VISUAL IMPACT ASSESSMENT TECHNICAL REPORT

Thirty Meter Telescope Project

Maunakea Northern Plateau and Hale Pōhaku,
Island of Hawai'i
TMK 4-4-15: 9 and 12

Proposing Agency:
University of Hawai'i at Hilo

This document was prepared to support the Environmental Impact Statement for the project, which was prepared pursuant to Hawai'i Revised Statutes, Chapter 343, Environmental Impact Statement Law and Chapter 200 of Title 11, Hawai'i Administrative Rules, Department of Health, Environmental Impact Statement Rules

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EXHIBIT A-54

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Acronyms and Abbreviations

3D	Three dimensional

AO	Adaptive Optics
BLNR	Board of Land and Natural Resources
CFHT	Canada France Hawai'i Telescope
CMP	Comprehensive Management Plan
CSO	California Institute of Technology Submillimeter Observatory
DEM	Digital Elevation Model
DHHL	Department of Hawaiian Home Lands
EA	Environmental Assessment
EIS	Environmental Impact Statement
EISPN	Environmental Impact Statement Preparation Notice
FEIS	Final Environmental Impact Statement
GIS	Geographic Information Systems
HAR	Hawai'i Administrative Rules
HRS	Hawai'i Revised Statutes
IRTF	NASA Infrared Telescope Facility
LUC	Land Use Commission
NED	National Elevation Dataset
NGLT	Next Generation Large Telescope
NPDES	National Pollutant Discharge Elimination System Permit
OMKM	Office of Mauna Kea Management
SMA	Submillimeter Array
TMT	Thirty Meter Telescope
UH	University of Hawai'i
UHIFA	University of Hawai'i Institute for Astronomy
UKIRT	United Kingdom Infrared Telescope
USGD	United States Geologic Services

1.0 Introduction and Background

1.1 Introduction

The TMT Observatory project (Project) would consist of the construction and operation of an optical/infrared telescope observatory below the summit of Maunakea[1] and the associated permanent and temporary ancillary facilities. The permanent ancillary facilities would include an Access Way from the Mauna Kea Access Road to the TMT Observatory 13N site, potential housing and support facilities at TMT Mid-Level Facility within and near by the mid-elevation Hale Pōhaku facility, and a Headquarters in the University Park of University of Hawaii (UH) Hilo to support operation of the observatory. Temporary construction facilities would also include potential worker housing at Hale Pōhaku and construction yards near the summit, at Hale Pōhaku, and near the port where the telescope components would be received.

The purpose of this document is to describe the existing visual conditions, discuss and quantify the visual impacts the Project would have, and identify how the Project mitigates its potential visual impact. The information contained in this discipline report will be used to support the Project's Environmental Impact Statement (EIS).

1.2 Policy Documents and Previous Studies

The following is a summary of the discussion of existing visual conditions of Maunakea and the Island of Hawai'i, and the visual impacts and guidance for new projects contained in existing policy documents and recent environmental studies prepared for the Mauna Kea Astronomy Precinct.

1.2.1 Mauna Kea Comprehensive Management Plan, 2009

The Mauna Kea Comprehensive Management Plan (CMP) provides a management framework for the UH to address existing and future activities in the UH Management Areas. The CMP generally discusses the existing views of Maunakea around the Island of Hawai'i and notes "when skies are clear, the summit region and observatories can be seen from Hilo, Honoka'a, Waimea, the summit of Kīlauea, sections of the Mauna Kea Summit Access Road and much of Puna" (UH 2009). The CMP also generally discusses the views available from the summit of Maunakea and the physical characteristics that make it a good location for astronomy viewing.

[1] Maunakea is spelled as one word in this document because it is considered the traditional Hawaiian spelling (Ka Wai Ola, Vos. 25 No. 11). The common "Mauna Kea" spelling is considered an English spelling and is only used in this document where Mauna Kea is used in a proper name, such as the "Mauna Kea Science Reserve."

The CMP also recommends actions to address environmental impacts related to the visual environment. One of the recommended actions is to require new observatories to prepare a site restoration plan upon their decommissioning. In addition, the CMP includes an action that allows the leaving of traditional offerings to continue unrestricted, while implementing culturally appropriate guidelines for removing offerings to protect the visual landscape. The CMP also prohibits off-road vehicle use to protect visual resources by reducing the associated scarring of the landscape. The CMP also recommends developing and implementing consistent interpretive signage for the observatories.

1.2.2 Mauna Kea Science Reserve Master Plan, 2000

The 2000 Mauna Kea Science Reserve Master Plan is an update of the 1983 plan and addresses issues and concerns that have arisen in 30 years of development on Maunakea. The 2000 Master Plan provides guidance relative to the physical development of the summit area, such as the location of facilities, character, size, mass, color, and other physical attributes (UH 2000).

The 2000 Master Plan states that new facilities will be located within the Astronomy Precinct because it would "limit visual impact and scattering of facilities by clustering within the existing development area, recognizing that facilities have already been built in this area" (UH 2000). Within the Astronomy Precinct new areas to locate observatories, because they would have minimal visual impacts, were identified as areas D, E and F. The 2000 Master Plan limits future telescope redevelopment on the summit ridge to a maximum height and diameter of approximately 130 feet.

The 2000 Master Plan includes a discussion of a "Next Generation Large Telescope (NGLT)", which it describes as a telescope with a mirror of 82 to 164 feet (25 to 50 meters) in diameter that may be proposed for the summit of Maunakea. The 2000 Master Plan recognizes that the large scale of a NGLT makes the visual impact considerations very important, and recommends siting such a facility within Area E of the Astronomy Precinct because it would "minimize its visibility" (UH 2000). The 2000 Master Plan also recommends implementing strict design guidelines for the size and color of the NGLT, and recommends that the observatory be built below grade to minimize the apparent height and mass.

1.2.3 Mauna Kea Science Reserve Development Plan, 1983

The 1983 Mauna Kea Science Reserve Development Plan included a visibility analysis for two areas on the summit of Maunakea where future observatories may be proposed. This visibility analysis identified areas on the Island of Hawai'i where the future observatories could be seen. These figures are shown in Figure 1-1.

1.2.4 Conservation District, 1961

In 1961 the Hawaiian State Land Use Law (Act 187), granted the State Land Use Commission (LUC) the power to zone all lands in Hawai'i into three districts: Agriculture, Conservation and Urban. The Conservation District has five subzones: Protective, Limited, Resource, General and Special. Maunakea is designated as Conservation District land, within the Resource subzone. Because the UH Management Areas consist of lands owned by the State, land uses within the UH Management Areas are regulated by the Board of Land and Natural Resources (BLNR), and

all activities must be in compliance with the laws and regulations applicable to Conservation District Lands (UH 2009).

Figure 1-1. Visibility Analysis from the 1983 Mauna Kea Science Reserve Development Plan

1.2.5 Outrigger Final EIS, 2005

The EIS prepared for the Outrigger Telescopes provided a brief description of the existing visual conditions within Mauna Kea's Astronomy Precinct and of places on the Island of Hawai'i where the existing observatories are visible. This EIS stated that the proposed Outrigger Telescopes would be visible from within the Astronomy Precinct and from areas below the summit such as Waimea and Honoka'a. The EIS for the Outrigger Telescopes also stated that the visual impact of the proposed telescopes would have a "small impact on visual/aesthetic" resources, but stated that the cumulative visual impact would be substantial (NASA 2005).

2.0 Methods

This section applies to the methods used during the visual analysis of the proposed TMT Observatory on Maunakea.

2.1 Coordination

The following plans were reviewed and consulted:

- Mauna Kea Science Reserve Development Plan, 1983
- Mauna Kea Science Reserve Master Plan, 2000
- Outrigger Final Environmental Impact Statement (FEIS), 2005
- County of Hawai'i General Plan, 2005
- South Kohala Community Development Plan, 2008
- Final Mauna Kea Comprehensive Management Plan (CMP), 2009

Site visits were conducted from October 6 through 9, 2008. The purpose of these visits was to document existing views. Additional visits were made thereafter to take photographs of the summit from various viewpoints.

2.2 Establishing the Affected Environment

2.2.1 Viewer Groups

The potential visual impact of the proposed TMT Observatory at the proposed 13N site and the alternative E2 site depends on the type, or group, of people at a location, their activity and their expectation of their experience. An assessment of the various viewer groups and their expectations was made.

2.2.2 Viewpoints

Eighteen (18) representative viewpoints were selected to analyze the potential visual impact of locating the TMT Observatory on Maunakea. These viewpoints are locations such as population centers, resorts, Department of Hawaiian Home Lands (DHHL) land, and culturally important locations where various activities occur and where the identified viewer groups would visit. The viewpoints are all located in the northern portion of the island because both the proposed 13N site and the alternative E2 site for the TMT Observatory are north of and below the summit of Maunakea, within Area E as designated in the Mauna Kea Science Reserve Master Plan (2000), and would not be visible from the southern portion of the island.

For the purpose of this report the primary view from a viewpoint is the orientation of the most visually prominent feature. The direction of the primary view from a viewpoint was determined by considering the viewer group and the activities at that location. For example, at a beach

viewpoint where the main activity is sightseeing and swimming, the primary view would be toward the ocean. For those viewpoints where the panoramic view is important to the viewer group and the activity at that location, no primary view has been specified.

2.3 Visual Consequences

The analysis of potential visual impacts from the TMT Observatory at the proposed 13N site and the alternative E2 site includes four elements: 1) a viewshed analysis, including quantifying the area of the island and the island's population that could see it; 2) whether it would be visible within the direction of the primary view; 3) whether it would be in silhouette; and 4) photo simulations from select viewpoints where the TMT Observatory would be visible.

2.3.1 Viewshed Analysis

The first step in the analysis of visual consequences is a viewshed analysis. The viewshed of the TMT Observatory was calculated in terms of the percent of the area of the Island of Hawai'i where it could be visible, and the percent of the island's population that could see it.

The viewshed for the TMT Observatory was calculated using specific latitude and longitude points and a height for the facility of 180 feet (55 meters) above grade. Topographic data from the U.S. Geological Survey (USGS) was used; specifically the National Elevation Dataset (NED)[2]. Geographic Information Systems (GIS) software was used to determine areas on the island where at least the top of the TMT Observatory could be visible. The NED is used as a three dimensional (3D) surface in GIS. The topographical changes were calculated using Environmental Science Research Institute's ArcGIS software package and the associated 3D analyst extension. The viewshed analysis does not take into consideration existing vegetation or structures, which may further obstruct views. Therefore, the viewshed analysis can be considered a worst case scenario.

Once the viewshed was established, 2000 U.S. Census data for the County of Hawai'i was used to determine the population within the viewshed. Population data was taken at the block level; the smallest area in which census data is collected.

2.3.2 Primary View

If the viewshed analysis determined that the TMT Observatory would be visible from a viewpoint it was then determined whether it would be visible within the direction of the primary view. This criterion is not applicable to viewpoints where the panoramic view is important to the viewer group and the activity at the location.

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[2] The USGS National Elevation Dataset (NED) has been developed by merging the highest-resolution, best quality elevation data available across the United States into a seamless raster format. NED is the result of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous US and 1:63,360-scale DEM data for Alaska. The dataset provides seamless coverage of the United States, HI, AK, and the island territories. NED has a consistent projection (Geographic), resolution (1 arc second), and elevation units (meters). The horizontal datum is NAD83, except for AK, which is NAD27. The vertical datum is NAVD88, except for AK, which is NAVD29. NED is a living dataset that is updated bimonthly to incorporate the "best available" DEM data. As more 1/3 arc second (10m) data covers the US, then this will also be a seamless dataset.

2.3.3 Silhouette View

If the viewshed analysis determined that the TMT Observatory could be visible from a viewpoint it was then determined whether the view of the facility would be a prominent silhouette against the sky, or whether it would be seen against the backdrop of Maunakea or one of the existing observatories. The silhouette analysis consists of a profile of the topography between a viewpoint and the TMT Observatory and a line of sight extended from a representative viewer (with a height of 6 feet) at a viewpoint to the top of the proposed TMT Observatory and beyond. If the line of sight extended into the mountainside the view of the TMT Observatory would be against the backdrop of Maunakea; if the line of sight extended into air the view would be either a full or partial silhouette view.

To determine the amount of the TMT Observatory that would be in partial silhouette a line was drawn from the viewer and tangent to the top of the first rise of Maunakea either in front of or behind the TMT Observatory. If the line is tangent to a rise of Maunakea that is behind the TMT Observatory, the portion between the two lines is the amount that would be in silhouette. If the line is tangent to a rise of Maunakea that is in front of the TMT Observatory the portion below that line would not be visible from that viewpoint; the portion between the two lines is the amount that would be visible and in silhouette.

2.3.4 Photo Simulations

In compliance with CMP Management Action FLU-4, visual renderings of the TMT Observatory at the proposed 13N site were done for select viewpoints. These simulations help to evaluate the potential visual impact of the TMT Observatory in the context of its proposed setting. To evaluate the visual impact of the color and material of the dome enclosure simulations of the TMT Observatory were also done with different exterior finishes, and for when the summit is bare and when it is covered in snow.

To create these simulations, photos of the summit of Maunakea were acquired from the Canada–France-Hawai'i Telescope (CFHT) with accompanying information such as camera type, lens and frame size, and the latitude and longitude locations of where the photos were taken. The photos used in the simulation were taken with a 600mm/5.6 telephoto lens that shows the summit of Maunakea and the observatories as if a viewer was looking through binoculars. For a "naked eye" perspective, Project personnel took photos from the representative viewpoints using a 50mm focal length, which best approximates what the human eye sees. While in the field, Project personnel also held a ruler at arms length and measured the distance between the existing observatories. This provided an example of the scale of the existing observatories within the view of a typical viewer. For example, the distance between the Keck and Subaru Observatories is 1 millimeter (mm).

Terrain data or DEM (Digital Elevation Model) was acquired from the USGS Seamless Data Distribution Center. The Project's architect provided a 3D model of the TMT Observatory along with the latitude, longitude and elevation for the location of the proposed structure. Latitude, longitude and elevation data was also acquired for the existing observatories on Maunakea.

Using the above information a 3D model of the summit of Maunakea and the proposed TMT Observatory was created. Within the 3D model a "camera" was created and positioned based on imported location points, and the lens and frame size of the camera used in the original photo.

The 3D camera position was further refined by "camera matching"; a technique where the 3D camera view is slightly modified to allow for the 3D structures to align with coinciding objects seen in the original photograph. 3D lighting was approximated based on the time of day seen in the photograph. Finally, a composite image was created from a 2D rendering of the TMT Observatory and the original photograph.

2.4 Mitigation

The visual impact of the TMT Observatory is due to its proposed size and location on Maunakea. The proposed design and finish of the dome also have a visual impact. These aspects of the TMT Observatory were examined to assess how the Project mitigates its potential visual impacts.

3.0 Affected Environment

This section describes the existing visual environment related to Maunakea.

3.1 Maunakea

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 west side of the island consists of popular resorts and beaches but lacks vegetation. The southern and southeastern portions of the island receive lots of 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 rain-forest and cliffs along the coast.

Maunakea is the highest peak on the Island of Hawai'i; with an elevation of 13,796 feet above sea level. 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 the vegetation consists mainly of lichens, mosses and small ferns that grow in the cracks and crevices of the cinder cones that comprise the mountain's dome (UH 2000). 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", volcanic smog formed when sulfur dioxide and other volcanic gases emitting from Kīlauea mix with oxygen, moisture and sunlight. During the daylight hours thermally generated winds can draw the vog ashore and upslope (UH 2009). The vog has been especially thick since February 2008 when gas emissions from Kīlauea dramatically increased.

Maunakea is one of the best locations in the world for ground-based astronomical observations. The first telescope on the summit of Maunakea was constructed in 1964. Today, there are 11 observatories on Maunakea within the designated Astronomy Precinct and a twelfth located at a lower elevation. The existing facilities are visible from locations such as Hilo, Honoka'a and Waimea. On the west coast of the island the existing telescopes appear most visible at sunset, when they are lit by the setting sun; on the east coast the existing telescopes appear most visible at sunrise.

Existing telescopes on Maunakea as seen from Area E.

3.1.1 Scenic Vistas and Viewplanes

The State of Hawai'i Administrative Rules (HAR) Title 11, Chapter 200, § 11-200-12, lists the significance criteria for a State Environmental Impact Statement; the criteria for which an action shall be determined to have a significant effect on the environment. Significance Criteria 12 is if an action:

> *"Substantially affects scenic vistas and viewplanes identified in county or state plans or studies"*

The County of Hawai'i's 2005 General Plan 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. Goal 7.2(b) is to "Protect scenic vistas and view planes from becoming obstructed." Section 7.4, 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. Mauna Kea, Waipio Valley."

Around the Island of Hawai'i the following natural beauty sites have been identified that include Maunakea (County of Hawai'i 2005):

- View of Maunakea and Mauna Loa 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 Development Plan includes a policy to preserve Waimea's sense of place. 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" (County of Hawai'i 2008).

3.1.2 Viewer Groups

According to 2000 U.S. Census data, the Island of Hawai'i is home to roughly 148,000 people. The largest cities are Hilo on the east coast (with about 41,000 residents) and Kailua-Kona on the west side (with about 10,000 residents). There are also several smaller towns such as Waimea, Honoka'a and Hāwī.

Tourism is an important industry for all of Hawai'i. The Island of Hawai'i is famous for its volcanoes, such as Kīlauea which has been active for more than two decades. Visitors also visit the Island of Hawai'i for its beaches and recreational opportunities such as snorkeling, scuba diving and golf.

In Hawaiian culture Maunakea is recognized as a sacred place. Similar to other Polynesian cultures, the Hawaiians believed their highest points of land were most sacred; Maunakea being the highest mountain in Pacific Polynesia. Maunakea was host to early Hawaiian traditions including religious practices, study of the heavens, and tool making in the Keanakako'i adze quarry. Lake Wai'au was believed to contain pure water which was used in healing and worship

practices. Today, there are still Hawaiians who go to Maunakea for prayer and restoration. (OMKM 2000).

The people that view the Island of Hawai'i, and more specifically Maunakea, can be categorized into three groups, each with a different expectation of their visual experience:

- *Residents* – Residents place value on the existing condition of the surrounding landscape, particularly as viewed from their homes. Residents would also have views of the island and Maunakea from public places such as commercial centers, beaches and state parks. Residents experience the island's visual resources, including Maunakea, frequently and for a long duration.
- *Sightseers* – Sightseers visit the Island of Hawai'i to view the landscape, including the beaches and volcanoes, and for recreational activities. Sightseers would visit the larger cities of Kailua-Kona and Hilo for shopping, dining, and touring activities, and would take scenic drives along the island stopping at scenic overlooks. Sightseers may also be interested in astronomy and visit the observatories on Maunakea. Sightseers would have a temporary experience of Maunakea and the island's visual resources.
- *Cultural Practitioners*[3] – Cultural Practitioners are native Hawaiians who, as individuals or groups, may visit Maunakea for worship on special occasions or on a regular basis (OMKM 2000). Cultural Practitioners may also visit other important sites on the island with views of Maunakea. Cultural Practitioners place a high value on the island's visual resources, and particularly on pristine views of Maunakea.

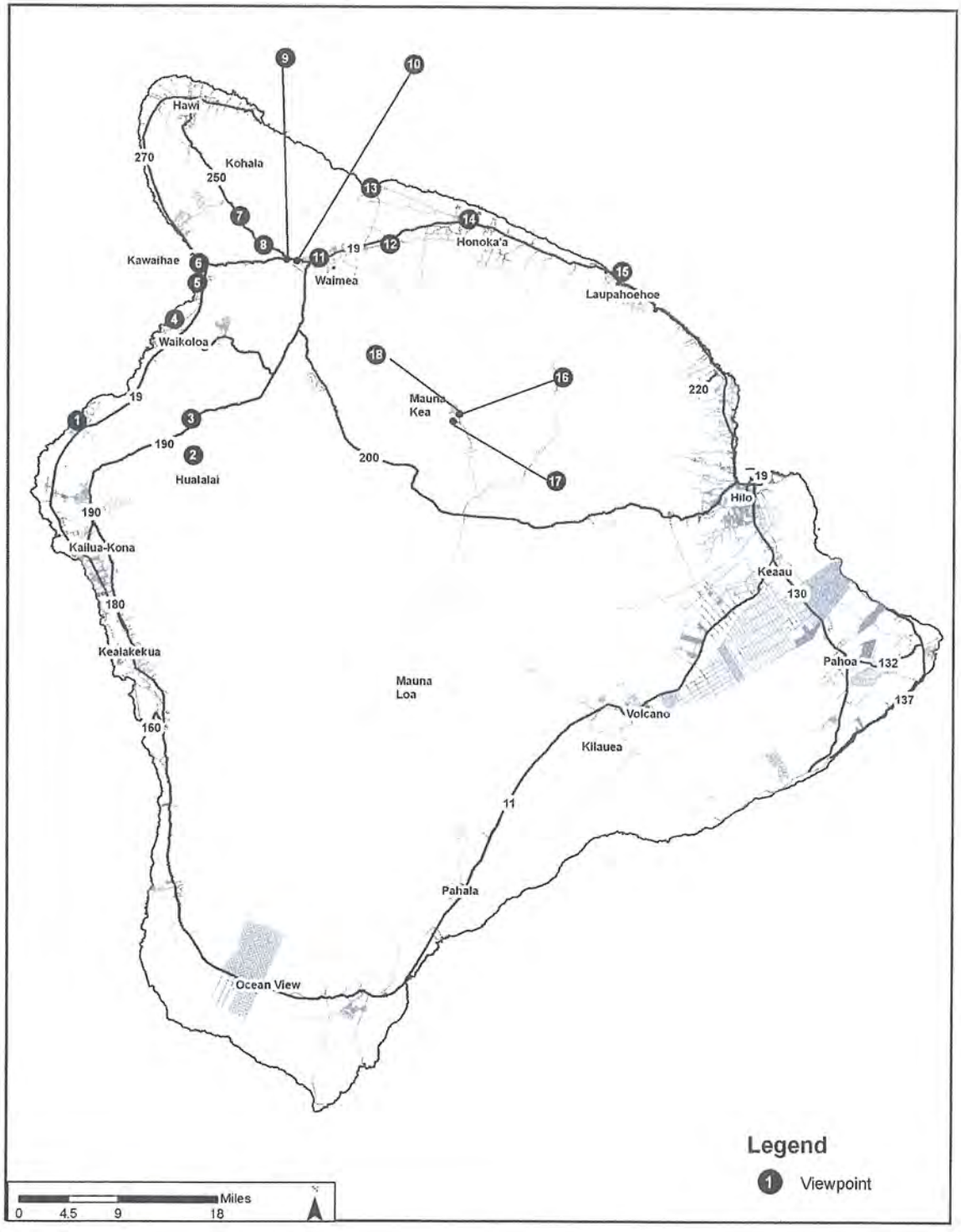
Existing shrine on the summit of Mauna Kea.

3.1.3 Viewpoints

Eighteen (18) representative viewpoints within the northern portion of the island have been identified as places that are of visual significance to the island's three viewer groups. The viewpoints are all located in the northern portion of the island because the proposed 13N site and the alternative E2 site for the TMT Observatory are north of and below the summit of Maunakea and would not be visible from the southern portion of the island. Figure 3-1 maps the locations of the 18 representative viewpoints.

[3] This report only discusses the project's potential visual impact. For more information on impacts to cultural sites or practices please see the *Cultural Impact Assessment, Thirty Meter Telescope.*

Figure 3-1. Viewpoints Used for the Visual Analysis



Primary view from Viewpoint # 13 – Waipio Valley Lookout

Table 3-1 provides the name and description of each viewpoint, including the main activity that occurs at that location, and states the primary viewer group at the viewpoint. For example, at the Waipio Valley Lookout the primary viewer group is Sightseers. For the Hualālai Resort, Big Island Country Club, Hāpuna Beach and Puukohola Heiau State Park, both Residents and Sightseers have been listed as the primary viewer group because of the activities that occur at these locations.

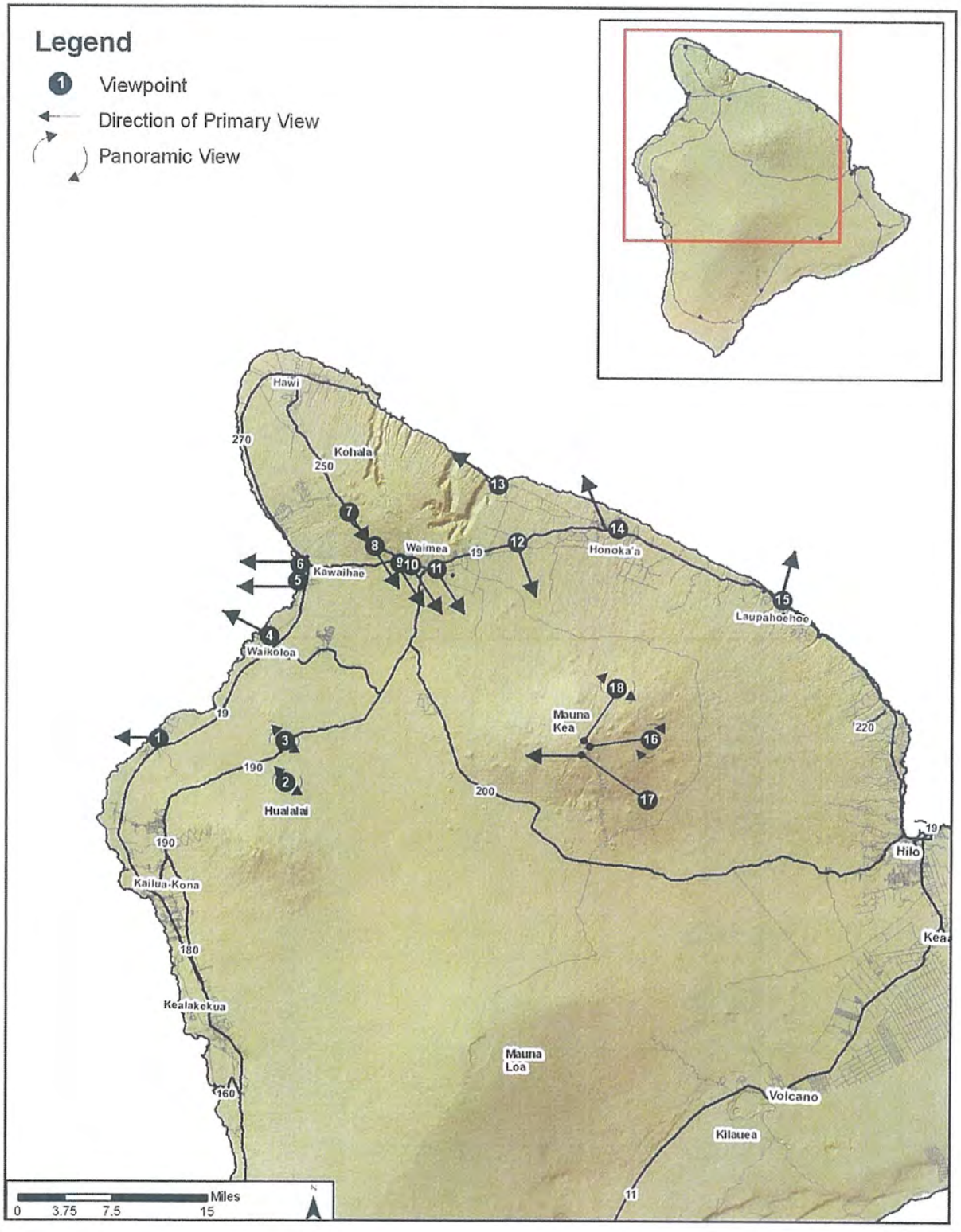
Finally, Table 3-1 states the direction of the primary view from each viewpoint; the orientation of the most visually prominent feature. The primary view has been determined relative to the viewer group and the activities at the viewpoint. The primary view for viewpoints near the coast, such as Hāpuna Beach and Laupāhoehoe Point, is toward the ocean (makai). For viewpoints that are more inland, such as the Route 250 Puu overlook and Waimea Park, the primary view is towards Maunakea (mauka). At the Big Island Country Club, Pu'u Waawaa and the summit of Maunakea, the panoramic view is important to the viewer group and the location's use. The direction of the primary view from each viewpoint is mapped in Figure 3-2.

Appendix A includes a photograph of or from the viewpoints. It has been noted if the photograph is of the primary view from the viewpoint.

Table 3-1. Description of Viewpoint, Viewer Group and Primary View Direction

Viewpoint	Location	Description	Viewer Group	Primary View
1	Hualālai Resort	Exclusive, luxury residential community and hotel.	Residents / Sightseers	West toward the ocean (makai)
2	Pu'u Waawaa	Summit of cinder cone that is of cultural importance to native Hawaiians.	Cultural Practitioners	Panoramic
3	Big Island Country Club	Independent (non-resort affiliated) daily-fee golf course. The club includes views of the coastline and of Maunakea.	Residents / Sightseers	Panoramic
4	Waikoloa/Mauna Lani	Resort development.	Sightseers	West makai
5	Hāpuna Beach	Public beach near a resort.	Sightseers / Residents	West makai
6	Puukohola Heiau	National historic site and Spencer Beach Park, which includes camping and picnic areas along a beach.	Residents / Sightseers	West makai
7	DHHL Kawaihae at Rt. 250	Summit of Hwy 250 between Waimea and Hāwī.	Residents	Southeast toward Maunakea (mauka)
8	Route 250 Pu'u overlook	Gravel shoulder where cars can pull off of the highway and view Maunakea and North Kona/South Kohala.	Sightseers	Southeast mauka
9	DHHL Lalamilo	Residential neighborhood within Waimea.	Residents	Southeast mauka
10	Waimea Park	Athletic facilities for sports such as baseball and tennis. Nearby a school.	Residents	Southeast mauka
11	DHHL Pu'u Kapu	Residential neighborhood within Waimea.	Residents	Southeast mauka
12	DHHL Waikoloa-Waialeale	Along Old Māmahaloa Hwy through ranch lands.	Residents	South mauka
13	Waipio Valley Lookout	Formal lookout with parking lot and trail to scenic view.	Sightseers	Northwest along the coast
14	Honoka'a	Main road into town.	Residents	Northwest up the coast
15	Laupāhoehoe Point	State park with parking lot and picnic facilities along the coast.	Sightseers	Northeast makai
16	Maunakea Summit (Kūkahau'ula)	Highest point on Maunakea. Recognized as a sacred place to native Hawaiians.	Cultural Practitioners	Panoramic
17	Lake Wai'au	Small lake near the summit of Maunakea, accessible by a trail. Waters used for healing and worship practices in Hawaiian culture.	Cultural Practitioners	West over the lake
18	North ridge of Maunakea summit cinder cone (Kūkahau'ula)	North ridge of Kūkalau'ula, near Keck, Subaru, IRTF, or CFHT observatories.	Sightseers	Panoramic

Figure 3-2. Primary View from Viewpoints



3.1.4 Existing Telescopes on Maunakea

There are 11 existing observatories near the summit of Maunakea, eight of which are optical/infrared and three of which are submillimeter/radio observatories. The heights of these existing observatories range from a little over 20-feet to 151-feet. The names, elevation and approximate heights of the existing observatories are listed in Table 3-2. The locations of these observatories within the Astronomy Precinct are shown in Figure 3-3.

