EXECUTIVE CHAMBERS

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JOHN WAIHEE
GOVERNOR

November 2, 1988

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OFC. OF ENV. QUALITY CONT.

Dr. Donald N. B. Hall
Institute for Astronomy
University of Hawaii
2680 Woodlawn Drive
Honolulu, Hawaii 96822

Dear Dr. Hall:

Based upon the recommendation of the Office of Environmental Quality Control, I am pleased to accept the Supplemental Environmental Impact Statement for the VLBA Antenna Facility, Mauna Kea, Hamakua, Hawaii, as satisfactory fulfillment of the requirements of Chapter 343, Hawaii Revised Statutes. This environmental impact statement will be a useful tool in the process of deciding whether the action described therein should be allowed to proceed. My acceptance of the statement is an affirmation of the adequacy of that statement under applicable laws and does not constitute an endorsement of the proposed action.

When the decision is made regarding the proposed action itself, I expect your agency to weigh carefully whether the societal benefits justify the environmental impacts which will likely occur. These impacts are adequately described in the statement, and, together with the comments made by reviewers, provide a useful analysis of the proposed action.

With kindest regards,

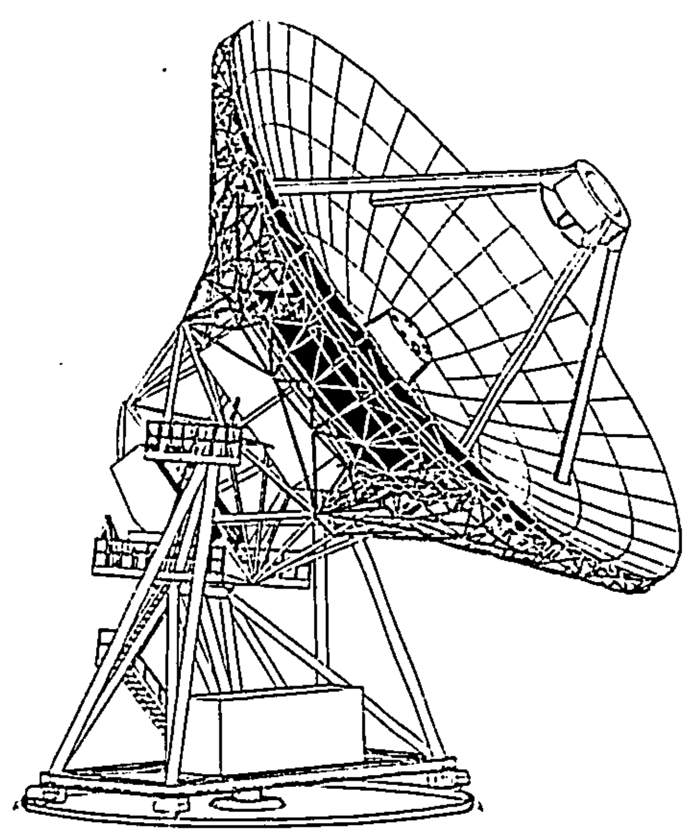
Sincerely,

John Waihee

JOHN WAIHEE

cc: Marvin T. Miura, Ph.D.
Hon. Albert Simone
Hon. John C. Lewin

AMENDMENT TO THE MAUNA KEA SCIENCE RESERVE COMPLEX DEVELOPMENT PLAN



FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT VLBA ANTENNA FACILITY

MAUNA KEA, HĀMĀKUA, HAWAI'I

University of Hawaii - Institute for Astronomy

September 1988

M C M PLANNING

LAND USE - ENVIRONMENTAL - ECONOMIC DEVELOPMENT

702 Honua Street, Honolulu, Hawaii 96816 (808) 732-7143

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FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

AMENDMENT TO THE MAUNA KEA SCIENCE RESERVE COMPLEX DEVELOPMENT PLAN FOR A VLBA ANTENNA FACILITY
At Hamakua, Mauna Kea, Hawaii

Proposed by:

THE UNIVERSITY OF HAWAII
INSTITUTE FOR ASTRONOMY

Donald N. B. Hall, Director

Prepared for:

THE NATIONAL RADIO ASTRONOMY OBSERVATORY
Socorro, New Mexico

Prepared by:

MCM PLANNING
Honolulu, Hawaii

September 1988

FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT
September 1988

PROJECT: AMENDMENT TO THE MAUNA KEA SCIENCE RESERVE COMPLEX DEVELOPMENT PLAN FOR A VLBA ANTENNA FACILITY

LOCATION: MAUNA KEA, HAMAKUA
ISLAND OF HAWAII
STATE OF HAWAII

PROPOSING AGENCY: UNIVERSITY OF HAWAII
INSTITUTE FOR ASTRONOMY
2680 WOODLAWN DRIVE
HONOLULU, HAWAII 96822
CONTACT: DR. DONALD N. B. HALL
TELEPHONE: (808) 948-8566

ACCEPTING AUTHORITY: GOVERNOR JOHN WAIHEE
STATE OF HAWAII

CONSULTANT: MCM PLANNING
703 HONUA STREET
HONOLULU, HAWAII 96816
CONTACT: MARILYNN C. METZ, AICP
TELEPHONE: (808) 732-7143

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Summary

This supplemental environmental impact statement (SEIS) was prepared to comply with Chapter 343, Hawaii Revised Statutes and with Section 11-200-27 of the Hawaii State Environmental Impact Statement Rules regarding supplemental statements. The SEIS evaluates the alternative sites that were considered for siting the Very Long Baseline Array (VLBA) and assesses the impacts of constructing and operating the antenna facility at the selected site.

The project is federally funded through the National Science Foundation (NSF). Compliance with the Council on Environmental Quality (CEQ) Regulations (40 CFR 1500-1508) for implementing the procedural provisions of the National Environmental Policy Act and NSF regulations (45 CFR 640) supplementing those of the CEQ will be the responsibility of NSF. The information contained in this SEIS is intended to provide the basis for the required Federal environmental compliance activities.

Description of the Action

The National Radio Astronomy Observatory (NRAO), operated by Associated Universities, Inc. (AUI), constructs and operates facilities for research in radio astronomy under contract with NSF. NRAO is building a major new instrument, the Very Long Baseline Array (VLBA). The VLBA is an aperture-synthesis radio telescope consisting of ten remotely operated antennas, sited across the country from the U.S. Virgin Islands in the east to Hawaii in the West. All ten antennas are located on U.S. territory; the Operations Center for the array is in Socorro, New Mexico. Construction of this array has been given top national priority by NSF.

Erection of one of the antennas in Hawaii is necessary to achieve the scientific goals of the VLBA. NRAO is negotiating with the University of Hawaii, Institute for Astronomy (UH IFA), for an antenna site within the Mauna Kea Science Reserve.

The site selected for the Hawaii antenna is between the 12,200- and 12,400-foot- elevations of Mauna Kea, about 2,600 feet northeast of the Mauna Kea Observatory (MKO) Access Road, TMK 4-4-15:09, in the Resource Subzone of the State Conservation District. An area of approximately two acres will be delineated for the use. NRAO intends to obtain a sublease for the property from UH and the Department of Land and Natural Resources (DLNR).

About one acre of the site will be enclosed by a seven-foot-high chain link fence. The VLBA antenna, a control building, an emergency generator, a propane fuel tank, a tower with weather instruments and miscellaneous concrete pads for equipment will be constructed within the fenced area.

The antenna will be a wheel and track, elevation over azimuth configuration with a 82-foot-diameter solid surface reflector, carried by a wheel and track mounting to permit pointing in any direction. It will rest on a circular concrete, 50-foot-diameter ring. When the antenna is aimed at the horizon, the top edge of the antenna will be at its maximum height of about 95 feet above the ground. The antenna must be painted white to minimize thermally induced distortions.

A 20-foot-wide, 2,600-foot-long, compacted gravel spur road will be constructed from the MKO Access Road to the site. A sign identifying the VLBA facility will be placed at the entrance to the spur road. Signs will also be posted along the road warning that off-road vehicle use is prohibited. UH, in coordination with DLNR, will also post signs identifying the "no-hunting" zone.

The site will require potable water, sewer, telephone and electric services. Domestic water will be trucked up from Hilo and stored in a 2,000-gallon buried tank, located just outside of the fenced area. The sanitary facilities will consist of an approved cesspool which will also be located outside of the fenced area.

The telephone and electric services will be underground from an existing pull box beside the MKO Access Road. The service will parallel the spur road to the site. A standby generator will be installed to keep critical equipment cold and to stow the antenna in a safe position during commercial power interruptions; NRAO will discontinue observing during the period of the power outage.

Construction of the VLBA facility on Mauna Kea is scheduled to begin in March 1989, and is expected to require a maximum of 18 months. Phase One of the construction period, which includes grading, road building, installation of the power and telephone lines, construction of the antenna foundation and control building and erection of the fence, will be done by local contractors. The estimated cost of this work is $1.3 million.

Phase Two will involve fabrication and assembly of the antenna, which will be shipped to Hawaii in pieces and assembled on-site, by the same contractor who is building the other nine antennas in the VLBA. Installation of the electronics and control systems will be done by NRAO technicians.

The antenna is a benign installation in that it is a receiving instrument only. It does not transmit or radiate any radio frequency energy. The facility is for basic research in astronomy and has no military applications.

The VLBA will be much less sensitive to low levels of radio-frequency interference (RFI) than any other radio telescope in the world, however, it would be sensitive to high levels of RFI (from a nearby high-power transmitter) that could overload or damage a receiver. The selected antenna site provides excellent terrain shielding from RFI interference in most directions.

The antenna is scheduled to be fully operational by early 1991. It will be remotely-operated 24 hours a day. A staff of two to four technicians, who will perform maintenance and other routine duties, will be hired locally. These people will work a regular 40-hour week. Accommodations will not be required at the Onizuka Center for International Astronomy at Hale Pohaku for NRAO staff.

In the event the antenna facility is permanently closed or abandoned, buildings and above-ground structures would be removed and the area in use returned to its natural condition by NRAO.

Potential Adverse Impacts and Mitigating Measures

Short-term construction-related impacts

- Traffic: An increase in traffic will be unavoidable during the construction phase of the project. This traffic will include large construction equipment and vehicles transporting workers to the site. This impact will end when construction is completed.

- Air quality: Increased vehicular traffic and internal combustion engines on heavy construction equipment will result in the generation of emissions into the air. Engine emissions will be mitigated by using properly functioning emission control devices as required by law.

- Visual: Construction equipment, related materials and temporary structures will be located on-site. This impact will be temporary since all equipment and materials will be removed at project completion.

Long-term Impacts

- Flora/fauna: The area surrounding the project site is not an important habitat for rare or endangered species of flora or fauna. However, existing biota within the designated construction area will be destroyed. This impact will be minimized by instructing the contractor to confine activities to specified areas. Furthermore, NRAO will direct its personnel not to disturb areas surrounding the VLBA facility, and ensure that predators are not inadvertently brought to the area.

- Visual character of the area: The VLBA facility and spur road will be constructed on land that is currently undeveloped. Within the Mauna Kea Science Reserve, the antenna will be partially visible from two locations along the MKO Access Road and completely visible along a 2,500-foot portion of the MKO Access Road at the 13,400-foot elevation. In addition, several hundred feet of the facility spur road will be visible near its intersection with the MKO Access Road.

  The antenna site and the spur road will be covered with compacted gravel to blend into the existing terrain. Although the antenna itself must be white, the color of the masonry block for the building will also be chosen to blend with the surroundings. Conformity to these design guidelines will serve to mitigate visual impact within the Science Reserve.

  Because the antenna will be built in a low-lying saddle between two cinder cones, the view of the antenna will be blocked out from most areas. It will not be visible from downtown Hilo. Long-range visual impact of the antenna facility will be low.

- Archaeological sites: Four archaeological sites were located in the project area; none are within the proposed construction site boundaries. In order to prevent inadvertent damage to the sites during construction, each will be fenced and its location plotted on construction drawings. Construction personnel will be made aware of the existence and location of the sites so that they will be avoided. If remains are uncovered, an archaeologist will be notified immediately.

Indirect Impacts

o Flora, fauna and archaeological sites: The presence of the facility and spur road could generate indirect impacts on the surrounding area. These impacts could include: disturbance of archaeological sites, geologic features, and habitat of endemic arthropod fauna by off-road vehicle use; and, increased mortality of birds (should they be present in the future) due to rodents and feral predators associated with the facility and light attraction leading to collision with facility structures.

  These potential impacts will be minimized by instituting the following mitigating measures:

  - Archaeological sites will be fenced. A sign near the entrance to the spur road will warn people of the penalties for disturbing them. On-site personnel will be instructed to notify the Enforcement Division of DLNR if anyone is seen disturbing a site.

  - Signs will be placed along the spur road warning that off-road driving is prohibited. Those ignoring this warning will be reported to Mauna Kea Support Services (MKSS) who will then call enforcement officers of DLNR or Hawaii County Police.

  - Mongoose-, rat-, and cat-proof refuse containers will be used and refuse will be removed from the area frequently so that these mammals do not establish themselves at the site.

  - Shielded lights will be used at the facility so as not to attract night-flying Petrels.

  - Management policies already established by the University of Hawaii for the preservation of biological and geological resources within the Science Reserve Complex will be followed by NRAO personnel.

o Radio-frequency interference (RFI): RFI from existing transmitters that comply with Federal Communications Commission (FCC) and National Telecommunications and

Information Administration (NTIA) regulations is not expected to be a problem at the site. Harmful RFI caused by emissions violating these regulations would be mitigated by cooperative efforts between NRAO and the source owner.

Potentially harmful RFI from new emitters would be mitigated by negotiations between NRAO and the applicant or licensee in order to find alternative emitter locations, to limit the effective isotropic radiated power (EIRP) toward the VLBA site, or correct potential problems when the transmitter is being designed.

Alternatives Considered

Alternative siting areas evaluated in this SEIS include: Haleakala, Maui; Hualalai, Hawaii; Mauna Loa, Hawaii; and three locations within the Mauna Kea Science Reserve on Mauna Kea, Hawaii. The Mauna Kea locations considered were: Telescope Siting Area C (SRCDP) at the 13,300 to 13,400-foot elevations of the summit; the 11,800-foot elevation of the Science Reserve, just off of the MKO Access Road; and, the selected site between the 12,200 and 12,400-foot elevations of the mountain.

Site evaluations were based on the following criteria:

o Intermediate to High Altitude. The antenna should be sited above the tropical inversion layer, which usually ranges from 8,000 to 9,000 feet above sea level.

o Low horizon to the east. The line of sight to the eastern horizon should be comparatively free of obstructions, such as terrain features or man-made structures.

o Low levels of man-made radio signals. The antenna should not be directly exposed to strong transmitters closer than 20 miles.

Haleakala, Hualalai, Mauna Loa and two locations on Mauna Kea (Telescope Siting Area C and the site at the 11,800-foot elevation) were eliminated from consideration as potential VLBA sites for the following reasons:

o Haleakala. This site was rejected because of the potential adverse impacts of the facility on existing operations in the summit area; the potentially harmful levels of RFI which could adversely affect the antenna's operation; and, frequent high wind conditions.

- Hualalai. This site was rejected because of the high probability of unacceptable RFI from existing transmitters in the area and the potentially high cost of constructing infrastructure to the site.

- Mauna Loa. This site was rejected because of the potential risk of harmful RFI from existing and proposed radio transmitters in the area and the potentially high risk from lava inundation (a 1 in 6 probability during the next 25 years).

- Mauna Kea summit. The major reasons for not siting the VLBA antenna at the summit are: potential snow and ice loading which would mean that the antenna would have to be housed in a radome, thus cancelling the advantage of placing the antenna above the tropical inversion layer; high (10 to 15 degree) horizon to the east and northeast; and, the fact that there is no reason to use a prime high-altitude site when there is no scientific advantage to putting the antenna at an elevation higher than just above the tropical inversion layer.

- Mauna Kea at the 11,800-foot elevation. The site was rejected because the risk of harmful RFI from present and future sources is high and may be above acceptable limits for operation of the VLBA antenna.

The site at the 12,200-foot elevation was selected for the VLBA facility primarily because it is protected from potentially harmful RFI from existing and proposed transmitters on Mauna Loa and secondarily because it will be barely visible from populated areas of the island. Even though construction costs for the road and utilities will probably be higher than at the 11,800-foot elevation, the fact that the natural terrain shields the antenna from harmful RFI led to the selection of the site.

The no action alternative means the western-most antenna of the VLBA would not be in Hawaii, thus limiting the project's ability to achieve its scientific goals. Hawaii is a critical element to the VLBA. Elimination of Hawaii as a site would significantly impair the performance of the array.

If the VLBA antenna is not built, the proposed site would be left in its natural state for the foreseeable future. At some later date, however, other antennas or telescopes, not requiring high altitude sites, may choose to locate there.

There are no alternative actions that would achieve the project's goals and no facilities in Hawaii which could substitute for the proposed antenna. Without a facility in

Hawaii, the performance of the array would be seriously impaired.

Unresolved Issues

Means to control public access to the VLBA antenna and off-road driving are being discussed by IFA and NRAO. At present, it is planned to allow public access along the VLBA spur road. Signs will be placed along the road warning people that off-road driving is forbidden. Those ignoring this warning will be reported to MKSS personnel who will then call enforcement officers of DLNR or Hawaii County Police to remove them from the mountain. People seen disturbing archaeological sites will also be reported.

Compatibility With Land Use Plans

- Hawaii State Plan. The VLBA project is in conformance to the objectives and policies (Part I) and priority directions (Part III) of the plan that relate to the economy and characteristics of desirable new industries for the State.

- Conservation District Policies and Regulations. The VLBA site is within the Resource subzone of the Conservation District. The objective of this subzone is to develop, with proper management, areas to ensure sustained use of the natural resources of the area. The proposed VLBA antenna is adding to the research capabilities of the Mauna Kea Observatory and meets the objective of the Resource subzone by utilizing the excellent astronomical resources that Mauna Kea possesses with minimal impact on the environment.

- 1977 DLNR Mauna Kea Plan. The Plan created specific areas to be managed by the University of Hawaii and states that the Science Reserve Area is to be used primarily for scientific research, in accordance with existing lease arrangements with the UH.

- University of Hawaii Research Development Plan (UH RDP). The plan serves as the programmatic master plan for the continued development of the Mauna Kea Science Reserve. The proposed VLBA facility meets the guidelines in the UH RDP for locating facilities within the Science Reserve.

- Mauna Kea Science Reserve Complex Development Plan (SRCDP). The telescope siting areas delineated in the SRCDP were specifically for optical, infrared, and millimeter/submillimeter-wavelength telescopes which require the extreme altitude of the summit area of Mauna Kea. The VLBA antenna belongs to an entirely new class of facility not included in the projection of telescopes anticipated through the year 2000.

  The VLBA has entirely different siting requirements than the types of facilities discussed in the SRCDP. These requirements have led to the need for an assessment of a new site at an intermediate altitude within the Mauna Kea Science Reserve. The SRCDP will be amended to incorporate the new site and to include the VLBA antenna as an additional facility.

  Existing transmitters on the summit of Mauna Kea are beginning to interfere with observing activities of optical and millimeter-wave telescopes. Although the University recognizes that Mauna Kea is a premier site for telecommunications, as well as astronomy, the two activities are not compatible.

  UH IFA proposes to amend the SRCDP by deleting references to future communications facilities in the summit area. The amendment will state that "no transmitters of any kind will be allowed within the Science Reserve in the future; those operating there now will be removed as soon as suitable alternative locations are found."

- Hawaii County General Plan. The plan encourages scientific research and development, along with other types of economic activities, as a suitable industry for broadening and diversifying the County's economic base. The project will create two to four new jobs, and will add to the critical mass necessary to support related jobs such as computer technicians and mechanical engineers.

Part VI lists policies and plans incorporated into the SEIS by reference.

Necessary Reviews and/or Approvals

The following list of necessary approvals does not include environmental compliance activities to be undertaken by the National Science Foundation.

- o State of Hawaii

  Board of Land and Natural Resources
    Conservation District Use Permit
    Right of Entry
    Sublease

  Department of Health
    Individual Wastewater Disposal System Approval

  University of Hawaii
    Amendments to the Science Reserve Complex Development Plan

- o County of Hawaii

  Planning Department
    CDUA Review Process
    Plan Approval

  Building Department
    Grading Permit
    Building Permit

Other permits required will be determined during the design phase of the project.

PART I: INTRODUCTION

A. OVERVIEW OF THE VLBA

The National Radio Astronomy Observatory (NRAO), operated by Associated Universities, Inc. (AUI), constructs and operates facilities for research in radio astronomy under contract with the National Science Foundation (NSF). NRAO is building a major new instrument, the Very Long Baseline Array (VLBA), capable of mapping celestial objects with milli-arc-second resolution. The VLBA is an aperture-synthesis radio telescope consisting of ten remotely operated antennas, sited across the country from the U.S. Virgin Islands in the east to Hawaii in the west (Figure I-1). It will synthesize a radio antenna 6,000 miles across, nearly the diameter of the earth. All ten antennas are located on U.S. territory; the Operations Center for the array is in Socorro, New Mexico. Construction of this array has been given top national priority by NSF.

Each antenna will be 82 feet in diameter and designed to operate at wavelengths as short as 3.5 millimeters. Each will be controlled through a local computer that will receive instructions over telephone lines from the VLBA Operations Center. Normally, two reels of tape will be recorded every day at each of the antennas and flown to the Operations Center; there they will be played back and the data correlated with data from the other antennas. (Figure I-2 presents a schematic drawing of a typical antenna).

> "The basic principle of the VLBA is that of the radio interferometer, a system that combines the signals received from a radio source by two or more antennas. The resulting interference pattern indicates the difference in the path lengths from the source to the antennas. ...Because the path lengths are determined by the position of the radio source in relation to the antennas, the interference pattern contains information about the location and detailed features of the source and can be used to construct an image. ...Antennas with wider spacings respond to finer detail (Kellermann and Thompson, 1988)."

Source: Kellerman and Thompson (1988)

THE VERY LONG BASELINE ARRAY Figure I-1

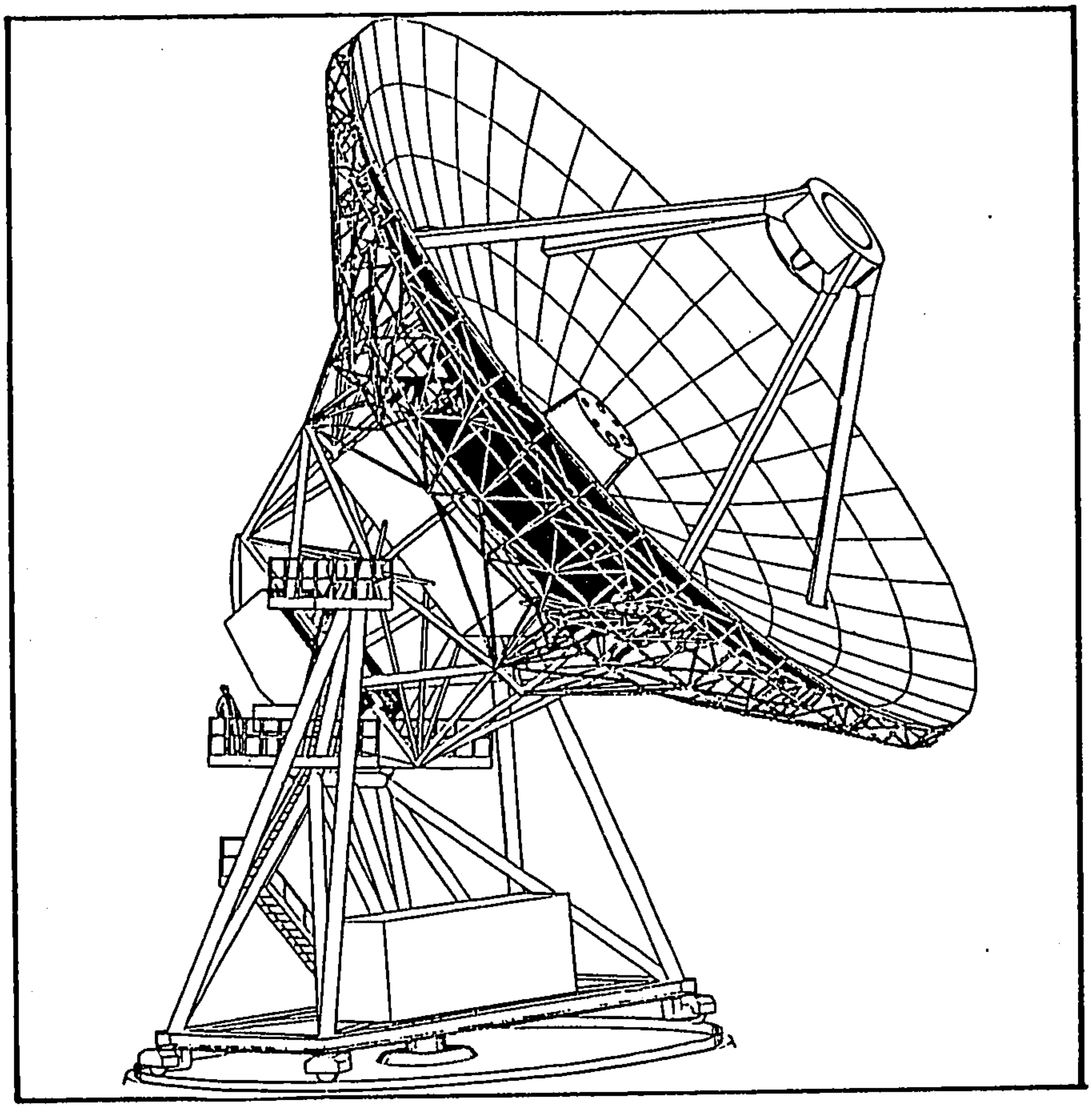


Figure I-2

Typical Antenna

The purpose of the VLBA is to provide high-quality radio images of remote astronomical objects at the highest angular resolution that can be achieved by a ground-based instrument. This unique instrument will be an improvement over existing telescopes by large factors. For example, the angular resolution will be 1,000 times greater than that of any ground-based optical telescope in existence at the present time or of the Very Large Array (VLA) in New Mexico, currently the most advanced radio telescopes in the world. It will be 100 times greater than that of the Hubble Space Telescope. The resolution that can be achieved by the VLBA is comparable to a person with eyes powerful enough to be able to read a newspaper in Los Angeles from a hotel room on Waikiki Beach.

The VLBA can help find answers to questions about the form of the clouds of matter falling into massive black holes in the centers of galaxies, the structural changes in the extremely distant quasistellar objects (active galaxies), and the evolution of "superluminal sources," that is, sources that appear to move faster than the speed of light. The array can probe radio phenomena associated with stellar activity in our own galaxy that cannot be resolved with conventional radio telescopes. This will help astronomers who are attempting to understand the life cycles of stars. The VLBA will also be able to provide the most accurate measurements yet to be made of cosmic distances, a problem of fundamental importance in astronomy.

In addition to being an astronomical tool, the VLBA will also study terrestrial phenomena such as plate-tectonic motion, rotation of the earth and distortions in the solid earth caused by tidal forces. These applications are possible because the response of the radio interferometer depends not only on the source under observation but on the earth's rotation and the length and orientation of the baseline separating a pair of antennas. Because it is possible to determine the distance between two widely separated antennas with high precision, the VLBA can detect changes in the earth's dimensions of less than one centimeter (Ibid.). Two articles by Kellerman and Thompson which were originally published in Scientific American and Science (including the article cited above), that describe the scientific and technical characteristics of the VLBA, are reproduced in Appendix A of this SEIS.

The antenna is a benign installation in that it is a receiving instrument only. It does not transmit or radiate any radio frequency energy. The facility is for basic research in astronomy and has no military applications.

The antenna location in the State of Hawaii has been selected by NRAO according to the detailed optimization plan for image quality of cosmic radio sources in order to provide the completed instrument with appropriate distances (baselines) among the several antennas. Erection of one of the antennas in Hawaii is necessary in order to achieve the scientific goals of the VLBA. NRAO is negotiating with the University of Hawaii, Institute for Astronomy (UH IFA), for an antenna site within the Mauna Kea Science Reserve (Figure I-3).

B. ASTRONOMY DEVELOPMENT ON MAUNA KEA

Since 1968, the University of Hawaii (UH) has been actively advancing mankind's understanding of the physical universe through operation of an astronomical facility on Mauna Kea, a 13,796-foot high shield volcano located on the island of Hawaii. In recognition of the unique qualities of the Mauna Kea summit area for astronomical research, the Board of Land and Natural Resources (BLNR) approved a 65-year lease (beginning January 1, 1968) with UH for lands above the plus or minus 12,000-foot elevation. The lease (General Lease No. S-4191) refers to these lands as the Mauna Kea Science Reserve (Figure I-4).

In recent years, many astronomical sites in the continental United States have been compromised, primarily as a result of air pollution and proliferating, uncontrolled city lights. Because the crucial problems of modern astronomy demand data obtainable only at the very finest sites, astronomers have come to set an increasingly high value on the few excellent ground-based sites remaining. Mauna Kea is among the very finest sites in the world and to date, the national and international scientific community has established six major telescopes (and two smaller ones) within the summit area of the Science Reserve; a ninth facility, the W. M. Keck Observatory, the world's largest telescope, is under construction.

Because of the excellence of the Mauna Kea site, it was expected that the State would continue to receive requests for permission to locate additional telescopes on Mauna Kea. In the early 1980's, UH IFA prepared a Research Development Plan for the Mauna Kea Science Reserve and Related Facilities (UH RDP). The plan projected thirteen telescopes within the Mauna Kea Science Reserve by the year 2000. At that time UH believed that thirteen was a reasonable forecast of possible astronomical activity on the mountain to the end of the century. Given the current high level of interest in the site, however, UH anticipates additional requests from national and international

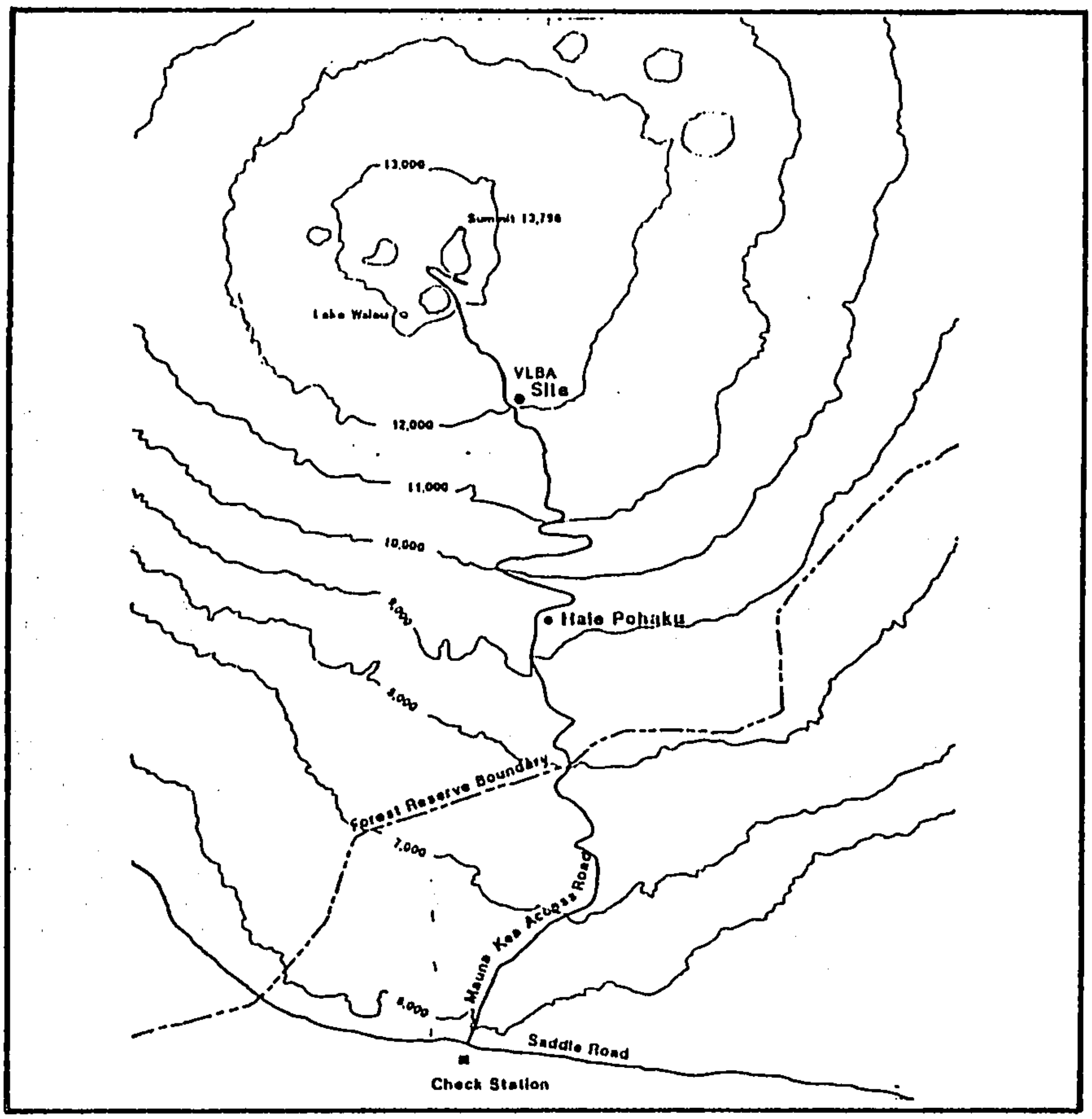


Figure I-3

North

Location

Location Map

1 0 1
Scale in Miles

MCM Planning 6-88

Mauna Kea Science Reserve

Figure I-4

institutions to construct and operate telescopes on Mauna Kea into the next century.

The Mauna Kea Science Reserve Complex Development Plan (SRCDP) incorporated the policies and criteria set forth in the UH RDP. The SRCDP was prepared to provide the physical planning framework necessary to implement the UH RDP. The BLNR also required the SRCDP as a condition to approving further development on the mountain. The FEIS for the SRCDP, which was accepted by the Governor in January 1983, is incorporated into this SEIS by reference.

C. PROPOSED AMENDMENTS TO THE SRCDP

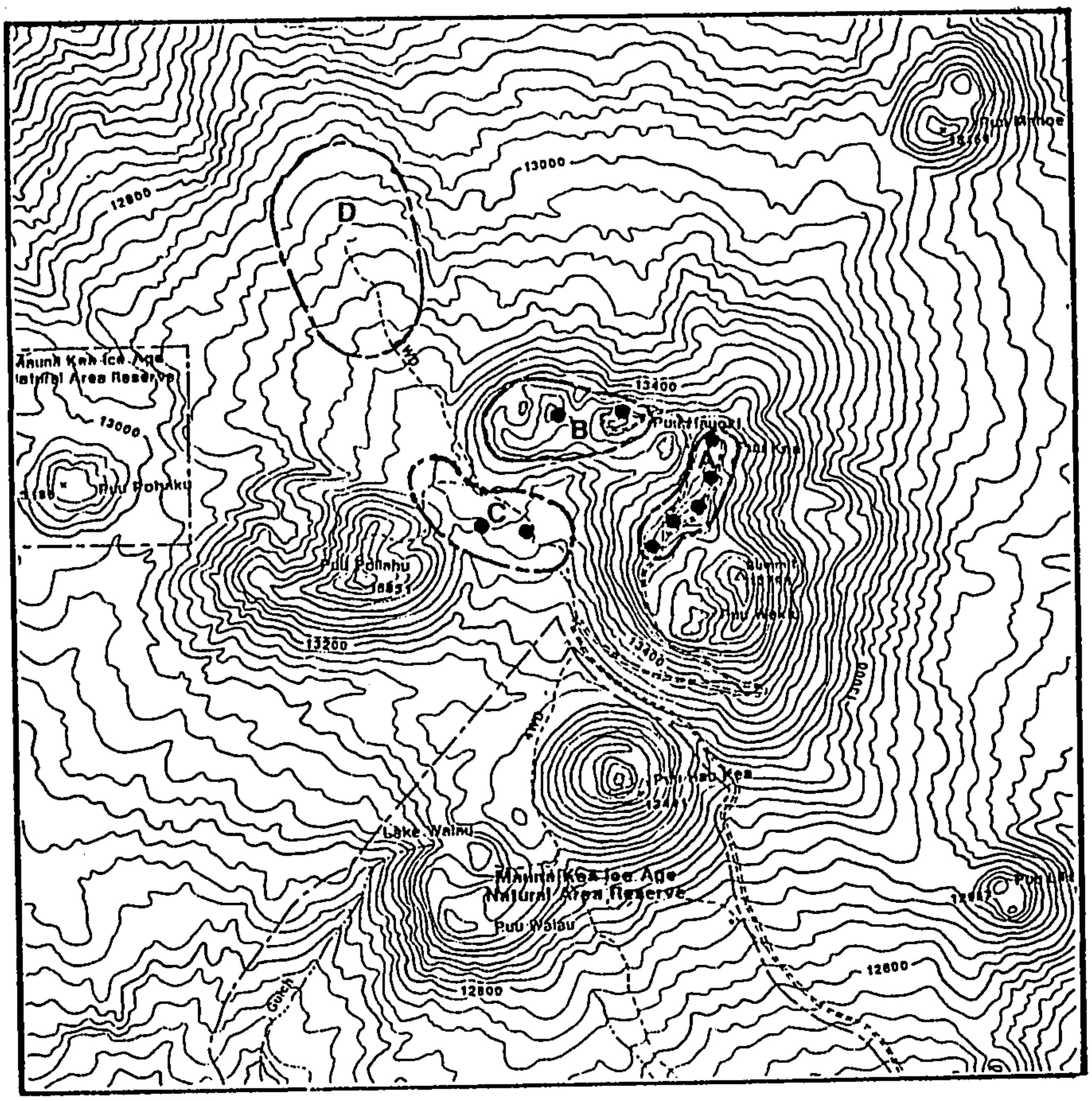
1.0 New Siting Area for the VLBA

All of the telescope siting areas assessed in the SRCDP FEIS were specifically for optical, infrared, and submillimeter wavelength telescopes which require the extreme altitude of the summit area of Mauna Kea. In general, optical and infrared telescopes are constructed in two designated areas along the summit ridge, and millimeter/submillimeter-wavelength telescopes are constructed in the valley to the southwest of these areas (Figure I-5). The proposed VLBA antenna belongs to an entirely new class of facility, not anticipated in the UH RDP nor the SRCDP. Such antennas were not included in the projection of telescopes anticipated through the year 2000.

The VLBA has entirely different siting requirements from optical, infrared and millimeter/submillimeter-wavelength telescopes (i.e., that it have a clear eastern horizon with minimum radio frequency interference and that it be located at an elevation high enough to be above the tropical inversion layer yet low enough to assure against wind, snow and ice loading on the structure). These requirements have led to the need for an assessment of a new site at an intermediate altitude within the Mauna Kea Science Reserve. The SRCDP will be amended to incorporate the new site and to include the VLBA antenna as an additional facility.

2.0 Transmitters Within The Mauna Kea Science Reserve

Existing transmitters on the summit of Mauna Kea will not affect the operations of the VLBA unless they are pointed directly toward the antenna. These emitters are, however, beginning to interfere with observing activities of the optical telescopes in the area. Although the University recognizes that Mauna Kea is a premier site for telecommunications, as well as astronomy, the two activities are not compatible.



LEGEND:
- ● Existing Telescope
- Telescope Siting Area

SRCDP: Telescope Siting Areas

2000 1000 0 1000 2000
Scale in Feet

Figure I-5

North Location

MCM Planning 6-88

Additional communications equipment and a satellite communications dish for the summit were approved in the SRCDP. Since then, UH IFA has received many proposals to install new or upgrade old transmitters at the summit; some of these requests have come from astronomy users themselves. It is the policy of IFA to reject all such proposals because they are inimical to the scientific complex within the Science Reserve. UH IFA proposes to amend the SRCDP by deleting references to a Microwave Link and Satellite Communications Dish from the Communications Facilities section of the plan and replace them with this statement: "No transmitters of any kind will be allowed within the Science Reserve in the future. Those operating there now will be removed as soon as suitable alternative locations are found."

D. ENVIRONMENTAL COMPLIANCE

This supplemental environmental impact statement was prepared to comply with Chapter 343, Hawaii Revised Statutes and with Section 11-200-27 of the Hawaii State Environmental Impact Statement Rules regarding supplemental statements. The SEIS evaluates the alternative sites that were considered for siting the VLBA and assesses the impacts of constructing and operating the antenna at the selected site. A Conservation District Use Application (CDUA) will be filed with the BLNR requesting the use of the selected site for the proposed project.

Compliance with Council on Environmental Quality (CEQ) Regulations (40 CFR 1500-1508) for implementing the procedural provisions of the National Environmental Policy Act and National Science Foundation regulations (45 CFR 640) supplementing those of the CEQ will be the responsibility of NSF. The information contained in this SEIS is intended to provide the basis for the required Federal environmental compliance activities.

PART II: DESCRIPTION OF THE PROPOSED ACTION

A. PROJECT SITE

The selected site for the proposed NRAO VLBA antenna is between the 12,200- and 12,400-foot elevation of the Mauna Kea Science Reserve, roughly 2.7 miles below the summit area about 2,600 feet northeast of the Mauna Kea Observatory (MKO) Access Road. It is situated in TMK 4-4-15:09, and is within the Resource Subzone of the State Conservation District (Figure II-1).

The antenna facility will be built on a flat plain in a low-lying saddle between two unnamed cinder cones (Figure II-2); the maximum topographic relief on the proposed construction site is 15 feet. An area of approximately two acres will be delineated for the use. NRAO intends to obtain a sublease for the property from UH and the Department of Land and Natural Resources (DLNR).

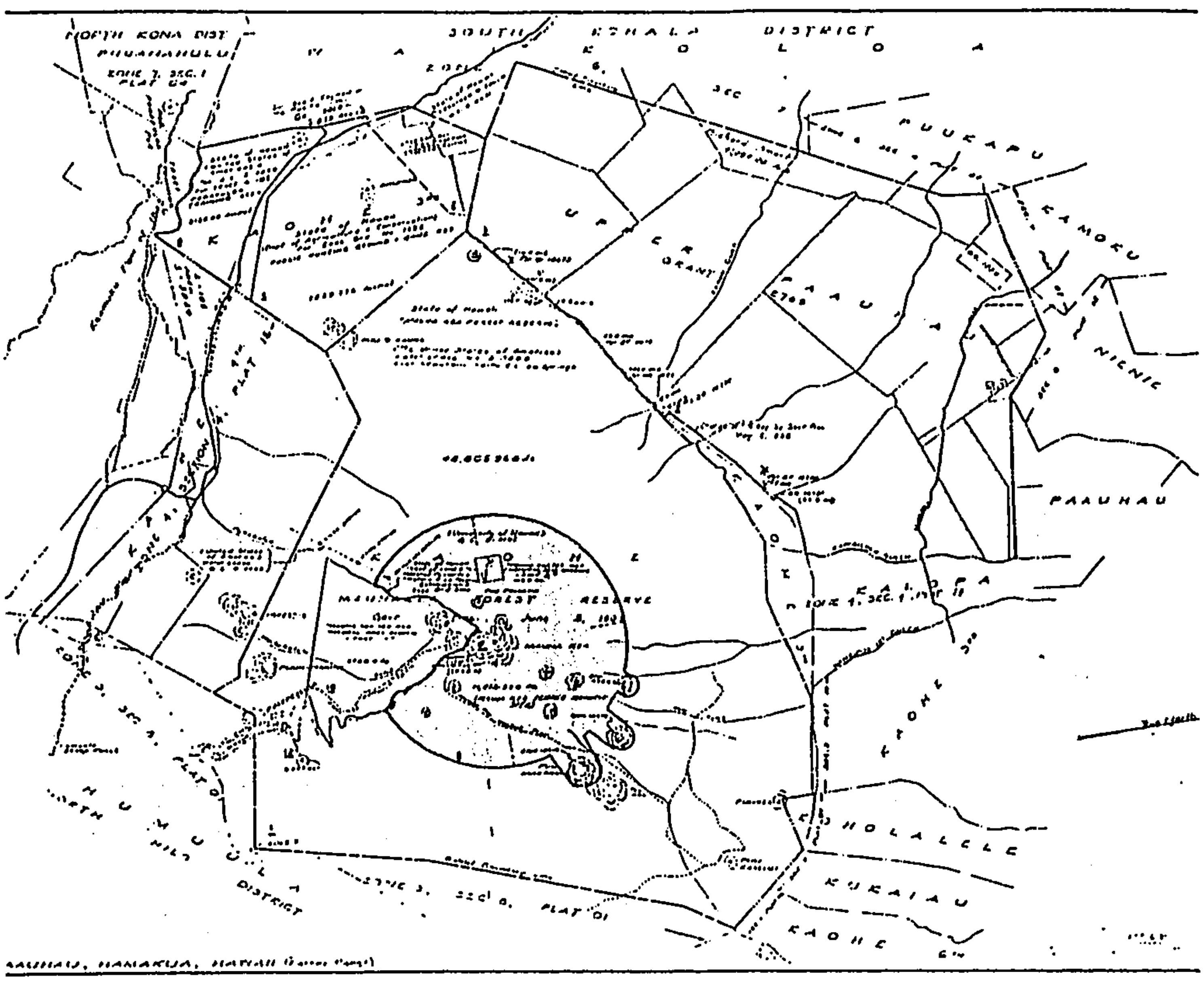
B. PROPOSED SITE IMPROVEMENTS

1.0 Antenna and Appurtenant Structures

Figure II-3 shows a conceptual site plan for the antenna facility. Precise locations of structures will be determined during the design phase of the project, after soils testing has been completed.

About one acre of the site will be enclosed by a seven-foot-high chain link fence, in a color that will blend into the surrounding terrain. The VLBA antenna, a control building, a 75-kVA emergency generator, a propane (LPG) fuel tank, a tower with weather instruments and miscellaneous concrete pads for equipment will be constructed within the fenced area.

The antenna will be a wheel and track, elevation over azimuth configuration with a 82-foot diameter solid surface reflector, carried by a wheel and track mounting to permit pointing in any direction. It will rest on a circular concrete,



MAUNA KEA SCIENCE RESERVE

FIGURE II-1

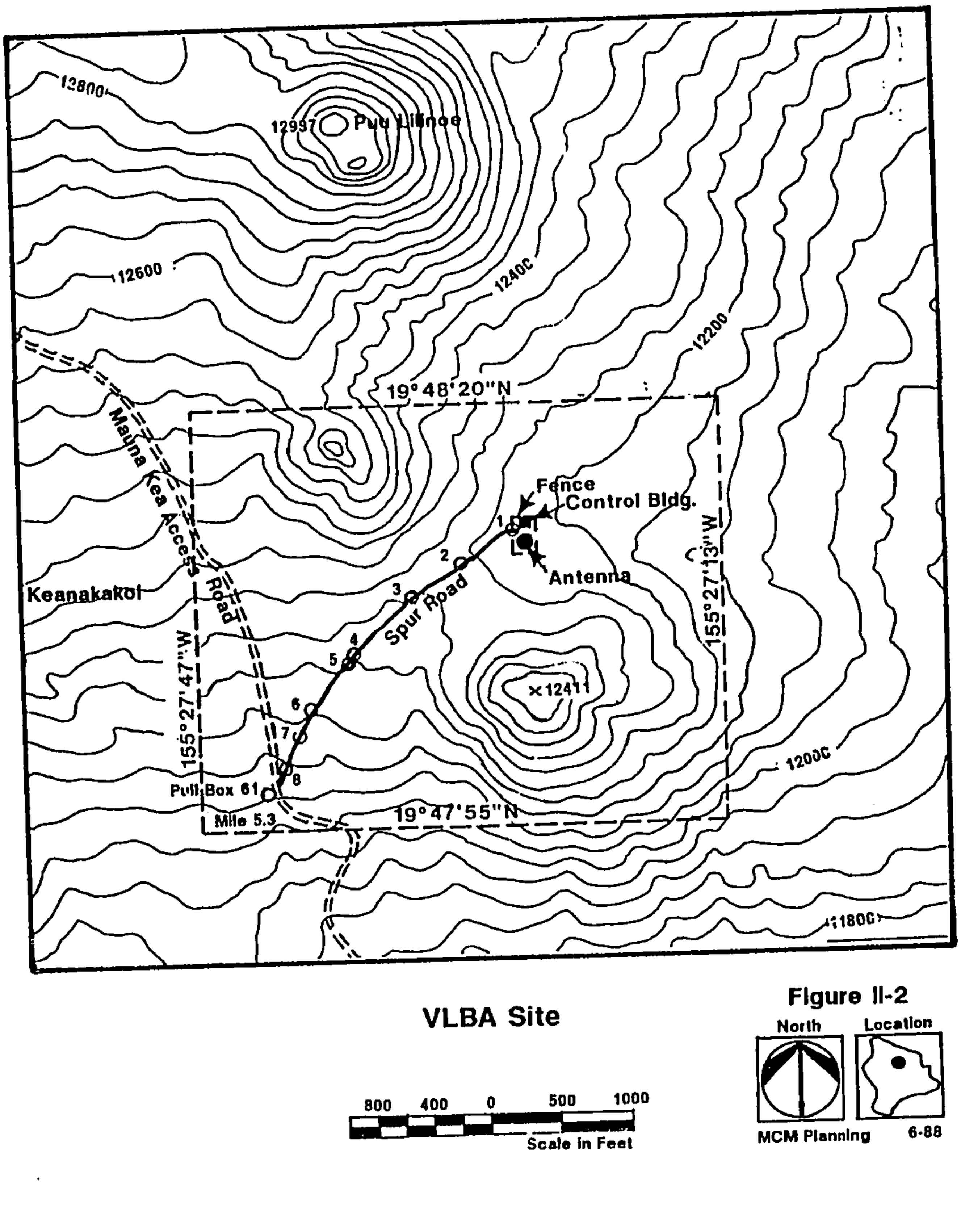
TAX MAP KEY
(4-4-15:09)

LOCATION

NORTH

MCM PLANNING

6/88



VLBA Site

Figure II-2

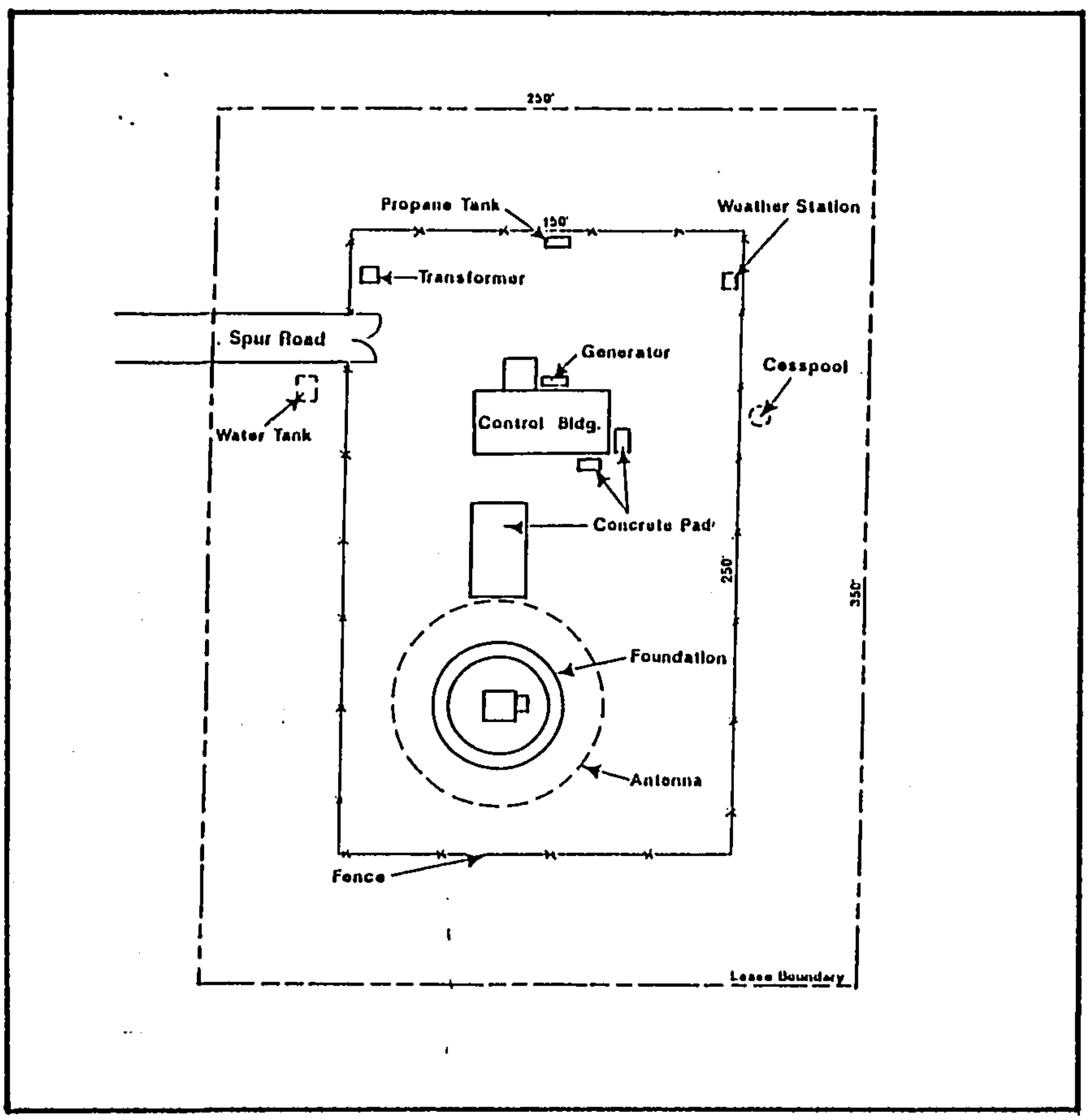


Figure II-3

VLBA Site Plan

MCM Planning 6-88

50-foot-diameter ring with concrete spokes, spaced at 90° intervals, to connect the outer ring to a pintle bearing support foundation at the center. When the antenna is aimed at the horizon, the top edge will be at its maximum height of about 95 feet above the ground (Figure II-4). The antenna weighs approximately 250 tons and must be painted white to minimize thermally induced distortions.

The site control building will be a single-story 1,350-square-foot masonry-block structure. It will be constructed on grade; the highest part of the roof will be approximately 17 feet above grade. The color of the masonry block will be chosen to blend with the surroundings. The building will house equipment and facilities for controlling and monitoring the antenna operation, data recording equipment, other electronic equipment, radiometers, magnetic tape storage space, a hydrogen maser clock system, mechanical equipment (building environmental system and electrical power system), toilets, and laboratory and shop space.

2.0 Infrastructure and Utilities

A compacted gravel spur road will be constructed in a northeasterly direction from Mile 5.3 on the MKO Access Road to the site. The road will be 20 feet wide and approximately 2,600 feet long; it will have a 40-foot right-of-way in order to allow underground utilities to be constructed adjacent to the travel-way. The route will be chosen so as to minimize cut and fill and cause minimum interference to the natural drainage patterns in the area (Figure II-5).

A sign identifying the VLBA facility will be placed at the entrance to the spur road. Signs will also be posted along the road to warn that off-road vehicle use is prohibited and to delineate "No Hunting" safety zones.

The site will require potable water, sewer, telephone and electric services. Normal water usage is estimated to be 100 gallons per day with an equal amount of wastewater requiring disposal. Domestic water will be trucked up from Hilo and stored in a 2,000-gallon buried tank, located just outside of the fenced area.

Wastewater disposal will be into an approved cesspool which will also be located outside of the fenced area. The wastewater will consist primarily of human washing and waste; there will be no food preparation or sleeping facilities at the site.

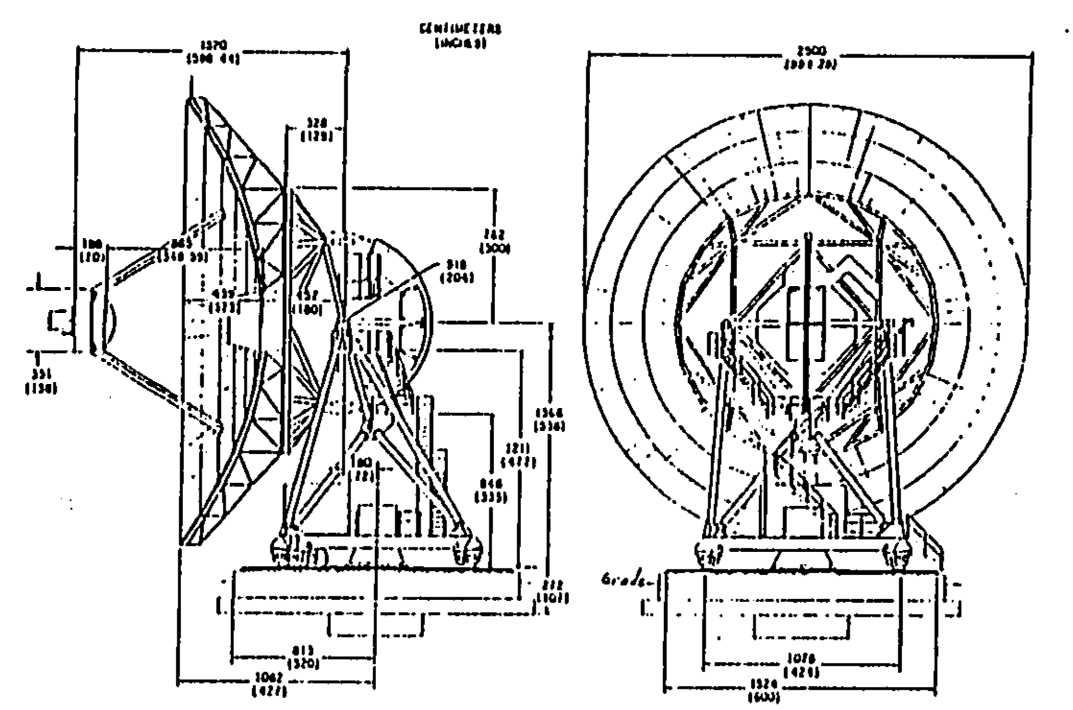
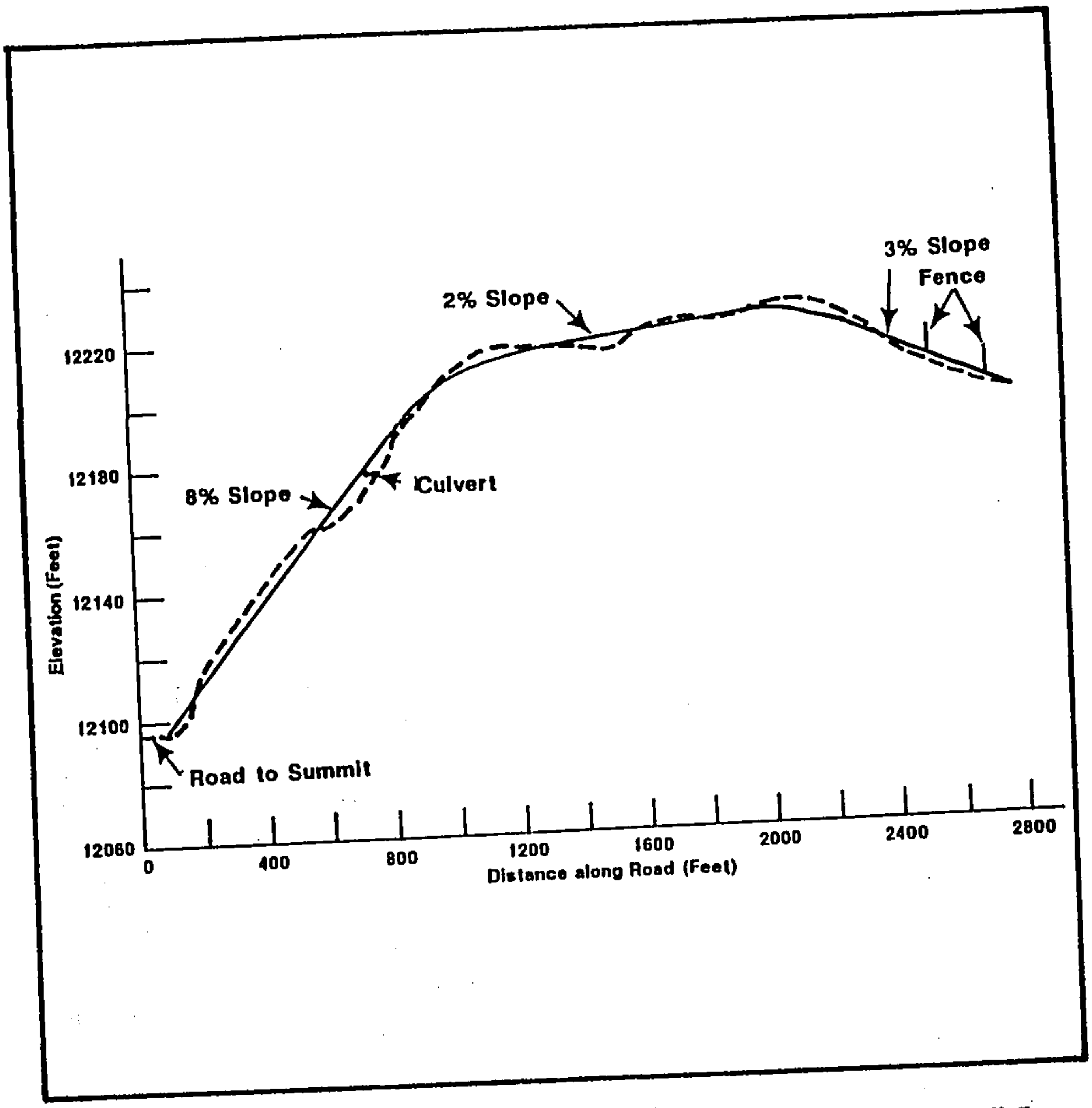


Figure II-4

Cross Sections of Typical Antenna



LEGEND:
- - - Existing Grade
—— Proposed Grade

Profile of Proposed VLBA Spur Road

Figure II-5

Location

MCM Planning 6-88

Cables for telephone and electricity will run underground from pull box 61, adjacent to the MKO Access Road. They will parallel the road to the site. Electric service to the building will be provided via a 150-kVA transformer which will be mounted on a pad inside the fenced enclosure. The demand for electricity is estimated to be 100 kW; 40,000 kWh per month. A standby generator will be installed to keep critical equipment cold and to stow the antenna in a safe position during commercial power interruptions. NRAO will discontinue observing during these outages. The telephone requirements are four digital grade circuits back to the nearest exchange.

