufacturing byproducts were found on or near the shrines at several points. These assemblages, like those found on many shrines in the quarry, are interpreted as offerings to the tutelary gods of adze making (Malo 1951; McCory 1990, 1999b). All of these sites are highly significant for the information they convey about the quarry as a social process.

3.9.2.7 <u>Isolated Artifacts</u>

A number of different kinds of isolated artifacts and objects were found in various localities. Isolated artifacts found in the survey include adze preforms, adze manufacturing waste flakes, hammerstones, and a horseshoe. The site and isolated find distinction is arbitrary. The decision to give a site number to the isolated artifacts in the MKSR is based on the definition of historic properties in both the National Historic Preservation Act (NHPA) and HAR Chapter 6E, even though the SIHP does not currently contain isolated artifacts.

All of the sites and isolated artifacts in the MKSR are contained within the proposed boundaries of the Maunakea Summit Region Historic District, which has been determined eligible for inclusion in the National Register of Historic Places (NRHP). The isolated artifacts found in the survey clearly fit the definition of a contributing property. They possess historic integrity and have yielded information that is contributing to a more detailed understanding of the adze manufacturing process on Maunakea. Their locations alone provide important data on the ascent and descent routes utilized by at least some of the adze markers whose homes would have been on the Hamakua Coast.

3.9.2.8 <u>Stone Markers/Memorials</u>

Nine sites are classified as either survey markers or markers left by unknown visitors. These include cairns, mounds, and less formal piles of rocks on top of a boulder. Morphologically, all are quite unlike those which have been interpreted as burials. Some of the more elaborate examples are cylindrical in shape and faced.

Some things that could possibly be interpreted as markers have been built in modern times. Jerome Kilmartin, who was in charge of topographic mapping of the Lake Wai`au quadrangle—later changed to the Maunakea Quadrangle—for the USGS, in 1925, mentions building an *ahu* to retard the wind (Kilmartin 1974:15).

It is possible that some of the simple stacked-stone constructions that have been interpreted as modern may be memorials of the kind described by Thomas Thrum on Haleakalā:

> *It was a recognized custom of Hawaiians to erect stone piles—pile is one meaning of the word ahu—as way marks, memorials to parties travelling or resting, division points of survey, and also guides to most accessible routes of travel. One such marks the safest of three ridges leading from the rim of the crater to the district of Nuu. That some ahu mark burial places is in accord with the present practice in certain districts of Maui and of Hawaii, and perhaps elsewhere. Most, if not all, of the ahus of three stones, one upon another, are tributes to the deity of the locality and are designed by travelers to assure their safety in their journey (Thrum 1921:259).*

The number of markers could thus change with a closer analysis of the survey date.

3.9.2.9 <u>Temporary Enclosures</u>

Crude stone walls were found at various localities in the MKSR, usually in association with other features, such as lithic scatters. Three sites consist of nothing more than walls. Two, to a maximum of four, walls were found at these sites. Some are linear, while others are roughly C-shaped in plan view. They are interpreted as temporary shelters based on their morphology and environmental setting. There is no means of dating any of these sites, which are probably either late prehistoric or historic in age.

3.9.2.10 Historic/Modern Campsite

One of the camps, known as Campsite 3, occupied by the USGS survey team in 1926 was found in 2007 on the north slope of the mountain near Pu`umahoe. Another possible USGS campsite was found near Pu`umākanaka, just outside of the MKSR.

3.9.2.11 Unknown Function

There are three sites of uncertain or unknown function, including the only known site on the summit. Two of the sites are either cairns or piles of rocks that could be markers. One site, a terrace with a possible upright, may be an unfinished shrine.

3.9.3 THE MAUNAKEA SUMMIT REGION HISTORIC DISTRICT

As previously noted, in 1999, during the preparation of the Master Plan, SHPD proposed that the cultural landscape on the top of Maunakea be recognized as the Maunakea Summit Region Historic District. The historic district proposal was summarized in the CIA for the Master Plan (PHRI 1999:30-32) and discussed in more depth in the early planning process for the proposed Keck Outrigger project (Hibbard 1999; NASA 2005). The IFA, NASA, and other parties agreed that the proposed district, which on current thinking would include all of the MKSR, portions of the NAR, and additional areas at selected locations lower on the mountain, meets the eligibility criteria for inclusion on the NRHP. The district is listed in the SIHP as Site No. 50-10-23-26869.

All of the sites in the MKSR are contained within the proposed boundaries of the Maunakea Summit Region Historic District. They are called “contributing properties” in the National Register:

> *A contributing building, site, structure or object adds to the historic architectural qualities, historic associations, or archaeological values for which a property is significant because a) it was present during the period of significance, and possesses historic integrity reflecting its character at at that time or is capable of yielding important information about the period, or b) it independently meets the National Register criteria (National Register Bulleting 24:15).*

SHPD has begun working on the nomination of the Maunakea Summit Region Historic District to the NRHP. The process will involve consulting with several agencies, including OMKM and DLNR-DOFAW, since the district includes within its boundaries a large portion of the Mauna Kea Ice Age NAR and state lands outside of both the MKSR and NAR. The historic district will include within its boundaries the three TCPs listed in the SIHP.

3.9.4 SITE SIGNIFICANCE EVALUATION

As noted in Section 3.9.2.7, evaluating the significance of sites or historic properties is a requirement for state projects under HRS Section 6E-8 and its implementing regulations, HAR Chapter §13-275-6, and Section 106 of the National Historic Preservation Act and its implementing regulations (36 CFR 800). The criteria used in evaluating site significance for state and federal projects are similar. The federal criteria of eligibility are set out in the National Park Services’ National Register regulations at 36 CFR 60.4. There are four National Register criteria which are also used in Hawai`i:

A. That they are associated with events that have made a significant contribution to the broad patterns of our history; or

B. That are associated with the lives of persons significant in our past; or

C. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

D. That have yielded, or may be likely to yield, information important in prehistory or history.

One other criterion (E) has been added to the list in Hawai`i. Historic properties evaluated as significant under Criterion E:

> *Have an important value to the native Hawaiian people or another ethnic group with cultural practices once carried out, or still carried out, at the property or due to associations with traditional beliefs, events or oral accounts—these associations being important to the group's history and cultural identity (Chapter 13-275-6).*

Historic properties that are significant under Criterion E include burials, shrines, heiau, and TCPs. Historic districts, which are comprised of a number of individual historic properties, may also be evaluated as significant under Criterion E if they include shrines, burials or other types of historic properties that are known to be associated with traditional beliefs, events or oral histories.

There are two basic ways in which historic districts and TCPs are recognized as significant under Hawai`i Administrative Rules. Under HAR Chapter 13-198, a process is established to determine historic properties significant by entering them into the Hawai`i Register of Historic Places (HRHP) and by nominating them to the NRHP. Historic districts are considered eligible for listing in the HRHP through the process outlined in HAR §13-198-2. The Hawai`i Historic Places Review Board determines which nominated properties meet the criteria for being entered in the Hawaii Register and for being forwarded to the National Register for consideration. It is important to note that the Hawai`i Register of Historic Places (HRHP) and the State Inventory of Historic Places (SIHP) are not synonymous.

The second way of establishing that historic districts and TCPs are significant is through the historic preservation review process set out in HAR §13-275 and §13-284. In both chapters, the significance of any historic property identified during the project review process must be evaluated by the agency or applicant. Once agreement is reached with SHPD on the significance of an identified historic property, the property is entered in the state's inventory, or SIHP, as a consensus determination [see HAR §§ 13-275-6(d)(3); 13-284-6(d)(4)]. This process recognizes districts as a type of significant historic property [HAR §§ 13-275-2; 13-275-6(b); 13-284-2; and 13-284-6(b)].

Site significance tends to be viewed as fixed and unchanging, but in reality it is both "dynamic and relative" (Moratto and Kelly 1978:2). Bowdler (1984:2) and others have noted how archaeological significance is anything but static. Charles McGimsey and Hester Davis emphasize the importance of having a frame of reference in making significance evaluations and why they are always relative.

> *The fact that archaeological sites and the information they contain are our only clues to much of human life in the past makes every site potentially significant. It is generally recognized, however, that defining site significance implies some frame of reference, problem orientation, geographic, temporal or other context, against which an archaeological phenomenon is to be evaluated. A site is therefore more or less significant relative to some criterion or criteria (McGimsey and Davis 1977:31).*

With the recognition of the Maunakea Summit Region Historic District as eligible for the NRHP, there is now a single frame of reference that can be used in evaluating site significance for all historic properties on the top of Maunakea. As noted in the SHPD Plan, the site significance evaluation process differs for individual sites within and outside of the historic district. Sites located outside of the proposed boundaries of the historic district will be evaluated individually, in contrast to those located in the historic district, as explained below:

> *...Within the historic district, the significance of properties is not evaluated individually because the summit region as a whole is considered eligible for inclusion in the National Register. Instead, the required assessments consider how each newly or previously recorded property potentially affected by a project contributes to the significance of the historic district*

as a whole...Determining that a property is significant and eligible for the Hawaii or National Registers does not necessarily mean the property will be placed on the Register, only that it possesses attributes and associations which would allow it to be considered eligible. Significance evaluation should conform with SHPD administrative rules or the National Register criteria (National Register Bulletin 15) if the project is federally funded or if the historic properties are located within the historic district (SHPD 2000:17, 20).

The Maunakea Summit Region Historic District is significant under all four National Register criteria and HAR §13-275-6, Criterion E:

- The district is significant under Criterion A because of the presence of the Maunakea adze quarry complex (a National Historic Landmark), which was used over a period of 500 years or more and the hundreds of shrines in and outside of the quarry. Both the quarry and the shrines are associated with a broad pattern of events in Hawaiian prehistory.
- The district is significant under Criterion B because of the association with several gods and goddesses who may have been deified ancestors. These include Kūkuhau`ula, Lilinoe and Waiau which are recognized as TCPs.
- The sites in the adze quarry and many of the shrines embody distinctive characteristics of traditional Hawaiian stone tool manufacture by craft specialists and a distinctive type of shrine construction found only in a few other places in the Hawaiian Islands. These make the district significant under Criterion C.
- Studies of the Maunakea adze quarry complex and the AIS of the MKSR have already made significant contributions to our understanding of Hawaiian prehistory and history, and hold the potential to make even more contributions. The district is thus significant under Criterion D.
- Finally, under Criterion E, the district is significant because of the presence of numerous burials, three TCPs, and the hundreds of shrines which have been interpreted as evidence of a previously unknown land use practice in the form of pilgrimages to the summit of Maunakea to worship the gods and goddesses.

3.9.5 FIND SPOTS

Other resources in the MKSR include a large number of remains that at present cannot be classified as sites as normally defined in state and federal law but which nevertheless need to be considered in developing appropriate management strategies and evaluating the impacts of the proposed action. As noted above in the summary of previous archaeological work in the MKSR, in 1997 SHPD instituted a process of recording what were initially referred to as "locations" but are now being termed "find spots" that are either obviously modern-era features (e.g., campsites with tin cans or glass associated with them) or features that cannot be classified with any degree of confidence as historic sites because of their uncertain age or function (e.g., a pile of stones atop a boulder).[42] A total of 21 "find spots" were recorded in 1997, and more have been identified since. The total combined number of find spots identified in archaeological surveys of the MKSR to date is now 336.

[42] Prior to the 1997 survey, the term "find spots" had been used to refer to isolated artifacts (McCoy 1984a), which are not modern-era features. The current convention on Maunakea is that "find spots" are modern-era features.

3.11 TRANSPORTATION FACILITIES

3.11.1 ROADS

3.11.1.1 Saddle Road

Access to Halepōhaku and the MKSR is via the Mauna Kea Access Road. This roadway begins at an intersection on State Route 200, which connects Hilo to Māmalahoa Highway near Waikoloa, and extends over 16 miles to the summit. State Route 200 is almost universally referred to as "Saddle Road" because it crosses the island through the saddle between Maunakea and Maunaloa.

Saddle Road is just over 53 miles along. It terminates on the east at the Hawai`i Belt Road (State Route 19); its western terminus is at Māmalahoa Highway, Route 190. Saddle Road reaches an elevation of 6,632 feet at its highest; it is approximately 6,585 feet above sea level at its junction with the Mauna Kea Access Road.

As shown in Figure 3.17, at its intersection with the Mauna Kea Access Road, Saddle Road has one through lane in each direction and turn deceleration/storage lands allowing vehicles to move between the highway and the Mauna Kea Access Road to the north and the Pu`u Huluhulu parking area to the south.

Figure 3.17: Intersection of Mauna Kea Access Road with Saddle Road

Source: Google Earth (2014)

3.11.1.2 Mauna Kea Access Road

The Mauna Kea Access Road is 16.3 miles long, has two lanes, guard rails in places, limited shoulders, and slopes up to 20 percent. Halepōhaku is approximately 6 miles up Maunakea Access Road from Saddle Road, and the 4.6 mile long segment just past Halepōhaku is unpaved. The road is paved again above 11,600 feet. A portion of the loop is unpaved between the Keck Observatory and the SMA. The average right-of-way width is approximately 45 feet. A 4-wheel drive vehicle is recommended, but not required, for trips beyond Halepōhaku on Mauna Kea Access Road.

Table 3.19: Mauna Kea Access Road

Road Section	Paved		Unpaved	
	Length (miles)	Right-of-way Area	Length (miles)	Right-of-way Area
Saddle Road to Halepōhaku	6.3 mi	34 acre	—	—
Halepōhaku to the Summit	3.7 mi	20 acre	4.6 mi	25 acre
Summit loop	1.7 mi	9 acre	—	—
Total	***11.7 mi***	***63 acre***	***4.6 mi***	***25 acre***

Source: Table 3-2, NRMP.

The existing observatories have mostly short paved or unpaved driveways off the main road. The unpaved SMA service roadways are the most extensive roads other than the main Mauna Kea Access Road. One branch of the SMA road extends northward toward the area where the TMT Observatory is being constructed.

3.11.1.3 Existing Vehicle Traffic and Parking

3.11.1.3.1 Saddle Road

In 2013 the average daily traffic (ADT) on Saddle Road was approximately 1,990 vehicles. This has been projected to grow to nearly 4,200 by 2020 and 6,500 by 2034 (HDOT 2012). The State of Hawai`i has nearly completed extensive improvements to most of the route to accommodate the projected traffic volumes. The configuration of the existing Saddle Road/Mauna Kea Access Road intersection is a product of this improvement program.

3.11.1.3.2 Mauna Kea Access Road: Halepōhaku to Summit

The creation of Mauna Kea Access Road that provided for the relative ease of accessing the summit, has led to increased traffic on the mountain. Traffic associated with recreation and tourism has increased over the past several decades; this has included an increase in the number of organized commercial and educational tours. More than 100,000 people have visited the mountain per year over the past few years. In 2013, the total number of visitations in vehicles on the mountain was approximately 37,000, with about 6,700 2-wheel drive vehicles, 21,000 4-wheel drive vehicles (including 6,700 commercial tour vehicles), 9,200 observatory vehicles, and 100 motorcycles. This represents about 100 vehicular round-trips per day. The existing roads have sufficient capacity to handle this level of traffic.