Table 3-2. Existing Observatories on Maunakea

Map Number	Observatory	Ground Elevation (feet)	Dome Height from Ground (feet)
Submillimeter/Radio Observatories			
1	California Institute of Technology Submillimeter Observatory (CSO)	13,362	63
2	James Clerk Maxwell Telescope (JCMT)	13,390	100
3	Submillimeter Array (SMA)	13,279-13,400	45
Optical/Infrared Observatories			
4	Subaru Observatory	13,578	141 (Subaru 2008)
5a, 5b	W. M. Keck Observatory (telescopes I and II)	Keck 1: 13,714, Keck 2: 13,659	111 (NASA 2005)
6	NASA Infrared Telescope Facility (IRTF)	13,652	53 (IRTF 2008)
7	Canada-France-Hawai'i Telescope (CFHT)	13,726	125(CFHT 2008)
8	Gemini Northern Observatory	13,764	151 (Gemini 2008)
9	University of Hawai'I (2.2M)	13,784	80
10	United Kingdom Infrared Telescope (UKIRT)	13,762	61 (UH 1975)
11	University of Hawai'i – Hilo (0.9M)	13,727	20.25 (UH 2006)

For each existing observatory, Table 3-3 shows the master plan siting area that they are located within, the percent of the area of the island from which the observatory is potentially visible, and the dome color of the observatory. Figure 3-4 shows the combined visibility of the existing 11 observatories near the summit, where the top of at least one of the existing observatories is visible. Individual viewshed maps are included in Appendix B. Based on this analysis, from approximately 43 percent of the island area a viewer would be able to see at least one existing observatory. According to 2000 U.S. Census data 72 percent of the Island of Hawai'i's population (roughly 107,000 people) is within the viewshed of the existing observatories.

Table 3-3. Existing Observatory Visual and Aesthetic Attributes

Observatory		Master Plan Siting Area	Viewshed (%)	Dome Color
Optical/Infrared Observatories				
UHH 0.9m		A	15	White
UH 2.2m		A	36	White
CFHT		A	35	White
UKIRT		A	26	White
Gemini		A	39	Aluminum
IRTF		B	14	Aluminum
W. M. Keck Observatory	Keck 1	B	17	White
	Keck 2	B	16	White
Subaru		B	20	Metallic
Submillimeter/Radio Observatories				
CSO		C	5	Metallic
JCMT		C	7	White
SMA		C	2	N/A

Figure 3-3. Map of Existing Observatories on Maunakea

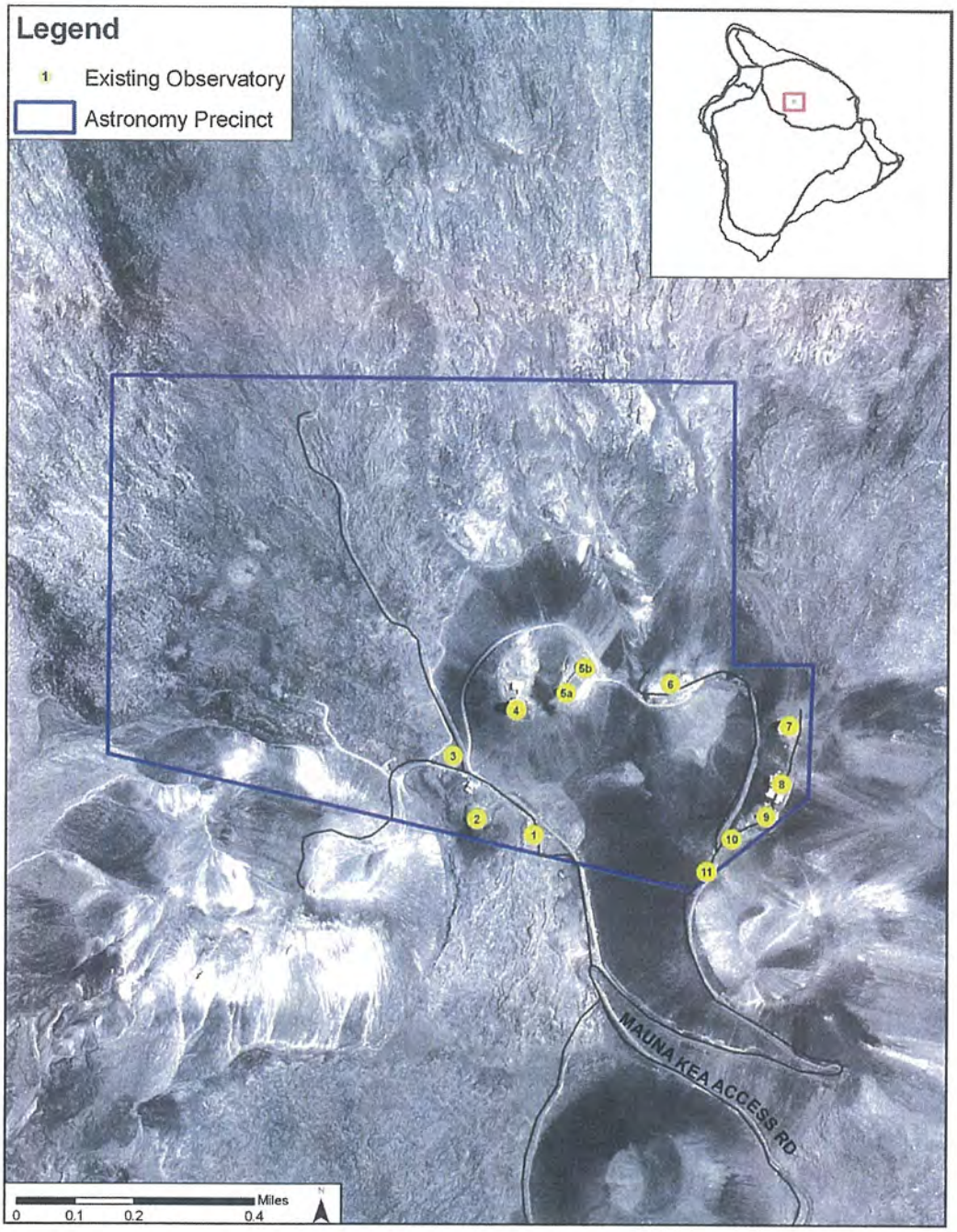
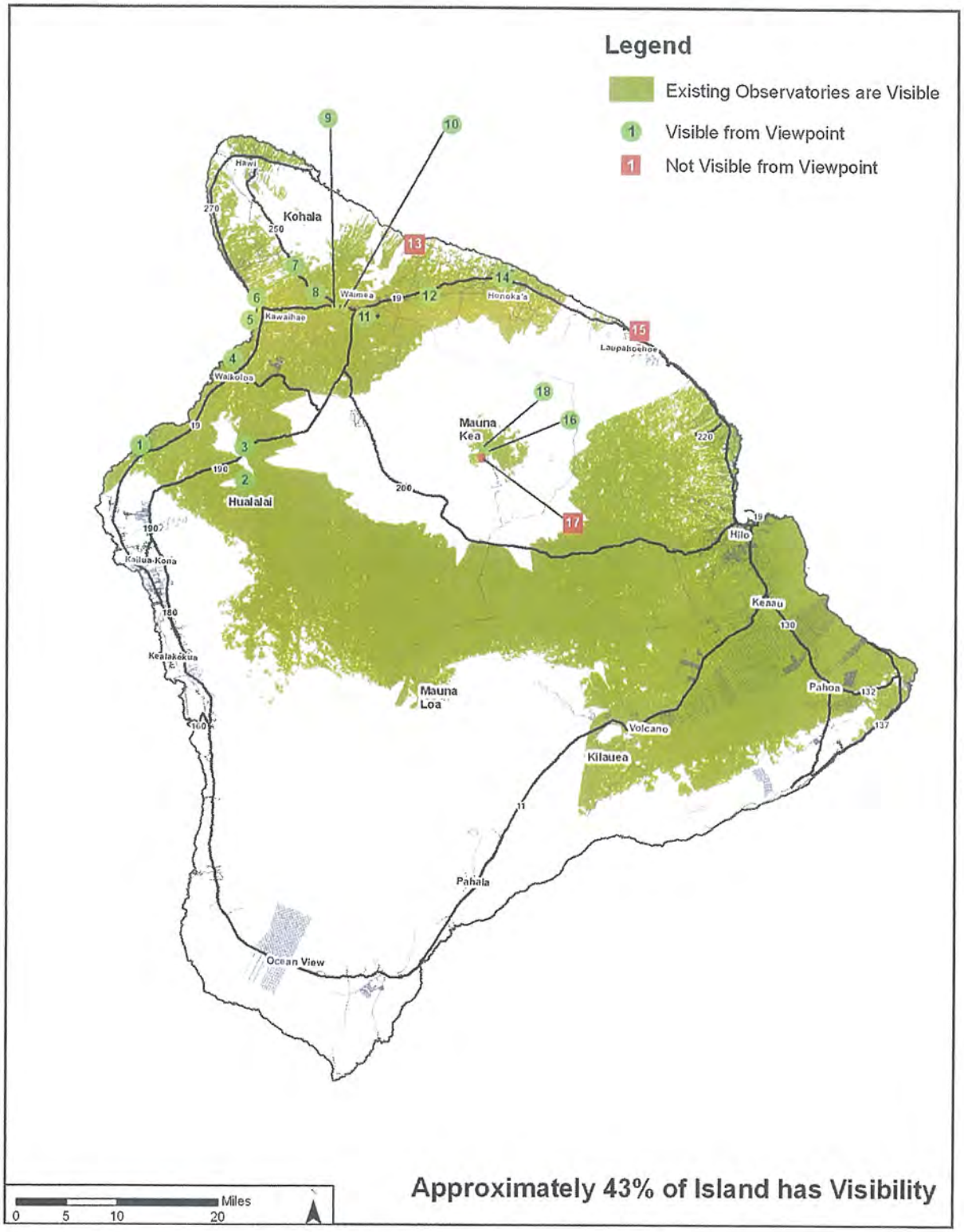


Figure 3-4. Combined Visibility of Existing Observatories on Maunakea



4.0 Consequences

This section presents the potential visual impacts that would occur from locating the TMT Observatory at the proposed 13N site and the alternative E2 site on Maunakea.

4.1 No Action Alternative

The No Action Alternative considers existing conditions and what would be reasonably expected to occur in the foreseeable future, absent the proposed project.

With this alternative the existing CSO Observatory on Maunakea would be decommissioned and the SMA would be expanded from eight to 20 antennas in Area C and D of the Astronomy Precinct. The other existing observatories would remain. These observatories can be seen from 43 percent of the area of the Island of Hawai'i, as shown in Figure 3-4; approximately 72 percent of the population (roughly 106,000 people) is within this existing viewshed.

TMT would not fund construction, installation, or future operation of the TMT Observatory and its supporting facilities at either Maunakea or Cerro Armazonas. The Pan-STARRS project, a telescope consisting of four mirrors each with a diameter of 6 feet (1.8 meters), similar to what is constructed on Haleakala, would occur either at the current location of the UH 2.2 Observatory or the UH 2.2 Observatory would move to Area E and become Pan-STARRS. Also, in the absence of the proposed TMT Observatory, it is likely that in the future another observatory would be developed within Area E pursuant to the CMP.

4.2 Maunakea

The proposed 13N site, and the alternative E2 site, for the TMT Observatory are within the Astronomy Precinct on Maunakea in an area northwest of the summit that was identified in the 2000 Master Plan as Area E. These two sites are shown in Figure 4-1. The 2000 Master Plan for Maunakea identified the Area E location as a potential site for a Next Generation Large Telescope (NGLT), similar to the TMT Observatory, primarily because it minimizes visual impacts (OMKM 2000).

In addition to the observatory within the Mauna Kea Astronomy Precinct the project would also require a Support Facility that would be located at Hale Pōhaku, at an elevation of 9,300 feet, Headquarters in the University Park of UH Hilo, and a satellite office in Waimea. These facilities are not anticipated to have a visual impact due to their limited visibility, because their design would be similar to other developments in these areas, and because there are no designated or recognized visual resources associated with them.

Figure 4-1. Proposed 13N Site and Alternative E2 Site

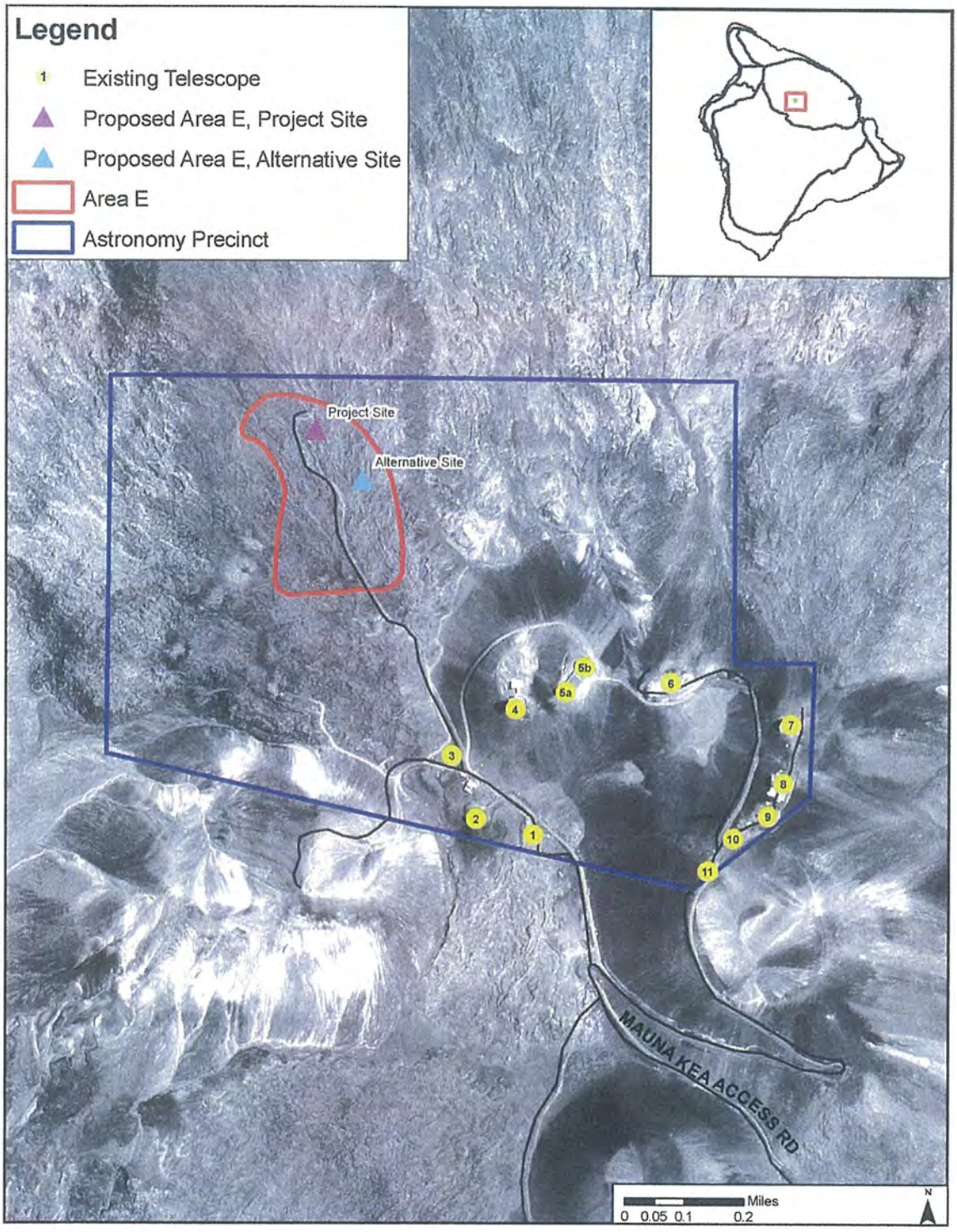


Figure 4-2 provides a simulation and cross section of the proposed design of the TMT Observatory. Figure 4-2 shows both the proposed dome enclosure for the telescope and the administrative facilities. In addition to the 13N and E2 sites being below the summit of Maunakea, the cross section shows that part of the TMT Observatory would be below existing grade, which would further minimize the potential visual impact. The proposed maximum height of the dome enclosure is approximately 180 feet (55 meters) above existing grade. The proposed diameter to the exterior of the structure is 216 feet (66 meters). To put this size into perspective, the area is roughly the size of a football field, which is 160 feet (48.8 meters) wide by 300 feet (91.4 meters) long, without sidelines and stands. For height, the TMT Observatory would be similar to the Ilikai Hotel in Honolulu.

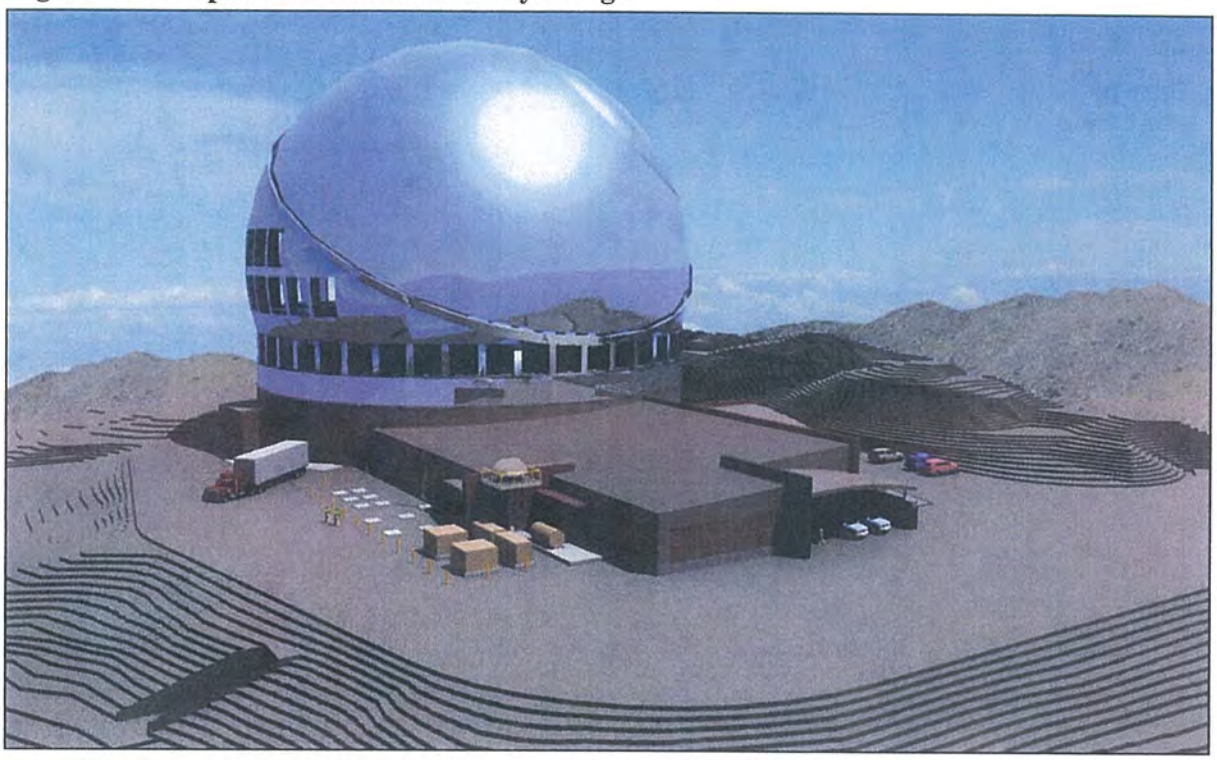
As shown in Figure 4-2, natural colors that blend into the landscape would be used for the exterior of the fixed enclosure and the administrative facilities. The proposed coating of the rotating dome enclosure is a reflective aluminum-like finish similar to the Subaru Observatory. The coating on the outer surface of an observatory dome is important to the function of the telescope. If the telescope and inner structure of the enclosure heat up during the day, or cools below the night air temperature, it will cause local air turbulence inside the enclosure that would degrade the telescope image quality. To maintain a consistent temperature inside the dome the TMT Observatory would be constructed with thick insulation and would require daytime air conditioning. The proposed metallic exterior coating on the dome would reduce the amount of energy needed to regulate the temperature.

In general, the existing observatories on Maunakea with a metallic coating (such as Gemini, IRTF, and Subaru) reflect the morning sunrise and evening sunset light and stand out during this period. However, during majority of the day the metallic coating reflects the sky, which helps reduce the visibility of the observatory.

Visibility of the Adaptive Optics Laser

The proposed TMT Observatory would use an adaptive optics (AO) system on the telescope to correct distortions in the view resulting from atmospheric affects. This greatly improves the image that can be obtained from the telescope. The TMT Observatory would be the first astronomy telescope designed from conception to use adaptive optics. The AO system uses a laser pointed into the sky. The multiple overlapping laser beams could be faintly visible to the naked eye as a single beam on moonless nights for a distance of up to 9 miles from the observatory. Figure 4-3 shows a circle with a 9 mile radius around the proposed location of the TMT Observatory; the maximum potential area where the adaptive optics laser may be visible. The area where the laser may be visible consists primarily of ranchlands and forest reserve which are not populated. Therefore, the laser used in the adaptive optics system is expected to have a less than significant visual impact.

Figure 4-2. Proposed TMT Observatory Design



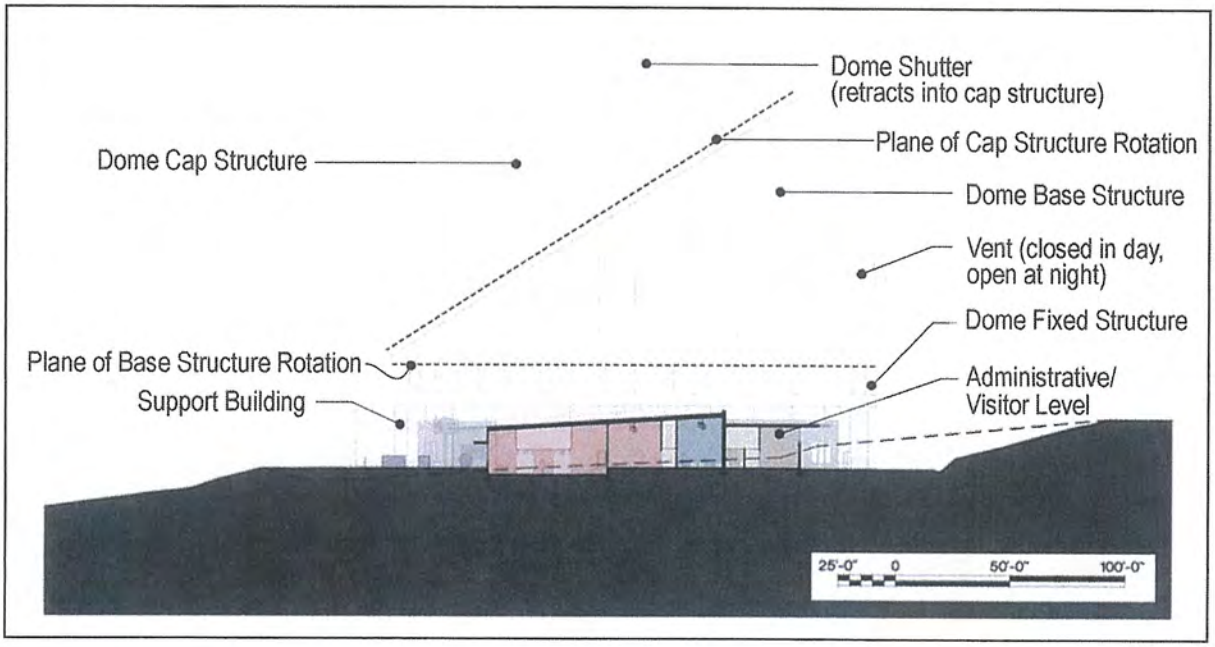
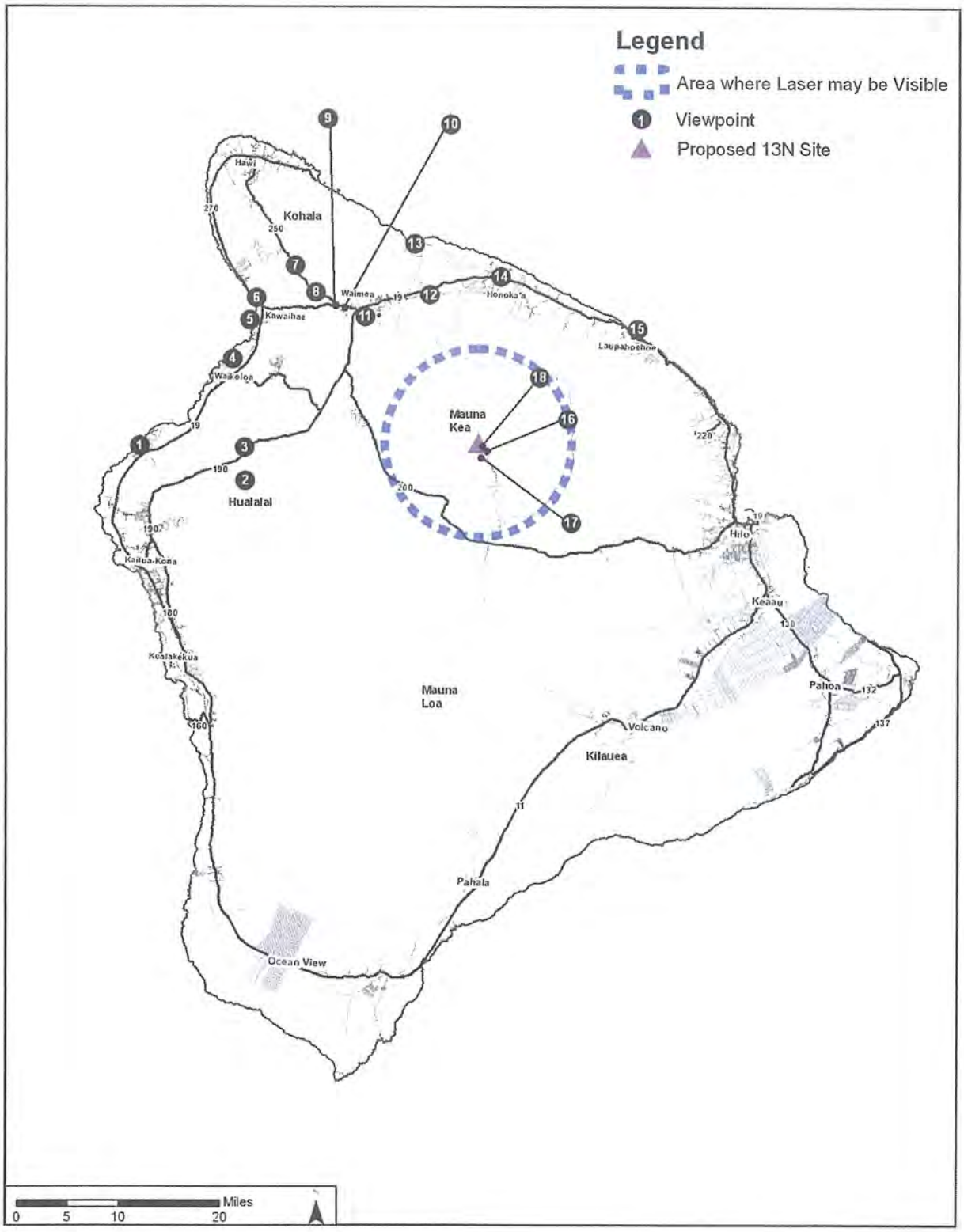


Figure 4-3. Potential Visibility of the TMT Observatory's Adaptive Optics Laser



4.2.1 13N Site

Temporary Impacts

Construction and Decommissioning

Temporary visual impacts from the proposed construction, and the potential future decommissioning, of the TMT Observatory would be associated with the presence of construction equipment and workers, material stockpiles, debris and staging areas. Most of the construction staging and material storage would occur in the area around Hale Pōhaku, at an elevation of 9,300 feet, which would not be visible from other areas of the island. Dust, and light and glare emanating from construction activities would also have a temporary visual impact. These temporary impacts would be less than significant.

Long-Term Impacts

Scenic Vistas and Viewplanes

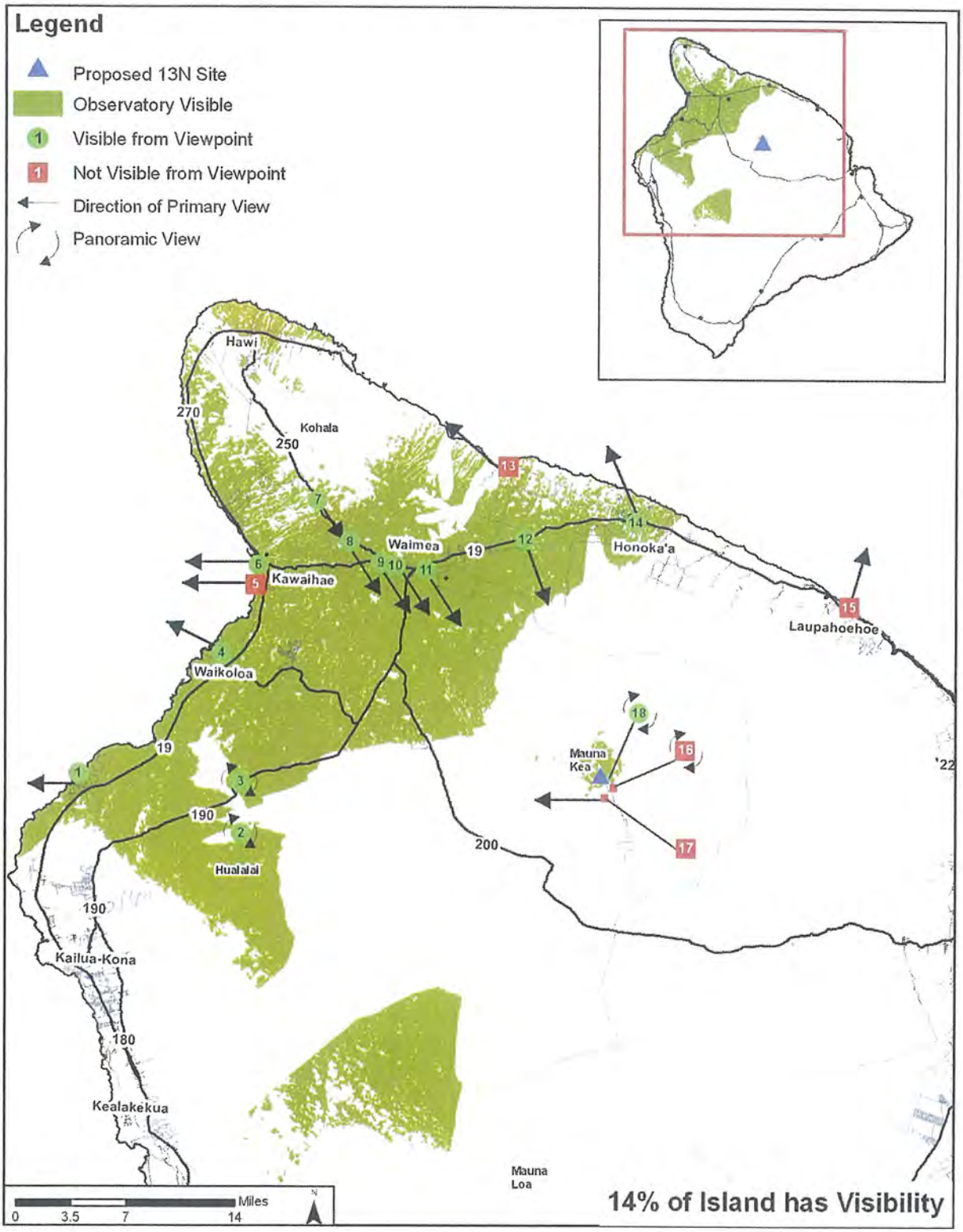
Locating the TMT Observatory at the proposed 13N site would not substantially affect scenic vistas and viewplanes identified in the Hawai'i County General Plan or the South Kohala Development Plan. The TMT Observatory would not be visible in the view from Hilo Bay with Maunakea in the background. The TMT Observatory would not be visible in the view of Maunakea from Pahoa-Kea'au, Volcano-Kea'au Roads, and various Puna subdivisions or from locations where Hilo Bay is visible with Maunakea in the background. Although the TMT Observatory may be visible in the view of Maunakea from portions of the South Kohala district and the area around Waimea, it would not block or substantially obstruct the views and viewplanes of the mountain. Therefore, the Project would not exceed significance criteria 12 as stated in §11-200-12 of the HAR.