3.0 Construction Activities

Construction of the VLBA facility on Mauna Kea is scheduled to begin in March 1989, if all permits can be obtained by then. Construction is expected to require a maximum of 18 months. There will be two primary phases; they are:

o <u>Phase One - Site Preparation, Building Construction and Installation of Infrastructure and Utilities:</u> This phase will involve grading the antenna site and spur road, laying the foundations for the antenna and control building, construction of the control building and other miscellaneous facilities, and installation of utilities in a trench along the spur road. After it is graded, the site will be covered with compacted gravel to blend into the existing terrain. Phase One is expected to take six to nine months for completion. A maximum of eight to ten workers will be located on site at any one time.

  The foundation for the antenna will be a concrete circle 50 feet in diameter. Construction for the foundation will require excavating a hole about 75 feet in diameter at an average depth of eight feet. About 1,350 cubic yards of material will be removed during excavation; 85 to 90 percent of these spoils will be used for fill around the foundation. The remainder will be used to level out the site and as fill on the spur road.

  Concrete directly under the antenna will be 14 feet thick. At the periphery, the foundation will only go to a depth of five feet. The top of the foundation will be 30 inches above the ground. A total of 350 tons of concrete is necessary for the foundation. It has not been decided as yet whether a concrete batching plant will be set up at the "skiers parking lot", the area which was designated in the SRCDP for this purpose. This will be determined by the contractor in coordination with UH IFA. Pilings are not expected to be required. Final determination on this will be made after soils testing is completed.

A 20-foot-wide by 2,600-foot-long spur road will be excavated, graded and surfaced with compacted gravel; if required, drainage improvements will be installed. A two-foot-wide by four-foot-deep trench will be excavated along the length of the spur road. Cables for electricity and telephone service to the facility will be buried in the trench. All spoils from excavation will be used on-site for fill, improving the road or for other site improvements.

Phase One construction will be done by local contractors. The estimated cost of this work is $1.3 million.

o <u>Phase Two - Antenna Assembly and Equipment Installation:</u> Fabrication and assembly of the antenna will be done by the same contractor who is building the other nine antennas of the VLBA. The electronics and control systems will be installed by NRAO technicians. The antenna will be shipped to Hawaii in pieces and assembled on-site. An estimated 25 to 30 trailer truck loads will be necessary to transport the various components of the antenna to the site. Assembly is expected to take six to nine months for completion. The number of workers on-site during this phase is expected to be five or six; some may be hired locally.

4.0 Decommissioning

In the event the antenna facility is permanently closed or abandoned, buildings and above-ground structures would be removed and the area in use returned to its natural condition by NRAO.

C. ANTENNA OPERATIONS

1.0 Radio Frequency Considerations

The VLBA antenna on Mauna Kea will not be a source of radio frequency interference (RFI) because it will only receive. It will be much less sensitive to low levels of RFI (i.e., from a distant high-power transmitter or a nearby low-power transmitter) than any other radio telescope in the world (50 dB less sensitive for a twelve-hour total-power observation). The antenna will, however, be as sensitive as any other radio telescope to high levels of RFI (from a nearby high-power transmitter) that will overload or damage a receiver.

The antenna will be equipped with radio receiving systems covering assigned radio astronomy bands in the frequency range from 330 MHz to 43 GHz, giving a broad range of resolution and surface-brightness sensitivities. The principal bands covered are listed in an article in Science (Kellermann and Thompson, 1985). The complete article is reproduced in Appendix A.

The VLBA antenna will initially be equipped to operate in the following nine frequency bands (in MHz):

312.0- 342.0	2150.0- 2350.0	14400.0 - 15400.0
580.0- 640.0	4600.0- 5100.0	21700.0 - 24100.0
1330.0- 1750.0	8000.0- 8800.0	42300.0 - 43500.0

Four other frequency bands (in MHz) may be added in the future; they are:

73.0- 74.6	10200.0-11200.0	86000.0 - 92000.0
5900.0- 6400.0		

The site selected for the antenna provides excellent terrain shielding from RFI in most directions that might be of concern. The unnamed cinder cone to the south of the site will attenuate signals from transmitters at Kulani Mauka on Mauna Loa, the Humuula microwave site in the saddle, and Hilo. The cinder cone and Mauna Kea itself will attenuate signals from most of the U.S. Army's Pohakuloa Training Area. The topography of Mauna Kea, particularly the summit itself, blocks emissions from the existing transmitters located near the summit and shields against high-power transmitters located on Maui and Oahu. Additional information on potential RFI appears in Appendix B.

2.0 Operational Characteristics

The antenna, which is scheduled to be fully operational by early 1991, will be controlled remotely through a local computer that will receive instructions over telephone lines from the VLBA Operations Center. It will be operated 24 hours a day. Normally, two reels of tape will be recorded every day at the antenna and flown to the Operations Center; there they will be played back and the data correlated with data from the other antennas. A staff of two to four technicians, who will perform maintenance and other routine duties, will be hired locally. These people will work a regular 40-hour week. Accommodations will not be required at the mid-level facility at Hale Pohaku for VLBA staff.

PART III: ENVIRONMENTAL SETTING OF THE PROPOSED PROJECT

A. THE REGION

The island of Hawaii is the southernmost island of the State. It is 200 miles southeast of the island of Oahu; about a forty minute flight from Honolulu, the State capital (Figure III-1).

Commonly called the Big Island, Hawaii is the youngest and geographically largest of the Hawaiian islands. Its climate and topography are diverse, ranging from dense tropical forests to seasonally snow-covered mountain peaks. Hawaii's land area was created by five volcanoes; two of which (Kilauea and Mauna Loa) are still active today .

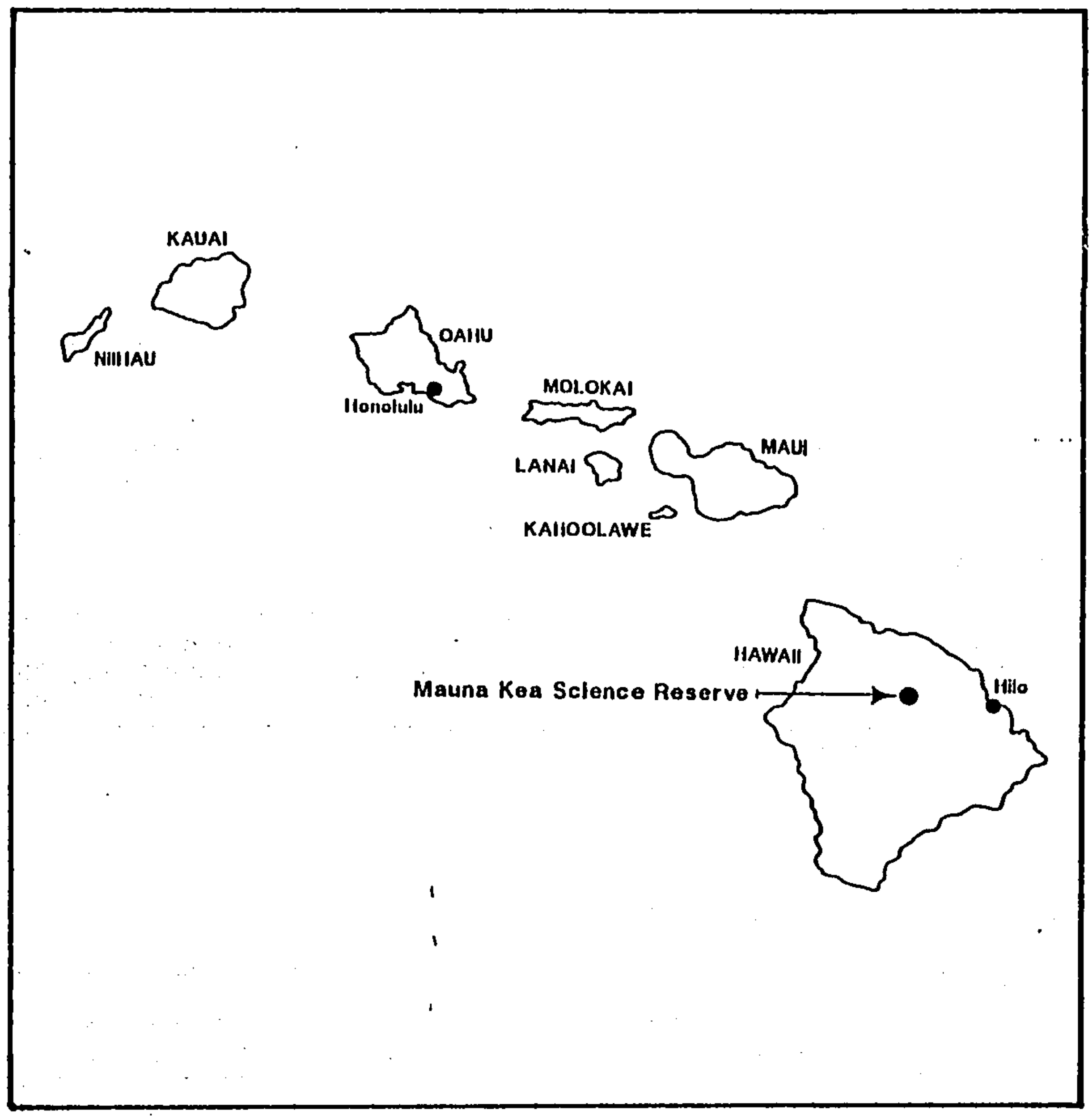
The County of Hawaii, which encompasses the entire island, has a population of 111,800; roughly 40 percent of whom live on the eastern coast of the island, in or near Hilo, the county's largest city (DBED, 1987). It is about a one and one half to two hour drive from Hilo to the project area at Mauna Kea (Figure III-2).

B. MAUNA KEA

1.0 Geology/Hydrology/Soils

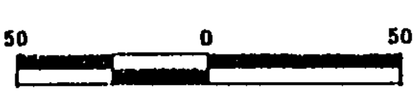
The summit of Mauna Kea is the highest point in the Pacific basin, rising 30,000 feet from the ocean floor to the top of Puu Wekiu, its highest cinder cone. Mauna Kea last erupted about 3,600 years ago (Porter, 1979a). Rubbly hawaiite a'a lava flows are visible in the area which extends from Hale Pohaku at the 9,200-foot elevation to the summit of the mountain at the 13,796-foot elevation. Postglacial stream sediments, largely gravelly sand or sandy gravel with a variable composition which reflects local bedrock, are also found there.

The only perennial surface water present in the area is Lake Waiau, a small body of water in the crater of the Waiau cinder cone, at the 13,020-foot elevation of the mountain.



State of Hawaii

Figure III-1



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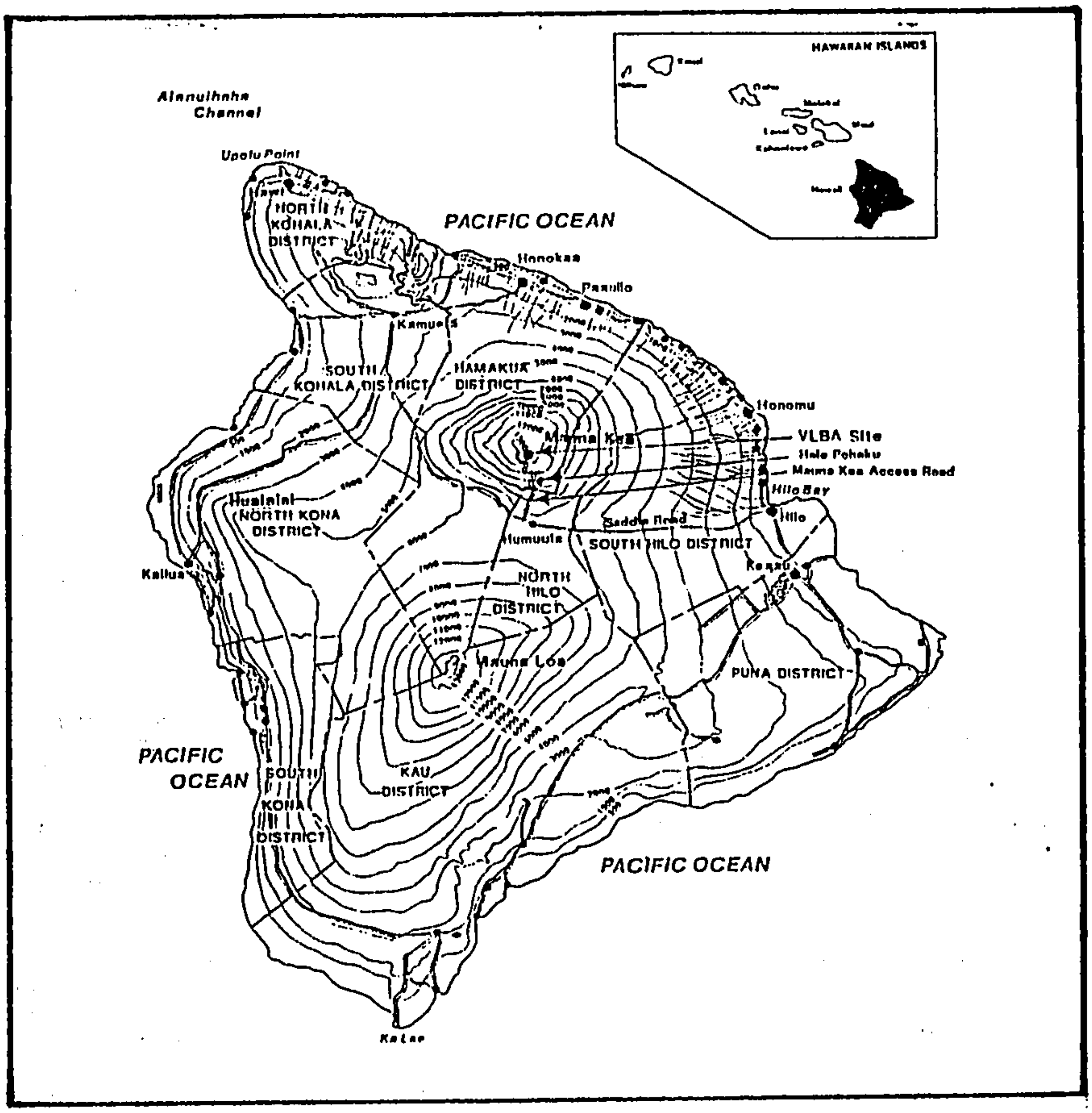
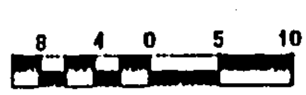


The Region

Figure III-2



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Because precipitation is limited and the soils are highly permeable, "the only groundwater known to exist consists of perched water in the center of some of the cones, including the area immediately east of Lake Waiau (Woodcock, 1974)."

2.0 Climate

Rainfall on Mauna Kea varies with elevation, averaging 15 inches per year within the Mauna Kea Science Reserve. At the higher elevations, most of the precipitation is in the form of freezing fog or snow, with extremes in monthly average temperature ranging from 25°F to 60°F. Winter storms often deposit several feet of snow on the mountain, on occasion down to the 9,000-foot elevation (RCUH, 1983b).

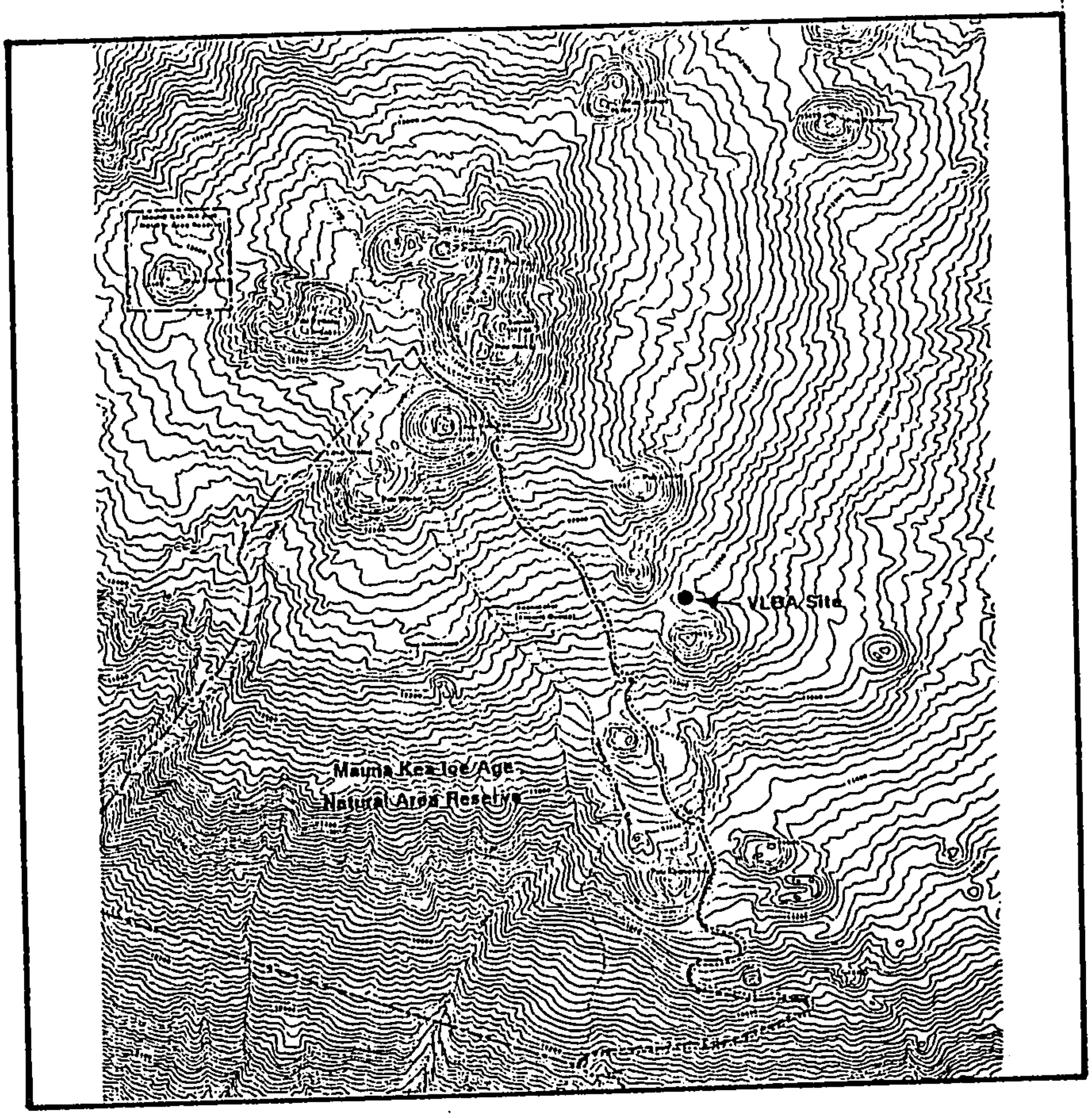
Winds at the summit follow a diurnal pattern of prevailing west/northwest daytime and east/northeast nighttime wind directions. Wind velocity, as a rule, ranges from 10 to 30 miles per hour, prevalently between 10 and 15 miles per hour. During severe winter storms, winds occasionally exceed 100 miles per hour on exposed summit areas, such as the top of cinder cones (RCUH, 1983b).

3.0 Cultural Resources

The Mauna Kea Ice Age Natural Area Reserve (NAR) is situated on the south slope of the mountain, between the 10,400-foot and 13,200-foot elevations (Figure III-3). The main ice age features present in the Reserve are: Pohakuloa Gulch (formed by glacial meltwater); glacial moraine and meltwater deposits of fine sediments; the glacially sculptured features of cinder cones and lava flows; and Lake Waiau, one of the highest lakes in the United States.

The Keanakakoi Adze Quarry, an ancient Hawaiian Historic Place, is also within the boundaries of the NAR; it was a very important center of Hawaiian adze manufacturing (McCoy, 1979). The Mauna Kea Adze Quarry Complex of Archaeological Sites was placed on the National Register of Historic Places (Site 4136) and designated a National Historic Landmark in 1962 (Appendix C).

The ancient Hawaiians apparently frequented other areas in the upper regions of Mauna Kea, outside of the adze quarry. A reconnaissance of a larger area (1,000 acres) on the summit and north slope of the mountain (McCoy, 1982) and a 1984 survey of the east/southeast flank of Mauna Kea (McCoy, 1984), resulted in the location of over 40 sites (Figure III-4). These were collectively given the state site number 50-10-23-10228. A summary of the most common types of



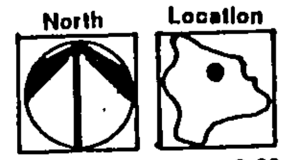
LEGEND:
–·–·– Reserve Boundary

Mauna Kea Ice Age Natural Area Reserve

4000 2000 0 2000 4000
Scale in Feet

Figure III-3

North Location



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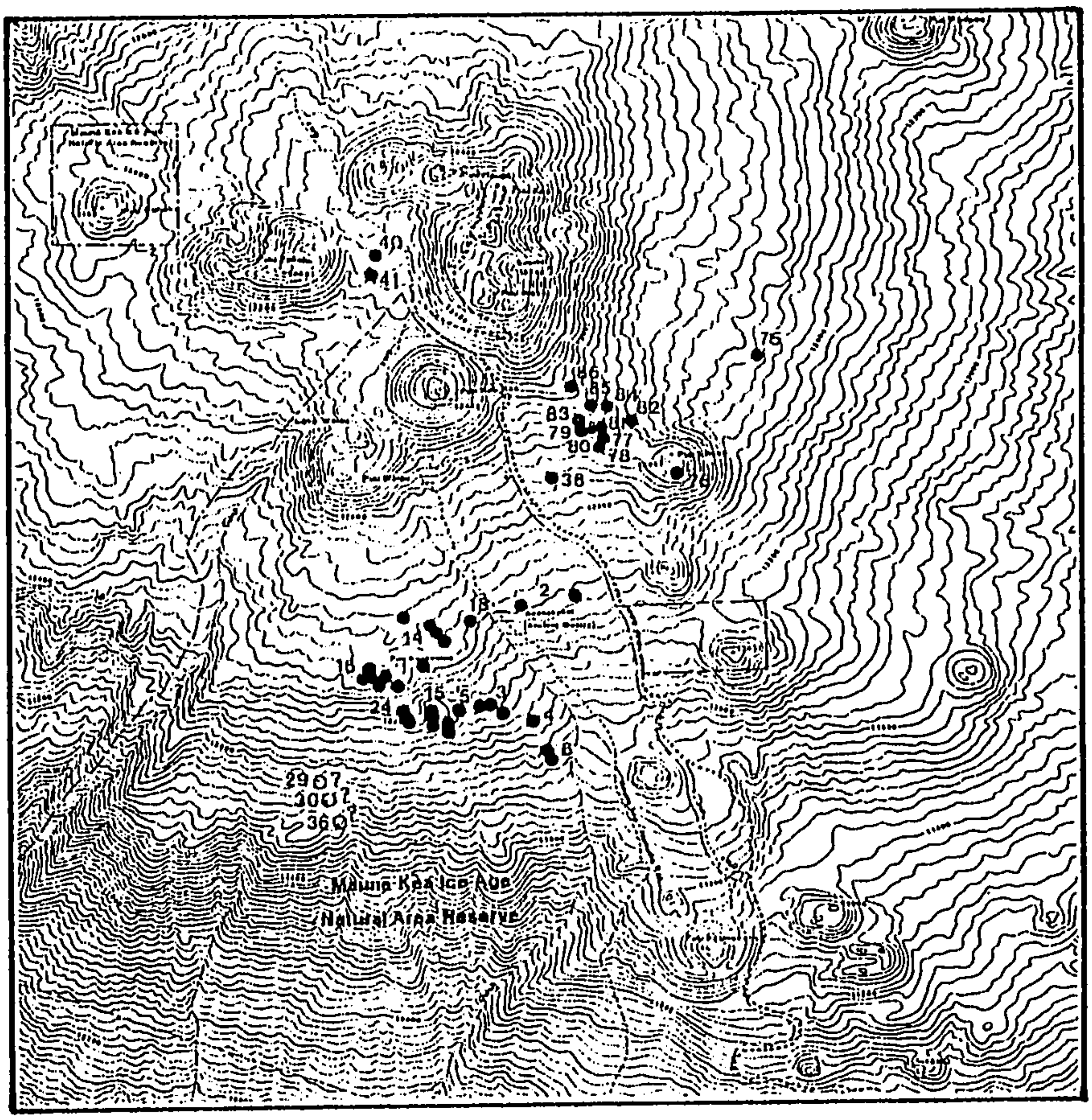
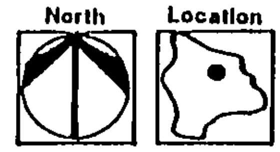


Portion of Historic Site
No. 50-10-23-10228

4000 2000 0 2000 4000
Scale in Feet

Figure III-4



MCM Planning 6-88

archaeological remains occurring on the high flanks of Mauna Kea is included in Appendix C.

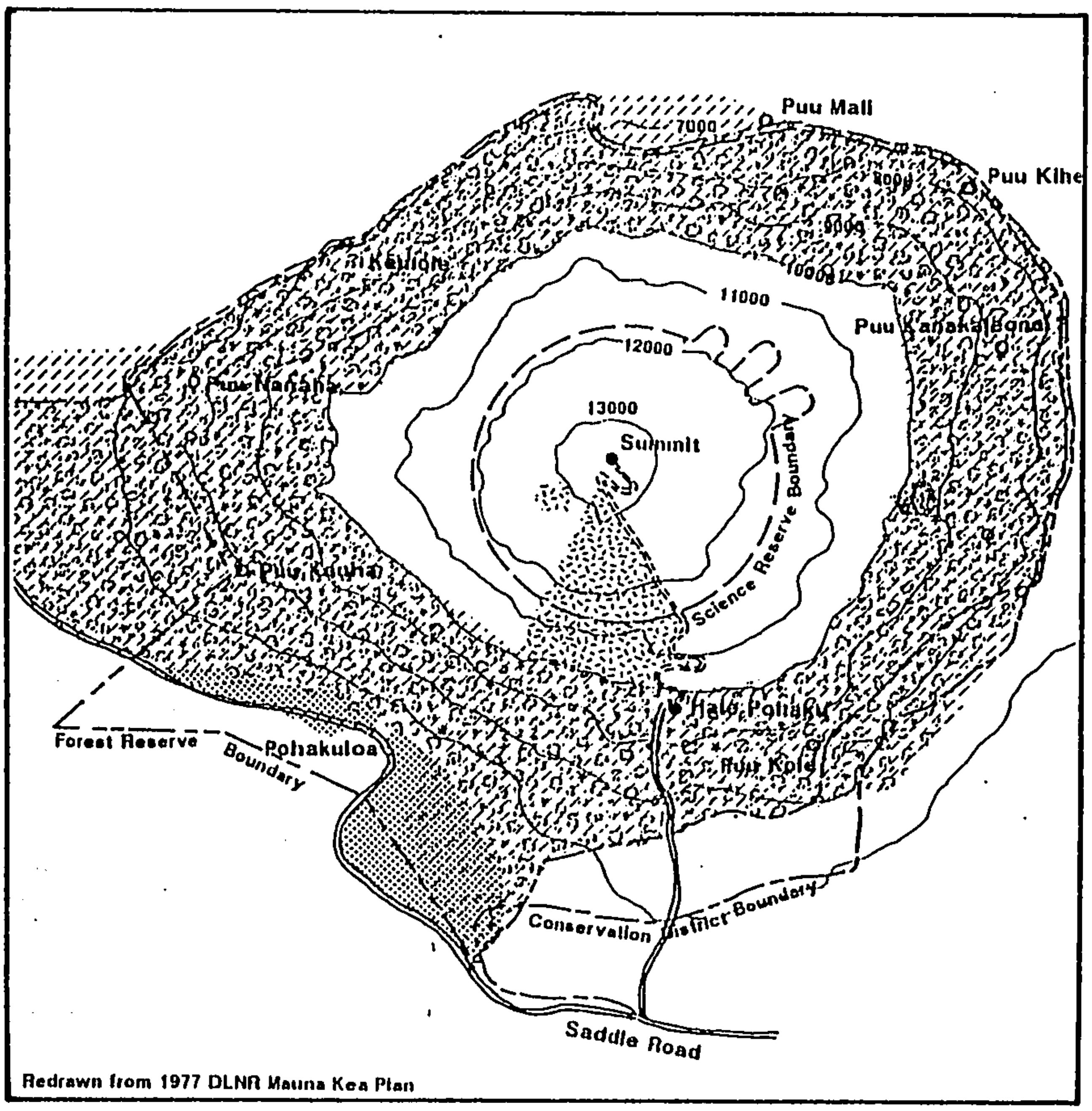
4.0 Flora and Fauna

Native Hawaiian flora and fauna, including rare plants and birds, inhabit the mountain's slopes. Several of these species subsist nowhere else in the world. Over 30,000 acres of the mamane/naio forest (below the 10,000-foot elevation) are designated as the critical habitat of the rare and endangered Palila, Loxioides (Psittirostra) bailleui (Figure III-5).

The Hawaiian Dark-rumped Petrel or 'Ua'u (Pterodroma phaeopygia sandwichensis), an endangered endemic subspecies of the Dark-rumped Petrel, were formerly abundant throughout the main Hawaiian chain (Olson and James, 1982a,b), but underwent a serious decline in numbers due to habitat disturbance, predation and hunting. On Hawaii, Dark-rumped Petrel were once abundant in the saddle area between Mauna Loa and Mauna Kea (Henshaw, 1902). They may also have been present at elevations of up to 12,400 feet on Mauna Kea as indicated by skeletal material found in these areas. No essential habitat is designated for the 'Ua'u (Telfer, 1982).

Vegetation in the upper regions of Mauna Kea is sparse. Smith and others (1982) reported that lichens (25 species) and bryophytes (12 species) are the principal components of the flora found above the 13,000-foot elevation. Two sensitive areas of lichen colonies (shown as crosshatched areas in Figure III-6) were identified during the 1982 survey. Six species of vascular plants and one alga were also recorded at that time. Although additional surveys were recommended for the sensitive areas should development occur there, the botanical consultants concluded that "none of the rare or uncommon species at the summit need to have their status monitored due to a restricted occurrence only on Mauna Kea (O'Connor, 1982)."

Biologists have recently discovered a resident community of native Hawaiian invertebrates living near the summit and feeding on material carried up the mountain by the wind (Howarth and Montgomery, 1980). One true bug, a highly aberrant species of the world wide genus Nysius, is part of this community. Other major arthropod components include spiders, moths, mites, springtails, centipedes, booklice, and barklice (Howarth and Stone, 1982).

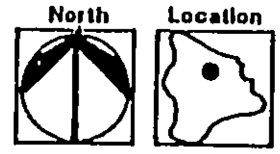


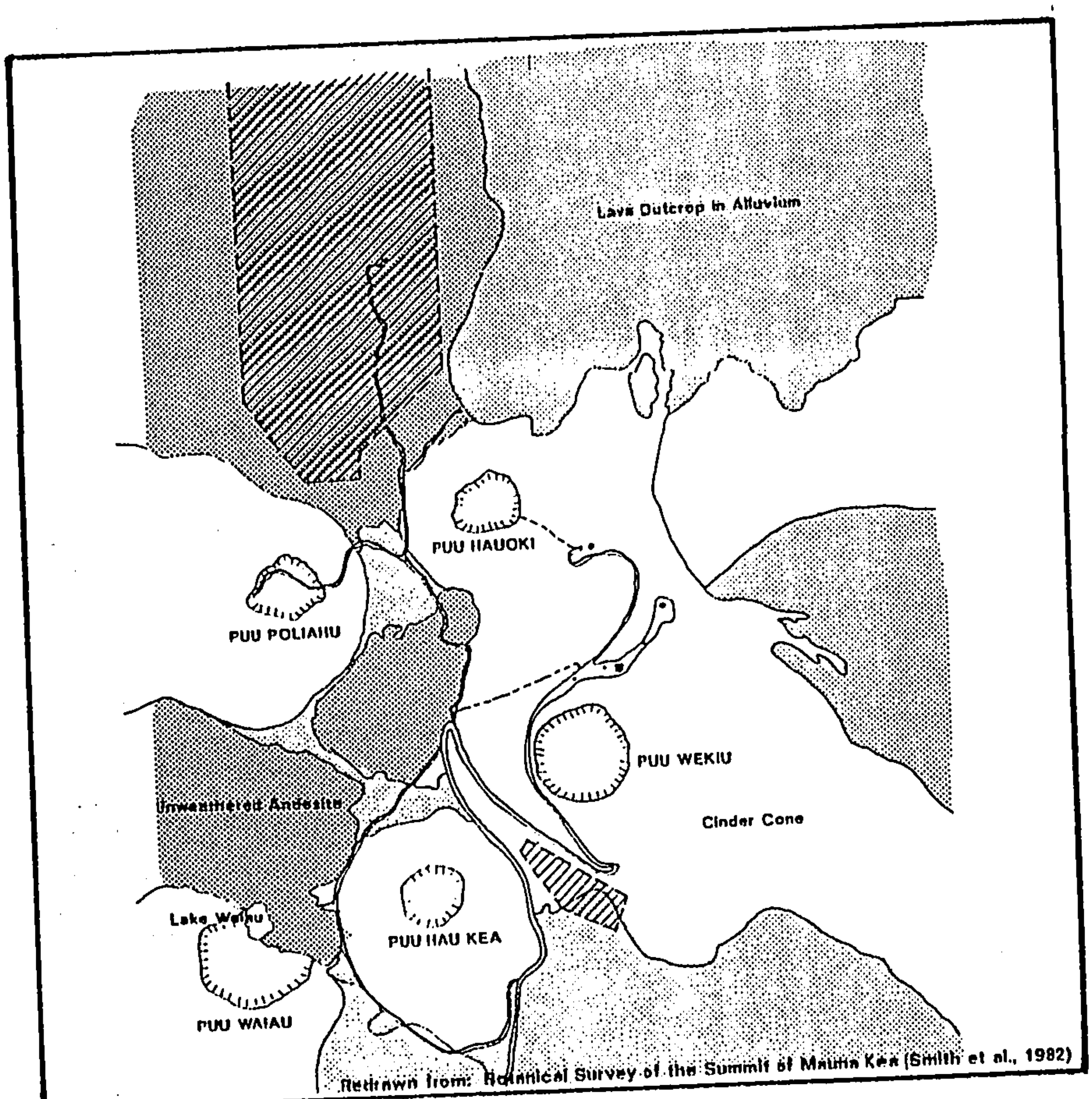
LEGEND:
Palila Critical Habitat
Silversword Area
Mamane-Naio & Associated Ecosystem
Natural Area Reserve
Military Area

Palila Critical Habitat

2 0 2
Scale in Miles

Figure III-5





LEGEND:
Sensitive Areas of Lichen Colonies

Figure III-6

Substrate Types and Location of Lichen Colonies

2000 1000 0 1000 2000
Scale in Feet

North Location

C. ASTRONOMY FACILITIES ON MAUNA KEA

1.0 Telescopes

At present, there are eight telescopes operating within the summit area of the Mauna Kea Science Reserve (Figure III-7). Six telescopes are located on summit cinder cones and two millimeter/submillimeter-wavelength telescopes are located in the valley (also known as Millimeter Valley) below and to the southwest of the summit ridge. Table 3.1 lists each of these telescopes and the date it became operational.

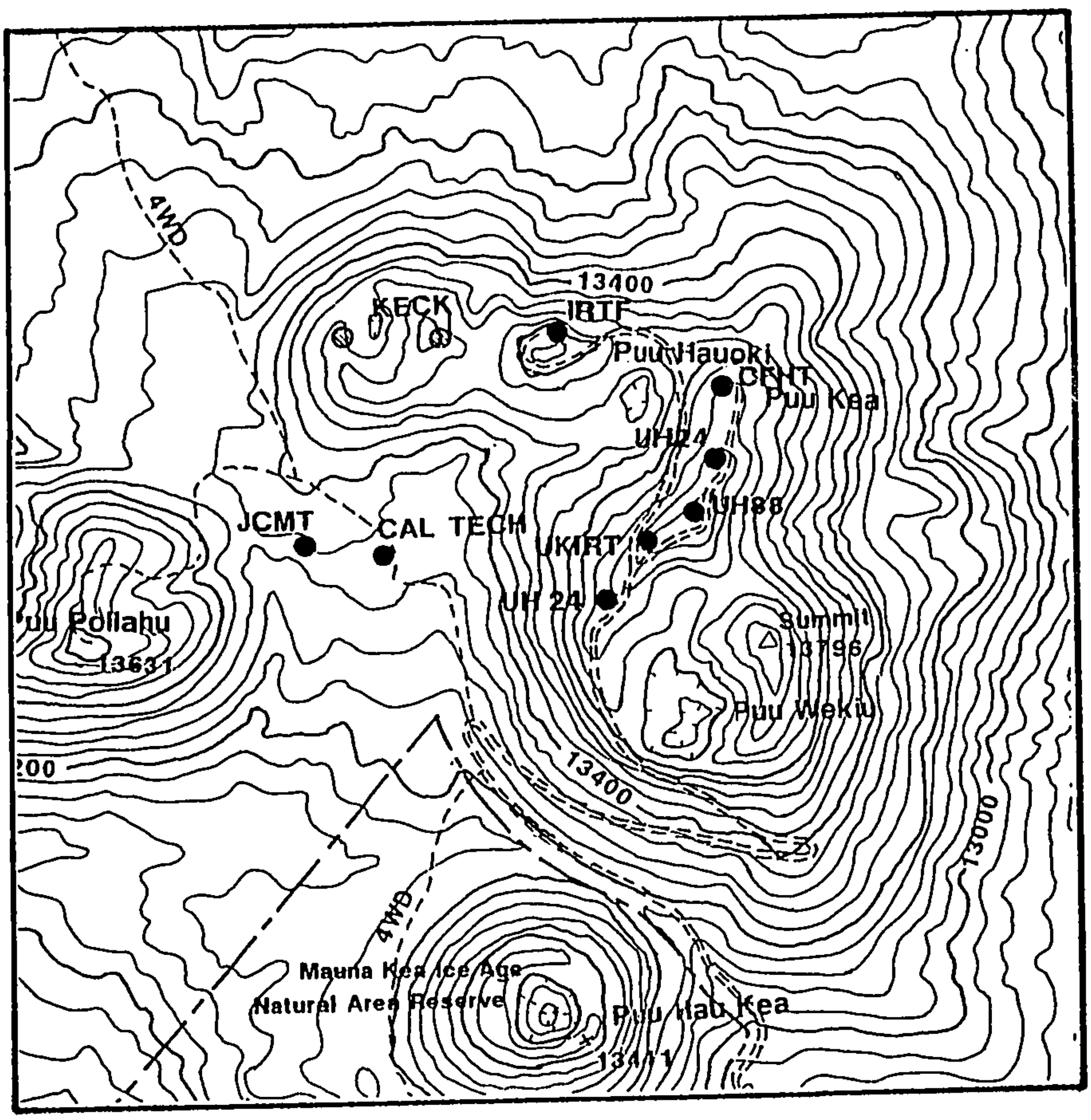
Several more major telescopes are expected to come on-line in the 1990's. The W. M. Keck Observatory, the world's largest optical/infrared telescope, which is under construction on the summit ridge, is expected to be operational in 1991. UH has preliminary understandings with a number of other astronomical projects to locate in areas consistent with the SRCDP.

2.0 Mid-level Facilities

Because the summit of Mauna Kea is 13,796 feet high, it is inefficient and physically hazardous for scientists, support staff and construction workers to go directly from sea level to work at the summit without acclimatizing themselves for a period of time at an intermediate elevation. A permanent mid-level facility at Hale Pohaku, elevation 9,300 feet, for acclimatization of personnel, was dedicated in 1983 (Figure III-8). The complex was rededicated and named the <u>Onizuka Center for International Astronomy (OCIA)</u> in late 1986, in honor of astronaut Ellison Onizuka, a resident of the island of Hawaii who lost his life in the Challenger disaster of January 1986.

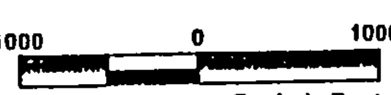
The complex consists of three buildings containing sleeping accommodations for astronomers, technicians and support staff; a common building which contains offices, kitchen/dining facilities and lounge areas; and a maintenance area which houses the generator and provides space for minor equipment repairs and other repair and maintenance functions (MCM Planning, 1985). An Information Station downslope serves both as an interpretive center for disseminating information about the man-made and natural features of Mauna Kea and as the control point for managing and monitoring visitors to the upper slopes of the mountain. Housing for construction workers is located below the Station.

Figure III-7



Legend:
- Existing Telescopes
- Telescopes Planned or Under Construction

Summit Telescopes



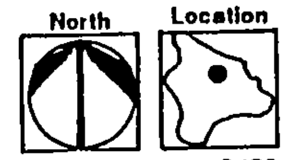


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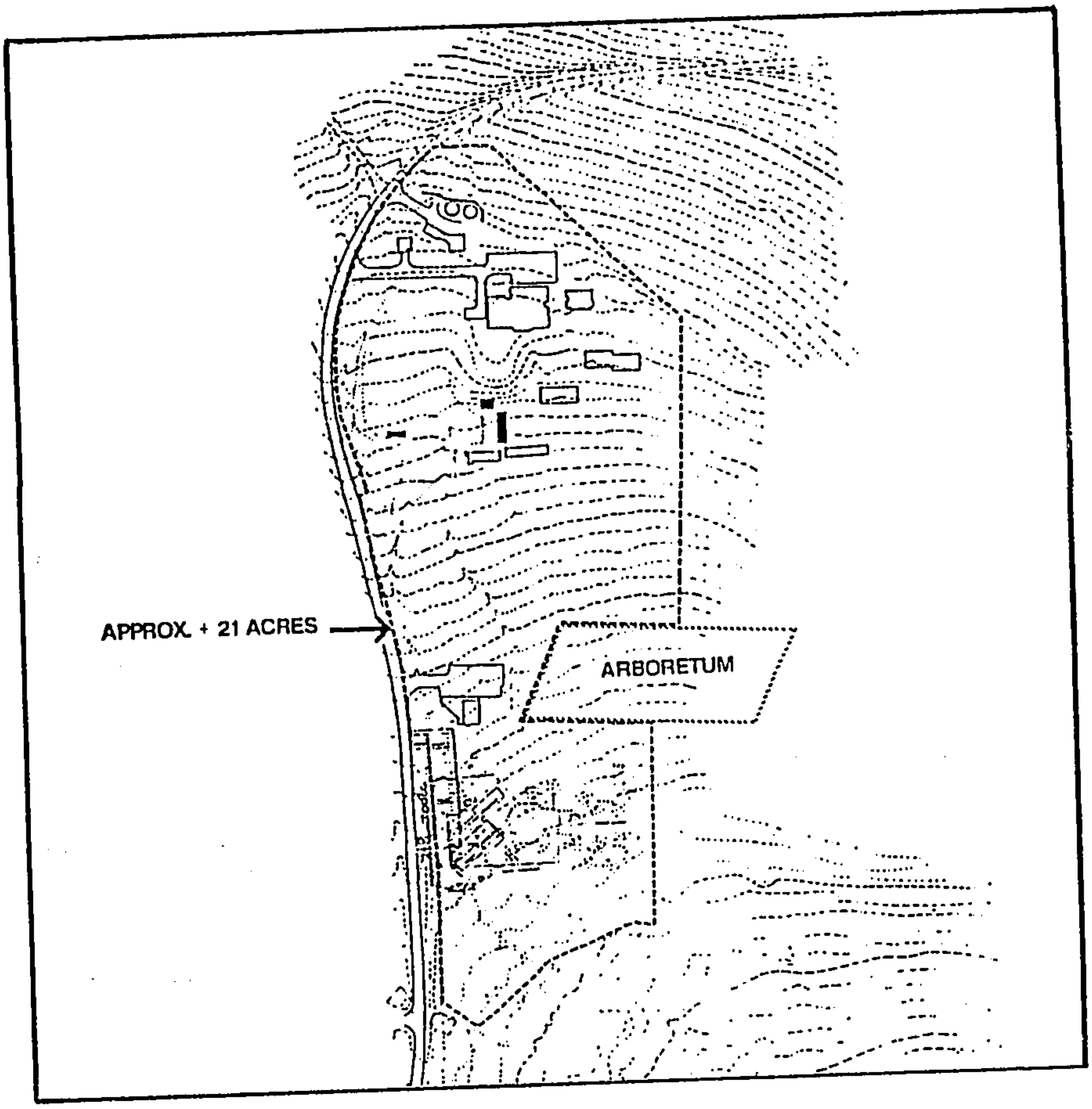
Table 3.1 TELESCOPES ON MAUNA KEA BY YEAR OPERATIONAL

Telescope	Year Operational
Summit Ridge	
UH 24-inch Telescope #1	1968
UH 24-inch Telescope #2	1969
UH 88-inch Telescope	1970
NASA Infrared Telescope (IRTF)	1979
Canada-France-Hawaii Telescope (CFHT)	1979
United Kingdom Infrared Telescope (UKIRT)	1979
W.M. Keck Observatory (Keck)	1991*
Millimeter Valley	
Caltech Submillimeter Observatory (CSO)	1987
James Clerk Maxwell Telescope (JCMT)	1987

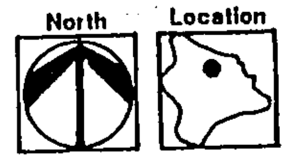
* Under Construction



Onizuka Center for International Astronomy

200 0 200
Scale in Feet

Figure III-8



3.0 Infrastructure, Utilities and Services

3.1 Access

Access to the astronomy facilities within the Mauna Kea Science Reserve from population centers on the island of Hawaii is via the Saddle Road (Route 20), to Pu'u Huluhulu and from there along a 6-mile-long, 20 foot-wide paved county road to Hale Pohaku at the 9,300-foot elevation. The 8.3 miles from Hale Pohaku to the summit is via the unpaved Mauna Kea Observatory (MKO) Access Road which is maintained by the Mauna Kea Support Services (MKSS). Improvements to this road, including paving, are under construction (Figure III-9).

3.2 Electrical Power

A permanent overhead 69-kV power line has been completed from the Saddle Road to a substation near the OCIA at Hale Pohaku. Underground utility conduits are being installed from Hale Pohaku to the summit. The underground conduits generally follow the alignment of the MKO Access Road. The system is expected to be operational in October 1988 (Longfield, personal comm.). When completed, the line will be connected to the Hawaii Electric Light Company (HELCO) power grid.

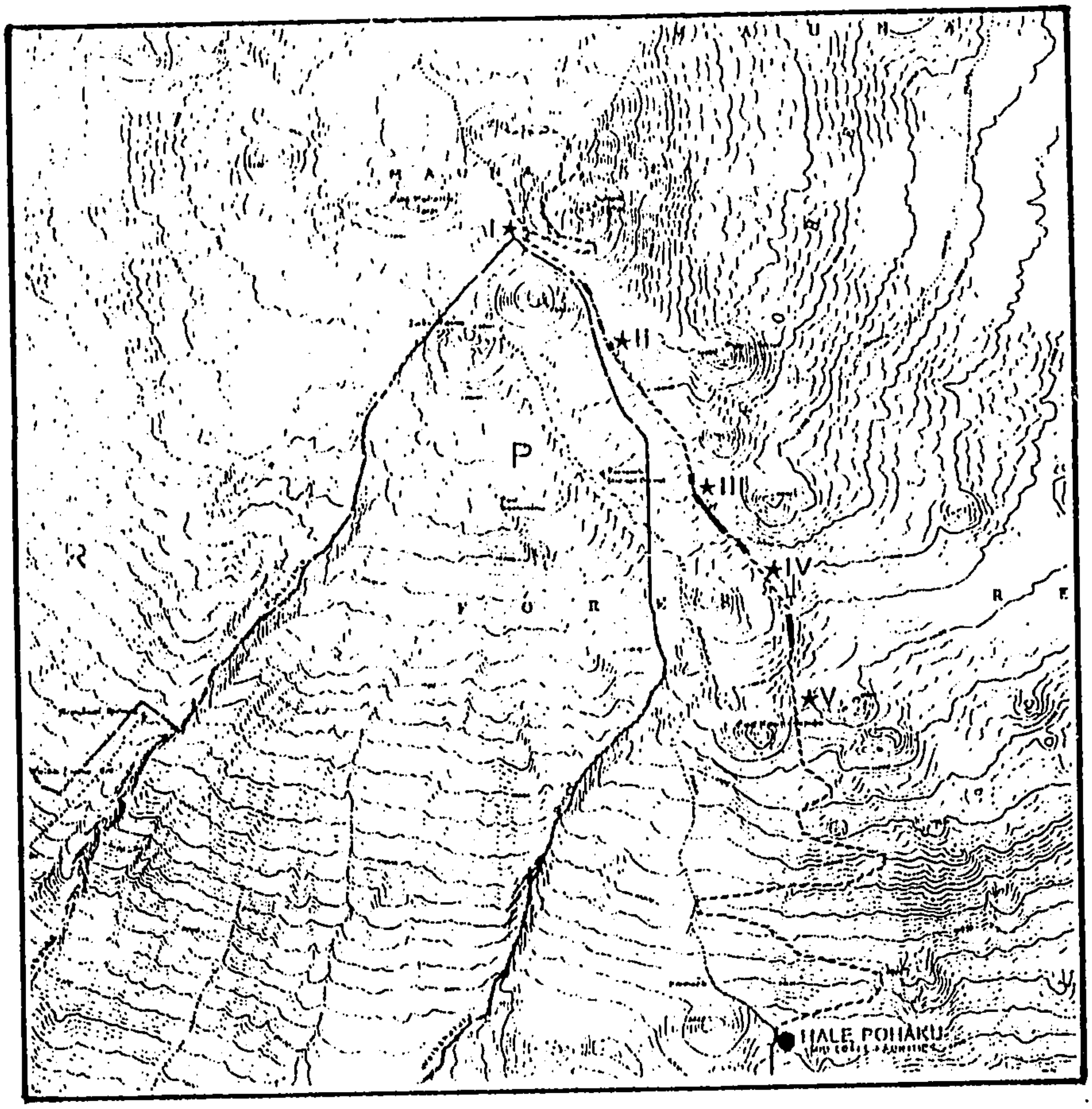
IFA is investigating the feasibility of retaining the existing 850-kW generator located at the summit for backup purposes. If UH decides to keep the generator, it will be stored at Hale Pohaku and only mobilized in case of an emergency, such as a prolonged HELCO power outage.

3.3 Potable water

There is no municipal water supply available on Mauna Kea. Water to service both the mid-level facilities at Hale Pohaku and the telescopes in the summit area is trucked from Hilo.

3.4 Communications

Telephone communication and data transmission from the summit are via a Hawaiian Telephone Company microwave system. Each of the telescopes is connected by phone cable to a common microwave antenna located on the UH 88-inch Telescope building. Transmissions are relayed to other Hawaiian Telephone facilities in Hilo. By the end of 1988, a fiber optic trunk line will be completed from Hale Pohaku to the summit. Once this line is installed,



LEGEND:

- ---- Proposed Paved Road
- ······· Future Road Extension
- ▬▬ Slope ≥ 16%
- ★ Parking Areas

Summit Access Road Improvements

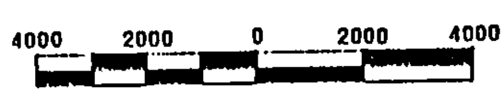
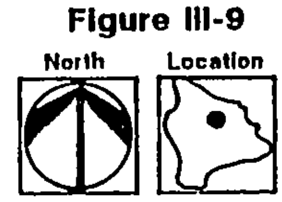


Figure III-9



and wide-band communication is available out of Hale Pohaku, the summit microwave system will be removed.

3.5 Sewage Disposal

Cesspools are used for wastewater disposal at both Hale Pohaku and the summit. State Health Department approval was received for each cesspool constructed.

3.6 Solid waste

All solid waste generated at the summit is carried down to Hale Pohaku by summit personnel. From there, it is combined with waste from the mid-level facility and trucked daily to a dumpster located at MKSS in Hilo.

3.7 Protective Services

o <u>Fire Protection.</u> UH has developed a fire plan for the summit and OCIA in cooperation with the Hawaii County Fire Department. A fire engine is stationed at OCIA and a fire brigade, consisting of MKSS personnel, has been trained in fire fighting techniques. In addition to protecting buildings, the brigade is prepared to fight brush fires in the area. Each telescope at the summit has large portable fire extinguishers and a fire escape plan. Telescope personnel are responsible for fire protection at their respective facilities.

o <u>Medical.</u> The nearest medical facilities to Mauna Kea are located in Hilo. Because response time for these services is longer than one hour, observatory personnel render volunteer emergency service to both visitors and staff. An emergency room is located in the common area of OCIA at Hale Pohaku to provide space for the treatment of injuries and illnesses. An ambulance, equipped with a stretcher and first aid supplies, oxygen, and a two-way radio is parked between the UKIRT and the UH 88-inch telescope buildings. It is available in case of emergencies at the summit. In addition, all MKSS personnel are trained in advanced first aid and cardio-pulmonary resuscitation.

o <u>Security.</u> Each telescope organization is responsible for the security of its own facility. Security at Hale Pohaku is provided by MKSS.

D. OTHER USES OF MAUNA KEA

1.0 Scientific Research

In addition to astronomy, the mountain's unique natural features make it an ideal site for other scientific research. Its volcanic and glacial history are of interest to geologists; meteorologists are attracted by the area's altitude, weather, and atmospheric conditions; and, Mauna Kea's remnant endemic ecosystems represent a unique research environment for biologists and botanists (RCUH, 1983a).

2.0 Recreation and Subsistence Activities

Hunters, skiers, snow-play participants and hikers engage in recreation and subsistence activities in various areas on Mauna Kea. Sight-seeing and photography are also popular activities in the area.

Hunting takes place within and on the perimeter of the mamane/naio forest. Among the species hunted are: Mouflon sheep (Ovis musimon); chucker partridge (Alecturis chukar); and, the California quail (Callipepla californica). During the winter months, the snow-covered mountain slopes are popular skiing and snow play areas. The most popular ski run, the "Poi Bowl", is located within the summit area, between the summit ridge and Millimeter Valley (Krutzler, personal comm.). Hiking takes place along the road and designated trails, particularly within the NAR, although the high altitude and extreme weather conditions make the activity dangerous for all but the most experienced hikers.

3.0 Transmitters

There are three transmitters located within the Mauna Kea Science Reserve. The DLNR Division of Forestry 100- 200-watt transmitter is mounted on the summit workers' lunchroom; it is for use in case of forest fires or other emergencies. The Volcano Observatory 100- 200-watt VHF transmitter/receiver translator (operated by NOAA) is also located there. It is used for monitoring the Kilauea and Mauna Loa volcanoes. Under agreements with the Board of Land and Natural Resources, these transmitters will be relocated when suitable alternative sites outside of the Science Reserve are found.

A Hawaiian Telephone/COMTEC 10- 20- watt, C-band microwave dish is located on one of the 24-inch-telescope buildings. Various portable transmitters, either in vehicles or hand-held for emergency use only, are also used in the summit area.

Other transmitters on Mauna Kea, outside of the Science Reserve, are located at the Humuula electronics site and the Army Pohakuloa Training Area. To date, these transmitters have not interfered with astronomical observations at the summit; it is not anticipated that they will do so in the future.

PART IV: ENVIRONMENTAL IMPACTS AND MITIGATING MEASURES

A. INTRODUCTION

The objective of this environmental impact analysis is to assess the construction and operating characteristics of the VLBA antenna facility in order to identify and evaluate the direct and indirect effects of the proposed action that have the potential to impact the natural and man-made resources within the project area and the affected region. Potential impacts can be either positive or negative, short-term or long-term. The analysis addresses the following areas of concern:

- Natural Hazards
- Drainage and Erosion
- Air Quality, Noise and Traffic
- Flora and Fauna
- Historical and Archaeological Features
- Aesthetics
- Visitors and Recreational Users
- Radio Frequency Interference
- Infrastructure, Utilities and Services

B. DESCRIPTION OF THE VLBA ANTENNA SITE

1.0 Geology, Topography and Soils

The antenna facility will be built on a flat plain in a low-lying saddle between two cinder cones (Figure II-2). The maximum topographic relief of the proposed construction site is 15 feet. The two cinder cones, one to the south and one to the northwest of the project area, rise 230 and 380 feet above the site elevation, respectively. Both cinder cones have steep, loose cinder slopes which are subject to continuous colluviation (Appendix C).

The antenna site is underlain by Pleistocene lava flows of the Waikahalulu Formation. All the rock in the area consists of hawaiite a'a flows, typical of late-stage eruptions from Hawaiian volcanoes. The a'a flows consist of layers of massive, dense rock intermixed with volcanic clinker (Appendix D).

The project site is covered by ground moraine deposits. The soils are mostly coarse gravels, with cobbles as large as two feet, and a variable amount of volcanic ash of silt and sand sizes. The soil cover at the site is estimated to be several feet thick (Ibid.).

Ground moraine deposits are also present along most of the spur road alignment. Soil thickness is estimated to be less than three feet along the western half of the road alignment and thicker along the eastern half (Ibid.).

Groundwater resources in the project area are presumed to be nonexistent. Localized zones of permafrost have been reported within the volcanic cinder deposits of two of the cones at the summit of Mauna Kea, roughly 8,000 feet northwest of and 1,000 feet higher in elevation than the VLBA site. No permafrost has been found outside of those cones and it is unlikely that there is any at the site (Ibid.).

2.0 Flora

According to Char & Associates (Appendix E), limited vegetation exists in the vicinity of the project site. Vascular plants present in the area include Hawaiian bent (<u>Agrostis sandwicensis</u>) and he'u-peo (<u>Trisetum glomeratum</u>), members of the grass family (Poaceae), and one specimen of <u>Asplenium adiantum-nigrum</u>, a member of the bird's-nest fern family (Aspleniaceae). Each of these species has been recorded previously in the summit area (Smith, <u>et al</u>., 1982).

Lichen species observed at the site include <u>Candelariella vitellina</u>, <u>Lecidea skottsbergii</u>, <u>Rhizocarpon geographicum</u>, two species of <u>Umbilicaria</u>, and <u>Lecanora murabilis</u>. These species are associated with larger rocks and occur just above the soil interface, usually facing north or west. Small, shaded, pockets and crevices, with ash, support moss clumps of silvery-gray to black-colored <u>Grimmia</u> sp. and bright green <u>Pholia cruda</u>. One specimen of <u>Asplenium adiantum-nigrum</u> was found along the spur road alignment.

Suitable habitats for lichens and mosses were found in small caves, crevices and overhangs at the base of the cinder cone, south of the antenna site. Fist-sized clumps of mosses were seen in small runoff channels among the rocks. Lichens found there include the whitish, crust-forming Lepraria sp. and Acarospora depressa. Lichen and moss colonies in this area are generally associated with north, northwest, and west-facing rocks. Moisture from snow melt and pockets of compacted snow were seen in some cave areas.

3.0 Fauna

3.1 Vertebrates

No vertebrates were recorded in the area of the project site during recent surveys (Appendix F). One species that was of concern is the Dark-rumped Petrel (Pterodroma phaeopygia sandwichensis), an endangered pelagic seabird endemic to the Hawaiian Islands.