Vehicle and visitor traffic to the summit can be particularly high on snow days, especially when they fall on weekends. Many people, especially local residents, visit the mountain only when there is snow. During the 19 days documented by OMKM rangers as snow days in 2007, a total of 2,547 vehicles were recorded on the mountain (134 per day). Presently, during periods of heavy snow, rangers keep the road closed at Halepōhaku until they receive confirmation that conditions are safe for visitors to precede up the mountain. Even though UH could restrict traffic on the Maunakea Access Road, the road is not closed or limited to daylight hours.

There are three visitor parking areas along the Maunakea Access Road above Halepōhaku. Parking Area 1 is located just after the paved road begins; Parking Area 2 is near the trailhead to Lake Wai`au; and Parking Area 3 is just past the junction of the access road and the summit loop, and is also known as the Batch Plant Staging Area.

These areas are shown on the map included in the safety brochure available to workers and visitors, but are not identified by signage on-site. At the summit, many visitors park near the UH 2.2-meter observatory if they plan to hike the summit trail. During the winter, before roads are fully cleared of snow and when there are large numbers of private vehicles in the summit area, parking becomes congested and visitors park their vehicles along the road wherever there is space. Commercial tour vehicles usually park in the area around the UH 2.2-meter observatory and Gemini observatory during the sunset viewing times. Observatory vehicles park in designated areas near their buildings. Parking Areas 1 and 2 are paved, but most other parking areas are graded but unpaved.

3.11.1.3.3 Mauna Kea Access Road: Saddle Road to Halepōhaku

The NRMP states that there are no data available for the number of vehicles making the trip from Saddle Road to Halepōhaku via the Mauna Kea Access Road. It speculates that it is likely to be more than double the number proceeding beyond Halepōhaku to the summit, as this accounts for the people that work at Halepōhaku and visitors that go the VIS but do not proceed to the summit, but no actual counts are provided to support this.

There are three main parking areas at Halepōhaku: (*i*) the cafeteria parking lot, (*ii*) the dormitory parking lot, and (*iii*) the VIS parking lot. There are other unpaved areas used for parking, including an area used by tours across the road from the VIS.

3.11.1.4 Mauna Kea Access Road Maintenance

The portion of the Mauna Kea Access Road above Halepōhaku is maintained by Maunakea Observatory Support Services (MKSS), which is made up of representatives of IFA, OMKM and the telescope operators. Although there is no official road maintenance plan, the unpaved portion of the road is graded approximately two times a week by MKSS to keep it drivable, and when necessary, cinder pieces fallen from the roadside are collected and used to fill in ruts. In the spring of 2008, MKSS brought in basalt gravel from a quarry at Pōhakuloa to use as a substitute for the cinder on the most severely washboarded areas.[43] This was the first time outside gravel has been used to cover the road surface (Koehler 2008) and this practice continues periodically. Other maintenance of the lower Mauna Kea Access Road that is either in progress or planned includes cleaning rocks and cinder from culverts, repairing retaining walls, and repairing erosion damage. In addition, soil additives designed to control dust (Durasoil and EK-35) have been approved by the MKMB Environmental Committee and applied to limited stretches of the unpaved road, all of the well below the summit (Koehler 2008). While both additives were found to reduce dust, they did not enable MKSS to decrease the frequency of grading, and MKSS does not intend to continue using them once the existing supply has been exhausted.

3.11.2 HARBORS

The State of Hawai`i Department of Transportation operates two deep-draft commercial harbors on Hawai`i Island. Hilo Harbor is situated on its northeast coast and Kawaihae Harbor located to the northwest coast. Nearly all the consumable goods, durables, building materials, and fuel used on the island arrive via one of these two facilities; most of it is transshipped there after first being offloaded at Honolulu Harbor on O`ahu. In 2008, cargo volume to Hawai`i Island reached 2.782 million tons and there were 1,674 vessel arrivals.

3.11.2.1 Hilo Harbor

According to the *Hawai`i Island Commercial Harbors 2035 Master Plan Update* (HDOT 2011), Hilo Harbor has three existing piers and a new pier and yard (Pier 4) to be constructed by 2015.

- Pier 1 is 1,265 feet long, has a yard area of 13.4 acres, and shed area of 81,635 square feet; it is is shared by cargo and cruise operators. Matson Navigation Company (Matson) services container barges at Pier 1 using top-pick and forklifts to move containers on and off of barges as needed; it also has a crane barge that typically arrives weekly from Honolulu. Pasha Hawai`i Transport Lines (Pasha) operates RO/RO movements at Pier 1. Pier 1 can accommodate cruise ships measuring up to 965 feet long, and the back side of Pier 1 where Radio Bay is located contains a number of berths for transient and other smaller vessels.
- Pier 2 is 703 feet long, has only 2 acres of yard space, and shed area of 37,884 square feet. It is used by cement barges and has a roll-on/roll-off (RO/RO) interisland barge facility.

[43] As recommended by the MKMB Environment Committee, the material was inspected for cleanliness and ants (MKMB Environment Committee 2007; Koehler 2008).

- Pier 3 is 763 feet long, has 7.3 acres of yard space and no shed; it is used primarily by fuel barges.
- The future Pier 4 will provide 602 feet of additional berth space and will have an expanded and upgraded yard for interisland cargo operations.

Combined cargo handling and storage area at Hilo Harbor is 13.65 acres.

3.11.2.2 Kawaihae Harbor

Kawaihae Harbor is located on the northwest coast of Hawai`i Island. Its basin measures 1,450 by 1,500 feet and has a depth of 35 feet. The entrance channel is 3,270 feet long and 500 feet wide. A 2,650 foot breakwater protects the harbor. Road access from the harbor to the remainder of the island is via Akoni Pule Highway (to the north), Kawaihae Road (to the east, and Queen Ka`ahumanu Highway to the south. It is located 28 miles north of Kona International Airport at Keahole.

Kawaihae Harbor has two piers.

- Pier 1 has 412 feet of berthing space, 4.6 acres of yard space and 8,300 square feet of shed space. It is used primarily by Hawaiian Cement, which unloads bulk cement from barges to a nearby storage facility using pneumatic pipelines. The north shed at Pier 1 is leased by Liquid Robotics for marine research. The south shed was vacant in 2010. Cattle transfer operations occur at Pier 1.
- Pier 2 has 1,150 feet of berthing space and 30.6 acres for storage and handling. Pier 2 is mostly used by interisland cargo and fuel barges. It is presently shared between Young Brothers and Matson, each of which presently typically send two barges a week to Kawaihae Harbor. Top-pick forklifts are used to load and unload containers from barges. One of the Matson barges, Mauna Loa, has its own ship-board equipment to load/unload containers.

In addition to these two piers, the US Army owns and operates a landing ramp at the coral stockpile area, which allows them to conduct military operations and transfer goods including troops, vehicles, and explosives. It is used by the 45th Army Corps Support Group (Forward) to off-load Logistics Support Vehicles (LSV) to be taken to Pōhakuloa Training Area (PTA). The off-loading generally occurs by dropping down a ramp from the shipping vessel, but at times they also make use of the state piers for this purpose. Kawaihae Harbor does not presently handle passenger traffic.

3.11.3 AIRPORTS

Two major airports serve the Island of Hawai`i. Both are owned and operated by the State of Hawai`i Department of Transportation. They are Hilo International Airport, which is situated on the eastern side of the town of Hilo, and Keahole International Airport, which is situated approximately ten miles south of the town of Kailua Kona.

3.11.3.1 Hilo International Airport

The passenger terminal complex, including commuter facilities, is at the southern edge of Hilo International Airport and is served by an access roadway from Hawai`i Belt Road at Kekūanaō‘a Avenue. The Airport has two runways.

- Runway 8-26 is 9,800 feet long and 150-feet wide and is used for nearly all air carrier operations. It is capable of accommodating overseas passenger service by aircraft as large as the Boeing 747 and is used occasionally by the Lockheed C-5 Galaxy, a military transport.
- Runway 3/21 is 5,600 feet long and 150-feet wide and is used for general aviation operations including take-off and landing of smaller commuter airplanes.

In 2010, there were 78,663 aircraft operations at the airport and approximately 1.28 million passengers passed through the facility. The main passenger terminal consists of three interconnected buildings totaling approximately 220,000 square feet. The apron fronting the passenger terminal has ten aircraft parking positions, but only eight of the positions are usable; two are used to provide eleven helicopter parking positions and there are just seven passenger loading bridges.

Over 25,000 tons of air cargo transited it as well, and this passed through the former passenger terminal, located on the western edge of Runway 3-21. The Northwest Apron, which serves this area of the airport, provides parking for transient military aircraft and is the site of some general aviation facilities. Other general aviation facilities are located to the south, near the Civil Air Patrol area. The commuter terminal is located in a small, stand-alone building a short distance to the west of the main passenger terminal.

3.11.3.2 Kona International Airport at Keahole

Kona International Airport at Keahole (KOA) occupies 3,450 acres of land about ten miles northwest of Kailua-Kona. The airport accommodates domestic overseas, international, interisland, commuter/air taxi, and general aviation activities. Covering approximately 2,700 acres of land, the airport's single runway (17/35) is 11,000 feet long and 150 feet wide runway. It is capable of handling the largest aircraft now operating with no takeoff or landing weight restrictions. Buildings along the eastern (mauka) side of the airfield include an open-air terminal complex for arriving and departing passengers, air cargo and mail, airport support and general aviation operations. An additional complex of facilities, used primarily by rental car agencies for returns, general maintenance and storage is located along the airport access roadway, midway between the passenger terminals and the main highway.

During 2013, there were just under 118,000 aircraft operations at the airport (an average of 323 operations per day. Approximately one-fifth (19 percent) of those were commercial aircraft consisting of interisland and overseas jet aircraft, 30 percent were local general aviation aircraft, 23 percent were air taxi, and 14 percent each were military and transient general aviation aircraft. A total of 59 aircraft were based at the airport; 39 were regular fixed-wing aircraft, 18 were helicopters, and 2 were ultralights.

3.12 EXISTING INFRASTRUCTURE

Underground power and communication lines supply Halepōhaku and summit facilities. The construction of power lines began in 1985, and once the lines reached Halepōhaku additional work was performed to provide the summit with power through an underground distribution system. This work was completed in 1988, and in 1995 an upgrade to the system added an underground distribution loop at the summit and provided service to the SMA observatory.

The communications system was installed together with the power system in 1985. Fiber optic cables were added in the 1990s, and the existing system allows for real-time communication between the summit facilities and on- and off-island headquarters offices, as well as an internet connection.

3.12.1 ELECTRICITY AND COMMUNICATION

3.12.1.1 Electrical Power Supply to Halepōhaku and MKSR

Electrical Power Generation. The electrical power that supplies the facilities at Halepōhaku and the MKSR comes almost entirely from the Hawai`i Electric Light islandwide grid.[44] The electricity is generated by a wide, and ever-changing array of generating facilities, an increasing proportion of which (over 40 percent in 2013, see Table 3.20) are powered by renewable sources of energy (wind, hydropower, geothermal, photovoltaic, etc.).[45]

[44] Only a few very small photovoltaic (PV) panels are present to supply power to isolated pieces of equipment which have low electrical power consumption.

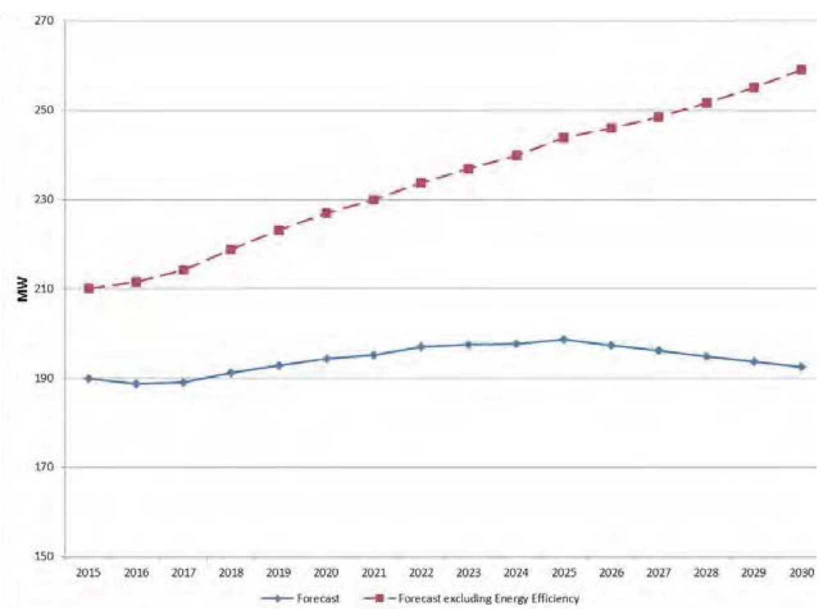
[45] In addition to utility-scale projects, more than 5,800 residential and commercial customers have photovoltaic, wind, and micro-hydro systems interconnected to the Hawai`i Electric Light grid, and these do not appear in the table.

Table 3.20: Hawai`i Electric Light Fuel Mix: 2013 Calendar Year*

Fuel Sources	*Percent of Total Energy*
Oil	59.46%
Coal	0
Biofuel	0
Biomass	0
Geothermal	24.28%
Hydro	3.05%
Solar	0.13%
Solid Waste	0
Wind	13.08%
TOTAL:	100%
Total Renewable	**40.54%**
*Note: Based on the amount of electricity generated by the Company and purchased from independent power producers.	
Source: http://www.hawaiianelectric.com/heco/Clean-Energy/Latest-Clean-Energy-News/About-Our-Fuel-Mix	

In addition to these existing renewable energy sources, Hawai`i Electric Light is continuing to substitute energy from renewable sources for fossil-fuel-fired energy wherever possible. Its forecasts of energy requirements as presented in the Hawaiian Electric Power Supply Improvement Plan dated August 2014 are shown in Figure 3.18.

Figure 3.18: Hawai`i Electric Light Peak Demand Forecast (Generation Level)



Source: Figure 4-6, Hawaiian Electric Power Supply Improvement Plan dated August 2014.

Electrical Power Delivery (Transmission and Distribution). Hawai`i Electric Light transmits electrical power from these generating sources through a 69 kilovolt (kV) overhead transmission line that feeds the Halepōhaku substation, which is located across Mauna Kea Access Road from Halepōhaku, in the saddle between Pu`ukalepeamoa and Kilohana. The substation consists of two 3,000 kilovolt-ampere (kVA) transformers, with a total capacity of 6,000 kVA (or 5,400 kilowatts (kW) assuming a system power factor of 0.9). An underground 12.47 kV dual loop feed system from the substation services the observatory facilities. The existing peak demand load documented by Hawai`i Electric Light at the substation, including all the observatories and the Halepōhaku facilities, is 2,230 kW, which is less than half the rated capacity of the substation.

The underground conductors from Halepōhaku to the summit region will be upgraded as part of the TMT project (the existing conduit will be used). Electrical service will be extended from the existing dual loop feed system near the SMA to the TMT site as part of that project as well.

In addition to this centralized supply source, certain observatories also have emergency diesel generators that, generally, are used to safely close down the facility in the event of a power outage on the Hawai`i Electric Light power distribution system; battery backup systems are also used to provide uninterrupted service if there are short power outages. .