Viewshed Analysis

A viewshed analysis was conducted to assess which areas of the Island of Hawai'i may have a view of the TMT Observatory at the proposed 13N site. The viewshed analysis is based on topographic information; it does not include existing vegetation or structures which may further obstruct views of the TMT Observatory. Therefore, the viewshed analysis can be considered a worst case scenario.

The results of this analysis are shown in Figure 4-4. In this figure the shaded portions of the island are areas where at least the top of the TMT Observatory may be visible. For the 18 representative viewpoints, a green circle shows that the TMT Observatory would be visible and a red square means it would not be visible. The TMT Observatory could be visible from viewpoints 1-4, 6-12, 14, and 18. The TMT Observatory would not be visible from viewpoints 5, 13 and 15-17.

Figure 4-4. Proposed 13N Site - Viewshed and Primary View Analysis



The viewshed analysis confirms that, because it would be located north of and below the summit of Maunakea, the TMT Observatory would not be visible in the southern portion of the island; this includes the large cities of Hilo and Kailua-Kona. According to the viewshed analysis the TMT Observatory would be visible from 14 percent of the area of the island (see Table 4-1). According to 2000 U.S. Census data, approximately 15.4 percent of the island of Hawai'i's population (approximately 23,000 people) would live within the viewshed of the TMT Observatory at the proposed 13N site. Others, including visitors and island residents that reside outside of the viewshed, would be able to see the TMT Observatory when they travel through and visit locations within the viewshed.

Table 4-1. Visibility of the Proposed 13N Site

Visibility	Area of Island (%)	Hawai'i's Population	
		%	People
Visible	14%	15.4%	23,000
Not Visible	86%	84.6%	125,000

Table 4-2 divides the viewshed, and the population within the viewshed, into five areas: Waimea, Honoka'a, Hāwī, Waikoloa and Kawaihae, and Hualālai. Of these areas, the TMT Observatory would be visible in the primary view direction only from the area around Waimea. For the other four areas the primary view direction is makai. Of the island's population 5.5 percent (approximately 8,100 people) are within the area around Waimea and may be able to see the TMT Observatory.

Table 4-2. Visibility of the Proposed 13N Site within the Primary View Direction

Location	Hawai'i's Population		Primary View Direction?
	%	People	
Waimea	5.5%	8,100	Yes
Honoka'a	2.8%	4,200	No
Hāwī	2.6%	3,900	No
Waikoloa and Kawaihae	4.3%	6,400	No
Hualālai	0.2%	303	No

Primary View

Of the 13 viewpoints where the TMT Observatory may be visible, it would not be within the primary view of four; the Hualālai Resort (1), Waikoloa/Mauna Lani (4), Puukohola Heiau (6) and Honoka'a (13). At these coastal locations, the primary view is makai.

The TMT Observatory could be visible and in the primary view direction from viewpoints along Highway 250 (7 and 8) and around the town of Waimea (9, 10, 11 and 12). The TMT Observatory could also be visible from the Big Island Country Club (3), from the summit of Pu'u Waawaa (2), and from the North ridge of Maunakea summit cinder cone (18), where the panoramic view of the water, the surrounding area, and Maunakea would be important to the viewer.

Silhouette View

For the 13 representative viewpoints where the TMT Observatory may be visible, an analysis of the line of sight from the viewpoint to the TMT Observatory was conducted to determine

whether the view of the facility would be a full or partial silhouette against the sky, or whether it would be seen against the backdrop of Maunakea. For some of these 13 viewpoints the silhouette analysis showed that the view of the TMT Observatory would be partially obstructed from a rise between the viewer and the viewpoint. Table 4-3 summarizes the silhouette analysis for the TMT Observatory at the proposed 13N site. The results of the silhouette analysis are in Appendix C.

Table 4-3. Proposed 13N Site - Silhouette Analysis

Viewpoint	Location	Portion of TMT Observatory in Silhouette		
		None	Partial	Full
1	Hualālai Resort	--	164 feet (50 m)	--
2	Pu'u Waawaa	--	58 feet (17 m)	--
3	Big Island Country Club	--	82 feet (25 m)	--
4	Waikoloa/Mauna Lani	--	164 feet (50 m)	--
5	Hāpuna Beach	Not Visible		
6	Puukohola Heiau	--	164 feet (50 m)	--
7	DHHL Kawaihae at Rt. 250	X	--	--
8	Route 250 Pu'u overlook	X	--	--
9	DHHL Lalamilo	--	49 feet (15 m)	--
10	Waimea Park	--	89 feet (27 m)	--
11	DHHL Pu'u Kapu	--	98 feet (30 m)	--
12	DHHL Waikoloa-Waialeale	--	164 feet (50 m)	--
13	Waipio Valley Lookout	Not Visible		
14	Honoka'a	--	82 feet (25 m)	--
15	Laupāhoehoe Point	Not Visible		
16	Maunakea Summit	Not Visible		
17	Lake Wai'au	Not Visible		
18	North ridge (Kūkahau'ula)	--		X

From the two viewpoints along Highway 250 (7 and 8) the view of the TMT Observatory would not be in silhouette; it would be visible against the backdrop of Maunakea. This may reduce the prominence of the TMT Observatory in the view from these locations; particularly at sunset, when Maunakea would be back-lit by the setting sun. Only from the northern ridge of Kūkahau'ula (18), which is located on a ridge at an elevation higher than the TMT Observatory, would the full observatory be in silhouette.

From the coastal locations of Hualālai Resort (1), Waikoloa/Mauna Lani (4) and Puukohola Heiau (6), approximately 165 feet (50 meters) of the TMT Observatory would be in silhouette. From the town of Honoka'a (14), approximately 80 feet (25 meters) of the TMT Observatory would be in silhouette. From these viewpoints the TMT Observatory would not be located within the direction of the primary view, which is makai.

In the area around Waimea (viewpoints 9 through 12), where the TMT Observatory would be visible within the direction of the primary view, the amount of the partial silhouette would range from 50 feet (15 meters) to 165 feet (50 meters). The silhouette analysis also showed that from the Big Island Country Club (3) and Pu'u Waawaa (2) the view of the TMT Observatory would be partially obstructed from a rise of Maunakea between the viewer and the observatory. From portions of the Big Island Country Club (2) the top 80 feet (25 meters) of the TMT Observatory

would be visible and in silhouette. From the summit of Pu'u Waawaa (3) the top 55 feet (17 meters) would be visible and in silhouette.

The existing observatories on the summit of Maunakea can also affect the silhouette view. From some areas on Hawai'i, the view of the TMT Observatory would be in front of one of Keck 1, Keck 2 or Subaru. These areas are shown in Figure 4-5.

Figure 4-5. Area where TMT would be Viewed in Front of an Existing Observatory

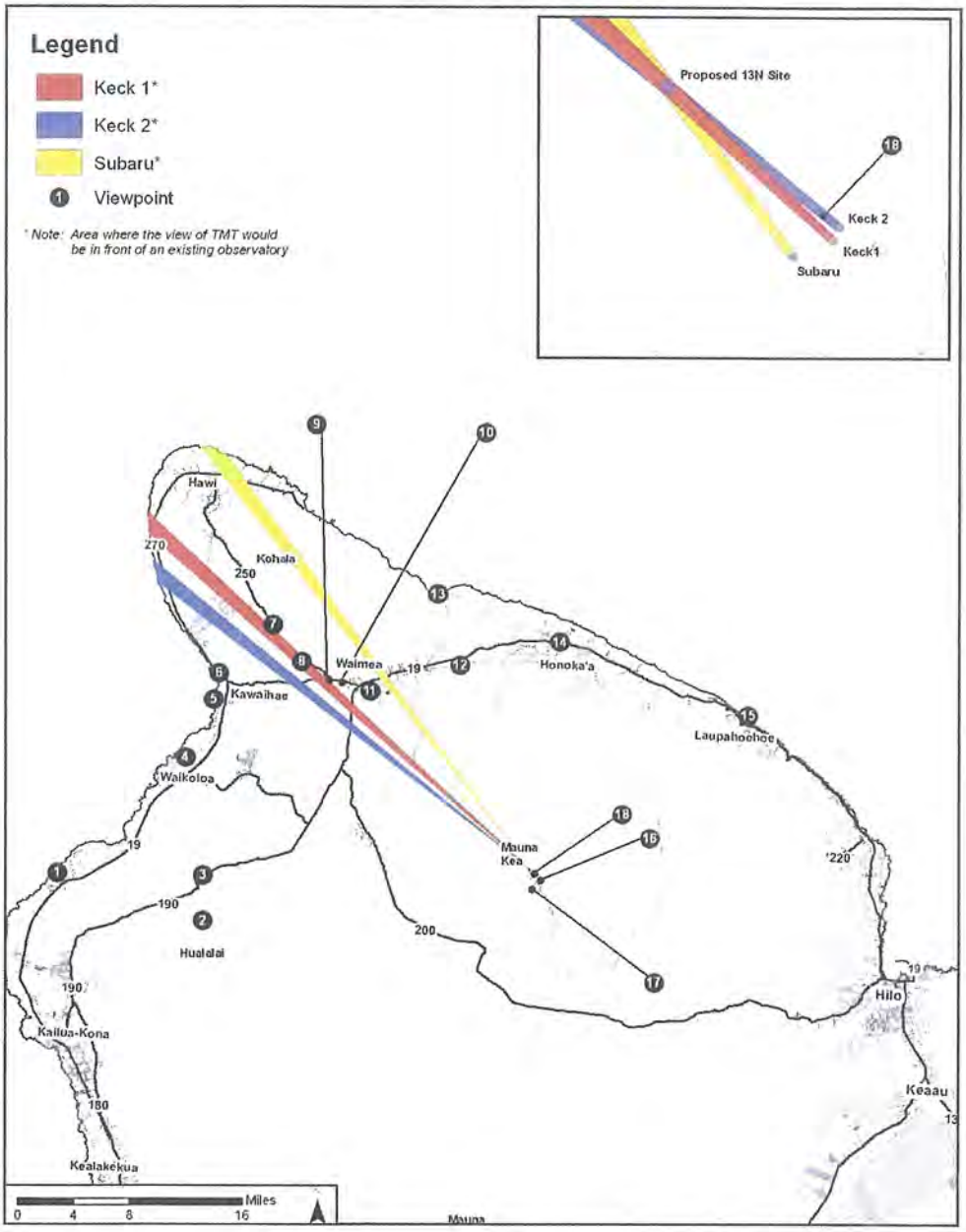


Photo Simulations

Views from Lower Elevation Developed Areas

Photo simulations of the TMT Observatory at the proposed 13N site were created for views from Waimea, near Honoka'a (in the area around viewpoint 12) and Waikoloa. The photos used in these simulations were taken with a 600 mm/5.6 telephoto lens, creating a "binocular view." For comparison purposes a "naked eye view," without the aid of binoculars or a telephoto lens, from Waimea, Honoka'a and Waikoloa are provided. These naked eye photos show how, from these locations that are a distance of approximately 19 miles from the summit of Maunakea, the existing observatories appear quite small and do not occupy much of the total view. The naked eye view of the TMT Observatory on Maunakea would be similar. Because the size and design of the TMT Observatory would not be discernable from the naked eye perspective, simulations at this scale were not prepared.

An example of the naked eye view of Maunakea from Waimea is shown in Figure 4-6. Figure 4-7 is a binocular view simulation of the TMT Observatory in the proposed 13N site from Waimea. This simulation shows how the location of the TMT Observatory would be below the summit of Maunakea and the existing observatories. In this view the lower portion of the TMT Observatory would be obscured behind a rise of Maunakea and it would be located in front of one of the existing domes of the Keck Observatory.

In Figure 4-7 the TMT Observatory is shown with a reflective aluminum-like finish on the dome enclosure. In Figure 4-8 the TMT Observatory is shown with a white exterior finish and in Figure 4-9 it is shown in a brown finish. The visual impact of the dome's exterior finish partly depends on the colors in the landscape of the summit of Maunakea. For much of the year the summit of Maunakea has a reddish-brown color from the volcanic rock. From November through March the summit of Maunakea is white from varying amounts of snow cover. Figure 4-10 through Figure 4-12 provide a photo simulation of the TMT Observatory, as viewed from Waimea, with the three exterior finishes when Maunakea is covered with snow.

Figure 4-13 shows the naked eye view from Honoka'a. Figure 4-14 through Figure 4-16 are binocular view simulations of the TMT Observatory, in the proposed 13N site, near Honoka'a (in the area around Waikoloa-Waialeale, viewpoint 12) with the reflective aluminum-like finish, and the white and brown exterior finish when Maunakea is covered in snow.

Figure 4-17 shows the naked eye view from Waikoloa in the northwest portion of the island. Figure 4-18 shows a binocular view simulation of the TMT Observatory, in the proposed 13N site with a reflective aluminum-like finish, as seen from Waikoloa. Figure 4-19 through Figure 4-21 are binocular view simulations of the TMT Observatory, as seen from Waikoloa when Maunakea is covered in snow, with the reflective aluminum-like, white and brown exterior finish.

As shown in these simulations while the white finish visually blends in with Maunakea when it is snow covered, it would be more visually prominent when the summit is bare. Conversely, the brown finish may blend better with the bare volcanic rock at the summit, but it would stand out more during the snow covered months. The reflective aluminum-like exterior finish reflects the colors of the sky and ground, which would better reflect its setting and have a reduced visual impact year round.

Figure 4-6. Naked Eye View of Maunakea from Waimea

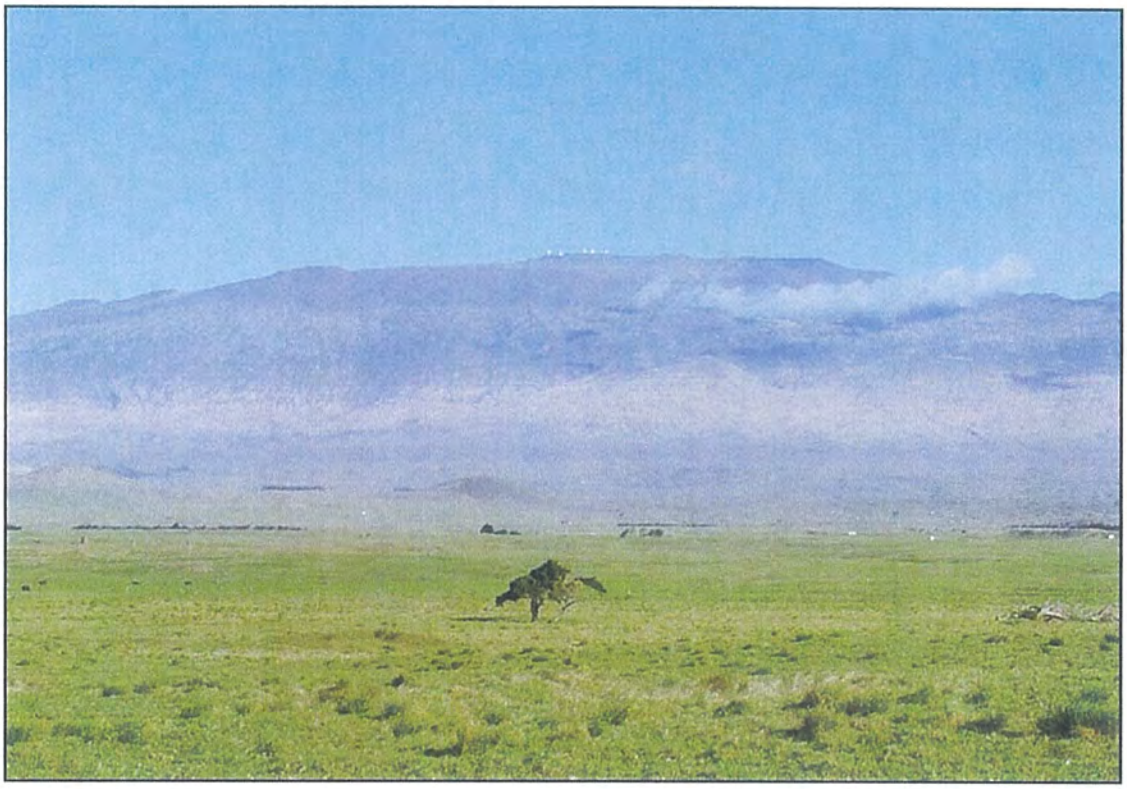


Figure 4-7. Simulation of TMT Observatory, Aluminum-Like Finish – Binocular View from Waimea

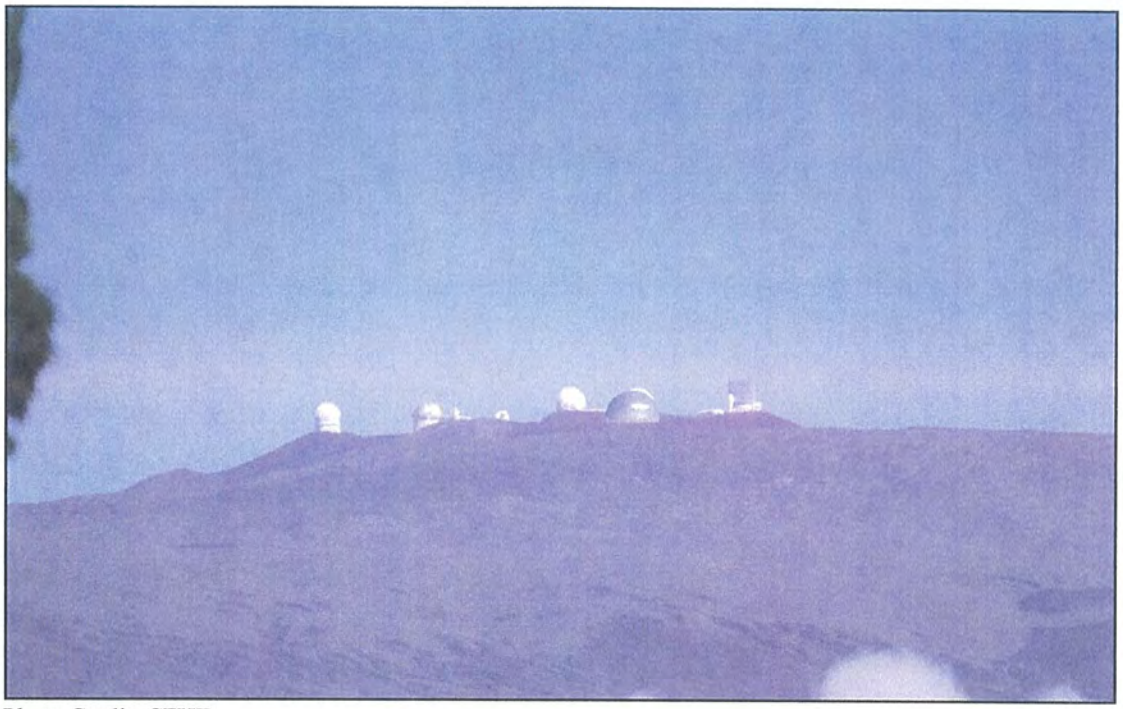


Photo Credit: CFHT

Figure 4-8. Simulation of the TMT Observatory, White Finish – Binocular View from Waimea

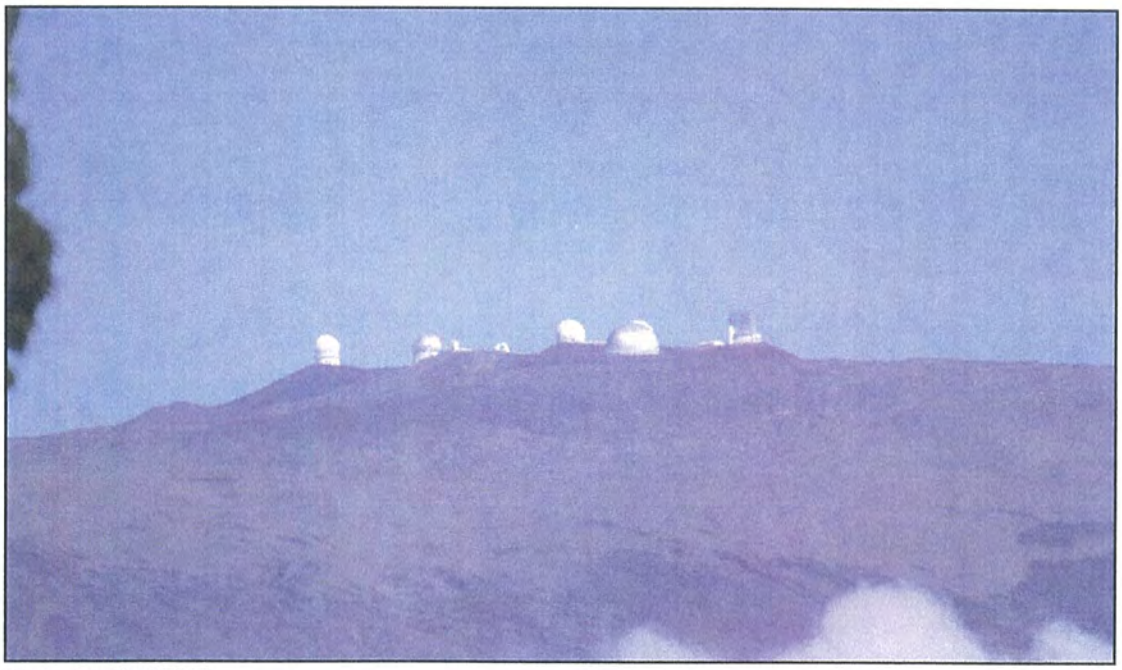


Photo Credit: CFHT

Figure 4-9. Simulation of the TMT Observatory, Brown Finish – Binocular View from Waimea

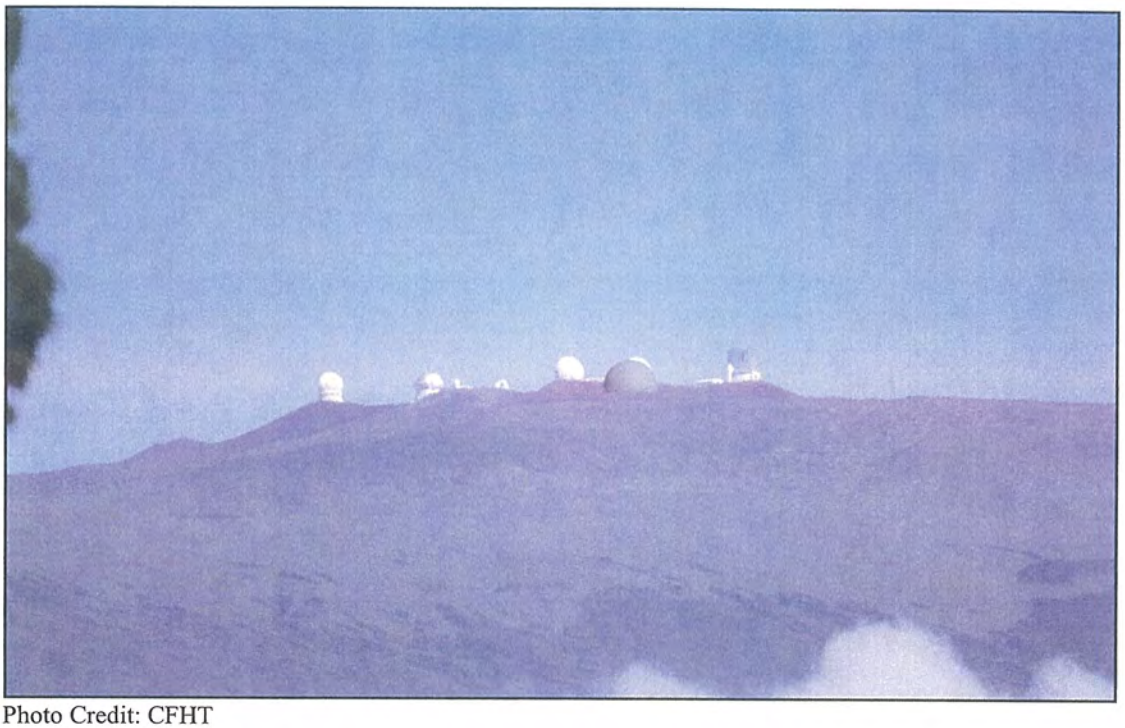


Photo Credit: CFHT

Figure 4-10. Simulation of the TMT Observatory, Aluminum-Like Finish – Binocular View from Waimea with Snow

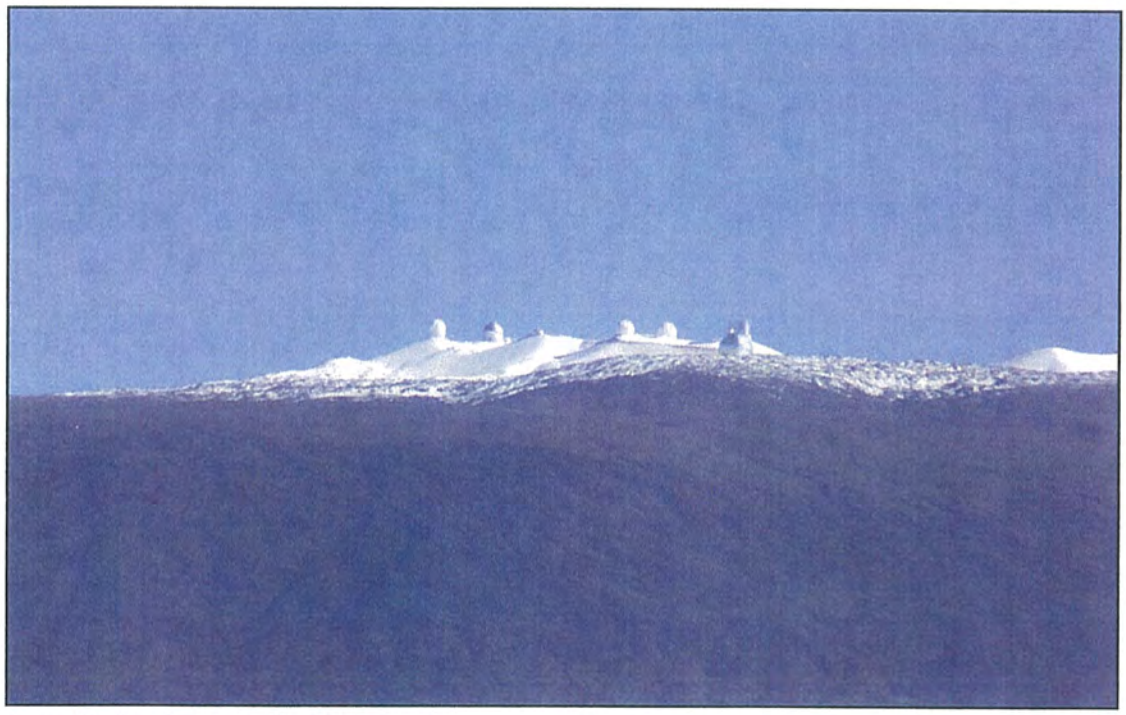


Photo Credit: Charles R. West Photography

Figure 4-11. Simulation of the TMT Observatory, White Finish – Binocular View from Waimea with Snow

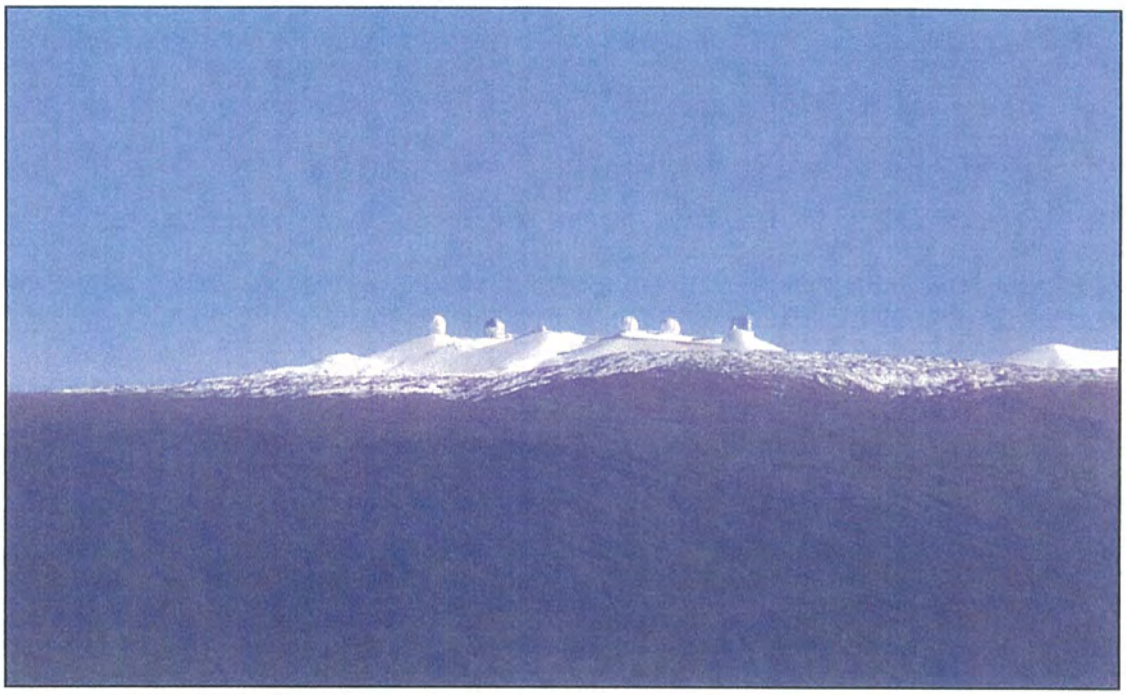


Photo Credit: Charles R. West Photography

Figure 4-12. Simulation of the TMT Observatory, Brown Finish – Binocular View from Waimea with Snow

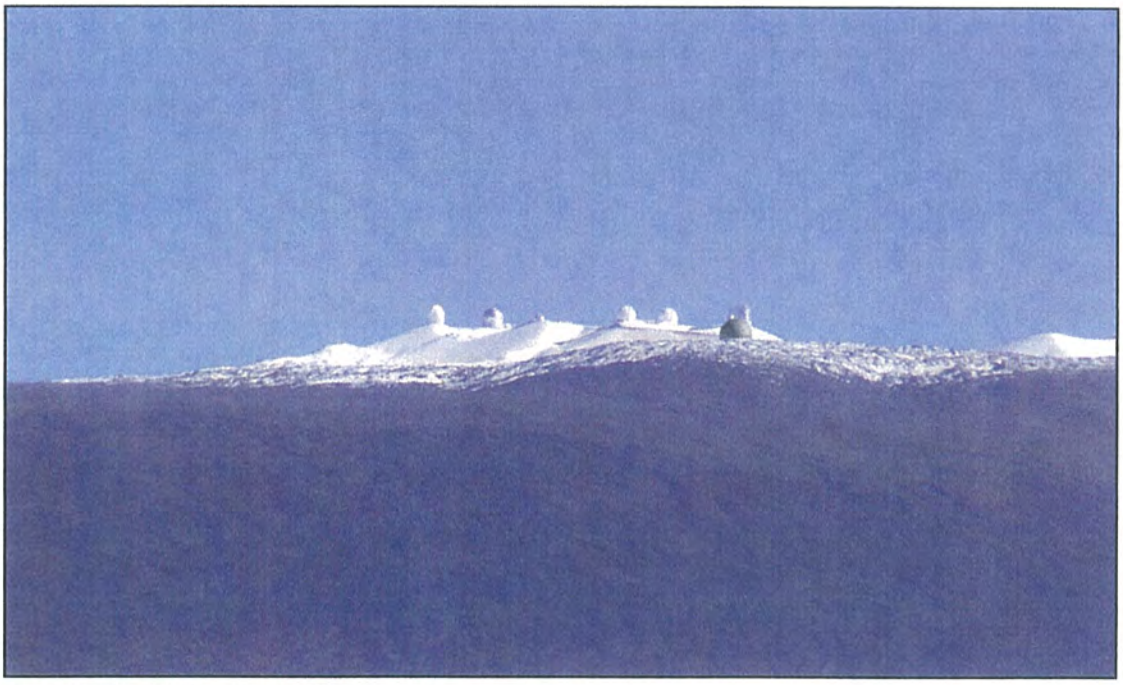


Photo Credit: Charles R. West Photography

Figure 4-13. Naked Eye View of Maunakea near Honoka'a

Figure 4-14. Simulation of the TMT Observatory, Aluminum-Like Finish – Binocular View from Honoka'a with Snow