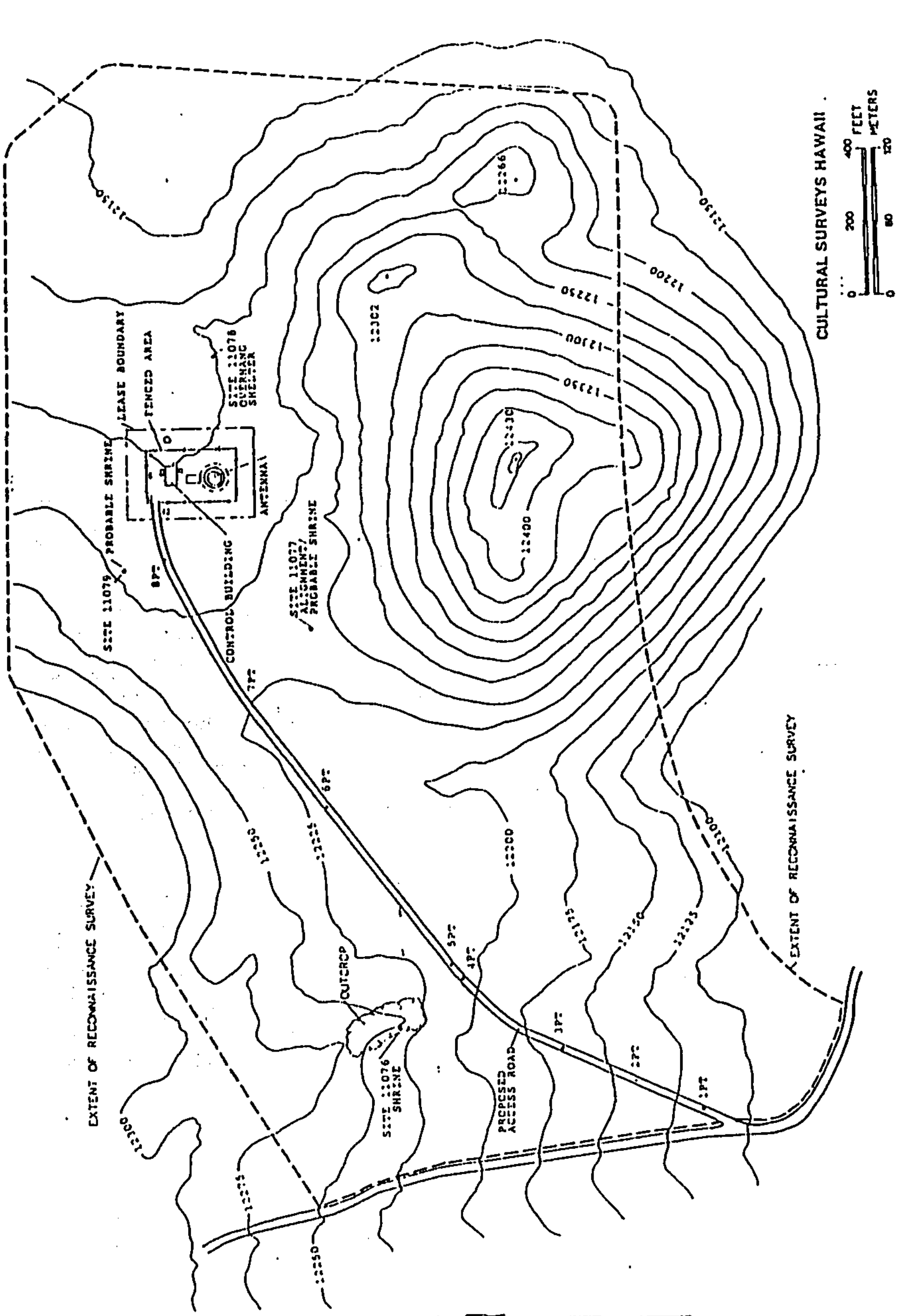
A nocturnal survey of the site was conducted by Ms. Maile Kjargaard on May 20, 1988. The purpose was to determine whether breeding Hawaiian Dark-rumped Petrel were present in the project area. The timing of the survey was planned so that there was a high probability of detecting any Petrel inhabiting the area. The survey was taken during the height of the breeding season, at a period of the lunar cycle when calling is maximized. No Petrel were detected at the site and there was no evidence of burrow sites in suitable habitat nearby (Appendix F).

3.2 Invertebrates

The alpine zone on Mauna Kea is habitat for a number of invertebrates. Only two Hawaiian species were recorded in the project area during a site visit (Appendix G). The only native herbivorous species present was the lichen feeding, diurnal cutworm moth, Agrostis. One endemic Erigone spider was also seen on the site. The exotic economic pests, Hydrellia and Pollenia, were by far the most prominent arthropods found at the site, probably because there are so many of them at mid elevations.

4.0 Cultural Resources

The VLBA site is about 2,000 feet east of the Mauna Kea Ice Age Natural Area Reserve (NAR). As shown on Figure IV-1, four archaeological sites were located during a recent reconnaissance survey by Cultural Surveys Hawaii (Appendix C).



Project Area Showing Extent of Survey and Location of Archaeological Sites; Mauna Kea, Hawai'i

ARCHAEOLOGICAL SITES

FIGURE IV—1

A brief evaluation of each site follows:

- Site 11076. A probable shrine. Although the site is not completely intact (the uprights have collapsed), it may be the best example of this type of site in the project area. In terms of its present integrity, the site is probably a poor example of a Type 1, single feature shrine (McCoy 1982:A36) as compared to those previously recorded in the Adze Quarry and northern summit area by McCoy (1982, 1984). This site is within the designated boundary of the Mauna Kea Adze Quarry National Historic Landmark.

- Site 11077. An ahu or possible shrine with a single upright boulder set in the top. A short alignment and level area are possibly associated with this feature. This may be an example of a single feature, Type 1 shrine (McCoy 1982:A36), however, it might be a simple ahu. The upright is not of the typical or tabular shape associated with other recorded shrines. If it is a shrine, it is a poorly expressed example.

- Site 11078. A small rock shelter which does not have any surface indication of human modification or cultural use. It was recorded as a site because as a natural feature it might have been used as a temporary shelter and it may have subsurface cultural material under the overhang or at the entrance. If subsurface cultural debris is present, it would be severely limited by the shallow depth of bedrock.

- Site 11079. A small rock pile (15-20 cobbles) on the top of a large glacially deposited boulder. A small ahu and a surface scatter of 10-15 basalt flakes are located nearby. One of the cobbles is a rectangular adze preform; therefore, it is possible that the piling may be a small shrine, although it does not match the structural pattern of those recorded in McCoy's surveys (1981, 1982, 1984).

A summary table of site significance evaluations is presented in Table 4.1.

It should be noted that both the ground moraine in the low lying saddle area and the cinder cone slopes in the project area are geomorphically active. Characteristics of this alpine desert environment include lack of vegetation, extreme diurnal temperature variations and frequent frost, all are conducive to gelufluction and other periglacial activity. These processes

Table 4.1 A SUMMARY OF ARCHAEOLOGICAL SITES RECORDED IN THE PROJECT AREA

Site	Description	Function	Significance Criteria Comments	Codes*
11,076 (CS1)	alignments of rock piles and fallen uprights	probable shrine	probable religious structure, cultural significance	a,d,e
11,077 (CS2)	ahu with upright	possible shrine	possible religious structure, cultural significance	a,d,e
11,078 (CS3)	rock shelter		minimal excavation potential, but could yield some information on prehistory	a,d
11,079(a) (CS4)	rock piling on boulders with adz preform and nearby ahu	possible shrine	possible religious structure, cultural significance	a,d,e
11,079(b)	small ahu	trail marker	may yield information important to prehistory	a,d

Codes*

a = site reflects major trends in the history of the State.

d = site may be likely to yield information important to prehistory or history

e = site has cultural significance, probable religious structure (shrine, heiau or burial)

Source: Cultural Surveys Hawaii, Appendix C.

tend to sort and rearrange surface rocks into natural pavements, alignments and faced terraces, particularly on slopes. These features can be mistaken for cultural constructs by those unfamiliar with the dynamic nature of this landscape. They are present in the survey area and are typical features throughout the Mauna Kea region (Appendix C).

5.0 Existing Infrastructure

There is no vehicular access or electrical power to the antenna site. The MKO Access Road and the electrical pull box are each about 2,600 feet from the site. It will be necessary to construct an spur road and extend utility lines to service the antenna facility.

6.0 Recreational Uses

At present, there is little if any recreational use of the project site. The Ski Association of Hawaii has indicated that the "King Kam Run", which originates on the eastern side of the Mauna Kea summit ridge, extends down to the 12,300-foot elevation and crosses between the two cinder cones in the vicinity of the antenna site. Because of lack of snow, the run is rarely used. There are no established hiking trails in the project area.

C. ENVIRONMENTAL IMPACT ANALYSIS

1.0 Natural Hazards

The island of Hawaii is located in Seismic Zone 3 for building design under the Uniform Building Code. Much of the seismic activity is associated with the active volcanism at Mauna Loa and Kilauea volcanoes. Large earthquakes have occurred elsewhere around the island, however, and are considered possible at any location. The geology of Mauna Kea has been mapped in detail (Porter, 1979a), but no tectonic faults have been observed. Foundation and building design in accordance with the Uniform Building Code is expected to be adequate for the structures.

Mullineaux and others (1987) classified the summit and upper flanks of Mauna Kea as Zone 7 for lava flow hazards. A total of nine zones were defined, with Zone 9 being the least hazardous. The risk of of volcanic eruptions affecting the proposed antenna facility is judged to be very low (Appendix D).

2.0 Drainage and Erosion

The following actions to be taken in the construction of the project have the potential of causing drainage problems, dust and soil erosion (construction activities are discussed more thoroughly in Part II):

- <u>Antenna Facility.</u> Removal of surface rocks during excavation; grading of the antenna site; excavation of about 1,350 cubic yards of material from a hole about 75 feet in diameter at an average depth of eight feet for the antenna foundation; excavation of a 1,350-square-foot pad for the site control building; excavation of post holes for the chain link fence; excavation of a five-foot-diameter cesspool; excavation of a hole for a 2,000 gallon water storage tank; and, addition of surfaced areas for the facility.

- <u>Spur Road and Utility Trench.</u> Removal of rocks during excavation; grading of the spur road; excavation for a 20-foot-wide by 2,600-foot long spur road; excavation of a two-foot-wide by four-foot-deep by 2,600-foot-long utility trench for electricity and telephone cables; excavation and installation of drainage improvements; leveling, compacting and surfacing the spur road with gravel; and installation of utility cables and filling of the trench.

The antenna site is flat. With the exception of excavation required for the antenna foundation, the amount of earthwork will be minimal; the maximum amount of cutting and filling is not expected to exceed five feet. All spoils from construction will be used on-site for improving the road or other site improvements. Some finer-grained material may have to be imported for finish grading. This will be determined by the soils and foundation investigation during final design (Appendix D).

There will be little if any runoff from the flat area prepared for the antenna facility. The limited precipitation can be expected to percolate directly into the ground. The roadway will concentrate runoff to some extent, primarily on the uphill side where a shallow ditch will collect any runoff. The rocky material along the roadway will not erode significantly, and one or more culverts will pass runoff under the road before it concentrates to the point where it could cause erosion further downslope (Ibid.).

Excavation and grading will alter the landform of the site and generate dust. Fine dust commonly occurs in the interstices of the volcanic rocks on Mauna Kea. Heavy construction equipment operations at the site and increased traffic along the spur road will lead to the temporary generation of small dust particles. In addition, dust will be generated by the abrasive action of construction equipment on rocks.

Dust control during construction will be maintained by exposing the smallest area possible at any time and halting construction during high winds and storms. To a degree, water will be sprinkled on exposed surfaces to suppress dust, however, as water must be hauled from Hilo, it will be used sparingly. Strict adherence by the contractor to County regulations concerning grading and excavation will be required.

3.0 Air Quality, Noise and Traffic

3.1 Construction phase

The following actions to be taken during the construction of the facility may generate noise and traffic and affect air quality:

- Site preparation and construction of the spur road, antenna foundation, control building and other miscellaneous facilities, and site preparation and installation of utilities in a trench along the spur road;
- Operation of a temporary auxiliary generator on site;
- Transferring 30 truck loads of concrete mix from Hilo to the project site and pouring 350 tons of concrete for foundation support of the antenna, control building, emergency generator, fuel tank, weather instrument tower, and other miscellaneous equipment;
- Transporting an estimated 25 to 30 trailer truck loads of various antenna components from Hilo to the site;
- Assembling the antenna on site.

Short-term negative impacts may occur as a result of the above actions; they will end when construction is completed. Construction of the facility is expected to take 12 to 18 months.

An increase in traffic will be unavoidable during construction. This traffic includes large construction equipment, trucks transporting construction-related materials and vehicles bringing workers to the site. Most heavy construction equipment will be stored on the site for the duration of the construction period. All trips of heavy trucks, such as those transporting antenna components, will be scheduled during off-peak hours so as not to interfere with normal traffic flow in Hilo or along the Saddle Road.

Emissions from vehicles and internal combustion engines on heavy construction equipment and the generation of dust by construction activities may affect air quality. Engine emissions will be mitigated by the use of properly functioning emission control devices as required by law. Dust will be mitigated through compliance with State Department of Health rules and regulation (Chapter 43, Section 10) and by covering exposed areas during heavy winds.

Construction equipment will generate high noise levels at the project site. Noise will be minimized through the use of equipment with proper noise muffling devices. Impacts of high noise levels on construction workers can be mitigated by adhering to appropriate OSHA standards.

3.2 Operations phase

The operation of the antenna facility will not have a significant adverse impact on air quality in the vicinity of the site. The only possible source of air pollutants from the antenna facility will be the standby generator, which will only be operated in the event of a commercial power outage or during routine maintenance and operational checks, and dust from the gravel-surfaced road. The road will be resurfaced with gravel periodically to minimize the problem of dust.

Because only two to four employees will be on site, traffic (including trips by the water truck, etc.) will not exceed a few vehicles per day. The anticipated volume of increased traffic is not expected to lead to a significant increase of emissions in the area.

The antenna is very quiet during operation, except when being repositioned rapidly. Generally, the only other noticeable noise which may be produced during operation will be from the standby power generator when it is running.

4.0 Flora and Fauna

4.1 Construction phase

There are no rare or endangered species present on the site. The site is sparsely vegetated and species occurring there are also found throughout the Mauna Kea summit area (Appendix E). Construction of the proposed antenna facility and spur road will have only a minor impact on botanical and faunal resources in the project area.

No evidence of Petrel breeding was found at the site during surveys taken in April (daytime) and May (nighttime) of this year (1988). Although the daytime survey identified several areas as being potentially suitable for burrow construction, the nocturnal survey confirmed that there were no burrow sites there (Appendix F).

The site is almost barren of invertebrates. No Wekiu bugs, Nysius wekiuicola, were found during a field visit in April, 1988, probably due to the lack of moisture from snow in slow melting drifts. The only native herbivorous species seen was the lichen feeding, diurnal cutworm moth, Agrostis. Because no sizeable patches of lichen grow along the spur route or on the facility site, construction of the project is not expected to affect the moth's habitat. The biomass in the project area is much smaller than at higher elevations, thus the impacts on native invertebrates are projected to be very minor (Appendix G).

In order to protect the aeolian ecosystem that is present in the area, all construction activities should take place within the defined areas of the antenna facility site and spur road alignment. Litter from construction material, packaging, etc., would be collected and removed from the area.

4.2 Operations phase

Indirect impacts can be generated during the operations phase of the VLBA project due to the presence of the facility and the spur road. These indirect impacts include: disturbance of geologic features (glaciated surface, glacial ground moraine, periglacial movement and sorting of rocks) and habitat of endemic arthropod fauna by off-road vehicles; killing of birds in the area (should they be present in the future) due to rodents and feral predators associated with the facility; and deaths of Petrels attracted by facility lights, as a result of collision with structures.

Indirect impacts would be mitigated by the following measures:

- o Enforcing the prohibition of off-road vehicle use in the area;
- o Instructing NRAO personnel on how to identify Petrel breeding areas;
- o Use of mongoose-, rat-, and cat-proof refuse containers and the frequent removal of refuse from the area. (While these mammals are not found in the area at the present time, they may become a problem once feeding opportunities become available. The use of traps could become necessary.);
- o Use of shielded lights at the facility; and
- o Management policies already established by the University of Hawaii for the preservation of biological and geological resources within the Science Reserve Complex will be complied with by NRAO personnel.

5.0 Historical/Archaeological Sites

According to Cultural Surveys Hawaii (Appendix C), all four sites recorded in the project area are significant for their information content and three may also have cultural or religious significance. None are good examples of site types.

5.1 Construction phase

None of the four identified archaeological sites in the area is located within proposed construction boundaries. Each site has been flagged for identification. In order to prevent inadvertent damage to the sites during construction, each will be fenced and its location plotted on construction maps. Construction personnel will be made aware of the location of the sites so they can be avoided. If these procedures are followed, no adverse impacts should occur and archaeological monitoring during construction should not be necessary.

Since the spur road and antenna facility are both located on bedrock and glacial moraine (and not on soft cinder deposits), the likelihood of discovering isolated burials is very small. If remains are uncovered, an archaeologist will be notified immediately.

A small portion of the spur road alignment is within the boundary of the Mauna Kea Adze Quarry National Historic Landmark. There are no archaeological sites included within the Landmark area that will be affected by the construction of the antenna facility spur road (Appendix C).

5.2 Operations phase

Indirect impacts can be generated during the operations phase of the VLBA project. The presence of the facility and the spur road could attract visitors to the site and encourage off-road vehicle use. Although the four archaeological sites within the project area are not of great significance in themselves and are not excellent examples of site types, they do form a portion of a larger context of Hawaiian religious and economic use of Hawaii's only glaciated landscape (Appendix C).

NRAO intends to protect the sites (by fencing or other means) and preserve them. A sign near the entrance to the spur road will warn people of the penalties for disturbing archaeological sites (the wording of this sign will be approved by the DLNR Historic Sites Section). On-site personnel will be instructed to notify the Enforcement Division of DLNR if any one is seen disturbing the sites.

6.0 Visibility and Aesthetics

6.1 Construction phase

The presence of construction equipment, construction materials, and temporary structures will impact the visual quality of the area. This effect will be temporary since these items will be removed when the project is completed.

6.2 Operations phase

The antenna facility was evaluated for short-range (within the summit area) and long-range (island-wide) visual impact. The complete analysis is presented in Appendix H. A summary of the findings follows:

Short-range: As shown in Figure IV-2, the antenna will be partially visible from two locations along the Mauna Kea Observatory (MKO) Access Road; once for about 100 feet from a point about 600 feet north of the entrance to the facility spur road and again for a stretch of about 250 feet about 1,000 feet farther north. The antenna will be completely visible along a 2,500-foot portion of the MKO Access Road at the 13,400-foot elevation. In addition, several hundred feet of the facility spur road will be visible from the MKO Access Road.

Long-range: The antenna facility will be built in a low-lying saddle between between two cinder cones which rise from 230 to 380 feet above site elevation. These landforms are expected to block out the view of the antenna from most areas. In addition, because the site is about 1,500 feet below the summit ridge on the southern face of the mountain, the facility will not be visible from the northern part of the island.

As shown in Figure IV-3, the antenna will not be visible from downtown Hilo. It may, however, be partially visible from Leleiwi Point, portions of Waiakea Homesteads, a two-mile stretch of the Saddle Road near Kaumana, and portions of the Puna District from Keeau to Kapoho, one small area near Onomea and an area near Kipuka Alala in the Mauna Loa Forest and Games Reserve.

Visual impact of the antenna facility will be low.

7.0 Recreational Users

According to the Ski Association of Hawaii, most skiing on Mauna Kea occurs near the summit. When snowfall reaches lower elevations, skiers generally tend to stay on runs that are close to the MKO Access Road. The "King Kam Run" is located far to the east of the spur road, and is therefore seldom used. Because snowfall sufficient for skiing is rare in the project area; recreational skiing should not be adversely impacted by the VLBA facility.

As required by DLNR, an area 400 yards around the facility and on either side of the spur road will be posted for no hunting. Although sheep or sheep-mouflon hybrids occasionally frequent the site, there is a lack of forage in the area and the site is probably seldom used by these animals (Appendix F). The presence of the VLBA antenna should not adversely impact hunting in the area.

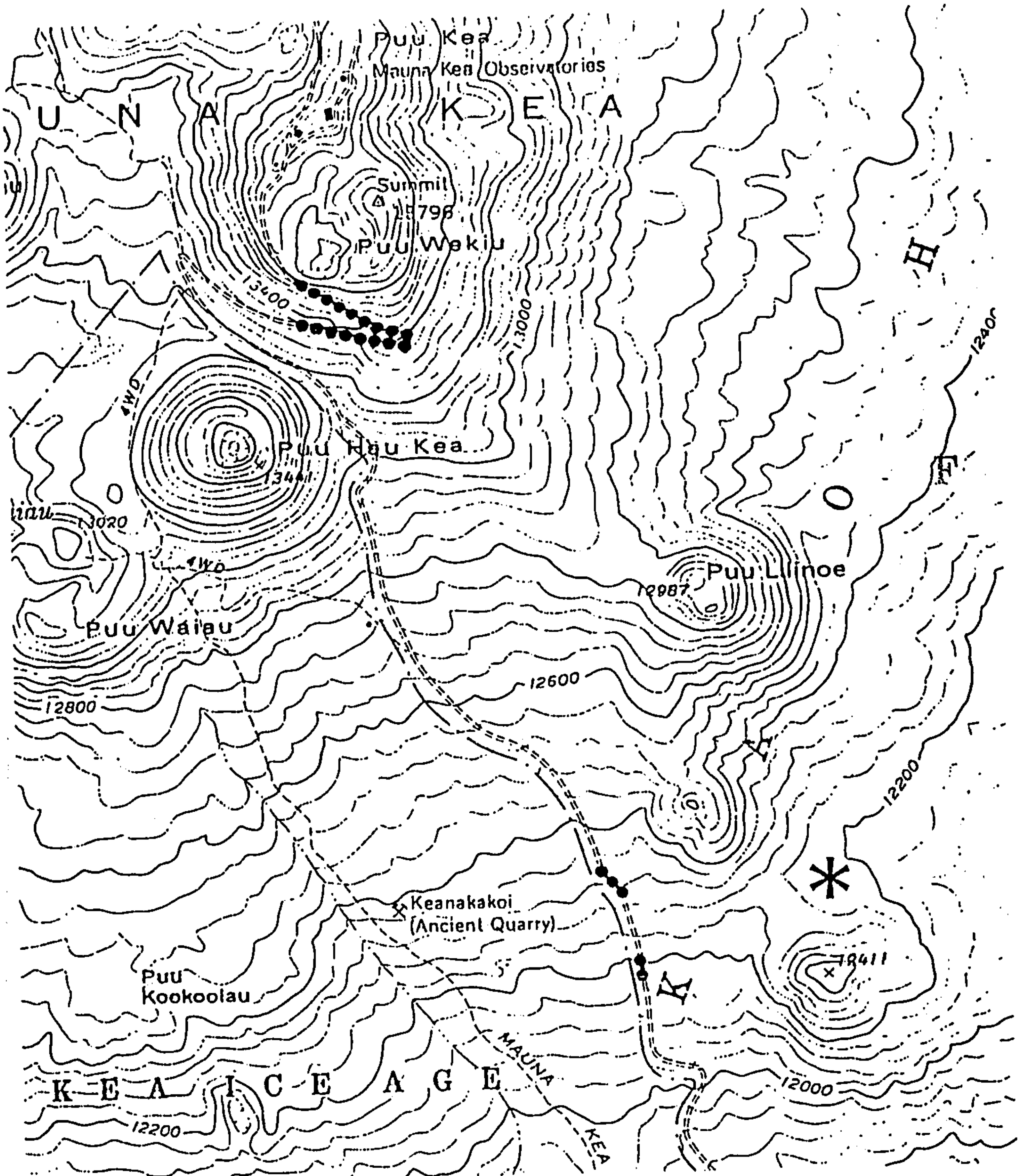


FIGURE IV–2

SHORT RANGE VISUAL IMPACT

OF SELECTED VLBA SITE
AT 12,200' ELEVATION

LEGEND

✱ SITE LOCATION

●●● AREAS OF VISIBILITY

0 1000 2000
SCALE IN FEET

HAWAII
LOCATION

NORTH

MCM PLANNING

6/88

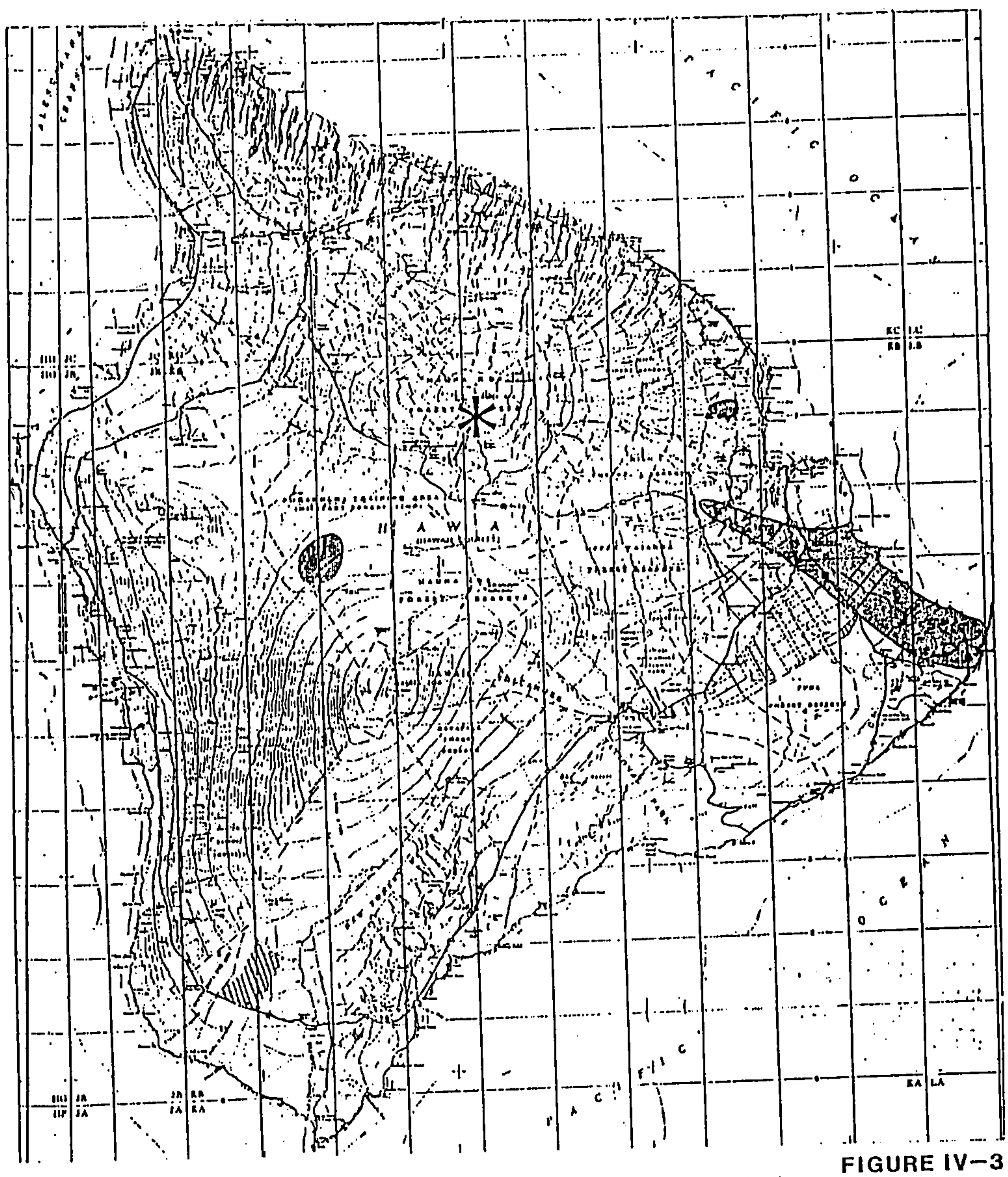


FIGURE IV–3

LONG RANGE VISUAL IMPACT

OF SELECTED VLBA SITE AT 12,200' ELEVATION

LEGEND

SITE LOCATION

AREAS OF VISIBILITY

0 5 10 15

SCALE IN MILES

NORTH

MCM PLANNING 6/88

8.0 Radio Frequency Interference (RFI)

A new radio astronomical observing site and telescope must operate within the existing radio spectral environment. The radio environment includes all radio communication and broadcast emissions authorized by the Federal Communications Commission (FCC) Regulations and by National Telecommunications and Information Administration (NTIA) Regulations. The VLBA site was selected because it is shielded from transmitters on Mauna Loa by a cinder cone. RFI from transmitters that comply with FCC and NTIA regulations is not expected to be a problem at the site.

Harmful RFI at the VLBA site caused by emissions violating FCC or NTIA regulations can be mitigated by cooperative efforts between NRAO and the source owner, or if necessary through FCC and NTIA administrative procedures. Recent studies indicate that radio communication emitters (such as police) at the kilowatt or lower EIRP level, and at current electronic sites, create little harmful RFI at the VLBA site. FM and TV broadcasting and other high-power emitters at the multi-kilowatt EIRP levels, however, could potentially create harmful RFI from both the fundamental and spurious emissions. In such cases NRAO would carefully analyze the proposal and negotiate with the applicant to mitigate problems when the transmitter is being designed.

9.0 Infrastructure, Utilities and Services

9.1 Potable water

It is estimated that on-site personnel will use 100 gallons per day of water for domestic consumption. Water will be trucked to the site and stored in a 2,000 gallon tank located just outside of the fenced area. Water for the telescopes in the summit area is trucked from Hilo. The same truck can stop at the VLBA site periodically to top off the storage tank.

9.2 Sewage disposal

Wastewater will be discharged into a cesspool at the edge of the antenna facility site. Any seepage out of the cesspool would likely be through the gravelly soils overlying bedrock and through fractures and other openings in the bedrock. It is anticipated that a five-foot-diameter cesspool could dissipate the planned flow of 100 gallons per day. (This is equivalent to less than a half-hour flow from a garden hose, or one-sixth the nominal wastewater flow from a three-bedroom house.) The cesspool will be sized and located to satisfy all State Department of Health regulations.

It is unlikely that wastewater will percolate beyond the immediate site area. There are no known springs downslope from the site. The depth to ground water is unknown, but is expected to be hundreds or thousands of feet. The antenna site is extremely isolated, roughly two miles from and 3,000 feet higher than Hale Pohaku, the closest development downslope. Lake Waiau is roughly 1,000 feet higher than the site and about 10,000 feet to the northwest, so could not be affected by wastewater seepage. Therefore, no adverse impact is expected from wastewater discharged into a cesspool at the site (Appendix D).

9.3 Electrical Power

The estimated demand for electricity is 100 kW; about 40,000 kWh are projected to be used per month. Electric service will be provided by an underground connection to the HELCO system; the capacity of the system is sufficient to accommodate the electrical needs of the VLBA antenna; there will be no adverse impact on other users of the system. The standby generator will only operate during a commercial power interruption, it will not impact other facilities within the Science Reserve.

9.4 Communications

The telephone requirements of the VLBA are four digital grade circuits back to the nearest exchange. Service will be provided by an underground connection to the trunk line which will run from the summit to Hale Pohaku. From there, transmissions will be relayed to other Hawaiian Telephone facilities in Hilo. The trunk line is scheduled to be installed by the end of 1988, before the VLBA antenna becomes operational. This system will eliminate a source of potentially harmful RFI.

9.5 Additional services

Solid waste generated at the site will be kept in mongoose-, rat-, and cat-proof refuse containers. It will be carried down to Hale Pohaku daily by NRAO staff. From there, it will be trucked daily to a dumpster located at the headquarters of the Mauna Kea Support Services (MKSS) in Hilo.

The facility will have an appropriate number of fire extinguishers and a fire escape plan. NRAO personnel will be responsible for fire protection at the antenna site.

The operation of the station does not present any particular type of safety threat to people or animals. Even so, the entire facilities area will be enclosed in a security fence to prevent inadvertent or unauthorized entry to the site.

Because the nearest medical facilities are located in Hilo, and the response time for these services is longer than one hour, NRAO personnel will be trained in first aid. In the event of an emergency that they cannot handle, they will either utilize the services of the emergency room which is located in the common area of OCIA or call for the ambulance which is parked between the UKIRT and the 88-inch telescope buildings at the summit.

E. PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

1.0 Short-term Impacts

1.1 Traffic

An increase in traffic will be unavoidable during the construction phase of the project. This traffic, which includes large construction equipment and workers' vehicles, will end when construction is completed.

1.2 Air quality

Increased vehicular traffic and internal combustion engines on heavy construction equipment will result in the generation of emissions into the air. Engine emissions will be mitigated by using properly functioning emission control devices as required by law.

1.3 Visual

Construction equipment, related materials and temporary structures will be located on-site during the construction phase of the project. This impact will be temporary since all equipment and materials will be removed at project completion.

2.0 Long-term impacts

2.1 Flora/Fauna

Biota within the designated construction area will be destroyed. This impact will be minimized by instructing the contractor to confine activities to specified areas. NRAO will also direct its personnel not to disturb areas surrounding the facility, and ensure that predators are not inadvertently brought to the area.

2.2 Visual Character of the Area

The VLBA facility and spur road will be constructed on land that is currently undeveloped. The antenna site and the spur road will be covered with compacted gravel to blend into the existing terrain. From the MKO Access Road below the summit area, only the facility spur road and the top of the antenna will be visible, and then for only two short stretches. It will be totally visible from the summit area looking down to the site.

The view of the antenna will be blocked out from most areas outside of the Science Reserve. It will not be visible from downtown Hilo. Long-range visual impact of the antenna facility will be low.

2.3 Historical/Archaeological Sites

Four archaeological sites were located in the project area; none are within the proposed construction site boundaries. In order to prevent inadvertent damage to the sites during construction, each will be fenced and its location plotted on construction drawings. Construction personnel will be made aware of the existence and location of the sites so that they will be avoided. If remains are uncovered, an archaeologist will be notified immediately.

3.0 Indirect Impacts

3.1 Flora, Fauna and Archaeological Sites

The presence of the facility and spur road could generate indirect impacts on the surrounding area. These impacts could include: disturbance of archaeological sites, geologic features, and habitat of endemic arthropod fauna by off-road vehicle use; and, increased mortality of birds (should they be present in the future) due to rodents and feral predators associated with the facility and light attraction leading to collision with facility structures.

In order to minimize these potential impacts, archaeological sites will be fenced and a sign near the entrance to the spur road will warn people of the penalties for disturbing them. Signs will also be placed along the facility spur road warning people that off-road driving is prohibited. Mongoose-, rat-, and cat-proof refuse containers will be used and refuse will be removed from the area frequently so that these mammals do not establish themselves at the site. Shielded lights will be used at the facility so as not to attract night-flying Petrels.

3.2 Radio Frequency Interference (RFI)

Potentially harmful RFI from transmitters would be mitigated by negotiations between NRAO and the applicant or licensee. In the case of FM and TV broadcasting and other high-power emitters, which could potentially create harmful RFI, NRAO would carefully analyze the proposal and negotiate with the applicant to mitigate problems when the transmitter is being designed.

F. RELATIONSHIP OF SHORT-TERM USES AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The proposed project will add to the State's growing research and development industry and will make long-term contributions to the advancement of our understanding of the universe. This can be accomplished without any significant disruption to the environment or to other activities on Mauna Kea.

G. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Construction and operation of the proposed VLBA project would involve the irretrievable commitment of money, construction materials, manpower and energy. The irretrievable commitment of land will be minimal since the buildings and above-ground structures would be removed in the event the facility is permanently closed. Through limited grading and the use of compacted gravel instead of pavement on areas used for the facility, the area could be returned to nearly its natural state.

H. SUMMARY OF UNRESOLVED ISSUES

Means to control public access to the VLBA antenna and off-road driving are being discussed by IFA and NRAO. At present, it is planned to allow public access along the VLBA spur road. Signs will be placed along the road warning people that off-road driving is forbidden. Those ignoring this warning will be reported to MKSS personnel who will then call enforcement officers of DLNR or Hawaii County Police to remove them from the mountain. People seen disturbing archaeological sites will also be reported.

The situation will be monitored. If off-road driving cannot be controlled by signs and warnings, other methods to restrict access will be developed in cooperation and coordination with DLNR personnel.

PART V: ALTERNATIVES TO THE PROPOSED ACTION

A. ALTERNATIVE SITES

1.0 Overview

It is the policy of the UH Institute for Astronomy (IFA) to reserve the summit siting areas for telescopes that will take maximum advantage of the attributes of the summit; a prime high-altitude site should not be used for a facility that does not need it. The VLBA antenna belongs to an entirely new class of facility than the existing and planned telescopes on the summit of Mauna Kea. It has entirely different siting requirements from the optical, infrared and millimeter/submillimeter-wavelength telescopes in operation there. As long as the VLBA antenna is above the tropical inversion layer, there is no scientific advantage to putting it at a higher elevation.

Because the VLBA does not require the extreme altitude of the summit area for optimal operation, six alternative siting areas, both within and outside of the Mauna Kea Science Reserve, were evaluated, they are: Haleakala, Maui; Hualalai, Hawaii; Mauna Loa, Hawaii; and three locations within the Science Reserve. A site at about the 12,200-foot elevation of Mauna Kea, within the Science Reserve, was selected as a result of this process.

2.0 Site Selection Criteria

At minimum, a potential site for the Hawaii antenna must have the following attributes:

- <u>Intermediate to High Altitude.</u> Because of the distance between the Hawaii station and the other antennas, it is especially important to the performance of the array that the antenna operates in an atmosphere of dry, stable air in order to assure that image quality is optimized and high quality data are received. Consequently, the antenna should be sited above the tropical inversion layer, which usually ranges from 8,000 to 9,000 feet above sea level.

- **Low horizon to the east.** All ten antennas of the VLBA must look at the same object simultaneously. In order to assure maximum coordination with other antennas in the array, from a site considerably west of the others, it is important that the line of sight to the eastern horizon be comparatively free of obstructions, such as terrain features or man-made structures.

- **Low levels of man-made radio signals.** The radio signals emitted from distant astronomical objects are very faint. In order to receive these radio signals without interference, the antenna should not be directly exposed to strong transmitters closer than 20 miles.

3.0 Preliminary Site Identification

The first phase of the site selection process looked for locations at elevations high enough to assure that the antenna would operate in a dry stable atmosphere almost all of the time. As a result, all potential sites located at elevations below the normal tropical inversion layer of 8,000 to 9,000 feet (such as available locations on Oahu) were eliminated from further consideration. Six potential siting areas that met the criterion were identified (Figure V-1), they are:

- **Haleakala, Maui.** The summit area, within and adjacent to Science City;

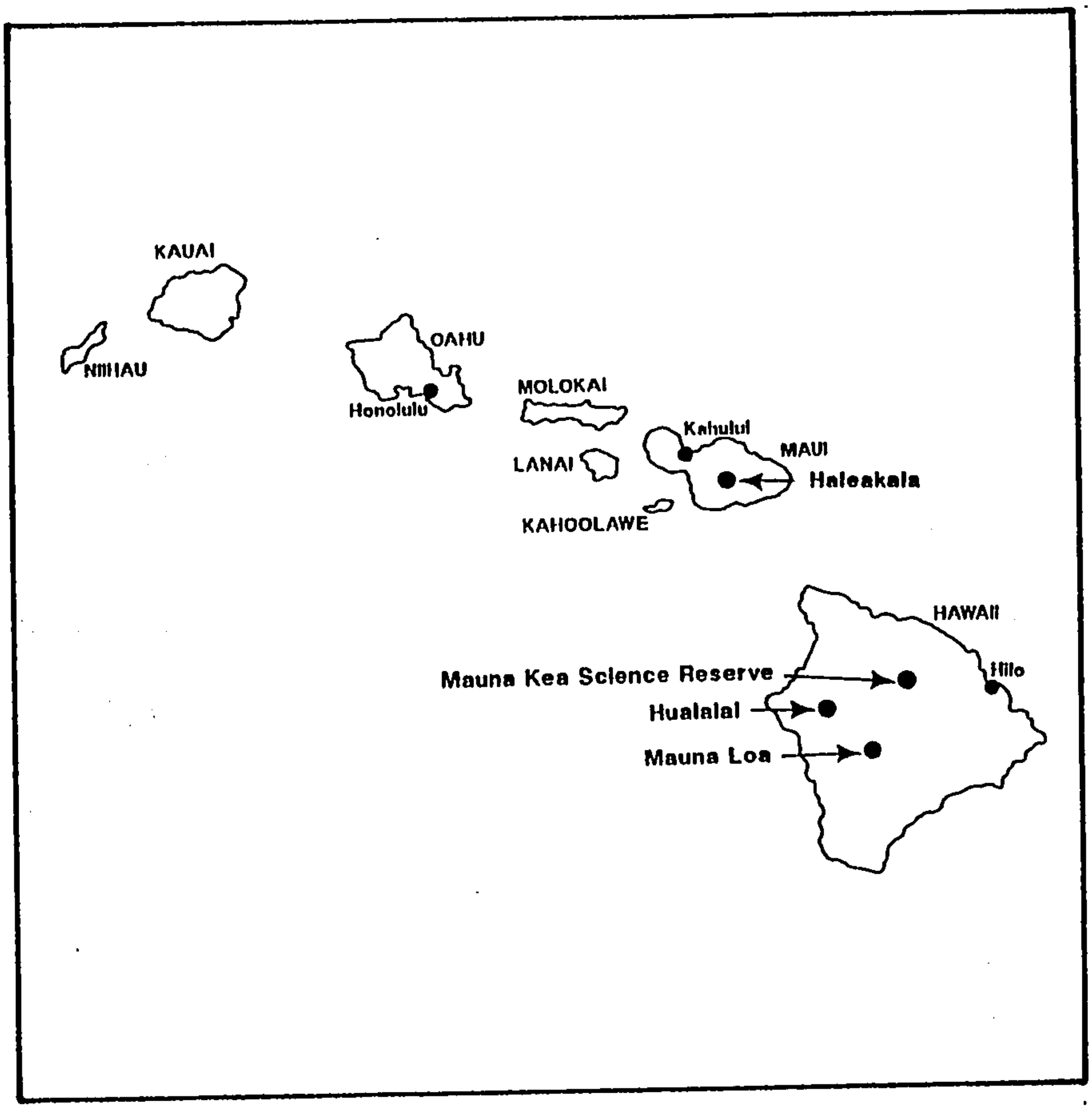
- **Hualalai, Hawaii.** The immediate summit area;

- **Mauna Loa, Hawaii.** The north slope, above the 8,000-foot elevation;

- **Mauna Kea, Hawaii.** Three locations within the Mauna Kea Science Reserve (Figure V-2):

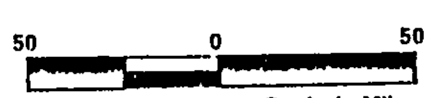
  (a) Telescope Siting Area C (SRCDP): the saddle area between the summit cinder cones at an elevation of 13,300 to 13,400 feet (a.k.a. Millimeter Valley) near the existing millimeter and submillimeter-wavelength telescopes.

  (b) The 12,200-foot elevation of the Science Reserve: a saddle area between two cinder cones, about 2,600 feet northeast of the Mauna Kea Observatory (MKO) Access Road.



Alternative Locations

Figure V-1



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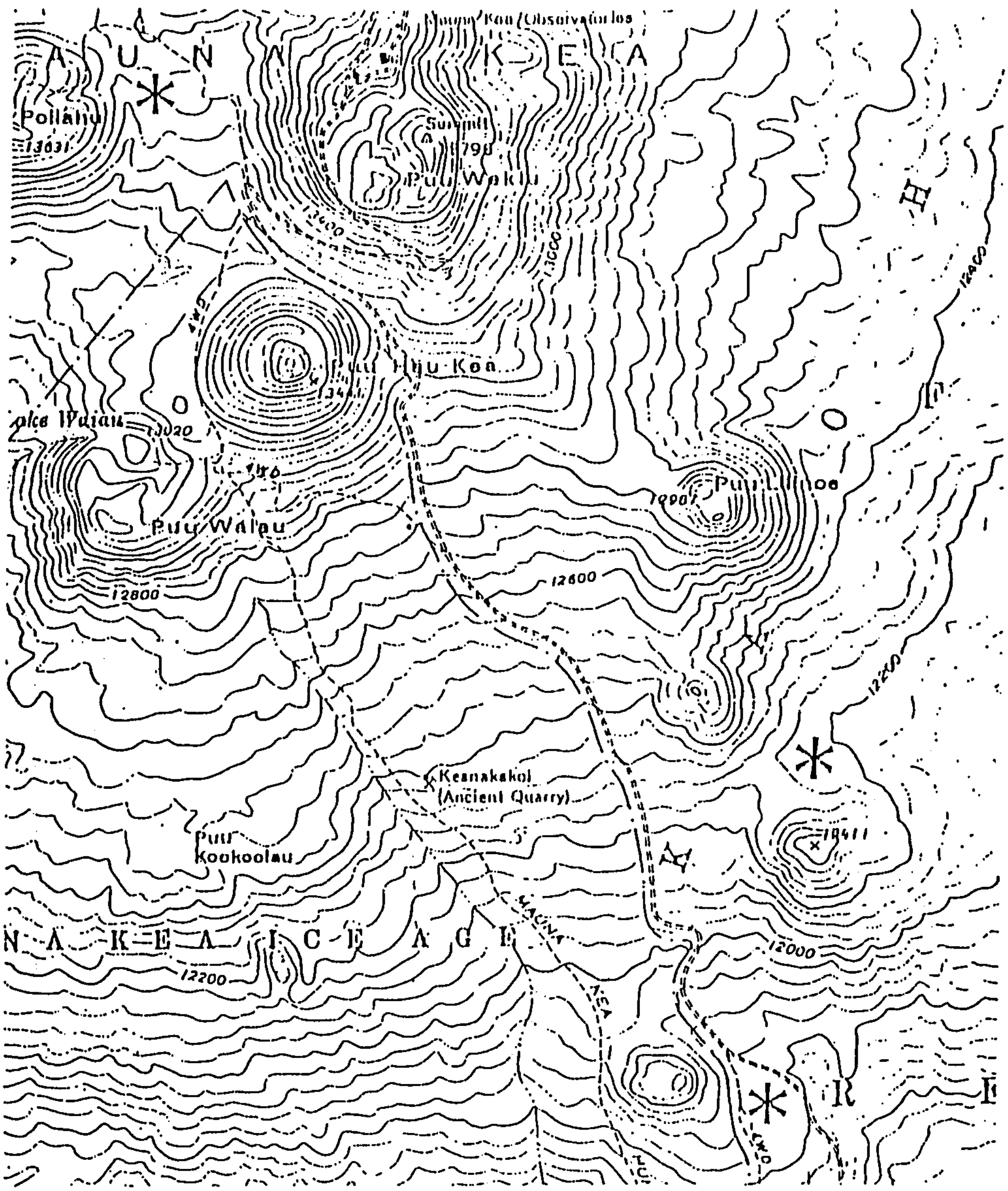


POTENTIAL VLBA LOCATIONS

FIGURE V—2

WITHIN THE MAUNA KEA
SCIENCE RESERVE

LEGEND

✱ POTENTIAL SITES

0 1000 2000 3000
SCALE IN FEET

LOCATION

NORTH

MCM PLANNING 6/88

(c) The 11,800-foot elevation of the Science Reserve: an area about 200 feet west of the MKO Access Road.

4.0 Second Screen Evaluation

A field visit was conducted to each of the six identified locations in order to observe site conditions, to verify whether the area in question would meet the basic siting criteria for the VLBA and to identify any other limitations and constraints that could affect its suitability as an antenna site. As a result, Haleakala, Hualalai, Mauna Loa and Telescope Siting Area C at the Mauna Kea summit were eliminated from further consideration as potential VLBA sites. Two potentially suitable locations (sites at the 11,800 and 12,200-foot elevations within the Mauna Kea Science Reserve) were selected as candidates for further, more detailed, evaluations.

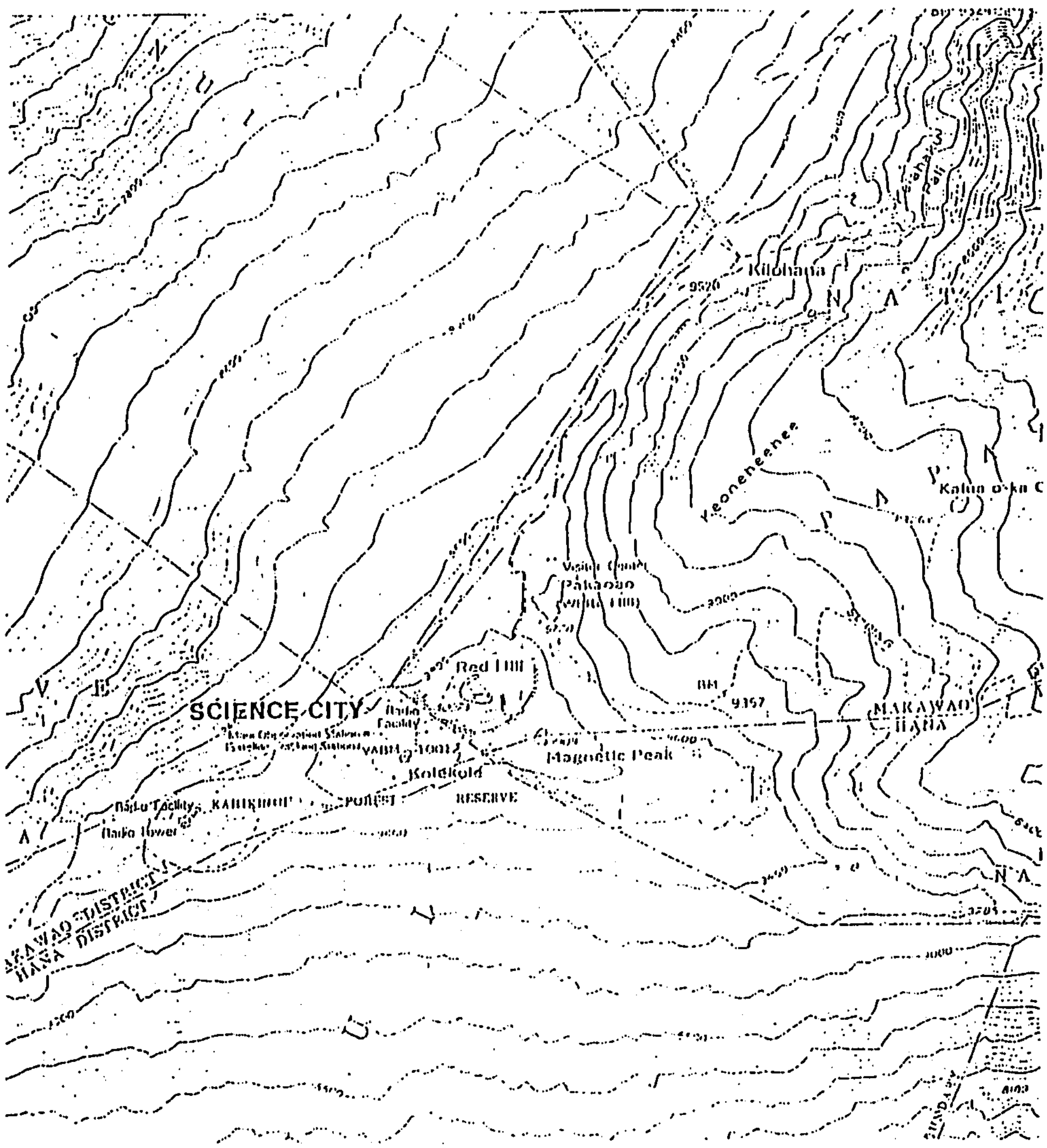
The following subsections describe the characteristics of four siting areas and the reasons each was rejected. (Evaluations of the two candidate Mauna Kea sites are presented in subsection 5.0):

4.1 Haleakala (Figure V-3)

Haleakala is a large shield volcano which makes up most of the eastern portion of the Island of Maui. The summit of the mountain (Red Hill, elevation 10,023 feet), is an isolated peak which rises high above the surrounding terrain. It is above the tropical inversion layer most of the time.

Science City, situated on an 18-acre site owned by the University of Hawaii (UH), is located to the southwest of Red Hill. Tenants of the complex include: the U.S. Air Force Maui Optical Station (AMOS); the UH Mees Solar and LURE observatories; a repeater station for Aeronautical Radio, Inc.; the Airglow Observatory; a radar antenna; and, the Smithsonian Tracking Station. Three television repeaters, a U.S. Air Force building, a remotely controlled Federal Aviation Administration (FAA) facility with transmitter repeater, and repeater stations for Maui and Hawaii County police radio are located nearby (U.S. Department of the Air Force, 1987).

There are two sites available within the Science City complex that have topography suitable for the VLBA antenna. After calculating the building envelope for the antenna and associated facilities, it was discovered that the presence of the antenna on either of these sites would



HALEAKALA SUMMIT
MAUI

FIGURE V–3

0 1000 2000 3000
SCALE IN FEET

LOCATION

NORTH

MCM PLANNING 6/88

cause severe sky blockage for the LURE Observatory; one would also interfere with the Mees Observatory.

Possible RFI from civil transmitters in the vicinity of the Haleakala summit was assessed (Brundage and Peery, 1983). The findings revealed that these transmitters generate a level of RFI that is above harmful interference levels for the VLBA.

The Haleakala summit is exposed to winds from all directions. Data collected during 1985 show that wind velocities exceeded 25 mph 30 percent of the time, ranging from a low of 13 percent during September to a high of 55 percent during March (Deuel, 1986). Operation of the VLBA antenna in precision pointing mode requires that the wind not exceed 25 mph.

Haleakala was rejected as a site for the VLBA antenna because of the potential adverse impacts of the facility on existing operations at Science City; the potentially harmful levels of RFI which could adversely affect the antenna's operation; and frequent high wind conditions.

4.2 Hualalai (Figure V-4)

The summit of Hualalai volcano, elevation 8,275 feet, is located eight miles east-northeast of the town of Kailua-Kona, on the western side of the Island of Hawaii. From the summit, the horizon is practically clear except for the summits of Mauna Kea (ENE, elevation 2.0^{o}) and Mauna Loa (SE, elevation 2.5^{o}). All of the upper portion of Hualalai is owned by the Bernice Pauahi Bishop Estate. It is closed to the public.

Even though Hualalai is one of the oldest volcanoes on the island, it erupted as recently as 1800 - 1801. The area is classified as risk zone de; risk increasing from a through f (Figure V-5). Future eruptions of Hualalai would be expected to originate in the summit area and along the northwest and southeast rift zones. "The next eruption of Hualalai could conceivably occur within the life-span of persons now living (Mullineaux and Peterson, 1974)".

There is little published meteorological data available about the summit of Hualalai. Extensive field testing would have to be undertaken to determine weather conditions at the summit.

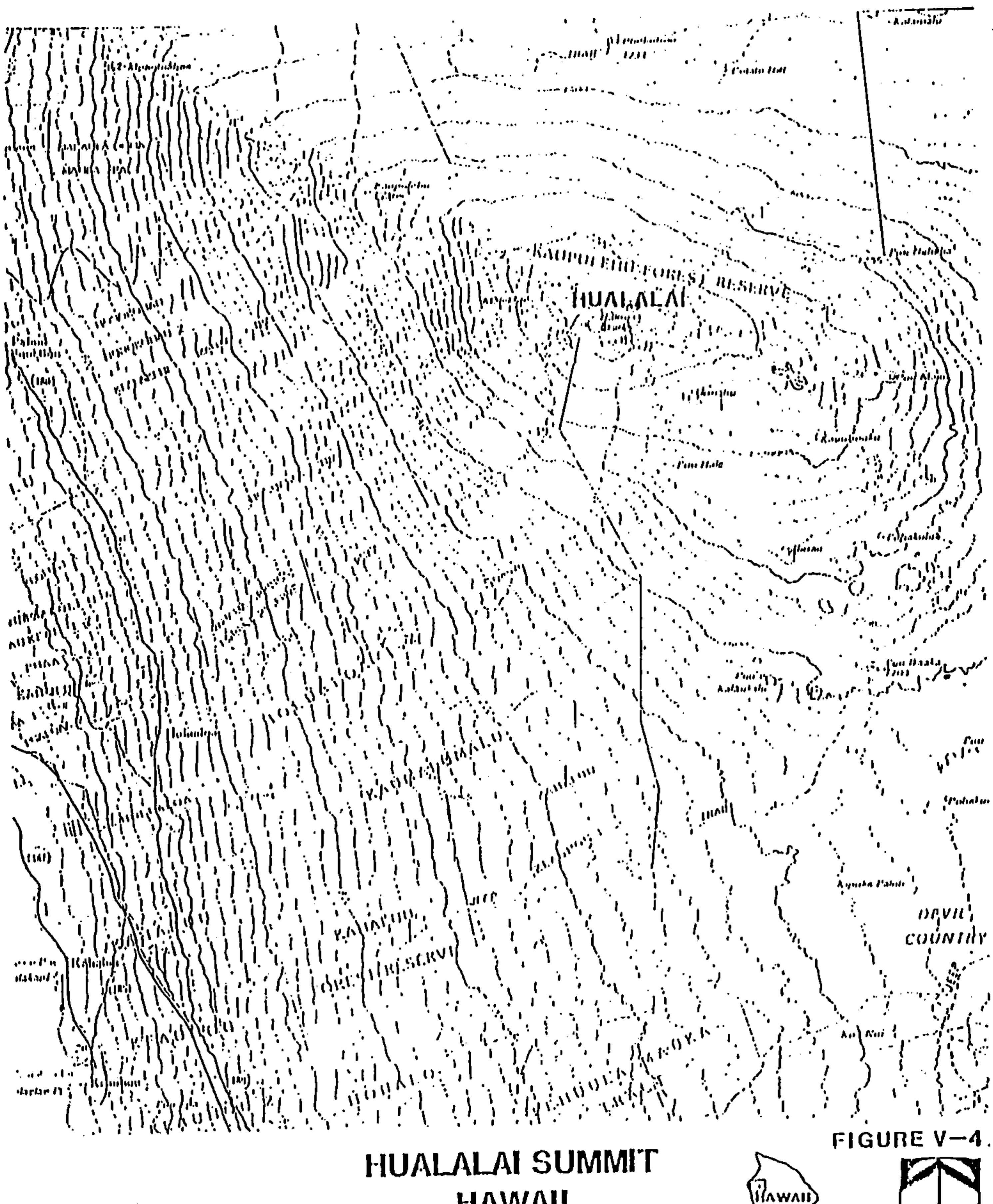


FIGURE V–4.

HUALALAI SUMMIT
HAWAII

0 5000 10000 15000
SCALE IN FEET

HAWAII
LOCATION

NORTH

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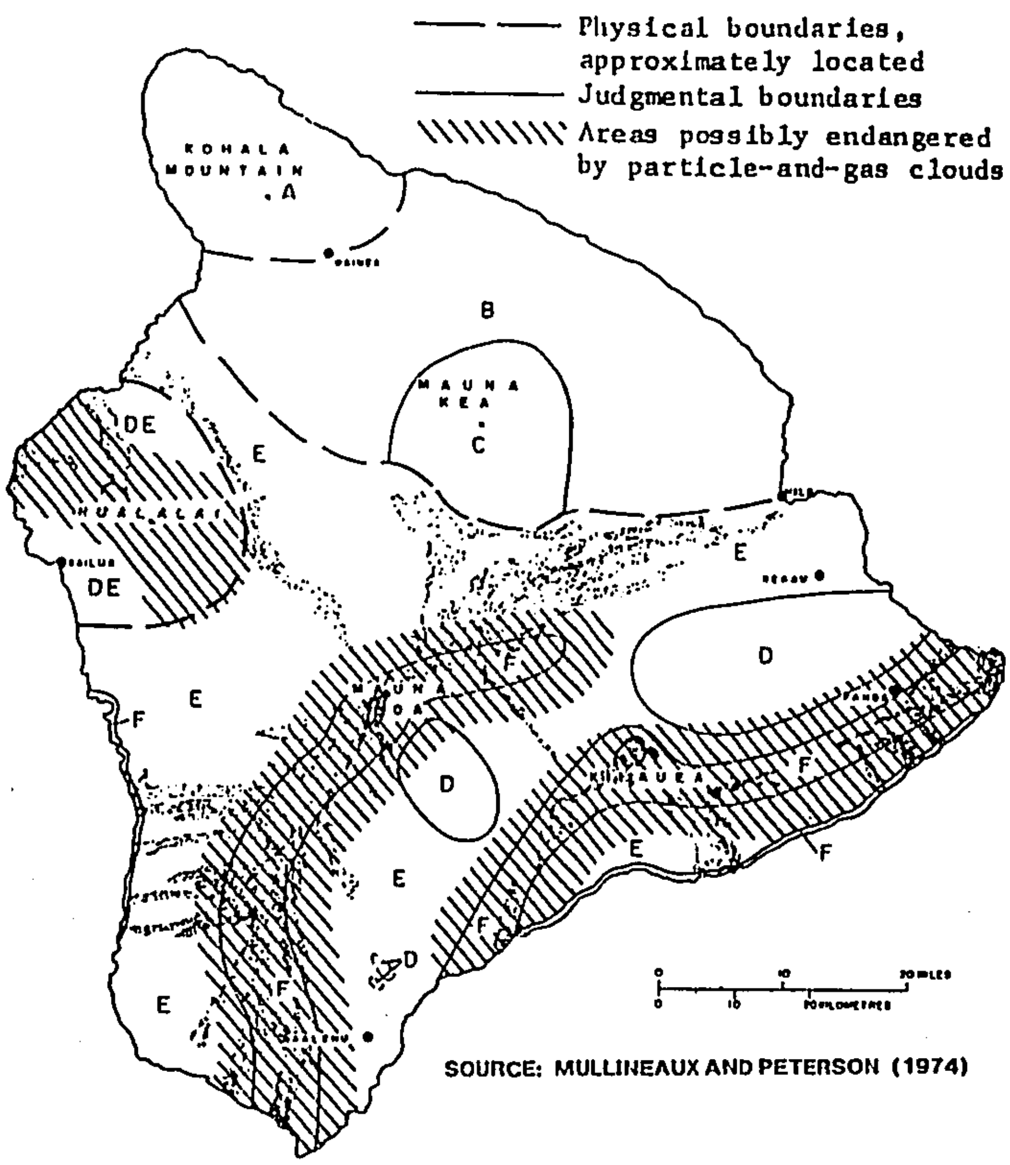


SOURCE: MULLINEAUX AND PETERSON (1974)

--Zones of overall relative risk from volcanic hazards. Risk increases from "A" through "F".