3.12.1.2 Communications to Halepōhaku and MKSR

The first underground communications system was installed on the mountain at the same time the underground power distribution grid was installed. In the mid-1990s, the installation of underground fiber optic lines provided high speed communications capability to the observatories using a Hawaiian Telcom fiber cable. The fiber optic communications system services the same facilities as the power distribution system, and allows for data flow between the summit and off-mountain base facilities, thereby supporting remote observing. The system is installed along the same right-of-way as the electrical power cables discussed above. The system has more than sufficient capacity to accommodate voice and data transmission needs from the existing facilities both now and into the future.

3.12.2 SOLID WASTE GENERATION, COLLECTION, AND DISPOSAL

3.12.2.1 Solid Waste Generation and Storage

Solid waste is generated and collected at summit observatories and Halepōhaku facilities.[46] Solid waste and trash at the existing observatories is primarily generated from three sources: (*i*) ongoing observatory operational and maintenance activities, (*ii*) visitors, and (*iii*) construction activity. The summit area is maintained and kept free of trash, debris, and other wastes through regular maintenance and the proper removal and disposal of all solid waste from the mountain. All trash containers are required to be covered and secured to prevent providing a food source for invasive fauna and to reduce the possibility of escaping debris, which can occur during periods of high winds that occur frequently. The observatories are responsible for removing their trash from the summit. Trash from Halepōhaku and the dormitories is taken off the mountain daily by the MKSS housekeeping staff and brought to the main Hilo office where it is removed by sub-contractors daily.

The solid waste generated by each of the existing 11 observatories and one radio telescope was estimated to range from about 4 cubic feet per week generated by the Joint Astronomy Center (JAC) to up 160 cubic feet per week at the Keck Observatory. Each facility puts its trash in standard containers for transport and disposal off the mountain. Recent estimates are that approximately 4,400 gallons (16.7 kl) of solid waste per week are removed from the MKSR and Halepōhaku facilities for disposal at an off-site landfill (see Table 3.21). Additional material is generated over short periods during construction activities.

[46] Solid waste, as defined under Section 1004(27) of the Resource Conservation and Recovery Act (RCRA), refers to any discarded solid, semisolid, liquid, or contained gaseous materials.

Table 3.21: Solid Waste Generated by Existing MKSR Facilities

Facility	***Trash Produced***
UH (0.6-m) (24-in) and 2.2-m (88-in))	Two to three 30-gal bags weekly
CFHT	Four bins, 2 yd^3 each, generated monthly
NASA IRTF	Three 30-gal trash bags weekly
UKIRT and JCMT	About one 30-gal trash bag for both facilities weekly
CSO	About 2,000 lbs generated yearly
VLBA	One 30-gal bag weekly
W.M. Keck	3 yd^3 dumpster emptied 1 to 2 times weekly
Gemini North	Several 50-gal trash bags weekly
Subaru Telescope	40 lbs generated daily
SMA	Two to four 50-gal drums weekly
Halepōhaku Mid-Elevation Support Facilities	0.9 to 1.5 yd^3 daily
Source: Table 3-3, NRMP	

Solid waste at Halepōhaku primarily consists of food, paper products, and other packaging materials generated by the cooking and housekeeping staff as a result of the activities of Halepōhaku guests and visitors to the VIS; it is also generated by construction and maintenance activities. On average, less than 10 cubic yards of solid waste are produced weekly. All trash containers are required to be covered and secured to prevent providing a food source for invasive fauna and to reduce the possibility of escaping debris. Trash from Halepōhaku is taken off the mountain daily by the MKSS housekeeping staff and brought to the main Hilo office, where it is removed by the subcontractors, who transport it to the nearest sanitary landfill for disposal.

Human activities, including astronomy, tourism, and recreation, generate trash and other solid waste that has been collected in containers, removed regularly, and disposed of at authorized landfills. In the past, researchers reported occurrences of a considerable amount of trash left around the mountain and in response, MKSS began collecting the trash, including that left by visitors to the summit, and it is now rarely seen within the MKSR.

<u>*Hazardous Materials: Summit Area*</u>. Limited quantities of hazardous materials are used at the summit observatories for a variety of maintenance and cleaning operations, and these are handled separately from all other solid waste. Each observatory has a written procedure for safely, handling, and disposing of hazardous materials and emergency procedures for attending to spills. Table 3.22 identifies the hazardous materials used and stored within UH Management Areas, as well as the quantities of those materials normally stored or used. To date, there have been no mercury spills in the outside environment at the Maunakea summit. Also, since the 2000 Master Plan’s new rules were put in place there have been no spills inside any of the existing observatories.

Certain observatories also have fuel tanks for emergency generator diesel fuel which is stored on site. The size of the tanks varies with the size of the facility and associated generator. Potential secondary sources of contamination from generator equipment include waste oil and coolant (e.g., ethylene glycol, etc.). In the past, there have been instances in which cinder was contaminated and then excavated to contain the potential effects of the spill.

All telescope mirror washing activities are done in accordance with the current wastewater management protocols. The waste is contained and transported off the mountain for treatment and disposal. The mirror washing activities do not generate hazardous waste.

Table 3.22: Hazardous Materials Used and Stored at Observatories and Halepōhaku

Substance	*UH (0.6 m and 2.2 m)*	*Halepōhaku*	*SMA*	*Subaru*	*Gemini North*	*W.M. Keck*
Hydraulic Fluid	400 gal in use, 150 gal in storage; replaced every 5 years	Normally has less than 55 gal on hand; recycle 200 gal yearly	100 gal in use, 40 gal in storage	690 gal reservoir, 55 gal in storage	400 gal (1,500 l) in use; replaced as needed every several years	1,200 gal (4,500 l) in 55 gal use, (208 l) in storage
Paint and Related Solvents	About 38 10 gal on site, mostly spray cans; several used per month as needed	Solvent, 50 gal mostly in parts washer; recycled	Paint and primer 12 gal in use and storage; mineral spirits 2 gal in use and storage	None on site.	About 20 gal in storage; thinner, several quarts in storage; used maybe once per week	Various amounts on site; used as needed
Oil and Lubricant	Lube, 20 to 30 gal	Oil, less than 50 gal in storage; less than 200 gal of used oil is generated yearly	Engine oil, 9 gal in use, 10 gal in storage; lubricant 10 lbs in use, 10 lbs in storage	Lubricant for periodic service of backup generator, none stored onsite	Grease, about 50 lbs; oils about 100 gal in storage	Oil, 1,000 gal in use, 100 gal in storage
Mercury	Primary mirror support for 2.2-m only, 30 lbs in use, 20 in storage	No mercury used	No mercury used	No mercury used	No mercury used, other than a few thermometers	1.4-m secondary mirror support; 13 lbs in use, 17 lbs in storage

Source: Table 3.10 of the TMT Final Environmental Impact Statement

Hazardous waste, as defined by the EPA (Title 40 of the CFR, Chapter 1, Subchapter I-Solid Wastes, Part 261-299), refers to substances that have "imminent and substantial danger to public health and welfare or the environment." The regulations provide criteria to define a waste a "characteristic" hazardous waste and a listing of "listed" hazardous wastes. Only small quantities of hazardous waste are generated by the observatories and are periodically transported to permitted treatment and disposal facilities. The volume of hazardous waste generated does not require any of the observatories to register as other than conditionally exempt of small quantity generators of hazardous waste.

Hazardous Materials: Halepōhaku. Hazardous materials are used at Halepōhaku for a variety of maintenance and cleaning operations, and primarily consist of fuel that is used by dormitory operations and transportation and road maintenance equipment. Halepōhaku has three Underground Storage Tanks (USTs): an 11,500 gallon tank for diesel fuel and a 2,000 gallon tank and 4,000 gallon tank for gasoline. In 1997 the USTs, which are located in front of the maintenance utilities shop, were retrofitted with a 24-hour a day leak sensor monitoring system that is checked daily. No releases have been reported from any of these USTs.

Observatory operations on Maunakea have required the use of hazardous materials, and generated waste from such materials; these include paint, solvents, vehicle and generator fuel, lubricants, hydraulic fluid, glycol coolants, acids, and mercury. A small number of mercury spills have occurred since observatory operations began; the best available information regarding such occurrences suggests that none of the spills reached the outside environment impacted soil or groundwater.

The limited amounts of hazardous wastes generated on UH Management Areas are placed in containers and removed from the mountain by licensed transport, treatment and disposal contractors to an offsite disposal facility. No hazardous wastes are disposed of within UH Management Areas.

3.12.2.2 Solid Waste Collection and Disposal

Solid waste generated by operation of the existing facilities within the MKSR and Halepōhaku is collected and stored at each of the facilities until it can be picked up (currently on a twice-weekly basis) by a private contractor and trucked off the mountain for disposal. Nearly all of that material is currently hauled to the West Hawai`i Sanitary Landfill (WHSL) located at Pu`uanahulu in North Kona, West Hawai`i.[47] The *County of Hawai`i Integrated Resources and Solid Waste Management Plan Update* (County of Hawai`i December 2009) estimates that WHSL has sufficient capacity to accommodate the solid waste that is generated on the island for at least the next several decades.

3.12.3 WATER, SANITARY SEWER, AND COMMUNICATION SYSTEMS

3.12.3.1 Potable Water

MKSS contracts with a trucking company to deliver potable water from Hilo to the summit observatories in 5,000-gallon-capacity tank trailers that are owned by MKSS. Each observatory stores its own water and is responsible for the maintenance of its water tanks; observatories also use 5-gallon water jugs for drinking water. The NRMP reports that water was being trucked to the summit about twice a week and potable water use averaged approximately 500,000 gallons per year over the past several years.

3.12.3.2 Wastewater Collection, Treatment, and Disposal

Domestic wastewater and refuse liquids, including mirror washing wastewater, are the primary sources of wastewater generated by activities in the MKSR. Keck, CFHT, Gemini, Subaru, and the UH 2.2-meter observatories have facilities to conduct mirror washing and/or recoating activities. The other observatories bring their mirrors to one of those observatories for washing and recoating. All mirror-washing effluent is collected and trucked off the mountain for off-site treatment and disposal. Each observatory operates its own wastewater system to collect and treat domestic wastewater, pursuant to the permits issued by the Hawai'i State Department of Health (HDOH). Existing restroom facilities at the summit available for visitor use include four portable toilets and the restrooms located in the Keck Observatory. The portable toilets are located at two different parking areas and are moved between the sites as needed. Portable toilets are serviced weekly and pumping is done on-site.

3.13 EMPLOYMENT AND ECONOMIC ACTIVITY

3.13.1 OVERVIEW OF REGIONAL DEMOGRAPHICS AND ECONOMY

The MKSR and Halepōhaku are located in the Hāmākua District of the County of Hawai`i. Table 3.23 shows the resident population by district in 2000 and 2010 as reported by the U.S. Census. The Hāmākua District's April 1, 2010 resident population of 6,513 accounted for roughly 0.4 percent of the state's resident population; the County of Hawai`i's total population of 185,079 accounted for approximately 13.6 percent of the state's resident population.

With approximately 3.5 percent of the island's total population, Hāmākua, North Hilo, and the North Kohala District are the least populated of the island's nine districts. With a population growth of only a half percent per year, it is also one of Hawai`i County's slowest-growing regions. Sugar was the leading industry in along much of the Hāmākua Coast for nearly a century, but the closure of the last sugar plantation in 1994 ended that source of economic activity, and since that time it has relied on small-scale farming, ranching, and tourism. Honoka`a town has two grocery stores, a couple of convenience stores, a hardware store, several restaurants, and other small shops and service-oriented businesses.

[47] The South Hilo Landfill has a very limited remaining capacity and is slated for closure within the next few years.

Table 3.23: Resident Population of Hawai`i Island by District: 2000 and 2010

Area	*April 1, 2000*	*April 1, 2010*	*Percent change*	
			1990 to 2000	*2000 to 2010*
Hāmākua	6,108	6,513	10.2	6.6
Puna	31,335	45,326	50.8	44.6
South Hilo	47,386	50,927	6.2	7.5
North Hilo	1,720	2,041	11.6	18.7
North Kohala	6,038	6,322	40.7	4.7
South Kohala	13,131	17,627	43.7	34.2
North Kona	28,543	37,875	28.1	32.7
South Kona	8,589	9,997	12.2	16.4
Ka'u	5,827	8,451	31.3	45.0
Hawaii County	148,677	185,079	23.6	24.5
State total	1,211,537	1,360,301	9.3	12.3

Note: The Hāmākua District consists of Honoka`a, Kapulena, Kukuihaele, Haina, Pā`auhau, Āhualoa, Kalōpā and Pa`auilo areas.

Source: State of Hawai`i 2011, Table 1.12.

The town of Hilo, which was once the center of economic activity on the island, has seen its relative importance diminish as tourism has replaced agriculture as the largest economic driver on the island, but with a 2010 population of 43,263, the Hilo Census Designated Place (CDP) remains by far the largest urban center (see Table 3.24 for the resident population of Hawai`i Island CDPs with a year 2010 population greater than or equal to 2,000).

Population Growth Rate. Hawai`i County's population increased by 36,400 persons between 2000 and 2010, an average of nearly 2.1 percent per year, compounded. That growth rate was about twice the statewide average for the period. The County of Hawai`i has been the most attractive county to in-migrants during recent years. Based on a survey conducted in 2012, a little more than 30 percent of the population increase resulted from in-migrants from another state; roughly two-thirds consisted of people who moved to the Big Island from another county in the state, and only 4.4 percent of the new arrivals in that year were from abroad.

Ethnicity. Together, Hawaiian/part-Hawaiian (32.8%), Japanese (10.0 percent), mixed/not-Hawaiian (24.4 percent), and Caucasians (26.0 percent) comprised over five-sixths of the island's residents in 2010 (Table 1.40, State of Hawai`i Data Book).[48]

[48] The ethnicity reported in this data series is based on the ethnicity of the father and mother (four possible listings for each parent). For the Census 2000 and the 2010 Census, people were allowed to select more than one race. The tabulation reported in this source is from the Hawai`i State Department of Health, Office of Health Status Monitoring, special tabulation from the Hawaii Health Survey.

Table 3.24: Resident Population of Hawai`i Island CDPs with 2010 Population Greater than or Equal to 2,000

2010 Census Designated Place	*Population*	*House-holds*	*Average household size*	*No. of Families*	*Average family size*
Hilo	43,263	15,483	2.69	10,287	3.20
Kailua	11,975	4,196	2.74	2,720	3.29
Hawaiian Paradise Park	11,404	3,892	2.93	2,743	3.39
Kalaoa	9,644	3,434	2.80	2,353	3.18
Waimea	9,212	3,150	2.85	2,260	3.30
Hōlualoa	8,538	3,433	2.49	2,131	2.95
Waikoloa Village	6,362	2,334	2.72	1,607	3.16
Hawaiian Ocean View	4,437	1,759	2.52	989	3.30
Hawaiian Beaches	4,280	1,471	2.91	1,025	3.40
Mountain View	3,924	1,318	2.98	966	3.42
Kahalu`u-Keauhou	3,549	1,456	2.37	957	2.75
Captain Cook	3,429	1,258	2.73	859	3.20
Ainaloa	2,965	1,005	2.95	708	3.43
Orchidlands Estates	2,815	1,011	2.78	652	3.38
Hawaiian Acres	2,700	1,119	2.41	637	3.09
Volcano	2,575	1,228	2.10	652	2.78
Hōnaunau-Napo`opo`o	2,567	932	2.75	613	3.25
Honalo	2,423	800	2.98	551	3.38
Honoka`a	2,258	751	2.91	529	3.46
Kea`au	2,253	701	3.20	522	3.68
Kealakekua	2,019	749	2.66	468	3.25
Island Total	***185,079***	***67,096***	***2.70***	***44,407***	***3.22***
Source: State of Hawai`i 2013, Table 1.13.					