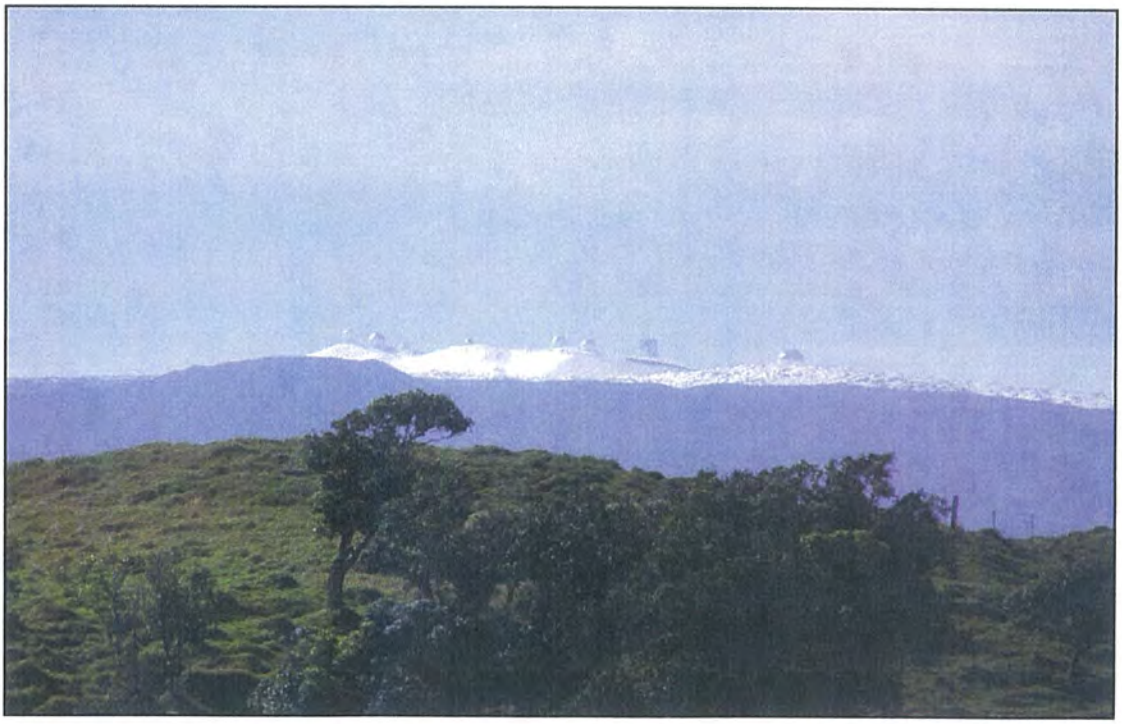


Figure 4-15. Simulation of the TMT Observatory, White Finish – Binocular view from Honoka'a with Snow

Figure 4-16. Simulation of the TMT Observatory, Brown Finish – Binocular view from Honoka'a with Snow

Figure 4-17. Naked Eye View of Maunakea from Waikoloa

Figure 4-18. Simulation of the TMT Observatory, Aluminum-Like Finish – Binocular View from Waikoloa

Photo credit: CFHT

Figure 4-19. Simulation of the TMT Observatory, Aluminum-Like Finish – Binocular view from Waikoloa with Snow

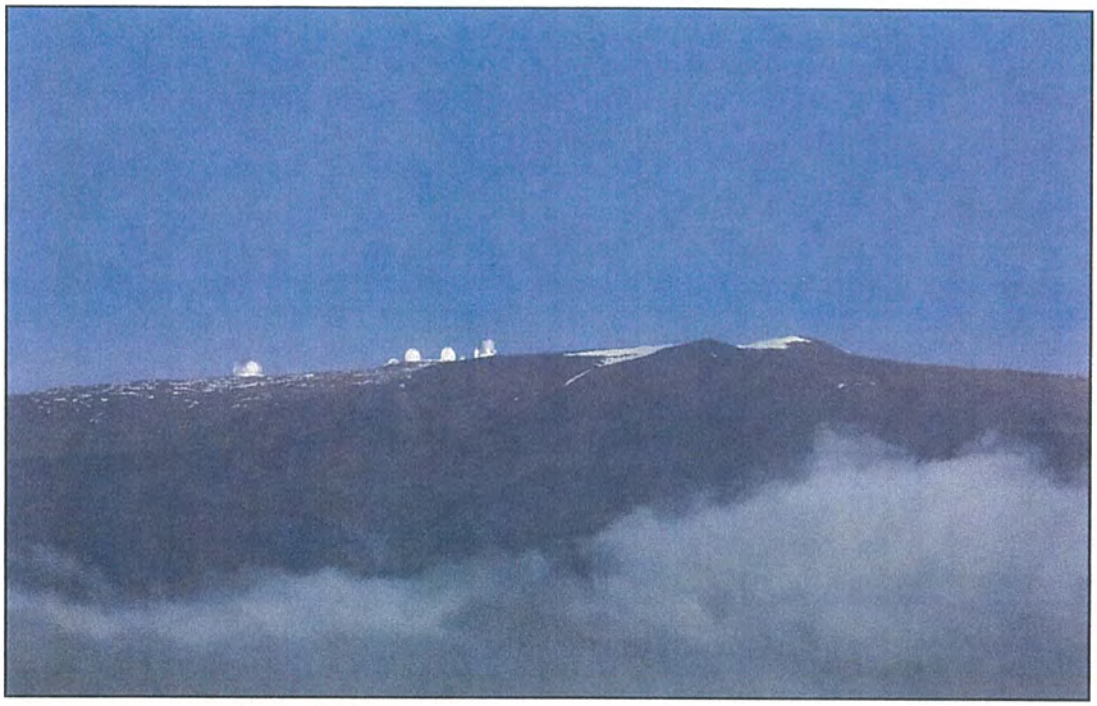


Photo Credit: Charles R. West Photography

Figure 4-20. Simulation of the TMT Observatory, White Finish – Binocular view from Waikoloa with Snow

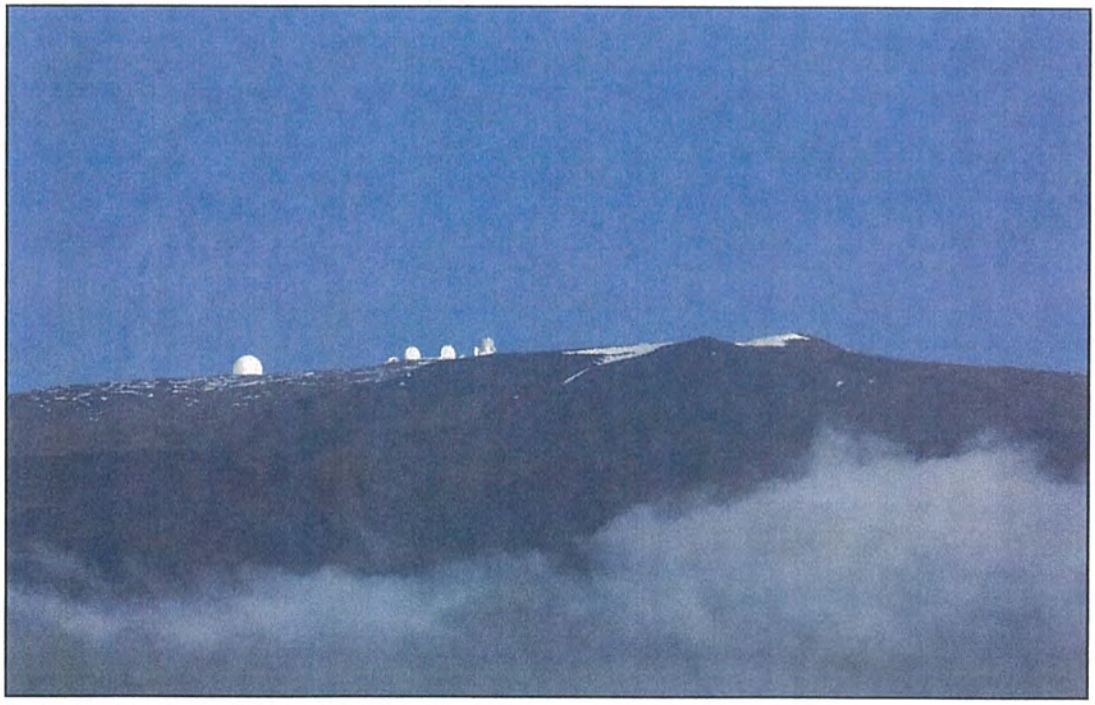


Photo Credit: Charles R. West Photography

Figure 4-21. Simulation of the TMT Observatory, Brown Finish – Binocular view from Waikoloa with Snow

Photo Credit: Charles R. West Photography

Views within the Summit Region

Although the TMT Observatory will not be visible from the summit of Maunakea, viewpoint 16, or Lake Waiau, viewpoint 17, it will be visible from other locations within the summit region; primarily, the northern plateau and the northern ridge of Kūkahau'ula, viewpoint 18, where the Subaru, Keck, IRTF, and CFHT observatories are located. Figure 4-22 shows the current view from near the Keck Observatory, viewpoint 18, looking to the northwest over the northern plateau and the TMT Observatory 13N site. Figure 4-23 is a simulation of the TMT Observatory with an aluminum-like finish from the same viewpoint.

As the simulation in Figure 4-23 shows, the TMT Observatory will add a substantial new visual element in the landscape that will be visible from viewpoints along the northern ridge of Kūkahau'ula and by people as they travel within the northern portion of the summit region. Views from the northern ridge of Kūkahau'ula are now dominated by views of observatories, including Subaru, Keck, IRTF, and CFHT, which are located on this ridge. The majority of visitors/sightseers to the summit region and cultural practitioners visit the Kūkahau'ula summit, not the northern ridge of Kūkahau'ula. In addition, TMT's lower elevation and minimal size and height mean it will not block the view of Maui from the ridge. Nevertheless, the TMT Observatory will add a substantial new visual element to a currently, relatively undeveloped portion of the summit region.

Figure 4-22. Naked Eye View from Near Keck Observatory, Viewing Northwest

Figure 4-23. Simulation of the TMT Observatory, Aluminum-Like Finish – from Near Keck Observatory, Viewing Northwest

Summary

The potential long-term visual impacts from the proposed 13N site for the TMT Observatory are summarized in Table 4-4.

Table 4-4. Proposed 13N Site - Summary of Potential Visual Impacts

Viewpoint	Location	Visual Impact				
		Is the TMT visible?	Visible in primary view?	Visible in silhouette?		
				No	Partial	Full
1	Hualālai Resort	Yes	No	--	164 feet (50 m)	--
2	Pu'u Waawaa	Yes	N/A[1]	--	58 feet (17 m)	--
3	Big Island Country Club	Yes	N/A[1]	--	82 feet (25 m)	--
4	Waikoloa/Mauna Lani	Yes	No	--	164 feet (50 m)	--
5	Hāpuna Beach	No	No	N/A		
6	Puukohola Heiau	Yes	No	--	164 feet (50 m)	--
7	DHHL Kawaihae at Route 250	Yes	Yes	X	--	--
8	Route 250 Pu'u Overlook	Yes	Yes	X	--	--
9	DHHL Lalamilo	Yes	Yes	--	49 feet (15 m)	--
10	Waimea Park	Yes	Yes	--	89 feet (27 m)	--
11	DHHL Pu'u Kapu	Yes	Yes	--	98 feet (30 m)	--
12	DHHL Waikoloa-Waialeale	Yes	Yes	--	164 feet (50 m)	--
13	Waipio Valley Lookout	No	N/A	N/A		
14	Honoka'a	Yes	No	--	82 feet (25 m)	--
15	Laupāhoehoe Point	No	N/A	N/A		
16	Maunakea Summit	No	N/A	N/A		
17	Lake Waiau	No	N/A	N/A		
18	North ridge of Kūkahau'ula	Yes	N/A1	--	--	X

[1] The primary view criterion is not applicable because at these viewpoints the panoramic view is important.

Visual Impact on Viewer Groups

Based on the above analysis, the following is a summary of the potential visual impacts on the three viewer groups from locating the TMT Observatory at the proposed 13N site.

Residents

Most residents of Hawai'i, such as in the cities of Hilo and Kailua-Kona, would not be able to see the TMT Observatory from their homes or public gathering places. From the viewshed analysis approximately 15 percent of the population (23,000 people) would be able to see at least the top of the TMT Observatory. Of these, it would only be within the direction of the primary view of 5.5 percent of the population (8,100 people) in the area around Waimea. However, residents that live outside of the viewshed would be able to see the TMT Observatory when they travel through and visit locations within the viewshed.

The TMT Observatory would also have a visual impact on residents in towns such as Waimea, Waikoloa and the area around Honoka'a. Within these towns the views of Maunakea that residents may have from their homes or gathering places, such as the Waimea Park (10), may be altered. The views from these viewpoints would be in partial silhouette (ranging from 15 meters at DHHL Lalamilo (9) to 50 meters at DHHL Waikoloa-Waialeale (12)), which could make the view more prominent, particularly in the morning when the facility would be back lit by the sun. The extent of the visual impact would be somewhat reduced by the times when the summit of Maunakea would be obscured by vog, clouds, or other causes of limited visibility. In general, the visual impact to the resident viewer group of Hawai'i would be less than significant. The impact to residents of Waimea, while slightly higher, would still be less than significant.

Sightseers

The visual experience for the sightseer viewer group would not be impacted by the TMT Observatory. This is because it would not be visible from the majority of the island including: the larger cities of Kona and Hilo; Volcanoes National Park; or from scenic viewpoints such as Waipio Valley Lookout (13) and Laupāhoehoe Point (15). From viewpoints, such as the Hualālai Resort (1), where the TMT Observatory could be visible, it would not be within the primary view and would not be expected to impact the visual experience. In addition, sightseers may be interested in astronomy, may plan on visiting the astronomy precinct and enjoy views of the TMT Observatory. The visual impact to sightseers on the island of Hawai'i would be less than significant.

Cultural Practitioners

Finally, as stated in Section 3.1.2, cultural practitioners on the Island of Hawai'i place a high value on pristine views of Maunakea. Of the three representative viewpoints that are from culturally important locations, the TMT Observatory would not be visible from two; the summit of Maunakea (16) and Lake Wai'au (17). The TMT Observatory could be visible from the summit of Pu'u Waawaa, where cultural practitioners may experience a visual impact. The silhouette analysis showed that from Pu'u Waawaa (2) the view of the TMT Observatory would be partially obstructed from a rise of Maunakea between the viewer and the observatory and that only the top 56 feet (17 meters) would be visible and in silhouette. The extent of the visual impact would be somewhat reduced at the times when the summit of Maunakea would be obscured by vog, clouds, or other causes of limited visibility.

Visual impacts are only a component of the Project's potential cultural impact. For information on the project's impacts to cultural practices see the *Cultural Impact Assessment, Thirty Meter Telescope*.

Overall Visual Impact

As discussed above, while the TMT Observatory would be a new visual element within the views of Maunakea (for approximately 14 percent of the island area and could be seen by approximately 15.4 percent of the population, or roughly 23,000 people) it would not obstruct or block existing views of Maunakea from around the Island of Hawai'i. Therefore, the Project would not exceed the applicable significance criteria in §11-200-12 of the HAR and would be expected to have a less than significant visual impact.

4.2.2 E2 Site

Temporary Impacts

Construction and Decommissioning

At the alternative E2 site the temporary visual impacts, from the proposed construction of the TMT Observatory and the potential future decommissioning of the TMT Observatory, would be the same as described in Section 4.2.1 for the proposed 13N site. These include the presence of construction equipment and workers, dust, and light and glare. These temporary impacts would be less than significant.

Long-Term Impacts

The long-term impacts from the alternative E2 site would be similar to the long-term impacts of the proposed 13N site.

Scenic Vistas and Viewplanes

Locating the TMT Observatory at the alternative E2 site would not substantially affect scenic vistas and viewplanes identified in the Hawai'i County General Plan or the South Kohala Development Plan. The TMT Observatory would not be visible in the view from Hilo Bay with Maunakea in the background. The TMT Observatory would not be visible in the view of Maunakea from Pahoa-Kea'au, Volcano-Kea'au Roads, and various Puna subdivisions or from locations where Hilo Bay is visible with Maunakea in the background. Although the TMT Observatory may be visible in the view of Maunakea from portions of the South Kohala district and the area around Waimea, it would not block the views and viewplanes of the mountain. Therefore, the project would not exceed significance criteria 12 as stated in §11-200-12 of the HAR.

Viewshed Analysis

The results of the viewshed analysis for the alternative E2 site are shown in Figure 4-24. The viewshed analysis confirms that, because it would be located north of and below the summit of Maunakea, the TMT Observatory would not be visible in the southern portion of the island; this includes the large cities of Hilo and Kailua-Kona. According to the viewshed analysis the TMT Observatory would be visible from about 13 percent of the area of the island (see Table 4-5). According to U.S. Census data, approximately 15.1 percent of the Island of Hawai'i's population (approximately 22,500 people) would be within the viewshed of the TMT Observatory at the alternative E2 site. Others, including visitors and island residents that reside outside the viewshed, would be able to see the TMT Observatory when they travel through and visit locations within the viewshed. Of the representative viewpoints, the TMT Observatory could be visible from viewpoints 1 through 12 and viewpoint 18. The TMT Observatory would not be visible from viewpoints 13 through 17.

Figure 4-24. E2 Alternative Site – Viewshed and Primary View Analysis

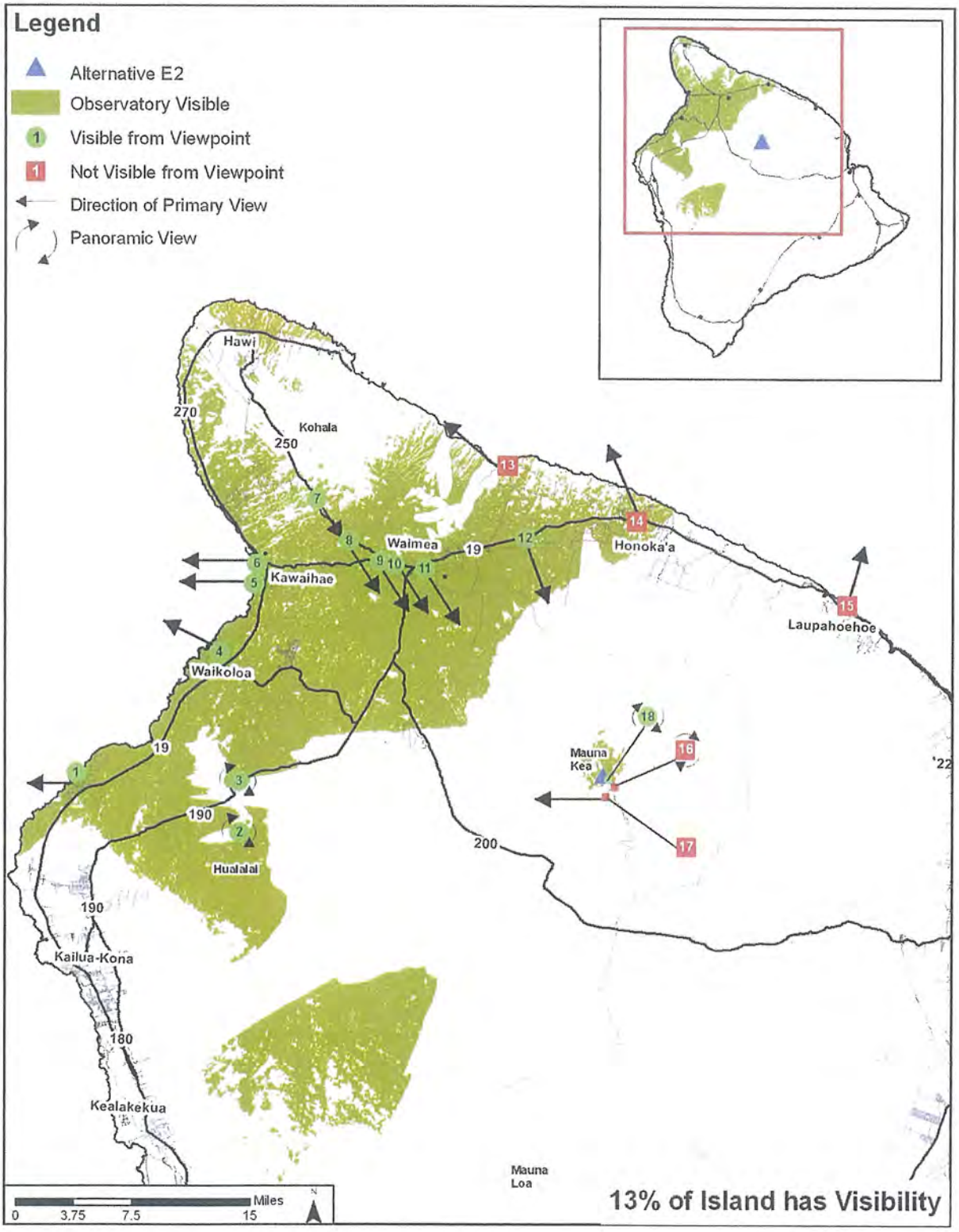


Table 4-5. Visibility of Alternative E2 Site

Visibility	Area of Island (%)	Hawai'i's Population	
		%	People
Visible	13%	15.1%	22,500
Not Visible	87%	84.9%	126,200

Table 4-6 divides the viewshed, and the population within the viewshed, into five areas: Waimea, Honoka'a, Hāwī, Waikoloa and Kawaihae, and Hualālai. Of these areas, the TMT Observatory would be visible in the primary view direction only from the area around Waimea. For the other four areas the primary view direction is toward the ocean. Of the island's population 5.4 percent (approximately 8,000 people) are within the area around Waimea and may be able to see the TMT Observatory.

Table 4-6. Visibility of the Alternative E2 Site within the Primary View Direction

Location	Hawai'i's Population		Primary View Direction?
	%	People	
Waimea	5.4%	8,000	Yes
Honoka'a	2.8%	4,200	No
Hāwī	2.6%	3,900	No
Waikoloa and Kawaihae	4.3%	6,400	No
Hualālai	0.04%	66	No

Primary View

Of the 13 viewpoints where the TMT Observatory may be visible, it would not be within the primary view of four; the Hualālai Resort (1), Waikoloa/Mauna Lani (4), Hāpuna Beach (5) and Puukohola Heiau (6). At these coastal locations, the primary view is westward makai.

The TMT Observatory could be visible and in the primary view direction from viewpoints along Highway 250 (7 and 8) and around the town of Waimea (9, 10, 11 and 12). The TMT Observatory could also be visible from the Big Island Country Club (3), from the summit of Pu'u Waawaa (2), and from the North ridge of Maunakea summit cinder cone (Kūkahau'ula) (18) where the panoramic view of the water, the surrounding area, and Maunakea would be important to the viewer.

Silhouette View

With the alternative E2 site the TMT Observatory would be in partial silhouette from all 13 of the viewpoints where it would be visible. Table 4-7 summarizes the silhouette analysis for the TMT Observatory at the alternative E2 site. The results of the silhouette analysis are shown in Appendix C.

Table 4-7. Alternative E2 Site - Silhouette Analysis

Viewpoint	Location	Portion of TMT Observatory in Silhouette		
		None	Partial	Full
1	Hualālai Resort	--	141 feet (43 m)	--
2	Pu'u Waawaa	--	43 feet (13 m)	--
3	Big Island Country Club	--	17 feet (5 m)	--
4	Waikoloa/Mauna Lani	--	148 feet (45 m)	--
5	Hāpuna Beach	--	144 feet (44 m)	--
6	Puukohola Heiau	--	105 feet (32 m)	--
7	DHHL Kawaihae at Route 250	X	--	--
8	Route 250 Pu'u Overlook	X	--	--
9	DHHL Lalamilo	--	40 feet (12 m)	--
10	Waimea Park	--	62 feet (19 m)	--
11	DHHL Pu'u Kapu	--	105 feet (32 m)	--
12	DHHL Waikoloa-Waialeale	--	128 feet (39 m)	--
13	Waipio Valley Lookout	Not Visible		
14	Honoka'a	Not Visible		
15	Laupāhoehoe Point	Not Visible		
16	Maunakea Summit	Not Visible		
17	Lake Wai'au	Not Visible		
18	North ridge of Maunakea summit cinder cone (Kūkahau'ula)	--	17 feet (5 m)	--

From the two viewpoints along Highway 250 (7 and 8) the view of the TMT Observatory would not be in silhouette; the observatory would be visible against the backdrop of Maunakea. This may reduce the prominence of the TMT Observatory in the view from these locations; particularly at sunset, when Maunakea would be back-lit by the setting sun. From the coastal locations of Hualālai Resort (1), Waikoloa/Mauna Lani (4), Hāpuna Beach (5), and Puukohola Heiau (6) between 105 feet (32 meters) and 148 feet (45 meters) of the TMT Observatory would be in silhouette. From these viewpoints the TMT Observatory would not be located within the direction of the primary view, which is toward the water.

In the area around Waimea (viewpoints 9 through 12), where the TMT Observatory would be visible within the direction of the primary view, the amount of the partial silhouette would range from 40 feet (12 meters) to 128 feet (39 meters). The silhouette analysis showed that from the Big Island Country Club (3) and Pu'u Waawaa (2) the view of the TMT Observatory would be partially obstructed from a rise of Maunakea between the viewer and the observatory. From portions of the Big Island Country Club only the top 16 feet (5 meters) of the TMT Observatory would be visible and in silhouette. From the summit of Pu'u Waawaa the top 43 feet (13 meters) would be visible and in silhouette.

In addition to the topography of Maunakea limiting the silhouette of the TMT Observatory, the existing observatories can also affect the silhouette view. The areas where the view of the TMT Observatory would be in front of one of the existing observatories would be similar to what is shown in Figure 4-5.

Photo Simulations

Photo simulations specific to the alternative E2 site were not created. Because the E2 site is located less than 1,000 feet south of the proposed 13N site the visual representations of the TMT Observatory shown in Figure 4-7 through Figure 4-21 for the 13N site would be very similar for the alternative E2 site.

Summary

The potential long term visual impacts of the alternative E2 site for the TMT Observatory are summarized in Table 4-8.

Table 4-8. E2 Alternative Site - Summary of Potential Visual Impacts

Viewpoint	Location	Visual Impact				
		Is the TMT visible?	Visible in primary view?	Visible in silhouette?		
				No	Partial	Full
1	Hualālai Resort	Yes	No	--	141 feet (43 m)	--
2	Pu'u Waawaa	Yes	N/A[1]	--	43 feet (13 m)	--
3	Big Island Country Club	Yes	N/A[1]	--	17 feet (5 m)	--
4	Waikoloa/Mauna Lani	Yes	No	--	148 feet (45 m)	--
5	Hāpuna Beach	Yes	No	--	144 feet (44 m)	--
6	Puukohola Heiau	Yes	No	--	105 feet (32 m)	--
7	DHHL Kawaihae at Route 250	Yes	Yes	X	--	--
8	Route 250 Pu'u Overlook	Yes	Yes	X	--	--
9	DHHL Lalamilo	Yes	Yes	--	40 feet (12 m)	--
10	Waimea Park	Yes	Yes	--	62 feet (19 m)	--
11	DHHL Pu'u Kapu	Yes	Yes	--	105 feet (32 m)	--
12	DHHL Waikoloa-Waialeale	Yes	Yes	--	128 feet (39 m)	--
13	Waipio Valley Lookout	No	N/A	N/A		
14	Honoka'a	No[2]	N/A	N/A		
15	Laupāhoehoe Point	No	N/A	N/A		
16	Maunakea Summit	No	N/A	N/A		
17	Lake Wai'au	No	N/A	N/A		
18	North ridge of Maunakea summit cinder cone (Kūkuhau'ula)	Yes	N/A1	--	17 feet (5 m)	--

[1] The primary view criterion is not applicable because at these viewpoints the panoramic view is important.
[2] At the specific location for Honoka'a used in the visual analysis the TMT Observatory was not visible. However, there are portions of Honoka'a where the TMT Observatory would be visible.

Visual Impact on Viewer Groups

Based on the above analysis, the following is a summary of the potential visual impacts on the three viewer groups from locating the TMT Observatory at the proposed alternative E2 site.

Residents

Most residents of the Island of Hawai'i would not be able to see the TMT Observatory in the alternative E2 site. From the viewshed analysis 15.1 percent of the population (approximately 22,500 residents) would be able to see at least the top of the TMT Observatory. Of these, it would only be within the primary view direction of 5.4 percent of the population (approximately 8,000 residents). However, residents that live outside of the viewshed would be able to see the TMT Observatory when they travel through and visit locations within the viewshed.

The TMT Observatory could also have a visual impact on residents in towns such as Waimea, Waikoloa and the area around Honoka'a. These residents may have their views of Maunakea from their homes, or gathering places, altered by the facility. The views from these viewpoints would be in partial silhouette (ranging from 40 feet (12 meters) (10) to 130 feet (39 meters) (12)), which could make the view more prominent, particularly in the morning when the facility would be back lit by the sun. The extent of the visual impact would be somewhat reduced by the times when the summit of Maunakea would be obscured by vog, clouds, or other causes of limited visibility. In general, the visual impact to the resident viewer group would be less than significant. The impact to residents of Waimea, while slightly higher, would still be less than significant.

Sightseers

The visual experience for the sightseer viewer group would not be impacted by the TMT Observatory. This is because it would not be visible from the majority of the island. From viewpoints, such as Hāpuna Beach (5), where the TMT Observatory could be visible, it would not be within the primary view and would not be expected to impact their visual experience. In addition, some sightseers may be interested in astronomy, may plan on visiting the astronomy precinct and enjoy views of the facility. The visual impact to sightseers would be less than significant.

Cultural Practitioners

Finally, as stated in 3.1.2, cultural practitioners on the Island of Hawai'i place a high value on pristine views of Maunakea. Of the three representative viewpoints that are from culturally important locations, the TMT Observatory would not be visible from two; the summit of Maunakea (17) and Lake Wai'au (18). The TMT Observatory could be visible from the summit of Pu'u Waawaa, where cultural practitioners may experience a visual impact. The silhouette analysis showed that from Pu'u Waawaa (2) the view of the TMT Observatory would be partially obstructed from a rise of Maunakea between the viewer and the observatory and that only the top 43 feet (13 meters) would be visible and in silhouette. The extent of the visual impact would be somewhat reduced by the times when the summit of Maunakea would be obscured by vog, clouds, or other causes of limited visibility.

Visual impacts are only a component of the Project's potential cultural impact. For information on the Project's impacts to cultural practices see the *Cultural Impact Assessment, Thirty Meter Telescope.*

Overall Visual Impact

As discussed above, while the TMT Observatory would be a new visual element within the views of Maunakea (for approximately 13 percent of the island area and could be seen by approximately 15.1 percent of the population, or roughly 22,500 people) it would not obstruct or block existing views of Maunakea from around the Island of Hawai'i. Therefore, the Project would not exceed the applicable significance criteria in §11-200-12 of the HAR and would be expected to have a less than significant visual impact.