VOLCANIC RISK ZONES

FIGURE V–5

NORTH

Infrastructure on the upper slopes of Hualalai is primitive. A paved road reaches to about the 5,000 foot elevation. Several radio transmitters, ranging in elevation from 5,400 feet to 6,100 feet, are located a short distance above this point. Vehicular access from above the transmitters to the summit is limited to rough jeep trails. There is no electrical power above the transmitters (Wade, 1987).

Hualalai was rejected from further consideration because of the high probability of unacceptable RFI from existing transmitters in the area and potentially high construction costs (e.g. in order to provide access and electrical power to the site, over three miles of transmission lines and 12 miles of new road would have to be built over very rough and steep terrain). In addition, not enough is known about prevailing weather conditions at the summit to make an informed decision as to the suitability of the site based on the prevalence of dry, stable air in the area.

4.3 Mauna Loa (Figure V-6)

Mauna Loa, elevation 13,677 feet, is the second largest of the five shield volcanos which make up the Island of Hawaii. It is an active volcano, last erupting in 1984. The area considered for the VLBA antenna is on the north slope of the Northeast Rift Zone of the mountain. A site at the 8,990-foot elevation, was selected for analysis because of its suitable topography and unobstructed line-of-sight to the eastern horizon. In addition, the tropical inversion layer on Mauna Loa is usually well below that elevation.

Existing facilities in the area include: the Mauna Loa Observatory (MLO), a meteorological station operated by the U.S. National Oceanic and Atmospheric Administration (NOAA), at the 11,100-foot elevation; the Kulani Mauka climatological station at the 8,300-foot elevation, also operated by the MLO; and, three transmitting towers containing microwave relay and VHF/UHF repeater facilities, located near Kulani Mauka. Access to these facilities is via a paved road which runs from the Saddle Road to MLO; vehicular access above the 11,100 elevation is restricted to four-wheel-drive vehicles.

Rainfall in the area averages about 30 inches per year. During 1986, winds averaged 12 mph, ranging from 8 mph during September to 17 mph in February (NOAA, 1987).

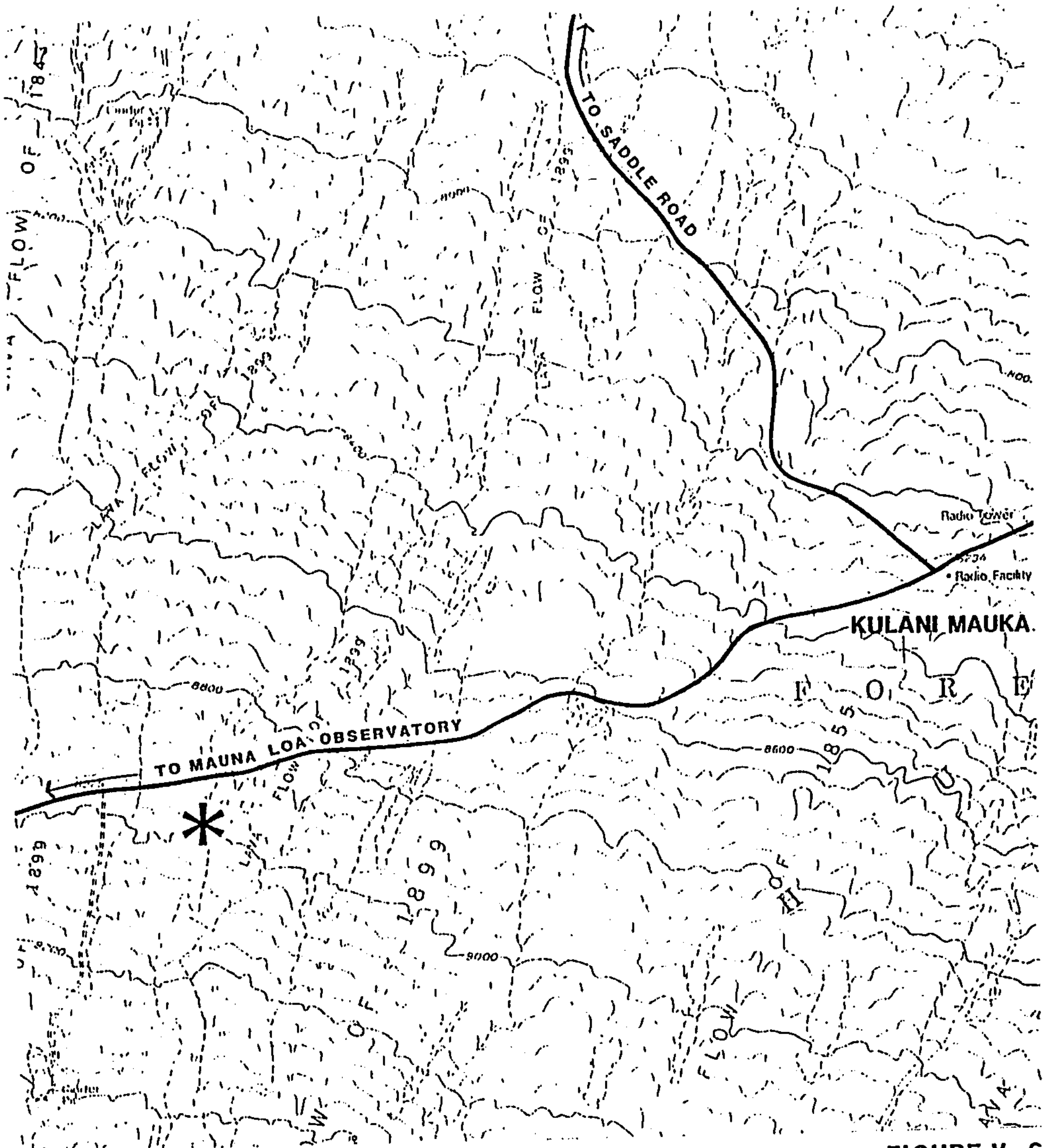


FIGURE V–6

MAUNA LOA SITE

LEGEND

* SITE LOCATION

0 1000 2000 3000

SCALE IN FEET

HAWAII

LOCATION

NORTH

MCM PLANNING

6/88

Potential impacts of the project on the environment in the vicinity of this site was assessed by Frederick R. Warshauer in August 1987 (Appendix H). He concluded that the major impact of the proposed project would be the destruction of about 1.5 acres of sparse, but relatively mature plant community (and any associated sessile arthropods) during construction. Since only 0.02 percent of this community type on Mauna Loa would be destroyed, the loss could be considered insignificant.

If the Mauna Loa location is selected, Warshauer recommends monitoring the site for introduced plants at least twice following construction, in order to prevent the spread of weeds into adjacent native vegetation. In addition, because the endangered 'ua'u (Dark-rumped Petrel) could be affected by lights on or next to the facilities, all exterior lighting associated with an antenna on this site would need to be kept to a minimum and effectively shielded to prevent upward and outward escape of light.

Lava flows are a hazard at the Mauna Loa site because of its location directly downslope from the volcano's active northeast rift zone. Mullineaux and Peterson (1974) classify the area as risk zone f for volcanic hazards; risk increasing from a through f (Figure V-5).

In order to more precisely characterize the volcanic hazard in the immediate area of this site, a detailed geological map of the area surrounding the site (about 12 sq. miles) was prepared and the number and ages of exposed flows were identified (Lockwood, <u>et al</u>., in press). Although sixteen distinct lava flows were found, almost 66 percent of the area is covered by flows occurring during five historical eruptions that traversed near the site between 1843 and 1935. If the historical coverage rate continues, the probability that the site will be covered by lava during the proposed 25-year-life-span of the facility is about 1 in 6. A lava diversion structure constructed upslope of the site could offer some protection from future lava flows in the area (Ibid.).

The Mauna Loa site was rejected for two reasons. First, it appears that the antenna will not only be in direct line-of-sight of existing radio transmitters located at the Kulani Mauka station, the Humuula electronics site and the Army Pohakuloa Training Area, but also of several high powered AM, FM and TV transmitters that may be constructed in the area in the near future. The potential risk of harmful RFI from these sources is high and above acceptable limits for operation of the VLBA antenna. Secondly, the risk of lava inundation was too high, especially since other, less hazardous, sites are available.

4.4 The Mauna Kea Summit (Figure (I-5)

Siting Area C, also called Millimeter Valley, is one of four telescope siting areas at the summit that were delineated in the Mauna Kea Science Reserve Complex Development Plan (SRCDP). It is a flat area, located between the 13,300- and 13,400- foot elevations, about 450 feet lower than the summit cinder cone (Puu Wekiu). The conditions in the area are ideal for submillimeter and millimeter-wavelength astronomy; both the Caltech Submillimeter Observatory and the James Clerk Maxwell Telescope are located there. According to the SRCDP (RCUH, 1983a), there is sufficient space in the area for one or two more similar telescopes.

The siting area is well above the tropical inversion layer; the surrounding cinder cones shield it from the wind. Data collected at the James Clerk Maxwell Telescope between October, 1987 and April, 1988, show that average winds ranged from a high of 10 mph during the month of February, 1988, to a low of 6 mph during the months of October and December, 1987 and January, 1988. The peak wind speed recorded during this period was 60 mph, which occurred in March, 1988.

Until recently, RFI did not affect the operations of summit telescopes. At the present time, personnel from the millimeter-wavelength telescopes and IRTF report that incidents of RFI are increasing. The source of the RFI has not been identified (Longfield, personal comm.).

According to the SRCDP FEIS (RCUH, 1983a), Millimeter Valley is not a sensitive botanical area. Because of the limited amount of vegetation, birds are rarely seen in the area. The elevation is too high and the climate too cold and windy to provide a suitable habitat for Dark-rumped Petrels.

Arthropods inhabiting the lavas in the area include: the moth Archanarta, the spider Lycosa and the centipede Lithobius. No specific measures for mitigating impacts on resident invertebrates, other than to minimize dust, were recommended by the SRCDP consultants (RCUH., 1983b).

There are two archaeological sites located approximately 450 feet and 700 feet respectively from the Caltech Submillimeter Observatory (Caltech, 1982). These sites are described as shrines. It is doubtful that construction of an antenna in this area would affect these sites.

There are three major reasons for not siting the VLBA antenna in Millimeter Valley (Siting Area C):

- o Snow tends to accumulate in the area and when temperatures become low enough ice loading is likely to occur. The antenna would have to be housed in a radome if it were sited there. The signal degradation caused by the radome would largely cancel the advantage of placing the antenna above the tropical inversion layer.

- o It would be a particularly poor site for the antenna because of the high (10 to 15 degree) horizon to the east and northeast, the directions in which it is most important to observe (since the Hawaii antenna is far to the west of the others). Inability to observe at or near the horizon in this quadrant would seriously compromise the performance of the array as a whole.

- o As stated previously, there is no scientific advantage to putting the antenna at an elevation higher than just above the tropical inversion layer. It is counter to the policies of the Institute for Astronomy in regard to the Science Reserve to use a prime high-altitude site for a facility that does not require it.

5.0 Selection of the Preferred Site

5.1 Evaluation criteria

A detailed analysis (including field surveys for flora, fauna and archaeological sites) and comparative evaluation of the two remaining candidate sites within the Mauna Kea Science Reserve was based on the following criteria:

- o <u>Radio frequency interference.</u> Is the site well protected from harmful radio frequency interference?

- o **Low eastern horizon.** Is the view of the eastern horizon clear and unobstructed?

- o **Endangered species.** Will construction of the antenna disturb rare or endangered plants or animals?

- o **Archaeological sites.** Are there important archaeological features in the area that could be disturbed during construction?

- o **Visibility.** How visible would the antenna be from populated areas of the island and from other areas within the Mauna Kea Science Reserve?

5.2 Mauna Kea at the 11,800-foot Elevation (Figure V-7)

The site is just north of the southern boundary of the Mauna Kea Science Reserve, adjacent to the MKO Access Road. A four-wheel-drive vehicle trail crosses a portion of the site. The area is flat and covered with ground moraine deposits. The soils are mostly coarse gravels, with cobbles as large as several feet in diameter. A cinder cone to the west rises about 100 feet above site elevation. As viewed from the site, the horizon is generally clear of obstructions, except for a small portion in the northeast which rises to about 5 degrees.

The 11,800-foot elevation of Mauna Kea is well above the tropical inversion layer and cinder cones in the vicinity of the site would protect the antenna from strong westerly winds. According to Dr. Andre Erasmus, UH IFA Meteorologist, average temperatures increase by $1^{o}C$ for every 100 meters of decreased elevation, thus the temperature at the site would be about $6^{o}C$ warmer than at the summit. It hardly ever snows at this elevation, precluding problems of snow and ice loading.

Preliminary analysis revealed that from this site, the antenna would be in direct line-of-sight of the Kulani Mauka transmitters on Mauna Loa. That area is also the most likely location of future AM, FM, and TV relay stations because signals emanating from there can reach more people than from any other place on the island.

There are no federally listed threatened or endangered species present on the site. Two field surveys failed to locate any remains or evidence of nesting activity of the 'ua'u (Appendix F).

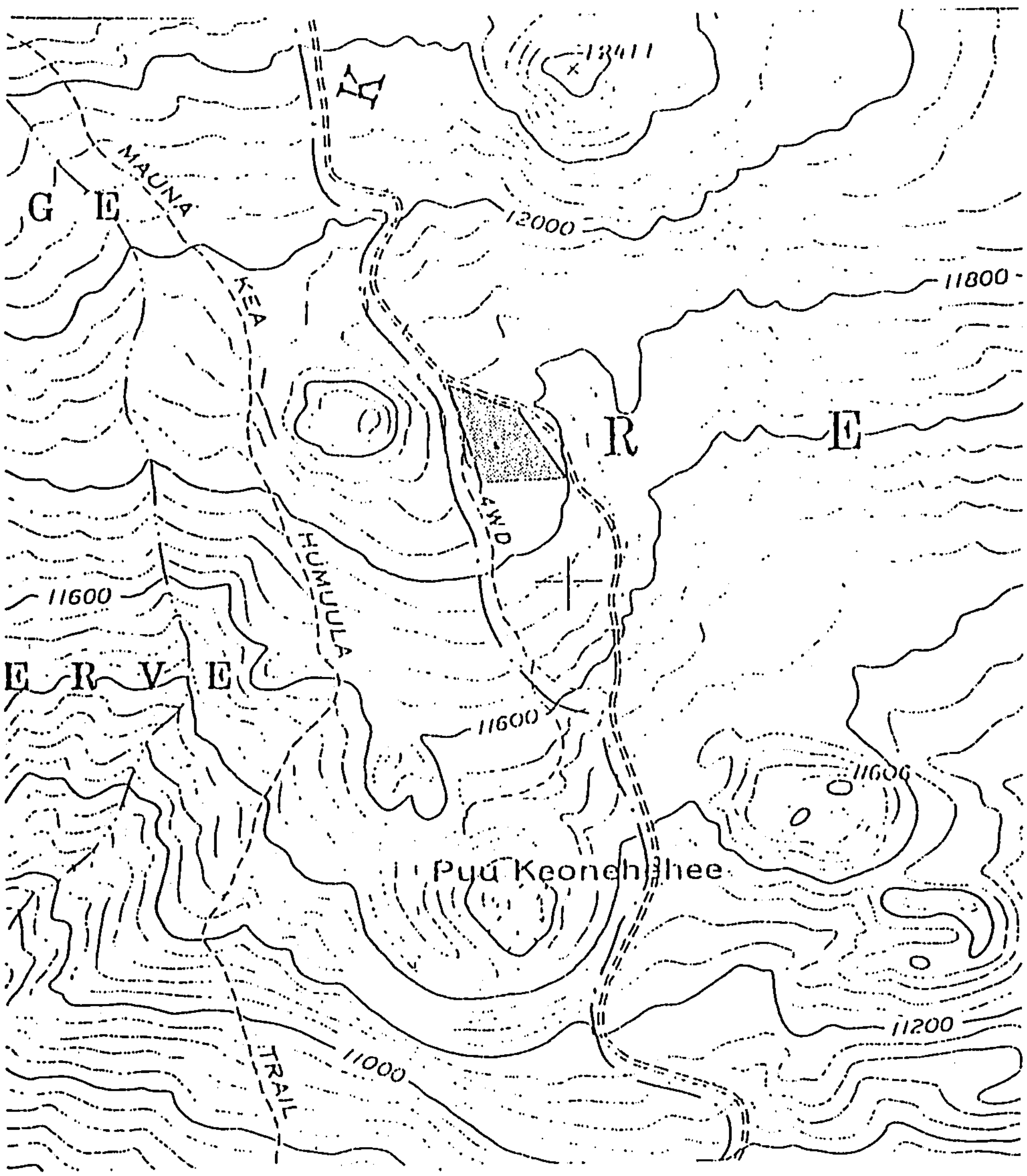


FIGURE V-7

POTENTIAL SITE
AT 11,800 FT. ELEVATION

LEGEND

SITE LOCATION

0 1000 2000
SCALE IN FEET

HAWAII
LOCATION

NORTH

MCM PLANNING 6/88

As described in Appendix E, the site is almost barren of vegetation. Small numbers of Hawaiian bent (Agrostis sandwicensis) and he'u-pueo (Trisetum glomeratum), members of the grass family Poaceae, and two species of lichen, Candelariella vitellina and Lecidea skottsbergii, were found on the site. Each of these species grows elsewhere and the site is not an important habitat for them.

Endemic wolf spider (Lycosa) skins were found under large stones on the site, but only one spider was sighted. Limited numbers of other invertebrates, including species of spiders (Erigone) and springtails (species undetermined) were also observed. The most common invertebrates in the area are exotic economic pests Hydrellia and Pollenia, members of the fly family Diptera. Impacts on native invertebrates inhabiting the site would be minor (Appendix G).

No cultural features are present on the site (Appendix C). The western boundary of the site is within several hundred feet of the Mauna Kea Ice Age Natural Area Reserve, therefore, indirect impacts of the antenna on the features within the Reserve must be considered if the facility is located on this site.

Both the short-range (within the summit area) and long-range (island-wide) visual impact of the VLBA antenna was evaluated (Appendix H). As shown in Figure V-8, at short-range the antenna will be visible along about two miles of the MKO Access Road from about 500 feet below the site to a point near Puu Hau Kea. It will be also be seen from a 2,500-foot stretch of the MKO Access Road at the 13,400-foot elevation near the summit. Because the terrain in the vicinity of the site is open and level, the entire complex (antenna and support facilities) will be visible from these vantage points.

As shown in Figure V-9, the antenna will be visible from Leleiwi Point, portions of the Saddle Road, all of Waiakea Homesteads, all of Keeau, Puna, portions of Hawaii Volcanoes National Park and the north face of Mauna Loa. There are no minor topographic variations which might obscure the lower portion of the antenna from the viewer, therefore the entire telescope may be visible from much of the area shown on the Figure.

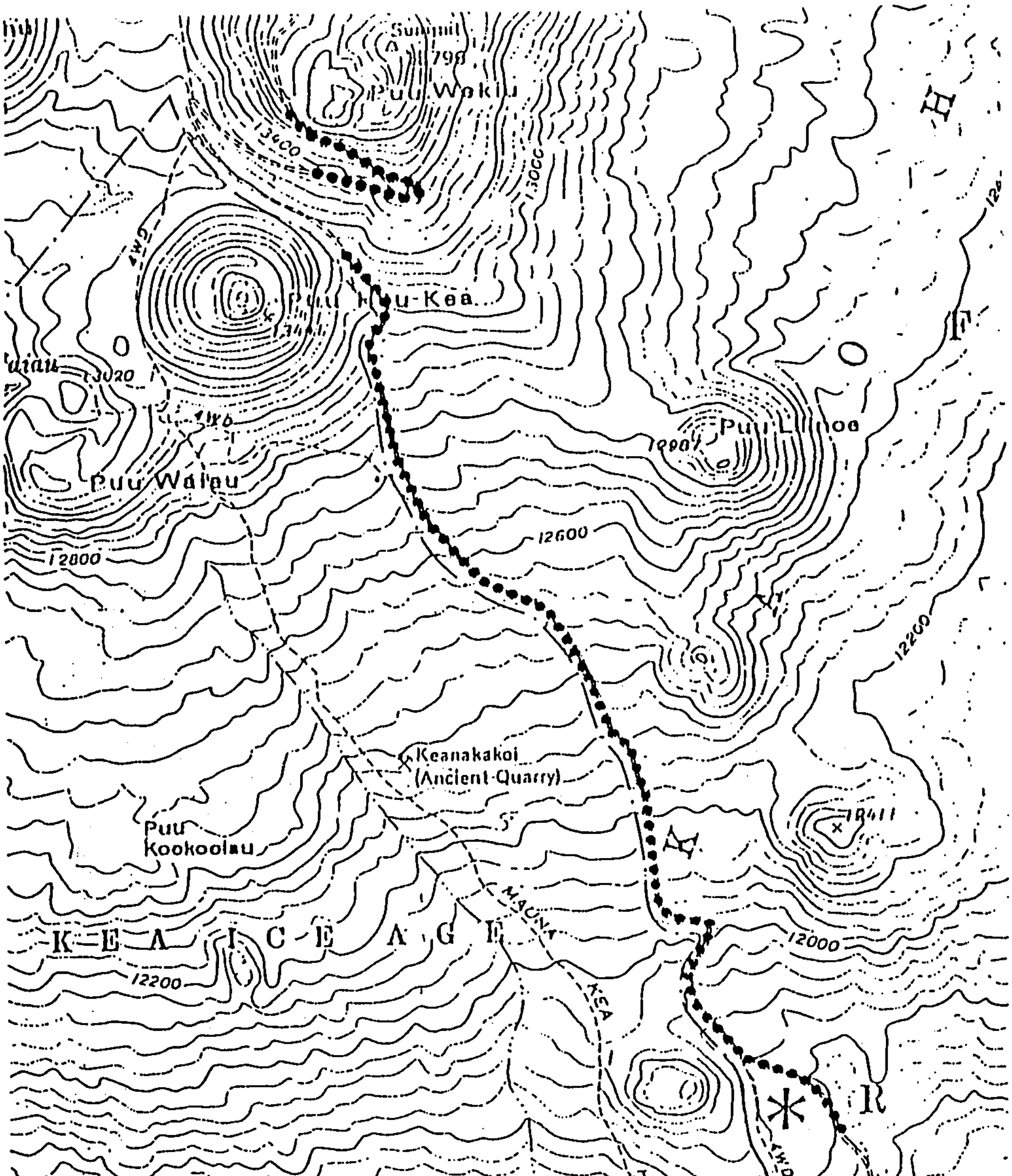


FIGURE V–8

LEGEND

SITE LOCATION

AREAS OF VISIBILITY

SHORT RANGE VISUAL IMPACT

OF VLBA SITE AT 11,800' ELEVATION

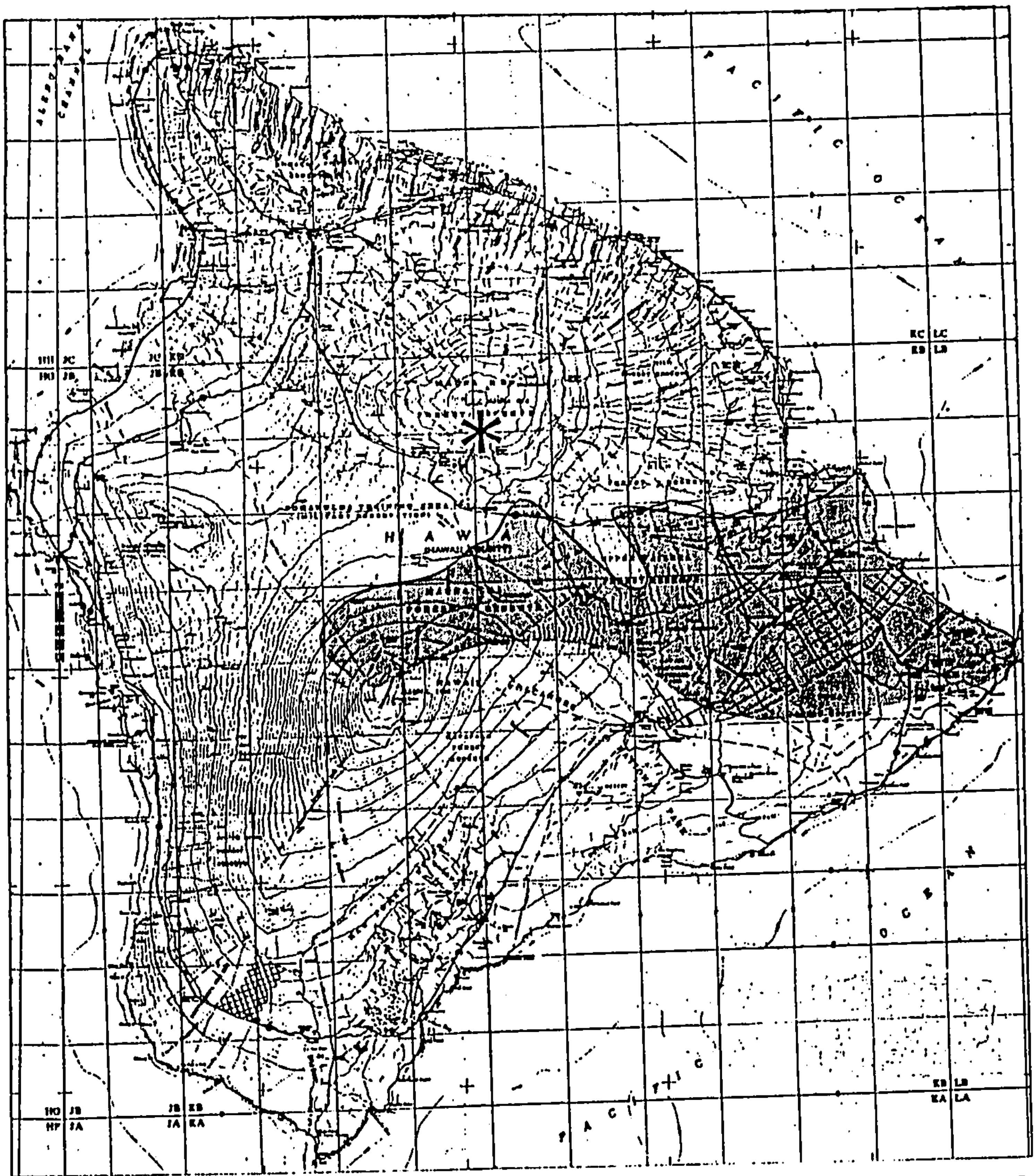
0 1000 2000
SCALE IN FEET

HAWAII

LOCATION

NORTH

MCM PLANNING 6/88



LONG RANGE VISUAL IMPACT

FIGURE V–9

OF VLBA SITE
AT 11,800' ELEVATION

LEGEND

* SITE LOCATION

AREAS OF VISIBILITY

0 5 10 15

SCALE IN MILES

NORTH

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5.3 Mauna Kea at the 12,200-foot Elevation (Figure II-2)

This site is described in detail in previous sections of this SEIS. To summarize, the proposed antenna site is on a flat plain between two cinder cones, roughly 2,600 feet northeast of the MKO Access Road. The area is essentially barren with no ground cover. Several species of grass and lichen grow there in small numbers. Invertebrates in the area are limited to several species of moths, spiders, and flies. There are no rare or endangered species present.

Four archaeological sites were located during a field survey of the area (Appendix C). Three of these sites, probable shrines, may have cultural or religious significance. The fourth is described as a rock shelter. None of the sites is within the proposed construction area.

Weather conditions (water vapor, temperature, and wind) are similar to those at the 11,800-foot elevation. The temperature at this site is estimated to average about 5°C higher than at the summit. Snowfall and freezing temperatures are rare in the area. The proposed antenna site is well protected from the occasional high winds from the west. Cloud cover conditions are similar to those at the summit, except during the midday hours when cloudiness may be more prominent.

RFI is not expected to be a problem at the site. The cinder cone to the south of the site will shield the antenna from transmitters on Mauna Loa. The eastern horizon, as viewed from this site, is not obstructed by natural or man-made features.

Two cinder cones, which rise from 230 to 380 feet above site elevation, are expected to block out the view of the antenna from most areas. At short-range the antenna will be partially visible from two locations along the MKO Access Road; it will be completely visible form selected areas at the summit (Figure IV-2). The antenna would not be visible from downtown Hilo. As shown in Figure IV-3, it may be partially visible from other areas outside of the Science Reserve such as, Leleiwi Point, portions of Waiakea Homesteads and portions of the Puna District from Keeau to Kapoho.

5.3 Comparative Evaluation of Sites

- Radio frequency interference. The site at the 12,200-foot elevation is superior because the cinder cone to the south will shield the antenna from transmitters on Mauna Loa. The risk of harmful RFI from present and future sources in direct line-of-sight of the 11,800-foot elevation site is high and may be above acceptable limits for operation of the VLBA antenna.

- Low eastern horizon. The two sites are equally suitable.

- Endangered species. There are no rare or endangered species present on either site, therefore, the sites are equally suitable.

- Archaeological sites. There are four archaeological sites present near the upper site. They will not be affected by construction activities and can be preserved. However, because there are no cultural remains on the lower site, it would be more suitable.

- Visibility. An antenna sited at the 11,800-foot elevation would be more visible from both short and long-range than an antenna at the 12,200-foot elevation site. The upper site, sheltered by cinder cones, is therefore superior to the lower site.

5.4 Results of the Analysis

The site at the 12,200-foot elevation was selected as the preferred location for the VLBA facility primarily because it is protected from potential RFI from existing and proposed transmitters on Mauna Loa and secondarily because it would be barely visible from populated areas of the island. Even though construction at the selected site would probably be more costly, the risk of harmful RFI compromising the effectiveness of the antenna led to the rejection of the lower site.

B. NO ACTION

The no action alternative means the western most antenna of the VLBA would not be in Hawaii, thus limiting the project's ability to achieve its desired scientific goals. The purpose of the VLBA is to produce the most detailed radio images of astronomical bodies that can be obtained with a ground-based instrument. The number and configuration of antennas was determined in order to optimize the resolution from within the United States. A key factor in achieving this optimal resolution is the baseline length between elements in both north-south and east-west directions. For this reason, Hawaii is a critical element to the VLBA. Elimination of Hawaii as a site would significantly impair the performance of the array.

If the VLBA antenna is not built, the proposed site would be left in its natural state for the foreseeable future. At some later date, however, other antennas or telescopes, not requiring high altitude sites, may choose to locate there.

C. ALTERNATIVE ACTIONS

There are no alternative actions that would achieve the project's goals. All ten antennas of the array are identical in design, and must operate in a coordinated manner. There are no facilities in Hawaii which could substitute for the proposed antenna. Without an antenna in Hawaii, the array would still function, but with such impaired performance that its construction would be hard to justify.

PART VI: RELATIONSHIP OF THE PROPOSED PROJECT TO POLICIES AND PLANS FOR THE AREA

A. HAWAII STATE PLAN

The Hawaii State Plan (Act 100) sets forth long range and comprehensive goals, objectives, and policies to guide future development in the State of Hawaii. It further details priority directions which indicate areas of statewide concern meriting immediate attention (DPED, 1978).

One stated objective of the State Plan is "increasing and diversifying Hawaii's economic base." The proposed VLBA facility fulfills this objective. It also fulfills a related policy of "promoting Hawaii's geographic, environmental and technological advantages to attract new economic activities into the State."

Characteristics of the type of new industry considered desirable for the State are described in Part III, Priority Directions, Section 103, subsection (e). These characteristics include:

- An industry that can take advantage of Hawaii's unique location and available manpower resources;
- A new industry should be a clean industry that would have minimal effect on Hawaii's environment; and,
- An industry which is willing to hire and train Hawaii's people to meet the industry's labor needs.

Astronomical development in general, and the VLBA facility in particular, possess these characteristics. Part IV of this SEIS demonstrates that the facility would have only a minimal impact on the environment. In addition, NRAO has stated that antenna staff would be hired locally.

B. GENERAL LEASE NO. S-4191

On June 21, 1968, the UH entered into an agreement with the BLNR to lease an estimated 13,000 acres on the summit of Mauna Kea for a Science Reserve. The lease ends on the last day of the year 2033.

The lease specifies that . . . "the land hereby leased shall be used by the Lessee as a scientific complex, including without limitation thereof an observatory, and as a scientific reserve being more specifically, a buffer zone to prevent the intrusion of activities inimical to said scientific complex." Activities inimical to the scientific complex include but are not limited to light and dust interference to observatory operation and certain types of electric or electronic installations.

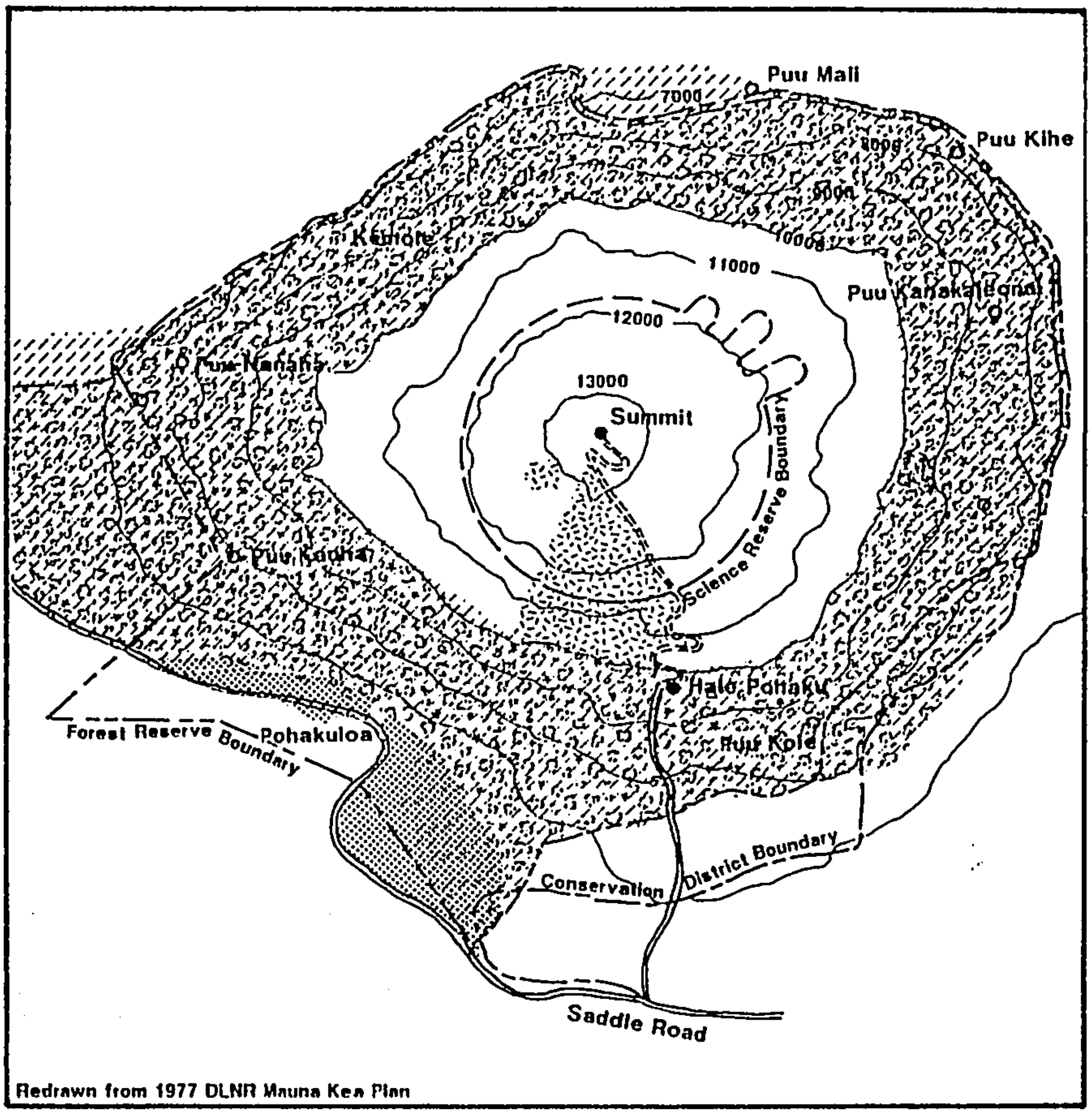
C. CONSERVATION DISTRICT POLICIES and REGULATIONS

The VLBA site is within the Resource Subzone of the Conservation District. The objective of this subzone is to develop, with proper management, areas to ensure sustained use of the natural resources of the area. The proposed VLBA antenna is adding to the research capabilities of the Mauna Kea Observatory and meets the objective of the Resource Subzone by utilizing the excellent astronomical resources that Mauna Kea possesses with minimal impact on the environment.

D. 1977 DLNR MAUNA KEA PLAN

Mauna Kea is an ideal site for a variety of scientific endeavors and recreational activities. It is also the location of a number of rare plants and birds found nowhere else in the world. In order to control development on the mountain and resolve conflicting demands on the area's natural resources, the Board of Land and Natural Resources (BLNR) adopted The Mauna Kea Plan in February 1977 (DLNR, 1977).

The area covered by the Mauna Kea Plan includes all of the Conservation District land on the mountain from the summit to the Saddle Road. The Plan created management areas for various resource areas on the mountain (Figure VI-1) and states that the Science Reserve Area is to be used primarily for scientific research, in accordance with existing lease arrangements with the UH. At the request of UH, and with the approval of the



LEGEND:

- Palila Critical Habitat
- Silversword Area
- Mamane-Naio and Associated Ecosystem
- Natural Area Reserve
- Military Area

1977 DLNR Mauna Kea Plan Management Areas

2 0 2
Scale in Miles

Figure VI-1

North Location

BLNR, the Plan was amended in 1985 to allow overhead powerlines from the saddle road to Hale Pohaku and paving of the MKO Access Road.

E. UNIVERSITY OF HAWAII RESEARCH DEVELOPMENT PLAN FOR THE MAUNA KEA SCIENCE RESERVE AND RELATED FACILITIES

The UH Research Development Plan (UH RDP) serves as the programmatic master plan for the continued development of the Mauna Kea Science Reserve. Adopted in January 1982, the plan sets forth future actions to be taken in the Science Reserve. It also addresses the procedures by which the University will review and assess applications for new facilities, and the types of agreements required of all new users of the summit and Hale Pohaku areas (University of Hawaii, 1982).

The proposed VLBA facility meets the guidelines in the UH RDP for locating facilities within the Science Reserve because:

- The proposed facility serves significant, identified needs;
- The identified objectives are achievable and the proposal realistic;
- The facility, in its unique qualities, matches the excellent properties of the site;
- Mauna Kea is the best site for the facility;
- The project enhances the overall capabilities of the Mauna Kea Science Reserve;
- NRAO has taken note of public policies and the concerns of interested groups in Hawaii in formulating its proposal; and,
- The project fills a unique and desired place in the UH program.

F. MAUNA KEA SCIENCE RESERVE COMPLEX DEVELOPMENT PLAN

The Mauna Kea Science Reserve Complex Development Plan (SRCDP) was approved by the UH Board of Regents in February 1983. It incorporates the policies and criteria set forth in plans described above (in addition to the 1980 DLNR Hale Pohaku

Mid-Level Facilities Complex Development Plan) and recommends amendments to these plans where appropriate. The primary objective of the SRCDP is to guide and control planned development in order to preserve the scientific, physical and environmental integrity of the mountain (RCUH, 1983a).

The SRCDP identified four siting areas for future telescopes at the summit of Mauna Kea. These siting areas were selected specifically for optical, infrared, and millimeter/submillimeter-wavelength telescopes which require the extreme altitude of the summit area of Mauna Kea. The VLBA antenna belongs to an entirely new class of facility not included in the projection of telescopes anticipated through the year 2000.

The VLBA has entirely different siting requirements than the types of facilities discussed in the SRCDP. These requirements have led to the need for an assessment of a new site at an intermediate altitude within the Mauna Kea Science Reserve. The SRCDP will be amended to incorporate the new site and to include the VLBA antenna as an additional facility.

UH IFA also proposes to amend the SRCDP by deleting references to future communications facilities in the summit area. The amendment will state that "no transmitters of any kind will be allowed within the Science Reserve in the future; those operating there now will be removed as soon as suitable alternative locations are found."

G. HAWAII COUNTY GENERAL PLAN

The Hawaii County General Plan contains general economic policies which pertain to NRAO'S proposed antenna:

- Strive for an economic climate which provides its residents an opportunity for choice of occupation;
- Continue to encourage the expansion of the research and development industry by working with and supporting the university, private sector, and other agencies' programs developed to aid the County of Hawaii;
- Strive for diversification of its economy by strengthening existing industries and attracting new endeavors; and,

- Encourage the research, development and implementation of advanced technologies and processes in existing and potential economic endeavors.

Hawaii County has encouraged scientific research and development, along with other types of economic activities, as preferred industries to broaden and diversify its economic base. The proposed project will create two to four new jobs, and will add to the critical mass necessary to support related jobs such as computer technicians and mechanical engineers. In doing so, the VLBA facility will contribute to the potential of creating a new range of jobs for Hawaii's youth.

H. POLICIES AND PLANS INCORPORATED BY REFERENCE

Policies and plans incorporated in this document by reference include:

- 1980 DLNR Hale Pohaku Mid-Level Facilities Complex Development Plan
- Chapter 343 HRS - EIS Regulations
- Chapter 344 HRS - State Environmental Policy Act
- State Higher Education Functional Plan
- Northeast Hawaii Community Development Plan
- Endangered Species Act of 1973 (U.S.C. 1536) and 1978 amendments to the Act
- Clean Air Act, as amended (42 U.S.C. 1857h-7 et. seq.) -- no adverse effect expected
- National Historic Preservation Act of 1966, as amended (16 U.S.C. Sec. 470 et. seq.) -- no adverse effect expected.
- Clean Water Act of 1977 (33 U.S.C. 1251 et. seq.) -- no adverse effect.
- Potable Water Systems, (Chapter 20, formerly Chapter 49, HRS) -- no adverse effect.

I. AN INDICATION OF WHAT OTHER INTERESTS AND CONSIDERATIONS OF GOVERNMENTAL POLICIES ARE THOUGHT TO OFFSET THE ADVERSE ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTION

Adherence to the policies and conditions set forth in the Mauna Kea Science Reserve Complex Development Plan concerning development in the area act to curtail adverse environmental impacts of new projects. The Conservation District Use Permit required before the facility is constructed will also assure that important environmental aspects have been considered in the design of the facility and that all restrictions placed on the permit as a condition of approval will be strictly adhered to.

PART VII: LIST OF NECESSARY APPROVALS

The following list of necessary approvals does not include environmental compliance activities to be undertaken by the National Science Foundation.

State of Hawaii

Board of Land and Natural Resources

- Conservation District Use Permit
- Right of Entry
- Sublease

Department of Health

- Individual Wastewater Disposal System Approval

University of Hawaii

- Amendments to the Science Reserve Complex Development Plan
- Memorandum of Understanding
- Sublease

County of Hawaii

Planning Department

- CDUA Review Process
- Plan Approval

Building Department

- Grading Permit
- Building Permit

Other required permits and approvals will be determined during the design phase of the project.

PART VIII: AGENCIES, ORGANIZATIONS AND INDIVIDUALS CONSULTED DURING THE PREPARATION OF THE SUPPLEMENTAL EIS

Associated Universities, Inc. (AUI) has entered into Contract No. NSF AST 84 - 03744 with the United States of America, represented by the National Science Foundation (NSF), to construct, operate, and maintain a Radio Astronomy Observatory. This SEIS for the Hawaii antenna of the Very Long Baseline Array (VLBA), which will be part of the instrumentation of the National Radio Astronomy Observatory (NRAO), was prepared under Subcontract VLBA - 131 between AUI and MCM Planning.

A. AGENCIES, ORGANIZATIONS AND INDIVIDUALS CONSULTED

The following individuals, agencies and firms were contacted for professional services and/or specialized advice during the preparation of the SEIS.

Sub-Consultants to MCM Planning

Char & Associates Winona Char Maile Kjargaard Steven Montgomery, Ph. D.	Flora and Fauna Botany Vertebrates Invertebrates
Cultural Surveys Hawaii	Archaeological Studies
Harding Lawson Associates	Soils, Drainage and Erosion
R. M. Towill Corporation	Topographic Maps

Sub-Consultants to AUI

Frederick Warshauer	Flora/Fauna Assessment of the Mauna Loa Site
U.S. Dept. of Interior, Geological Survey	Volcanic Risk Assessment of the Mauna Loa Site

Federal Government

National Science Foundation

Ludwig Oster, Ph. D.	Astronomy Division
Julian Shedlovsky, Ph. D.	Chair, Committee on Environmental Matters

U.S. Department of Commerce - National Oceanic & Atmospheric Administration

Elmer Robinson	Director, Mauna Loa Observatory
Saul Price	Meteorologist, National Weather Service

U.S. Department of Interior - Geological Survey

John P. Lockwood	Geologist, Hawaii Volcano Observatory

State of Hawaii

Board of Land and Natural Resources

William W. Paty	Chairperson
Herbert Arata	Hawaii Island Member

Department of Budget and Finance

Ernest Shima	Telecommunications Manager

Department of Land and Natural Resources

Libert K. Landgraf	Deputy to the Chairperson
Ross Cordy, Ph. D.	Historic Sites
Roger C. Evans	Conservation and Environmental Affairs
Ronald L. Walker	Forestry and Wildlife
Maurice Marsuzaki	Conservation and Resources Enforcement
Noah Pekolo	Conservation and Resources Enforcement

Research Corporation of the University of Hawaii

Thomas Krieger	Mauna Kea Support Services

University of Hawaii - Institute For Astronomy

Donald N. B. Hall, Ph. D.	Director
Andre Erasmus, Ph. D.	Meteorologist
Richard Longfield	Assistant Director
Beverly T. Lynds, Ph. D.	Scientific Assistant to the Director

County of Hawaii

Lorraine Jichaku-Inouye	Chair, Economic Development Committee Hawaii County Council
Tim Lui Kwan	Planning Department
Ralph Yoshigami	Fire Department
Richard Matsurami	Police Department
Ronald Okamura	Parks & Recreation Department
Glenn Miyao	Parks & Recreation Department
Larry Mosher	Legislative Auditor
Albert Nakano	Safety
Steven Todd	Research & Development
Bruce McClure	Planning Department

Organizations and Individuals

AUI - NRAO

Campbell Wade, Ph. D.	Head, VLBA Site Development Group
William Brundage, Ph. D.	Project Engineer
Patrick C. Crane, Ph. D.	Systems Scientist Frequency Coordinator
Buck Peery	Project Engineer

AVCO Research Laboratory, Haleakala, Maui

Rob Deuel, Ph. D.	Senior Scientist, Atmospheric Characterization

GTE Hawaiian Tel

J. Eric Anthony	Senior Engineer, Transmission Systems
Mary Matsuda	Land & Buildings

James Clerk Maxwell Telescope

Graeme Watt, Ph. D.	Deputy Astronomer in Charge

National Ski Patrol

Thomas Fake	Leader, Mauna Kea Ski Patrol

Ski Association of Hawaii

Terry D. Krutzler	Secretary

B. COORDINATION WITH THE NATIONAL SCIENCE FOUNDATION

The National Science Foundation, Committee on Environmental Matters (NSF), distributed copies of the SEIS Preparation Notice (NOP) to six federal agencies; none responded with comments. A copy of the NSF transmittal letter is reproduced in this section. Agencies receiving NOP's from NSF were:

Advisory Council on Historic Preservation, Washington D.C.
Attention: Don Klima

Environmental Protection Agency
Office of Federal Activities

U.S. Department of Agriculture, Forest Service
Attention: Wildlife and Fisheries

U.S. Department of the Army
U.S. Army Engineering and Housing Support Center

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Attention: David Cottingham

U.S. Department of Interior
Assistant Secretary of Fish & Wildlife & Parks

C. COMMENTS ON THE SEIS PREPARATION NOTICE (NOP)

The SEIS Preparation Notice was officially filed with the State Office of Environmental Quality Control (OEQC) on March 16, 1988; notice of availability was published in the OEQC Bulletin on March 23, 1988. Comments on the NOP were requested on or before April 22, 1988. All comments received up to May 15, 1988 were acknowledged. A total of 24 letters were received; 11 expressed "no comment" and therefore did not require a response. The following agencies, organizations and individuals received copies of the NOP; those identified with asterisks (*) responded. Those with substantive comments are identified by double asterisks (**); these letters, together with the UH Astronomy responses, are reproduced in this section of the SEIS.

Federal Agencies

Advisory Council on Historic Preservation
  Golden, Colorado

U.S. Department of Agriculture
** Soil Conservation Service

U.S. Department of the Army
** Army Engineer District, Hawaii
  HQ Army Support Command, Hawaii

U.S. Department of Commerce
  National Oceanic & Atmospheric Administration
    Mauna Loa Observatory

U.S. Department of the Interior
  Fish and Wildlife Service
  ** Office of Environmental Services
  Geological Survey
  ** Hawaiian Volcano Observatory
  * Water Resources Division
  National Park Service
    Hawaii Volcanoes National Park

State of Hawaii

* Department of Agriculture
* Department of Accounting & General Services
** Department of Budget & Finance
** Department of Business & Economic Development
* Department of Defense
Department of Hawaiian Home Lands
* Department of Health
** Department of Land and Natural Resources
Department of Transportation
Office of Environmental Quality Control
Office of Hawaiian Affairs
Hilo Office
Office of State Planning
University of Hawaii

** President's Office
Board of Regents
Chairperson
Hawaii Island Member
Environmental Center
Institute for Astronomy
UH 88-inch Telescope
NASA Infrared Telescope
Lyon Arboretum
Water Resources Research Center

State Legislature

Senate

President
Senators, Island of Hawaii
Senate Committees
Business Development and Pacific Relations
Planning & Environment
Housing, Hawaiian Programs & Natural Resources

House of Representatives

Speaker
** Representatives, Island of Hawaii
House Committees
Planning, Energy, Ecology & Environ. Protection
Water, Land Use, Development & Hawaiian Affairs

County of Hawaii

- ** Mayor's Office
- Hawaii County Council
  - Chairman's Office
  - Committee on Economic Development
- * Fire Department
- * Parks and Recreation
- Planning Department
- ** Police Department
- Public Works Department
- Research and Development
- ** Water Supply Department

Organizations and Individuals

- Big Island Amateur Radio Club
- California Association For Research in Astronomy
  - W. M. Keck Observatory
- California, France, Hawaii Telescope Corporation (CFHT)
- California Institute of Technology (Caltech) Submillimeter Observatory
- Conservation Council for Hawaii
- ** GTE Hawaiian Tel
- Hamakua District Development Council
- ** Hawaii Audubon Society, Mrs. Mae Mull
- Hawaii Electric Light Company, Inc.
- Hawaii Environmental Land Planning
- Hawaii Island Chamber of Commerce
- Hawaiian Electric Company
- Hilo Chamber of Commerce
- Life of the Land
- Mauna Kea Ski Tours
- Mauna Kea Support Services
- James Clerk Maxwell Telescope
- Power Sogo, Ph. D.
- Sierra Club
- ** Ski Association of Hawaii
- Sportsmen of Hawaii
- United Kingdom Infrared Telescope (UKIRT)
- Frederick Warshauer
- West Hawaii Amateur Radio Society

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

MAR 22 1988

Environmental Protection Agency
Office of Federal Activities
Mailstop A-104
401 M Street, S. W.
Attn. Ken Mittelholt
Washington, DC 20460

Dear Sir or Madam:

Enclosed please find a copy of a document entitled "Environmental Assessment and Notice of Preparation: Supplemental Environmental Impact Statement for Construction and Operation of a VLBA Antenna Facility Within the Mauna Kea Science Reserve" submitted by the Institute for Astronomy of the University of Hawaii for the National Radio Astronomy Observatory (NRAO), a national observatory funded by the National Science Foundation.

NRAO is currently constructing the Very Long Baseline Array, an aperture-synthesis radio telescope with 10 antennas located in the continental United States, the Island of Hawaii, and the U. S. Virgin Islands. The enclosed document refers to siting the antenna on the Island of Hawaii.

I would appreciate receiving written comments on the enclosed document by COB April 15, 1988, for forwarding to the University of Hawaii.

Very truly yours,

\s\

Dr. Julian Shedlovsky, Chair
Committee on Environmental Matters
Directorate for Geosciences, Rm. 641
National Science Foundation
1800 G Street, N. W.
Washington, DC 20550

Enclosure

AST:Oster:WLC:03/22/88:X5079

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

P. O. BOX 50004
HONOLULU, HAWAII
96850

April 18, 1988

Dr. Donald N.B. Hall, Director
University of Hawaii
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, HI 96822

Dear Dr. Hall:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice (EISPN) - Construction and Operation of a Very Long Baseline Array (VLBA) Antenna Facility within the Mauna Kea Science Reserve by the National Radio Astronomy Observatory (NRAO), Hilo, Hawaii

We have no comments to offer at this time, however, we would appreciate the opportunity to review the draft EIS.

Sincerely,

RICHARD N. DUNCAN
State Conservationist

cc:
Ms. Marilynn C. Metz, MCM Planning, 703 Honua Street, Honolulu, HI 96816

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 8, 1988

Richard N. Duncan
State Conservationist
U.S. Department of Agriculture
Soil Conservation Service
P.O. Box 50004
Honolulu, Hawaii 96850

Dear Mr. Duncan:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve

Thank you for reviewing the subject assessment and notice. We look forward to your comments on the draft SEIS.

Yours sincerely,

L. Cowie for D. Hall.

Donald N. B. Hall
Director

DNBH:nll

cc: MCM Planning
C. Wade
William Porter
Dr. Julian Shedlovsky, NSF

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, HONOLULU
BUILDING 230
FT. SHAFTER, HAWAII 96858-5440

REPLY TO
ATTENTION OF:

April 11, 1988

RECEIVED
APR 13 1988
DIRECTOR
INSTITUTE FOR ASTRONOMY

Planning Branch

Dr. Donald N. B. Hall, Director
Institute for Astronomy
University of Hawaii
2680 Woodlawn Drive
Honolulu, Hawaii 96813

Dear Dr. Hall:

Thank you for the opportunity to review the Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice for Construction and Operation of a Very Long Baseline Array (VLBA) Antenna Facility Within the Mauna Kea Science Reserve. The following comments are offered:

a. No work is planned in waters of the U.S. or adjacent wetlands. A Department of the Army permit is therefore not required.

b. According to the Flood Insurance Study for the County of Hawaii, the project site is located in an area outside of the 500-year floodplain (Zone X, unshaded).

Sincerely,

Kisuk Cheung
Chief, Engineering Division

Copy Furnished:

MCM Planning
ATTN: Ms. Marilynn C. Metz
703 Honua Street
Honolulu, Hawaii 96816

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director
June 8, 1988

Mr. Kisuk Cheung, Chief
Engineering Division
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858-5440

Attention: Planning Branch

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve

Thank you for reviewing and commenting on the subject assessment and notice. The information that you provided is noted. We look forward to your comments on the draft SEIS.

Yours sincerely,

Donald N. B. Hall
Director

cc: MCM Planning
C. Wade
William Porter

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 ALA MOANA BOULEVARD
P. O. BOX 50167
HONOLULU, HAWAII 96850

ES
Room 6302

APR 2 1 1988

RECEIVED
APR 22 1988
DIRECTOR
INSTITUTE FOR ASTRONOMY

Dr. Donald N. B. Hall, Director
University of Hawaii
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, Hawaii 96822

Re: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice for Construction and Operation of a Very Long Baseline Array (VLBA) Antenna Facility Within the Mauna Kea Science Reserve by the National Radio Astronomy Observatory (NRAO).

Dear Dr. Hall:

We have reviewed the subject document and find that fish and wildlife resources and issues within our jurisdiction have been adequately identified and will be addressed in future environmental documents prepared for the proposed action. We have no other specific comments to offer at this time.

Thank you for providing us with this opportunity to review this document.

Sincerely,

for
Ernest Kosaka, Field Supervisor
Environmental Services
Pacific Islands Office

cc: RD, FWS, Portland, OR (AFWE)
MCM Planning, Honolulu, HI

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 8, 1988

Mr. Ernest Kosaka, Field Supervisor
Environmental Services, Pacific Islands Office
U.S. Department of the Interior
Fish and Wildlife Service
P.O. Box 50167
Honolulu, Hawaii 96850

Dear Mr. Kosaka:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve

Thank you for reviewing the subject assessment and notice. We look forward to your comments on the draft SEIS.

Yours sincerely,

L.L. Cowie for D.N.B. Hall.

Donald N. B. Hall
Director

DNBH:nll

cc: MCM Planning
C. Wade
William Porter
Dr. Julian Shedlovsky, NSF

RECEIVED

APR 20 1988

DIRECTOR
INSTITUTE FOR ASTRONOMY

United States Department of the Interior

GEOLOGICAL SURVEY

Hawaiian Volcano Observatory
P.O. Box 51
Hawaii National Park
Hawaii 96718

April 18, 1988

University of Hawaii
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, HI 96822
ATTN: Dr. D.N.B. Hall, Director

Dear Dr. Hall:

Thank you for sending me the Environmental Assessment for the proposed VLBA antennae facility within the Mauna Kea Science Reserve. I am happy to review the geological aspects of this E.A. for you, although in the future such requests would be better directed to the Scientist-In-Charge of the Hawaiian Volcano Observatory.

The geological description of the site is concise but adequate, and correctly points out that volcanic hazards are minimal. Although the site is not directly located along or above any fault zone, the presence of loose cinders underlying this area will likely cause amplification of seismic waves from distant sources; structural design should assume the potential for significant ground shaking. Considerable experience in evaluating seismic intensities on Mauna Kea was gained during the November 1983 earthquake and can be used for structural design.

I also note that the Mauna Loa site was rejected for the VLBA facility only because of radio interference (p. 14,b). In fact, the relatively high volcanic hazard in this area was another critical factor which led to rejection of this site.

I feel that the location chosen on Mauna Kea is a good selection in view of the other options evaluated, and find the Environmental Assessment very adequate.

Sincerely,

John P. Lockwood
Geologist

cc: T.L. Wright, HVO Scientist-In-Charge

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 8, 1988

Mr. John P. Lockwood
Geologist
Hawaiian Volcano Observatory
P.O. Box 51
Hawaii National Park
Hawaii, 96718

Dear Mr. Lockwood:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve.

Thank you for reviewing and commenting on the subject assessment and notice. The EA was sent to you personally as a courtesy because of your known interest in the proposed project.

Additional information on the volcanic hazards at the Mauna Loa site will be included in the draft SEIS.

Yours sincerely,

L. Cowie for D. Hall.

Donald N. B.Hall
Director

cc: MCM Planning
C. Wade
William Porter

BF(T)-88.340

JOHN WAIHEE
GOVERNOR

EMPLOYEES' RETIREMENT SYSTEM
HAWAII PUBLIC EMPLOYEES HEALTH FUND
OFFICE OF THE PUBLIC DEFENDER
PUBLIC UTILITIES COMMISSION

STATE OF HAWAII
DEPARTMENT OF BUDGET AND FINANCE
STATE CAPITOL
P.O. BOX 150
HONOLULU, HAWAII 96810-0150

YUKIO TAKEMOTO
DIRECTOR

ROBERT P. TAKUSHI
DEPUTY DIRECTOR

THOMAS I. YAMASHIRO
DEPUTY DIRECTOR

DIVISIONS:
BUDGET, PLANNING AND MANAGEMENT
ELECTRONIC DATA PROCESSING
FINANCE
TELECOMMUNICATIONS

April 20, 1988

RECEIVED
MAY 4 1988
DIRECTOR
INSTITUTE FOR ASTRONOMY

MEMORANDUM

TO: Donald N. B. Hall, Director
University of Hawaii
Institute for Astronomy

FROM: Director of Finance

SUBJECT: ENVIRONMENTAL ASSESSMENT AND NOTICE OF PREPARATION: SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR CONSTRUCTION AND OPERATIONS OF A VERY LONG BASELINE ARRAY (VLBA) ANTENNA FACILITY AT MAUNA KEA

Thank you for the opportunity to comment on the subject environmental assessment and the Notice of Preparation of a Supplemental Environmental Impact Statement (SEIS).

For your information, the State, through the Hawaii Public Broadcasting Authority, Department of Commerce and Consumer Affairs, will be installing a 6 GHz microwave system at Humuula (sheep station) at approximately the 7500 foot elevation on the Mauna Kea Access Road. Currently, the Hawaiian Telephone Company, Hawaiian Electric Company, Comtec, and Telnet are all located at the Humuula site. We also understand that you are planning a microwave system from Hale Pohaku to Mauna Loa for data transmission.