<u>*Labor Force, Employment, and Wages*</u>. In the 2008-2012 period, the labor force in Hawai`i County averaged a little more than 91,000 (see Table 3.25). The unemployment rate averaged 9.6 percent during those years, more than 40 percent higher than the Statewide average of 6.7 percent and 65 percent higher than the average unemployment on O`ahu. Nearly all of the jobs were in the civilian sector, as there were fewer than 200 armed forces-related jobs on the island during that period. In 2010, approximately 15 percent of the jobs were in the government sector and 85 percent in the private sector (see Table 3.26). The public sector/private sector ratio is declining, so that by the year 2040 it is expected to be closer to 12 percent government and 88 percent private sector.

The average annual wage in Hawai`i County in 2012 was $34,054. This represented only 80 percent of the $42,944 per year average annual wage reported for O`ahu and gave Hawai`i County the distinction of having the lowest average annual wages in the State during that year.[49]

[49] The City and County of Honolulu average was $42,944, the Maui County average was $36,546, and the Kauai County average was $35,681.

Table 3.25: Selected Labor Force Characteristics: Hawai`i Island 2008-2012

Subject	*State*	*Hawaii County*
Population 16 years and over	1,093,852	148,314
Total Persons In labor force	727,728	92,167
Persons in Civilian labor force	688,508	92,001
Persons Employed	642,284	83,150
Persons Unemployed	46,224	8,851
% unemployed	6.7	9.6
Persons in Armed Forces	39,220	166
Not in labor force	366,124	56,147
Note: U.S. Census Bureau, 2008-2012 American Community Survey 5-Year Estimates, Selected Economic Characteristics: 2008-2018 Hawaii, counties, and places as extracted by Hawaii State Department of Business, Economic Development & Tourism, Hawaii State Data Center, American Community Survey 2012 Hawaii Geographic Area Profiles (5-Year Estimates) "DP03: Selected Economic Characteristics". Figures are averages for the period.		
Source: State of Hawaii Department of Business, Economic Development, and Tourism 2012. Table 12.03.		

Table 3.26: Hawai`i County Jobs Existing & Forecast by Sector and Type: 2010–2040

Year	*Total civilian jobs*	*Jobs by Sector*		*Jobs by Type*	
		Private	*Government*	*Wage and salary*	*Self-employed*
2010	**93,927**	**79,769**	**14,158**	**66,310**	**27,610**
2015	102,880	87,940	14,940	70,990	31,890
2020	112,230	96,440	15,790	75,660	36,570
2025	121,620	104,960	16,660	80,070	41,550
2030	131,430	113,860	17,570	84,520	46,910
2035	141,390	122,960	18,430	88,810	52,580
2040	151,690	132,400	19,290	93,090	58,600
Note: 2010 is actual data from the U.S. Bureau of Economic Analysis, Regional Economic Accounts, State Personal Income series. (http://www.bea.gov/regional/index.htm) with DBEDT estimate for counties. Compiled by the State of Hawai`i Department of Business, Economic Development & Tourism, Population and Economic Projections for the State of Hawaii to 2040 (March 2012), Appendix Tables A-42 to A-56 (http://hawaii.gov/dbedt/info/economic/data reports/2040-long-range-forecast, accessed April 2, 2012.					
Source: DBEDT *2013 State of Hawai`i Data Book*, Table 12.16.					

3.13.2 MKSR-RELATED EMPLOYMENT AND ECONOMIC ACTIVITY

3.13.2.1 Introduction

The Institute for Astronomy (IfA) was founded at UH in 1967 to manage the Haleakalā Observatory on Maui and to guide the development of the Maunakea Observatories on Hawai`i Island, as well as to carry out its own program of fundamental research. Several UH departments conduct research programs and offer degrees in astronomy, and five public astronomy-related facilities are open to the public on O`ahu and Hawai`i Island (Bishop Museum Planetarium, Aerospace Lab and Planetarium at Windward Community College, Maunakea Observatory VIS, `Imiloa Astronomy Center of Hawai`i, and Onizuka Space Center).

The Economic Research Organization at the University of Hawai`i (UHERO) has analyzed the economic impact of astronomy in Hawai`i. Its August 28, 2014, report (Burnett et al., August 28, 2014) estimates that the IfA presently has a total staff of 250, including 55 faculty members, and an annual budget of $32.5 million. Of that amount approximately $10.5 million is from funds appropriated by the State of Hawai`i while $22 million is made up of external funds, mostly federal grants and contracts. Astronomy activity in Hawai`i also creates jobs for hundreds of people in related industries, purchases goods and services from local businesses, and invests in capital improvements. The UHERO report notes that the research and education components also contribute to Hawai`i through investment in human capital and the spillovers of knowledge important in a budding technology and innovation community.

IfA shares responsibility for the UH Mānoa graduate astronomy program with UH's Department of Physics & Astronomy. In fall 2012, the program had 45 students working for MS or PhD degrees. In addition to teaching and advising graduate level research, IfA provides research opportunities to undergraduate students. Beginning in 2015, IfA will offer undergraduate degree programs in astronomy and astrophysics. The UH Mānoa College of Engineering also engages in some space-related activities, including the Small Satellite Program, which was established in 2001.[50]

UHERO's analysis used survey data collected from the IfA, UH Mānoa, UH Hilo, and other astronomy-related entities in Hawai`i in an input-output analysis to estimate astronomy's contribution to local business sales, employee earnings, tax revenues, and number of jobs throughout the State.[51] Its report notes:

> *Currently, UH Hilo offers the only undergraduate astronomy major in the state of Hawai`i and tops the nation in the number of undergraduate astronomy degrees awarded per year (44 students were declared astronomy majors in Fall 2012).[52] The program emphasizes training in observational astronomy, physics, mathematics, and computer science. Astronomy majors get hands-on experience by participating in research that makes use of the University Park of Science and Technology and the Hubble Space Telescope. Students also benefit from the astronomy department's numerous international collaborations, including the All-sky Survey High Resolution Air Shower (ASHRA) cosmic ray detection program, the Panoramic Survey Telescope and Rapid Response System (PanSTARRS) asteroid detection system, the Pacific International Space Center for Exploration Systems (PISCES) that focuses on sustainable human habitats for the Moon and Mars, and the Taiwan-American Occultation Survey (TAOS) that studies the outer solar system.*

Astronomical research is an international undertaking, and a number of foreign countries conduct research at the MKSR. These include Canada, France, the United Kingdom, Japan, Argentina, Australia, Brazil, Chile, Taiwan, Korea, and soon China and India. The University shares in the scientific use of all of the telescopes, except the VLBA, at the level of 10-15 percent of the observing time. This use is available to anyone within the UH system who has a valid proposal; the observing time is awarded on a competitive basis. The observatory base facilities are located at lower elevations such as Waimea and Hilo, where hundreds of employees contribute to the local economy. The research facilities also participate in outreach activities such as field trips, stargazing programs, class-room visits and science nights at libraries.

[50] Sponsored by NASA's Educational Launch of Nanosatellites Program, 30 engineering students have spent the past three years designing and building a cube satellite, dubbed Ho`oponopono 2 (or H2), to calibrate and monitor radar stations that track objects in space.

[51] In order to accurately quantify the economic impact of astronomy, the input-output framework requires information about expenditures for all astronomy-related activities through-out the State. The scope of astronomy includes mountaintop observatory activities, astronomy research including instrument development and assessment, graduate and undergraduate astronomy programs, astronomy spin-off companies, bookstore operations, visitor operations, and the `Imiloa Astronomy Center of Hawai`i.

[52] Of the 35 departments where the bachelor's degree was the highest astronomy degree offered, only five averaged five or more degrees annually from 2008-2010. UH Hilo was at the top of that list with an annual average of 10 degrees per year (http://www.aip.org/statistics/trends/reports/astro2010.pdf).

While most astronomy facilities focus on generating research and providing community outreach from a purely scientific standpoint, the `Imiloa Astronomy Center of Hawai`i was designed specifically to promote the integration of modern astronomical science and the Hawaiian culture. Open since 2006, the $28 million, 42,000-square-foot exhibition and planetarium complex is located within UH Hilo. Since opening, it has served thousands of students through educational programs including field trips, family workshops, afterschool programs, other extra-curricular activities, robotic tournaments, and overnight sleepover events.

The observatories typically either develop their instruments in-house or outsource them to out-of-state companies or labs. Some, however, contribute to the Hawaii Island economy by requesting services from astronomy spinoff companies located on the island. For example, Mauna Kea Infrared (MKIR), LLC has been building custom hardware since 1985. Its 3,500-square-foot facility in Hilo is equipped with instrument design, assembly, and testing areas, and its biggest project to date was a $4 million coronagraphic camera for the Gemini South 8-m Telescope in Chile. GL Scientific, Inc. in Honolulu designs, manufactures, and services precision scientific instruments and custom components, many of which are used for astronomy research conducted elsewhere in Hawai`i, especially on Maunakea.[53]

Astronomy has become a local industry, and has provided significant economic and educational benefits to the State and local communities. The majority of the funding for the construction and operation of the observatories has been provided by organizations outside of the state. At least one-third of the funds for construction were spent on local services; more than 80 percent of the operating funds are spent in Hawai`i, mostly within the County of Hawai`i. Payments of fees and tax obligations by the observatories flow into the State and the County on an annual basis, as do payments for utilities and other services. The staff and other employees contribute to the local economy directly through income tax and other payments, and indirectly through purchases of local goods and services.

Of the approximately 600 people currently employed by the existing observatories, it is estimated that roughly half moved to Hawai`i, and about half of the employees were already in Hawai`i when they began working for the observatories. The astronomy sector of the local economy has provided the County of Hawai`i with many beneficial social and education opportunities that would otherwise not exist. These include programs such as the Observatory Directors Lecture Series, the Universe Tonight program at the VIS, the Astronomy Educators in the Classroom program, the activities and facilities at `Imiloa, the Doing Astronomy with Kūpuna program, and astronomy internship programs. In addition, the astronomy community helps sponsor a number of non-astronomy events in the community.

3.13.2.2 Methodology and Data Used in UHERO Analysis

The astronomy sector generates economic activity in the community through local business sales, employee earnings, tax revenues, and job creation. UHERO used data on labor earnings and astronomy-related expenditures for three major spending categories – astronomy operations, students and visitors – to calculate the total local expenditures by industry (see Table 3.27. It classified expenditure types using the North American Industry Classification System (NAICS) industry descriptions and estimated the total amount of economic activity generated in each county using the 2007 inter-county input-output (I-O) model of Hawai`i's economy.[54]

[53] Customers include Gemini Observatory, Canada-France-Hawaii Telescope Corporation, W.M. Keck Observatory, University of California, and California Institute of Technology.

[54] An I-O model accounts for all sales and purchases made by firms in each sector of the economy, thus creating a comprehensive picture of the interdependence among industries in the economy.

Table 3.27: Total Local Expenditures

Industry	***Expenditure***	***Industry***	***Expenditure***
Agriculture	$614,000	Real estate and rentals	$15,711,000
Mining and construction	$928,000	Professional services	$4,485,000
Food processing	$1,438,000	Business Services	$1,089,000
Other manufacturing	$3,847,000	Educational Services	$1,788,000
Transportation	$2,878,000	Health Services	$9,737,000
Information	$2,425,000	Arts and Entertainment	$1,100,000
Utilities	$9,561,000	Accommodation	$4,522,000
Wholesale trade	$4,638,000	Eating and Drinking	$2,151,000
Retail trade	$11,877,000	Other services	$3,960,000
Finance and insurance	$3,102,000	Government	$2,241,000
		TOTAL	***$88,093,000***

Source: UHERO 2014, Table 1.

Astronomy Operations. In collaboration with the IfA, a survey was designed to obtain information from astronomy related entities about in-state expenditures for the calendar year 2012. Expenditure categories included salaries and wages, rent on facilities and equipment, capital purchases, supplies, information services, utilities, professional services, repair and maintenance, and construction. Data was collected from numerous sources.[55] UHERO researchers organized the collected expenditure data by county and by spending category, each of which corresponds to one of 20 industries, and then aggregated individual responses for each industry-county combination. In order to calculate the economic impacts, they then converted the in-state retail level expenditure data produced by the survey into producer level expenditures by industry categories.

The survey on astronomy related in-state expenditures included specific questions on total salaries and wages, employee benefits, retirement contributions, and FICA taxes, and net labor earnings were calculated using this information for each county as the sum of wages, salaries, and benefits, less FICA taxes. Total labor earnings in each county were then adjusted for out-of-state imports (14.6% for all counties) and within-state imports (4.4% for Honolulu and 13.8% for Hawai`i). Because a substantial portion of labor earnings are injected back into the economy in the form of household purchases of goods and services, within-state imports for each county were redistributed across 20 industries in that county using fixed personal consumption expenditure (PCE) shares calculated from the 2007 Hawai`i Inter-County I-O Transactions table.

Student Expenditures. There are three astronomy degree programs in Hawai`i: the UH Mānoa MS and PhD programs and the UH Hilo undergraduate program. Fall 2012 enrollment data for each of the programs was obtained from the UH System Institutional Research and Analysis Office Data Portal. The number of students from each county, 45 and 44 for Honolulu and Hawai`i respectively, was then multiplied by average spending by category –"graduate student on O`ahu" for PhD students and "undergraduate student on all neighbor islands" for undergraduate students – to calculate total student expenditures in each of the 20 NAICS-classified industries.

Visitor Expenditures. UHERO's visitor expenditure estimates were based on visitors who came to Hawai`i specifically (and solely) to work at astronomy facilities. The analysis used data on the number of astronomy facility work visits and average duration of stay collected by the IfA to calculate total astronomy visitor spending (this was done by multiplying the total number of person-days in each county by the corresponding 2012 visitor average personal daily expenditures in that

[55] These included observatories on Mauna Kea and Haleakalā, other astronomy research facilities, MKSS, OMKM, the UH Mānoa graduate astronomy program, the UH Hilo undergraduate astronomy program, the 'Imiloa Astronomy Center of Hawaii, astronomy spin-off companies in Hawai`i, and the Visitor Information Station at Halepōhaku.

county).[56, 57] Within-state imports for each county were redistributed across 20 industries in that county using fixed visitor expenditure (VE) shares calculated from the 2007 Hawaii Inter-County I-O Transactions table.[58]

Finally, total local expenditures by county were calculated as the sum of operations, student, visitor, and personal consumption expenditures, adjusted for out-of-state and in-state imports. Type-II inter-county total requirement tables[59] were used to calculate economic impacts for each county in terms of output, earnings, taxes, and jobs.[60] The inter-county type II "multipliers" capture the direct, indirect, and induced effects per dollar of spending in each sector of Hawai`i's economy.