4.2.3 Indirect and Cumulative

Indirect Impacts

The TMT Observatory is not expected to have any indirect visual impacts.

Cumulative Impacts

A cumulative impact is the incremental impact of a proposed project together with other past, present and reasonably foreseeable future actions. For cumulative visual impacts, the analysis for the TMT Observatory looks at the following two components:

- Would the TMT Observatory be visible in an area of the island where currently no telescopes are visible?
- Which areas of the island would the TMT Observatory be visible in addition to the existing telescopes?

Proposed 13N Site

Table 4-9 summarizes the cumulative visual impact of the TMT Observatory at the proposed 13N site.

Table 4-9. Cumulative Visibility of Proposed 13N Site

Visibility	Area of Island (%)	Hawai'i's Population	
		%	People
Existing	43%	72%	107,000
New (TMT)	1.2%	Less than 1%	72

Figure 4-25 shows the visibility/viewshed of the existing summit observatories on Maunakea (see Section 3.1.4) combined with the viewshed of the TMT Observatory at the proposed 13N site. The green shaded area indicates where the existing summit observatories on Maunakea are visible. This area is approximately 43 percent of the island and is home to approximately 72 percent of the Island of Hawai'i's population. The portions of the island that are shaded in red are areas where the TMT Observatory would be visible where currently none of the existing telescopes can be seen. The new area where a telescope would be visible is roughly 1.2 percent of the area of the Island of Hawai'i. The majority of this new area is ranch land south of Waimea. Off of Saddle Road there is a residential area, Waikii Ranch, which would be within the area where the TMT Observatory would be the only visible observatory. Using the 2000 U.S. Census average household size of 2.75 people for the County of Hawai'i, the estimated

number of people living in this area is 72 (substantially less than 1 percent of the island's population).

Figure 4-25. Proposed 13N Site – Cumulative Visibility Analysis

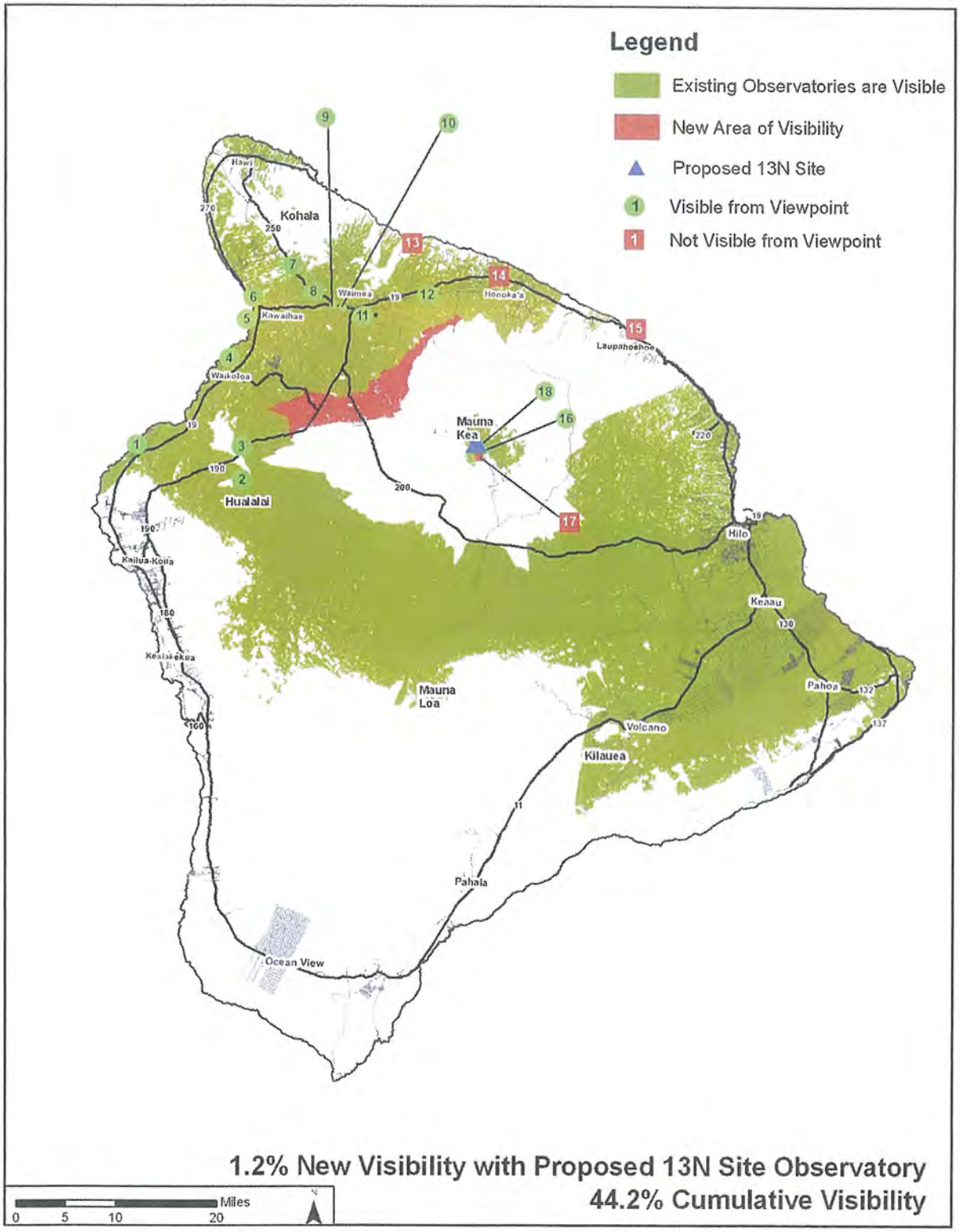


Table B-1, in Appendix B, shows which of the existing observatories are visible at the 18 representative viewpoints. At the viewpoints where the TMT Observatory would be visible, six to eight of the existing 11 summit observatories are currently visible.

The visual impact of the existing observatories on Maunakea is significant; particularly considering the visual sensitivity of the cultural practitioner viewer group. The visual impact of the TMT Observatory at the proposed 13N site would be less than significant. Nonetheless, when combined with the past, present (existing conditions) and reasonably foreseeable future actions the cumulative visual impact of development on and near the summit of Maunakea, including the proposed TMT Observatory, would continue to be significant.

E2 Alternative Site

The cumulative visual impact of the TMT Observatory at the alternative E2 site would be similar to the proposed 13N site.

Table 4-10 summarizes the cumulative visual impact. Figure 4-26 shows the visibility/viewshed of the existing observatories combined with the viewshed of the TMT Observatory at the alternative E2 site. The new area where a telescope would be visible is roughly 0.9 percent of the area of the Island of Hawai'i. The majority of this new area is ranch land south of Waimea. Off of Saddle Road there is a residential area that would be within the area where the TMT Observatory would be the only telescope visible. Using the 2000 U.S. Census average household size of 2.75 people for the County of Hawai'i, the estimated number of people living in this area is 28 (substantially less than 1 percent of the Island of Hawai'i's population).

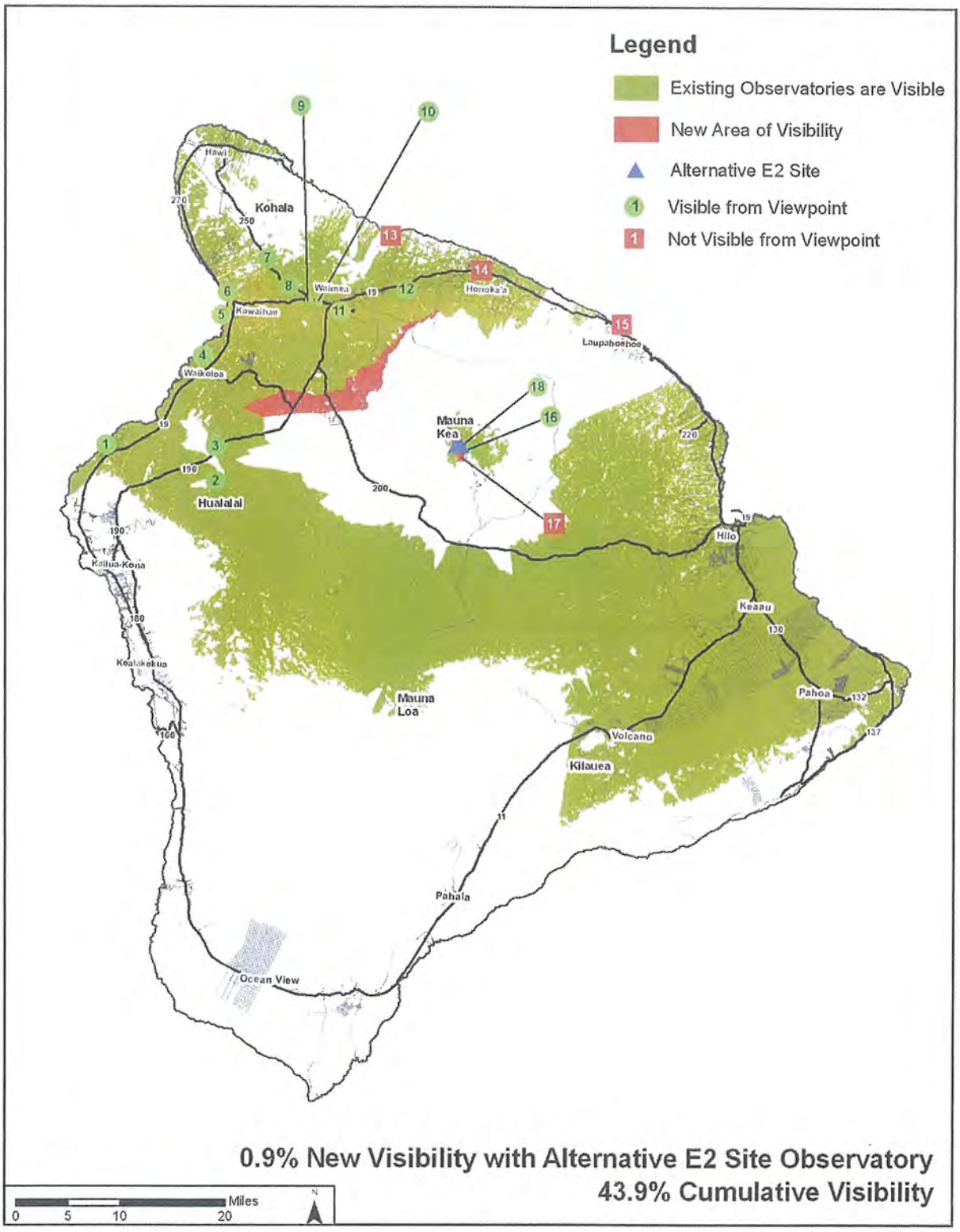
Table 4-10. Cumulative Visibility of Alternative E2 Site

Visibility	Area of Island (%)	Hawai'i's Population	
		%	People
Existing	43%	72%	107,000
New (TMT)	0.9%	Less than 1%	28

Table B-1, in Appendix B, shows which of the existing observatories are visible at the 18 representative viewpoints. At the viewpoints where the TMT Observatory would be visible, six to eight of the existing 11 summit observatories are currently visible.

The visual impact of the existing observatories on Maunakea is significant; particularly considering the visual sensitivity of the cultural practitioner viewer group. The visual impact of the TMT Observatory at the alternative E2 site would be less than significant. Nonetheless, when combined with the past, present (existing conditions) and reasonably foreseeable future actions the cumulative visual impact of development on and near the summit of Maunakea, including the proposed TMT Observatory, would continue to be significant.

Figure 4-26. E2 Alternative Site – Cumulative Visibility Analysis



5.0 Mitigation

5.1 No Build Alternative

There are no Project visual impacts from the No Build Alternative, therefore mitigation is not proposed.

5.2 Maunakea

The proposed location for the TMT Observatory is the primary mitigation for the Project's potential visual impacts. As shown in Section 4.2 because the proposed location of the TMT Observatory is north of and below the summit of Maunakea it would be visible in roughly 14 percent of the Island of Hawai'i and to approximately 15 percent of the population (23,000 people). This is significantly different than if the TMT Observatory were to be placed in a more visible location, such as the summit ridge or pu'u.

The visual impacts of the TMT Observatory, which would house a telescope with a mirror 98 feet (30 meters) in diameter, are also due to the size of the dome enclosure. The proposed diameter of the TMT dome is 216 feet (66 meters). Because the center of the dome would be placed only 36 feet (11 meters) off the ground surface the TMT Observatory would have a height of approximately 180 feet (55 meters) above grade level. This would be the tallest observatory on Maunakea. However, the TMT telescope and the dome enclosure have been designed to minimize the height of the structure, which in turn minimizes the visual impacts (Figure 5-1). The TMT telescope itself has been designed to be much shorter to allow for a much smaller dome. In addition, the enclosure has been designed to fit very tightly around the telescope, leaving only about 20 inches between the telescope and the dome; just enough room for a person.

For comparison purposes, the Keck Observatory consists of two telescopes each with mirrors 33 feet (10 meters) in diameter. The diameter of each Keck dome is 121 feet (37 meters); the height of the Keck dome and other observatories on Maunakea are listed in Table 3-2. Using this ratio of mirror to dome size the TMT telescope would result in a dome with a diameter of 364 feet (111 meters); almost twice what is proposed (Figure 5-2).

Finally, the color, or coating, of the dome enclosure has substantial visual implications. As discussed in Section 4.2 the fixed enclosure and support facilities would be painted with colors that would blend into the landscape. The coating of the dome enclosure would be a reflective aluminum-like finish, similar to the Subaru Observatory. In general, the visual impacts of the existing observatories on Maunakea with an aluminum-like finish (such as Gemini, IRTF and Subaru) are that they reflect the morning sunrise and evening sunset light and stand out during this period. However, during most of the day the coating can reflect the sky, which helps reduce the visibility of the observatory.

Figure 5-1: Overview of TMT Telescope and Dome Design

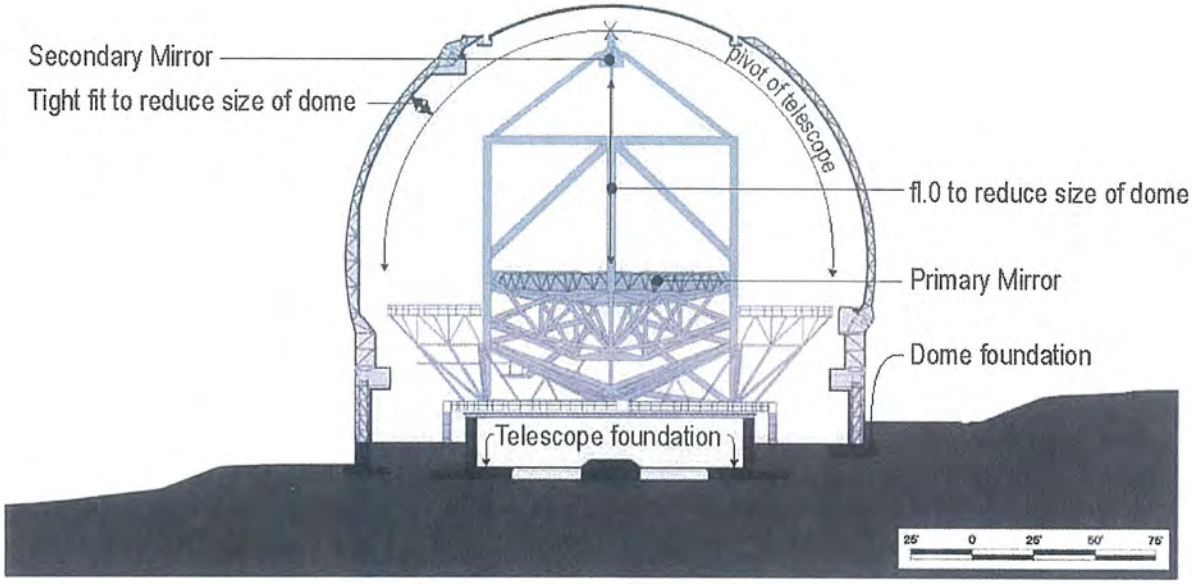
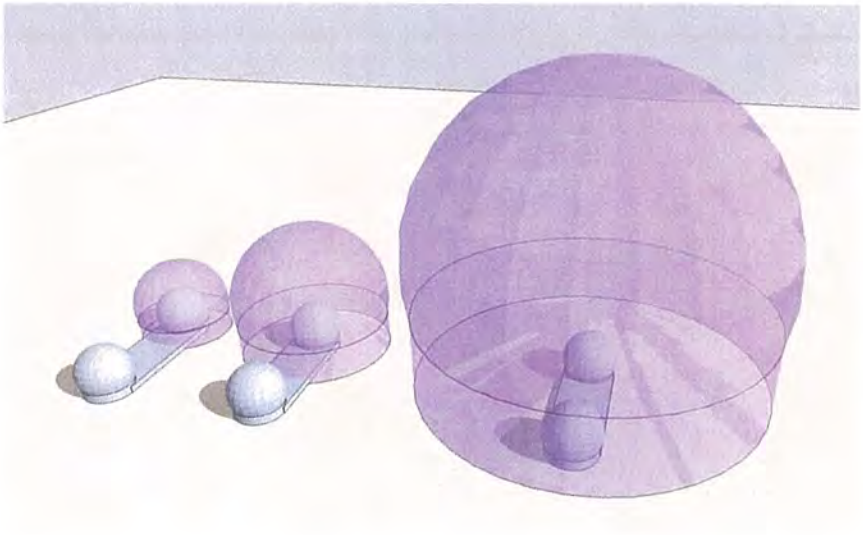


Figure 5-2: Comparison of Observatory Dome Sizes to Telescope Focal Ratios



In summary, the location and design of the TMT Observatory incorporate measures that mitigate for the potential visual impacts. No further visual mitigation measures are proposed.

6.0 References

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Appendix A. Photographs of or from the Representative Viewpoints

Viewpoint 1: Hualālai Resort

Photo not available.

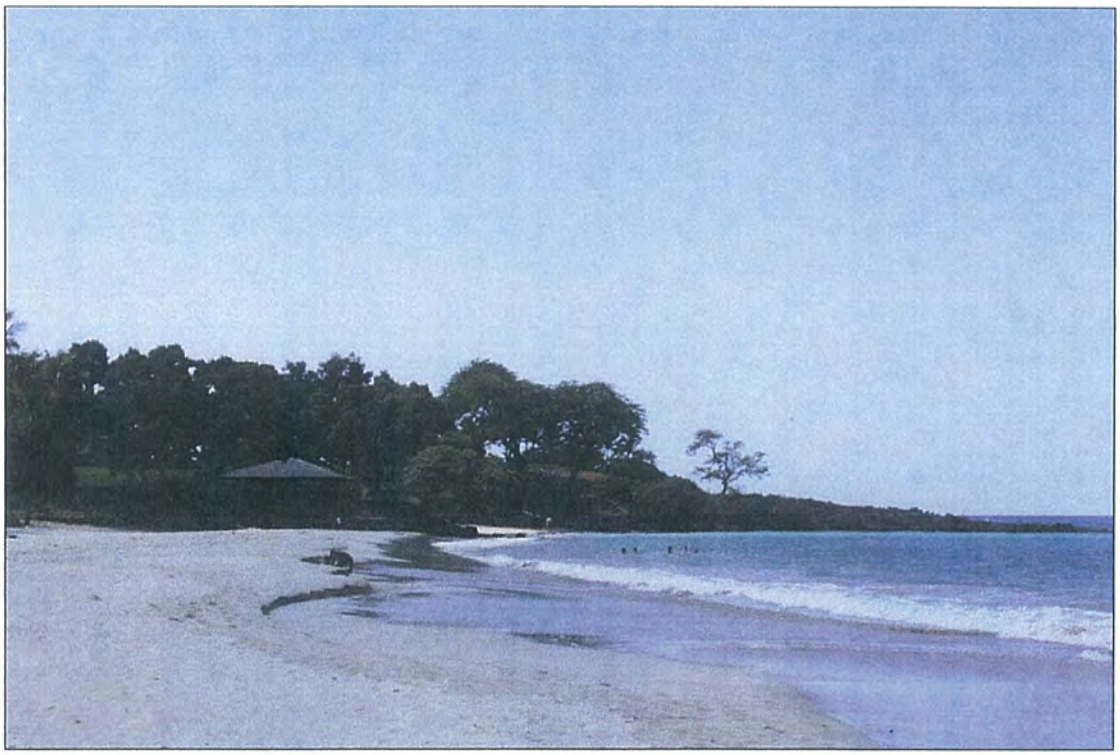
Viewpoint 2: Pu'u Waawaa

Photo not available.

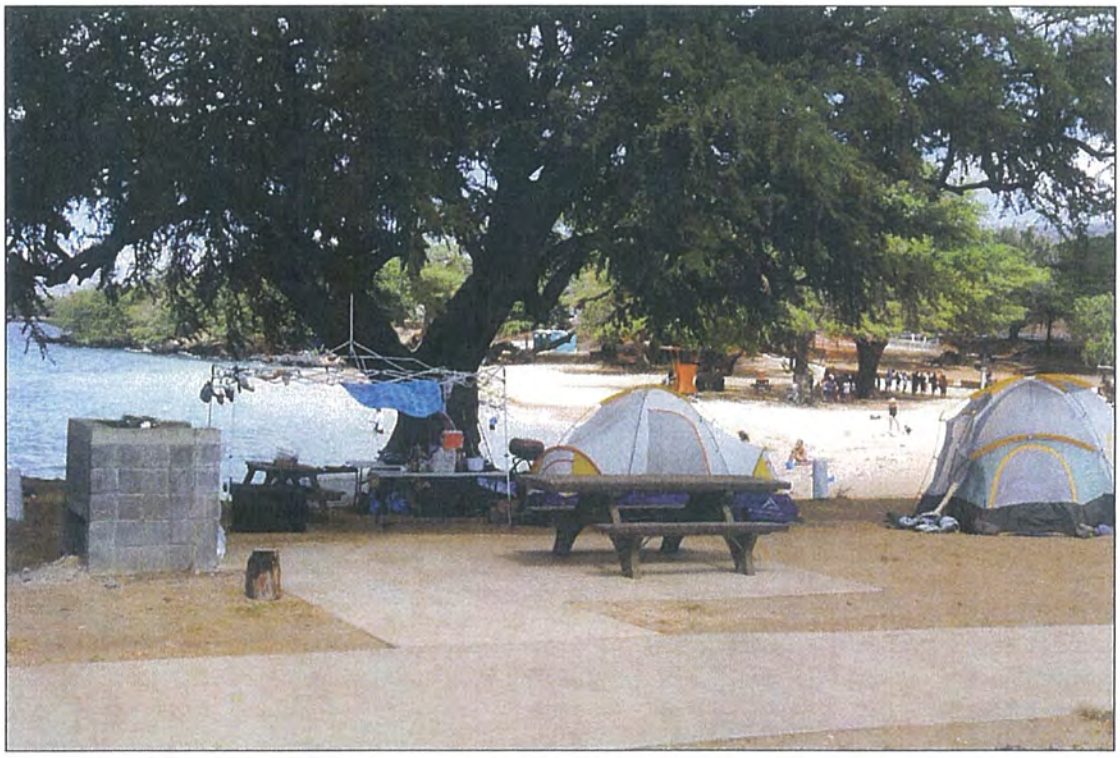
Viewpoint 3: Big Island Country Club

Viewpoint 4: Waikoloa/Mauna Lani (View toward Maunakea)

Viewpoint 5: Hāpuna Beach (Primary View)



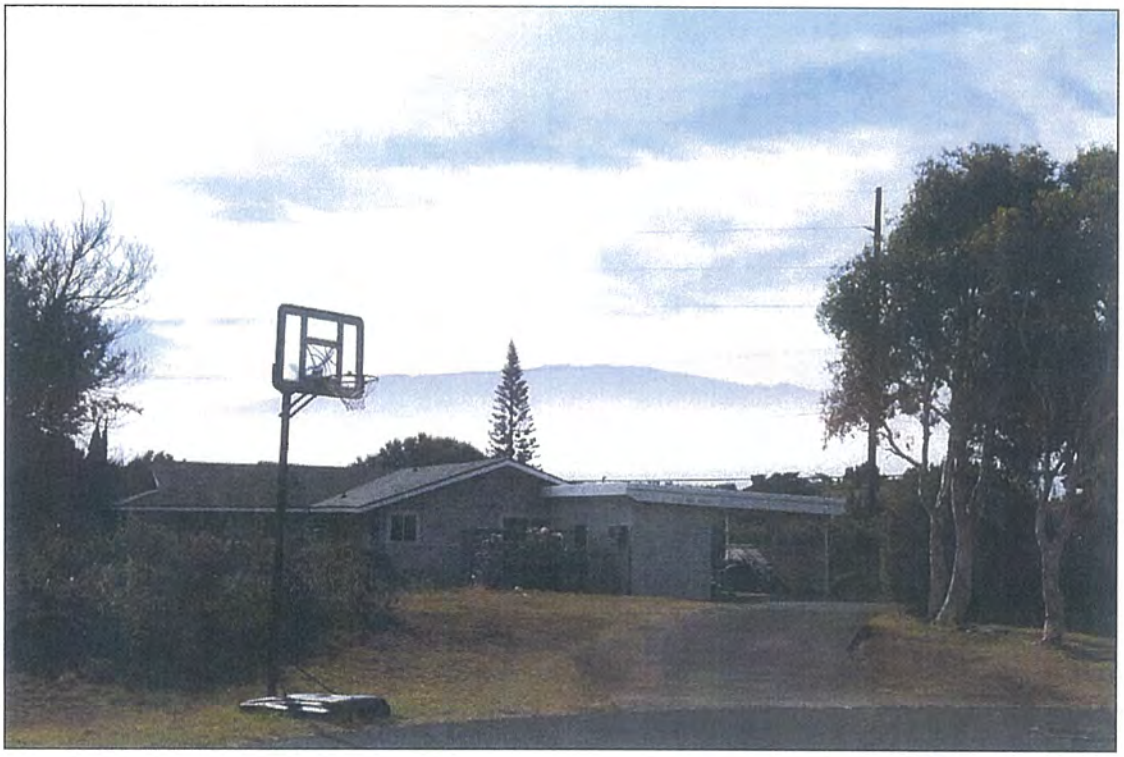
Viewpoint 6: Puukohola Heiau (Primary View)



Viewpoint 7: DHHL Kawaihae at Rt. 250 (In the direction of Maunakea)

Viewpoint 8: Route 250 Pu'u Overlook (Primary View)

Viewpoint 9: DHHL Lalamilo (Primary View)



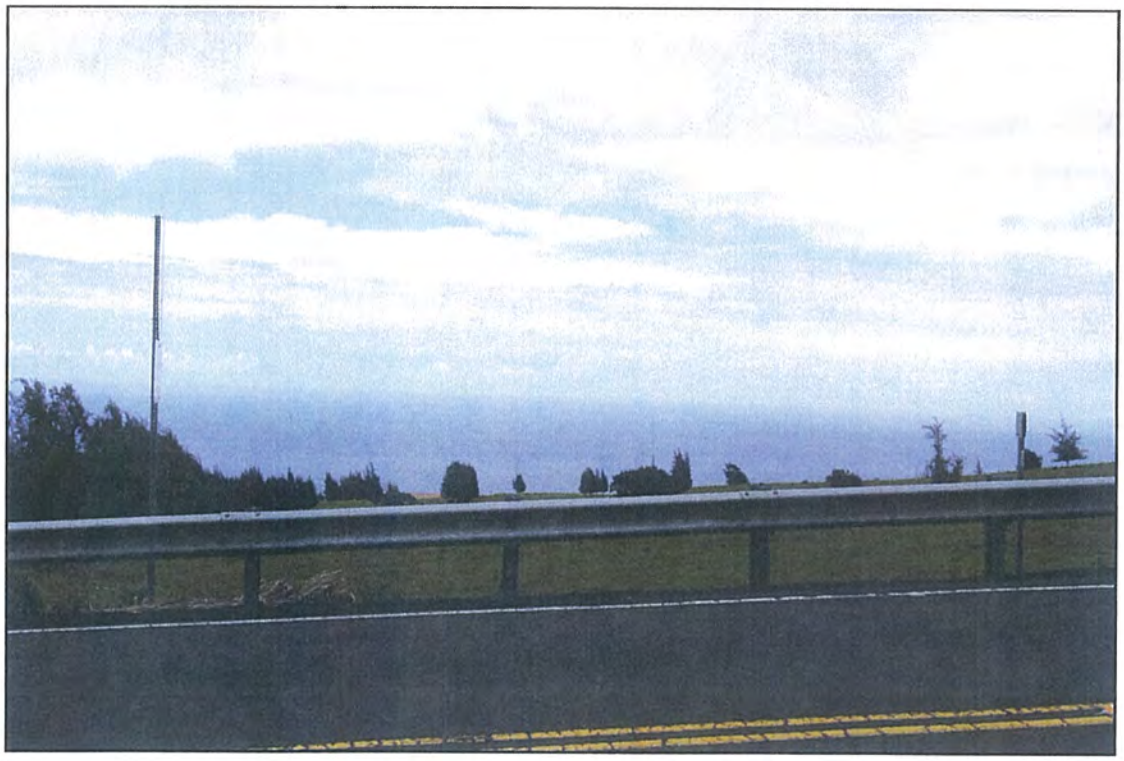
Viewpoint 10: Waimea Park (Primary View)

Viewpoint 11: DHHL Pu'u Kapu (Primary View)

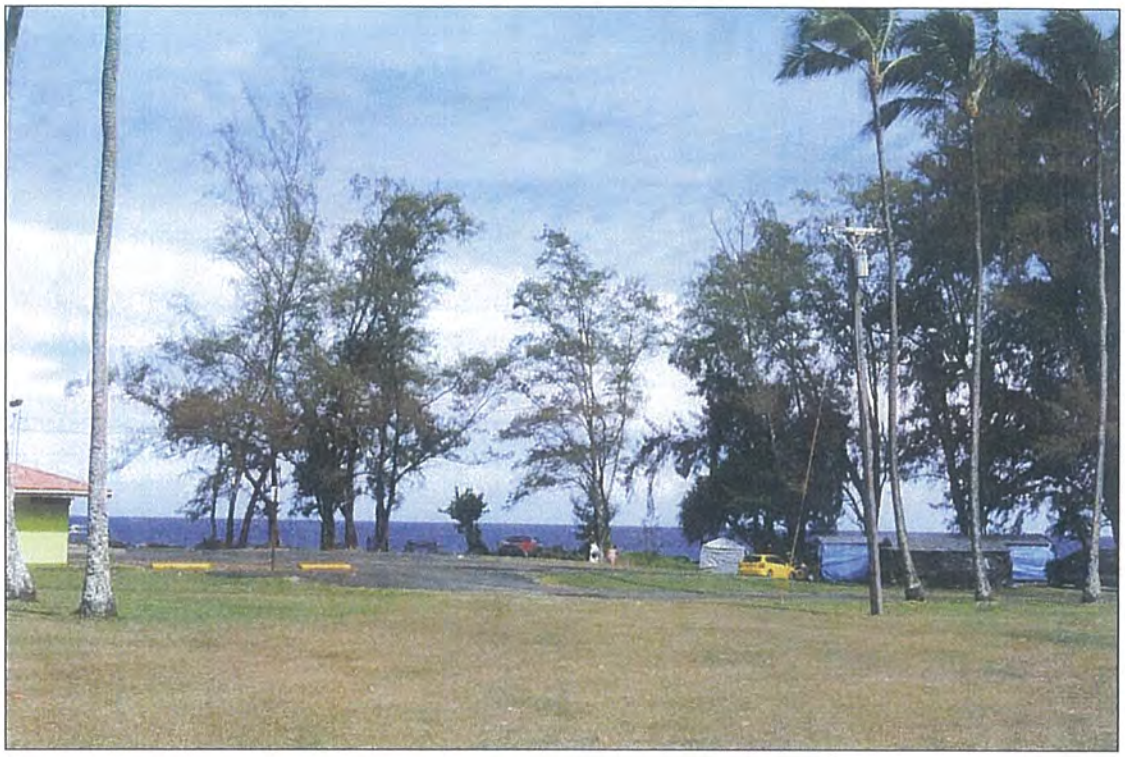
Viewpoint 12: DHHL Waikoloa-Waialeale (Primary View)