Considering existing and future radio systems to be installed in an area approximately 2 through 4 miles from the proposed VLBA site, a thorough discussion of radio frequency interference should be included in the SEIS to insure that the present and planned microwave systems will not interfere with the millimeter-wave telescope (300 GHz). If for example, your microwave link to Mauna Loa would cause RF interference with the National Radio Astronomy Observatory's VLBA, an alternate solution must be identified and funds budgeted to implement that solution. Another question raised is whether VHF or UHF radios will interfere with the VLBA since these radios are omnidirectional.

While we support the research opportunities that Mauna Kea offers the international astronomy community, it is imperative that the consultant review and analyze all known or planned radio systems, as well as the physical environment, to determine the impact and sensitiveness of radio frequency interference. By doing this, the consultant can develop mitigating solutions to identified problems, thereby alleviating future conflicts.

Once again, thank you for the opportunity to comment on the subject project. Please feel free to call Mr. Ernest Shima at 548-2104 if you or your staff have further questions in regard to this matter.

YUKIO TAKEMOTO

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 16, 1988

Mr. Yukio Takemoto
Department of Budget and Finance
State Capitol
P.O. Box 150
Honolulu, Hawaii 96810-0150

Dear Mr. Takemoto:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice - Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve.

Thank you for reviewing the subject notice and sending Mr. Shima of your staff to a briefing on the VLBA project at the BLNR boardroom on June 2, 1988. We hope that we were able to alleviate some of your Department's concerns. In response to your specific comments:

1. The proposed 6GHz microwave system at Humuula should not effect the VLBA operations. Cinder cones located to the south of the VLBA site will shield the antenna from the Humuula electronics station. In addition, the frequencies you propose to use would not generate a level of radio frequency interference (RFI) harmful to the VLBA.

2. The University of Hawaii microwave link to Mauna Loa is being reconsidered. If such a link is established, it will be designed so that it does not cause RFI which would be harmful to the VLBA.

3. Recent studies indicate that radio communication emitters at the kilowatt or lower EIRP level, such as VHF and UHF radios, create little harmful RFI at the VLBA site.

4. NRAO has analyzed existing and proposed radio systems that might affect the VLBA. The facility site was selected because surrounding terrain will shield the antenna from harmful RFI sources.

We appreciate your thoughtful comments and we look forward to your review of the draft SEIS.

Yours sincerely,

Donald N. B. Hall
Director

DNBH:jec

cc: MCM Planning
NRAO:
W. Porter
C. Wade

JOHN WAIHEE
GOVERNOR
ROGER A. ULVELING
DIRECTOR
BARBARA KIM STANTON
DEPUTY DIRECTOR
LESLIE S. MATSUBARA
DEPUTY DIRECTOR

DEPARTMENT OF BUSINESS AND ECONOMIC DEVELOPMENT

KAMAMALU BUILDING, 250 SOUTH KING ST., HONOLULU, HAWAII
MAILING ADDRESS: P.O. BOX 2359, HONOLULU, HAWAII 96804 TELEX: 7430250 HIDPED

April 19, 1988

RECEIVED
APR 2 6 1988
DIRECTOR
INSTITUTE FOR ASTRONOMY

MEMORANDUM

TO: Dr. Donald N. B. Hall, Director
University of Hawaii, Institute for Astronomy

FROM: Roger A. Ulveling

SUBJECT: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -- Construction and Operation of a Very Long Baseline Array (VLBA) Antenna Facility within the Mauna Kea Science Reserve by the National Radio Astronomy Observatory (NRAO), Mauna Kea, Hamakua, Island of Hawaii.

We have reviewed the subject Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice. It is our understanding that the VLBA antenna facility has entirely different siting requirements from the telescopes in operation at the summit which has resulted in the need for an assessment of a totally new site between the 12,200 and 12,400-foot elevation on Mauna Kea. Due to unforeseen advances in technology, the proposed location of this site for the antenna was not assessed in the University of Hawaii Mauna Kea Science Reserve Complex Development Plan (SRCDP) or the original EIS for the Plan.

Siting criteria includes a clear eastern horizon, low radio frequency interference, and an elevation of approximately 12,000 feet to avoid wind, snow and ice loading on the structure.

Based on our review of the proposed VLBA facility, we find no apparent areas of State concern and have no comments to offer.

We appreciate being notified of the subject proposal and this opportunity to provide comments.

Roger A. Ulveling

cc: MCM Planning
Mr. Harold S. Masumoto

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 8, 1988

Mr. Roger A. Ulveling, Director
Department of Business and Economic Development
P.O. Box 235
Honolulu, Hawaii 96804

Dear Mr. Ulveling:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve

Thank you for reviewing the subject assessment and notice. We look forward to your comments on the draft SEIS.

Yours sincerely,

Donald N. B. Hall
Director

DNBH:nll

cc: MCM Planning
C. Wade
William Porter

RECEIVED

APR 26 1988

DIRECTOR
INSTITUTE FOR ASTRONOMY

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

LIBERT K. LANDGRAF
DEPUTY

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND ENVIRONMENTAL AFFAIRS
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

APR 25 1988

DOC. NO.: 3226E
FILE NO.: 88-427

University of Hawaii
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, Hawaii 96822
Attn: Dr. Donald N. B. Hall, Director

Dear Dr. Hall:

SUBJECT: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice-Very Long Baseline Array, Mauna Kea

We have reviewed the document cited above and have the following comments to offer you.

The proposed VLBA appears to be incompatible with radio transmitters and related appurtenances. We are concerned that this will affect the future use of Mauna Kea and will effectively exclude all others that are "incompatible."

The major concern is the stated need for "minimum radio interference". Despite the statement on page 14 to the contrary, the Division of Forestry and Wildlife presently has a two-way radio repeater on the summit of Mauna Kea (100 watts). It is one of our key repeaters, servicing much of Hawaii, and also some of Eastern Maui. It is also our main radio link to the Big Island. The University of Hawaii has tried in the past to get us to relocate this repeater, but we have not been able to find a site that gives us similar performance. As this radio link serves a public welfare and safety purpose (fires, search and rescue, and employee safety) relocating our repeater is not negotiable. Therefore, conditions we would requre are:

1. The present 2-way radio equipment of the Department of Land and Natural Resources remain on Mauna Kea and not be compromised in any way.

2. That the rights for future development of State telecommunications on the summit of Mauna Kea in the interests of public safety be reserved.

APR 2 5 1988

This facility should not preclude other radio emissions within a 20-mile radius. This would effectively allow the influence of astronomy to encompass much more than the Mauna Kea Science Reserve. The U.S. Army at Pohakuloa may object to this also.

Other comments include:

Page 10. If it is determined that petrel inhabit the area, then lights should be placed on top of the towers to alert night flyers.

Page 12. Cesspools should not be acceptable with the increased activity on Mauna Kea. Portable "luas" should be used.

Page 14.(d) In the interest of aesthetics having the facility visible from the summit road is better than from Hilo. A roadway of approximately 1/2 mile wouldn't be necessary if the facility was closer to the existing roadways.

Page 25. G Any areas to be posted as safety zones or no hunting areas should be identified and posted by the University of Hawaii.

Furthermore, the project may possibly provide more undesirable opportunity for illegal vehicular joy-riding. Regarding the latter, the report comments erroneously on "existing jeep trails". The only legal roads are the summit access road and the transmission easement road (which is closed to the public) next to the summit road. Off-road vehicle trespass, causing erosion and leaving unsightly scars, is the most serious and most often occurring violation in the Mauna Kea Ice Age Natural Area Reserve. The impact on aesthetic quality and how off-road driving will be prevented are concerns that should be properly addressed in the EIS.

Thank you for the opportunity to comment on this project.

Very truly yours,

Bill

WILLIAM W. PATY, Chairperson
Board of Land and Natural Resources

cc: MCM Planning

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 16, 1988

Mr. William W. Paty, Chairperson
Board of Land and Natural Resources
P.O. Box 621
Honolulu, Hawaii 96809

Dear Mr. Paty:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice - Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve.

Thank you for reviewing the subject assessment and for allowing us to brief members of your staff about the VLBA project on June 2, 1988. In response to your specific comments:

1. Transmitters on the summit of Mauna Kea would not affect the operations of the VLBA unless they are directed toward the antenna. These emitters are, however, beginning to interfere with observing activities of the optical telescopes in the area. Although the University recognizes that Mauna Kea is a premier site for telecommunications as well as astronomy, the two activities are not compatible.

   The University leased 13,000 acres from BLNR (S-4191) for the Mauna Kea Science Reserve so that there would be a buffer zone adequate to prevent the intrusion of

   activities inimical to observatory operations at the summit. Activities defined in the lease as being "inimical to the scientific complex" include light and dust interference to observatory operation and certain types of electric or electronic installations.

The Institute for Astronomy (IFA) has received many proposals to install new or upgrade old transmitters at the summit; some of these requests have come from astronomy users themselves. It is the policy of IFA to reject all such proposals because they are inimical to the scientific complex within the Science Reserve.

In the context of our mission to preserve the qualities of the Science Reserve, so that Mauna Kea remains the premier site for ground-based astronomy in this hemisphere, we have asked your Department to find an alternative location for the Forestry and Wildlife repeater on the summit. IFA promises to do everything possible to assist you in this endeavor so that an amicable solution to this potential problem can be found. We assure you that no new transmitters of any kind will be allowed in the Science Reserve.

2. The VLBA will not be affected by radio emissions from known sources on the island of Hawaii. The antenna site was selected because it is shielded from these sources by cinder cones.

3. No Petrels were found during avian surveys of the project area. These surveys will be described in detail in the draft SEIS.

4. Wastewater discharge is estimated to be 100 gallons per day. Because it is unlikely that wastewater will percolate beyond the immediate site area, a cesspool is being considered for the facility. There are no known springs downslope from the site. The depth to ground water is unknown, but is expected to be hundreds or thousands of feet. The antenna site is very isolated, roughly two miles from and 3,000 feet higher than Hale Pohaku, the closest development downslope. There will be no cumulative effect of wastewater seepage from the VLBA facility and the telescopes at the summit. In addition, Lake Waiau is roughly 1,000 feet higher than the site and about 10,000 feet to the northwest, so could not be affected by wastewater seepage from a cesspool located at the 12,200-foot elevation. Wastewater discharge will be addressed in the draft SEIS.

5. The antenna will not be visible from Hilo. A visibility analysis will be incorporated into the draft SEIS. A site closer to the road was evaluated during the site selection process. We agree that it would have been more suitable from the standpoint of amount of land disturbed and construction and maintenance costs, however, the site was in direct line-of-site to transmitters on Mauna Loa which could generate potentially harmful radio frequency interference.

6. The University of Hawaii, in cooperation and coordination with your Department, will identify and post safety zones and no hunting areas required by the presence of the VLBA facility.

7. We are also concerned that the project may possibly provide more undesirable opportunities for illegal vehicular joy-riding. We recognize the problems caused by off-road vehicle trespass. At present, NRAO plans to post signs along the road warning that off-road driving is illegal. Violators will be warned; if they do not cease their illegal activity, the proper authorities will be called (either DLNR Division of Enforcement of the Hawaii County Police). This concern will be addressed in the SEIS.

We look forward to your review of the draft SEIS.

Yours sincerely,

Donald N. ~~B. Hall~~
Director

DNBH:jec

cc: MCM Planning
NRAO:
C. Wade
W. Porter

RECEIVED

APR 22 1988

DIRECTOR
INSTITUTE FOR ASTRONOMY

UNIVERSITY OF HAWAII

Vice President for Finance and Operations

April 21, 1988

MEMORANDUM

TO: Donald N. B. Hall
Director, Institute for Astronomy

FROM: Ralph T. Horii, Jr.
Vice President for Finance and Operations

SUBJECT: Very Long Baseline Array (VLBA) Antenna Facility

The proposed National Radio Astronomy Observatory (NRAO) antenna installation requires an amendment to the Complex Development Plan (CDP). The proposed Supplemental Environmental Impact Statement (SEIS) indicates that the CDP would be revised after the antenna siting location is approved by the Department of Land and Natural Resources (DLNR).

Proper sequence would have the matter: 1) addressed in a revised CDP, 2) approved by the Board of Regents (BOR), then 3) DLNR's approval.

The proposed SEIS would still require the amended CDP for BOR's review, and the proposed agreement with NRAO would also be needed.

The SEIS should also explore the following items:

1. In the event that endangered flora and fauna are found, what measures will be taken?

2. What will be the effects of thermal and discharge pollutants from the emergency generator on the existing observatory sites?

3. The visibility analysis should be explored beyond the summit site.

2444 Dole Street • Honolulu, Hawaii 96822 / Cable Address: UNIHAW

4. Present CDP plans include provisions for microwave and satellite communication dishes. What impact would such installations have on the NRAO facility?

Please call Michael Yoneda, Director of Facilities Management Office, at ext. 8961 if there are any questions on this matter.

cc: Marilynn C. Metz, MCM Planning
Allan Ah San
Michael Yoneda

University of Hawaii at Manoa

Institute for Astronomy

MEMORANDUM

June 16, 1988

TO: Ralph T. Horii, Jr.
Vice President for Finance and Operations

FROM: Donald N. B. Hall, Director
Institute for Astronomy

SUBJECT: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve

Thank you for reviewing the subject assessment and notice. In response to your specific comments:

CDP AMENDMENT

The Mauna Kea Science Reserve Complex Development Plan (SRCDP) did not address amendments. The amendment process described in the subject NOP was developed in 1985 in order to incorporate housing for construction workers at Hale Pohaku into the plan. I would be happy to discuss an alternative process with you at your convenience. The SEIS will, however, emphasize that amending the SRCDP is an essential component of the action being assessed.

It is the present policy of IFA to recommend rejection of proposals for new transmitters at the summit of Mauna Kea. Existing transmitters will be removed as soon as alternative locations are found. We intend to amend the CDP to remove the provision allowing microwave and satellite communication dishes.

OTHER CONCERNS

The SEIS will address mitigating measures for any endangered flora or fauna on the site and the visibility of the antenna from Hilo, Puna, Mauna Loa and the Saddle Road. In regard to emergency generators, each telescope within the Science Reserve has such a generator in order to insure that operations can be efficiently shut down in the event that the commercial power fails. The emergency generator will not be used for ongoing operations.

We look forward to your comments on the draft SEIS.

DNBH:jec

cc: MCM Planning
NRAO:
C. Wade
W. Porter

HOUSE OF REPRESENTATIVES
THE FOURTEENTH LEGISLATURE

STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

April 26, 1988

RECEIVED

APR 29 1988

DIRECTOR
INSTITUTE FOR ASTRONOMY

Donald N.B. Hall, Ph.D.
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, HI 96822

Dear Dr. Hall:

Upon reviewing the environmental assessment for the proposed Very Long Baseline Array (VLBA), I have the following concerns:

First, it is my understanding that there is an ancient Hawaiian "shrine" complex in the area--if so, this should not be disturbed as it is important historically. It is also possible that this Scientific area overlaps the Natural Area Reserve System (NARS) and that would need to be addressed.

Second, I believe the SEIS should reflect the impact to the area as a result of the construction. Since the ecosystem at this elevation is fragile and the habitat for the endemic dark-rumped petrel, unique arthropods and high altitude plant life, there could be a negative impact from off-road travel and accidentally-introduced species.

Third, what will be the follow-up monitoring of the surrounding environment? There should be some comparative study of the area once the station is operational.

I request that these concerns be addressed in the SEIS.

Sincerely,

Virginia

Virginia Isbell
State Representative - Kona

EVI:ds

cc: Dr. C.M. Wade
Nat'l Radio Astronomy Observatory

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 8, 1988

Honorable Virginia Isbell
State Representative - Kona
State Capitol - Room 427
Honolulu, Hawaii 96813

Dear Representative Isbell:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve

Thank you for reviewing and commenting on the subject assessment and notice. Your concerns about historical/ archaeological sites, preservation of fragile eco-systems, impacts from off-road travel and accidentally introduced species and follow-up monitoring will be addressed in the SEIS.

We look forward to your review of the draft SEIS.

Yours sincerely,

L. C. Cowie for D.N.B. Hall.

Donald N. B. Hall
Director

DNBH:nll

cc: MCM Planning
C. Wade
W. Porter

HOUSE OF REPRESENTATIVES
THE FOURTEENTH LEGISLATURE

STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

May 3, 1988

RECEIVED
MAY 16 1988
DIRECTOR
INSTITUTE FOR ASTRONOMY

Dr. Donald N.B. Hall, Director
INSTITUTE FOR ASTRONOMY
2680 Woodlawn Drive
Honolulu, Hawaii 96822

Dear Don:

It is my understanding that you have received expressions of concern from the Hawaii Audubon Society with respect to a proposal to build a VLBA Antenna Facility on Mauna kea.

I know you will give this matter your serious attention, and I would like to be kept informed. I would appreciate receiving a copy of any response you send to the Audubon Society as well as any additional information which you think might be of value to me.

Very truly yours,

[signature]

ANDREW LEVIN
State Representative
First District of Hawaii

AL:sr

cc: Mae E. Mull

HOUSE OF REPRESENTATIVES
THE FOURTEENTH LEGISLATURE

STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

March 28, 1988

Dr. Donald N. B. Hall
Institute for Astronomy
University of Hawaii at Manoa
2680 Woodlawn Drive
Honolulu, HI 96822

Dear Dr. Hall:

This is to acknowledge the receipt of your letter dated March 23, 1988 transmitting a copy of the Environmental Assessment and Notice of Preparation of a Supplemental Environmental Impact Statement.

Thank you for providing me with this useful reference source.

Please be advised, however, that at this time I wish to reserve comment on the subject.

With warm personal regards.

Sincerely,

WAYNE METCALF
Chairman
House Committee on Judiciary

WM:mn

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 8, 1988

Honorable Wayne Metcalf
House of Representatives
State of Hawaii
State Capitol
Honolulu, Hawaii 96813

Dear Representative Metcalf:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve

Thank you for reviewing the subject assessment and notice. We look forward to your comments on the draft SEIS.

Yours sincerely,

L. Cowie for D. Hall.

Donald N. B. Hall
Director

DNBH:nll

cc: MCM Planning
C. Wade
William Porter

xc: ...

RECEIVED

APR 13 1988

DIRECTOR
INSTITUTE FOR ASTRONOMY

Office of the Mayor

Dante K. Carpenter
Mayor

April 7, 1988

Dr. Donald N.B. Hall, Director
University of Hawaii
Institute of Astronomy
2680 Woodlawn Drive
Honolulu, HI 96822

Dear Dr. Hall:

Re: National Radio Astronomy Observatory
Very Long Baseline Array (VLBA) Telescope
Environmental Impact Statement Preparation Notice (EISPN)

Thank you for including the Planning Director and myself as consulted parties in the review of this EISPN. We are certainly intrigued with the technology required to make these astronomical observations.

We note that a key to selecting the proposed site is a clear eastern horizon with minimum radio frequency interference and that several alternative sites were rejected on the basis of potential radio interference. Your Supplemental EIS should describe the existing and projected levels of radio interference. Since our Police and Fire Departments as well as our local utilities use relay stations within 20 miles of your proposed site, the Supplemental EIS needs to discuss the conditions above which all operations would be compromised.

We look forward to reviewing the Supplemental EIS.

Sincerely,

DANTE K. CARPENTER
Mayor

RKN:lv

cc: Planning Director
Police Department
Fire Department

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 18, 1968

The Honorable Dante Carpenter
Mayor, County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mayor Carpenter:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice - Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve.

Thank you for reviewing and commenting on the subject assessment and notice. The VLBA site was selected because it is protected from radio emissions by two cinder cones. Because there is no direct line-of-sight to Hilo from the antenna site, it is unlikely that the agencies and organizations mentioned in your letter will be affected. The supplemental EIS will address your concerns.

We look forward to your review of the draft SEIS.

Yours sincerely,

Donald N. B. Hall
Director

DNBH:jec

cc: MCM Planning
NRAO:
C. Wade
W. Porter

✓

POLICE DEPARTMENT

COUNTY OF HAWAII
349 KAPIOLANI STREET
HILO, HAWAII 96720

RECEIVED
APR 4 1988
DIRECTOR
INSTITUTE FOR ASTRONOMY

GUY A. PAUL
CHIEF OF POLICE

WAYNE G. CARVALHO
DEPUTY CHIEF

OUR REFERENCE

YOUR REFERENCE

March 30, 1988

Dr. Donald N. B. Hall, Director
University of Hawaii
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, Hawaii 96822

The construction and operation of the VLBA antenna facility within the Mauna Kea Science Reserve by the National Radio Astronomy Observatory (NRAO) will not affect police radio communications. We express concerns, however, regarding the possibility of police transmission causing interference with the VLBA antenna.

Your reply to the following questions will satisfy our concerns and eliminate unforeseen conflicts in the future.

1. Were in-depth studies and measurements made to ensure that any interference from the radio communications stations operating within a 25-mile radius of the selected site will be negligible?

2. Does NRAO assure us that after the facility is in operation, NRAO will not tell us to modify our communications stations because they find that the interference level is too high?

We appreciate the opportunity to comment on this EA and look forward to your response.

Guy A. Paul
GUY A. PAUL
CHIEF OF POLICE

RM:amy

cc: Marilynn Metz
MCM Planning

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 16, 1988

Mr. Guy A. Paul
Chief of Police
County of Hawaii
344 Kapiolani Street
Hilo, Hawaii 96720

Dear Chief Paul:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice - Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve.

Thank you for reviewing and commenting on the subject assessment and notice. In response to your concerns:

A new radio astronomical observing site and antenna must operate within the radio spectral environment existing at the time of construction. The radio environment includes all radio communication and broadcast emissions authorized by Federal Communications Commission (FCC) Regulations and by National Telecommunications and Information Administration (NTIA) Regulations. Recent studies indicate that radio communication emitters (such as police) at the kilowatt or lower EIRP level, and at current electronic sites, create little harmful radio frequency interference at the VLBA site. In addition, the primary reason this particular antenna site was selected is because it is shielded from potentially harmful radio emission sources by two cinder cones.

Mr. Guy A. Paul
June 16, 1988
Page 2

We look forward to your comments on the draft SEIS.

Yours sincerely,

Donald N. B. Hall
Director

DNBH:jec

cc: MCM Planning
NRAO:
C. Wade
W. Porter
D.Carpenter
H. W. Sewake

DEPARTMENT OF WATER SUPPLY • COUNTY OF HAWAII
25 AUPUNI STREET • HILO, HAWAII 96720

April 27, 1988

RECEIVED
MAY 2 1988
DIRECTOR
INSTITUTE FOR ASTRONOMY

University of Hawaii
Institute for Astronomy
ATTENTION: DR. DONALD N. B. HALL
DIRECTOR
2680 Woodlawn Drive
Honolulu, HI 96822

ENVIRONMENTAL ASSESSMENT AND SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT PREPARATION NOTICE - CONSTRUCTION AND OPERATION OF A VERY LONG BASELINE ARRAY (VLBA) ANTENNA FACILITY WITHIN THE MAUNA KEA SCIENCE RESERVE BY THE NATIONAL RADIO ASTRONOMY OBSERVATORY (NRAO)

Thank you for the opportunity to review the subject report.

Because the Department of Water Supply does not have a technical radio section, we requested assistance on this matter from the Radio Section of the Hawaii County Police Department.

We agree with their comments whereby we feel the proposed installation will not affect our radio communication system; however, we feel that a study should be made on whether our radio communication system will affect your proposed operations.

William Sewake
H. William Sewake
Manager

KO

cc - MCM Planning

... Water brings progress...

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 16, 1988

Mr. H. William Sewake, Manager
County of Hawaii
Department of Water Supply
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Sewake:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice - Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve.

Thank you for reviewing and commenting on the subject assessment and notice. We are attaching a copy of our letter to Mr. Guy Paul, Chief of Police. We hope that it also responds to your concerns.

Yours sincerely,

Donald N. B. Hall
Director

DNBH:jec
Att.

cc: MCM Planning
NRAO:
C. Wade
W. Porter
G. Paul

GTE Hawaiian Tel

P O Box 2200
Honolulu, Hawaii 96841
Telephone (808) 546-4511

MAY -6 1988

RECEIVED

MAY 10 1988

DIRECTOR
INSTITUTE FOR ASTRONOMY

University of Hawaii
Institute of Astronomy
2680 Woodlawn Drive
Honolulu, Hawaii 96822

Attention: Dr. Donald N. B. Hall
Director

Gentlemen:

Environmental Assessment and Supplemental
Environmental Impact Statement Preparation Notice —
Construction and Operation of
(Very Long Base Array) VLBA Antenna Facility
Within the Mauna Kea Science Reserve

Eric Anthony of our Transmission Systems Engineering Section, has had discussions with Campbell Wade, a scientist with National Radio Astronomy Observatory (NROA), and was informed that the proposed facility is a Receive Only antenna. There is no potential for interference into our microwave facilities.

It should be noted that we discovered three of twelve frequency bands which they will be working with are common carrier bands (2.15 - 2.35 GHz, 5.9 - 6.4 GHz, and 10.2 - 11.2 GHz). This was mentioned to C. Wade during the discussions. He, however, has assured us that there is no line-of-sight path from our microwave facility to the proposed antenna location. Furthermore, he is aware that the microwave equipment which HTC uses is highly stable and is not a potential source of interference into his receivers. He also mentioned that they have a facility on the mainland which is in close proximity to an ATT facility and an MCI facility, and they have no problems with the co-existence of all these facilities.

Engineering recommends that the NRAO carry out a study, before the construction of the facility, to determine, if indeed, there is no line-of-sight path from their proposed antenna location to our facilities. This precautionary step will ensure both parties that there will be no future microwave interference problems between HTC and the NRAO. We will be prepared to assist in the study to ensure its accuracy.

Should you have any questions, please call me at 546-2688.

Sincerely,

GTE HAWAIIAN TELEPHONE COMPANY
INCORPORATED

F. Chang

Frank C. K. Chang
Engineering Manager
Land & Buildings

cc: MCM Planning
Attn: Ms. Marilyn C. Metz
703 Honua Street
Honolulu, Hawaii 96816

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 16, 1988

Mr. Frank C.K. Chang
Engineering Manager
Land and Buildings
Hawaiian Telephone Company
P.O. Box 2200
Honolulu, Hawaii 96841

Dear Mr. Chang:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice - Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve.

Thank you for reviewing and commenting on the subject assessment and notice. NRAO has selected a site at the 12,200-foot elevation for the VLBA. This site is shielded from transmitters on Mauna Loa by two cinder cones. In addition, there is no line-of-sight from the antenna to Hilo. Dr. Campbell Wade and Dr. Patrick Crane from NRAO met with members of your staff on June 2, 1988. I hope that they were able to assuage your concerns.

We look forward to your review of the draft SEIS.

Yours sincerely,

Donald N. B. Hall
Director

DNBH:jec

cc: MCM Planning
NRAO:
C. Wade
W. Porter

For the Protection of Hawaii's Native Wildlife

HAWAII AUDUBON SOCIETY

P.O. BOX 22832
HONOLULU, HAWAII 96822

P. O. Box 275
Volcano, HI 96785

April 21, 1988

RECEIVED

APR 25 1988

DIRECTOR
INSTITUTE FOR ASTRONOMY

Dr. Donald N. B. Hall, Director
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, HI 96822

Re: Supplemental Environmental Impact Statement for the Construction and Operation of a Very Long Baseline Array (VLBA) Antenna Facility Within the Mauna Kea Science Reserve, Mauna Kea, Hamakua, Island of Hawaii, to be prepared by the Institute for Astronomy, University of Hawaii

Dear Dr. Hall:

Thank you for sending the EIS Preparation Notice and soliciting the Society's comments on the proposed new radio telescope. Audubon concerns involve the increased negative impacts on the highly fragile and vulnerable aeolian ecosystem in the summit region — already degraded or destroyed in part by construction, roads and powerlines for the nine existing telescopes.

Entomologists F. G. Howarth and F. D. Stone made a signal contribution to Hawaiian biology with their 1982 report, "An Assessment of the Arthropod Fauna and Aeolian Ecosystem Near the Summit of Mauna Kea, Hawaii," 18 pp., that was published in the EIS for the Mauna Kea Science Reserve Complex Development Plan. They found seventeen species of resident arthropods in this remarkable high-elevation aeolian ecosystem. What is astonishing is that in this newly recognized ecosystem at least eleven of these invertebrate species turned out to be new to science!

These newly discovered Hawaiian animals that adapted to a wind-swept environment of snow, tephra cinders and slopes, lava flows and talus slopes include such creatures as predatory "seed" bugs, moths, several kinds of spiders, springtails, centipedes and mites. These endemic animals evolved in Hawaii and occur nowhere else.

Mauna Kea's oceanic aeolian ecosystem far above treeline has scarcely been studied by scientists, and most of those small animals without backbones have yet to be described. There may be more species awaiting discovery. It is essential that astronomers and construction crews know of the existence of this marvelous ecosystem where they work, and that they take precautions not to destroy or degrade this unusual habitat through ignorance or carelessness.

In their report, Drs. Howarth and Stone described the destructive impacts of off-road vehicle use and road construction on the fragile summit habitats. The heavy off-road traffic needlessly destroyed ideal habitat for some of these uncommon animals. Howarth and Stone made eleven carefully reasoned recommendations for environmental protection of summit habitats. They are attached here.

We request that you adopt an environmental protection plan that encompasses these eleven recommendations, so that Hawaii's rare aeolian ecosystem is properly recognized and maintained by all who visit or work in the Mauna Kea Science Reserve.

We welcome your reply to the issues raised here.

Sincerely yours,
Mae E. Mull
Mae E. Mull
Island of Hawaii Representative

encl.

principal habitat of the moth Archanarta new species, (fide Riotte, pers. comm.) the larva of which feeds on foliose lichens. The spider, Lycosa species, and the centipede, Lithobius species, are also most common in this habitat. The most diverse habitat in terms of number of resident species near the summit appears to be in the ash and loess and under stones at the base of these lava cliffs. The centipede burrows in the silt and aeolian debris in the cracks and under rocks. The Wekiu bug appears to be relatively rare in much of this habitat, presumably because of the rarity of suitable microclimate and the lower surface area within the cracks and voids of the rocks.

5) Talus slopes and highly fractured rock outcrops: This habitat is a special subdivision of no. 4 and usually occurs as islands within no. 4. It combines several environmentally favorable features of both no. 2 and no. 4, and often supports greater diversity. The greater number of smaller voids with the large underground surface area adjacent to stable rocks provide favorable microclimates for arthropods and plants. The Wekiu bug population is locally moderately high. Also included in this category are many of the depressions between the lava flows on the north and west slopes where glacially deposited rounded cobbles and rocks lie on fine loess. This material has been sortd by frost and wind so that the larger rocks lay on the surface with smaller material neatly graded in layers below. Where the rocky layers are shallow, the habitat intergrades with no. 6.

6) Compacted ash, silt, and mud: This habitat is found on roadways, disturbed areas, and in areas where fine aeolian debris (loess) has accumulated. The interstitial voids are mostly filled with fine-grained material and are, therefore, no longer suitable habitat for the Wekiu bug and spiders. Some of the springtails and mites were found in this habitat, and the centipede was rarely found here. In general, species diversity was low. The inside slopes of Poliahu, which contain fine loess substrate, are included here.

Impacts of off-road vehicle use and road construction

Several segments of new roadways totalling about one kilometer were established mostly by tire tracks (legally?) within the project area during June, July, and August, 1982, by skiers,astronomers, and other visitors. Most of this recent activity occurred on the plateau betweeen Poliahu and Puu Wekiu and was done in an effort to gain access across the snow fields to the proposed telescope sites and the north slope. These tracks are new alignments of an existing road, which crosses the plateau and which was buried under snow. The relatively heavy traffic on these tracks by off-road vehicles to date has created in many places well-defined dirt roads paralleling the existing roadway and permanently defacing the landscape. A shorter track about 200 metres long was made between 12 July and 10 August, 1982, by a vehicle driving out onto the west rim of Puu Wekiu south of the Air Force telescope. The vehicle crossed once ideal bug habitat and destroyed one of our pitfall traps.

The tephra cinders are easily crushed to dust-sized particles, and vehicular traffic quickly and permanently changes the character of rocky tephra habitats to compacted silt and mud. Furthermore, this crushed silty tephra, when dry, becomes the dust which is detrimental to telescope viewing, plant growth, and animal dispersal. Besides the dust problem, the roads restrict the percolation of water, and, therefore, roadways become channels for drainage of surface water, which greatly increase erosion, especially on the steeper slopes. Significant erosional gullies are now forming along the summit road to Puu Wekiu telescope sites.

RECOMMENDATIONS

1) In view of the above impacts of road construction, it is recommended that off-road vehicle use be prohibited or severely restricted and that new road alignments be carefully planned and kept to a minimum size and length.

2) There is an oil spill covering about 18 sq. meters. and originating from the generator at the base of Puu Wekiu. In this cold, dry, environment, such oil spills will remain a very long time and be highly damaging to life, especially when this oil is tracked over the summit area by hikers, skiers, and off-road vehicles. It is strongly recommended that oil spills be prevented and any that do occur be expeditiously cleaned up.

3) Sensitive areas: Even though all the animal species found living within the project area appear to be widely distributed on the summit, for some species the major populations occur only in relatively limited areas within the project area. Thus, proper planning of construction activities and monitoring their impacts are essential for their continued survival. Monitoring should include one or more site visits by a biologists during construction and a limited biological survey that assesses the resultant impacts after completion in order to develop additional mitigative measures. The special vulnerability of the Tephra habitats are given below.

4) The distribution and biology of the Wekiu bug and its close relationship with the tephra cinder cones are now more clear. Unfortunately, these tephra habitats are particularly vulnerable to degradation by human activities. These tephra habitats quickly and permanently degrade to compact silty habitats during construction activities and

become unsuitable as a habitat for the Wekiu bug, the spiders, and some of the mites and springtails. Therefore, mitigative measures, and monitoring of the impacts should be required for any construction activities in this habitat, particularly near the three craters on Puu Hau Oki and Puu Wekiu. Monitoring recommendations are given above in no. 3. Mitigative measures should include (1) keeping all construction activities within the mininum possible defined area, (2) preventing cinders or debris from falling downslope on the cones, (3) preventing wind dispersal of trash and material outside of construction area, (4) keeping new road alignments to minimum size and length with no unnecessary vehicle movement or grading activity off the designated alignment, (5) cleaning up oil spills and other pollutants promptly and removing them from the mountain, not just burying them, and (6) minimizing disturbance to sensitive areas, such as the inside slopes of the cinder craters on Puu Wekiu and Puu Hau Oki. It was understood that the summit of Puu Wekiu, at least, is not slated for telescope development, but the new vehicle track there points to the necessity for a more formal management plan with enforcement power.

5) The lava flows on the north and west slopes are more problematical. It is more difficult to inventory the species present in this environment, and some additional new or undetected species may be expected there. On the other hand, except for the dust and pollution problems, this habitat appears to be less vulnerable to human impacts than are the tephra cinder cones. It is strongly recommended that further site specific surveys be done in the lava flow areas, particularly the shelter cave areas on the western slope, if they are selected as potential telescope sites.

6) Because of the strongly seasonal nature of the environment near the summit, a longer term study will be needed to answer some management questions. The baseline data on the distribution and biology of many of the resident animals are now available to assess the impacts of future construction activities; however, monitoring, as outlined above, the impacts should be required for future construction projects.

7) Debris from construction and existing facilities must not be allowed to litter the mountain top. In addition to being an eyesore such materials may contain compounds toxic to arthropods. Construction materials, equipment, and debris should be kept on site or removed from the mountain.

8) Vehicles should not park with the motors running, in order to reduce lead and other toxic emissions into this environment.

9) Agencies importing components for the observatories

should ensure that the packing material and shipment are free of animal pests and weeds. Proper quarantines and inspection procedures should be stipulated before import into Hawaii.

10) In view of the special fragile nature and vulnerability of the aeolian ecosystem to human disturbance, an enforcible access plan that informs visitors of the special management problems found on Mauna Kea and limits their activities in sensitive areas should be developed.

11) Since many specific impacts caused by land use changes cannot be assessed until specific information becomes available on the location, construction methods, infrastructure needs, road alignments, etc., site specific assessments will still be needed for new developments which are outside of the four prime areas (no. I, II, IV, VI on the draft Development Plan Map of October 1982) and also is recommended for significant alterations within those areas. The site specific surveys in this study were hindered by the unavailability of maps of the proposed sites with road alignments and other infrastructure needs indicated.

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 8, 1988

Mrs. Mae E. Mull
Island of Hawaii Representative
Hawaii Audubon Society
P. O. Box 275
Volcano, Hawaii 96785

Dear Mrs. Mull:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice -Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve.

Thank you for reviewing and commenting on the subject assessment and notice. Our botanical and biological consultants (which include an entomologist) have been given copies of your letter and attachments. Your concerns will be addressed in their reports which will be appended to the draft SEIS.

A management plan for the Mauna Kea Science Reserve was approved by the Board of Land and Natural Resources in 1985. This plan addresses your management concerns. At present, the University of Hawaii, Institute for Astronomy, is working with the Department of Land and Natural Resources to resolve some remaining jurisdictional issues, including enforcement, so that all aspects of the plan can be implemented.

We look forward to your review of the draft SEIS when it is published.

Yours sincerely,

L. Cowie for D. Hall.

Donald N. B. Hall
Director

cc: MCM Planning
C. Wade
William Porter
Representative Andrew Levin

RECEIVED
APR 22 1988
DIRECTOR
INSTITUTE FOR ASTRONOMY

SKI ASSOCIATION OF HAWAII
P.O. BOX 8327
HONOLULU, HI 96815

17 April 1988

University of Hawaii
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, HI 96822

Dr. Hall;

Enclosed you will find a ski map of Mauna Kea ski runs.

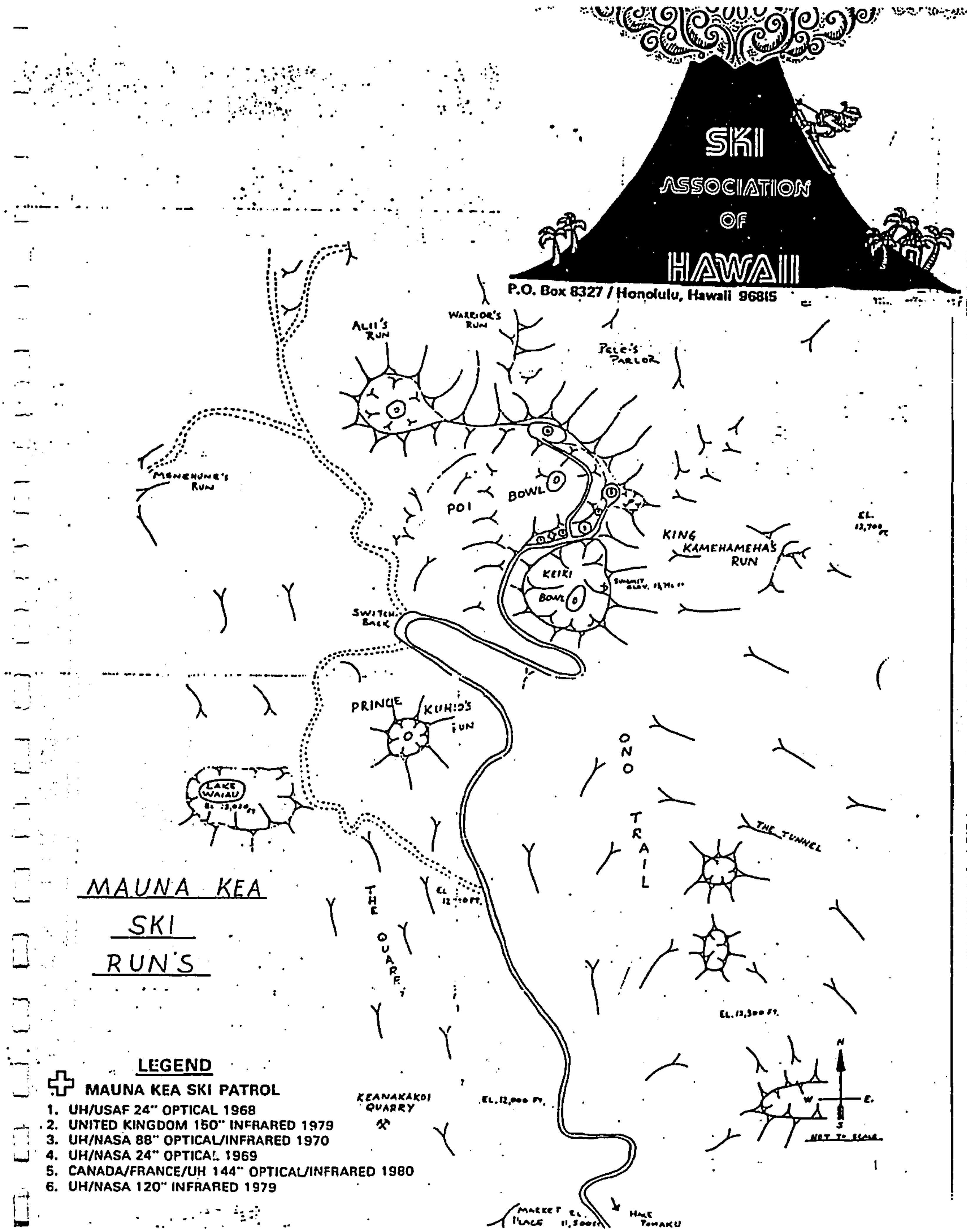
Adverse effect that the spur road would cut off a whole ski run.

Also please delete Dick Tilson and address all further correspondence to "President" of Ski Association of Hawaii.

Thank you

Terry D. Kratzler
Seceraty

Copy to: MCM Planning


SKI ASSOCIATION OF HAWAII
P.O. Box 8327 / Honolulu, Hawaii 96815
MAUNA KEA
SKI
RUN'S
ALII'S RUN
WARRIOR'S RUN
PELE'S PARLOR
MENEHUNE'S RUN
POI BOWL
KEIKI BOWL
KING KAMEHAMEHA'S RUN
SWITCH-BACK
PRINCE KUHIO'S RUN
LAKE WAIAU
ONO TRAIL
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MAUNA KEA SKI PATROL
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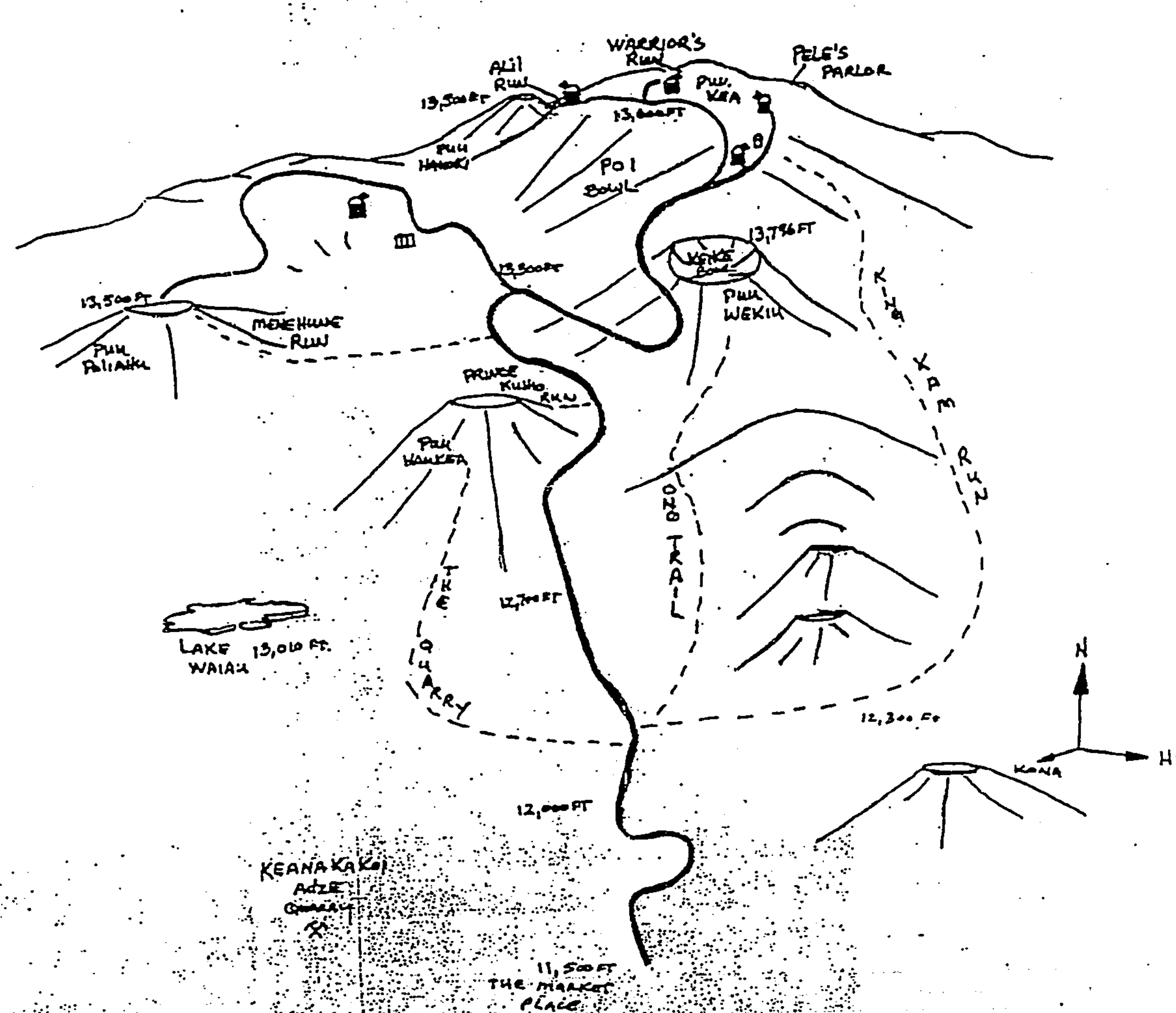
2. UNITED KINGDOM 150" INFRARED 1979
3. UH/NASA 88" OPTICAL/INFRARED 1970
4. UH/NASA 24" OPTICAL 1969
5. CANADA/FRANCE/UH 144" OPTICAL/INFRARED 1980
6. UH/NASA 120" INFRARED 1979

TRAIL MAP MAUNA KEA HAWAII



MAUNA KEA SKI CORPORATION

SKI GUIDES HAWAII

Ski Services

'ALII' Ski Tour $250 per person

An exclusive, one of Da-Kind Ski Experiences. You'll never forget the backside, hidden places on the mountain, spectacular vistas and miles of wide-open expansive skiing. Mauna Kea VIP luncheon and Mountain Ski Services all inclusive.

Day Tour $125.00 per person

Our most popular ski tour! All tours include 4-by-4 'ski gondola' with driver, ski equipment, Red Cross Certified Ski Guide, homemade mountain lunch.

Ski Rentals $25.00 per day for Skis, Boots and Poles

Ski Specials Prices Available Upon Request.

Ski Guides Hawaii give more kick to the glide!

- Out-of-Bounds (OB) Single Runs
- Cross Country (XC) Tours
- Ski School–7 days per week
- Designer Tours
- Ski to the Sea
- Inter-Island Airfare & Tour

Advanced registration and deposits are recom-mended due to the popularity and high demand during the season (November through July). A $20 deposit is required to hold and confirm all reservations; this is applicable toward ski services.

IMPORTANT INFORMATION

Mauna Kea is a national science reserve and is not maintained as a ski area. Skiing areas may have un-marked and exposed rocks. Adverse weather conditions may arise unexpectantly— be prepared with adequate clothing. Dark sun glasses and good sun-screen lotions are also a must. Due to the high altitude of Mauna Kea (there is a third less oxygen available!), it is advisable to check with your personal physician in all cases, including heart, lung and obesity problems.

SKI GUIDES HAWAII

(808) 885-4188

'The Big Island IS Hawaii'

MAUNA KEA SKI CORPORATION

SKI GUIDES HAWAII

SKI

GUIDES

HAWAII

The name is Mauna Kea or White Mountain, from its undersea base of -19,000 feet to the windswept peaks of 13,796 feet, it's the world's highest mountain! It offers some of the world's highest skiing.

This massive extinct volcano is blessed with the finest snow in the world, opening almost 100 square miles of skiable terrain. At this latitude the conditions are spring like; the snow is sugar corn. We call it 'Pineapple Powder'.

The access is by road in four-wheel drive vehicles. The road serves the internationally famous observatories on the summit, but it also makes accessible numerous pu'us (volcanic cones) that are a skier's delight. Consider five-mile plus runs and the possibility of 2500' to 4500' of vertical per run! Add to that a 360° panorama of Mauna Kea's moonscape, lush tropical vegetation below, the encircling ocean and Maui's Haleakala visible on the horizon. This is one of the most exotic skiing experiences anywhere. You can ski in the Pineapple Powder and surf off a tropical beach all in the same day!

If you thought that Hawaii could offer only sun, sand, surf and Hula dancers, think again! We'd like to take you high above the clouds for a ski experience you'll never forget.

MAUNA KEA SKI CORPORATION's
SKI GUIDES HAWAII
P O BOX 2020, KAMUELA, HAWAII 96743
(808) 885-4188 or 889-6398

SKI HAWAII

SKI ASSOCIATION OF HAWAII

P.O. Box 8327 / Honolulu, Hawaii 96815

Facilities

The Mauna Kea Ski Patrol affiliated with the National Ski Patrol System Inc is on the mountain on weekends when there is snow to assist [redacted] They h[redacted] the summit The Ski Patrolm[redacted] of the State and their warnings and directions should be needed

Important Things to Remember

The high altitude (13 796) sometimes causes headaches slight nausea shortness of breath and fatigue Anyone with known respiratory or heart problems is advised not to go skiing on Mauna Kea

The sun at the summit is many times as powerful as at Waikiki in addition to the reflection from the snow Sun screens and hats are strongly advised Sunglasses are an absolute must Snowblindness (sunburn of the eye) is a painful and dangerous consequence without sunglasses

Never ski alone The Ski Patrol is very small compared to the size of the mountain Ski only patrolled areas If you explore, be sure a responsible person knows where you are

Cold weather clothing is necessary even if it seems like a nice day The weather can change quickly, and wind and snow can be miserable and dangerous without proper clothes

Please do not disturb any instruments or equipment on the mountain. The Mauna Kea Observatory, operated by the University of Hawaii, may have test instruments and equipment in serveral locations Lake Waiau is under scientific study Please keep the lake free of any pollution and the mountain free of litter

Over 175 skiers are members of SAH of Hawaii, composed of several chapters of which the Honolulu Chapter is the largest.

The SAH offers its members monthly meetings, ski trips and travel to, domestic, national and international ski destinations, monthly newsletter, fitness programs and year-round monthly social and athletic events.

FOR MEMBERSHIP INFORMATION WRITE:

SKI ASSOCIATION OF HAWAII

P.O. Box 8327 / Honolulu, Hawaii 96815

Reprinted from Hawaiian Time

History

Mauna Kea is a dormant volcano on the island of Hawaii, once covered by Ice Age glaciers. These glaciers carved grooves in the lava and are responsible for forming Lake Waiau near the summit. High on the mountain is Keanakakoi, where ancient Hawaiians stayed in wind break caves while chipping glacier hardened blue gray lava into tools and weapons

Skiing in Hawaii began in 1936. In 1937 members of the Hilo Ski Club traveled three-quarters of the way around Mauna Kea to reach 7,000 feet and then climbed eight miles to the summit.

After a decline in activity due to World War II, skiers formed the Ski Club of Hawaii in Honolulu in 1953. There were trips to Mauna Kea in 1953 and 1956, but skiers still had to climb above 9,000 feet. In 1967, a jeep road was completed to the summit in order to build the Mauna Kea Observatory. Since then, interest in skiing on Mauna Kea has increased rapidly. This interest led to the formation of the Ski Association of Hawaii in 1967 to promote skiing in Hawaii. This organization now has over 400 members.

Snow permitting, there are weekend trips all winter On President's Day weekend, there is a Ski Meet and races are held for all levels of skiers. To join the Ski Association of Hawaii, mail your application to P.O. Box 8327, Honolulu Hawaii 96815. You will receive a newsletter to advise you of meetings, special events and ski packages. Mainland and foreign members are welcome, in addition to local members.

Facts

Mauna Kea is the only ski area in Hawaii as Mauna Loa is too rocky and Haleakala does not have enough snow The cinder cones at the summit provide steep runs while the bowl areas have gentle slopes making skiing a challenge for all as well as an experience never to be forgotten

The summit of Mauna Kea reaches to 13,796 feet where the day temperature usually varies from 35 to 50 degrees It is above the clouds 80% of the time with beautiful warm sunny days Bikinis have been spotted on occasion However storm conditions can arise quickly and be accompanied by high winds, which reduce the effective temperature considerably

The ski season is unpredictable ranging from 0 to 6 months The snow is usually light corn with occasional powder.

Slopes all above the timber line vary from beginner in the lower wide bowl areas to expert on the summit and slopes of the cinder cones Runs of 3 to 5 miles are possible after a heavy snowfall, but more often, runs are a half mile to a mile

The prime means of getting up and down the slopes is four wheel drive jeeps Skiers ride to the top then ski down and meet the jeep along the road for another trip to the summit Some of the runs require hiking A portable rope tow is planned for the near future

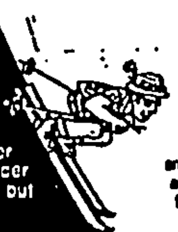
Transportation and Accomodations

Fly into Hilo, Hawaii from Honolulu or the U.S. mainland. It is also possible to fly into Kona or Kamuela from Hilo or Honolulu.

Ground transportation to the summit of Mauna Kea is by four-wheel drive vehicle either by renting on the individual basis or by joining a group.

Accomodations range from luxury hotels in Hilo and Kona [redacted] Hotels in the shoreline areas are from 1 hour and 45 minutes to 2 hours and 45 minutes away from the summit.

Independent parties must make all their own reservations for housing and vehicles.



The Mauna Kea Ski Patrol, affiliated with the National Ski Patrol System, Inc. is on the mountain on most weekends when there is snow to patrol the slopes and assist those in trouble. They have a first aid room and equipment at the summit. The Ski Patrolmen work directly with the State and their warnings and directions should be heeded.

SKI ASSOCIATION OF HAWAII MEETINGS

1ST THURSDAY OF EVERY MONTH

SKIING THE VOLCANO: MAUNA KEA'S SNOWY SLOPES

By Dick Tellson

High above the beautiful blue Pacific and the tropical beaches, I start my descent.

I drop and turn to the right, and the snow crackles as I drop and turn again. I am skiing in paradise, high above the clouds, on the edge of space. I am skiing on Hawaii's sacred white mountain, Mauna Kea.

Skiing the snows of Mauna Kea is exciting and exotic. With fine powdery snow in the early season and dry corn snow (Hawaiian sugar corn) later, Hawaii's skiing has an excellence all its own.

Equipped with parkas, sweaters, sunscreen, shorts and bikinis, we ascended Mauna Kea, an extinct volcano. We drove up and unloaded on the rim at the top crater, then skied across a small saddle and climbed 100 feet to the very top of Mauna Kea, 13,796 feet above sea level.

The day is clear above the clouds, with strong sun and a strange silence. Sound does not travel far in the thin air, and you often hear your pulse beat above the gentle breeze. For a moment we were spellbound, lost in the silent beauty of this place where the Goddess of the Snow, Puliahu (Madam Pele's sister), dwells.

Blue ocean lies for miles around, with a lush, green carpet of ranches just below.

The chain of Hawaiian islands stretch away to the northwest, and on the clearest of days I have seen the cliffs of Mokapu on Oahu, 175 miles away. The south is dominated by the long mountain Mauna Loa, 13,680 feet, sister to Mauna Kea (the white mountain). Its almost flat, gently sloping top seems to stretch for miles, and its snow cap is 25 miles across, a challenge for cross country skiers.

We skied over to the cornice at the top of King Kamehameha's Run, looking down to the wide sloping plateau below. The slope angles 45 to 60 degrees all the way down the big smooth face. You can almost hear the ancient Hawaiian conch shells trumpeting, inviting you to challenge yourself and ski with Hawaiian gods. A near-vertical takeoff on this 1,000 foot slope is a little bit unnerving until you make the first turn. The rest is easy.

I hear the others yell close behind, but I cannot look back. I reach out and set my pole, lift and turn, set, and lift and turn again. The snow feels bottomless. I am floating. I set and lift and turn again and again. I hear someone fall and another yell. But I can't stop yet, and I turn and turn again. My legs are on fire. Now it's time to stop and see how the others are doing.

The criss-cross tracks form a figure eight halfway down the slope. The yells of excitement tell me they are doing well. As they catch up and stop, one of them says "I could ski like this forever." I smile; we are only halfway down.

We ski down King Kamehameha's run to the sloping plateau with miles of rolling, dipping valleys that wind through out-croppings of smooth lava rock. I follow the ridge until I find a little cornice and ski down the valley.

From here it becomes an open, easy run. We ski around the base of Puu Lilihou, across a big open valley, and wiggle through a lava flow dike, keeping a little speed to catch the pass between two big cones below. We cross through Keanakakoi, where ancient Hawaiians stayed in shallow caves for days, chipping the fine basalt stone and shaping it into tools.

The snows have been here in Hawaii for a long time. Part of the mountain is an Ice Age preserve, where signs of the glacier are obvious. Mauna Kea's first ski club was formed in 1936-37 by hardy alpineers Kamada, Ide and Iwamoto and joined by Higashi, Ho and Pence. They had to hike from 7,000 feet to reach the snow.

Today, although there is a road built for the Mauna Kea Observatory, difficult access and the lack of facilities still discourage the less adventurous skiers. The snow line, which varies from 9,000 feet to 13,000 feet in little over a month's time, would make a fixed ski lift very limited. But our four-wheel-drive pick-up, which we call our "gondola on wheels," allows us to ski four- and five-mile runs for a few weeks and then adjust to one-mile runs and 600 feet of vertical as the snow line moves. On the best day last season, we skied 29 miles of runs with 15,000 feet of vertical.

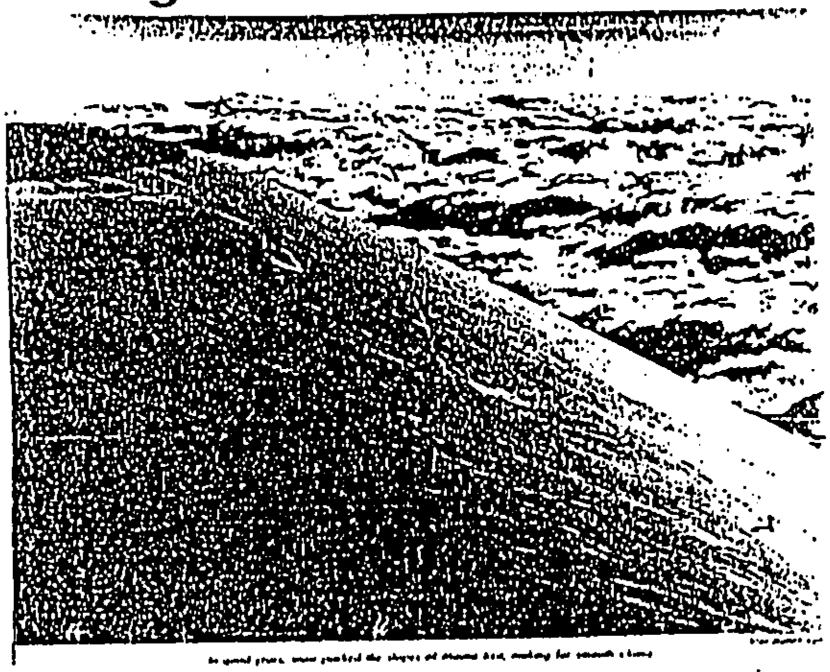
Mauna Kea hosts the world's highest scheduled ski races and races in early March, late April and early June. Perhaps the most unusual event is the King Kamehameha Holua Ski in early June, featuring demonstrations with the Hawaiian holua (wooden) sleds and even holua snowboards.

The big 4 x 4 pick-up is coming down the road, and a skier glides to a stop and falls down laughing. He just lies there, exhausted and happy. Now he knows "The Snows of Mauna Kea" are real. ☐

Dick Tellson has skied Mauna Kea for 20 years and still teaches skiers the joys of the mountain. For more information, contact Box

SKI ASSOCIATION OF
HAWAII
P.O. BOX 8327
HONOLULU, HI 96815

Riding the Snow Cones



Skiing Mauna Kea Is a Rarified Experience

By Suson Manuel
Star-Bulletin Writer

SOME of the riskiest skiing in the country happens on the Big Island, the gamble being whether it snows on a tropical island.

When snow does pack the slopes and *pu'us* of Mauna Kea—and it hasn't to any consistent degree for the past two years—it's a skiier's paradise. The granular "corn" snow is heavy enough to guide a turn, light enough to transform intermediates into experts-for-a-day, until the sun slicks a thick crust in the afternoon.

The smooth mountainside never develops muguls, the bumps that delight and confound skiiers in the rest of the world. The runs can stretch for five miles with vertical drops of up to 4,500 feet. And the volcano hasn't erupted for 2,807 years.