3.13.2.3 UHERO Estimate of Economic Impact of Astronomy Expenditures

UHERO estimates that in calendar year 2012, astronomy related local expenditures totaled $88 million. It also calculated that, together with additional indirect and induced benefits from these activities, astronomy had a total impact of nearly $168,000,000 million on Hawai`i's economy. Those expenditures generated:

- $52.26 million employee earnings,
- $8.15 million in state tax revenues, and
- 1,394 jobs.

The UHERO report estimates that nearly 70% of local spending occurred in Hawai`i County. The $58.43 million of expenditures attributed to astronomy activities on that island alone generated $91.48 million in local business sales (or 55% of the total impact on the business sales), $27.98 million in employee earnings (or 54% of the total effect), $4.00 million in state tax revenues (50% of the total effect), and over 800 jobs or 60% of the total effect.

UHERO also disaggregated the total effect by industry, and the resulting breakdown of the initial local spending and the overall impacts on the state of Hawai`i by industry are shown in Table 3.28. Most of the astronomy activity spending occurred in the real estate and rentals industry (17.84%), the retail trade sector (13.48%), and the health services sector (11.05%).[61]

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[56] Total expenditures were adjusted in each county for out-of-state imports (15.5% for all counties) and within-state imports (using County-specific percentages of 1 percent and 15 percent for Honolulu and Hawai`i Counties, respectively).

[57] A more complete visitor expenditure calculation would include data on tourist visitors who spent a portion of their vacation participating in astronomy related activities. However, identifying the proportion of total vacation spending attributed to astronomy activities by persons who participated in other visitor activities while here would be very difficult, and so this element is not accounted for in the analysis. Consequently, the methodology underestimates the economic impact of astronomy-related visitor expenditures.

[58] The transaction table is part of the "2007 Hawaii Inter-County I-O Study," Department of Business, Economic Development, and Tourism, May 2012 and can be downloaded at http://dbedt.hawaii.gov/economic/reports_studies/2007-inter-county-io/

[59] A total requirements table is a matrix of coefficients showing the sum of direct and indirect purchases required to produce one dollar of output, one dollar of earnings, one dollar of taxes, or one job.

[60] Each 80×80 requirement table was multiplied by the corresponding local expenditures in county-industry, resulting in four 80×80 matrixes. For a given impact category (e.g., output), total impact for county X was calculated by summing across all rows corresponding to that county (20 rows and 80 columns), i.e., summing over all industries. Total impact for industry Y was calculated by summing all elements for industry Y (4 rows and 80 columns), i.e., over all counties.

[61] The impact this spending has on the state is not directly proportional to the spending due to structural differences in the way each sector allocates spending throughout the state and the four counties. Two examples help illustrate this point: (1) while expenditures to the retail sector was over 13% of total, the output to the state resulting from this was less than 10%; (2) the "other manufacturing" sector saw just over 4% of total spending but had an output impact to the state of almost 9%. The differences in these two result largely from the fact that in many cases most of the funds received from retail sales go directly out of state to pay for the goods that are sold, dollars that go to the manufacturing sector may go largely towards paying for the produced good in Hawaii and/or may generate larger indirect and induced effects.

Table 3.28: Total Local Expenditures by Industry

Industry	*Local Expenditure (%)*	*Industry Share (%)*			
		Output	*Earnings*	*State Taxes*	*Jobs*
Agriculture	0.70	0.77	0.53	0.33	2.08
Mining and construction	1.05	1.61	1.77	1.73	1.16
Food processing	1.63	1.31	1.63	0.65	1.74
Other manufacturing	4.37	8.94	2.51	1.19	1.97
Transportation	3.27	3.15	3.28	2.43	2.85
Information	2.75	3.08	2.63	2.89	2.00
Utilities	10.85	8.01	3.09	4.88	1.20
Wholesale trade	5.27	4.28	5.49	10.90	4.12
Retail trade	13.48	9.88	11.04	12.15	14.91
Finance and insurance	3.52	4.75	3.90	3.68	3.49
Real estate and rentals	17.84	19.91	4.54	14.04	6.65
Professional services	5.09	4.99	8.58	7.08	7.10
Business Services	1.24	3.69	6.26	5.28	7.49
Educational Services	2.03	1.50	3.12	2.28	3.96
Health Services	11.05	9.43	15.53	1.30	12.51
Arts and Entertainment	1.25	0.94	1.80	7.01	2.83
Accommodation	5.13	3.16	3.85	3.45	2.74
Eating and Drinking	2.44	2.66	3.32	4.26	5.45
Other services	4.50	4.68	7.82	2.19	10.31
Government	2.54	3.26	9.32	2.58	5.43

Source: UHERO 2014, Table 3.

In 2012, the output related to astronomy was about half that estimated for the agriculture, forestry, fishing, and hunting sector; one-third the size of the output from the arts, entertainment, and recreation sector; and nearly one-fourth of the output attributed to either the educational services or the management of companies and enterprises sectors. The total impact of astronomy to the state is nearly twice the size of the impact estimated for the Natural Energy Laboratory Hawaii Authority Tenants and larger than the impact of the UH Maui and Kaua`i systems combined.[62] It is also approximately one-third the size of the UH system's impact on Hawai`i County.

3.14 PUBLIC SERVICES AND PUBLIC FACILITIES

3.14.1 PUBLIC SAFETY

3.14.1.1 <u>Fire Protection</u>

The Hawai`i County Fire Department provides multiple emergency services for the island, including fire suppression, emergency medical services (EMS), land and sea rescues, vehicular and other extractions, and hazardous materials mitigation. The county is divided into two battalion areas, east and west, with one Assistant Fire Chief for each battalion area. There are twenty full-time fire/medic stations and twenty volunteer fire stations, with over sixty pieces of equipment available for a variety of emergencies that may occur on the island.

3.14.1.2 <u>Police Protection</u>

The Hawai`i County Police Department provides law enforcement for the island; operations are separated into two areas of the island. Area I covers the eastern side of the island and includes the

[62] "The Economic Impact of the University of Hawaii System," University of Hawai`i Economic Research Organization, April 2013.

districts of Hāmākua, North Hilo, South Hilo, and Puna, and is home to Police Headquarters and four stations; Area II covers the western side of the island and includes the districts of North Kohala, South Kohala, Kona, and Ka`ū, with five stations located throughout the districts. Each of the two areas is run by a Commander, and each district in the county is headed by a captain. The most recent data presented in the County of Hawai`i Data Book is for the year of 2006, and lists the per capita ratio of resident population to police officers at 425 to 1; there is no further breakdown of the number by district.

3.14.1.3 Resource Protection

The Maunakea Ranger program operated by OMKM provides daily oversight of activities on UH managed lands, protecting the resources and providing for public safety. A key responsibility is informing visitors about the cultural, natural and scientific significance, as well as the hazards of visiting the mountain. The Rangers conduct daily patrols of the area between the mid-level facilities and the summit, providing emergency assistance, assisting stranded motorists, coordinating litter removal, conducting trail maintenance, inspecting the observatories for compliance with their Conservation District Use Permits, and providing visitors with cultural information about Maunakea.

3.14.2 EDUCATIONAL FACILITIES

There are over 40 public, 12 charter, and 19 private schools located around the island; some serve grades K-12, while others serve only certain grade levels. State of Hawai`i Department of Education enrollment for the 2014-2015 school year is shown in Table 3.29. They indicate that there are nearly 23,000 students enrolled in public schools during the 2014-2015 school year. An estimated 2,500 students are enrolled in charter schools and nearly 4,000 are in private schools on the island.

UH Hilo is one of the ten branches of the UH system. Its main campus is located at 200 West Kawili Street, Hilo. UH Hilo is composed of six colleges, and has received recognition for numerous academic programs including the marine biology, volcanology, astronomy, Hawaiian language, pharmacy, agriculture, computer science, and nursing programs. Ka Haka ‘Ula O Ke‘elikōlani, College of Hawaiian Language is the only school in the United States to offer graduate degrees for study in an indigenous language, and the Daniel K. Inouye College of Pharmacy is the only ACPE-approved pharmacy school in the State of Hawai‘i and the Pacific Islands. During the 1990s, UH Hilo's University Park of Science and Technology opened on campus under UH Hilo management. The first tenants, Joint Astronomy Centre, were several base facilities for international observatories with telescopes on Maunakea. In 2006, UH Hilo opened its `Imiloa Astronomy Center of Hawai`i.

3.14.3 RECREATIONAL FACILITIES

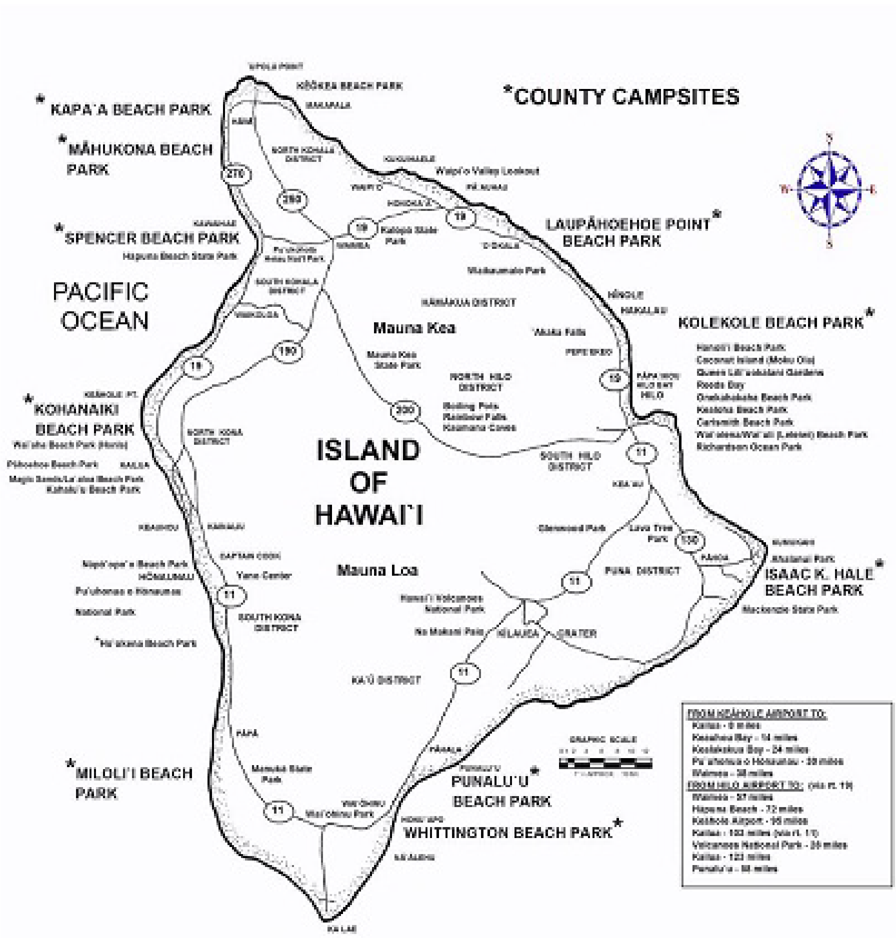
The County of Hawai`i, State of Hawai`i, and National Park Service own and operate numerous parks, swimming pools, and senior and community centers on the island. . Public school facilities are also available to the community as recreational facilities when school is not in session. Figure 3.19 shows the location of county facilities as of early 2014. State of Hawai`i parks and campgrounds are listed on the right-hand side of Figure 3.19. The UH Management Area can also be considered a recreational area. It is open to the public and provides opportunities for recreations, including hiking, sightseeing, and skiing.

Table 3.29: Hawai`i Island Public Schools

District	*School*	*K-6 Total*	*Jr. HS Total*	*HS Total*	*SED Total*	*Grand Total*
Hilo-Waiākea	De Silva	416	0	0	25	441
	Ha`aheo	182	0	0	10	192
	Hilo Hi	0	0	1002	222	1224
	Hilo Int		396	0	74	470
	Hilo Union	381	0	0	71	452
	Kalaniana`ole El & Int	202	48	0	27	277
	Kapiolani	295	0	0	39	334
	Ka`ūmana	266	0	0	24	290
	Keaukaha	320	0	0	61	381
	Waiākea El	748	0	0	58	806
	Waiākea Hi	0	0	1051	168	1219
	Waiākea Int	0	752	0	96	848
	Waiākeawaena	599	0	0	58	657
Honoka`a-Kealakehe-Kohala-Konawaena	Hōlualoa	455	0	0	24	479
	Hōnaunau	123	0	0	14	137
	Honoka`a El	327	0	0	12	339
	Honoka`a Hi & Int	0	100	446	125	671
	Ho`okena	121	0	0	11	132
	Kahakai	651	0	0	40	691
	Ke Kula `o `Ehunuikaimalino	124	39	42	17	222
	Kealakehe	924	0	0	79	1003
	Kealakehe Hi	0	0	1154	145	1299
	Kealakehe Int	245	393	0	71	709
	Kohala El	315	0	0	35	350
	Kohala Hi	0	0	214	51	265
	Kohala Mid	53	95	0	33	181
	Konawaena El	509	0	0	39	548
	Konawaena Hi	0	0	660	70	730
	Konawaena Mid	165	321	0	63	549
	Pa`auilo El & Int	157	36	17	18	228
	Waikoloa	599	116	0	69	784
	Waimea El	477	0	0	48	525
Ka`ū Kea`au-Pāhoa	Ka`ū Hi/Pāhala El	121	135	224	70	550
	Keaau El	702	0	0	87	789
	Keaau Hi	0	0	723	148	871
	Keaau Mid	180	372	0	77	629
	Keonepoko	519	0	0	72	591
	Mt View El	447	0	0	46	493
	Nā`ālehu	353	0	0	32	385
	Pāhoa El	402	0	0	48	450
	Pāhoa Hi & Int	0	204	351	129	684

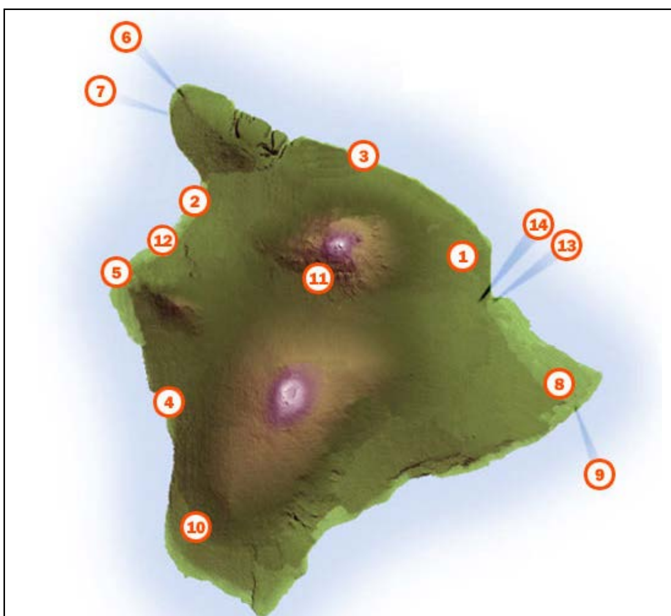
Source: State of Hawai`i Department of Education 2014.