Viewpoint 13: Waipio Valley Lookout (Primary View)

Viewpoint 14: Honoka'a (Primary View)

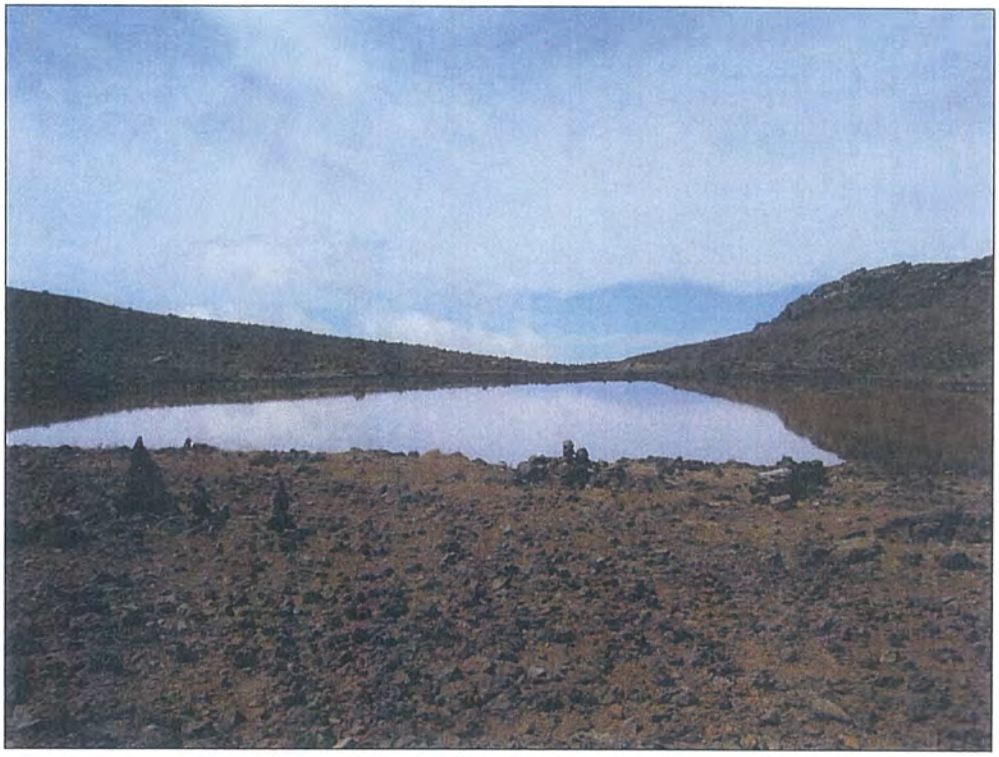


Viewpoint 15: Laupāhoehoe Point (Primary View, Top Photo)



Viewpoint 16: Maunakea Summit

Viewpoint 17: Lake Wai'au (Primary View)



Viewpoint 18: North ridge of Maunakea summit cinder cone (Kūkuhau'ula)

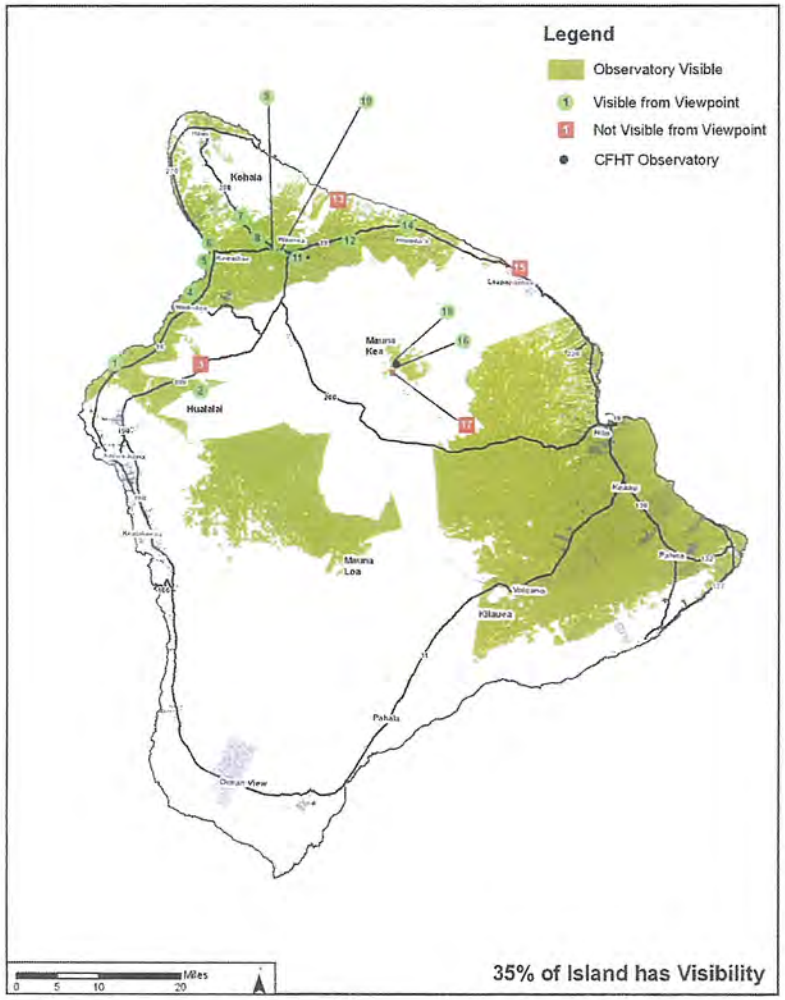
Appendix B. Viewsheds of Existing Observatories

Table B-1. Visibility of the TMT Observatory and the Existing Observatories from the Representative Viewpoints

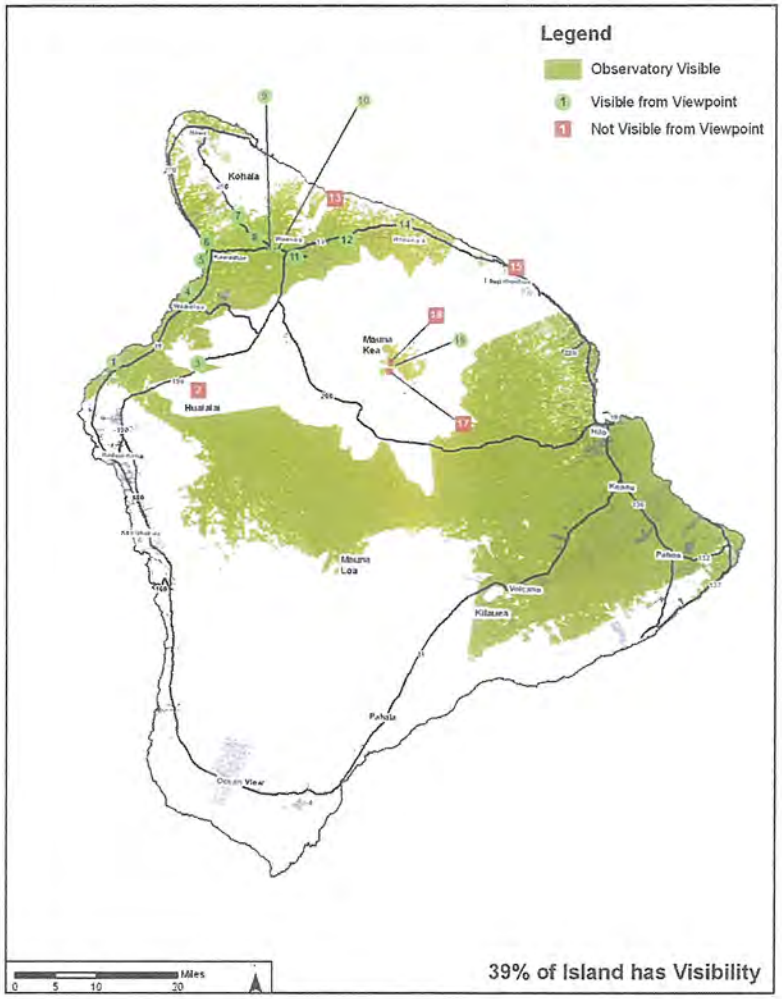
Viewpoint Number	Viewpoint Name	TMT Proposed 13N Site	TMT Alternative E2 Site	CFHT	Gemini	UH 2.2 M	IRTF	Keck	UKIRT	Subaru	Hilo	CSO	JCMT	SMA
1	Hualālai Resort	X	X	X	X	X	X	X		X				
2	Pu'u Waawaa	X	X	X			X	X		X				
3	Big Island Country Club	X	X		X			X		X				
4	Waikoloa/Mauna Lani	X	X	X	X	X	X	X	X	X				
5	Hāpuna Beach		X	X	X	X	X	X	X	X	X			
6	Puukohola Heiau	X	X	X	X	X	X	X	X	X	X			
7	DHHL Kawaihae at Route 250	X	X	X	X	X	X	X	X	X	X		X	X
8	Route 250 Pu'u Overlook	X	X	X	X	X	X	X	X	X				X
9	DHHL Lalamilo	X	X	X	X	X	X	X		X				
10	Waimea Park	X	X	X	X	X	X	X		X				
11	DHHL Pu'u Kapu	X	X	X	X	X	X	X		X				
12	DHHL Waikoloa-Waialeale	X	X	X	X	X	X	X	X	X				
13	Waipio Valley Lookout													
14	Honoka'a	X		X	X	X	X	X	X					
15	Laupāhoehoe Point													
16	Maunakea Summit			X	X	X			X	X	X			
17	Lake Wai'au													
18	North ridge of Kūkahau'ula	X	X	X			X	X						

CFHT = Canada France Hawai'i Telescope Gemini = Gemini Northern Observatory UH 2.2M = University of Hawai'i 2.2 m IRTF = NASA Infrared Telescope Facility Keck = W.M. Keck Observatory UKIRT = United Kingdom Infrared Telescope Subaru = Subaru Observatory CSO = California Institute of Technology Submillimeter Observatory Hilo = University of Hawi'i 0.9 m JCMT = James Clerk Maxwell Telescope SMA = Submillimeter Array

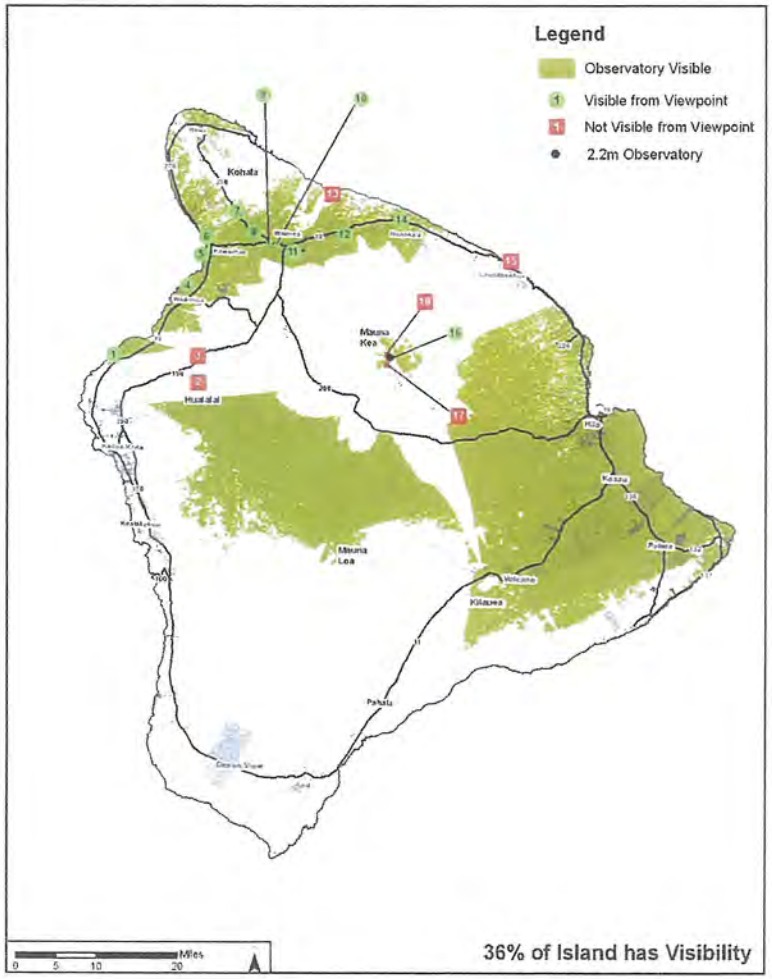
1) Canada-France-Hawaii Telescope (CFHT)



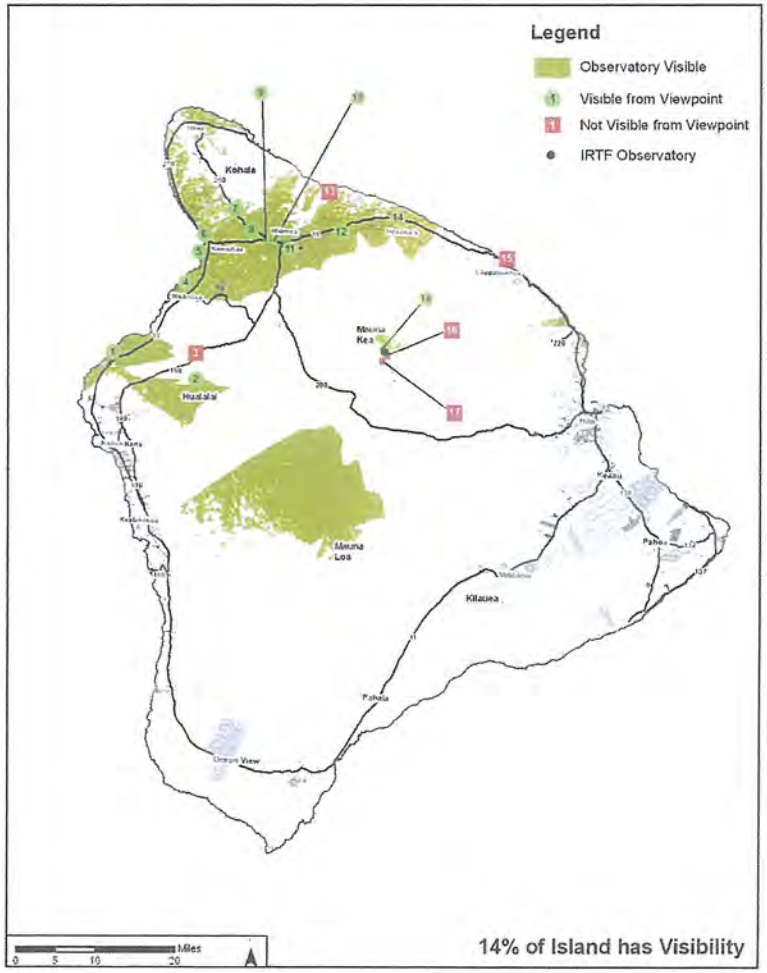
2) Gemini Northern Observatory



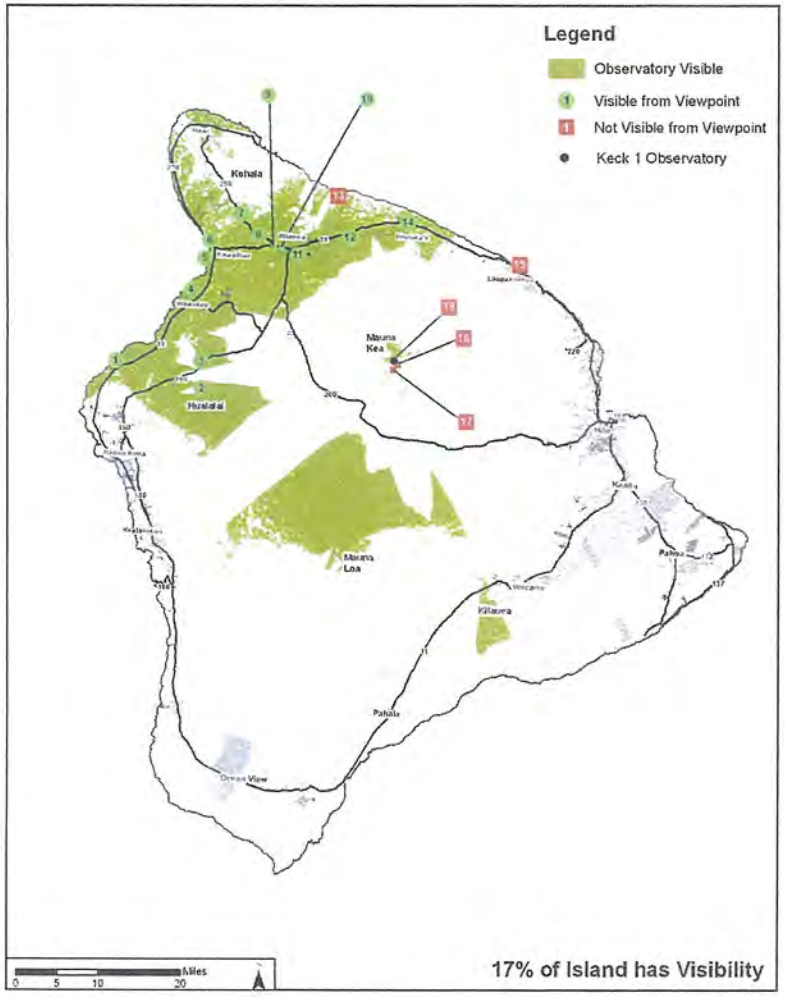
3) University of Hawaii 2.2 m Observatory

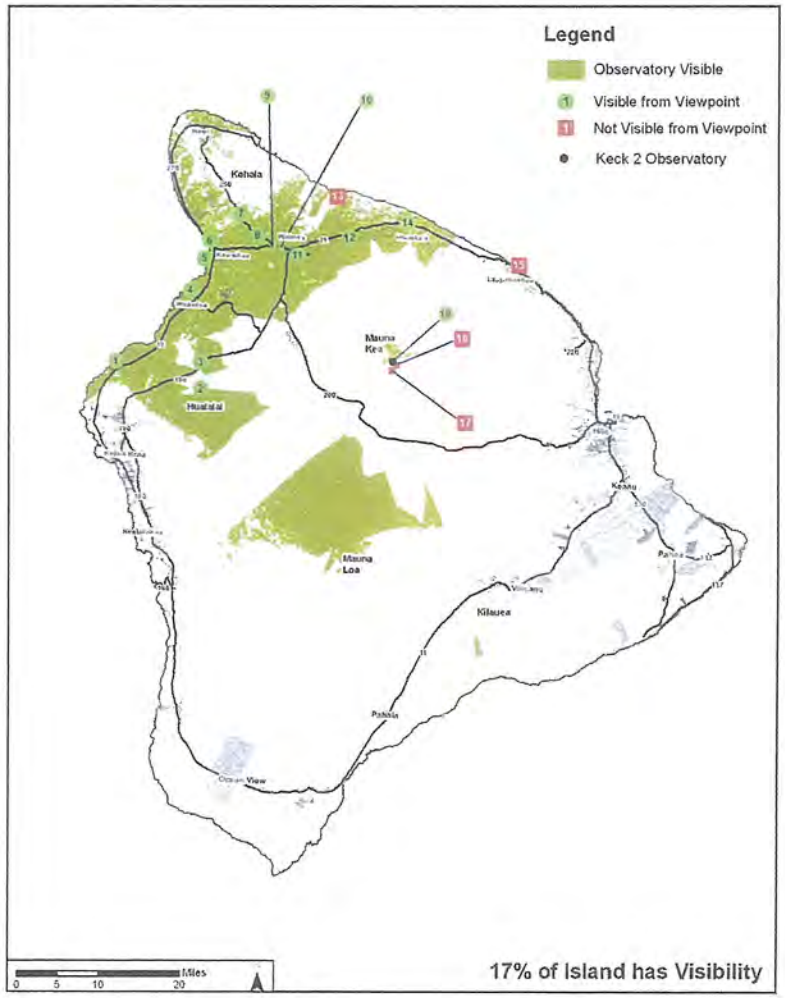


4) NASA Infrared Telescope (IRTF)

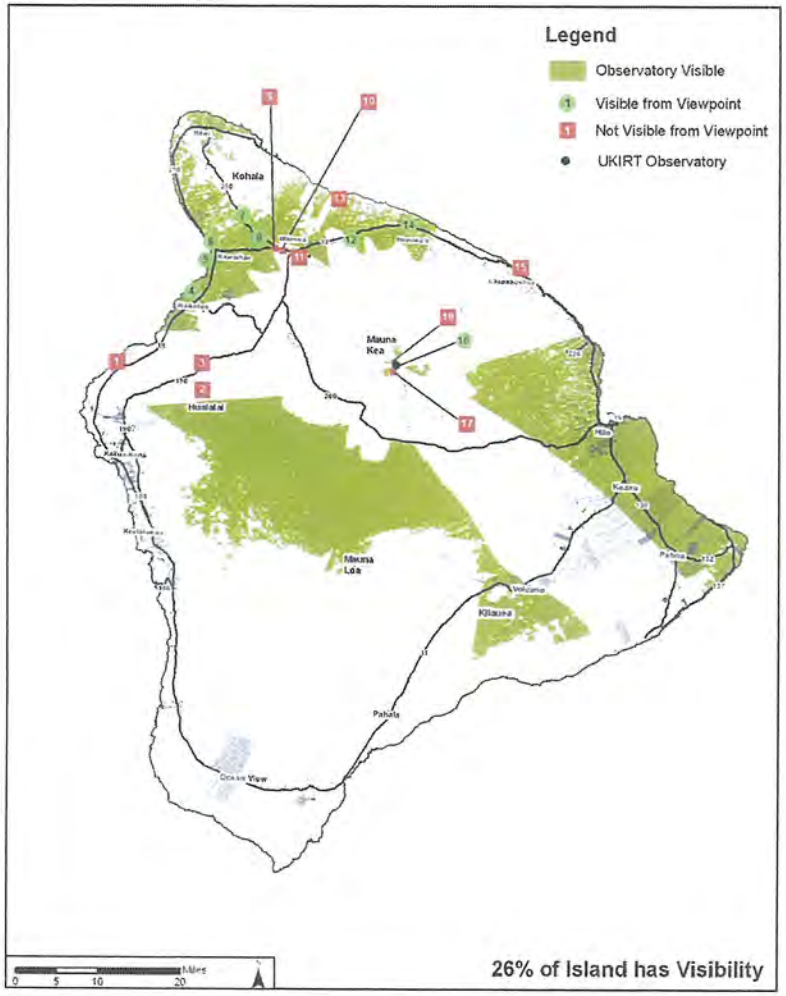


5) Keck 1 and Keck 2

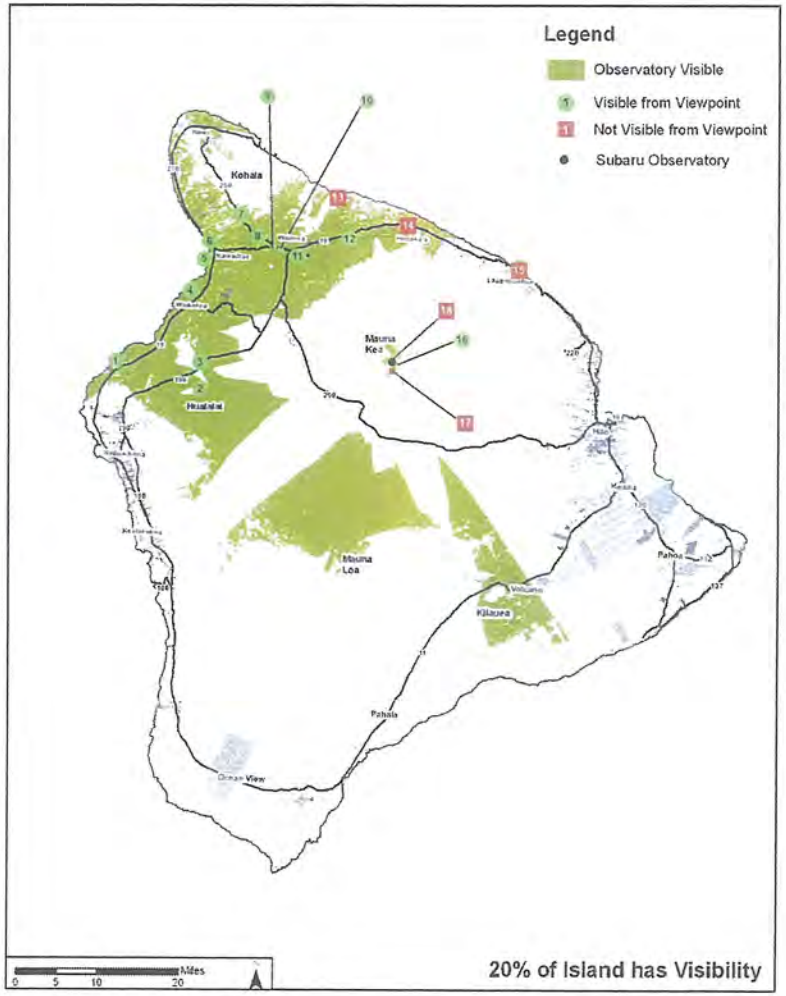




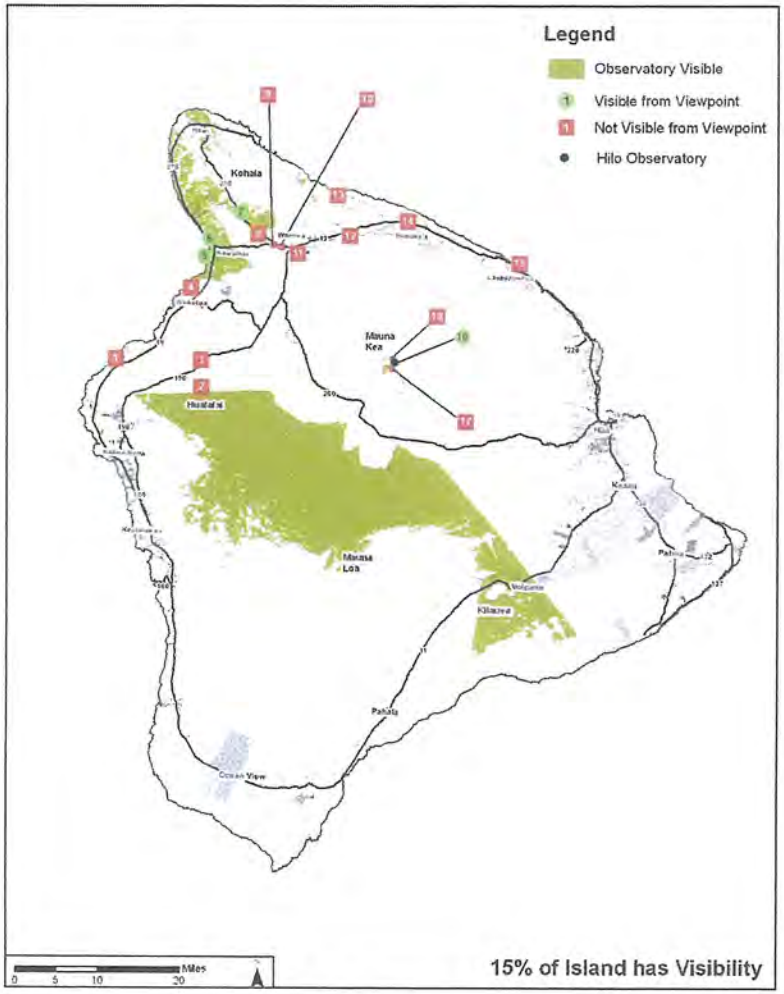
6) United Kingdom Infrared Telescope (UKIRT)



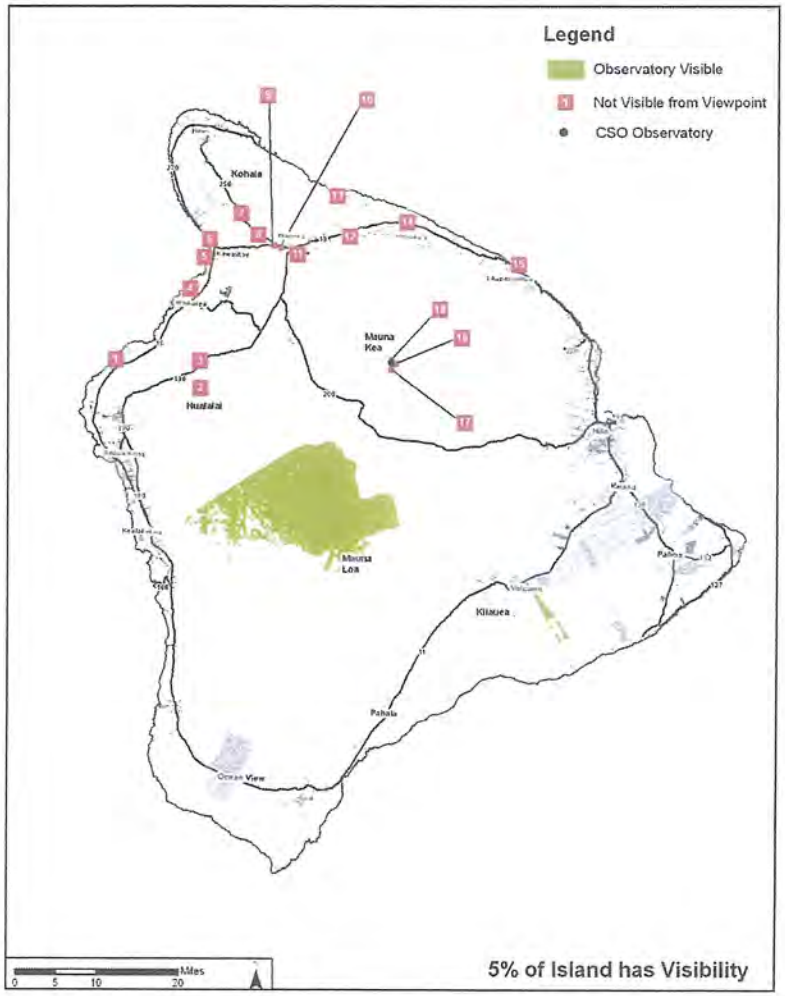
7) Subaru Observatory



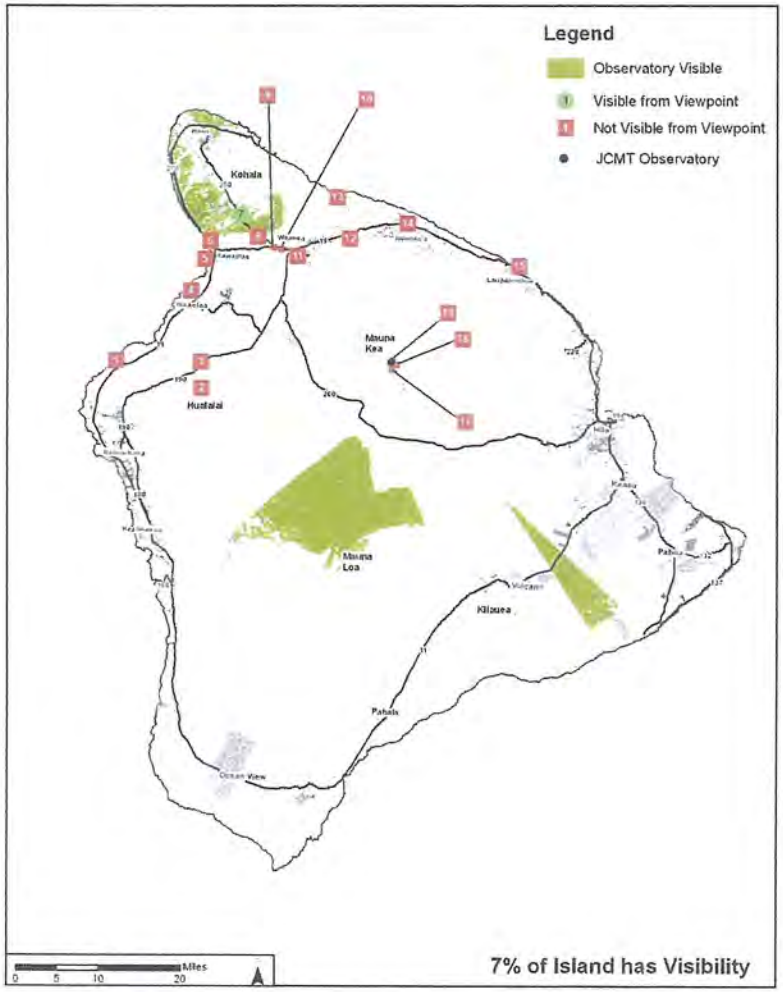
8) University of Hawaii 0.9 m Telescope (Hilo)