Punchdrunk from the low-oxygen altitude of 13,796 feet, higher than any chairlift will climb on the Mainland, skiiers take a 360-degree view of red, black and green fields and cones of former volcano spouts becoming earth. Everything's topsy-turvy. Beyond the clouds the ocean rises. Maui haunts the horizon below.

It's all wonderful when it happens. In the meantime careers have risen and fallen on Mauna Kea. Dick Tillson, the Massachusetts man who led most skiers around the mountain over the past 20 yeass has "disappeared." The Ski Association of Hawaii, a non-profit social group that sponsored trips with Tillson, has seen neither "hide nor hair of him," according to vice-president Ed Dunbar.

His supply of ski equipment sits unused in Kamuela, where two of his former guides have taken over Mauna Kea Ski Corp. as Ski Guides Hawaii.

Two snowless years led to a divorce for Pat Doe, who, with partner Christopher Langan, is waiting out yet another season. Without the finances for a shop, they operate out of a house and a truck.

"We're trying to run an entire ski area with just a couple of people and no money," Doe said. "It's tough to get backing for a business like this: If they don't have enough faith in it, I do."

The snow usually comes in heaps in March and April. Some years ski races have been held on the Fourth of July. It dumped last year on Thanksgiving, then nothing until some sporadic days in the spring. Mauna Kea has received only a momentary dusting so far this year.

But Doe, a former Telluride, Colo., ski shop owner, is optimistic:

"1981-82 was the last good year of skiing. We've already surpassed the rainfall for that this year."

National Weather Service forecaster Mike Morrow says rainfall doesn't indicate anything for Mauna Kea. The weather service can predict white stuff "about the time it starts snowing."

The necessary ingredients are freezing temperatures at or below the summit, thick clouds and lots of precipitation.

Some trivia about Mauna Kea snow: It doesn't melt; it "sublimates," turning to water vapor because of low air pressure on the volcano slopes.

For snow and road conditions, call the University of Hawaii's Mauna Kea Support Services in Hilo at 935-3371.

If and when it does snow, a few options are available: Skiers can fly into Kamuela or Kailua-Kona, rent a four-wheel-drive vehicle and ski equipment from the two guide outfits and drive 2½ hours to the summit, taking the Saddle Road from Kamuela, or Waimea toward Hilo and turning up the toward the summit at Humuula Junction.

Although the skiing itself isn't difficult—the slopes are steep but uncluttered, and members of a volunteer ski patrol cruise the volcano—getting lost in the lava or in a blizzard can happen. Guides know the terrain and provide

Riding the Snow Cones

Continued from Page C-1

drivers at the bottom of each run.

The lack of oxygen—35 to 40 percent less than at sea level—can make people dizzy and nauseous. Ski patrol members carry oxygen masks, but Doe recommends being in basic good shape before attempting to ski Mauna Kea.

"It's something not to be taken lightly," he said, also warning parents to leave small children behind. "We've had people make one run and just give up."

Taking aspirin ahead of time and during the day, and skiing at half-speed can help conquer altitude sickness. Good dark glasses and layers of sunscreen are absolute necessities. On a single weekend, 22 snow-watchers developed snow blindness; a few had permanent eye damage.

Doe and Langan, both certified members of the National Ski Patrol, have big visions for this winter's tours, possibly including portable rope tow systems, and snowmobile or helicopter pick-ups from areas not reached by the road.

They plan to offer day tours at $120 a person, air-and-ski packages from Honolulu at $175-$180, "alii" tours to the volcano's backside over 10 miles of terrain at $250 a person, cross-country ski tours, "ski to sea" tours, camping trips and ski school. Beginners should inform guides ahead of time of their inexperience.

Doe brought 250 pairs of skis from his shop in Colorado and says he can service up to 60 skiers. He's operating from his house and will meet skiers with a four-wheel drive vehicle. Contact Ski Guides at P.O. Box 2020, Kamuela, HI 96743 or 885-4188.

Nick Terstenjak, a former ski school director at Telluride, guides up to 10 skiers a day on the volcano and rents out equipment. He charges $100 for tourists and $80 to kamaainas for a whole day of skiing.

"It's a sideline. You cannot depend on it," said Terstenjak, who has a lumber business. "In 1982-83 I made real good money. I could make $1,000 a day."

SKI GUIDE
808-889-6398

The Ski Association of Hawaii also sponsors trips to Mauna Kea on a shared cost basis. Members sign a list and are notified when the snow is adequate. The association also sponsors three Mainland ski trips a year, beginning in January, and it hosts several non-skiing events like sailing to keep members occupied during the sunny winter days here.

The group meets the first Thursday of each month at PIZZA HUT on Keeaumoku St at 6:30 pm.

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

June 8, 1988

Mr. Terry D. Krutzler, Secretary
Ski Association of Hawaii
P. O. Box 8327
Honolulu, HI 96815

Dear Mr. Krutzler:

Subject: Environmental Assessment and Supplemental Environmental Impact Statement Preparation Notice - Construction and Operation of a VLBA Antenna Facility within the Mauna Kea Science Reserve

Thank you for reviewing and commenting on the subject assessment and notice. In response to your concern about the project cutting off a ski run:

Based on the map which you attached to your comment letter, it appears that the "King Kam" ski run originates on the southeast slopes of the summit area, travels downward on the eastern slopes of cinder cones in the area and terminates at the Mauna Kea Observatory (MKO) Access Road at about the 12,300-foot elevation. The run crosses the saddle areas between two cinder cones in the vicinity of the proposed VLBA antenna. A second run, known as the "Ono Trail," ends in the same general area.

According to people contacted during the preparation of the environmental impact statement (including Dr. Andre Erasmus, meteorologist for the UH Institute for Astronomy and Tom Fake, Leader of the Mauna Kea Ski Patrol), it rarely snows in the area of concern. If snowfall does occur, it melts rapidly. As a result, the ski runs in question are seldom used.

In any event, the proposed access road to the VLBA facility will not cut off either the "King Kam" or the "Ono Trail" runs. The access road originates at about the 12,100-foot elevation and proceeds in a northeasterly direction to the antenna site. Skiers on the "King Kam" run will have sufficient space to traverse the saddle area above the proposed facility. In addition, the "Ono Trail" will not be affected as the entrance to the VLBA access road is at a lower elevation than the termination point of the trail at the MKO access road.

We look forward to your review of the draft SEIS.

Yours sincerely,

L. Cowie for D. Hall

Donald N. B. Hall
Director

cc: MCM Planning
C. Wade
W. Porter

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PERSONAL COMMUNICATIONS

Krieger, Thomas. Mauna Kea Support Services
Krutzler, Terry D. Ski Association of Hawaii
Longfield, Richard. University of Hawaii, Institute for Astronomy

APPENDIX A

SCIENTIFIC AND TECHNICAL
CHARACTERISTICS OF THE VLBA

REPRINTS OF ARTICLES IN
SCIENCE AND SCIENTIFIC AMERICAN
BY
K.I. KELLERMANN AND A.R. THOMPSON

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SCIENCE

The Very Long Baseline Array

K. I. Kellermann and A. R. Thompson

12 July 1985, Volume 229, Number 4709 SCIENCE

The Very Long Baseline Array

K. I. Kellermann and A. R. Thompson

The earliest radio telescopes had barely enough resolving power to distinguish one constellation in the sky from another, and for many years it was widely accepted that, because radio telescopes operate at such long wavelengths, their angular resolution must be fundamentally poorer than that of optical telescopes.

Actually, this is not the case, for two reasons. First, the resolution of large, ground-based optical telescopes is ordinarily limited to about 1 arc second, not by the size of the telescope but by irregularities in the earth's atmosphere. At radio frequencies, the atmospheric fluctuations in the path length of the incoming signal are small compared with the wavelength of radio waves, so that the effect of atmospheric irregularities is less important. Second, to form clear images, the phase of the signals must be preserved over the entire dimensions of the instrument. Because of their longer wavelength, radio waves are easier to manipulate than light waves, so that radio telescopes of very large size can be built and operated close to the theoretical diffraction limit given by the ratio of wavelength, λ, to overall array dimensions, D.

This history of radio astronomy has been one of ever-increasing angular resolution achieved by increasing the dimensions of the instruments and operating at the highest frequencies (shortest wavelengths) technically feasible. But even the largest single-radio antennas, such as the 100-m steerable reflector near Bonn, Germany, operating at their shortest wavelengths (~1 cm) provide only an angular resolution (λ/D) of approximately 1 arc minute, which is comparable to that of the unaided human eye (D, reflector diameter).

Summary. The Very Long Baseline Array is a high-resolution synthesis radio telescope consisting of ten antennas, each 25 meters in diameter, located throughout the United States from Puerto Rico to Hawaii. Each antenna will be equipped with low-noise receivers spaced throughout the frequency range from 330 megahertz to 43 gigahertz, a hydrogen-maser frequency standard for time and frequency reference, and broadband digital tape recorders. Tapes recorded at each antenna will be simultaneously replayed and correlated in a specially built digital correlator, and the correlator output will, by Fourier transformation, be used to construct images of celestial radio sources with an angular resolution better than one thousandth of an arc second.

For this reason, radio astronomers long ago turned to interferometric techniques to increase the effective aperture size beyond that feasible from a single structure. A radio interferometer can be regarded as a radio analog of the well-known optical instrument developed by Michelson in the early part of this century to measure stellar diameters. Two antennas, spaced by a baseline of length D, are connected to a receiving system (Fig. 1A). After amplification and filtering, the signals are combined in a correlator. The difference Δ in the path lengths of an incoming wavefront from a distant source determines the delay difference of the two signals and thus their relative phase. Signals of the same phase, which occur when Δ is an integral number of wavelengths, produce a maximum in the correlator output, and signals in antiphase produce a minimum. With respect to the angle of incidence of the radiation, θ, the response is proportional to

$$F(\theta) = \cos[(2\pi D/\lambda)\sin\theta] \quad (1)$$

$F(\theta)$ is the fringe pattern shown in Fig. 1B. The fringe spacing varies with the wavelength. Over the finite bandwidth of the receiving system, this variation causes the fringe amplitude to decrease for large values of the relative delay. The corresponding effect in optics is the white-light fringe phenomenon (*1*).

The fine structure in the fringe pattern enables the position and structure of a source to be studied with an angular resolution comparable to the fringe width, which is $\lambda/(D \sin\theta)$ radians. In terms of Fourier analysis, the interferometer responds to the Fourier component of the source with spatial frequency on the sky equal to $(D \sin\theta)/\lambda$ at a position angle given by the projection of the baseline onto the sky. To obtain a full two-dimensional map of a radio source, it is necessary to scan it with fringe patterns covering a wide range of fringe widths and position angles. The rotation of the earth provides part of this required variation because an observer looking down at the earth from the direction of the source sees the position angle of the baseline rotate through 180° in 12 hours (Fig. 1C). Thus the required information can be obtained by using antennas that track a source across the sky, together with different baseline lengths obtained by using a number of antennas or by moving the positions of the antennas and repeating the observation on another day (or both). The range of spatial frequencies included in the measurements is conveniently presented in the Fourier transform plane, which shows the projected interferometer spacings as seen from the direction of the source. Figure 1D shows an example of the form of the coverage for an array consisting of three antennas in an east-west line (see Fig. 1C). Although a linear arrangement is

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adequate for mapping sources at high declinations, a two-dimensional array is needed for sources near the celestial equator, where the earth's rotation introduces foreshortening rather than rotation of the baselines.

The measured response to a radio source is expressed in terms of visibility, a complex quantity that represents the magnitude and phase of the fringe oscillations at the interferometer output. The source brightness distribution is reconstructed from the two-dimensional visibility function by an inverse Fourier transformation, a technique known as synthesis mapping (2).

The recently completed Very Large Array (VLA) radio telescope gives, for the first time at radio wavelengths, images of high sensitivity with angular resolution and image quality equal to or better than that given by optical telescopes. The VLA consists of 27 antennas, each 25 m in diameter, located at intervals along the three linear arms of a Y-shaped configuration. The arms run outward from the array center at 120° intervals in azimuth and extend to 21 km. A double railroad track allows the nine antennas on each arm to be moved between four sets of foundations to provide four configurations with arm lengths ranging from 600 m to 21 km. With the largest configuration, the resolution is better than 1 arc second, which is comparable with that of large optical telescopes at the best observing sites; the lower resolution of the more compact configurations enables extended objects (such as nebulae) to be observed without loss in sensitivity. Circular waveguide is used to carry the phase-reference signal to each antenna and to carry the received signals back to the main control building, where they are combined in a digital correlator. Each of the 351 [(27 × 26)/2] interferometer outputs, corresponding to a different antenna pair, is averaged and sampled at intervals as short as 1 second and then Fourier transformed to produce a high-resolution image.

The VLA is the most powerful radio telescope in the world and has given a tremendous improvement in angular resolution, sensitivity, and image quality over previous radio telescopes (3, 4). More than 500 scientists each year use the VLA for a wide variety of extragalactic, galactic, and solar system studies. Of particular interest have been the observations of the radio emission from galaxies and quasars. Up to 10^{53} J of energy is found in clouds of relativistic plasma ejected from these objects, and understanding the source of this energy has been one of the most challenging problems of modern astrophysics. Observations made with the VLA indicate that the origin of the energy may be traced to a remarkably compact but highly luminous core found in quasars and in the nuclei of active galaxies, from which long thin jets extend up to millions of light years toward the giant extended radio clouds (5). These compact nuclei radiate as much as 10^{39} W (the radio power of 100 million normal galaxies) from a volume of space only a few light years across, or about 10^{-9} of the volume of the Milky Way system (see Fig. 2).

The angle subtended by the radio nuclei is very small, typically about one-thousandth of an arc second, or a factor of 100 to 1000 beyond the resolution limit of the VLA. In order to obtain radio pictures on this angular scale array, dimensions comparable to the radius of the earth are needed. However, for dimensions much larger than those of the VLA, physical interconnections of antennas by transmission lines become costly, and there are practical problems of avoiding obstacles such as rivers and hills.

As early as the 1950's, radio astronomers in England and Australia experimented with microwave radio links to connect the distant elements of interferometer systems. Although baselines of more than 100 km were used, there were too few antenna elements to synthesize the structure of radio sources in detail. Several years ago, the Nuffield Radio Astronomy Laboratory at Jodrell Bank brought the multielement radio-linked interferometer (MERLIN) system into operation, which uses up to six simultaneous antennas with overall dimensions of 134 km (7). Operating primarily at wavelengths of 18 and 70 cm, MERLIN has been used to investigate the angular structure of radio sources with sizes as small as 0.1 arc second.

In principle, there is no limit to the dimensions that can be achieved with radio links, but the need to install repeaters every 50 km or so would make the cost prohibitive for an array of continental dimensions. Satellite repeaters have been used to distribute a phase-reference signal to distant antennas and to link the received signals at intermediate frequency (IF) to a central station. But the operation of a multielement, broad-bandwidth array would require the full capacity of a modern communications satellite, and so far only experimental satellites have been used for brief periods (8).

Fortunately, it is not necessary to have a direct, real-time connection between interferometer elements. A more cost-effective method is to record the IF signals on magnetic tape at each antenna and to transport the tapes to a central facility where they are replayed simulta-

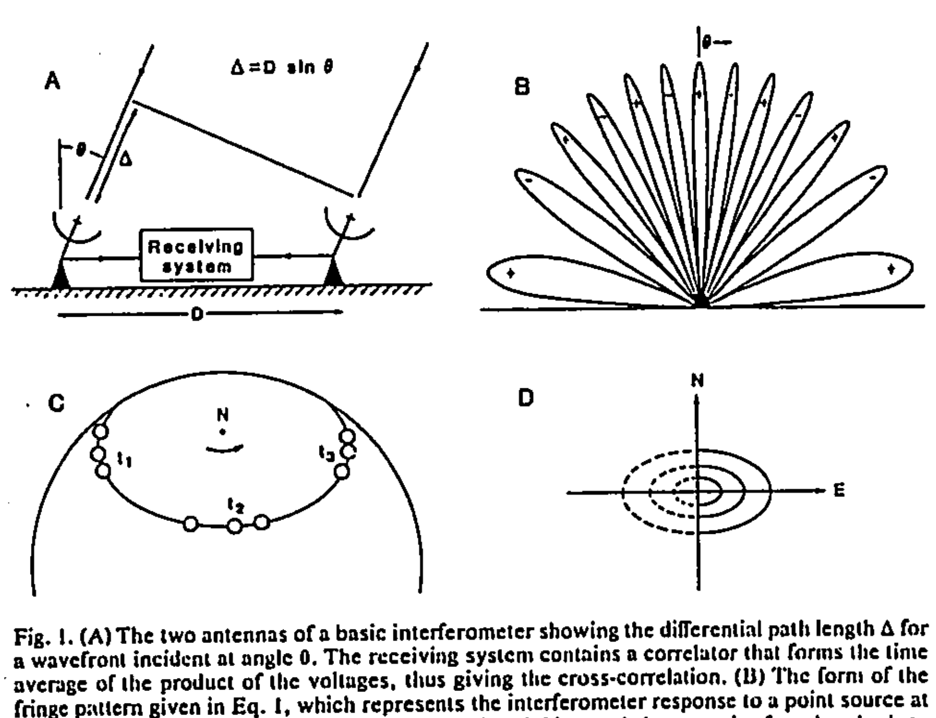

Fig. 1. (A) The two antennas of a basic interferometer showing the differential path length Δ for a wavefront incident at angle θ. The receiving system contains a correlator that forms the time average of the product of the voltages, thus giving the cross-correlation. (B) The form of the fringe pattern given in Eq. 1, which represents the interferometer response to a point source at position θ. In practice, the number of fringes in the 180° interval shown varies from hundreds to more than a million. (C) An east-west array of three antennas as viewed from the direction of a radio source at three instants of time, t_1, t_2, and t_3, showing how the position angle of the baseline changes with time. (D) The projected antenna spacings for the three-element array in (C), N and E being the directions on the celestial sphere. The full lines represent a 12-hour interval; during the remaining 12 hours (indicated by the broken curves), the same spacings and position angles are repeated and no new information is obtained.

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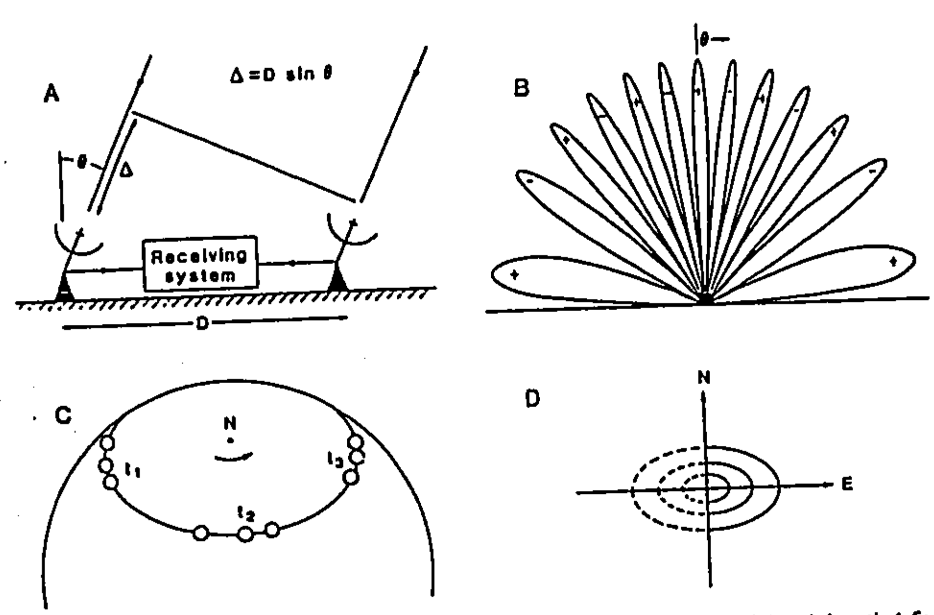

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A-2

neously. Time synchronization of the recordings is provided by atomic frequency standards at each antenna, which also supply a stable reference signal for the local oscillators. This technique of using independent oscillators and tape recorders is known as Very Long Baseline Interferometry (VLBI) and was developed in the late 1960's, primarily in response to the need for ultrahigh resolution to study the compact radio nuclei in quasars and active galactic nuclei (*9*).

Since that time, more than 25 independently operated radio telescopes throughout the world have been used in coordinated VLBI programs, with up to 18 antennas being employed simultaneously. Approximately every 2 months, 1 to 2 weeks are set aside at six or more radio telescopes in the United States for simultaneous VLBI observations. In Europe, similar sessions are scheduled four times per year. Frequently a number of European and North American antennas are combined to form a global network. Regular VLBI observations are also scheduled by NASA, the National Geodetic Survey, and the Jet Propulsion Laboratory for a variety of terrestrial experiments to study global tectonics, polar motion, earth rotation, and time synchronization. Many pioneering discoveries have been reported from these networks of existing antennas, but by 1975 the need for a full-time dedicated array of specially designed and strategically located antennas had become apparent (*10*).

The VLBA

In 1982, after 7 years of study and evaluation, the National Radio Astronomy Observatory submitted a request to the National Science Foundation to construct a dedicated Very Long Baseline Array (VLBA) to provide high-quality radio images of very small galactic and extragalactic radio sources (*11*). The VLBA is being designed to give resolutions ranging from a few tenths of a milliarc second to a few hundredths of an arc second, which correspond to the planned wavelength range from about 1 cm to 1 m. The VLBA will consist of ten precision antennas, each 25 m in diameter, located throughout the United States, including Puerto Rico and Hawaii. The configuration of the elements (Fig. 3) has been chosen to optimize the resolution from within the United States while maintaining uniform coverage of projected interferometer spacings to minimize the sidelobes. However, it is also necessary to choose locations that minimize

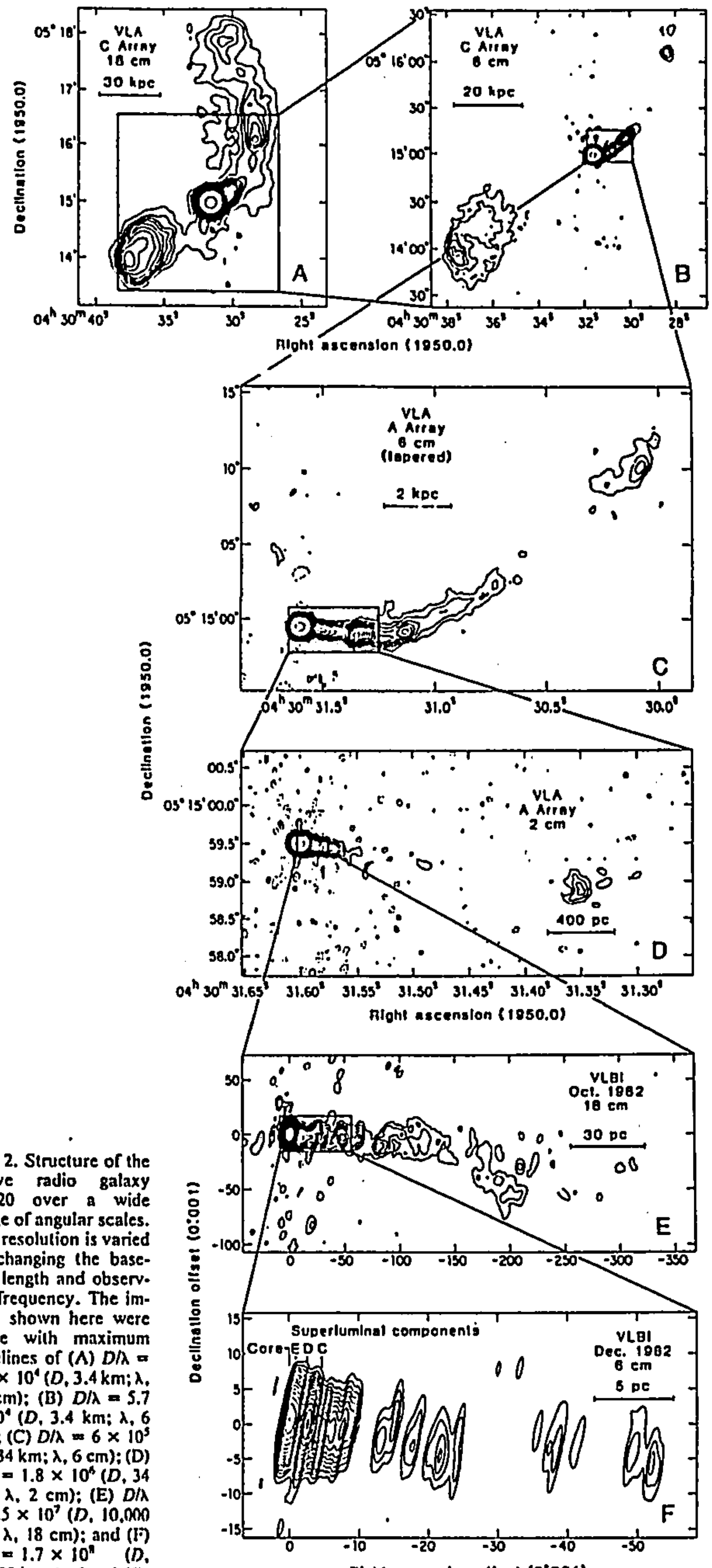


Fig. 2. Structure of the active radio galaxy 3C120 over a wide range of angular scales. The resolution is varied by changing the baseline length and observing frequency. The images shown here were made with maximum baselines of (A) $D/\lambda = 1.9 \times 10^4$ (D, 3.4 km; λ, 18 cm); (B) $D/\lambda = 5.7 \times 10^4$ (D, 3.4 km; λ, 6 cm); (C) $D/\lambda = 6 \times 10^5$ (D, 34 km; λ, 6 cm); (D) $D/\lambda = 1.8 \times 10^6$ (D, 34 km; λ, 2 cm); (E) $D/\lambda = 5.5 \times 10^7$ (D, 10,000 km; λ, 18 cm); and (F) $D/\lambda = 1.7 \times 10^8$ (D, 10,000 km; λ, 6 cm) (*6*).

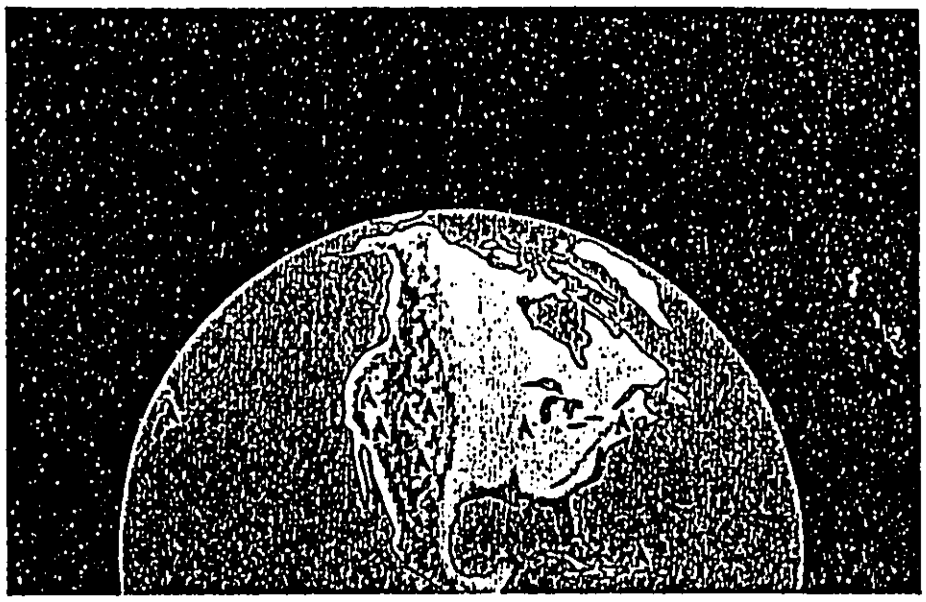


Fig. 3. The VLBA configuration showing the antennas in Hawaii, California, Oregon, Arizona, New Mexico (two), Texas, Iowa, Massachusetts, and Puerto Rico.

radio interference and atmospheric water vapor, which introduce phase fluctuations. Proximity to major transportation centers has been an important consideration and, wherever feasible, sites at existing radio observatories or other sources of technical support have been preferred. Considerable weight has therefore been given to locating as many elements as possible in the relatively dry, cloud-free southwestern United States. It is also desirable that the resolution gap between the VLBA and the largest configuration of the VLA be kept to a minimum. This in particular influences the location of the elements nearest the VLA to allow coordinated observations to be made with the combined VLA and VLBA to cover angular scales that range over a factor of more than 100,000.

Each VLBA antenna will be equipped with radio receiving systems covering assigned radio astronomy bands in the frequency range from 330 MHz to 43 GHz, giving a broad range of resolution and surface brightness sensitivity. The principal bands covered are listed in Table 1. Feeds for 330 and 610 MHz will be located at the prime focus of each antenna, and for the other frequencies feeds will be at the Cassegrain focus. The Cassegrain feeds will be arranged on a circle 1.7 m in diameter, and the subreflector will be mounted so that it can be adjusted under computer control to direct the received radiation to any desired feed element. Each feed will have outputs for opposite senses of circular polarization, and two low-noise amplifiers for each band will allow both polarizations to be received simultaneously. Most of these amplifiers will use gallium arsenide field-effect transistors (GASFET's), and for frequencies above 1 GHz they will be cooled to 15 K by closed-cycle helium refrigerator systems. By cooling the amplifiers, system noise temperatures in the range of 30 K to 70 K can be obtained, thus providing high sensitivity. At the two highest frequency bands, high-electron mobility transistors (HEMT's) and superconductor-insulator-superconductor (SIS) mixers will be used.

Recording System

In recording the signals on tape, a digital rather than an analog representation is almost always used. The signal is then sampled periodically, and the accuracy with which the phase is preserved depends on the timing of the sampler. In a digital system, the accuracy of the tape speed and similar mechanical factors are less critical. For preserving the information in the signal, the sampling frequency should be no less than the Nyquist rate, which is twice the signal bandwidth. Thus, if the received bandwidth is Δf, the bit rate (number of bits per second) that must be recorded is

$$f_r = 2\Delta f\, n_s \qquad (2)$$

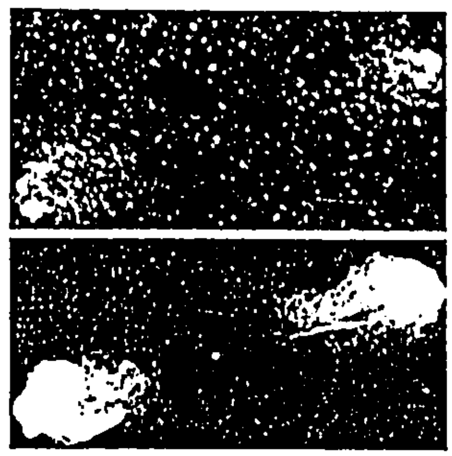
where n_s is the number of bits per sample. The overall sensitivity (signal-to-noise ratio) increases as Δf and n_s are increased. In the common situation where the limit on the received bandwidth is imposed by the tape recorder, which limits f_r in Eq. 2, optimum performance is obtained by using two-level or three-level quantization for which n_s is 1 or about 1.6, respectively. In two-level quantization only the sign of the signal voltage is recorded, and information about the magnitude of the voltage is lost. However, the output of the interferometer is the cross-correlation of the signals received in two antennas, which take the form of Gaussian random processes. The effect of two-level quantization in this case is simply the reduction of the output signal-to-noise ratio by a factor of 0.64 relative to that for similar signals without quantization. Because of its simplicity, two-level quantization has been used almost universally in VLBI systems, with the signal bandwidth equal to half the recorded bit rate. However, in cases where the signal bandwidth is limited by factors such as the width of a spectral line or an interference-free frequency band, increasing the number of quantization levels offers an increase in sensitivity.

When the first VLBI system went into operation in the United States in the late 1960's, conventional computer tape drives were used, and the recorded bandwidth was restricted to a few hundred kilohertz (*12*). Since that time, in response to commercial and consumer needs, bandwidths and bit densities have increased significantly.

Table 1. Sensitivity and angular resolution in various frequency bands.

Frequency (GHz)	Receiver input state: Type*	Receiver input state: Physical temperature (K)	System noise temperature (K)	Noise level†	Angular resolution (milli-arc seconds)
0.312 to 0.342	GASFET	300	120	0.2	24
0.608 to 0.614	GASFET	300	75	0.1	13
1.35 to 1.75	GASFET	15	30	0.04	5.4
2.15 to 2.35	GASFET	15	35	0.04	3.5
4.6 to 5.1	GASFET	15	35	0.04	1.6
8.0 to 8.8	GASFET	15	45	0.06	0.9
14.4 to 15.4	GASFET	15	65	0.08	0.5
22.2 to 24.6	HEMT	15	70	0.1	0.4
42.3 to 43.5	SIS mixer	3	75	0.1	0.2

*High-electron mobility transistors (HEMT's) may replace the standard GASFET's at other high-frequency bands as development permits. †Root-mean-square noise level for an 8-hour observation, measured in millijanskys (1 millijansky is equivalent to 10^{-29} W m^{-2} Hz^{-1}).



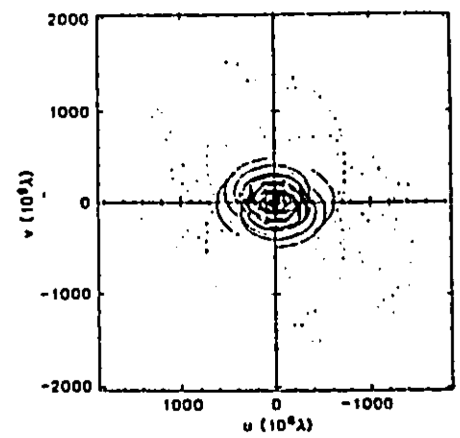


Fig. 4 (left). (Top) Unprocessed image of the radio galaxy Cygnus A obtained with the VLA by Perley, Dreyer, and Cowan. The splotchy background does not represent real structure but is the result of the inability of the VLA to measure the entire Fourier transform of the object. (Bottom) Top image corrected for incomplete coverage of the Fourier transform plane (CLEAN) and atmospheric phase fluctuations (self-calibration). The dynamic range (ratio of peak brightness to root-mean-square noise) has been improved from about 100:1 to 4000:1, and *structural details obscured in the top image are now readily discernible.* Fig. 5 (right). Coverage of Fourier transform plane of VLBA (solid lines) with proposed extension to space by means of the QUASAT satellite (dotted lines). *u* and *v* are the projected interferometer spacings in wavelengths at a frequency of 22 GHz.

Two VLBI recording systems are in common use today. One, the MKII system, is based on a modified home video cassette recorder (VCR) that is used to obtain 4 hours of uninterrupted digital recording with a sampling rate of 4 megabits per second for a 2-MHz bandwidth with two-level quantization. More than 25 radio telescopes throughout the world have recording systems of this type. The recorded data can be replayed at any one of three processing facilities located at the Max-Planck Institut für Radioastronomie in Bonn, Germany; at the National Radio Astronomy Observatory in Charlottesville, Virginia; and at the California Institute of Technology in Pasadena, California.

The newer MKIII system, developed at the Massachusetts Institute of Technology Haystack Observatory largely under NASA sponsorship, uses a 28-track longitudinal instrumentation recorder to obtain data rates up to 224 megabits per second (112-MHz signal bandwidth) with a tape speed of 270 inches per second. But because the bit density of the MKIII recording system is an order of magnitude less than that of the MKII system, the high data rate is achieved only at the expense of using prodigious amounts of magnetic tape.

In recent experiments at the Haystack Observatory, good signal reproduction has been achieved with narrow recording heads machined from gap bars used to fabricate standard VHS heads for the home VCR market. The VLBA will use 32-track head stacks, with each track 20 μm wide, writing at a data rate of 4 megabits per second for a recording rate of 128 megabits per second. A piezoelectrically controlled mechanism will be used to reposition the head stack to allow 26 passes of 1-inch-wide tape. In this way a single 16-inch reel of tape (13,000 feet) will last for 8 hours and will hold approximately 3×10^{12} bits of information. Even longer recording times may be possible with thinner tapes or larger reels (or both). Tests run with a prototype system at the Haystack Observatory have been successful in keeping the position of the recorded track to within 1 μm over tape lengths of up to 9000 feet (*13*).

The recording rate of 128 megabits per second will accommodate a total bandwidth of 64 MHz with two-level quantization. Provision will also be made for use of four-level quantization for spectral-line observations. Higher recording rates will be possible for short periods of time to increase the sensitivity for special experiments. The total recorded bandwidth may be subdivided into as many as 16 subbands, over which the received signals can be distributed in frequency and polarization. For example, the most common form of observing is likely to make use of a single frequency band with both senses of circular polarization being received and with half the recorded bandwidth assigned to each one. It will be possible to position the subbands contiguously in frequency or to spread them out over a wide range (up to 500 MHz). It will also be possible to make simultaneous observations in certain pairs of frequency bands.

Time and Frequency Standards

The VLBA will use a hydrogen maser frequency standard at each antenna as an independent time and frequency standard. A hydrogen maser makes use of the well-known line of atomic hydrogen at 21-cm wavelength that is emitted when the spin vector of the electron changes sign relative to that of the proton in the ground-state atom. In the maser molecular hydrogen is dissociated, and atoms with the desired excitation are selected by a magnetic field and passed into a cavity that is resonant at the line frequency of 1420.405 MHz. The resulting stimulated emission provides a signal that is stable in frequency to the order of 1 part in 10^{15} for periods up to a few thousand seconds. The maximum possible integration time is set by the requirement that the relative oscillator phase must drift by no more than, say, 0.2 radians. Then at the maximum VLBA frequency f of about 40 GHz, with $0.2/(2\pi f\tau)$ approximately equal to 10^{-15}, the maximum integration time (τ) is about 1000 seconds.

In maintaining coherence over the entire signal bandwidth, the incoming wavefront must be sampled at the two antennas of each interferometer with an accuracy of the order of the reciprocal bandwidth, and this accuracy must be preserved on playback. With a bandwidth of 50 MHz, time synchronization accurate to 20 nsec is required to detect interference fringes. In actual practice, the signals are combined with a range of possible delays, so that the necessary timing accuracy is easily achieved with hydrogen maser clocks.

The Playback System

Approximately 7 miles of data tape will be accumulated each day at each antenna element and sent by commercial transport to the VLBA Operating Center in New Mexico, where it will be simultaneously played back and correlated with tapes from each of the other antennas. The processor system will allow for up to 20 playback recorders, so that additional antenna systems in the United States and other countries can be used to enhance the sensitivity and resolution of the VLBA. This processor, which is being developed at the California Institute of Technology, will contain about 50,000 complex digital correlators and will provide playback rates of at least up to 256 megabits per second (bandwidths up to 128 MHz) in the continuum mode. For spectroscopic applications, the received bandwidth can be subdivided into as many as 512 frequency channels with channel bandwidths as narrow as 125 Hz. An attached fringe processing computer will generate the frequency channels by Fourier transformation of the measured delay function and will perform other routine normalization and calibration tasks (*14*).

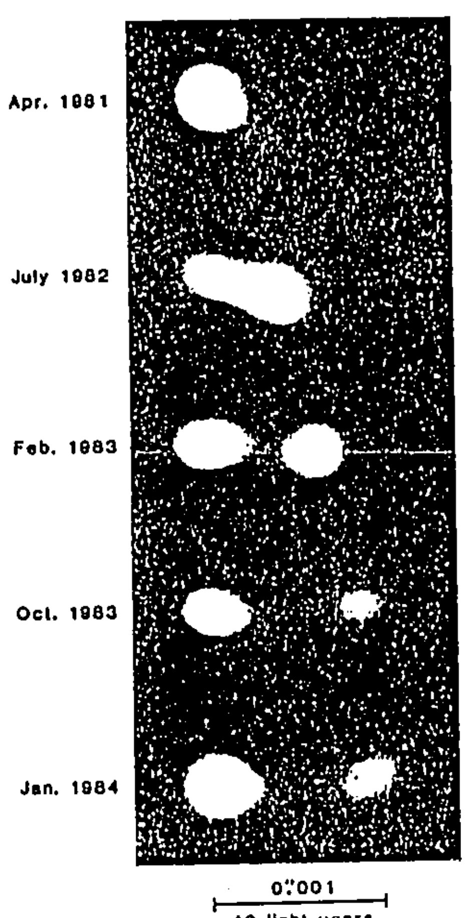
Image Formation

The image of a radio source obtained by Fourier transformaton of the measured visibility is the true brightness distribution convolved with the synthesized beam pattern, which is the response of the array to a source of infinitesimal angular dimensions. The beam pattern is determined mainly by the range of spatial frequencies covered in the observations (see Fig. 1D) and is derived easily. It is desirable that the beam pattern should have a well-defined main beam with a minimum of sidelobes. This constrains the distribution of the baselines and was a major consideration in selecting the antenna sites. However, with only ten antennas there are sidelobes with amplitudes of the order of 5 percent of the synthesized main beam. Because the pattern of the residual sidelobes is accurately known, their effect on the radio image can be effectively reduced by numerical computation with an algorithm known as CLEAN. In this process the radio image is analyzed into a set of beam patterns (including sidelobes), and then the image is reconstructed with a clean beam (that is, one without sidelobes) (Fig. 4).

The effect of tropospheric and ionospheric irregularities on the signal phase is more serious because the resulting fluctuations are not predictable and are often too rapid to remove by using a separate calibration source, especially at short centimeter and millimeter wavelengths. However, adaptive calibration techniques have been developed that use preliminary images contaminated by phase errors to estimate the unknown phases by iterative procedures. For N antennas there are many more measured interferometer phases, $N(N - 1)/2$, than unknown relative antenna phases, $N - 1$; because of this, the procedure converges rapidly. Several practical algorithms now exist under the names of "hybrid mapping," "self-calibration," or "adaptive-calibration" (*15*). However, the atmospheric effects are mitigated at the expense of increased computing time because the procedures require many iterations of the basic mapping processes. These procedures are presently in use at the VLA, and the two instruments will largely share the same software and computing facilities.

Operation

The operation of a radio telescope with elements dispersed over 8000 km presents a number of problems. With the present ad hoc VLBI activities, each antenna is operated by the local resident



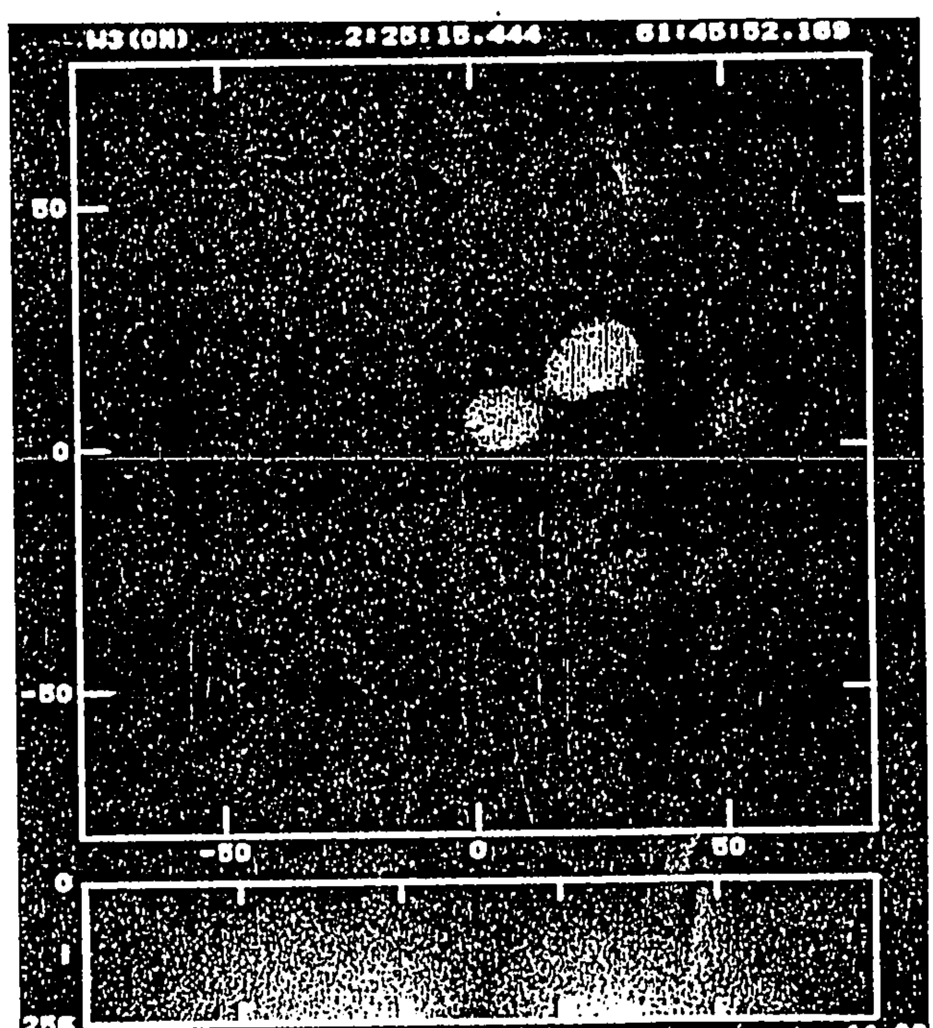


Fig. 6 (left). Five images of the quasar 3C345 showing the increase in separation of 21 light years during a 2.75-year period, or an apparent average expansion velocity of about 8*c* (*17*). Fig. 7 (right). Image of the OH maser in the envelope of a newly formed star in the constellation Cassiopeia. The colors indicate Doppler velocities of recession increasing from blue to red. Each spot is a maser source emitting radio radiation equivalent to a black body heated to 10^{11} K. This image was formed from an eight-station VLBI observation with antennas in Massachusetts, West Virginia, Texas, Illinois, Maryland, California (two), and Canada (*18*).

staff who carry out a prearranged observing program. All the elements of the VLBA will be controlled from an Operations Center in Socorro, New Mexico. This location was chosen to simplify the combined operation with the VLA, including some sharing of personnel and equipment.

Normally, each antenna will be unattended, but a technician-operator will be available at each site for inspection, routine maintenance, and the simpler unscheduled repairs. The local staff will also update the operating systems at the local control computer, change the data tapes, and ship them to the Operations Center and will be responsible for security, emergency intervention, and routine start-up and shut-down procedures.

The Operations Center will provide for major maintenance and repair requiring personnel with special skills, special equipment, or major replacement parts. However, because there are plans to build much of the electronics in modular units and to replace complete modules in the case of failure, most such replacements can be performed easily by the local site personnel. Defective modules will be returned to the Operations Center for repair. This procedure, although requiring a somewhat larger than normal inventory of spare parts, will reduce travel and personnel costs. The modular packaging was used in the design of the VLA and has proved to be highly practical.

The VLBA will be operated by means of a preplanned program under the control of a central computer that will simultaneously monitor the performance of the antennas and receivers as well as the meteorological conditions at each site. An array control operator will be present at all times at the Operations Center to intervene when necessary and to carry out various bookkeeping tasks. From time to time brief samples of the received signal at each antenna will be sent to the Operations Center via telephone lines and correlated in nearly real time to check that all components of the VLBA are functioning properly.

For special experiments, additional antennas such as the VLA and antennas in North America, Europe, Japan, and Australia may be included to increase even further the resolution, sensitivity, and image quality of the array. Of particular importance will be the dedicated VLBI antennas now being constructed in Italy and an array of four to nine elements under discussion in Canada.

These global systems will approach the best practical resolution obtainable from the surface of the earth, but even higher resolution will be possible from space. Plans already exist for a joint European Space Agency–NASA project to orbit a 15-m radio telescope known as QUASAT to operate together with the VLBA and other terrestrial arrays. QUASAT will give a further increase in baseline length over the VLBA by a factor of about 3 (Fig. 5). But perhaps more important, it will be the first step toward larger and more distant antennas in space that will permit even further improvement in resolution.

Research with the VLBA

Completion of the full VLBA, which will give high-quality radio images with unprecedented angular resolution, is planned for 1990. When completed, the array will allow detailed studies of the tiny energetic cores of galaxies and quasars, as well as pulsars, radio stars, interstellar molecular masers, and other compact sources of radio emission. In addition to astronomical studies, the array will be of importance in geodetics, crustal dynamics, and space navigation.

VLBI observations made with existing radio telescopes have already given a glimpse into the heart of quasars and galaxies, but the nature of the central energy source still remains a mystery. With the VLBA it will be possible to see in detail the dynamics of the energy generation process. Of particular interest will be the apparent faster-than-light motions resulting from the explosive ejection of relativistic material from quasars and galactic nuclei (*16*) (see Fig. 6).

Even within our own galaxy, there are various compact radio stars of interplanetary dimensions that are unresolved by conventional radio telescopes but can be studied with the VLBA. One of the most important problems in galactic astronomy is understanding the life cycle of stars. Clouds of OH, H_2O, and SiO are often found in regions where stars are formed and in the atmospheres of very old stars. They are excited by the stellar radiation and act as interstellar masers. High-resolution radio pictures made with the VLBA will be used to probe the dynamics and magnetic fields in these regions on a scale of 10^{13} to 10^{18} cm and to give information on the birth and death of stars (see Fig. 7).

Hydroxyl radical masers contain magnetic fields of the order of a few milligauss that cause the spectral features to exhibit Zeeman splitting. Observations of this splitting reveal the three-dimensional magnetic field vectors throughout these regions, which give some insight into the manner in which the magnetic field affects cloud collapse and star formation. The high resolution of the VLBA will also extend the range of direct distance measurements by trigonometric parallax. Observations of proper motions will be possible both throughout our galaxy and in other galaxies. This will open up an exciting range of astrometric solutions to the important problems of the structure and rotation of the galaxy.

One type of H_2O maser source contains clusters of hundreds of bright spots whose relative motions are nearly random. The distance to such sources can be determined by statistical parallax methods, that is, by comparison of dispersions of the radial velocity and angular motions. The distances to the maser sources in Orion and W51 (1,600 and 23,000 light years, respectively) have already been measured by this technique with an accuracy of about 20 percent (*19*). With the VLBA it will be possible to make similar measurements on a larger number of objects, including H_2O masers in nearby galaxies, thus extending this relatively direct distance measurement by a factor of about 100. This will have major implications for cosmology because knowledge of the correct scale of the universe will lead to a better understanding of its mass, energy content, age, and eventual evolution.

The VLBA will also be used for a broad range of problems in physics and geophysics as well as for astronomy and astrophysics (*20*). Because the spacing of the interferometer fringes depends on the separation of the antennas, precise analysis of the received signals makes it possible to measure the antenna separations with great accuracy. This measurement has a variety of applications to geodesy and crustal dynamics (plate tectonics). VLBI techniques have already been used to measure transcontinental distances to an accuracy of a few centimeters (*21*), and systematic measurements made over a period of time may well detect the small changes in separation among the various VLBA elements that are due to motions within the earth's crust. Tides in the solid earth amount to several tens of centimeters each day, and the ability to make systematic measurements of their effect will lead to a better understanding of the interior of the earth. In particular, measurements of this type may lead to the predictions of earthquakes and the detection of continental drift over time spans of several years.

Because the directions of the baselines connecting the individual elements can also be determined from the celestial observations, the VLBA may also be used to locate the instantaneous position of the Earth's rotation axis and the wandering of the poles. Accurate determination of the rate of the earth's rotation (time) and a better evaluation of the rate of its slowing down will also be possible.

The VLBA can also be used to measure with great accuracy the relativistic bending of radio signals as they pass close to the sun. Classical optical measurements of stars near the limb of the sun made during times of solar eclipses provided one of the first experimental demonstrations of general relativity. But even now, it is difficult to measure the bending of starlight with an accuracy better than 10 percent. Radio measurements made with connected element interferometers have already given an order of magnitude improvement in accuracy, and the much greater resolution of the VLBA will lead to further improvements. Indeed, the sensitivity to relativistic effects will be so great that even position measurements made 90° away from the sun will need to be routinely corrected for relativistic bending.

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The Very-Long-Baseline Array

An array of 10 radio antennas across the U.S. will provide the most detailed images yet of the universe. With it astronomers will explore such cosmic puzzles as the mysterious processes powering the quasars

by Kenneth I. Kellermann and A. Richard Thompson

Ever since Galileo pointed his telescope to the night sky nearly 400 years ago, astronomers have been building instruments of ever increasing sophistication with which to observe the universe. Each improvement in the resolving power of their instruments has enabled them to examine the universe in increasing detail and to discover new kinds of objects unknown to earlier generations. Galileo's telescope achieved a twentyfold improvement in resolution and allowed human eyes to see for the first time the phases of Venus, the rings around Saturn, the four bright moons of Jupiter, the craters and mountains on the moon and the myriad stars of the Milky Way. The giant optical instruments of today, such as the 200-inch Hale telescope on Mount Palomar, can detect objects more than a million times fainter than those Galileo could see. But because of limits imposed by turbulence in the atmosphere, they can distinguish features only one-tenth the size of those that could be detected with Galileo's rudimentary telescope.

The development of radio technology in World War II opened a completely new window on the universe. When astronomers turned radio antennas to the heavens, they began to find a previously unknown universe of solar and planetary radio bursts, quasars, pulsars, radio galaxies, giant molecular clouds and cosmic masers. Not only do the radio waves reveal a new world of astronomical phenomena but also—because they are much longer than light waves—they are not as severely distorted by atmospheric turbulence or small imperfections in the telescope.

To the pioneers in radio astronomy, however, the long wavelengths appeared to be a severe handicap. The resolving power of a telescope depends on the wavelength divided by the diameter of the aperture. To obtain a resolution comparable to that of an optical telescope operating at a typical light wavelength of 5,000 angstrom units (5×10^{-7} meter), a radio antenna operating at a one-meter wavelength would have to be a million times as large. Therefore although the early radio telescopes could detect signals from remote galaxies that are faint or invisible with even the largest optical telescopes, they had such poor resolution that they could not always tell individual sources apart. Even the largest steerable single-dish antenna, a 100-meter reflector in Germany operating at wavelengths of about one centimeter, can attain a resolution of only one minute of arc, roughly the same as that of the unaided eye. To build a radio telescope with a resolution of one second of arc, comparable to that of the Hale telescope, would require an antenna with a diameter in the tens of kilometers.

Fortunately there is a way around the dilemma. About 25 years ago radio astronomers became aware that they could synthesize a resolution equivalent to that of a large aperture by combining data from smaller radio antennas that are widely separated. The effective aperture size would be about equal to the largest separation between the antennas. The technique is called synthesis imaging and is based on the principles of interferometry. Radio astronomers in the U.S. are now building a synthesis radio telescope called the Very-Long-Baseline Array, or VLBA. With 10 antennas sited across the country from the Virgin Islands to Hawaii, it will synthesize a radio antenna 8,000 kilometers across, nearly the diameter of the earth. The VLBA's angular resolution will be less than a thousandth of an arc-second—about three orders of magnitude better than that of the largest conventional ground-based optical telescopes. Astronomers eagerly await the completion early in the next decade of the VLBA, which is expected, among other things, to give an unprecedentedly clear view into the cores of quasars and galactic nuclei and to reveal details of the processes—thought to be powered by black holes—that drive them.

Radio Interferometry

The basic principle of the VLBA is that of the radio interferometer, a system that combines the signals received from a radio source by two or more antennas. The resulting interference pattern indicates the difference in the path lengths from the source to the antennas. If the paths differ by an integral number of wavelengths, wave crests will arrive at the antennas in phase, or simultaneously, and produce an intensity maximum when the signals are combined. Conversely, if the paths differ by an odd number of half wavelengths, a crest and a trough will coincide and cancel, thereby creating an intensity minimum in the combined signal. Because the path lengths are determined by the position of the radio source in relation to the antennas, the interference pattern contains information about the location and detailed features of the source and can be used to construct an image.

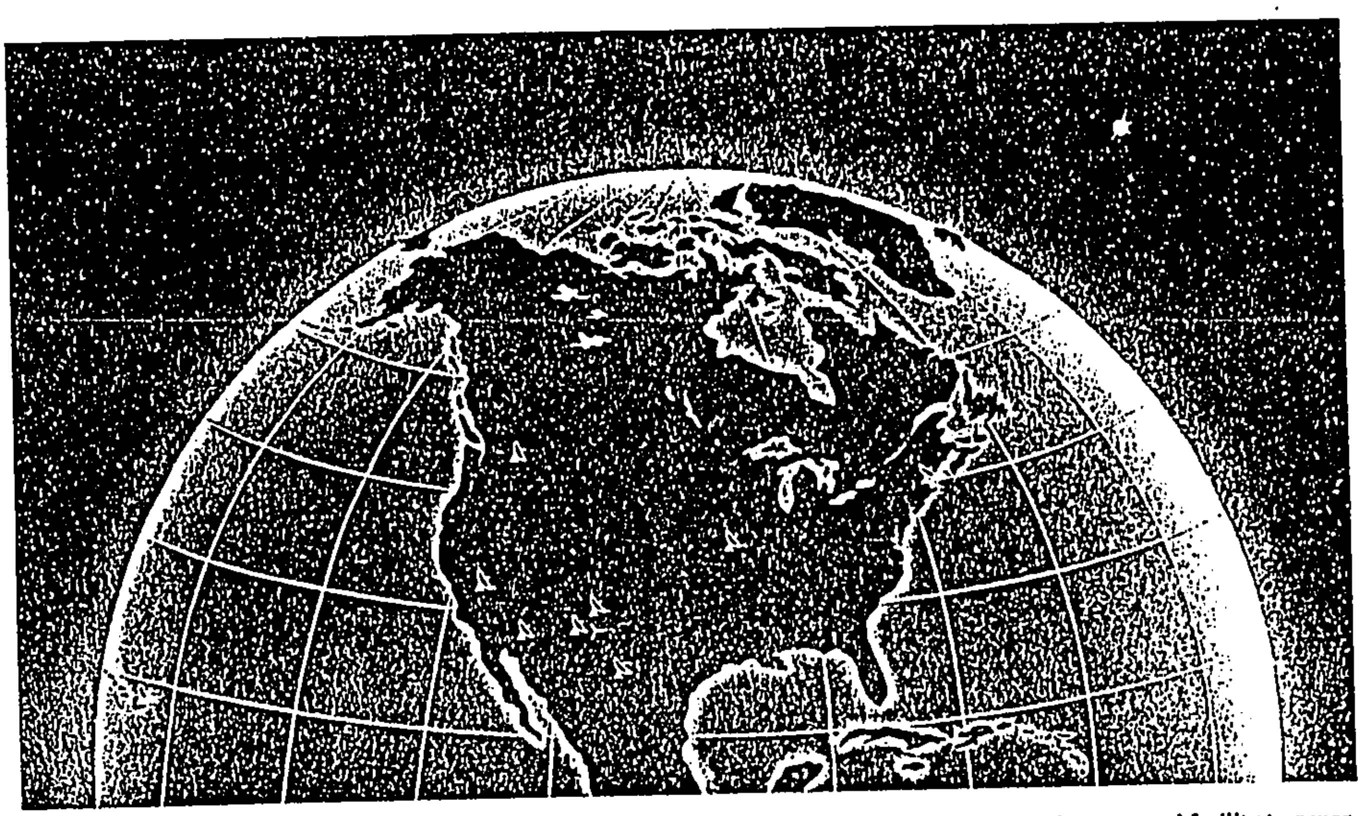
When a celestial object is observed with a radio interferometer, the rotation of the earth causes the path-length difference to vary and the received signal to oscillate between being in and out of phase, creating a sinusoidal pattern of maximums and minimums called interference fringes. The earth must rotate through a greater angle between one maximum and the next for short baselines than it must for long ones. Closely spaced antennas therefore produce broad fringes and respond only to the coarser structure of a source. Antennas with wider spacings respond to finer detail. To gather full information on the structure of a source it is necessary to have an array of antennas with a variety of baseline lengths. Moreover, the baseline orientations must be carefully distributed in order to obtain good two-dimensional images. The rotation of the earth itself causes foreshortening and reorientation of a baseline in relation to the source, so that a series of observations over a period of time has the effect of adding more baselines to the array.

The most powerful radio telescope operating today, the Very Large Array (VLA), is a giant Y-shaped array spread out on a high desert plateau in central New Mexico. It consists of 27 fully steerable parabolic antennas distributed along the three arms of the Y. A 21-kilometer railroad track runs along each arm with fixed stations along the way that provide bases for the antennas. The antennas are connected by buried waveguides to a central facility where the incoming signals are combined to produce the interference fringes. The nine antennas on each arm can be moved along the track and arranged in four different configurations so that the arm lengths range from 600 meters to 21 kilometers. The antennas operate in several frequency bands from 330 megahertz (90-centimeter wavelength) to 23 gigahertz (1.3-centimeter wavelength). The VLA yields high-sensitivity images with a resolution as good as a tenth of an arc-second, and the image quality equals or surpasses that of the best ground-based optical telescopes. With the VLA astronomers have obtained radio images of such objects as sunspots, the rings of Saturn, dark clouds in our galaxy and the mysterious energetic jets emanating from quasars and from the center of radio galaxies.