Figure 3.19: County of Hawai`i Parks and Campsites



Source: County of Hawai`i Department of Parks and Recreation, November 7, 2014.

Figure 3.20: State of Hawai`i Parks on Hawai`i Island



(1) `Akaka Falls State Park
(2) Hāpuna Beach State Recreation Area
(3) Kalōpā State Recreation Area
(4) Kealakekua Bay State Historical Park
(5) Kekaha Kai (Kona Coast) State Park
(6) Kohala Historical Sites State Monument
(7) Lapakahi State Historical Park
(8) Lava Tree State Monument
(9) MacKenzie State Recreation Area
(10) Manukā State Wayside
(11) Mauna Kea State Recreation Area
(12) Kīholo State Park Reserve
(13) Wailoa River State Recreation Area
(14) Wailuku River State Park

Source: State of Hawaii Department of Land and Natural Resources 2014.

3.14.4 HEALTHCARE SERVICES

There are five hospitals on the island: Hilo Medical Center in Hilo, Ka`ū Hospital in Pāhala, Kohala Hospital in Kapa`au, Kona Community Hospital in Kealakekua, and North Hawai`i Community Hospital in Kamuela. . These facilities offer varying services and levels of care, but all offer 24-hour emergency medical services.

3.15 LAND USE PLANS, POLICIES, AND CONTROLS

A number of State land use plans, policies, and controls are relevant to the MKSR, Halepōhaku, and surrounding areas. They include the Hawai`i State Plan, the State Land Use Law (and related Conservation District Use Regulations), the State's overall Environmental Policy, and the Coastal Zone Management (CZM) Program. The most relevant aspects of these plans, policies, and controls will be fully presented in the EIS, along with a discussion of the project's consistency with them.

The construction and operation of observatories in the MKSR, the Halepōhaku facilities, and access roadways have all been consistent with State and local land use policies and land use designations, including the CMP that provides the framework for managing existing and future activities, including astronomy, recreational and commercial activities, scientific research, and cultural and religious activities within the UH management area – which consists of the MKSR, Halepōhaku, and the Mauna Kea Access Road between Halepōhaku and the MKSR. Each of the existing observatories on the summit underwent required permitting processes and reviews.

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4 POTENTIAL IMPACTS TO BE EXPLORED

This chapter summarizes the kinds of adverse and beneficial effects that are likely to result from the alternatives being considered. It was prepared using information concerning project alternatives presented in Chapter 2 and the preliminary information concerning the existing environment contained in Chapter 3.

The discussion presented in this Chapter is not intended to be an in-depth analysis. Instead, it briefly describes the issues that have been identified to date and outlines the kinds of analysis that UH expects to include in the Environmental Impact Statement (EIS). By highlighting the kinds of analyses UH believes are needed and will undertake during preparation of the EIS, it provides reviewers an opportunity to consider whether all issues that are important to them are likely to be addressed and to identify additional areas of concern that they believe should be included in the EIS.

The "potential mechanisms of resources impact" sections are based on the "threats to the resource" discussions in the CMP. The mechanisms are the same for all alternatives being considered.

4.1 PHYSIOGRAPHY, GEOLOGY, AND SOILS

4.1.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

There are two main mechanisms through which physiography, geology, and soils could be impacted. They are: (a) loss due to development (e.g., grading, building or roadway construction, etc.); and (b) accelerated erosion. Development carries this potential only when it disturbs pristine areas. Erosion can result from the continuation of existing activities and conditions such as:

- Road grading and travel by vehicles on unpaved roads.
- Hiking, skiing, and off-road vehicle use, particularly around Halepōhaku and on MKSR area cinder cones, that cause the finer material to (a) move downslope at an accelerated rate, and/or (b) become compacted resulting in greater storm water runoff and erosion.
- Maintenance and construction that requires grading and/or the use of water that generates runoff.
- Concentration of storm water runoff from buildings, roadways, and other impervious areas.

4.1.2 POTENTIAL EFFECTS TO BE DISCUSSED

The discussion in the EIS will be based on existing information, including the CMP and previously prepared environmental disclosure documents; no new field investigations or analyses will be undertaken.

4.1.2.1 No Action Alternative

Under this alternative it is unlikely that any new development would occur within the UH Management Area. Hence, there would be no further loss of physiographic, geologic, or soils resources through this mechanism. However, many existing activities and their associated effects would continue for the duration of the existing master lease.

The EIS will describe the way in which the existing facilities would be decommissioned and the measures that would be taken to stabilize the sites once their present use for astronomical research is terminated. It will also describe the permanent change to the original topography that will remain once astronomical use of the area is discontinued.

The discussion will take into account the implications for this resource of returning the area to DLNR management, with a decrease in access road maintenance/grading and decreased vehicular use of the unpaved roadways.

4.1.2.2 New Master Lease Alternatives

Granting UH a new master lease, whether under Alternative #2 or #3, would not cause or lead directly to any developments that have the potential to remove natural physiographic, geological, or soil resources because the activities that are proposed would take place within already disturbed areas. Ongoing roadway maintenance will require a continuation of the existing maintenance grading for these two alternatives, and the effects of this work and other potential erosion-accelerating activities will be summarized in the EIS. The decommissioning of certain observatory sites will occur if either of the two new master lease alternatives is implemented and these activities would have the same effects on those locations as would the No Action Alternative, and will be summarized in the EIS.

4.2 CLIMATE AND AIR QUALITY

4.2.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

4.2.1.1 Mechanisms Affecting Climate

On a global to local scale there is no mechanism by which activities within the project area could measurably affect climate. On a sub-local level, such as a single pu`u or along the side of a road, dust deposited on snowfields has the potential to decrease surface albedo, which accelerates snow melt.

4.2.1.2 Mechanisms Affecting Air Quality

Mechanisms for affecting air quality on a local level include the generation of vehicle exhaust, chemical fumes, and fugitive dust. Of these, the generation of dust is considered the primary concern due to the use and maintenance of unpaved roadways.

4.2.2 POTENTIAL CLIMATE AND AIR QUALITY EFFECTS TO BE DISCUSSED

The discussion in the EIS will be based on existing information, including the CMP and previously prepared environmental disclosure documents; no new field investigations or analyses will be undertaken.

4.2.2.1 No Action Alternative

Under the No Action Alternative, the existing facilities and activities within the UH Management Area would continue to occur for a period of time. This would continue the existing internal combustion engine and roadway particulate (dust) emissions from astronomical-related vehicular travel described in Chapter 3 until the facilities are decommissioned. Similar emissions from vehicular travel unrelated to the observatories would continue as well. Small, short-term spikes in particulate emissions are likely to occur while active decommissioning and site-restoration work is underway on individual observatory sites.

The EIS will provide a qualitative discussion of these emissions and their likely effect on air quality based on typical dust emission factors and an understanding of the best management practices that are likely to be employed while the unpaved portion of the Mauna Kea Access Road continues to be used and as the individual observatory sites are decommissioned. Because the potential for these activities to substantially affect air quality is very limited, no computer modeling will be performed.

The analysis of likely air quality effects beyond the termination of the existing master lease, when the land that is now in the UH Management Area would be returned to DLNR control, will consider both the reduced vehicular traffic and the reduced roadway maintenance that would occur if a new master lease is not issued.

4.2.2.2 New Master Lease Alternatives

Approval of UH's request regarding extension of the term of the master leases and easement would not cause or lead directly to any new activities that have the potential to adversely affect climate or air quality. It would allow vehicles to continue to use the Mauna Kea Access Road, and vehicular emissions from the cars and trucks that use the roadways, as well as dust from the passage of vehicles over the unpaved portion of the roadway, would continue beyond 2033.

The EIS will present a qualitative discussion of these emissions. It will also identify existing and possible future management measures that could be implemented to reduce these emissions. The analysis will indicate the extent to which ambient air quality with the proposed project will continue to meet federal and state ambient air quality standards. It will also describe the pollution control measures that are and will continue to be used to maintain the best achievable air quality.

The decommissioning of certain observatory sites will occur if either of the two new master lease alternatives is implemented and these activities would have the same effects on those locations as would the No Action Alternative, and will be summarized in the EIS.

4.3 HYDROLOGIC RESOURCES

4.3.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

Contamination of surface water and groundwater is a potential side effect of a variety of human activities, including some that presently take place on land that is the subject of this EIS. The nature of the uses that currently take place within the UH Management Area result in the potential for such contamination being limited to small volume releases resulting from vehicular accidents or accidental releases of petroleum products (e.g., fuel for vehicles and backup generators, lubricants, and cleaning fluids) and other chemicals transported, stored, and used in the observatories or at Halepōhaku. Domestic wastewater generated within the UH Management Area is disposed of via permitted septic systems. This has little potential to affect water quality unless chemicals not meant for disposal through the permitted septic systems are introduced.

4.3.2 POTENTIAL HYDROLOGIC EFFECTS TO BE DISCUSSED

The discussion in the EIS will be based on existing information, including the CMP and previously prepared environmental disclosure documents; no new field investigations or analyses of hydrologic resources will be undertaken.

None of the alternatives being considered entail activities that consume substantial amounts of potable water, require alteration of drainage patterns, or measurably alter the volume of surface water runoff or groundwater recharge. Neither do they entail actions that would affect Lake Wai`au, the only permanent surface water feature in the area.

4.3.2.1 No Action Alternative

Under the No Action Alternative, the existing hydrologic conditions would largely remain as they currently are through the term of the existing master lease. The level of astronomical research activity would decline as facilities are decommissioned, reducing the potential for work-related accidents and spills. The number of non-research trips is expected to remain the same or diminish over this period, and this could decrease the potential for spills and contamination from that source as well. No potential for astronomical research-related spills would exist from 2034 onward under the No Action Alternative. DLNR’s reduced maintenance of Mauna Kea Access Road would reduce the potential for spills or leaks from maintenance and construction equipment as well. To the extent that private vehicles still continued to use the road, some potential for spills or leaks would continue, and no rangers would be present to clean up the spills.

The EIS will provide a qualitative discussion of the reasons why no substantial hydrologic effects are anticipated under the No Action Alternative. It will use information from existing documents to characterize the residual risk of contamination that will exist during the interim period while the current uses continue and then are decommissioned. The discussion will include the use of best management practices as provided for in the CMP.

4.3.2.2 New Master Lease Alternatives

Approval of either of the new master lease alternatives will allow for the continuation of existing uses, none of which are believed to be directly harming streams, lakes, or other surface water features. Moreover, because the activities that are proposed will take place within already disturbed areas and do not entail changes in the drainage pattern or increases in the volume or quality of storm water runoff, they do not have the potential for indirect effects on these resources.

Granting UH's request will not cause or lead to any activities that have the potential to affect groundwater recharge. Neither do they entail activities that will require or lead to substantial groundwater withdrawals. Hence, there are no mechanisms through which either of the action alternatives have the potential to have significant direct or indirect effects on surface water or groundwater resources.

The EIS will contain a brief discussion of the reasons for the absence of the potential for significant adverse effects on surface water and groundwater resources. The discussion will include information related to the best management practices that will be used to minimize pollutant loads in surface runoff, avoid accidental discharges, and to limit water use to amounts equal to or below present levels.

4.4 SPECIES AND HABITAT

4.4.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

Because none of the alternatives being considered involve development of new sites, the potential for adverse impact on existing biota and their habitats is much more limited than would be the case if extensive new facilities were proposed. However, two mechanisms through which biota could be affected exist. The first has to do with the potential for activities to introduce new species to areas where they would not otherwise occur. The second has to do with the potential for inadequate/improper management of already disturbed areas, including management during site maintenance, modification, restoration, or other activity.

Although Maunakea's higher elevations are somewhat insulated from invasive species, due to its inhospitable environment, certain species have been able to survive. Hence, virtually any user, vehicle, equipment, or material that comes to Maunakea could unintentionally transport alien species to the summit. Invasive species may be introduced through several pathways, including on footwear or tires, on heavy equipment, in fill material, in shipments of materials, or offerings. Most species introduced through these pathways will be small (e.g., seeds or insects), although larger species, such as rodents, may be found in shipping containers containing supplies or equipment.

Inadequate or improper management may allow activities that: (i) modify the existing environment in such a way as to make it more hospitable to species not previously found there and in that way further their spread, (ii) modify the existing environment in such a way as to make it less hospitable to native species, and/or (iii) provide a vector promotes the spread of invasive species into previously pristine areas. The main potential sources of invasive species and opportunities for inadequate/improper management include:

- Modifications and maintenance to existing facilities (materials, vehicles, equipment).
- Road maintenance (importing gravel and grading).
- Landscaping (materials, at lower elevations).
- Operation of observatories and support facilities (materials, vehicles, researchers).
- Recreational use (hikers [off-trail use], snow-players, hunters; footwear, and vehicles).
- Conduct of cultural practices (off-trail use, offerings).
- Scientific inquiry (off-trail use, direct sampling).

4.4.2 POTENTIAL BIOLOGICAL EFFECTS TO BE DISCUSSED

The discussion of potential biological effects in the EIS will be based on existing information, including the CMP and previously prepared environmental disclosure documents; no new field investigations or analyses of biotic species, environment, and habitat will be undertaken.

4.4.2.1 No Action Alternative

Under the No Action Alternative, the existing activities that affect the biotic environment would continue to occur for a period of time. Decommissioning will require the use of heavy equipment and a greater number of workers. This increased presence and traffic, of all types, would have the potential to transport invasive species, but this potential impact would be mitigated through the implementation of best management practices, including those outlined in the CMP.

Once day-to-day management responsibility returns to DLNR following the termination of the lease, recreational and research activities would continue to be regulated in accordance with the Conservation District regulations, but the area would not be regularly policed or maintained and existing policies that are part of UH's CMP would no longer be in effect.[63] With the decrease in vehicular traffic that is anticipated following closure of the observatories and the consequent cessation of regular road maintenance, there would be a reduced risk of transporting invasive species to the summit area; although with the lack of active management natural dispersal would be unmitigated. People could continue to access areas above Halepōhaku by hiking, which could potentially spread invasive species throughout the area. Off-trail hiking would have the potential to impact habitat, and this potential could be greater if use of existing trails dwindles and the existing disturbed paths are not as easy to follow. The absence of rangers could result in increased off road driving by all-terrain vehicles (ATV) and other vehicles; off road driving can adversely affect the natural landscape and habitat.

4.4.2.2 New Master Lease Alternatives

Approval of either of the new master lease alternatives would allow for the continuation of existing uses. The uses that are proposed would take place within already disturbed areas; therefore, the threat of habitat disturbance is minimized. However, continued observatory operations and human uses do have the potential to transport invasive species to the mountain and spread existing invasive species into other areas of the mountain. Increased awareness and education for observatory employees and visitors help to minimize these potential effects. In addition, activities identified in the CMP will result in the development of measures to mitigate invasive species threats.

The EIS will contain a brief discussion of the reasons for the minimized potential for significant adverse effects on Maunakea's ecosystems. The discussion will include information related to the best management practices that will be used to minimize the spread of invasive species and habitat impacts.