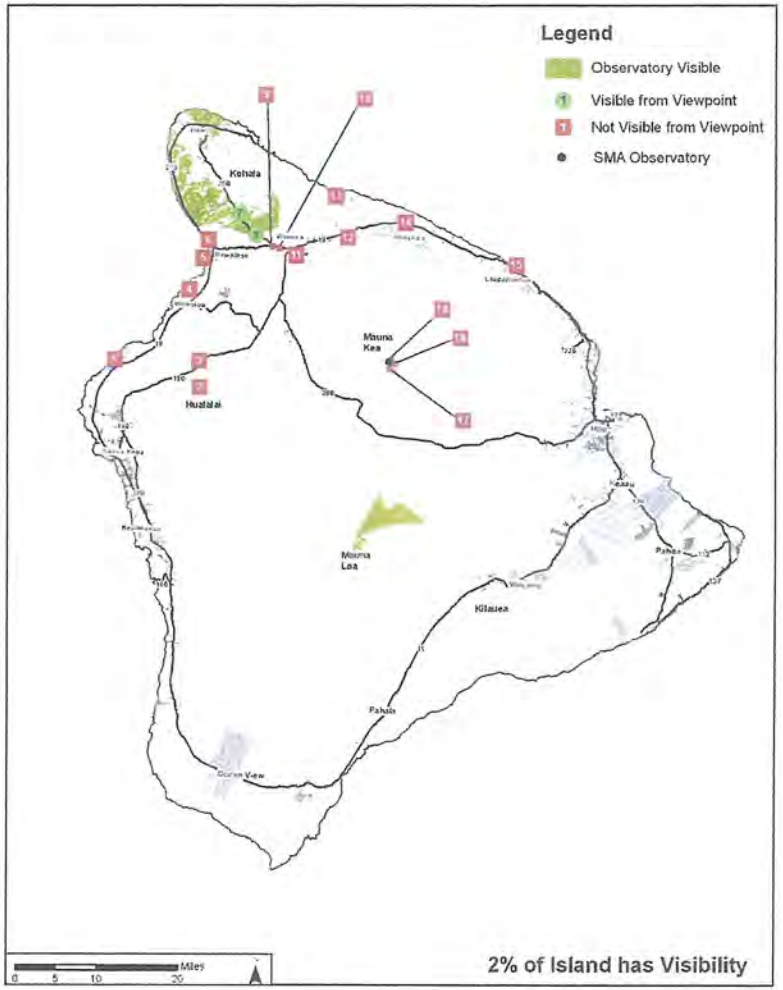
9) Caltech Submillimeter Telescope (CSO)



10) James Clerk Maxwell Telescope (JCMT)

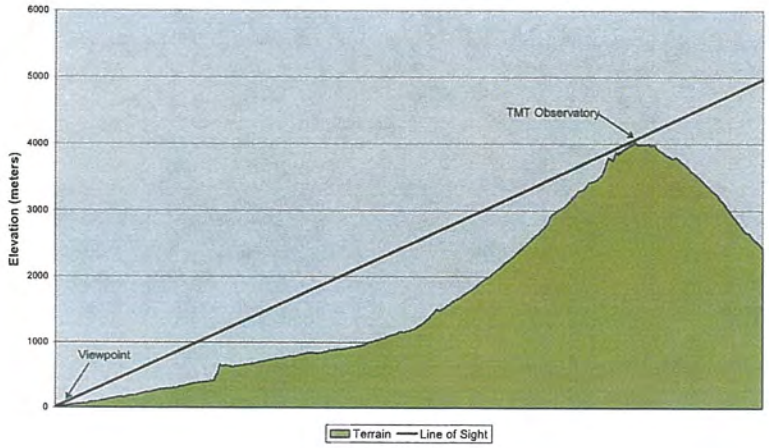


11) Submillimeter Array (SMA)

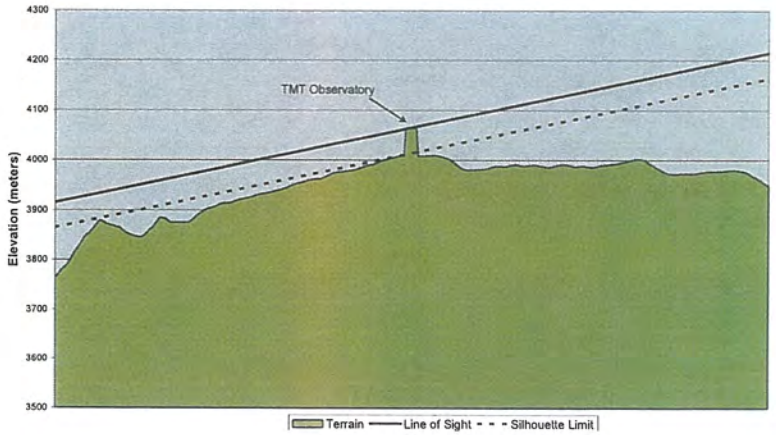


Appendix C. Silhouette Analysis by Viewpoint

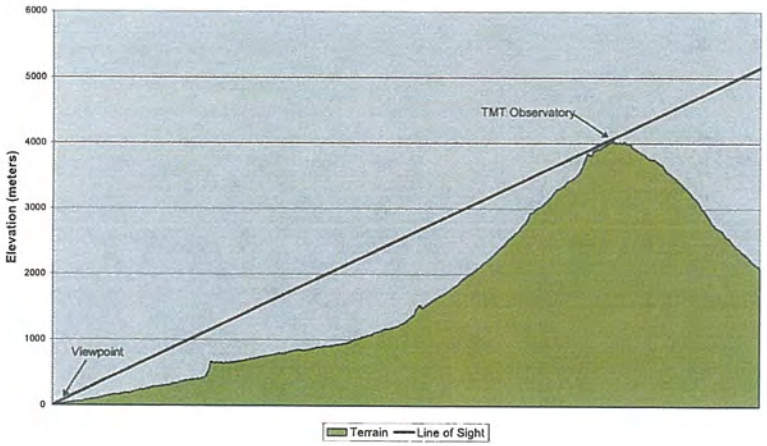
Hualalai Resort - TMT Proposed 13N Site



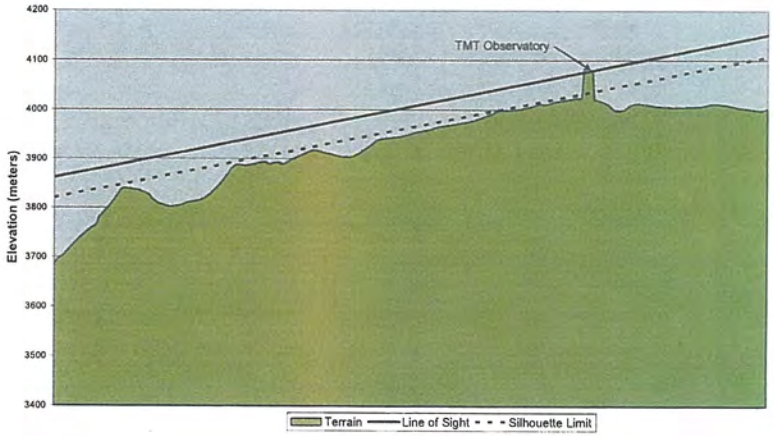
Hualalai Resort - Near TMT Proposed 13N Site



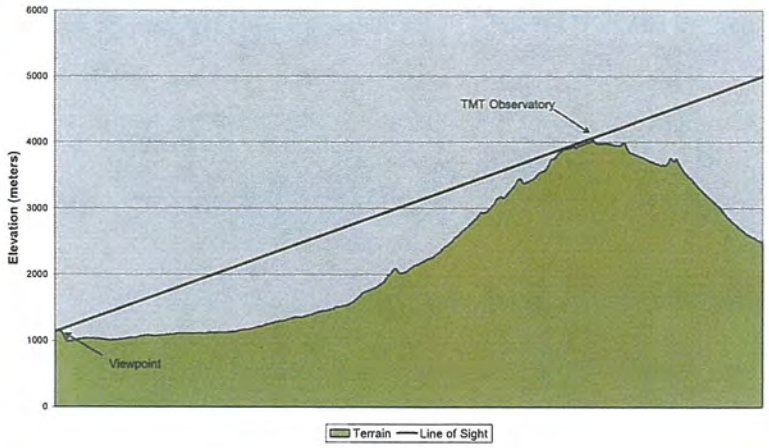
Hualalai Resort - TMT Alternative E2 Site



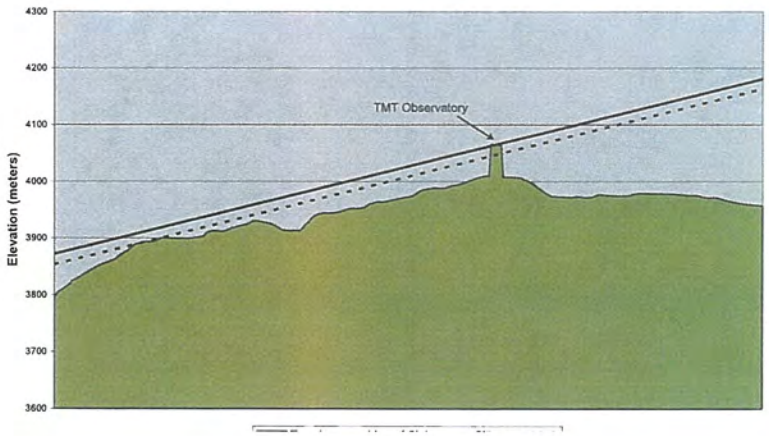
Hualalai Resort - Near TMT Alternative E2 Site



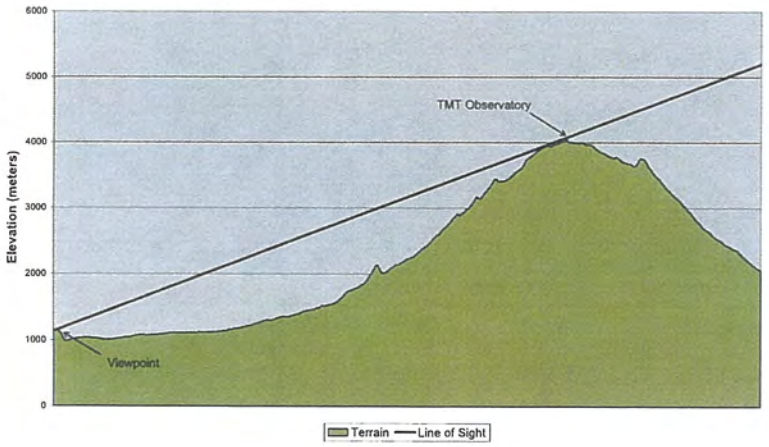
Puu Waawaa - TMT Proposed 13N Site



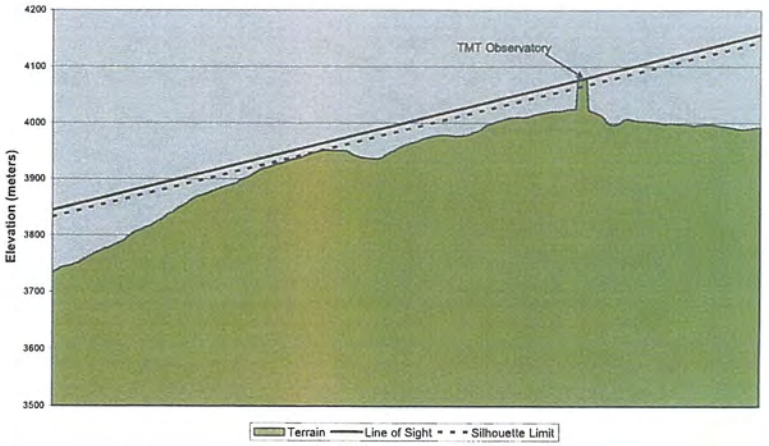
Puu Waawaa - Near TMT Proposed 13N Site



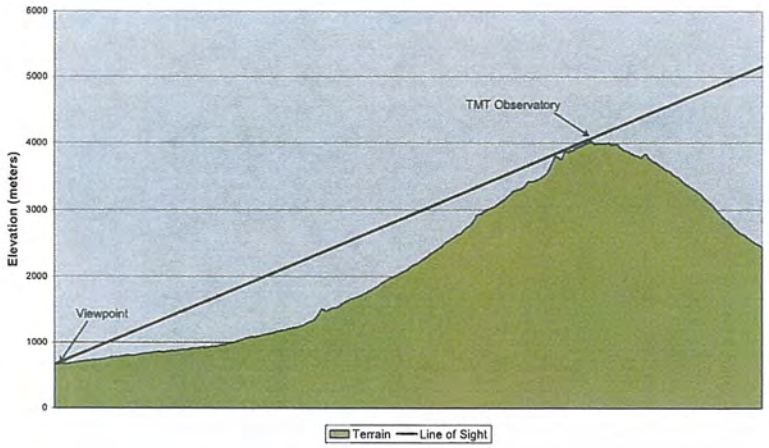
Puu Waawaa - TMT Alternative E2 Site



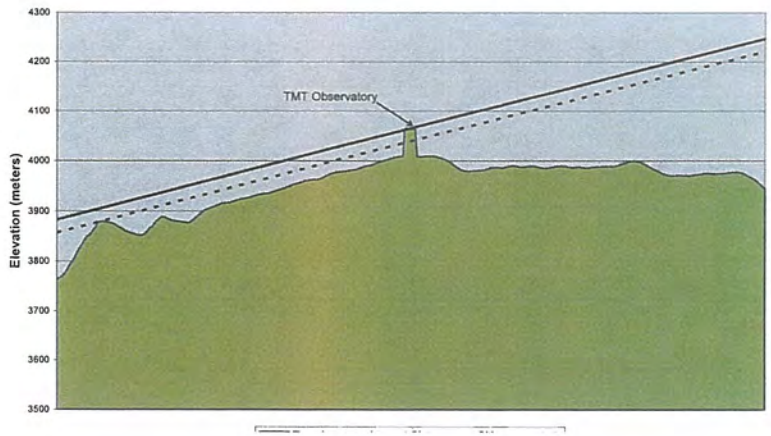
Puu Waawaa - Near TMT Alternative E2 Site



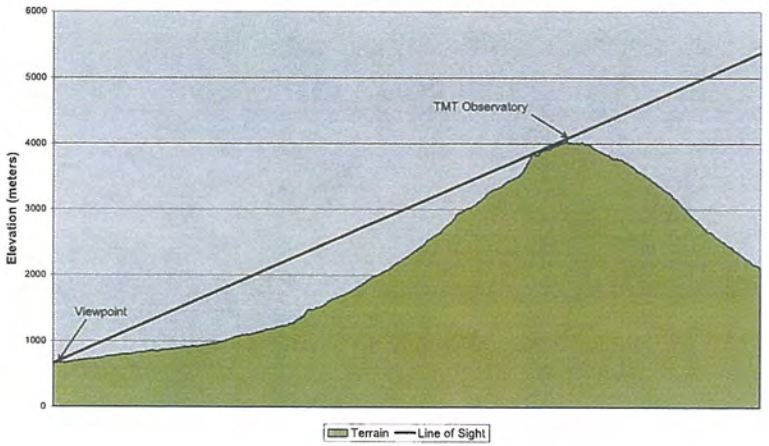
Big Island Country Club - TMT Proposed 13N Site



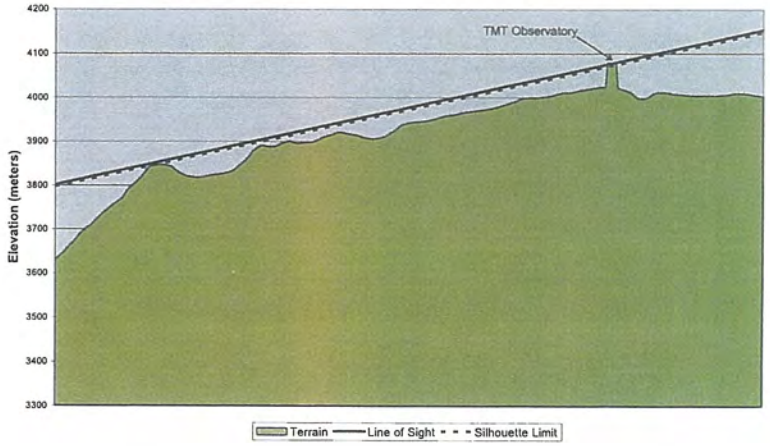
Big Island Country Club - Near TMT Proposed 13N Site



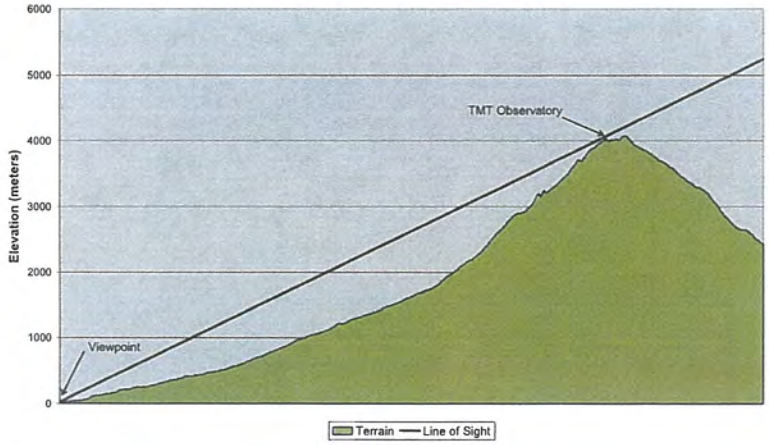
Big Island Country Club - TMT Alternative E2 Site



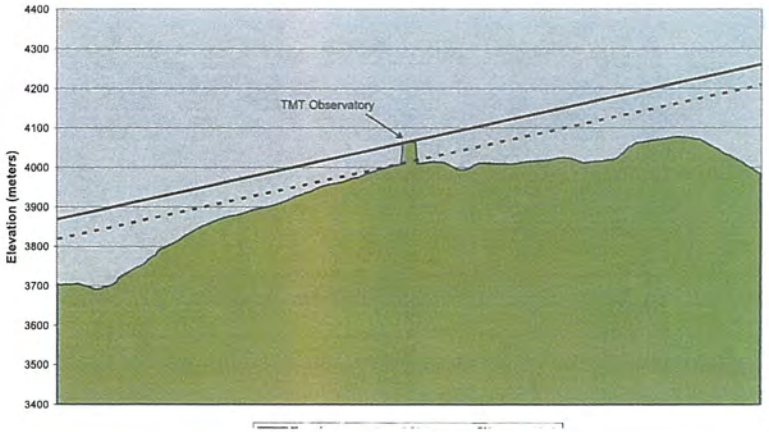
Big Island Country Club - Near TMT Alternative E2 Site



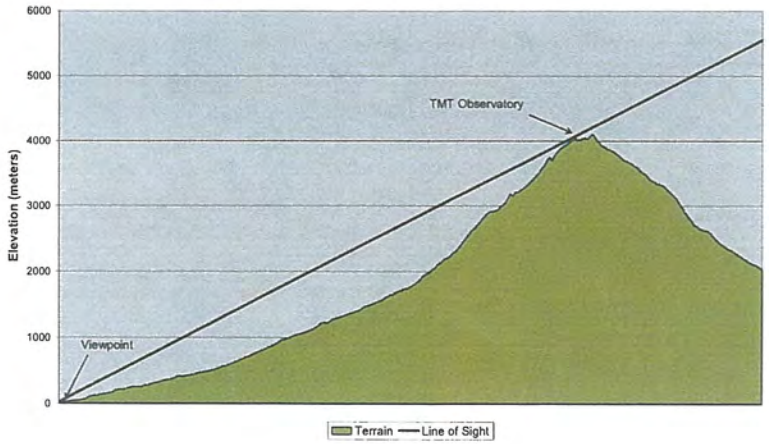
Waikoloa/Mauna Lani - TMT Proposed 13N Site



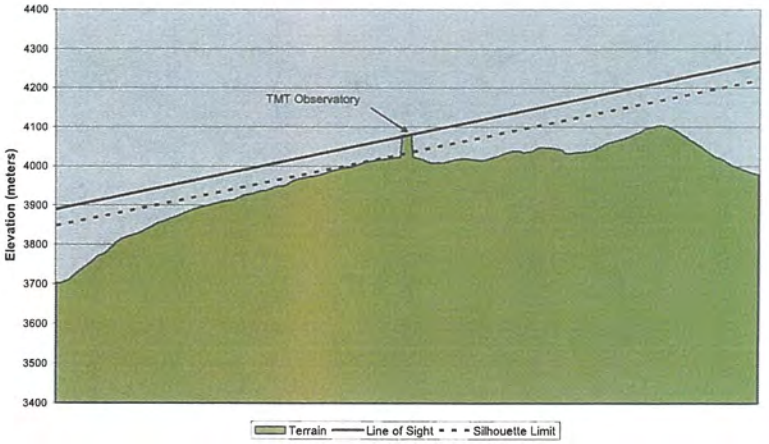
Waikoloa/Mauna Lani - Near TMT Proposed 13N Site



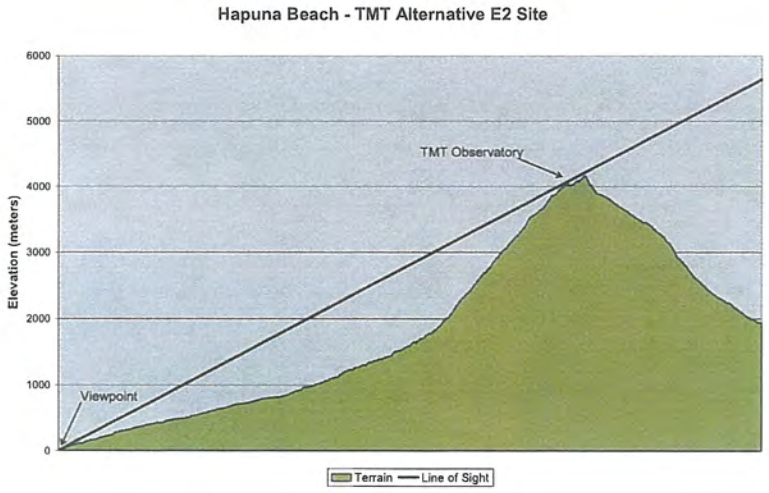
Waikoloa/Mauna Lani - TMT Alternative E2 Site

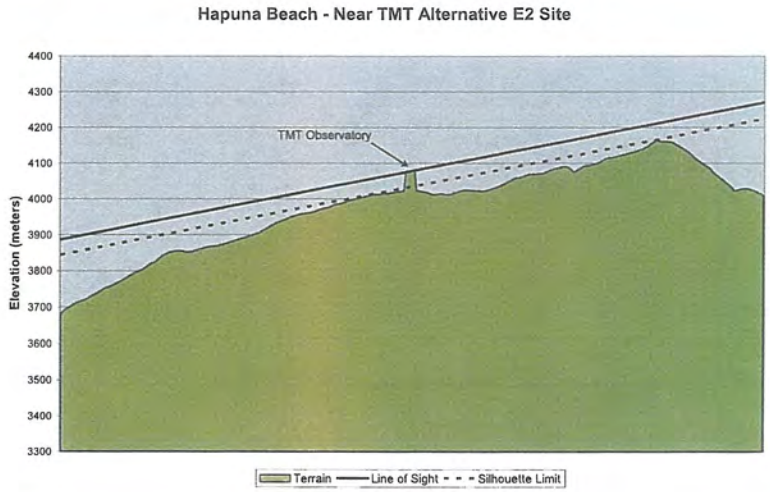


Waikoloa/Mauna Lani - Near TMT Alternative E2 Site

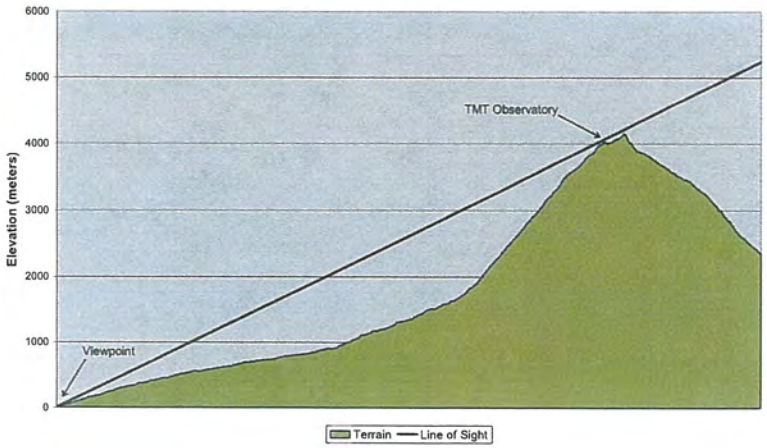


At site 13N the TMT Observatory would not be visible from Hapuna Beach.

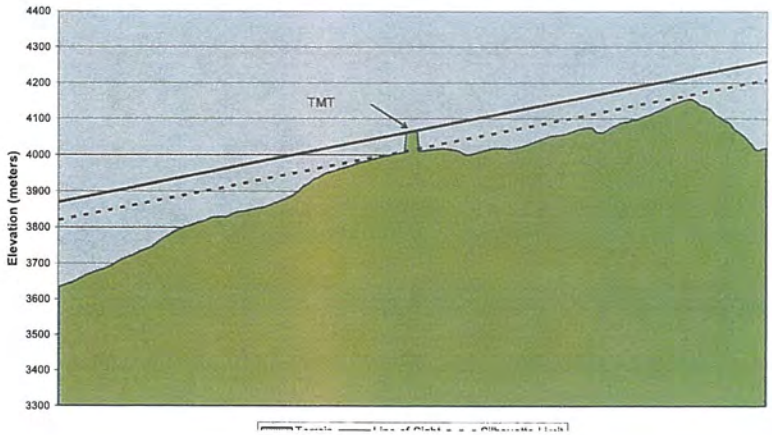




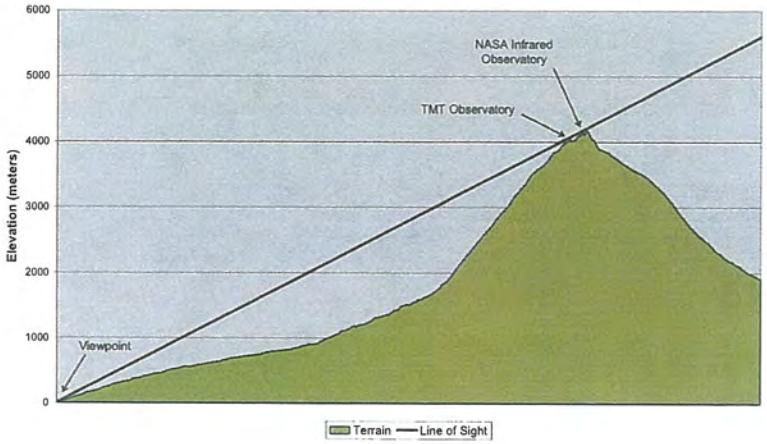
Puukohola Heiau - TMT Proposed 13N Site



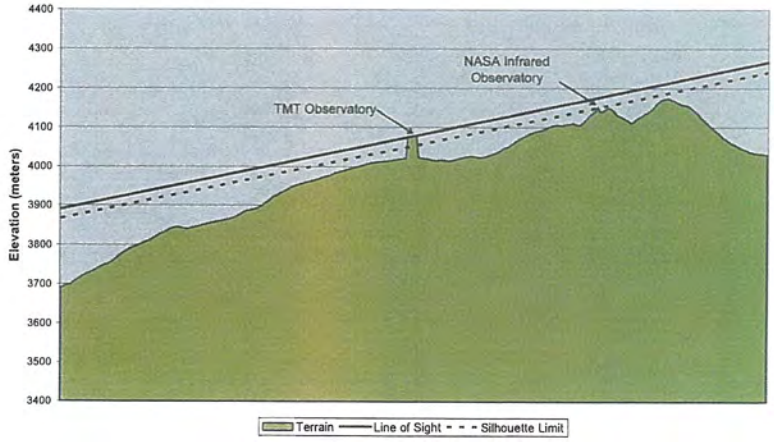
Puukohola Heiau - Near TMT Proposed 13N Site



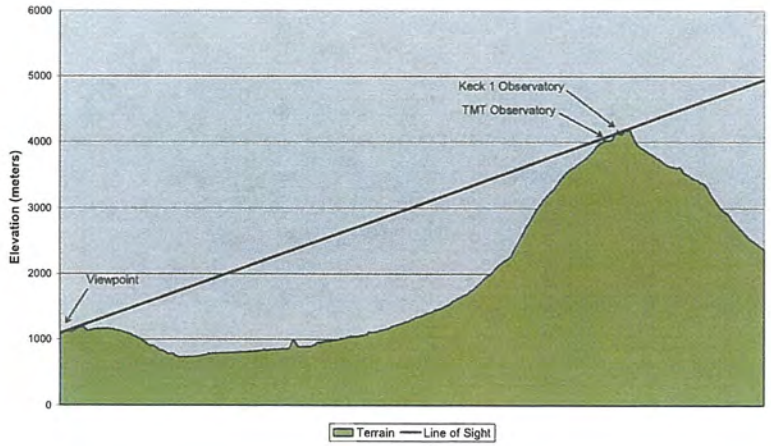
Puukohola Heiau - TMT Alternative E2 Site



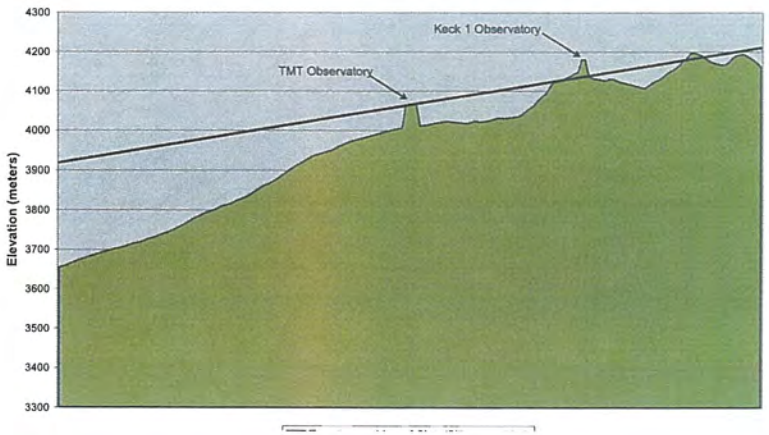
Puukohola Heiau - Near TMT Alternative E2 Site