But many cosmic radio sources, such as the *enigmatic quasars*, are much too small to be resolved even with the VLA. They can be studied only by extending the antenna spacings to thousands of kilometers. Because of the distances involved, the antennas cannot be physically interconnected. Instead signals received at each antenna are recorded on magnetic tapes, which are transported to a central laboratory and there replayed simultaneously to simulate the resolution of a single enormous antenna. This technique is called very-long-baseline interferometry (VLBI), and it has been exploited with great success since the 1960's [see "Radio Astronomy by Very-Long-Baseline Interferometry," by Anthony C. S. Readhead; SCIENTIFIC AMERICAN, June, 1982]. Every few months radio observatories around the globe, mainly in the U.S. and Europe but including at times antennas in Australia, Brazil, Canada, China, India, Japan, South Africa and the Soviet Union, coordinate their schedules to track selected objects. Tapes recorded at each of the antennas are then replayed at one of three processing locations: the Max Planck Institute for Radio Astronomy in Bonn, the National Radio Astronomy Observatory in Charlottesville, Va., and the California Institute of Technology. As many as 18 antennas have taken part in this VLBI system to obtain remarkable images of quasars, active galactic nuclei, cosmic masers and other compact radio sources.

Details of the VLBA

This ad hoc VLBI system nonetheless leaves much to be desired. It is not easy to arrange for a sufficient amount of coordinated observ-

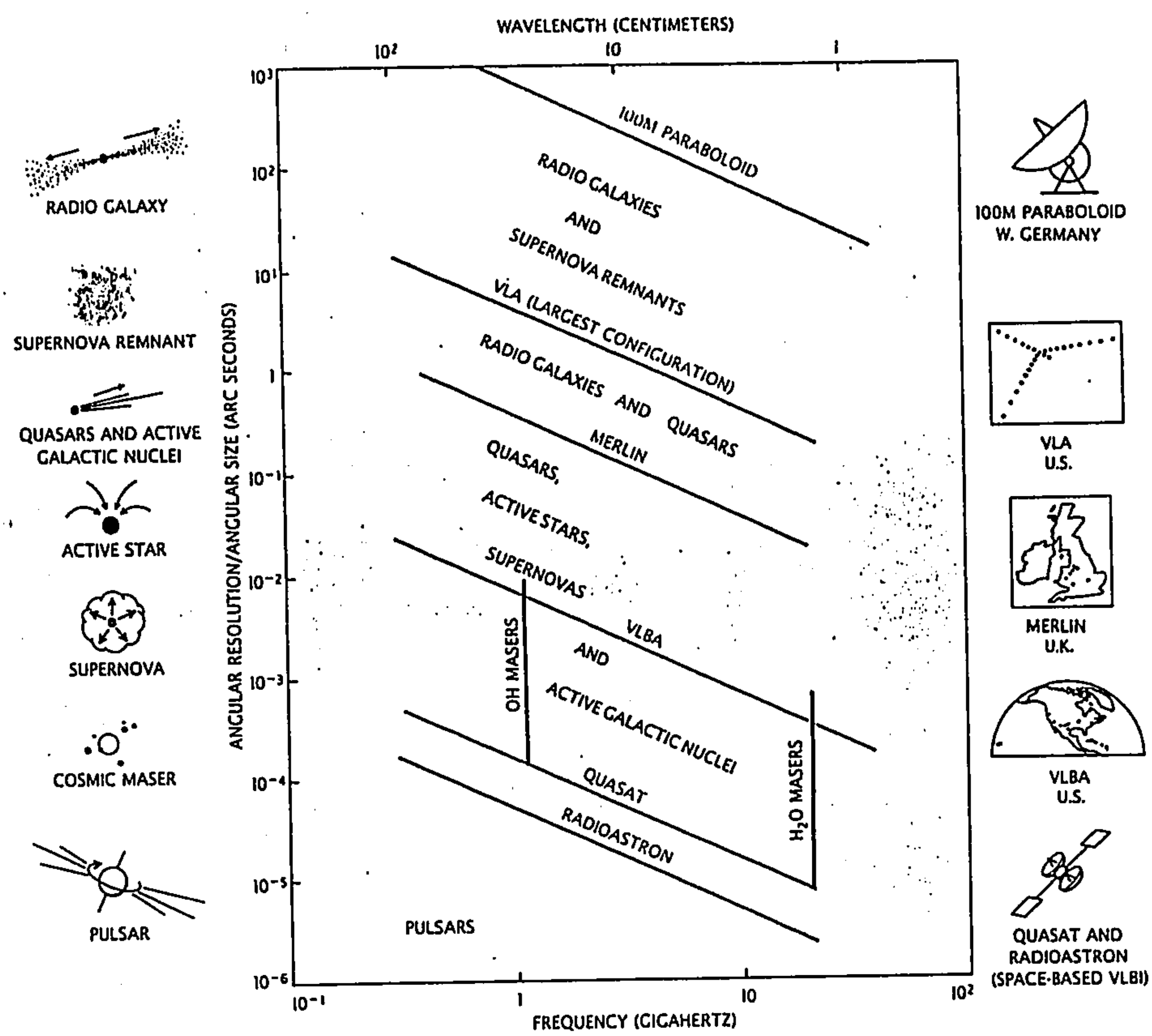


VERY-LONG-BASELINE ARRAY (VLBA) of 10 radio antennas will extend 8,000 kilometers across the U.S. and have a resolution comparable to that of a single antenna nearly as wide as the earth. Each antenna will record radio signals from cosmic sources, and the data will be correlated at a central facility to generate interference patterns from which images can be obtained. The Y-shaped symbol marks the location of the Very Large Array (VLA), which will provide additional data to supplement the VLBA.

ing time, and individual antennas are not properly sited to give good image quality. Moreover, the antennas vary in accuracy and sensitivity. In order to exploit the VLBI technique better, the National Radio Astronomy Observatory, with funds from the National Science Foundation, began in 1985 to construct the VLBA, a dedicated VLBI network of 10 antennas. Each antenna will be 25 meters in diameter and designed to operate at wavelengths as short as 3.5 millimeters. The antennas will be at sites throughout the U.S. chosen so that the distribution of baselines will provide good image quality. Other important objectives in the choice of antenna sites were to avoid strong manmade radio signals, to minimize atmospheric water vapor, to be near major transportation centers and to have access to local technical support. Five of the antennas will be at high elevations in the relatively dry, cloudless southwestern states.

Each antenna will be controlled through a local computer that will receive instructions over telephone lines from the VLBA Operations Center in Socorro, N.M. The array will follow a planned program under the control of a central computer that will monitor the antennas and receivers as well as weather conditions at each site. An array-control operator will be able to make changes on short notice if there is an unexpected cosmic event, such as a supernova. The operator will also be able to intervene when necessary, for example if there are technical problems or poor atmospheric conditions. For special experiments requiring even better images it will be possible to include data from as many as 10 other radio telescopes around the world.

At the present time the first VLBA



RESOLUTION OF RADIO TELESCOPES is plotted against the frequency of observed radio emissions for various antennas and arrays. The larger the effective aperture, the finer the resolution (measured by the angle subtended by the smallest distinguishable feature). The graph also indicates the angular size of various types of astronomical radio sources. The Bonn telescope is a single, 100-meter antenna. The Very Large Array (VLA) consists of 27 movable antennas physically linked by waveguide. MERLIN, operated by the Nuffield Radio Astronomy Laboratories in England, is a seven-antenna array extending over 200 kilometers and linked by microwave transmission. The VLBA, with a maximum baseline of 8,000 kilometers, will use recorded data. *Quasat* and *Radioastron* orbiting telescopes will employ both microwave links and recordings to extend baselines into space.

antenna, in Pie Town, N.M., is coming into operation, and five others are in various stages of construction. The full VLBA should be completed by 1992. By the mid-1990's astronomers hope to see the first antenna for radio interferometry launched into space. The VLBA will at that time provide ground-based observations to be combined with the data gathered from space. The VLBA, then, is not only a major advance in high-resolution astronomy but also a step toward the even more powerful space-based arrays of the future.

Clocks and Recorders

Fifty years of innovations, from hydrogen-maser clocks to home videocassette recorders, have contributed to the technologies that make the VLBA possible. The highly accurate clocks are needed to synchronize the data from the antennas; the magnetic-tape recorders store the huge volumes of data collected at each antenna. The radio receivers at each antenna will be among the most sensitive available. Most of the receivers will have transistor preamplifiers that will be cooled to 15 degrees Kelvin (degrees Celsius above absolute zero) to minimize noise in the instruments. Each antenna will be equipped to cover nine separate bands in the frequency range from 330 megahertz (90-centimeter wavelength) to 43 gigahertz (seven-millimeter wavelength). In the future the frequency range may be extended to 86 gigahertz (3.5-millimeter wavelength), which approaches the operational limit of the antennas.

In order for the VLBI technique to work there must be an accurate clock at each antenna so that the data can be synchronized. In addition, because the data are converted into a lower frequency, there must be an extremely stable frequency standard so that the phase of the signal is preserved. Both functions will be carried out in the VLBA by a hydrogen-maser clock, which bases its time standard on a characteristic frequency of the hydrogen atom. (Maser stands for microwave amplification by stimulated emission of radiation—the microwave counterpart of the laser.) The clock's frequency is stable to a few parts in 10^{15} for periods of up to an hour. This means that at the VLBA's highest frequency of 43 gigahertz the data from separate antennas can be synchronized over a time interval of about half an hour before the relative phases drift by an appreciable amount. It is therefore possible to condense half-hour segments of data by taking the average and thus to greatly reduce the amount of computation needed to obtain an image.

VLBI signals are recorded digitally on magnetic tape. The timing of individual samples is controlled by the maser clock and is not affected by mechanical factors such as the accuracy of the tape speed. When the first VLBI system went into operation in the early 1960's, conventional computer tapes were used and the recorded data rate was limited to a few hundred kilobits per second. Today modified home videocassette recorders are employed to record digital samples of the signal at a rate of four megabits per second. This system, called Mark II, provides four hours of uninterrupted recording at a two-megahertz signal bandwidth on a single cassette. More than 25 radio telescopes around the world have recording systems of this type. The newer Mark III recording system developed at the Massachusetts Institute of Technology's Haystack Observatory, largely under the sponsorship of the National Aeronautics and Space Administration, uses a reel-to-reel instrumentation recorder to obtain data rates of up to 224 megabits per second. This recorder provides for signal bandwidths of 112 megahertz, but it consumes a full 10,000-foot reel of tape every six minutes.

The VLBA requires bandwidths of at least 100 megahertz in order to be sensitive to weak celestial radio sources, but this must be balanced against a need to hold down the volume of tape. The Haystack Observatory has devised a new system for the VLBA that has 512 tracks and will be able to handle 256 megabits per second while using up tape more slowly than Mark III. A single 16-inch reel holding eight kilometers of tape will last for more than 12 hours and store about seven trillion bits of data—enough to contain the information found in 1,000 years' worth of issues of a major daily newspaper.

Two reels of tape will normally be recorded every day at each of the antennas and flown to the VLBA Operations Center, where they will be played back and the data combined with data from the other antennas. Up to 20 tapes can be played back simultaneously, so that non-VLBA radio telescopes can also contribute data to enhance the sensitivity and resolution of the VLBA. Even with many baselines the data will contain gaps, which can cause spurious features, called sidelobes, to show up in the computed image. These sidelobes, however, are well understood and can generally be removed from the image by means of a well-tested computer algorithm. More serious errors can be caused by unpredictable effects in the earth's atmosphere, but practical algorithms exist for handling these as well.

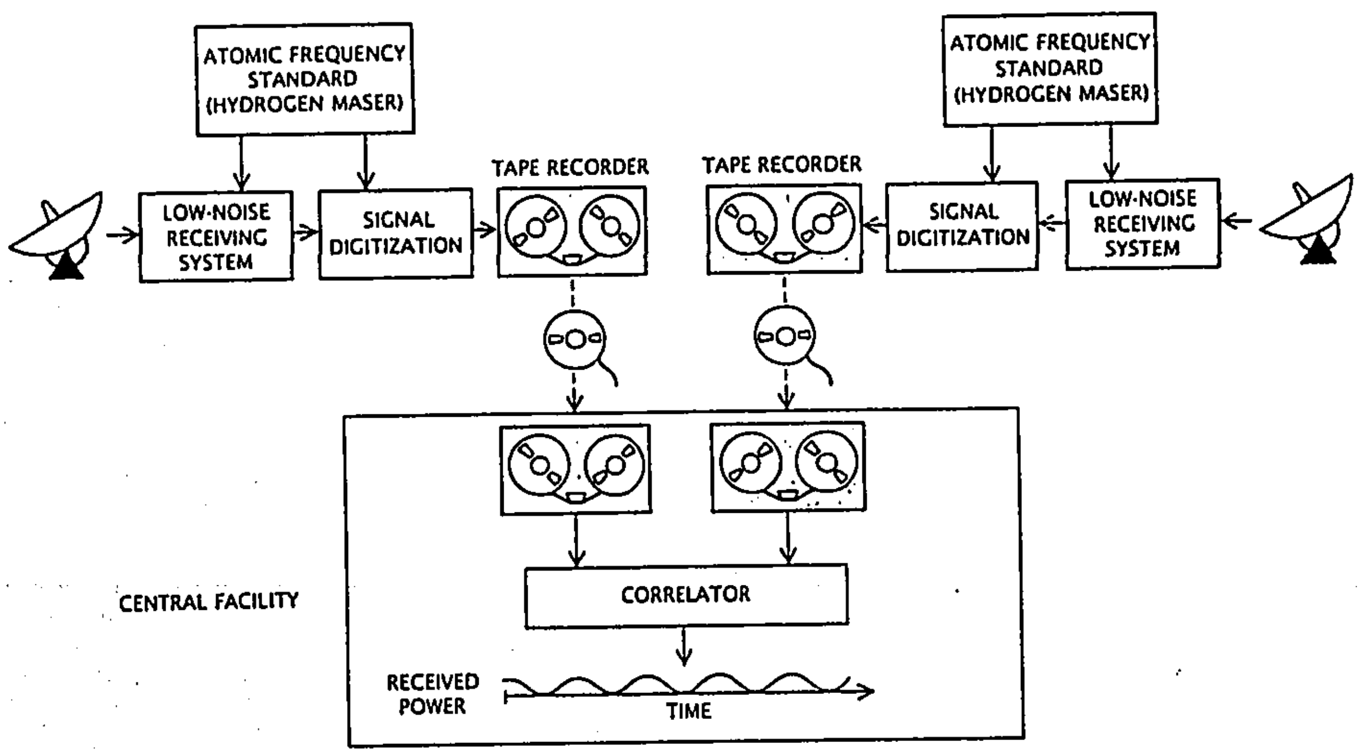
Jets and Stellar Evolution

The VLBA will give high-quality radio images with a resolution of a few ten-thousandths of an arc-second, which is equivalent to the angle subtended by a pea in San Francisco as seen from New York. On an astronomical scale this corresponds to an ability to detect features with diameters as small as 100 million miles anywhere in our galaxy or as small as a few light-years even in the remotest parts of the cosmos. High on the list of targets will be the cores of galaxies and quasars, the most powerful objects known in the universe.

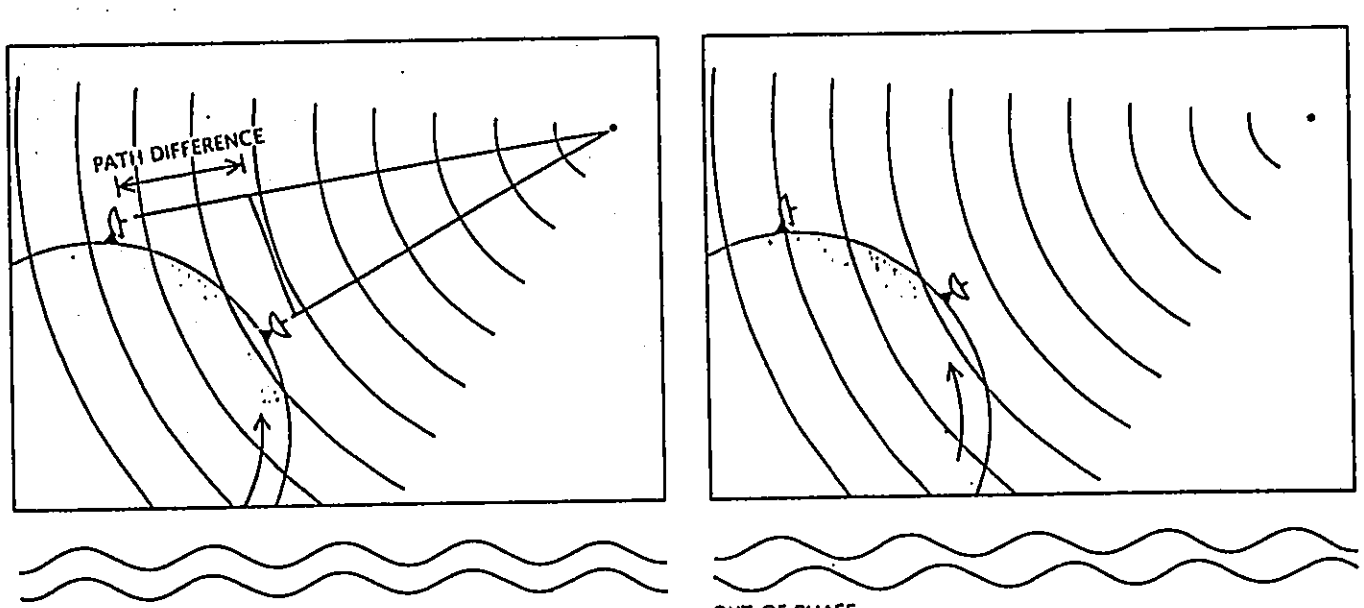
The ad hoc VLBI networks have already enabled radio astronomers to glimpse the inner regions of quasars and active galactic nuclei, where plasma is expelled in narrow jets. These violently energetic events are among the most perplexing problems in astronomy today. The blobs of plasma are ejected at velocities close to the speed of light and create several remarkable relativistic effects. First, the radiation becomes focused into a narrow beam along the direction of motion. If the object is moving close to the line of sight and toward the observer, a relatively weak galactic nucleus may appear to be as bright as a quasar. There is considerable debate among astronomers over whether the intense luminosity of quasars results from this effect.

An even more remarkable consequence of relativistic motion is the illusion that the plasma blobs are moving faster than the speed of light. This arises because the object is moving toward the observer so fast that it nearly keeps up with its own radiation. If the object travels for many hundreds of years, radiation emitted at intervals of hundreds of years will reach the observer only a few years apart. As seen from the earth, the path of travel can be foreshortened and appear to be tens of light-years, giving rise to the illusion that the object has traveled tens of light-years in only a few years. The phenomenon is called superluminal motion and often occurs when a radiating plasma blob is ejected from the nucleus of a quasar. These ejections seem to take place every few years, and it is speculated that the engine driving the activity is a massive black hole. The VLBA's resolution will enable astronomers to understand in greater detail the processes generating the jets.

Closer to home, astronomers are studying objects in our own galaxy in an attempt to understand the life cycle of stars—how they are born and how they die. Here too the VLBA can probe radio phenomena associated with stellar activity that cannot be resolved with conventional radio telescopes. Of particular interest is the intense microwave radiation from cosmic hydroxyl (OH) and water-vapor masers that are found in the gaseous envelopes of very young



VERY-LONG-BASELINE INTERFEROMETRY (VLBI) makes use of widely spaced antennas to observe cosmic radio sources. A hydrogen-maser clock at each antenna synchronizes the observations and provides a frequency standard so that phase relations will be preserved when the data are recorded on magnetic tape. The recordings are taken to a central facility and replayed into the correlator, which combines the signals. The resulting interference pattern yields an image by Fourier transformation.



THE EARTH'S ROTATION causes a pair of radio-interferometer antennas to oscillate between being in phase and out of phase with each other. The amount of rotation needed to change the phase relations depends both on the wavelength of the observed radio waves and on the distance separating the antennas: the shorter the wavelength or the greater the antenna separation, the less rotation required. This in turn determines the amount of detail that the pair of antennas can resolve as they scan the sky.

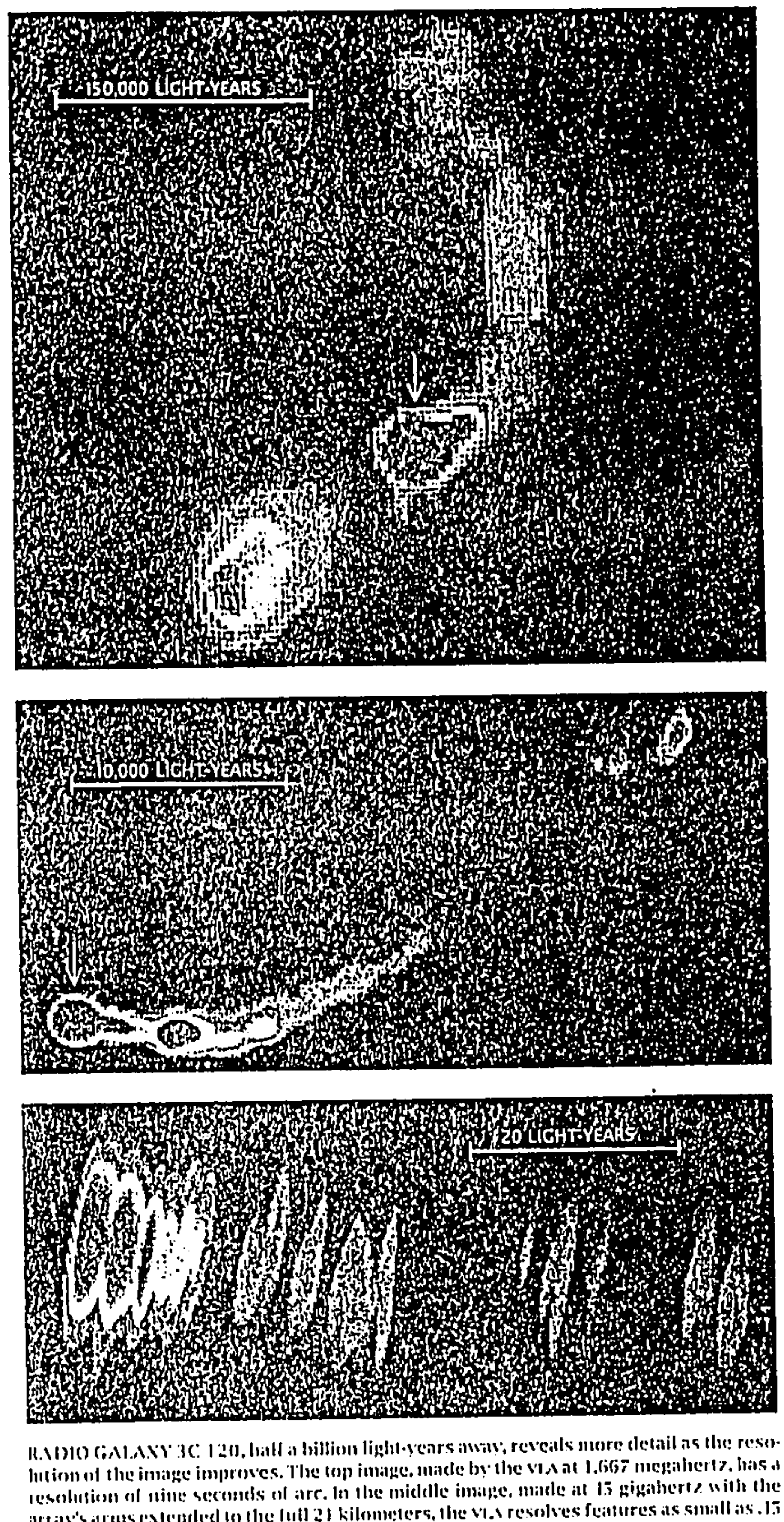
stars as well as in the dusty clouds around aging red giants.

These cosmic masers, among the brightest microwave sources in the sky, emit radiation when clouds of hydroxyl radicals or water molecules are stimulated to drop from a high energy state to a lower one. The excess energy is released as intense narrow-band microwave signals at characteristic wavelengths near 18 centimeters for the hydroxyl radical and 1.3 centimeters for water. Maser sources often contain many separate bright spots whose velocities can be determined by the Doppler shifts of their radiation. The VLBA images of maser motions should reveal much about the dynamics of the turbulent clouds, such as whether they are rotating or are *flying apart in the aftermath* of a cosmic explosion.

The hydroxyl maser may also act as a sensitive probe of magnetic fields in the maser cloud. Magnetic fields create small differences in the energy levels of the hydroxyl radical. The emitted radiation is split into pairs of spectral lines whose wavelengths are slightly different, a phenomenon called the Zeeman effect. High-resolution observations of the splitting can reveal details of the magnetic field in three dimensions throughout the maser cloud and so make it possible for astronomers to study the role of magnetic fields in causing clouds to collapse and form embryonic stars.

Measuring Cosmic Distances

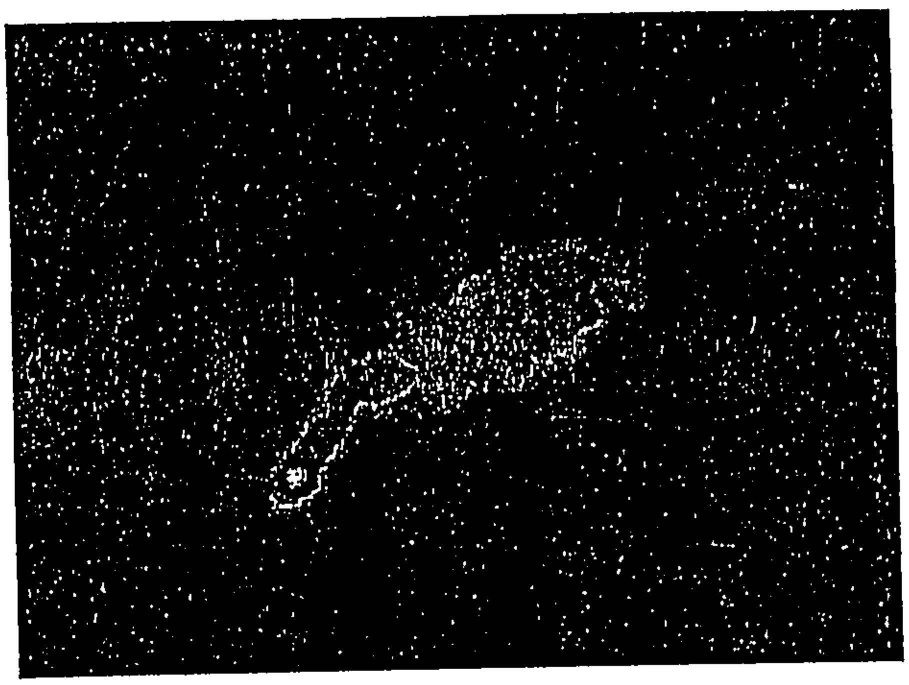
The VLBA will also be able to yield the most accurate measurements yet of cosmic distances, a problem of fundamental importance in astronomy. An accurate scale of the universe is vital to any understanding of its total mass and energy and of its past and future evolution, and yet the overall scale of the universe is uncertain by a factor of two. High-resolution instruments provide a way to determine distance directly. For example, in the case of a supernova remnant that is assumed to be expanding evenly in all directions, the velocity of the expansion can be measured by the Doppler shift in its radiation. Then, by comparing the velocity with observations of the changing diameter, one can infer the distance. The technique was recently applied by an international team of radio astronomers to determine the distance to a supernova that occurred in the Virgo cluster in 1979. VLBI observations gave an angular



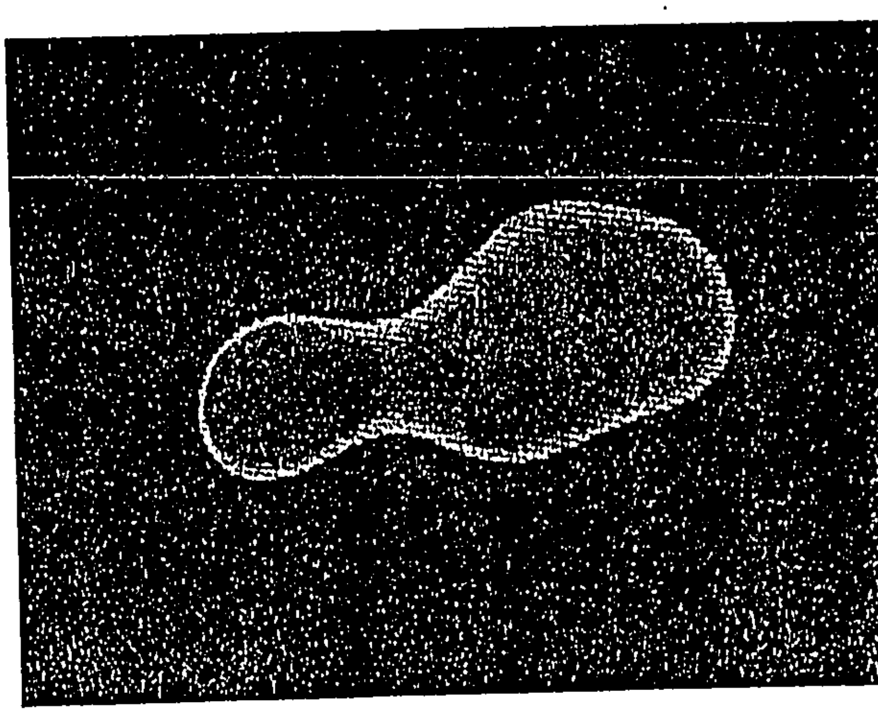
RADIO GALAXY 3C 120, half a billion light-years away, reveals more detail as the resolution of the image improves. The top image, made by the VLA at 1,667 megahertz, has a resolution of nine seconds of arc. In the middle image, made at 15 gigahertz with the array's arms extended to the full 21 kilometers, the VLA resolves features as small as .15 arc-second and shows a narrow jet curving away from the active nucleus. The bottom image, obtained by an 11-antenna VLBI observation made at five gigahertz, reveals details as small as .001 arc-second. The VLBI observations measured the apparent superluminal motion of plasma blobs in the jet as being about seven times the speed of light.

expansion rate of about .003 arc-second per year. Optical and ultraviolet spectra indicated that the supernova is expanding at 11,000 kilometers per second, which corresponds to .003 arc-second per year at a distance of about 60 light-years. So far the technique is about 35 percent accurate, but the VLBA is expected to improve the performance significantly.

VLBI has also provided a highly precise measurement of the relativistic bending of radio waves by the gravitational field of the sun. Originally proposed as one of the three classical tests of general relativity, the effect was confirmed in a landmark experiment in 1919, when stars observed during a total solar eclipse appeared to be deflected by the gravitational field of the sun. The optical observations, however, have been plagued by the difficulties of carrying out experiments in remote corners of the globe during the few minutes when a solar eclipse darkens the sky. Radio waves, on the other hand, can be observed at any time. Using data collected by two VLBI projects, POLARIS (Polar-Motion Analysis by Radio Interferometer Surveying) and IRIS (International Radio Interferometric Surveying), investigators at the U.S. National Geodetic Survey have measured relativistic bending over almost the entire sky. Thousands of observations over several years confirm the accuracy of theoretical predictions to a few tenths of a percent.



POWERFUL ENERGY SOURCE inside quasar 3C 380 appears in this VLBI image as a bright spot less than 10 light-years wide. It is thought the intense energy can be generated only by a black hole. The VLBA will be able to reveal details of such processes.



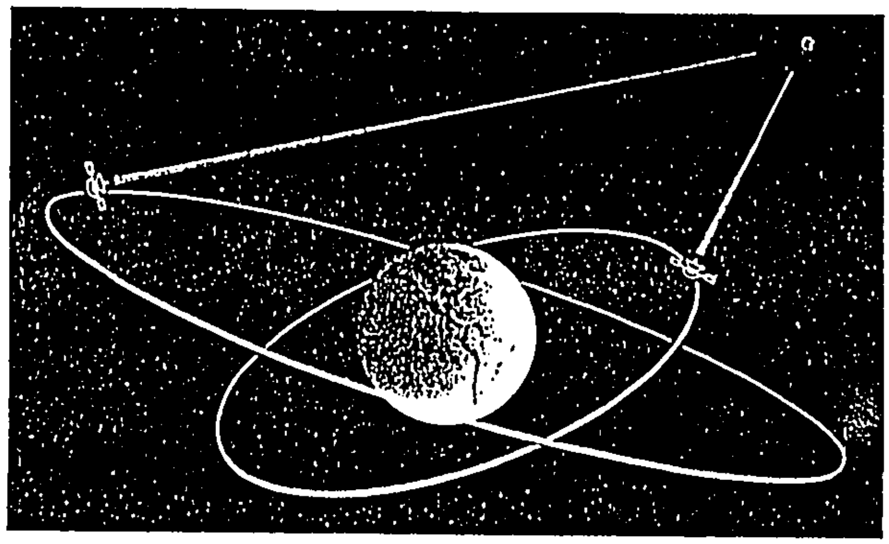
INTENSE RADIO OUTBURST in binary star UX Arietis was recorded in July, 1983. The image, made by a six-antenna VLBI system operating at five gigahertz, is barely able to distinguish the two parts of the binary. The radio emissions are thought to be generated by relativistic electrons accelerated in the stars' magnetic field. The VLBA will be able to observe the phenomenon in greater detail throughout the orbital cycle of the binary.

Measuring the Earth

Although it was conceived as an astronomical tool, the VLBA will be employed to study a variety of important terrestrial phenomena as well, such as plate-tectonic motion, rotation of the earth and distortions in the solid earth caused by tidal forces. These geodetic applications are possible because the response of the radio interferometer depends not only on the source under observation but also on the earth's rotation and the length and position of the baseline separating a pair of antennas. The technique is based on repeated observations of reference sources, such as quasars, so distant that they can be treated as fixed points in the sky. Changes in the earth's shape or rotation alter the results from one observation to the next [see "Studying the Earth by Very-Long-Baseline Interferometry," by William E. Carter and Douglas S. Robertson; SCIENTIFIC AMERICAN, November, 1986].

With geodetic VLBI it is possible to determine the distance between two widely separated antennas with a precision somewhat better than the wavelength at which the observation is made. VLBI can therefore detect changes in the earth's dimensions of less than one centimeter. The Jet Propulsion Laboratory's project ARIES (Astronomical Radio Interferometer Earth Surveying) is making extensive measurements in an effort to relate the incidence of earthquakes to small shifts across fault lines. Not surprisingly, earthquake-plagued countries such as China, Italy and Japan have shown great interest in geodetic VLBI and have already built radio telescopes dedicated to fault-line measurements. Because VLBI fringe oscillations are caused by the rotation of the earth, geodetic observations can measure the earth's rate of rotation in units of time provided by the maser clocks. The length of the day has thus been measured to an accuracy of a tenth of a millisecond, and the location of the earth's spin axis has been pinpointed to within a few tens of centimeters on the earth's surface.

To make the geodetic measurements, one needs to disentangle the terrestrial effects from the astronomical data. This is a complex problem and is made more difficult by the fluctuations in the radio sources, the unpredictable effects of the earth's atmosphere and ionosphere on the radio signals, the slow drift of the atomic clocks at the various stations and even the relativistic bending of radio waves by the sun. In order to refine the important geodetic and geophysical parameters, radio telescopes throughout the world have combined forces under the aegis of NASA's Crustal Dynamics Project and the POLARIS and IRIS projects mentioned above. With the VLBA it will be possible to obtain accurate images of the cosmic radio sources that provide the geodetic reference points. At the same time the VLBA will provide regular observations to supplement and extend the geodetic VLBI networks already in operation.



ORBITING RADIO TELESCOPES will extend interferometer baselines into space. During the 1990's the U.S. and Europe plan to launch *Quasat* into orbit three earth-diameters away, and the Soviet Union plans an even higher orbit for its *Radioastron* satellite.

VLBI in Space

Still another application of the versatile VLBA will be in interplanetary navigation. VLBI networks demonstrated this capability with spectacular success during the recent Soviet Vega mission to Venus and Halley's comet. In the largest international VLBI venture yet organized, a network of 20 antennas around the world tracked the two spacecraft deployed in the mission. Each of the spacecraft, which reached Venus in June of 1985, released a balloon carrying a 1.7-gigahertz transmitter into the planet's forbidding atmosphere. The VLBI network tracked the balloons as they were buffeted by the Venusian winds and measured gales of up to 140 miles per hour.

Following the encounter with Venus, the two spacecraft continued on to rendezvous with Halley's comet on March 6 and 9, 1986, a week before the scheduled flyby of the European *Giotto* spacecraft. European Space Agency scientists hoped to steer *Giotto* to the sunny side of the comet in order to take pictures, but because they could not be sure of the comet's precise location, there was a real danger that their cameras would end up on the dark side. Optical images of the comet made by Vega, combined with VLBI data on the spacecraft positions, enabled the Europeans to make last-minute corrections to *Giotto's* trajectory and bring it to within a few hundred miles of the sunlit side of the icy core. There *Giotto's* cameras were able to make spectacular photographs of Halley's comet on March 14, during its closest approach, just before communications with the spacecraft were cut off by collisions with the comet's debris.

Even when the VLBA is used in conjunction with other radio telescopes around the world, its resolution will ultimately be limited by the size of the earth. To achieve higher resolution the baselines will have to be extended into space, perhaps to the moon or even to the planets. Space-based VLBI will present a challenge to engineers, who must develop large, precise antennas and sensitive radio receivers that can operate unattended in the harsh space environment. The feasibility of space VLBI has already been demonstrated by a team of American, Australian and Japanese scientists, who employed a small antenna aboard a NASA satellite as one element of an earth-space VLBI system.

Plans for dedicated VLBI satellites are already being discussed in the U.S., Western Europe, Japan and the Soviet Union. It has been proposed that NASA and the European Space Agency jointly launch a satellite to be called *Quasat*, which would carry a 10-to-15-meter antenna into earth orbit by the middle of the next decade. Recent setbacks to the NASA space-science program have made U.S. participation in this project uncertain. The Soviet Union has also announced a space VLBI program and expects to launch two or three *Radioastron* satellites in orbits of up to 75,000 kilometers. European and American scientists have been invited to take part, but the U.S. Government's reluctance to share advanced space technology with the Soviet Union may limit U.S. involvement.

In the more distant future, some Soviet scientists envision building giant antennas, each as much as several kilometers across, to be placed in orbit around the sun. This array would provide baselines up to several hundred million miles long and an angular resolution that could be better than a millionth of an arc-second. A radio telescope of such power would open up a new frontier of astronomy. In theory it would enable scientists to observe "sunspots" on other stars in our galaxy and to resolve features in neighboring galaxies comparable to the supposed size of black holes. Fascinating as it is to speculate about the future, there remain many uncertainties about the feasibility and effectiveness of such an array. These issues should become clearer as we gain experience with the VLBA and earth-orbiting antennas.

APPENDIX B

THE RESPONSE OF THE VERY LONG BASELINE ARRAY TO INTERFERING SIGNALS

PATRICK C. CRANE

THE RESPONSE OF THE VERY LONG BASELINE ARRAY

TO INTERFERING SIGNALS

Patrick C. Crane

11 September 1985

I. Introduction

Radio astronomy studies the nature of the Universe, based upon the reception of radio waves of cosmic origin. These cosmic emissions constitute the "cosmic background noise" of communications engineering. The emissions are random, noise-like signals that are indistinquishable from the noise generated in the receivers or from the Earth and its atmosphere. Furthermore, the intensity of cosmic radiation is usually much weaker than that of the noise (the weakest cosmic signal detected is about -234 dBW/m^2.)

The National Radio Astronomy Observatory began construction of a new radio telescope, the Very Long Baseline Array (VLBA), in May 1985; construction should be completed by 1992. The characteristics of the VLBA have been described by Kellermann and Thompson (1985). Like any other radio telescope the VLBA will be sensitive to radio interference but several features of its design will greatly reduce its sensitivity to such interfering signals.

In the following sections I will summarize the responses of a single antenna and an aperture-synthesis radio telescope to interfering signals, followed by a discussion of the response of the Very Long Baseline Array.

II. A single antenna

The harmful interference level for observations with a single antenna has been analyzed in CCIR Report 224-5: The harmful interference level is that level of interference which equals 0.1 of the rms noise level which sets the fundamental limit of the data. For a total-power receiver the harmful interference level is given by

$$F_i = \frac{0.4\pi f^2 k T_s \sqrt{B}}{c^2 G_s \sqrt{2t}} ,$$

where f is the observing frequency; k, Boltzman's constant; T_s, the system temperature; B, the observing bandwidth; c, the speed of light; G_s, the gain, with respect to an isotropic antenna, of the antenna in the direction of arrival of the interfering signal; and t, the total integration time. As derived in the report, the harmful interference levels, for continuum observations with modern receivers and an integration time of 2000 seconds, range between -202 and -114 dBW/m^2 at 20 MHz and 235 GHz, respectively.

III. An aperture-synthesis radio telescope

As discussed by Thompson (1982a), two effects reduce the sensitivity to interfering signals of an aperture-synthesis radio telescope:

The first is an averaging effect that applies to any interfering signal. The motion of an astronomical source across the sky results in changes in the relative phases of the signals received at the antennas, so that if the signals from any pair of antennas are multiplied together, the output voltage will vary quasi-sinusoidally with time. The frequency of the output signal is called the natural fringe frequency and depends upon the spacing of the antennas and the position of the radio source on the sky (it ranges between a few milliHertz and tens of Hertz for existing radio telescopes.) On the other hand, a terrestrial source of interference is fixed with respect to the earth, and the corresponding output voltage will be constant. If the data are averaged for a time T, the interfering signal will be reduced by a factor of sinc(πfT), where f is the natural fringe frequency. Thompson's complete analysis includes the variations with the position of the source and the spacings of the antennas, and the harmful interference level for a twelve-hour observation time is given by

$$F_i = \frac{0.4\pi f^2 k T_s \sqrt{2\omega_0 B}}{c^2 G_s} \sqrt{\frac{L}{\lambda}} ,$$

where ω_0 is the angular rotation velocity of the earth and L is a measure of the physical size of the array.

The second effect mentioned above reduces the sensitivity of an aperture-synthesis radio telescope to broadband interfering signals. Because the signals from cosmic radio sources have the characteristics of broadband noise, such a telescope introduces computer-controlled delays to equalize the time delays from the source through the antennas to the multipliers and to maintain the coherence of the signals. For broadband interference entering the antenna sidelobes, the delays will generally differ from those of the cosmic signal, and the interfering signal will be decorrelated by an amount given by sinc($\pi B t_d$), where t_d is the delay inequality. The maximum delay inequality is given by twice the delay corresponding to the maximum baseline. Obviously, for an interfering signal arriving from the same general direction as the cosmic signal, the delay inequality may be near zero. The decorrelation factor is not amenable to a general analysis, but will vary significantly with bandwidth, declination of the radio source, and the configuration.

IV. The Very Long Baseline Array

The Very Long Baseline Array (VLBA) will be much less sensitive to interfering signals than any other radio telescope, primarily because of its vastly greater geographical scale: Because the antenna spacings in the VLBA range between 200 and 8000 km (L is about 3950 km), the natural fringe frequencies are much greater (of the order of kiloHertz) than for other aperture-synthesis radio telescopes, and the averaging effect reduces the sensitivity to interfering signals by about a factor of 10,000 over a single antenna. Also the delay inequalies and the decorrelation factor are corresponding greater. Finally, except for an interfering signal originating from a satellite, such a signal is unlikely to be present at a harmful level at more than one antenna.

More significant for the VLBA will be the degradation of its performance by the addition of uncorrelated power at the individual antennas which effectively increases the noise level. The harmful level for such interference is estimated to be one percent of the system noise level (Thompson 1982b), or

$$F_i = \frac{0.04\pi f^2 k T_s B}{c^2 G_s} .$$

At much higher levels interfering signals occurring anywhere within the passband of the front-end receiver will cause gain compression and other nonlinear behavior. The harmful levels for such interference depend upon the design of the receiver but can be estimated for each observing band.

Table 1 presents the harmful interference levels for the thirteen observing bands planned for the VLBA, which were calculated for a G_S of 1 and bandwidths of 8 MHz (1.6 MHz at 75 MHz). The estimates of the interference levels that will cause one-percent gain compression are from Thompson and Schlecht (1985). We see that the averaging effect increases the harmful interference levels of the VLBA to values comparable to those which will increase the system noise level by one percent. The 70-dB differences between the interference levels adding one percent to the system noise level and causing one-percent gain compression allow considerable leeway for processing at the IF.

V. Conclusions

The Very Long Baseline Array is far less sensitive to interfering signals than any other radio telescope. The sites of the VLBA antennas have been selected, furthermore, to minimize the potential for terrestrial sources of interference, but the VLBA will be particularly susceptible to interfering signals from air- and satellite-borne transmitters. A transmitter in geostationary orbit, isotropically broadcasting one watt, produces a signal level of -162 dBW/m^2 at the earth's surface. Allowing for a more powerful transmitter or more antenna gain at the receiver or transmitter, we see that such a transmitter could easily interfere with the VLBA.

Table 2 lists the VLBA observing bands and the adjacent and overlapping U.S. frequency allocations (international and U.S. footnotes are noted in parentheses when appropriate.) Most of the allocations for radio astronomy are adjacent to or share allocations for aeronautical radionavigation, mobile-satellite, radionavigation-satellite, meteorological-satellite, and broadcasting-satellite. Radio astronomers have already encountered problems with the U.S. Global Positioning System and the corresponding Soviet GLONASS system.

VI. References

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TABLE 1. VLBA OBSERVING BANDS AND HARMFUL INTERFERENCE LEVELS

FREQUENCY (MHz)	EFFICIENCY	TSYS (K)	RECEIVER	10% NOISE (dBW/m^2)	1% SYSTEM (dBW/m^2)	1% GAIN (dBW/m^2)
73.0- 74.6	0.50	1000	GAsFET	-168	-158	
312.0- 342.0	0.50	126	GAsFET	-157	-147	-72
580.0- 640.0	0.49	84	GAsFET	-152	-143	-67
1350.0- 1750.0	0.67	28	Cooled GAsFET	-150	-140	-59
2150.0- 2350.0	0.71	33	Cooled GAsFET	-142	-136	-55
4600.0- 5100.0	0.73	35	Cooled HEMT	-134	-129	-49
5900.0- 6400.0	0.72	38	Cooled HEMT	-131	-127	-47
8000.0- 8800.0	0.72	49	Cooled HEMT	-126	-123	-44
10200.0-11200.0	0.71	48	Cooled HEMT	-124	-121	-42
14400.0-15400.0	0.70	54	Cooled HEMT	-119	-117	-39
21700.0-24100.0	0.65	70	Cooled HEMT	-114	-113	-35
42300.0-43500.0	0.64	75	Cooled SIS	-107	-107	-30
86000.0-92000.0	0.42	300	Cooled SIS	-93	-94	

TABLE 2. VLBA OBSERVING BANDS AND U.S. FREQUENCY ALLOCATIONS

Specified Band (Accessible Band)	Frequency Allocations	
73.0- 74.6 MHz	54.0- 72.0 MHz	Broadcasting
	72.0- 73.0 MHz	Fixed, Mobile
	73.0- 74.6 MHz	RADIO ASTRONOMY
	74.6- 74.8 MHz	Fixed, Mobile
	74.8- 75.2 MHz	Aeronautical Radionavigation
	75.2- 76.0 MHz	Fixed, Mobile
	76.0- 108.0 MHz	Broadcasting
312.0- 342.0 MHz	225.0- 328.6 MHz	Fixed, Mobile
	322.0- 328.6 MHz	Radio Astronomy (644)
	328.6- 335.4 MHz	Aeronautical Radionavigation
	335.4- 399.9 MHz	Fixed, Mobile
580.0- 640.0 MHz	512.0- 608.0 MHz	Broadcasting
	608.0- 614.0 MHz	RADIO ASTRONOMY
	614.0- 806.0 MHz	Broadcasting
1350.0- 1750.0 MHz	1240.0- 1300.0 MHz	Radiolocation
(1300.0- 1800.0)	1300.0- 1350.0 MHz	Aeronautical Radionavigation
	1330.0- 1400.0 MHz	Radio Astronomy (718)
	1350.0- 1400.0 MHz	Radiolocation
	1400.0- 1427.0 MHz	RADIO ASTRONOMY Earth Exploration-Satellite (1) Space Research (1)
	1427.0- 1429.0 MHz	Fixed, Mobile (6) Space Operation (2)
	1429.0- 1435.0 MHz	Fixed, Mobile
	1435.0- 1530.0 MHz	Mobile (7)
	1530.0- 1544.0 MHz	Maritime Mobile-Satellite (3)
	1544.0- 1545.0 MHz	Mobile-Satellite (3)
	1545.0- 1559.0 MHz	Aeronautical Mobile-Satellite (3)
	1559.0- 1610.0 MHz	Aeronautical Radionavigation Radionavigation-Satellite (3)
	1610.0- 1626.5 MHz	Aeronautical Radionavigation
	1610.6- 1613.8 MHz	Radio Astronomy (734)
	1626.5- 1645.5 MHz	Maritime Mobile-Satellite (2)
	1645.5- 1646.5 MHz	Mobile-Satellite (2)
	1646.5- 1660.0 MHz	Aeronautical Mobile-Satellite (2)
	1660.0- 1660.5 MHz	RADIO ASTRONOMY Aeronautical Mobile-Satellite
	1660.5- 1668.4 MHz	RADIO ASTRONOMY Space Research (1)
	1668.4- 1670.0 MHz	RADIO ASTRONOMY Meteorological Aids
	1670.0- 1690.0 MHz	Meteorological Aids Meteorological-Satellite (3) Radio Astronomy (US211)
	1690.0- 1700.0 MHz	Meteorological Aids Meteorological-Satellite (3)
	1700.0- 1710.0 MHz	Fixed Meteorological-Satellite (3)
	1710.0- 1850.0 MHz	Fixed, Mobile

	1718.8- 1722.2 MHz	Radio Astronomy (US256)
2150.0- 2350.0 MHz	1990.0- 2110.0 MHz	Fixed, Mobile
(2100.0- 2600.0)	2110.0- 2200.0 MHz	Fixed
	2200.0- 2290.0 MHz	Fixed (8), Mobile (8)
		Space Research (3,4)
	2290.0- 2300.0 MHz	Space Research (3,5)
		Fixed, Mobile (6)
	2300.0- 2310.0 MHz	Radiolocation
	2310.0- 2390.0 MHz	Radiolocation, Mobile
	2390.0- 2450.0 MHz	Radiolocation
	2450.0- 2500.0 MHz	Fixed, Mobile
	2500.0- 2655.0 MHz	Broadcasting-Satellite
		Fixed
		Radio Astronomy (US269)
	2655.0- 2690.0 MHz	Broadcasting-Satellite
		Fixed
		Radio Astronomy
	2690.0- 2700.0 MHz	RADIO ASTRONOMY
		Earth Exploration-Satellite (1)
		Space Research (1)
4600.0- 5100.0 MHz	4400.0- 4500.0 MHz	Fixed, Mobile
	4500.0- 4800.0 MHz	Fixed, Mobile
		Fixed-Satellite (3)
	4800.0- 4990.0 MHz	Fixed, Mobile
	4825.0- 4835.0 MHz	Radio Astronomy (US203,778)
	4950.0- 4990.0 MHz	Radio Astronomy (US257)
	4990.0- 5000.0 MHz	RADIO ASTRONOMY
	5000.0- 5250.0 MHz	Aeronautical Radionavigation
		Radio Astronomy (US211)
5900.0- 6400.0 MHz	5850.0- 5925.0 MHz	Radiolocation
		Fixed-Satellite (2)
	5925.0- 6425.0 MHz	Fixed
		Fixed-Satellite (2)
8000.0- 8800.0 MHz	7750.0- 7900.0 MHz	Fixed
(7900.0- 8900.0)	7900.0- 8025.0 MHz	Fixed-Satellite (2)
		Mobile-Satellite (2)
	8025.0- 8175.0 MHz	Earth Exploration-Satellite (3)
		Fixed
		Fixed-Satellite (2)
	8175.0- 8215.0 MHz	Earth Exploration-Satellite (3)
		Fixed
		Fixed-Satellite (2)
		Meteorological Satellite (2)
	8215.0- 8400.0 MHz	Earth Exploration-Satellite (3)
		Fixed
		Fixed-Satellite (2)
	8400.0- 8450.0 MHz	Fixed
		Space Research (3,5)
	8450.0- 8500.0 MHz	Fixed
		Space Research (3)
	8500.0- 9000.0 MHz	Radiolocation
10200.0-11200.0 MHz	9500.0-10550.0 MHz	Radiolocation
	10550.0-10600.0 MHz	Fixed

	10600.0-10680.0 MHz	Earth Exploration-Satellite (1)
		Fixed
		Space Research (1)
		Radio Astronomy (US277)
	10680.0-10700.0 MHz	RADIO ASTRONOMY
		Earth Exploration-Satellite (1)
		Space Research (1)
	10700.0-11700.0 MHz	Fixed
		Fixed-Satellite (3)
		Radio Astronomy (US211)
14400.0-15400.0 MHz	14200.0-14500.0 MHz	Fixed-Satellite (2)
	14470.0-14500.0 MHz	Radio Astronomy (US203,862)
	14500.0-14714.5 MHz	Fixed
	14714.5-15136.5 MHz	Mobile
	15136.5-15350.0 MHz	Fixed
		Radio Astronomy (US211)
	15350.0-15400.0 MHz	RADIO ASTRONOMY
		Earth Exploration-Satellite (1)
		Space Research (1)
	15400.0-15700.0 MHz	Aeronautical Radionavigation
		Radio Astronomy (US211)
21700.0-24100.0 MHz	19700.0-20200.0 MHz	Fixed, Mobile
(20000.0-26300.0)		Fixed-Satellite (3)
	20200.0-21200.0 MHz	Fixed-Satellite (3)
		Mobile-Satellite (3)
	21200.0-21400.0 MHz	Earth Exploration-Satellite (1)
		Space Research (1)
		Fixed, Mobile
	21400.0-22000.0 MHz	Fixed, Mobile
	22000.0-22210.0 MHz	Fixed, Mobile (6)
	22010.0-22210.0 MHz	Radio Astronomy (874)
	22210.0-22500.0 MHz	RADIO ASTRONOMY
		Fixed, Mobile (6)
		Earth Exploration-Satellite (1)
		Space Research (1)
	22500.0-22550.0 MHz	Fixed, Mobile
		Broadcasting-Satellite
		Radio Astronomy (US211)
	22550.0-23000.0 MHz	Fixed, Mobile
		Inter-Satellite
		Broadcasting-Satellite
	22810.0-22860.0 MHz	Radio Astronomy (879)
	23000.0-23550.0 MHz	Fixed, Mobile
		Inter-Satellite
	23070.0-23120.0 MHz	Radio Astronomy (879)
	23550.0-23600.0 MHz	Fixed, Mobile
	23600.0-24000.0 MHz	RADIO ASTRONOMY
		Earth Exploration-Satellite (1)
		Space Research (1)
	24000.0-24050.0 MHz	Amateur
		Amateur-Satellite
		Radio Astronomy (US211)
	24050.0-24250.0 MHz	Radiolocation
	24250.0-25250.0 MHz	Radionavigation
	25250.0-27000.0 MHz	Fixed, Mobile

42300.0-43500.0 MHz	40500.0-42500.0 MHz	Broadcasting-Satellite Broadcasting Radio Astronomy (US211)
	42500.0-43500.0 MHz	RADIO ASTRONOMY Fixed, Mobile (6) Fixed-Satellite (2)
	43500.0-45500.0 MHz	Fixed-Satellite (2) Mobile-Satellite (2)
86000.0-92000.0 MHz	84000.0-86000.0 MHz	Fixed, Mobile Broadcasting-Satellite Broadcasting Radio Astronomy (US211)
	86000.0-92000.0 MHz	RADIO ASTRONOMY Earth Exploration-Satellite (1) Space Research (1)
	92000.0-95000.0 MHz	Fixed, Mobile Fixed-Satellite (2) Radiolocation
	93070.0-93270.0 MHz	Radio Astronomy (914)

(1) Passive
(2) Earth-to-Space
(3) Space-to-Earth
(4) Space-to-Space
(5) Deep Space only
(6) Except aeronautical mobile
(7) Aeronautical telemetering
(8) Line-of-Sight

APPENDIX C

ARCHAEOLOGICAL RECONNAISSANCE OF
TWO PROPOSED ANTENNA SITES FOR
THE NATIONAL RADIO ASTRONOMY
OBSERVATORY, MAUNA KEA, HAWAII

CULTURAL SURVEYS HAWAII

ARCHAEOLOGICAL RECONNAISSANCE OF TWO PROPOSED ANTENNA SITES FOR THE NATIONAL RADIO ASTRONOMY OBSERVATORY, MAUNAKEA, HAWAI'I

by

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Prepared for

MCM PLANNING

by
Cultural Surveys Hawaii
May 1988

ABSTRACT

This archaeological reconnaissance covered two alternative locations for a National Radio Astronomy Observatory Antenna site on the south eastern slope of the summit region of Mauna Kea. The first location between 11,560 and 11,840 feet (3523.49 and 3608.83 m.) is a 15-acre (6.07 hectares) level area on the west side of the present summit road. No archaeological sites were observed in this area. The second and preferred location is an approximately 100-acre (40.47 hectares) area on the east side of the summit road in a saddle between 2 cinder cones at 12,100 - 12,225 feet (3688.08 - 3726.18 m.) elevation. Four archaeological sites were observed in this project area - 3 probable shrines and a small rock shelter. All four of these sites are removed from the proposed access road and antenna site and can easily be preserved in place without modifying construction plans. Preservation in place is recommended with plotting of site locations on construction maps and reflagging of sites before construction.

ACKNOWLEDGEMENTS

We would like to thank Ms. Marilyn Metz of MCM Planning for coordinating this project and supplying maps and other information. Mr. Tom Crieger kindly allowed use of the Hale Pohaku facilities during the field work. We would also like to thank Ms. Ginger Plasch of the University of Hawaii for her assistance during the September 1987 field inspection. Field work was conducted by the authors, Mr. David Shideler and Mr. Mark Stride. Mr. Steve Clark prepared the drafted figures and Ms. Vicki Creed of Windword Processing typed this manuscript. Dr. Ross Cordy of the State Historic Preservation Office was very helpful in providing copies of previous surveys of the summit area. This report has been revised to incorporate his review comments as stated in a letter from the Department of Land and Natural Resources, dated may 12, 1988

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I. INTRODUCTION, SCOPE OF WORK AND PROJECT AREA DESCRIPTION

This reconnaissance survey was performed at the request of MCM Planning to assess archaeological impact of the proposed construction of a VLBA (Very Long Baseline Array) radio telescope within the Mauna Kea Science Reserve. The purpose of the survey was to locate, map, and document the archaeological features within two alternative antenna site areas (Figs 1-4). Each of these areas is described below.

A. Antenna Site 1

This project area (Fig. 3) is located between the 11,560 and 11,840 foot (3523.49 and 3608.83 m.) elevation on the west side of the main summit road at its junction with a utility line road. "This project area is approximately 15 acres (6.071 hectares) of level terrain bounded on the east side by the main summit road and on the west side by a utility road. The southern boundary extends approximately 1,000 feet (304.8 m.) south of the junction of the two roads.

The proposed antenna site has been impacted by bulldozing on the west side associated with the utility road, and bulldozing tracks are evident in the northern portion of the parcel. On the edge of a bedrock knoll toward the southern end a few small natural gelufluction terraces are present. A careful examination of the ground surface showed no cultural features or materials other than modern litter associated with road and utility line construction.