4.5 POTENTIAL EXPOSURE TO SPECIAL HAZARDS

4.5.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

Granting a lease to UH that would allow for the continued operation of astronomical facilities on the summit of Maunakea would increase the period of time during which such facilities would be exposed to those hazards. To the extent that the time extension encourages (as the UH believes it

[63] Because the CMP is a UH instrument, it would no longer be enforceable once the leases terminate (though DLNR could presumably continue any elements of the CMP that it has authority and funding to implement). The rangers that are now paid for by the UH would be disbanded and all enforcement would be the responsibility of DOCARE officers with other, generally higher priority, duties.

will) re-equipping/reconstruction of existing facilities, it could increase the value (i.e., replacement cost) of facilities exposed to these special hazards as well.

4.5.2 POTENTIAL SPECIAL HAZARDS EXPOSURE TO BE DISCUSSED

The EIS' discussion of the extent to which each of the alternatives would affect the exposure of workers, visitors, and other persons to special hazards will be based on existing information, including the CMP and previously prepared environmental disclosure documents; no new field investigations or analyses will be conducted.

4.5.2.1 No Action Alternative

Under the No Action Alternative, the existing potential for exposure to special hazards would diminish over time. With respect to the built environment (i.e., to the observatories and other facilities that have been constructed under the terms of the existing lease) the reduction in exposure would decrease incrementally as ongoing research is first stopped and then the facilities are decommissioned. The decommissioning would require the presence of construction workers and heavy equipment for brief periods, but the equipment is mobile and the workers would be kept away from the summit during periods known to be hazardous, thereby limiting any potential exposure.

Once DLNR reassumes management responsibility and the area is returned to the Forest Reserve, the number of people and the value of facilities present would be greatly reduced, thereby lessening the exposure to these hazards. At the same time, the reduced accessibility that would accompany the greatly decreased maintenance of the existing road infrastructure would lessen the ability to come to the aid of anyone who is affected by one of the hazards. The EIS will contain a brief discussion regarding the way that the abandonment of the MKSR would affect the degree of human exposure to special hazards.

4.5.2.2 New Master Lease Alternatives

Approval of either of the new master lease alternatives would allow for the continuation of existing uses. These uses and visitors to the area would continue to be exposed to the special hazards; however, infrastructure would be in place to address them. The EIS will contain a brief discussion regarding the exposure to the special hazards that would accompany issuance of a new master lease.

4.6 SOUND LEVELS

4.6.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

The main noise sources that have the potential to raise sound levels above their natural background levels include;

- Vehicles bringing workers and supplies to the observatories near the summit and visitors to the mid-level facilities and to the summit region.
- Equipment (e.g., HVAC systems) located in or near the observatories that is essential to their operation.
- Construction equipment and activities needed to periodically maintain and/or upgrade the existing observatory operations.

None of these entail the extensive excavation or new foundation construction that was required for the existing observatories, although some foundation work could be required if one or more of the new facilities required greater support or stability than the facility it replaced. Similarly, none involve alternate viewing technologies that would produce noise greater than that from the facilities they replace.

4.6.2 POTENTIAL NOISE EFFECTS TO BE DISCUSSED

The discussion in the EIS will be based on existing information, including the CMP and previously prepared environmental disclosure documents; no new field investigations or analyses of sound or noise will be undertaken.

4.6.2.1 No Action Alternative

Under the No Action Alternative, the existing observatories would continue to operate, vehicles would continue to use the existing roads, and occasional maintenance activities would occur until each individual facility is closed. Decommissioning activities at each of the existing observatory sites would require short periods of demolition work at the individual sites, and the heavy equipment used for this purpose would produce relatively high noise levels immediately adjacent to the observatory sites while this is underway. There would likely be higher volumes of vehicles in the area to remove materials as well, and this would marginally increase sound levels adjacent to the roadways that are used for this purpose. As decommissioning proceeds, noise from observatory HVAC equipment would diminish, as would noise from vehicles that presently support observatory operations.

Noise from non-observatory vehicles would probably continue and not diminish as quickly as that from the observatories themselves so long as the summit area continues to contain sufficient astronomical facilities to make it a popular tourist destination. Once the observatories close and UH is no longer maintaining the summit roadway, vehicular noise is expected to decrease sharply as only a few 4-wheel drive vehicles would be present. In the absence of vehicles in the area, wind would be the principal noise source in the summit area.

The EIS will provide a qualitative discussion of the extent to which sound levels will decrease under the No Action Alternative. It will use information from existing documents to characterize the residual noise level that will exist during the interim period while the current uses continue and then are decommissioned.

4.6.2.2 New Master Lease Alternatives

Approval of either of the new master lease alternatives will allow for the continuation of existing uses, and in the course of normal operations the observatories would continue to produce approximately the same amount of noise as is presently the case. Because these alternatives allow for the continued use of existing facilities for a longer period of time than the No Action alternative, the slightly elevated sound levels that occur close to existing observatories has the potential to continue. Moreover, these alternatives also carry with them the potential for periods of increased construction noise as a result of equipment additions or facility reconstruction. The EIS will contain a brief discussion of the sound level changes that could result from these activities. It will also address the effect that maintaining vehicular access to the summit is likely to have on sound levels.

4.7 VISUAL AND AESTHETIC RESOURCES

4.7.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

Visual impacts are generally related to the placement of structures on Maunakea of sufficient size to be visible from inhabited areas of the island (e.g. Hilo, Waimea). Also, the disturbance and alteration of pu`u, through activities such as grading, roadway construction, and the creation of trails, can have an effect on the visual environment of Maunakea when viewed from within the region.

4.7.2 POTENTIAL VISUAL AND AESTHETIC EFFECTS TO BE DISCUSSED

The discussion in the EIS will be based on existing information, including the CMP and previously prepared environmental disclosure documents. Because it does not entail the construction of substantial new structures, visual simulations will be limited to comparisons between existing views of the observatories and the area's likely appearance once the facilities have been decommissioned and site restoration activities are completed.

4.7.2.1 No Action Alternative

Under the No Action Alternative, the existing visual environment in the summit area would remain for a period of time. Decommissioning activities would result in short periods during which construction activity would be underway. During these periods heavy equipment would be present on one or more observatory sites and earthwork would be conducted during daylight hours. The EIS will discuss the extent to which restoration activities will temporarily alter the visual environment of the summit region and the areas from which the existing facilities and sites are visible. It will also address the extent to which the restoration activities will remove the visual evidence of the observatory use and the extent to which visual evidence of that activity will remain.

Once returned to DLNR management, the only activities in the summit area will be those that are permissible within the Forest Reserve and Conservation District. None of these have a pronounced visual footprint, and the limited accessibility of the summit region will keep the number of people who see the restored area to a minimum. The EIS will describe the general character of the "re-naturalized environment", but it will not attempt to quantify these changes.

4.7.2.2 New Master Lease Alternative

Approval of either of the new master lease alternatives will allow for the continuation of existing uses, and the current observatories would continue to be a part of the visual environment until they are decommissioned. While there is no planned expansion of astronomical uses into areas not already used for that purpose, UH anticipates that existing observatories could be reconstructed in order to accommodate more modern equipment or that one or more observatory sites could be reused (i.e., recycled). At the present time UH believes that any such reuse would entail activities and facilities of a scale commensurate with those now present. In any event, detailed plans would need to be submitted and approved by the BLNR prior to any such major reconstruction. The EIS will describe why the kinds of facilities that would be present within the Astronomy Precinct during the term of the lease are likely to be similar to those already in place and discuss the way in which these facilities would affect the visual environment.

4.8 CULTURAL RESOURCES

4.8.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

The principal threats to cultural practices involving Maunakea stem from the potential degradation of the natural environment resulting from human activity and construction, as well as possible reductions in access to the summit area for cultural practitioners. Beneficial and adverse impacts to historic properties and the overall cultural landscape, addressed in Section 4.9, would have parallel, secondary impacts on cultural practices.

4.8.2 POTENTIAL EFFECTS OF THE ALTERNATIVES

The discussion of potential effects in the EIS will be based primarily on existing information. Past studies have documented that the construction of the Mauna Kea Access Road and summit area observatories have had both beneficial and adverse effects on cultural practices. Improved access to the summit area for cultural practitioners has resulted from past development. That same development has degraded the natural environment in which cultural practices occur. Management programs under the CMP are improving the awareness of and respect afforded to cultural practices by visitors and employees.

4.8.2.1 No Action Alternative

Under the No Action Alternative, the previously documented beneficial and adverse effects on cultural practices would continue for a period of time. Some temporary, adverse effects would be associated with future decommissioning activities. The environmental setting for cultural practices in the summit area would be expected to improve as facilities are decommissioned, with most or all currently developed areas eventually returning to a natural-appearing condition that is more conducive to cultural practices. However, this benefit would be somewhat offset by the loss of education and enforcement activities that currently help reduce improper alteration of the cultural landscape and decrease inappropriate and illegal behavior by visitors.

After the return of leased lands to DLNR, access to the summit area would be expected to diminish for all cultural and recreational activities. The extent to which access would be reduced will be further evaluated in the EIS along with its possible impacts on cultural practices.

4.8.2.2 New Master Lease Alternatives

Under both master lease alternatives, existing beneficial and adverse impacts on cultural practices would continue for an extended period. Some temporary, adverse effects would be associated with future decommissioning and recycling construction, which are considered disruptive to cultural practices in the vicinity of the construction. Permanent decommissioning of currently developed areas would eventually improve the natural appearance of those locations, making them more conducive to cultural practices.

Continued maintenance of the Mauna Kea Access Road by OMKM will ensure that access to the summit areas does not diminish for cultural practitioners. The EIS will also discuss how continued implementation and improvement of cultural resource protection programs under the CMP is anticipated to improve and maintain the environment for cultural activities.

4.9 ARCHAEOLOGICAL, HISTORIC, AND CULTURAL RESOURCES

4.9.1 POTENTIAL MECHANISMS OF RESOURCE IMPACT

The major threats that can lead to the degradation of archaeological sites, historic properties, and the overall cultural landscape, including burials, include visitor disturbance, damage from off road vehicles, ground disturbing activities (construction, maintenance, and emergency procedures), scientific research, debris, and lack of enforcement of existing rules and policies. Because none of the alternatives being considered involve development of new sites, the potential for adverse impact on historic resources is much more limited than would be the case if extensive new facilities were proposed.

4.9.2 POTENTIAL EFFECTS OF THE ALTERNATIVES

The discussion in the EIS will be based on existing information, including the CMP and previously prepared environmental disclosure documents. Because construction of new structures is not inherent in any of the alternatives, the discussion will be focused on the uses that will continue under each alternative and their potential to affect these resources.

4.9.2.1 No Action Alternative

Under the No Action Alternative, the existing effects on archeological, historic, and cultural resources would continue to occur for a period of time. Decommissioning would require the temporary use of heavy equipment to disassemble the existing structures and perform activities associated with site restoration. The EIS will discuss how decommissioning activities may increase the potential for impacts to these resources, but also discuss the fact that such activities would occur in areas that have already been disturbed and that best management practices would reduce the potential impact.

Once returned to DLNR management, the only activities in the summit area will be those that are permissible within the Forest Reserve and Conservation District. Recreational and research activities would be permitted as appropriate. These activities have a relatively low opportunity for impact to archaeological, historic, and cultural resources; however, there would be comparably little visitor education or ranger program to inform visitors of the presence of the resources and how to avoid impacts to them. If off-trail hiking continues to occur in the summit area, there is the potential to impact these resources, and this potential could be greater if use of existing trails dwindles and the existing disturbed paths are not as easy to follow.

The EIS will describe the relative potential impacts to the resources during the two management paradigms that would occur under the No Action Alternative.

4.9.2.2 New Master Lease Alternatives

Approval of either of the new master lease alternatives will allow for the continuation of existing uses, which includes the implementation of the CMP and its efforts to minimize and avoid impacts to the archaeological, historic, and cultural resources through visitor education and the ranger program, among other efforts. Because neither of the two action alternatives would result in disturbance of currently undisturbed areas, the potential for impact to these resources is significantly reduced; however, potential redevelopment of the currently disturbed sites may require modifying the existing foundations, which could result in native material movement within the previously disturbed areas.

The EIS will contain a brief discussion of the reasons for the minimized potential for significant adverse effects on Maunakea's archaeological, historic, and cultural resources. The discussion will include information related to the best management practices that will be used to minimize the potential for impacts by staff and visitors.

4.10 TRANSPORTATION FACILITIES

4.10.1 POTENTIAL METHODS OF RESOURCE IMPACT

The existing transportation system on Maunakea is generally threatened by the weather and is related to the portions that are not paved. Regular maintenance is required to keep the road in drivable condition. High winds and storms, including their aftermath such as melting snow, can create unsafe conditions on the mountain's roadways through erosion and runoff.

4.10.2 POTENTIAL EFFECTS OF THE ALTERNATIVES

4.10.2.1 No Action Alternative

Under the No Action Alternative, the existing observatory operations would continue until the end of 2033, at the latest. Observatory personnel would continue to travel to the summit area, along with people that would access the area for recreational, cultural, and other uses and the roadways would be regularly maintained. Regular UH-led maintenance of the roadways would cease after the expiration of the lease. DLNR would reduce the level of maintenance on the existing roadway between Halepōhaku and the summit to the level given to roads across other unimproved lands in Forest Reserves and other unencumbered state property. This means that beginning in January 2034 these roads would likely become unusable during the winter and would be reduced to 4-wheel drive only use during all seasons very shortly thereafter.

4.10.2.2 New Master Lease Alternative

Approval of either of the new master lease alternatives will allow for the continuation of existing uses, and the current roadways would continue to be regularly maintained and traveled. There are no new roadways planned as part of either of the master leases alternatives. Observatory personnel and other users would continue to use the roadways to access the summit area. There are no projects or other changes in uses at the summit area that would result in any substantial changes to the level of traffic using these roadways.

The EIS will describe the current roadways that are present in the study area and why it is likely that they will remain similar to their existing state during the term of a new master lease. The EIS will also include discussion regarding the level of traffic on these roadways and why that, too, is likely to remain unchanged.

4.11 EXISTING INFRASTRUCTURE

4.11.1 ELECTRICAL POWER AND TELECOMMUNICATIONS SYSTEMS

4.11.1.1 Potential Methods of Resource Impact

The existing power and telecommunications infrastructure that serves Maunakea faces minimal threat from the severe weather that can occur in the summit area because it is buried.

4.11.1.2 Potential Effects of the Alternatives

4.11.1.2.1 No Action Alternative

Under the No Action Alternative, the currently authorized observatories would continue to operate for a period of time. Some observatories would likely be decommissioned prior to the end of the current lease in 2033. The level of electrical power required for the observatories would therefore increase as the TMT Observatory is goes into operation and then may decrease as observatories are decommissioned and disconnected. At the end of the current lease, the infrastructure would be unused but would remain in underground conduits; to minimize disturbance, underground infrastructure would generally be left as-is. Service to the area would be turned off to minimize the potential for any accidents, such as electrical fires.

4.11.1.2.2 New Master Lease Alternative

Approval of either of the new master lease alternatives would allow the current infrastructure to continue to be used and maintained. . There is the potential for some observatories to be modernized, which could result in changes in the energy requirement and overall amount of electricity required for the summit area, but the direction of change is likely to be downward (i.e., less electrical energy use) and would not require any further upgrading of the overall infrastructure.