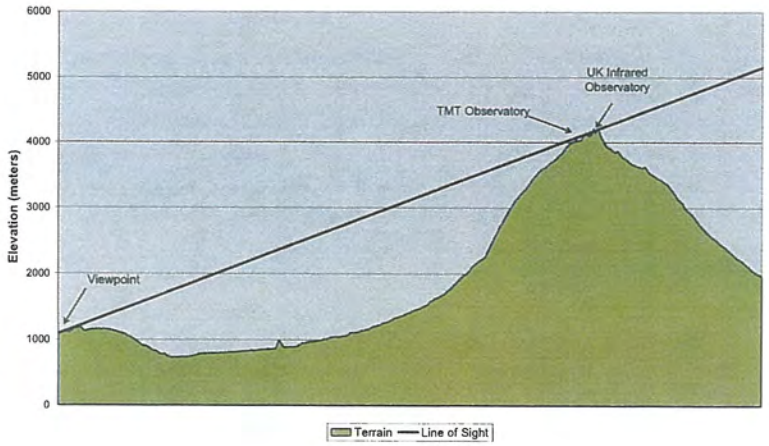
DHHL Kawaihae at Rt. 250 - TMT Proposed 13N Site



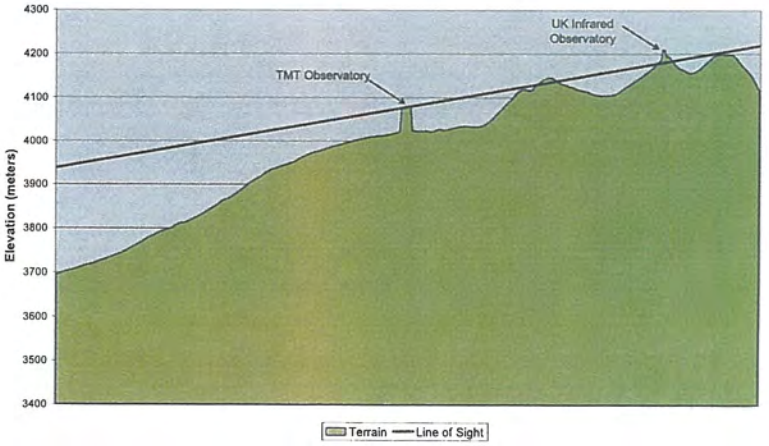
DHHL Kawaihae at Rt. 250 - Near TMT Proposed 13N Site



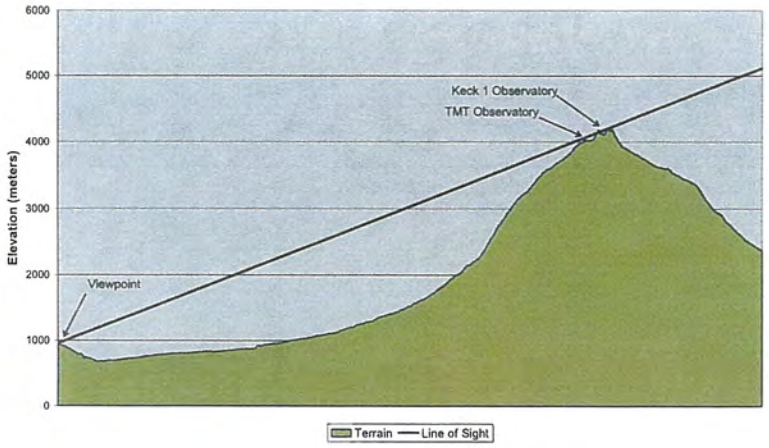
DHHL Kawaihae at Rt. 250 - TMT Alternative E2 Site



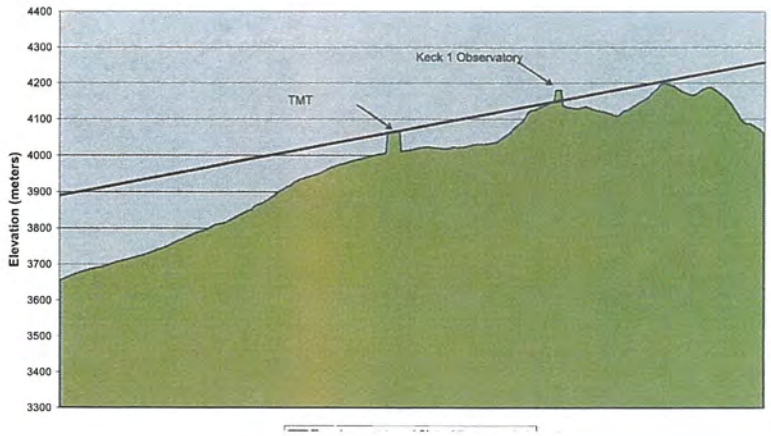
DHHL Kawaihae at Rt. 250 - Near TMT Alternative E2 Site



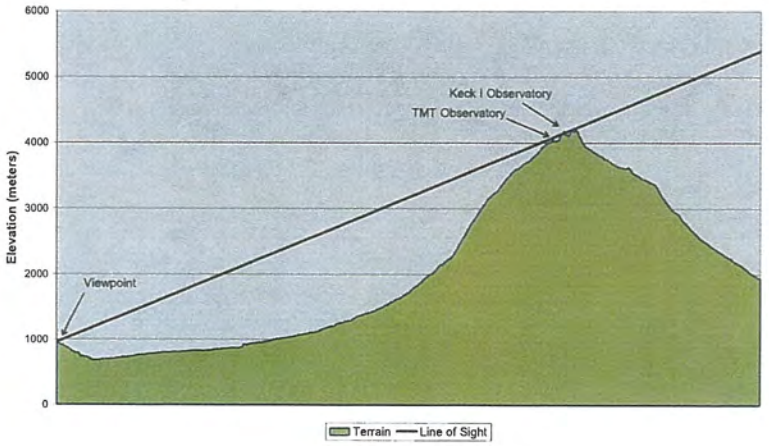
Route 250 Puu overlook - TMT Proposed 13N Site



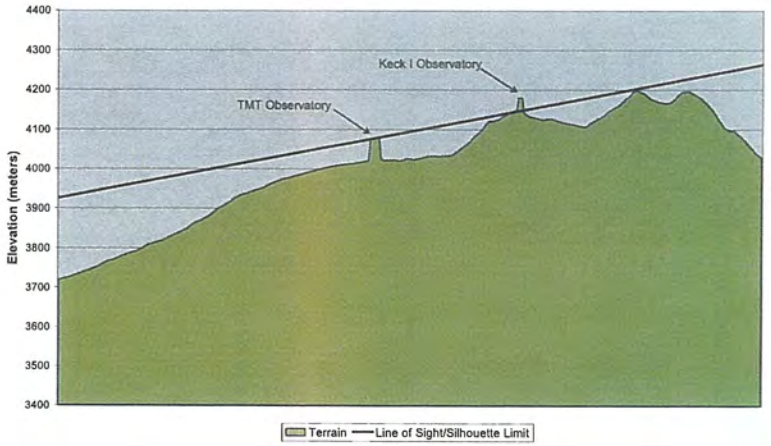
Route 250 Puu overlook - Near TMT Proposed 13N Site



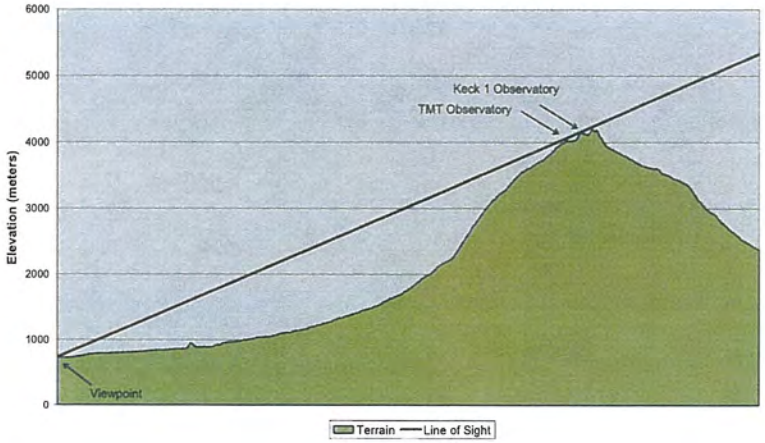
Route 250 Puu overlook - TMT Alternative E2 Site



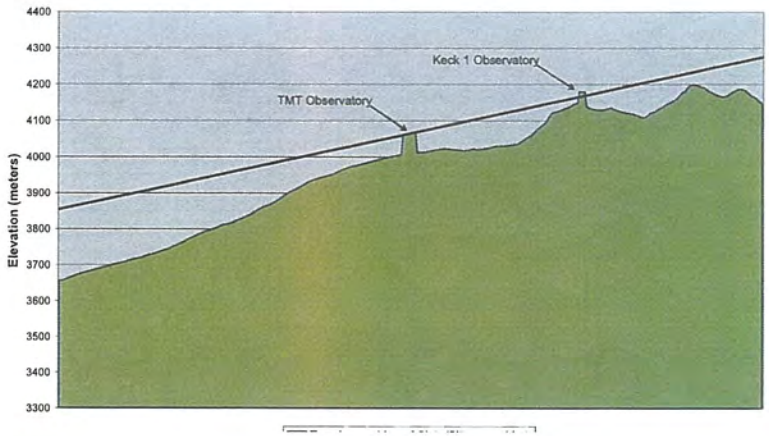
Route 250 Puu overlook - Near TMT Alternative E2 Site



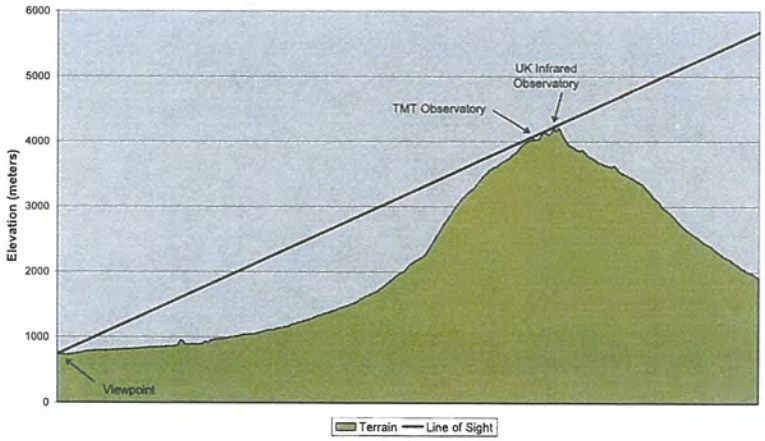
DHHL Lalamilo - TMT Proposed 13N Site



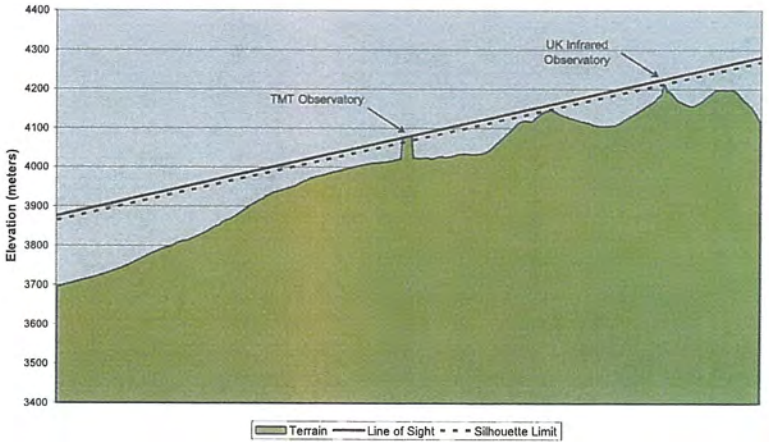
DHHL Lalamilo - Near TMT Proposed 13N Site



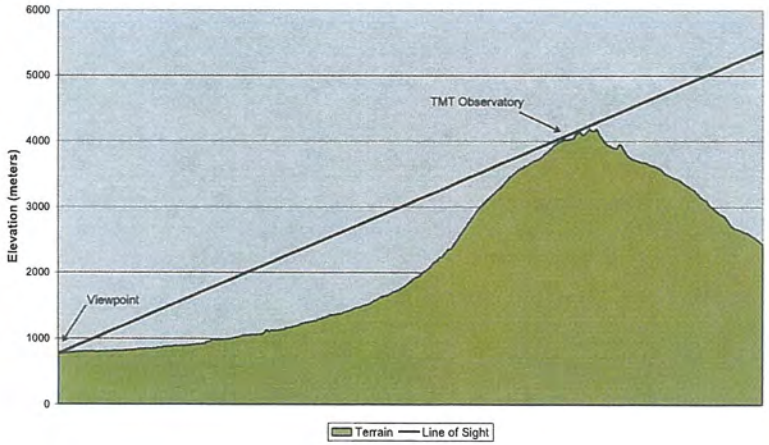
DHHL Lalamilo - TMT Alternative E2 Site



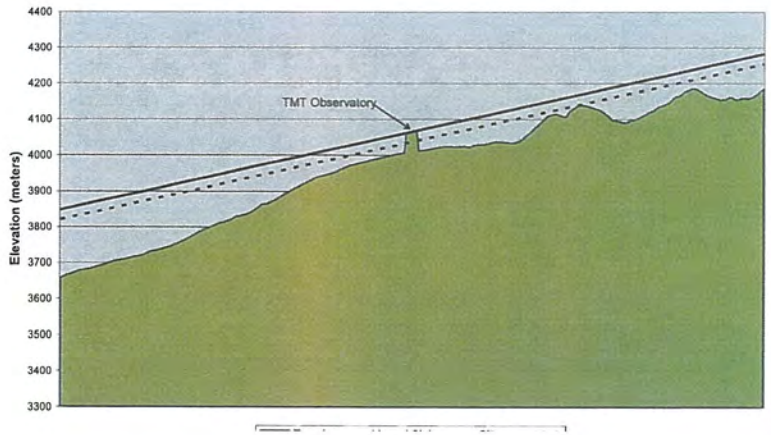
DHHL Lalamilo - Near TMT Alternative E2 Site



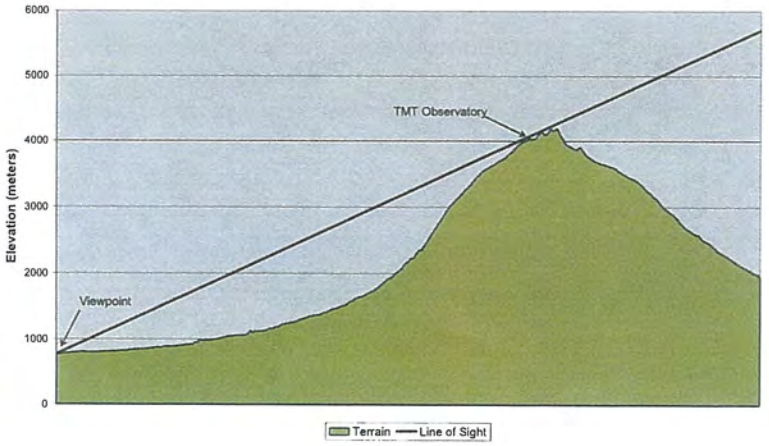
Waimea Park - TMT Proposed 13N Site



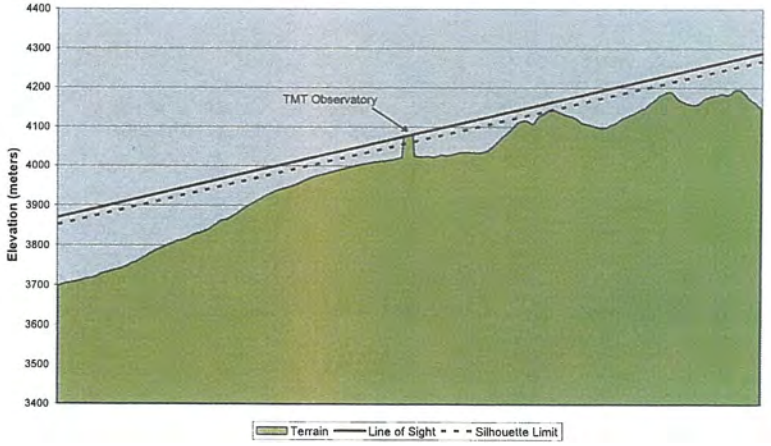
Waimea Park - Near TMT Proposed 13N Site



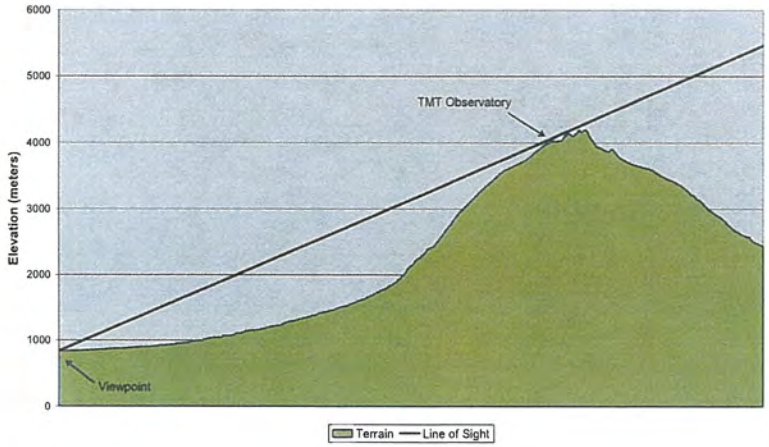
Waimea Park - TMT Alternative E2 Site



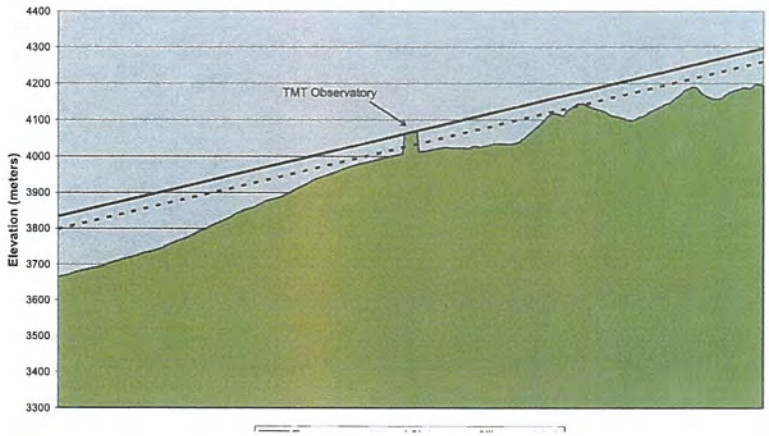
Waimea Park - Near TMT Alternative 13N Site



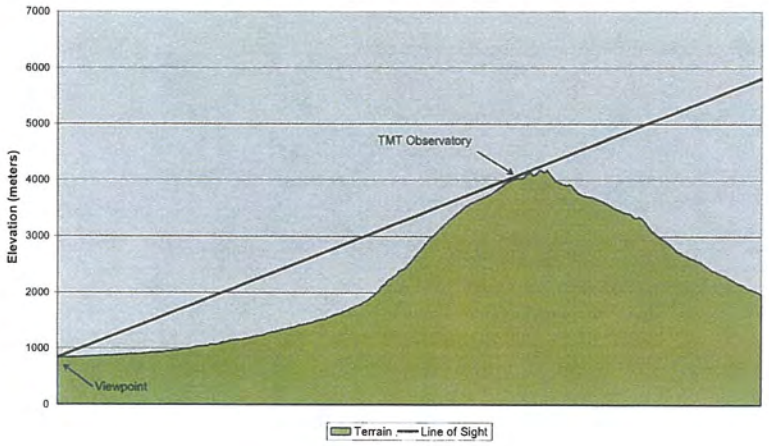
DHHL Puu Kapu - TMT Proposed 13N Site



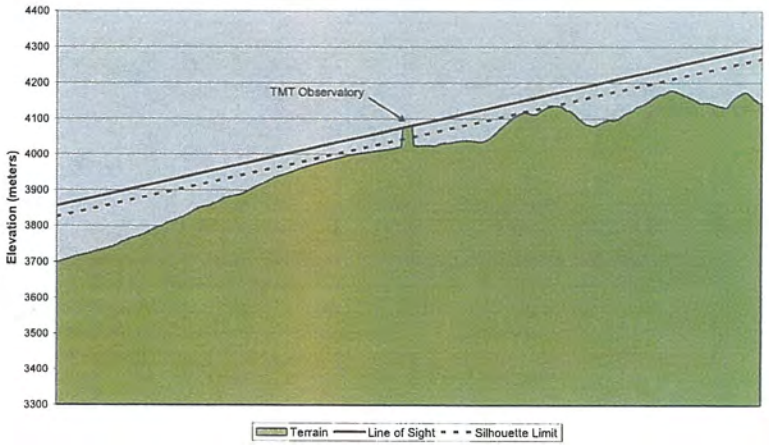
DHHL Puu Kapu - Near TMT Proposed 13N Site



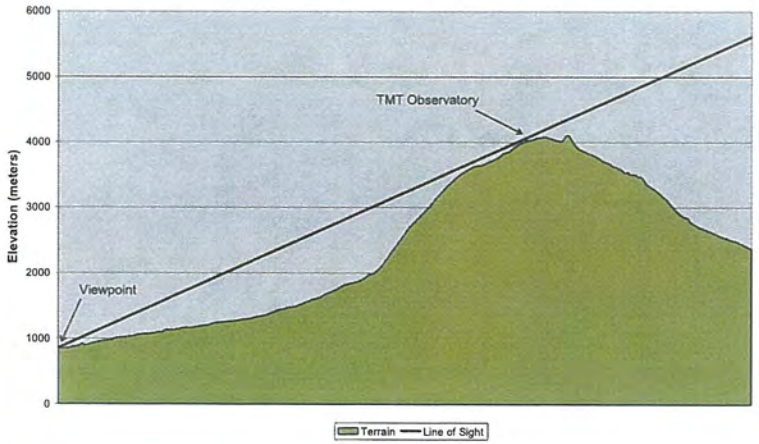
DHHL Puu Kapu - TMT Alternative E2 Site



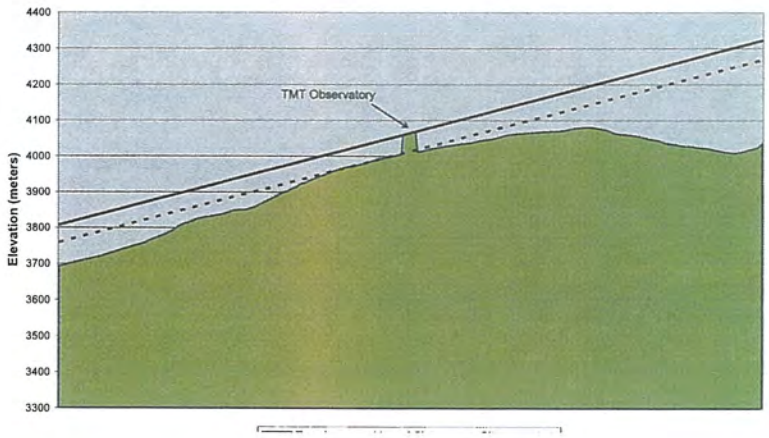
DHHL Puu Kapu - Near TMT Alternative E2 Site



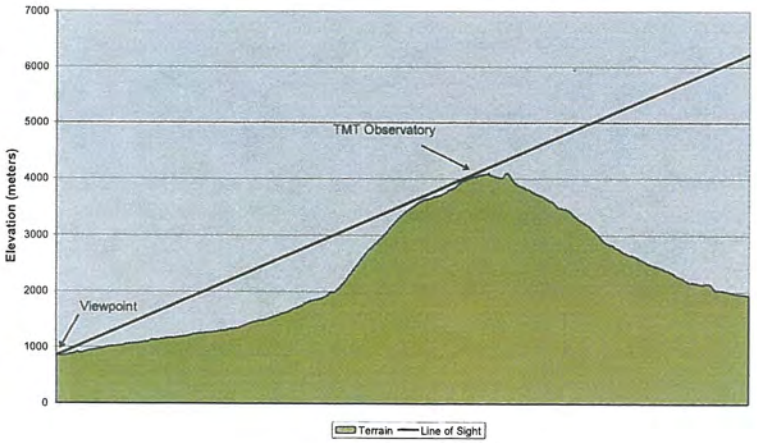
DHHL Waikoloa-Waialeale - TMT Proposed 13N Site



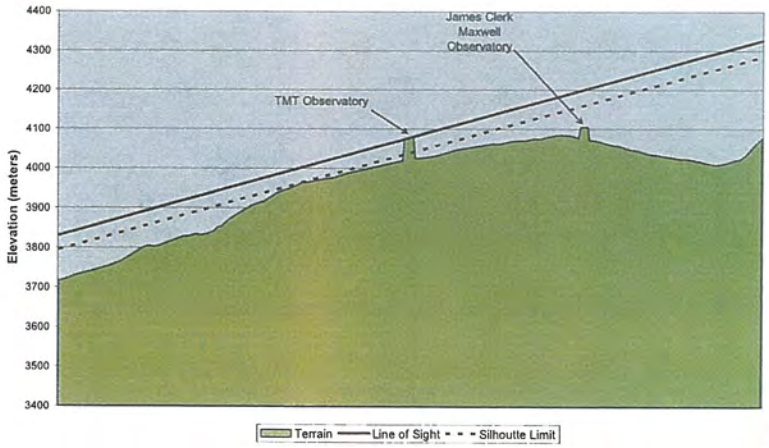
DHHL Waikoloa-Waialeale - Near TMT Proposed 13N Site

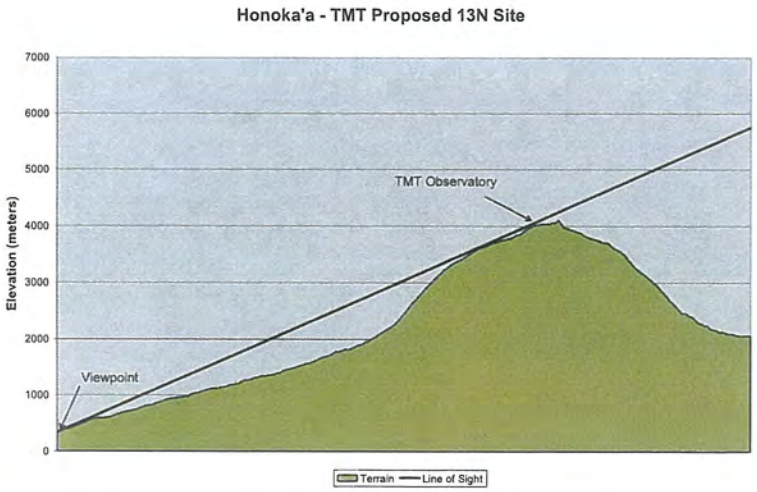


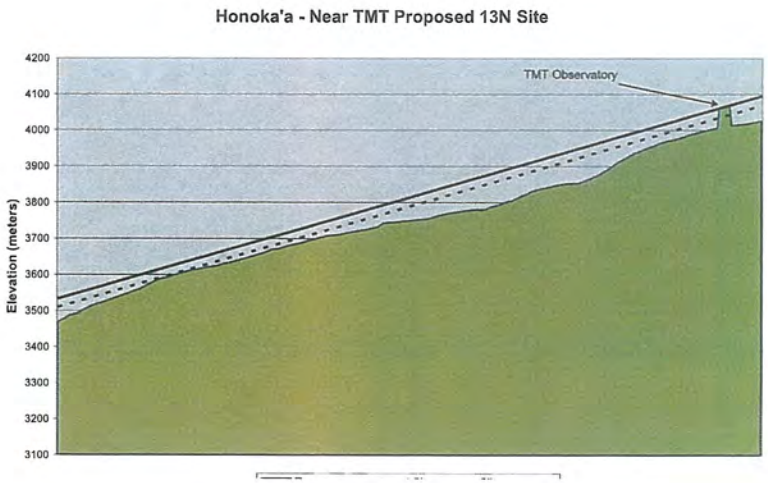
DHHL Waikoloa-Waialeale - TMT Alternative E2 Site



DHHL Waikoloa-Waialeale - Near TMT Alternative E2 Site

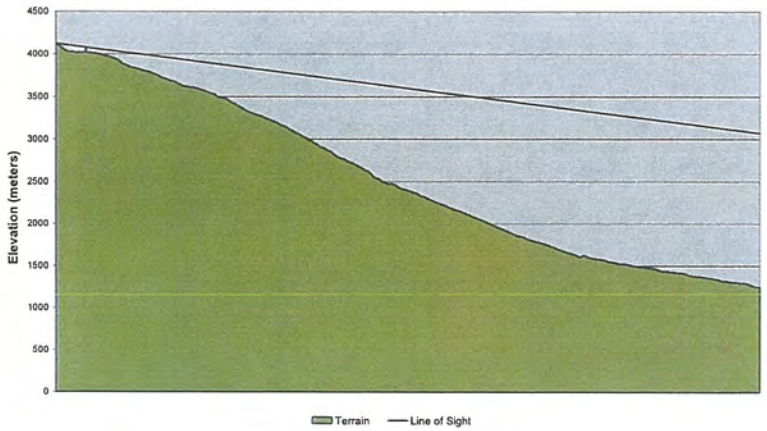




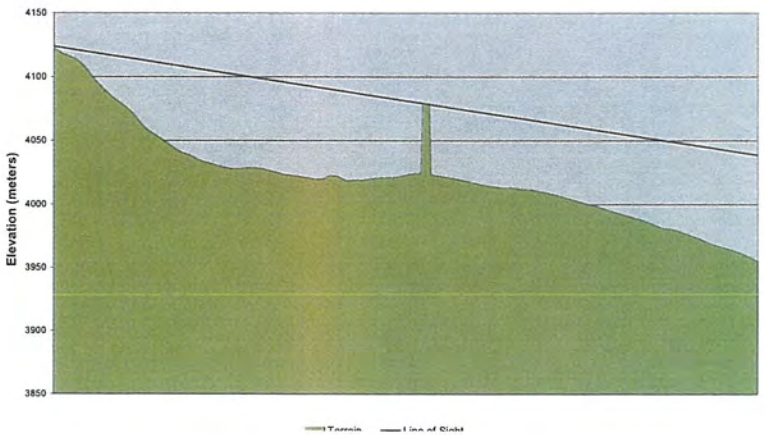


At site E2 the TMT Observatory would not be visible from Honoka'a.

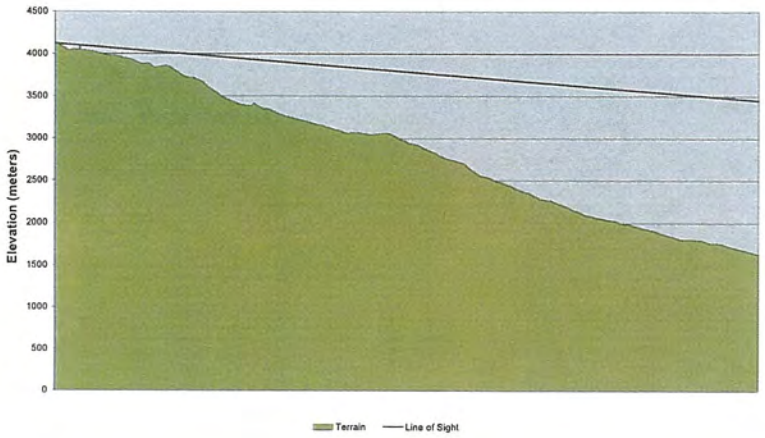
Kūkahau'ula - TMT Proposed 13N Site



Kūkahau'ula - Near TMT Proposed 13N Site



Kūkahau'ula - TMT Alternative E2 Site



Kūkahau'ula - Near TMT Alternative E2 Site