The EIS will describe the current electrical and telecommunications systems that serve the summit area and discuss why the level of electricity used by the observatories is likely to remain the same or decrease during the term of a new master lease.

4.11.2 SOLID WASTE GENERATION, COLLECTION, AND DISPOSAL

4.11.2.1 Potential Methods of Resource Impact

If not properly managed litter and larger fugitive trash would impact the visual aesthetics of the UH Management Area and degrade the landscape. The high winds that frequently occur in the summit region can exacerbate the problem by spreading unattended waste/material over a large area and blowing away materials that people feel are safe. Solid waste may interfere with deposition of food resources in the aeolian ecosystem, shade out vegetation, and damage geological resources upon impact. Food waste may provide a resource to support pest species and predators of native biota. Collection of debris is also of concern as the removal activity may do more harm than the actual debris if people or vehicles crush cinder in sensitive habitats (Howarth et al. 1999). The main activities and users that produce solid waste include:

- Observatories and support facilities (trash);
- Construction (materials);

- Recreational users (litter, snow-play debris); and
- Commercial tour groups (litter).

4.11.2.2 Potential Effects of the Alternatives

4.11.2.2.1 No Action Alternative

Under the No Action Alternative, the existing CMP-guided management of solid waste would continue for a period of time. Decommissioning would result in the generation of large amounts of materials that would either be recycled or disposed of as solid waste. The EIS will discuss how decommissioning activities may increase the potential for solid waste to affect the UH Management Area but outline how best management practices would minimize the potential for effects.

Once returned to DLNR management, the only activities in the summit area that would potentially generate solid waste would likely be recreational users and cultural practices. These activities typically generate a relatively small volume of solid waste; however, in the alpine environment even small volumes of waste can accumulate in wind sheltered areas and in the vicinity of cultural offering sites and impact the visual aesthetics. Under DLNR management there would be no ranger program or regular trash collection efforts to the control the solid waste that would accumulate

The EIS will describe the relative potential impacts associated with solid waste during the two management paradigms that would occur under the No Action Alternative.

4.11.2.2.2 New Master Lease Alternative

Approval of either of the new master lease alternatives will allow for the continuation of existing uses, and the current CMP solid waste management system would remain in place. Decommissioning, facility modifications, and site recycling would have the potential to periodically increase the volume of solid waste generated. No new activities generating solid waste are envisioned to occur. The EIS will contain a brief discussion of the reasons for the absence of the potential for significant adverse effects on solid waste creation or management, which will include the implementation of the CMP-based best management practices related to solid waste management and fugitive trash.

4.12 EMPLOYMENT AND ECONOMIC ACTIVITY

4.12.1 POTENTIAL METHODS OF RESOURCE IMPACT

The loss of direct employment associated with astronomical uses and associated indirect and induced employment would have an adverse impact on the economy of the Island of Hawai`i and the State of Hawai`i. Direct employment in this case would be considered those that manage, maintain, and operate the individual observatories; those employed by OMKM and MKSS; and certain positions within UH. Indirect employment is created when jobs are created in other sectors as a result astronomical activities, such as maintenance during operation and construction during decommissioning. Induced employment results from an overall expansion of the regional economy as a result of the infusion of capital from a given sector of the economy, in this case astronomy. The tour operators that visit the summit region are another example of indirect employment associated with astronomical operations. A decrease in direct employment or capital investment within the astronomy sector of the economy would have an adverse effect on other sectors of the economy due to the loss of indirect and induced employment.

4.12.2 POTENTIAL EFFECTS OF THE ALTERNATIVES

4.12.2.1 No Action Alternative

Under the No Action Alternative, the existing level of direct employment would continue for a period of time but investments in capital improvements would quickly start to drop off, which would adverse affect the indirect employment. Decommissioning would mean the immediate loss of most direct employment and eventual total loss of all direct employment; however, it would temporarily increase the indirect employment. Ultimate the astronomy sector of the economy would be eliminated within the County of Hawai`i; this would be a significant adverse impact to the County.

Once returned to DLNR management there would be an opportunity for DLNR to work with a new operator for the Halepōhaku facilities. It is not known what operations would be interested in the Halepōhaku facilities, but an eco-tourism type of operation or some alternative use associated with the high altitude or the unique resources present nearby may be considered. Such an operation would provide some direct employment and associated indirect and induced employment; however, it would likely be minor relative to the astronomy sector.

The EIS will discuss the adverse effects associated with the loss of the astronomy sector of the economy in quantitative terms and the potential benefits of the potential Halepōhaku alternative use in qualitative terms.

4.12.2.2 New Master Lease Alternative

Approval of either of the new master lease alternatives would allow for the continuation of existing uses, and the current employment levels related to the astronomy uses would generally remain, along with the associated economic activity related to astronomy sector of the economy. Granting UH's request would not cause or lead to any activities that have the potential to adverse affect the socioeconomic environment of Hawaii Island.

The EIS will outline the benefits of the astronomy sector of the economy for the Island of Hawai`i and contain a brief discussion of the reasons for the absence of the potential for significant adverse effects on the socioeconomic environment.

4.13 PUBLIC SERVICES AND PUBLIC FACILITIES

4.13.1 POTENTIAL METHODS OF RESOURCE IMPACT

These services and facilities generally do not face any potential threats, other than issues with funding. Because they are generally publicly-operated many of them rely on funding through taxes collected by various levels of government. Other threats could relate to misuse and abuse, such as graffiti at parks; such impacts generally don't affect the use of the facilities, but rather their setting and users' potential enjoyment of them.

4.13.2 POTENTIAL EFFECTS OF THE ALTERNATIVES

4.13.2.1 No Action Alternative

Public services and facilities, such as fire and police services and parks, would continue much as they are today with the exception of the UH Management Area being returned to DLNR control when the existing lease expires. The transition to DLNR management would result in the cessation of the OMKM-managed ranger program, which provides numerous public services within the UH Management Area, among many other CMP-related resource management efforts. Other services and facilities provided by UH would also be discontinued, including the VIS and sanitation facilities/services in the summit region. Other parties could assume responsibility for some or all of these, thereby mitigating the potential adverse effect of the reduced UH funding. However, at this time no successors have been identified.

Local community oversight of UH management that occurs via the MKMB and Kahu Kū Mauna would cease in 2033. DLNR resources would manage the area as available with oversight by Division administrators and ultimately the BLNR.

The UH system, particularly UH Hilo and UH Mānoa, would be adversely affected by the loss of the research opportunities provided by the observatories on Maunakea and the loss of research grants associated with those opportunities. The loss of such a successful and world-renown program within UH would reduce UH's attractiveness to potential students and faculty. The EIS will discuss the adverse effects associated with the loss of astronomy-related research and grants to the UH system in both quantitative and qualitative terms.

4.13.2.2 New Master Lease Alternative

Approval of either of the new master lease alternatives will allow for the continuation of existing uses, including the operation of facilities at Halepōhaku. It would also allow for the continuation of community-based oversight of management and operation of other services and facilities, such as the ranger program and VIS.

Granting UH's request will not cause or lead to any activities that have the potential to affect public services or facilities on Maunakea. Neither do they entail activities that will require or lead to substantial changes to any existing public services or facilities. Hence, there are no mechanisms through which either of the action alternatives could have significant direct or indirect effects on public services or facilities.

The EIS will contain a brief discussion of the reasons for the absence of the potential for significant adverse effects on public services and facilities. .

4.14 LAND USE PLANS, POLICIES, AND CONTROLS

4.14.1 POTENTIAL METHODS OF RESOURCE IMPACT

A number of State land use plans, policies, and controls are relevant to the MKSR, Halepōhaku, and surrounding areas. They include the Hawai`i State Plan, the State Land Use Law (and related Conservation District Use Regulations), the State's overall Environmental Policy, and the Coastal Zone Management (CZM) Program. The existing facilities and the facilities that UH anticipates being present if it is granted the lease it is seeking are consistent with all existing land use regulations and controls (e.g., the State Land Use Law, the Conservation District Regulations, and the County of Hawai`i Zoning Ordinance). The Hawai`i State Plan, the Hawai`i County General Plan, the Hawai`i Coastal Zone Management Program (among others) contain policies related to the kinds of land uses and activities believed to be beneficial to the people of Hawai`i. The continuation or cessation of astronomical research on Maunakea has a bearing on the extent to which the goals and objectives established in these plans are likely to be achieved.

4.14.2 POTENTIAL EFFECTS OF THE ALTERNATIVES

4.14.2.1 No Action Alternative

The No Action Alternative would result the observatories being decommissioned gradually as the end of the current lease approached. The MKSR would revert to Forest Reserve designation at the end of the current lease. Hence, the way in which the land in the summit region and the area around Halepōhaku would be used would be transformed relative to present conditions.

The land use plans, policies, and controls would remain as they are today, unless future legislative or executive actions are taken to modify them. Alternative uses or similar uses by other parties could occur should they be approved following appropriate review in compliance with applicable land use plans, policies, and controls, but it is not possible to speculate on what these might be, and any such uses that micht be established would be approved only following appropriate public review and decision-making by the regulatory authorities.

The No Action Alternative would not result in a modification of the land use plans, policies, and controls. It would, however, lead to the termination of astronomical research activities that policies in certain plans seek to promote. The EIS will discuss these implications.

4.14.2.2 New Master Lease Alternatives

The proposed action does not require the modification of any current land use plans, policies or controls.[64] The existing uses have previously been found to comply with the existing land use plans, policies, and controls. Approval of either of the new master lease alternatives will allow for the continuation of uses that are consistent with existing land use plans, policies, and controls, including those that encourage the promotion of scientific research on the mountain.

Land uses changes that would occur under this alternative include the decommissioning of some existing observatories. No new areas would be developed, and some areas would be restored in accordance with the approved Decommissioning Plan.

The EIS will discuss the extent to which the uses that would continue if the master lease is granted are consistent with all of the applicable public plans, policies, and controls.

[64] Under Alternative 3 UH would ask the BLNR to establish an easement over certain lands that are removed from the MKSR to ensure that uses do not take place on the surrendered land during the term of the lease that would degrade the value of the summit for astronomical research. This would not, however, take the form of a land use control.

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5 DETERMINATION

5.1 DETERMINATION CRITERIA

Section 25-3.3 of the Revised Ordinances of the City & County of Honolulu state:

> *Any proposed development within the special management area requiring a special management area use permit shall be subject to an assessment by the agency in accordance with the procedural steps set forth in HRS Chapter 343. The director may allow the assessment to be conducted concurrently with the processing of the application for a special management area use permit.*

As noted in Section 1.1.2, UH's request requires environmental impact assessment in compliance with HRS Chapter 343. HAR §11-200-11.2 establishes procedures for determining if an environmental assessment (EA) is sufficient or if an environmental impact statement (EIS) should be prepared for actions that may have a significant effect on the environment. HAR §11-200-12 lists the following criteria to be used in making such a determination. An EIS is required if the proposed project:

- Involves an irrevocable commitment to loss or destruction of any natural or cultural resource;
- Curtails the range of beneficial uses of the environment;
- Conflicts with the State's long-term environmental policies or goals and guidelines as expressed in Chapter 344, HRS, and any revisions thereof and amendments thereto, court decisions, or executive orders;
- Substantially affects the economic or social welfare of the community or State;
- Substantially affects public health;
- Involves substantial secondary impacts, such as population changes or effects on public facilities;
- Involves a substantial degradation of environmental quality;
- Is individually limited but cumulatively has considerable effect upon the environment or involves a commitment for larger actions;
- Substantially affects a rare, threatened, or endangered species, or its habitat;
- Detrimentally affects air or water quality or ambient noise levels;
- Affects or is likely to suffer damage by being located in an environmentally sensitive area such as a flood plain, tsunami zone, beach, erosion-prone area, geologically hazardous land, estuary, fresh water, or coastal waters;
- Substantially affects scenic vistas and view planes identified in county or state plans or studies; or
- Requires substantial energy consumption.

5.2 CHAPTER 343 HRS DETERMINATION

Issuance of the requested master lease and easements will allow astronomical uses to continue for a substantially longer period than would be the case if they are not granted, the proposed action has the potential to substantially affect the economic welfare of the community. These uses will continue on lands that are habitat for rare, threatened, and endangered species. They also affect scenic vistas and view planes identified in county or state plans. In view of this, UH has, in consultation with the DLNR, determined that the proposed action could have potentially significant impacts and that these should be evaluated and discussed by preparing an environmental impact statement in accordance with Chapter 343 and HAR 11-200.

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6 DISTRIBUTION

UH will distribute this EISPN to the individuals and organizations listed in Table 6.1 and request their comments on the proposed scope of the analysis and on the completeness of the alternatives that it proposes to evaluate. It will provide a limited number of loan copies of this document to libraries.

Table 6.1: EISPN Distribution List

County of Hawaiʻi	**Libraries and Depositories**
Department of Environmental Management	DBEDT – Research Division Library
Fire Department	Hawaiʻi State Library, Hawaiʻi Documents Center
Department of Parks and Recreation	Legislative Reference Bureau
Planning Department	UH – Thomas H. Hamilton Library
Police Department	UH Hilo – Edwin H. Moʻokini Library
Department of Public Works	Hilo Public Library
Department of Research and Development	Kailua-Kona Public Library
Department of Water Supply	Kealakekua Public Library
State Agencies	North Kohala Public Library
Department of Agriculture	**Elected Officials**
Dept. of Accounting & General Services (2 copies)	U.S. Senator Mazie Hirono
Dept. of Bus., Econ. Develop., & Tourism (3 copies)	U.S. Senator Brian Schatz
DBEDT – Energy Division	US Representative-elect Mark Takai
DBEDT – Office of Planning	US Representative Tulsi Gabbard
Department of Defense	State Senator Gilbert Kahele
Department of Education	State Senator Russell Ruderman
Department of Hawaiian Home Lands	State Senator Josh Green
Department of Health (3 copies)	State Senator Lorraine Inouye
Department of Human Services	State Representative Mark Nakashima
Department of Labor and Industrial Relations	State Representative Clift Tsuji
Department of Land & Natural Resources (5 copies)	State Representative Richard Onishi
DLNR – Historic Preservation Division	State Representative Joy San Buenaventura
Department of Transportation	State Representative Richard Creagan
Office of Hawaiian Affairs	State Representative Nicole Lowen
UH – Environmental Center	State Representative Cindy Evans
UH – Water Resources Research Center	County Councilmember Valerie Poindexter
Federal Agencies	County Councilmember Aaron Chung
US Army Corps of Engineers	County Councilmember Dennis Onishi
US Geological Survey	County Councilmember Greggor Ilagan
US Fish and Wildlife Service	County Councilmember Daniel Paleka, Jr.
US National Marine Fisheries Service	County Councilmember Maile David
US National Park Service	County Councilmember Dru Kanuha
US Natural Resources Conservation Service	County Councilmember Karen Eoff
US Federal Aviation Administration	County Councilmember Margaret Wille
US EPA – Pacific Islands Office	**OtherParties**
News & Media	
Honolulu Star Advertiser	
Hawaiʻi Tribune Herald	
West Hawaiʻi Today	
Local Utilities	
Hawaiian Telcom	
Hawaiʻi Electric Light Company	
Hawaiʻi Gas	
Source: Compiled by Planning Solutions, Inc. (2014)	

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