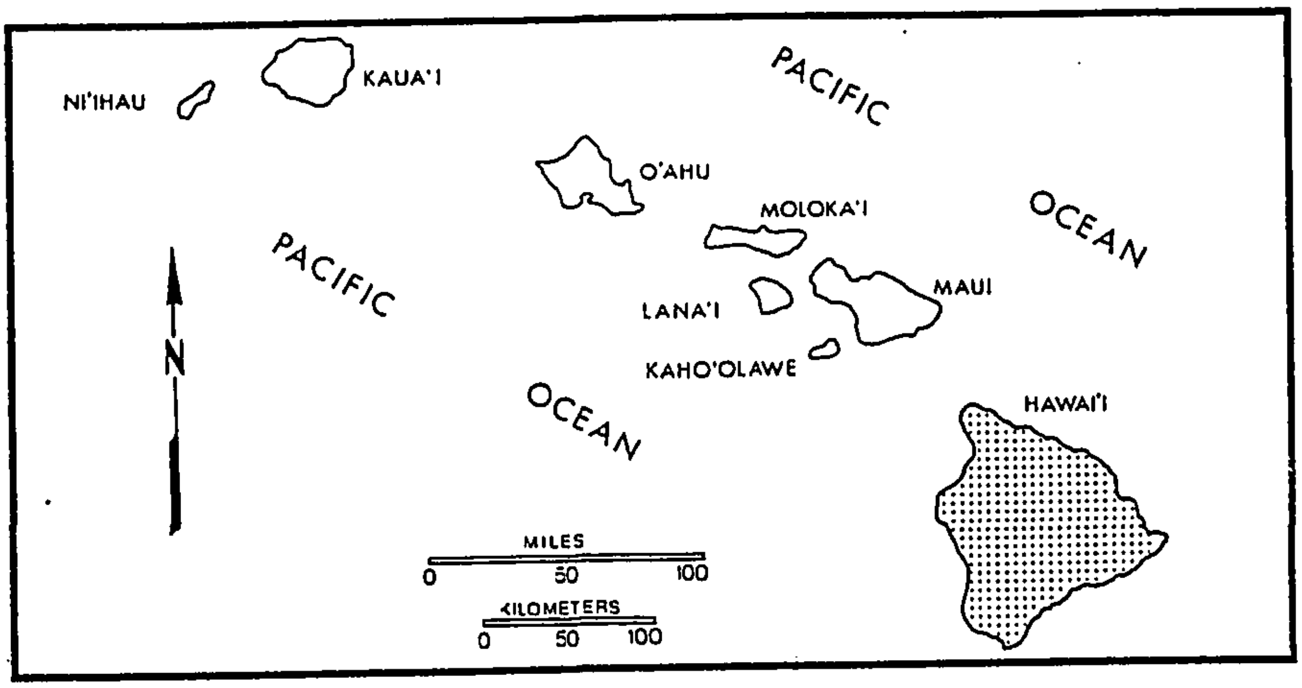

FIGURE 1
State of Hawai'i

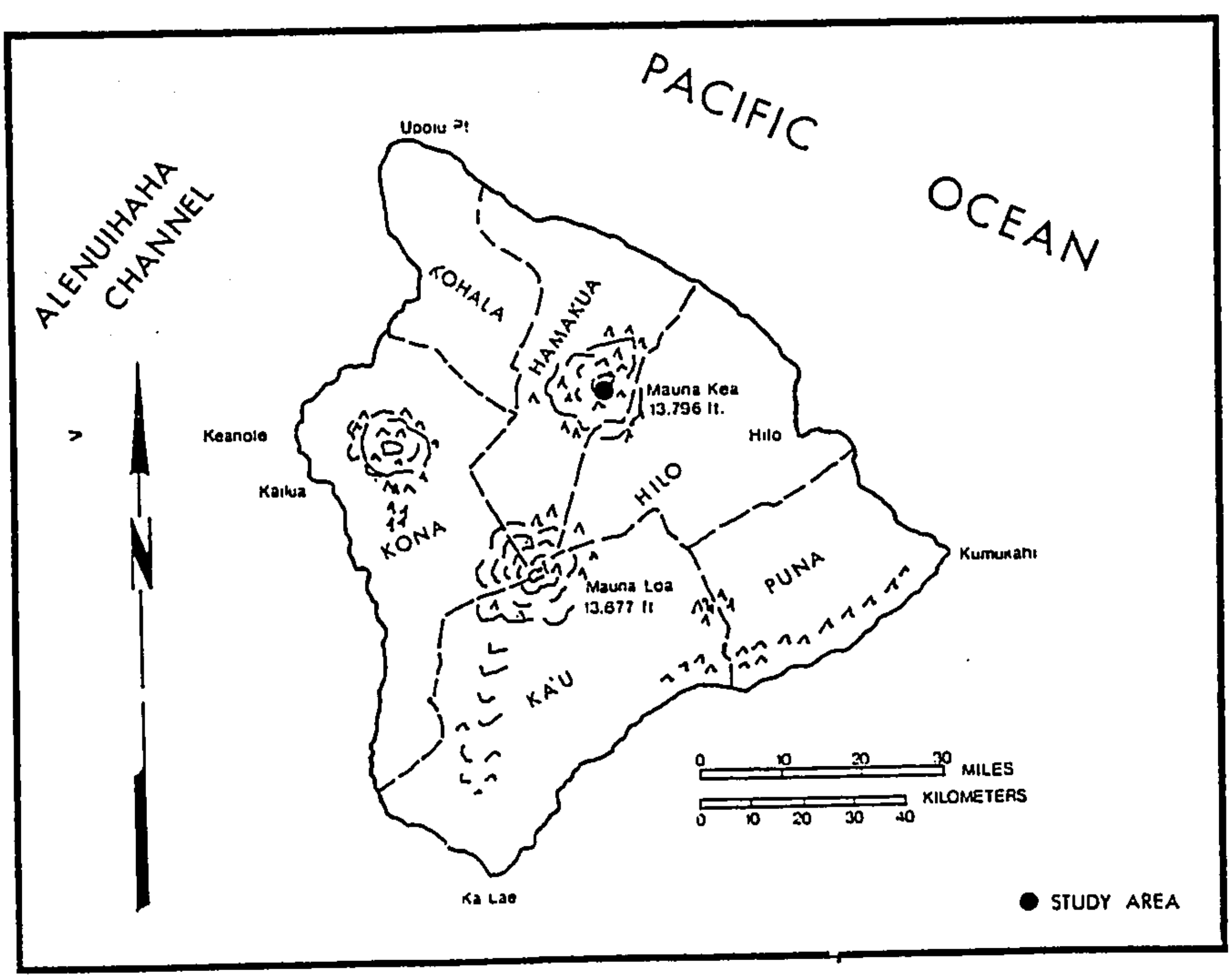

FIGURE 2
General Location Map, Hawai'i Island

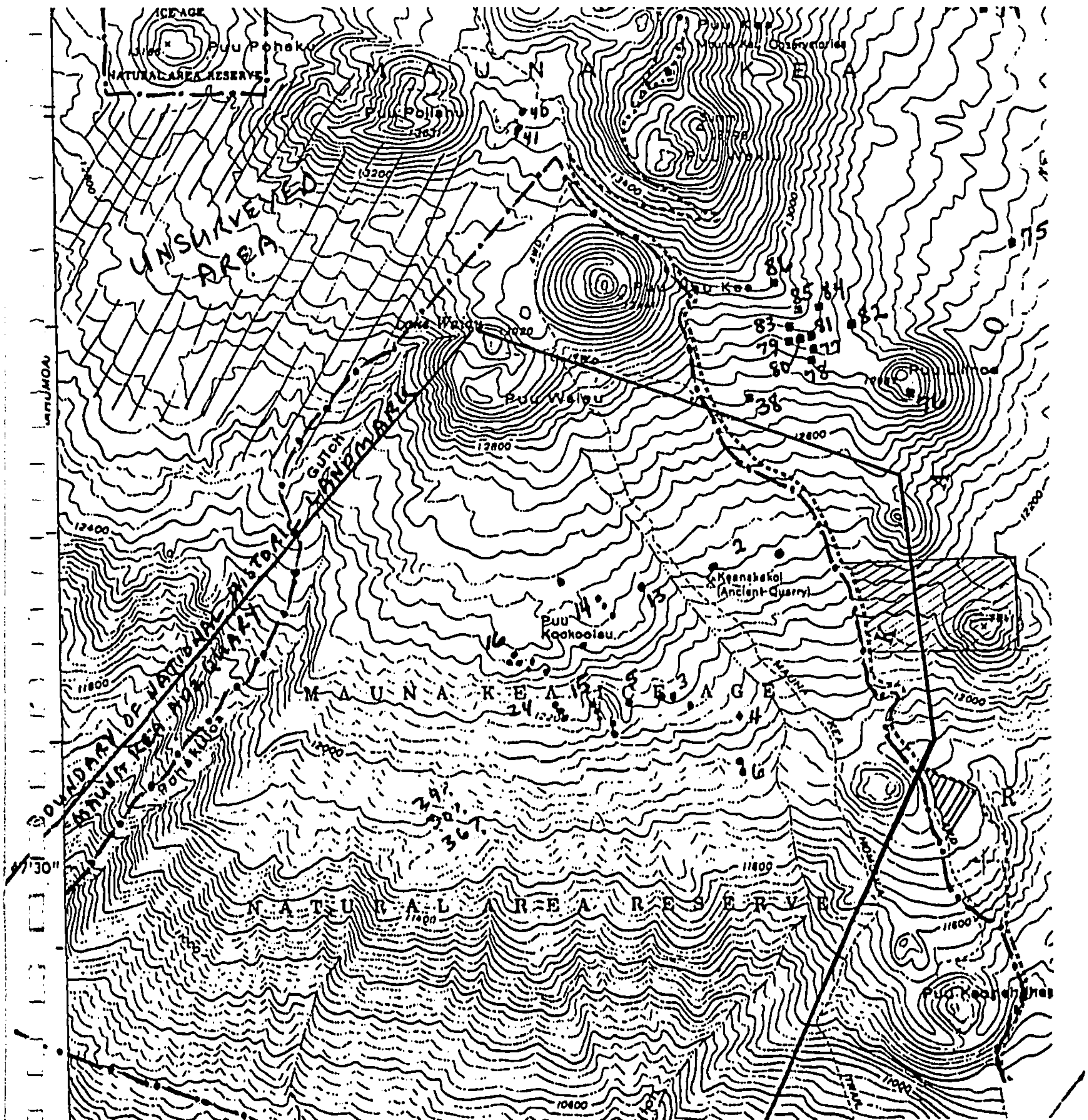

Figure 3 U.S.G.S. Quad Map 1 inch = 2000 feet Showing Two Proposed Antenna Sites (Shaded) and the Boundary the Mauna Kea Adz Quarry National Landmark.

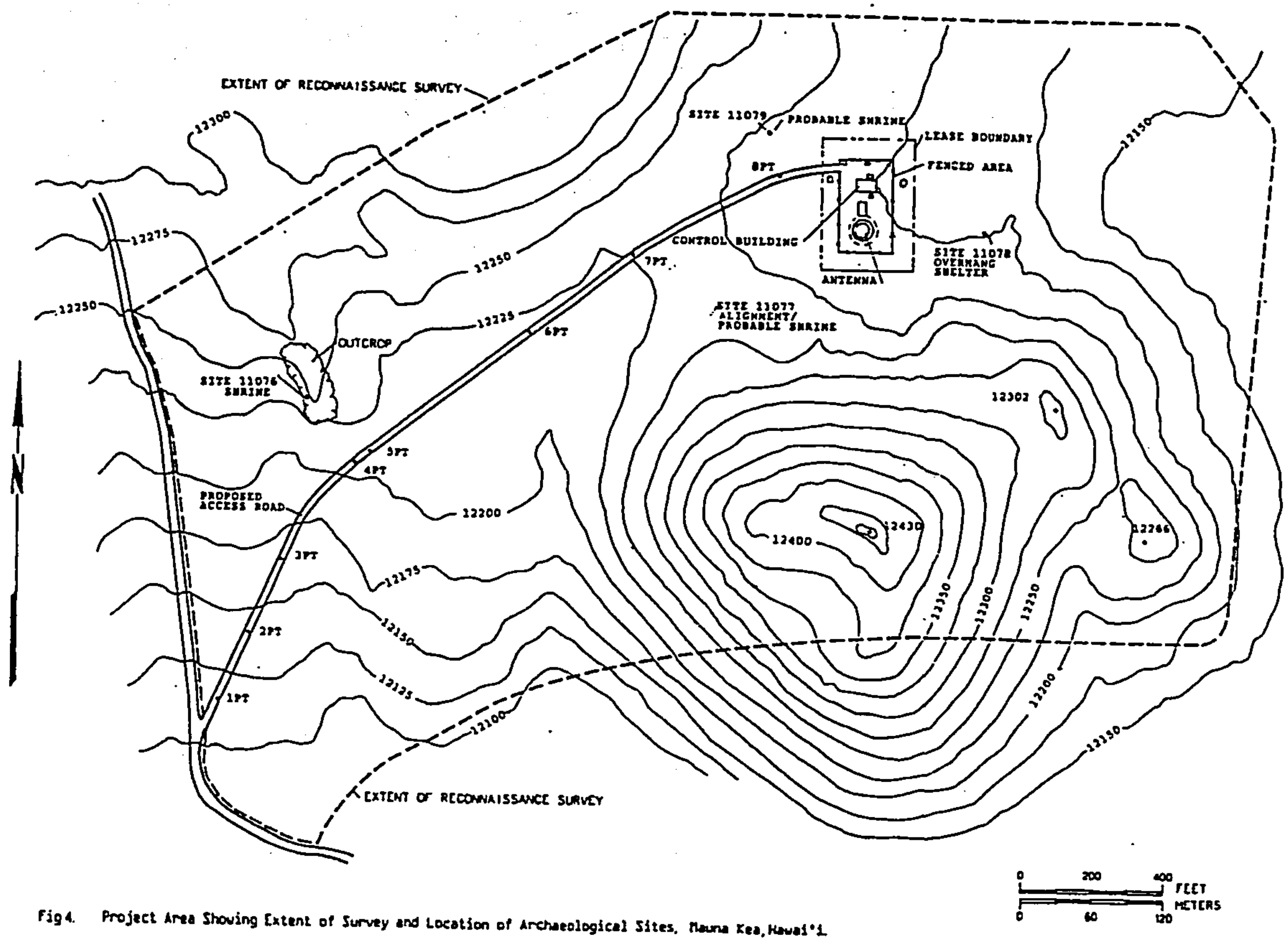

Fig 4. Project Area Showing Extent of Survey and Location of Archaeological Sites, Mauna Kea, Hawai'i.

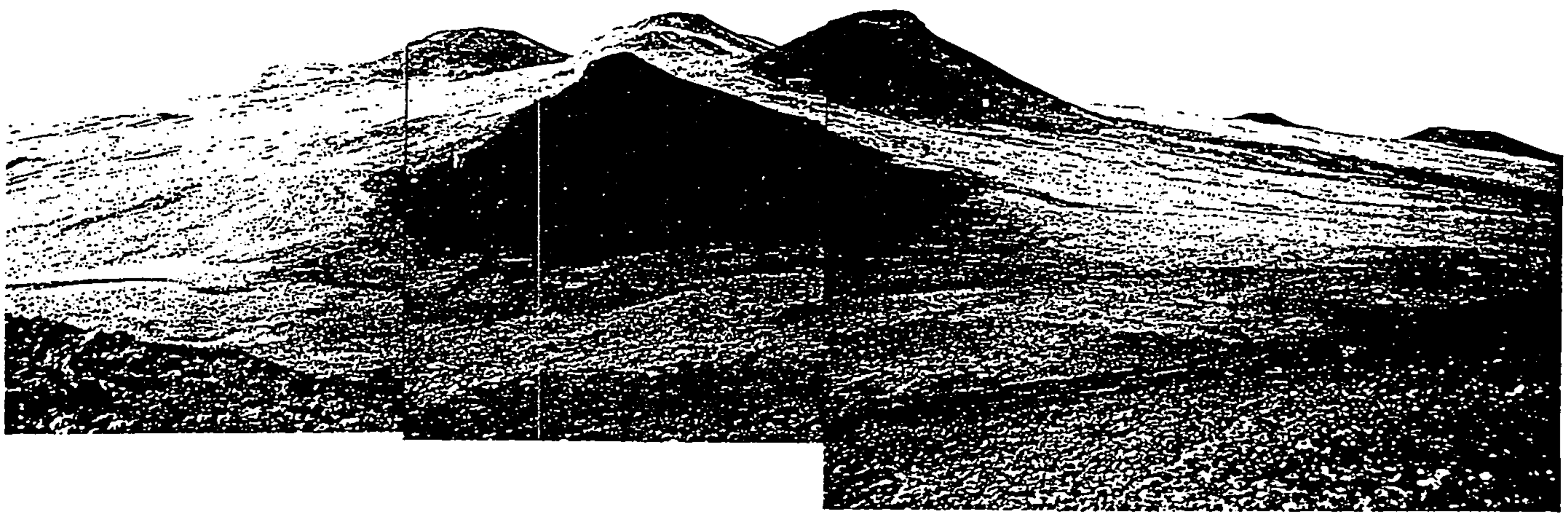

Figure 5. Panoramic View of Proposed Antenna Area 2, View to North, Taken from South Cinder Cone.

B. Antenna Site 2.

The second alternative site for antenna construction (Fig. 3-5) is located on the east side of the main summit road between elevations 12,100 and 12,225 feet above sea level. This proposed facility includes an approximately 2,400 foot long access road connecting the main summit road to an antenna and control building complex measuring 150 feet east/west by 250 feet north/south.

The area surveyed includes approximately 100 acres stretching eastward from the main summit road and encompasses an unnamed cinder cone (elevation 12,430) to the south of the proposed facility, as well as two bedrock knolls to the southeast and slopes of a larger, also unnamed cinder cone in the northwestern portion of the project area. The proposed access road and facility lie on gently sloping to level terrain forming a saddle between the two large cones.

It is of interest to note that Antenna Site 2 is partially located within the boundary of the Mauna Kea Adz Quarry National Historic Landmark. The northeast boundary of this Landmark area is approximately 1,000 feet east of the summit road and includes the summit of the cinder cone to the northwest of the proposed antenna site. This boundary line was designed to include all sites within the adz quarry complex.

C. Surficial Geology of the Survey Areas

The main geologic activity which has shaped the terrain of both study areas is glaciation. The 15-acre area of Antenna Site

1, as it is in a low point between cinder cones has been glacially scoured. The ground surface is composed of rubbly ground moraine deposits from the last phase of Pleistocene glacial advance (25-12000 Before the Present). The bedrock knobs at the south end of the area are both glacially scoured and contain glacial striations on smooth rock surfaces.

The saddle between the two cinder cones within the antenna Site 2 (Fig. 5) also shows rubbly glaciated surfaces and scoured bedrock outcrops with striations. The two cinder cones which rise to the northwest and south of this saddle were created by secondary flank eruptions. During the Pleistocene a glacial till thinly mantled the northwestern cone which indicates that its formation predates the last glacial advance. Both cinder cones have steep loose cinder slopes which are subject to continuous colluviation.

Both the ground moraine in the low lying saddle area and the cinder cone slopes are geomorphically active. Characteristics of this alpine desert environment include lack of vegetation, extreme diurnal temperature variations and frequent frost, all are conducive to gelufluction and other periglacial activity. These processes tend to sort and rearrange surface rocks into natural pavements, alignments, faced terraces, particularly on slopes. These features can be mistaken for cultural constructs by those unfamiliar with the dynamic nature of this landscape. They occur in both survey areas and are typical features throughout the Mauna Kea region.

II. FIELD METHODS

A. General Methods

The purpose of this reconnaissance survey was to locate and document all archaeological features within the two project areas described above. The field work involved one day with four archaeologists. There were, of course, no vegetational limits to survey visibility and on February 24, when the field work was performed, there were only small isolated patches of snow in partially shaded areas.

Antenna area 1 was surveyed first and the absence of cultural remains observed on a previous inspection (H.H. Sept.2, 1987) was again confirmed by systematic coverage.

The bulk of the time was spent in coverage of the approximately 100-acre (40.47 hectares) Antenna Site 2. The access road was surveyed with 2 archaeologists spaced 100-200 feet (30.48 to 60.96 m.) apart on either side of the proposed road alignment. The remaining area was surveyed in the same manner. The survey area extended up the slopes of the northwest cinder cone to approximately the 12,350 foot (3764.28 m.) contour. The south cinder cone and the two glaciated knobs to its east were entirely surveyed.

Each site was described verbally with field sketches and photographic documentation. In addition, a photographic record was made of the general terrain of the project area, particularly the geologic features.

B. Locating Sites

Naturally survey emphasis was placed on the areas of the proposed access road and facility. There were eight previously marked survey points along the proposed access road route. In addition, a small stone cairn was erected by previous land surveyors to mark the approximate location of the southwest corner of the planned facility. The four archaeological sites were located by compass and tape or compass triangulation to adjacent survey points. These site locations when plotted on the project area map varied from where the sites would be located according to the mapped topographic features. This disparity can only be explained by assuming error in placing the survey points on the project map. The site locations as shown on Fig. 4 are probably not entirely accurate, except as in the case of Site 1 which could be located to a prominent ridge line. In any case, given this difficulty in map locations it is still clear that no archaeological sites are within 100 feet of the proposed road or building area.

State site numbers were kindly provided by Dr. Ross Cordy of the State Historic Sites Section of the Department of Land and Natural Resources. Each individual site number to be completed should be preceded by 50-10-23 signifying the state, Island and Quad codes respectively.

III. PREVIOUS ARCHAEOLOGICAL RESEARCH

Previous archaeological research at or near the summit region of Mauna Kea is summarized in McEldowney (1982), McCoy (1982), and various publications and reports by McCoy (1976-1985). Most of these works focus on the Mauna Kea Adz Complex on the southern flank of the summit region. There are more specialized studies of lithic technology of adz manufacturing processes contained in Cleghorn (1982). The most thoroughly reported archaeological excavations in the Adz Quarry area are those of the Hopukani and Liloe Spring rock shelters near Pohakuloa Gulch between the 8,900 and 10,000 foot (2712 and 3048 m.) elevation. Radiocarbon dates from these shelters range from A.D. 1,000 to 1,800 A.D. and are believed to relate to Hawaiian exploitation of the lithic resources of the quarry complex (McCoy, 1986).

The Mauna Kea Adz Quarry Complex of Archaeological Sites was designated a National Historic Landmark in 1962 and placed on the National Register of Historic Places (Site 4136). Although the designated boundaries for the registered site complex included most of the larger adz quarrying localities, many other sites, possibly associated with quarrying activities, especially shrines, lie outside these established boundaries.

Specific archaeological reconnaissance surveys have focused on small areas proposed for telescope development at, or near, the summit. In 1982 Patrick McCoy performed a reconnaissance of a larger area (1,000 acres) (405 hectares) on the summit and north slope of the mountain (McCoy 1982). This survey, in conjunction with a 1984 survey of the east/southeast flank of Mauna Kea (McCoy 1984), resulted in the location of over 40 sites. These were collectively given the state site number 50-10-23-10228.

A summary of the most common types of the archaeological remains occurring on the high flanks of Mauna Kea area is as follows:

1) **Adz Quarry Areas**

These are the most visible cultural features on the landscape and consist of man-made talus deposits of flaked Hawai'i basalt which are the by-products of systematic adz preform manufacturing. These deposits of flaked stone occur around quarried exposures of fine grained basalt both in level areas on slopes. They vary from small scatters to extensive talus deposits which reach considerable thickness. These deposits and associated quarry areas collectively represent the remains of the largest native adz quarrying industry in the Hawaiian Islands.

2) **Shrines**

Shrines of widely varying size and complexity occur both in the adz quarrying area and along the north and east flank of the summit and have been mapped and described by McCoy (1982, 1984). The most common element of these features is thin tabular slabs of rock set upright to form altars. These can occur as single vertical slabs or as clustered series of slabs held vertical by rocks piled at the base (Types 1 and 2, McCoy 1982:A36). The most complex forms are those termed marae (Emory 1928) which consist of main upright altars with smaller uprights set in a constructed pavement or court area (Type 3, McCoy 1982:A36).

There are well over 40 of these shrine sites recorded in the summit area. Although they are clearly of religious function, the exact nature of the rituals and the specific gods involved in these rituals are unknown. Those shrines occurring within the adz quarrying area itself are considered "occupational shrines" because many contain offerings of stone tools or by-products (McCoy 1981, McCoy 1982:A36). In general, the shrines appear to indicate "a single coherent building tradition . . . although not necessarily the same function or use" (Mccoy 1984).

3) Burials

There are many general historic accounts of the use of Mauna Kea summit region as a burial ground (Alexander 1892, Preston 1895). The thin air and cold temperature would aid greatly in long-term preservation of human remains. Archaeological surveys have not located specific burial grounds or burial structures. Given the frequent mention of the summit region as a burial place in the historic and ethnographic literature, it is likely that many of these interments were isolated and unmarked. Burials would be placed in areas which are easy to dig and there are three specific references to unmarked interments in loose cinder deposits (Gregory 1921; Kilmartin 1974:15; Bryan 1927:106; Loo and Bonk 1970:12-13). It is likely that many unmarked human burials are contained within shallow graves on the slopes of cinder cones in the summit region. A summary of ethnographic and historic sources related to these high elevation burials is contained in McEldowney (1982:A11).

4. Cairns and Trails

Anyone who has hiked or driven through the summit region of Mauna Kea can observe stone piles and stackings. These are common cultural features of stony alpine environments throughout the world and were erected on Mauna Kea for similar purposes - to mark travelling routes or survey points, to commemorate visits and special places and to mark established trails. These features are, of course virtually impossible to date and they were certainly constructed from prehistoric times to the present day. In the first historically documented ascent of the mountain (1823) the traveller Goodrich noticed a heap of stones "erected by a former visitor" (Ellis 1969:401).

The only established trail route which survives on historic and modern maps is the Mauna Kea - Humuula Trail which goes upslope from Hale Pohaku past the summit to Pu'u Mahoe. It appears that the routes of earlier travellers, including ancient Hawaiians, were not preserved in historic records (McEldowney 1982:1-12).

IV. SITE DESCRIPTIONS

Mauna Kea Site Descriptions

Site 11,076 (CS1) is a probable shrine consisting of a discontinuous alignment of a low (max. 1 foot) pile of rocks with 6 to 7 slab-like boulders (Fig. 6-7). The alignment is a total of 27 feet (8.23 m.) long and the slab-like boulders are probably collapsed uprights which were roughly evenly spaced along the discontinuous alignment. This probable shrine is situated on an outcrop at ca. 12,250 ft (3733.8 m.) elevation, some 450 feet (137.16 m.) to the east of the summit road. There are no artifacts or midden present and buried cultural deposits appear to be absent. The site is considered prehistoric in age on the basis of the assumed age of the other Mauna Kea shrines and association with the prehistoric adz Quarry.

Site 11,077 (CS2) is a probable prehistoric shrine (Fig. 8) located at approximately the 12,240 ft. (3730.75 m.) elevation on the lower NW slope of a prominent pu'u. The site consists of an ahu-like structure of stacked boulders, on a natural bedrock outcrop. The stacking of boulders and cobbles is roughly 3 feet (.914 m.) in diameter with a maximum height of 2 feet (.610 m.). At the top of the stacked rocks is a set in, sub-angular, upright boulder, with a similar shaped rock at the base of the ahu. Adjacent to the shrine, on the eastern side, is a low (1-1.5 ft or .305 to .457m.) 3 foot (.914 m.) long alignment of stacked boulders with a 3 by 3 ft.(.914 by .914 m.) leveled area on the north side, which may be a natural feature. No midden or arti-

Figure 6 Site 11076, Probable Shrine Showing Alignment on Glaciated Knoll

Figure 7 Site 11076 Showing One of the Collapsed Uprights, View to West.

Figure 8 Site 11077, Probable Shrine Showing Upright in Place, View to Northwest.

Figure 9 Site 11078, Overhang Shelter, View to South.

factual deposits are present.

Site 11,078 (CS3) is a overhang shelter (Fig. 9) located approximately at the 12,225 ft. (3726.18 m.) elevation. The overhang area is 6 ft.(1.829 m.) long by a maximum of 4 ft. (1.219 m.) wide and a maximum ceiling height of 2.5 feet (.762 m.). There is a roughly level area, fronting the small overhang, which measures 7 by 9 ft. (2.134 by 2.743 m.) with 1 ft. (.305 m.) high stacked stone alignment on the eastern side. No cultural material was observed at this site which is situated at the base of a low bedrock ledge. If the shelter was used it was probably used in prehistoric times.

Site 11079 (CS4) consists of 2 features; a probable shrine and an ahu. The probable prehistoric shrine consists of 15 to 20 large cobble-sized rocks stacked on the top of a large, 4 to 5 ft. (1.219 to 1.524 m.) in diameter erratic boulder (Fig. 10). The rocks on the top include one adz preform, which measures 13 cm. long, 5 cm. wide and 3.5 cm. thick, and is rectangular in cross section. Within an area 10-20 feet (3.948-6.096 m.) to the south of this boulder are 10-15 basalt flakes - by-products of adz preform flaking which indicate some minimal flaking was done here. These flakes are scattered on the rocky ground surface over an area 6-8 feet (1.829-2.438 m.)in diameter. No other cultural deposits are present.

Some 15 ft. (4.572 m.) to the NW (Fig. 11) is a low (1.5 ft. or .457 m. max.) loose pile of rocks that probably represents a collapsed prehistoric ahu-type structure. Site 11079 is situated

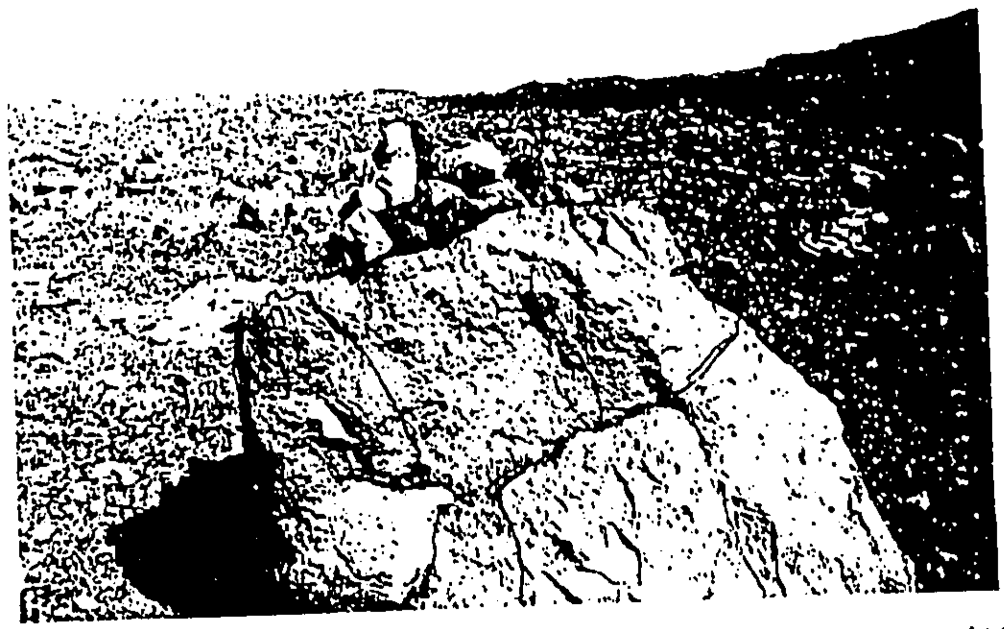

Figure 10 Site 11079, Probable Shrine with Adz Preform, View to Northeast.

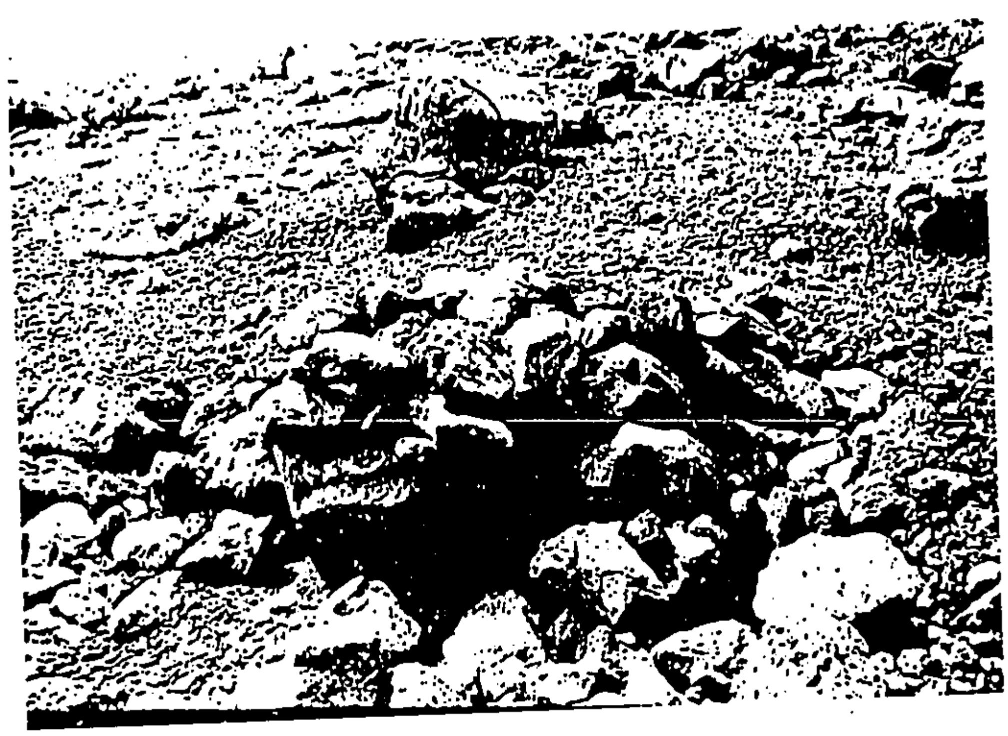

Figure 11 Ahu at Site 11079, View to West.

at approximately the 12,235 ft. (3729.23 m.) elevation, at the base of the SE facing slope of a prominent pu'u. This ahu structure may be a trail marker type feature(s) as it is located in the saddle between two prominent pu'u. It is generally on the same elevation as the main adz quarry area which is some 4,000 ft. (1219.2 m.) to the west. An additional possibility is that it represents an "occupational shrine" with the adz preform representing an offering (McCoy 1981, McCoy 1982:A-36).

V. SUMMARY OF RESULTS AND SITE SIGNIFICANCE

At antenna site 1 no cultural remains were located and the 15-acre area has been impacted by road and utility line construction on the east and west sides.

Four archaeological sites were located and documented in Antenna area 2. These are shown on Figure 4 and described in the previous section. Each of these sites is briefly evaluated as follows:

Site 11076 is a probable shrine which although not entirely intact (the uprights have collapsed) may be the best expressed example of this type of site in the project area. It is somewhat difficult to separate natural glacial rubble from collapsed foundation stones for the uprights, but one can visualize a former shrine with multiple uprights aligned along the long axis of the bluff. In terms of its present integrity the site is probably a poor example of a Type 1 single feature shrine (McCoy 1982:A36) compared to those previously recorded in the Adz Quarry and northern summit area by McCoy (1982, 1984). It is of interest to note that this is the single site within the project area that is inside the boundary designated as the Mauna Kea Adz Quarry National Historic Landmark. This site may have been examined during previous archaeological surveys but is not recorded as a site in any of the survey reports examined.

Site 11077 is an ahu or possible shrine with a single upright boulder set in the top. A possible short alignment and level area is associated. This could be another example of a single feature, Type 1 shrine (McCoy 1982:A36), but could just as well be a simple ahu. The upright is not of the typical or tabular shape associated with other recorded shrines. If it is a shrine it is a poorly expressed example.

Site 11078 is a small rock shelter which does not have surface indication of human modification or cultural use. However, it was recorded as a site because as a natural feature it would have been useful as a temporary shelter and may have subsurface cultural material under the overhang or at the entrance. The size of the shelter would limit its use to only one person at a time. It is one of many such features within the glaciated regions of the Mauna Kea Summit. If subsurface cultural debris is present this debris would be severely limited by the shallow depth of bedrock. If the shelter was used by Hawaiians, one would expect some surface indication of this, which is not the case.

Site 11079 consists of a small rock pile (10-15 cobbles) on the top of a large glacially deposited boulder. There's a nearby small marker ahu and a surface scatter of 10-15 basalt flakes. The rock piling on top of the boulder would be interpreted as a shrine and one of the cobbles is a rectangular adz preform. Its presence reinforces the possibility that this piling may be a small shrine, although it does not match the structural pattern of those recorded in McCoy's surveys (1981, 1982, 1984).

In summary, three of the four sites recorded in the project area may have cultural or religious significance to the Hawaiian ethnic group. None are good examples of site types. All four (including both features of Site 11,079) are likely to yield information important to prehistory or history and are part of the larger context of the hawaiian religious and economic use of Mauna Kea. A summary table of site significance evaluations is presented below.

Site	Description	Function	Significance Criteria Comments	Codes*
11,076 (CS1)	alignments of rock piles and fallen uprights	probable shrine	probable religious structure, cultural significance	a,d,e
11,077 (CS2)	<u>ahu</u> with upright	possible shrine	possible religious structure, cultural significance	a,d,e
11,078 (CS3)	rock shelter		minimal excavation potential, but could yield some information on prehistory	a,d
11,079(a) (CS4)	rock piling on boulders with adz preform and nearby <u>ahu</u>	possible shrine	possible religious structure, cultural significance	a,d,e
11,079(b)	small <u>ahu</u>	trail marker	may yield information important to prehistory	a,d

Codes*
a = site reflects major trends in the history of the State.
d = site may be likely to yield information important to prehistory or history
e = site has cultural significance, probable religious structure (shrine, heiau or burial)

VI. RECOMMENDATIONS FOR MANAGEMENT

The Mauna Kea summit area is a unique natural and cultural environment in Hawai'i. Although the 4 sites located in this reconnaissance are not excellent examples of site types, they do form a portion of a larger context of Hawaiian religious and economic use of Hawai'i's only glaciated landscape and those which can be identified as shrines have cultural significance to Hawaiians. One of the sites (11,076) is within the boundary of the Mauna Kea Adz Quarry National Landmark. This landmark was designated in 1962 to provide Federal recognition of the importance of the complex to the State and Nation. Since the proposed project will not impact archaeological sites included within the Landmark area there is no necessity for further consideration of the effects on the Landmark area. Since the adz quarry was designated as a National Landmark the main summit roads and utility lines have been constructed through its eastern boundary. Similarly, there was no effect on archaeological sites.

The nature of the antenna development proposed for the project area would easily allow for preservation of all four archaeological sites. Some visual impact is unavoidable, but this should be minimal because the proposed facility is relatively closely confined and the sites are all elevationally above the proposed antenna. The sites are already flagged on the ground and they are located a reasonable distance from the proposed facilities. Even so, construction personnel should be made aware of the existence and location of these archaeological sites so that even inadvertent damage by heavy equipment can be avoided. The sites should be reflagged immediately before construction and their locations plotted on construction maps. If these simple procedures are followed archaeological monitoring during construction should not be necessary. Since the access road and the facility are both located on bedrock and glacial moraine (and not on soft cinder deposits) the likelihood of discovering isolated burials is very small. However, if remains are uncovered during construction an archaeologist should be immediately called. If the above recommendations are followed there should be no adverse effect on the archaeological resources.

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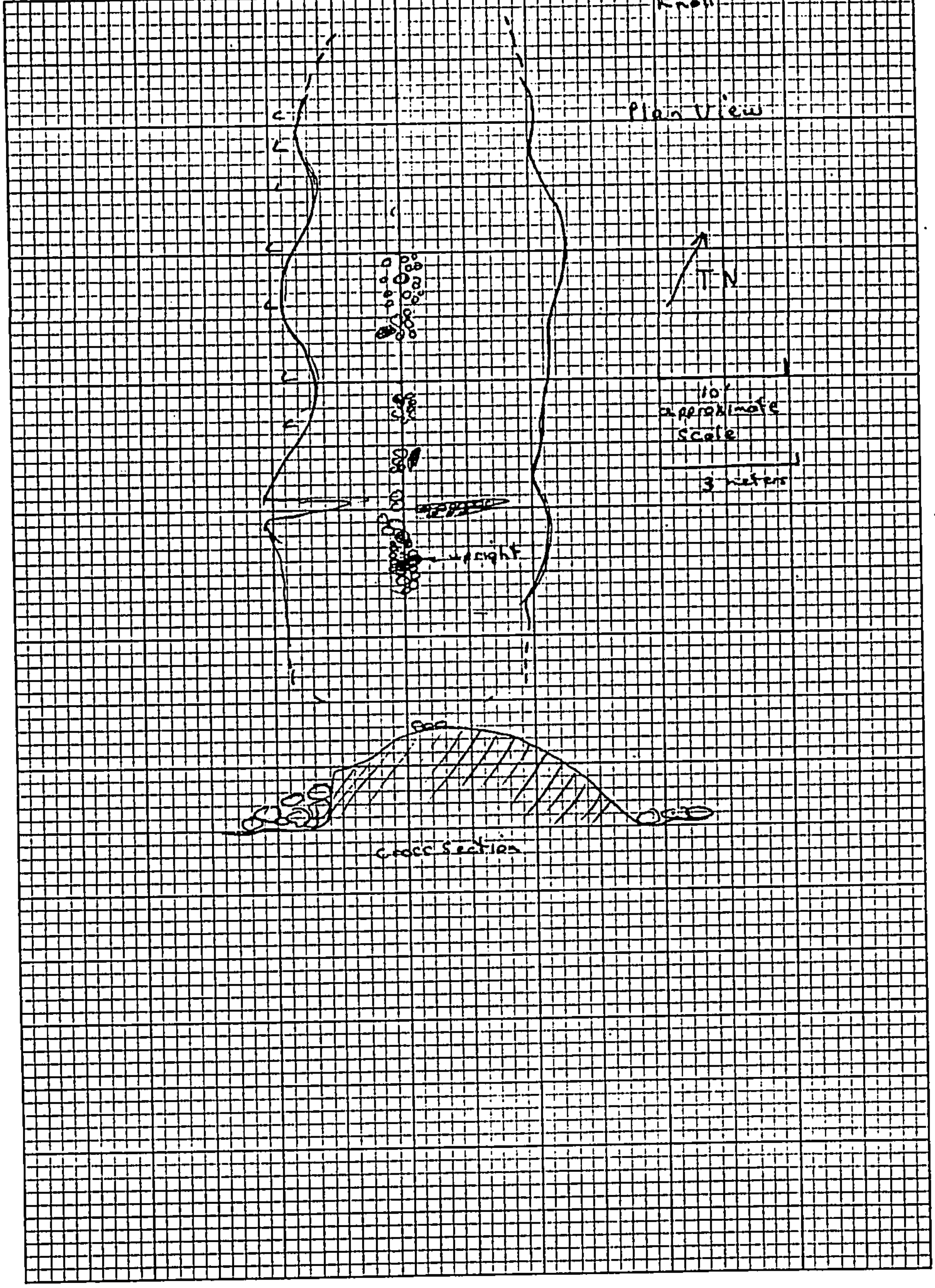
APPENDIX

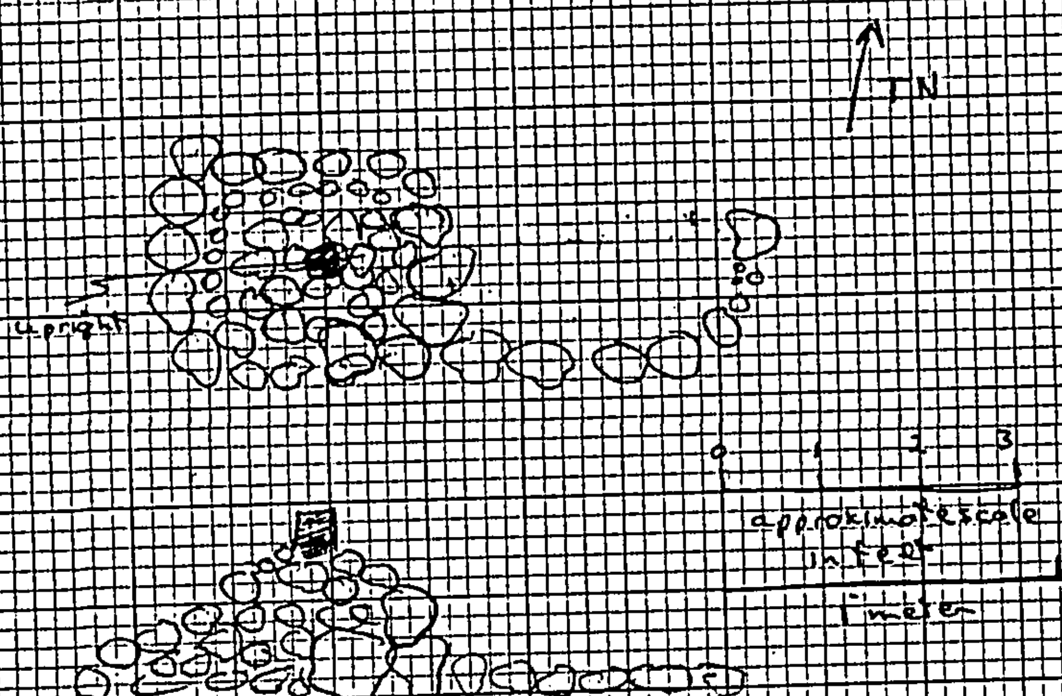
FIELD SKETCHES OF SITES

Mauna Kea

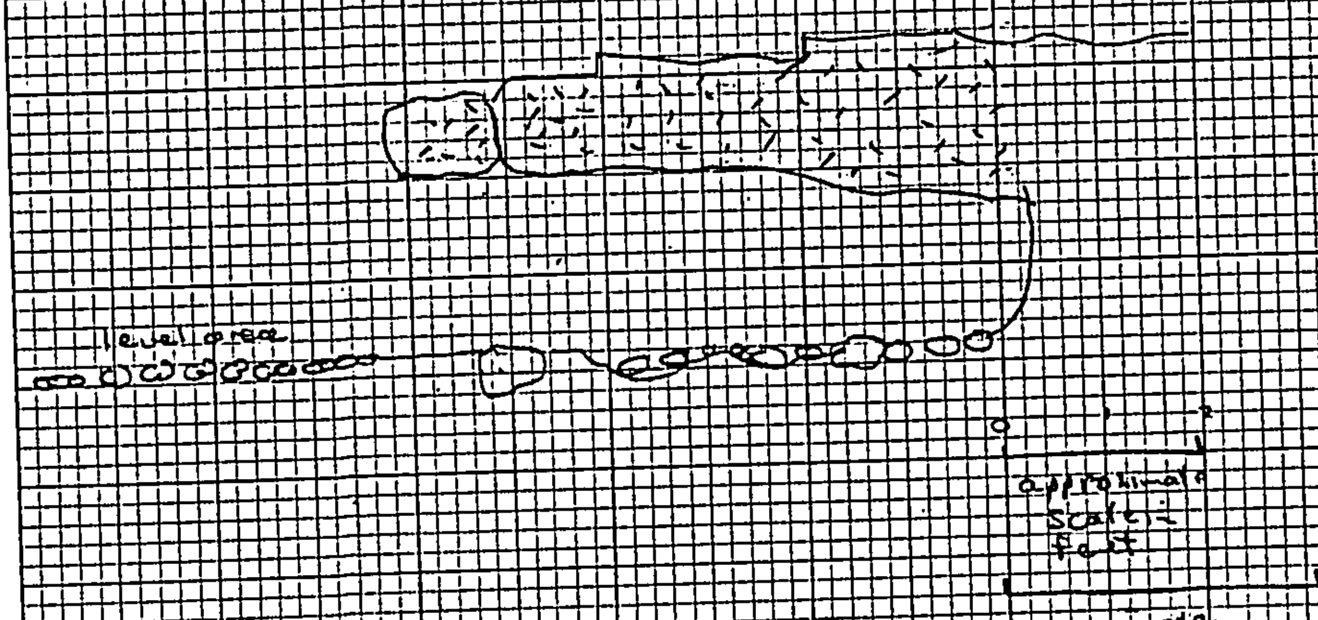
Field Sketch of Site 11,076, shrine on glaciated Knoll



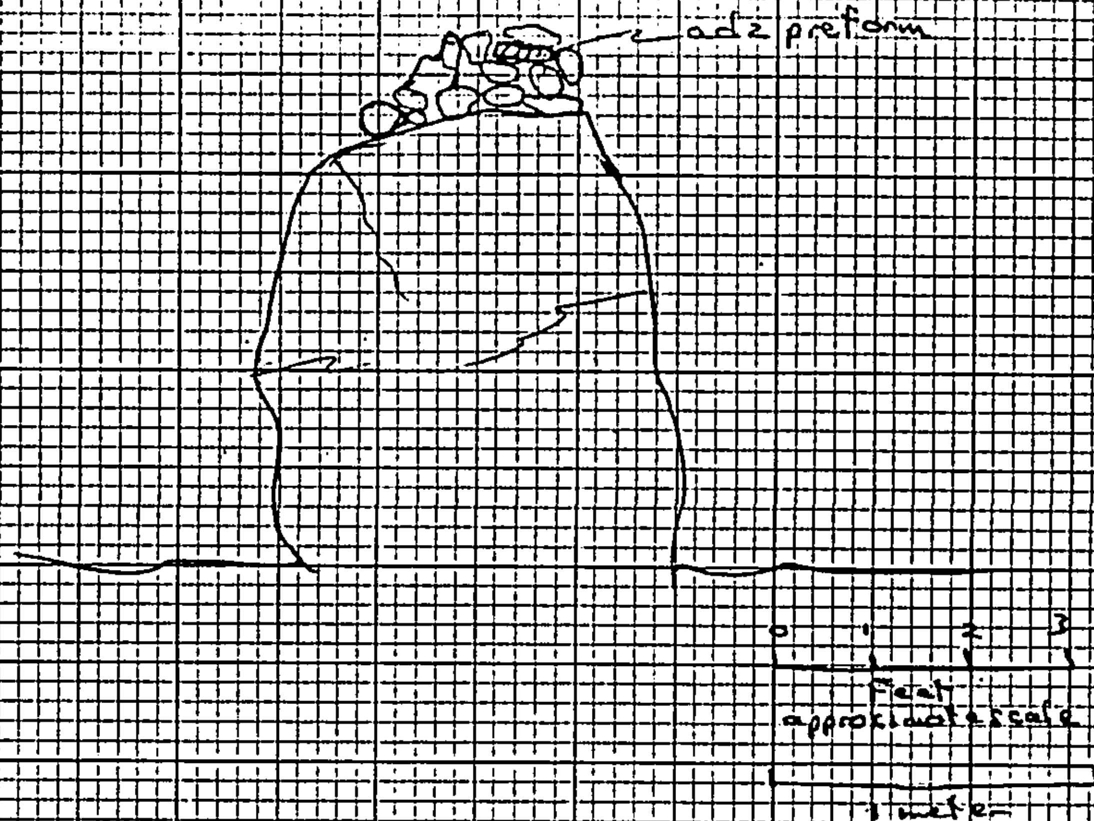
Mauna Kea
Field Sketch of Site 11077
Shrine



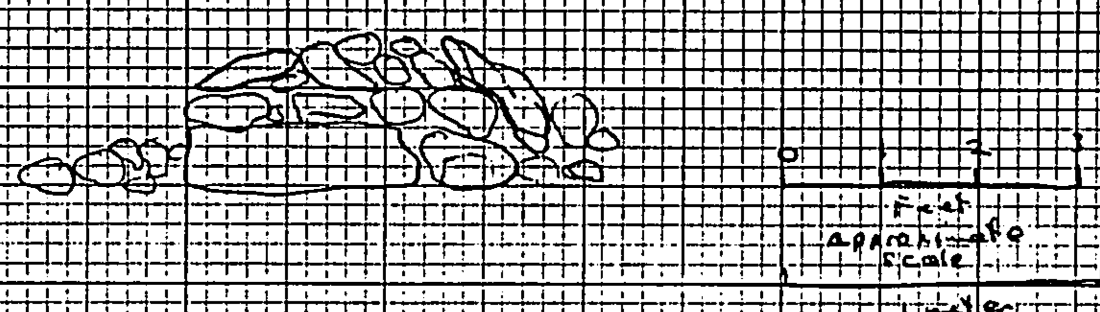
Mauna Kea
Field Sketch at Site 11078 overhang shelter



site 11079 shrine with adz preform
crosssection view



site 11079 ahu (15' northwest of shrine (above))



APPENDIX D

GEOTECHNICAL CONSULTATION

HARDING LAWSON ASSOCIATES

Harding Lawson Associates

May 3, 1988

18628,001.06

Mrs. Marilyn C. Metz, AICP
MCM Planning
703 Honua Street
Honolulu, Hawaii 96816

Dear Mrs. Metz:

Geotechnical Consultation
EIS for National Radio Astronomy Observatory VLBA
Antenna Facility
Mauna Kea, Island of Hawaii, Hawaii

INTRODUCTION

This report presents our evaluation of the geotechnical aspects of the proposed Very Long Baseline Array (VLBA) antenna facility on Mauna Kea, and the related environmental impacts. Our understanding of the project is based on the Environmental Assessment and Notice of Preparation for the project published in March 1988, supplemented by discussions with you and Mr. Buck Peery of the National Radio Astronomy Observatory. Our conclusions are based on a review of pertinent technical literature, a visit to the proposed sites, and experience from other observatory and roadway projects on Mauna Kea.

Two sites are being considered. The preferred site is at an elevation of 12,200 feet and is approximately 2,000 feet east of the Mauna Kea Observatory (MKO) Access Road. The alternate site is at an elevation of 11,800 feet and is on the west side of the MKO Access Road, roughly 4,000 feet south of the preferred site.

The site will be approximately two acres and graded essentially flat. The central area will contain the antenna, control building and equipment pads. It will be approximately 150 feet by 250 feet and will be enclosed by a chain-link fence. The antenna will be supported on a 50-foot-diameter concrete foundation. The control building will be 1,350 square feet in area and supported by a concrete

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slab. Other concrete pads will support an emergency generator, an LPG fuel tank, a weather instrument tower, and miscellaneous other equipment.

Water usage will be less than 100 gallons per day, primarily for human washing and waste. Wastewater will be essentially the same volume, discharged into a cesspool outside of the fenced area.

A 2,600-foot-long access road will be required for the preferred site. A 40-foot right-of-way will allow all utilities (telephone and electricity) to be buried along the roadway. The road will be surfaced with compacted gravel. No access road would be required for the alternate site.

GEOLOGY, SOILS AND FOUNDATIONS

Both sites are underlain by Pleistocene lava flows of the Waikahalulu Formation (Porter, 1979a). The preferred site is near the head of a flow of the Kuupahaau Stage, roughly 40,000 to 70,000 years old. The alternate site is on a different flow of similar, but less certain, age. All the rock in the area consists of hawaiite a'a flows. Hawaiite is a variety of andesite, typical of late-stage eruptions from Hawaiian volcanoes. The a'a flows consist of layers of massive, dense rock intermixed with volcanic clinker.

Both sites are covered primarily by ground moraine deposits. These deposits consist of rocky debris accumulated in the glacial ice cap which once covered the top of Mauna Kea. The debris was then dropped when the ice melted. The soils are mostly coarse gravels, with cobbles as large as 2 feet, and a variable amount of volcanic ash of silt and sand sizes. The thickness of the soil cover at the sites is not known but is estimated to be several feet. This will be determined during the soils investigation for foundation design.

Similar ground moraine deposits exist along most of the alignment for the access road to the preferred site. A bedrock ledge is exposed along the edge of the small channel crossing the alignment. Where the road crosses the saddle between two cinder cones just west of the site, most of the gravel consists of volcanic cinder fragments smaller than 6 inches. Soil thicknesses are unknown but are estimated to be less than 3 feet along the western half of the road alignment and thicker along the eastern half.

Foundations for all structures are expected to consist of concrete slabs resting on natural soils if sufficiently dense or on compacted, structural fill.

Localized zones of permafrost have been reported within the volcanic cinder deposits of two of the cones at the summit of Mauna Kea (Woodcock, 1974), roughly 8,000 feet northwest of and 1,000 feet higher in elevation than the preferred site. No permafrost is known to have been found outside of cinder cones and it is unlikely that any exists at either site.

The island of Hawaii is seismically active and is located in Seismic Zone 3 for building design under the Uniform Building Code. Much of the seismic activity is associated with the active volcanism at Mauna Loa and Kilauea volcanoes. Large earthquakes have occurred elsewhere around the island, however, and are considered possible at any location. The geology of Mauna Kea has been mapped in detail (Porter, 1979a), but no tectonic faults have been observed. Foundation and building design in accordance with the Uniform Building Code is expected to be adequate for the structures.

The last eruption on Mauna Kea occurred approximately 3,600 years ago (Porter, 1979b). Future eruptions are possible, but Mullineaux and others (1987) have classified the summit and upper flanks of Mauna Kea as Zone 7 for lava flow hazards on the island of Hawaii. A total of nine zones were defined, with Zone 9 being the least hazardous. Mullineaux and others (1987) note that lava covered about 20 percent of the Zone 7 area between 3,500 and 5,000 years ago. The risk of the site being affected by a volcanic eruption is judged to be very low.

EARTHWORK AND DRAINAGE

Both sites are relatively flat so that the amount of earthwork will be small. The maximum topographic relief at the preferred site is approximately 15 feet; and the maximum amount of cutting and filling is not expected to exceed 5 feet. Most of the excavated rocky soils will be usable for fill. Some finer-grained material may have to be imported for finish grading. Such details will be addressed by the soils and foundation investigation during final design.

Earthwork for the access road to the preferred site will be limited to that required to provide a smooth surface, involving cuts and fills mostly less than 5 feet thick.

There will be essentially no runoff from the flat area prepared for the antenna facility. The limited precipitation can be expected to percolate directly into the ground.

The access roadway to the preferred site will concentrate runoff to some extent, primarily on the uphill side where a shallow ditch will collect any runoff. The rocky material along the roadway will not erode significantly, and one or more culverts will pass runoff under the road before it concentrates to the point where it could cause erosion further downslope.

SEWAGE DISPOSAL

Wastewater will be discharged into a cesspool at the edge of the antenna facility site. Seepage out of the cesspool likely will be through the gravelly soils overlying bedrock and through fractures and other openings in the bedrock. It is anticipated that a 5-foot-diameter cesspool can easily dissipate the planned flow of 100 gallons per day. (This is equivalent to less than a half-hour flow from a garden hose, or one-sixth the nominal wastewater flow from a three-bedroom house.) Final sizing of the cesspool will be done following the soils and foundation investigation.

It is unlikely that wastewater will percolate beyond the immediate site area, so that no impact from wastewater discharge is expected. There are no known springs downslope from either site. The depth to ground water is unknown, but is expected to be hundreds or thousands of feet. The antenna sites are extremely isolated, roughly 2 miles from and 3,000 feet higher than Hale Pohaku, the closest development downslope. Lake Waiau is roughly 1,000 feet higher than the sites and 8,000 to 10,000 feet to the northwest, so could not be affected by wastewater seepage.

We trust this information is adequate for your purposes. If you have any questions, please call.

Sincerely yours,

HARDING LAWSON ASSOCIATES

Damon R. Runyan
Civil Engineer - 3121

Ronald L. Soroos
Geologist - 3455 (California)

DRR/RLS/bm:MCM

Attachment: References

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APPENDIX E

BOTANICAL SURVEY
NRAO VLBA ANTENNA FACILITY
MAUNA KEA SCIENCE RESERVE
MAUNA KEA, HAMAKUA, HAWAII

CHAR & ASSOCIATES

BOTANICAL SURVEY
NRAO VLBA ANTENNA FACILITY
MAUNA KEA SCIENCE RESERVE
MAUNA KEA, HAMAKUA, HAWAII

by

Winona P. Char

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Botanical/Environmental Consultants
Honolulu, Hawaii

Prepared for: MCM PLANNING

April 1988

BOTANICAL SURVEY

NRAO VLBA ANTENNA FACILITY

MAUNA KEA SCIENCE RESERVE

MAUNA KEA, HAMAKUA, HAWAII

INTRODUCTION

The National Radio Astronomy Observatory (NRAO) proposed to construct a Very Long Baseline Array (VLBA) antenna facility within the Mauna Kea Science Reserve between the 12,200- and 12,400-foot elevations. An access road to service the facility would also be constructed.

A botanical survey to assess the plant resources on the selected site and access road, as well as an alternative site at the 11,800-foot elevation, was conducted on 10 April 1988.

A walk-through survey method was used. The areas which would be directly impacted by the construction activities were more intensively surveyed. These areas had been previously staked out by NRAO personnel. Less intensive surveys were made of the adjoining areas. Wherever possible, specimens were collected for later comparison with herbarium material and the literature.

RESULTS AND DISCUSSION

Both the selected site and the alternative site are located on ash with a shallow, top layer of irregularly-shaped, smaller rocks, 2 to 4 inches across. Larger rocks, 1 to 3 feet or more across, are scattered or form piles among the smaller material. Both sites are almost uniformly flat without rocky outcrops.

Hawaiian bent (Agrostis sandwicensis) and he'u-pueo (Trisetum glomeratum), members of the grass family (Poaceae), can be found in small numbers on both sites (see Table 1), usually growing among the larger rocks. Neal and Hartt (1940) and Smith et al. (1982) have recorded both of these endemic grass species on the summit area above 13,000 feet, along with the introduced hairy cat's-ear (Hypochaeris radicata) and dandelion (Taraxacum officinale).

The only lichens observed on the two sites were Candelariella vitellina and Lecidea skottsbergii. Both species were associated with the larger rocks and occurred just above the soil interface,

Table 1. List of species on study sites.

	Selected site	Access road	Alternative site
LICHENS			
CANDELARIACEAE			
Candelariella vitellina (Ehrh.) Muell. Arg., E*	+	+	+
LECANORACEAE			
Lecanora muralis (Schreb.) Ach., I*	-	+	-
LECIDEACEAE			
Lecidea skottsbergii Mag., E	+	+	+
Rhizocarpon geographicum var. hawaiiensis Raes., E	-	+	-
UMBILICARIACEAE			
Umbilicaria hawaiiensis Magn., E	-	+	-
Umbilicaria magnussonii Llano, E	-	+	-
MOSSES			
BRYACEAE			
Pohlia cruda (Hedw.) Lindb., I	-	+	-
GRIMMIACEAE			
Grimmia sp., I	-	+	-
VASCULAR PLANTS			
PTERIDOPHYTA (Ferns)			
ASPLENIACEAE			
Asplenium adiantum-nigrum L., I	-	+	-
MONOCOTS (Flowering Plants)			
POACEAE			
Agrostis sandwicensis Hbd., E	+	+	+
Trisetum glomeratum (Kunth) Trin., E	+	+	+

*Biogeographic status

E = endemic species

I = indigenous species

usually facing north or west. Smith et al. (1982) notes that these two species, along with Lecanora muralis, are the more common lichens on the Mauna Kea summit area above 13,000 feet.

No bryophytes (mosses) were found as both sites lacked partially shaded small caves, crevices, or large rock overhangs.

The access road crosses substrate similar to the selected site but also contains areas with outcrops of andesitic lava and large boulders. The grass and lichen species mentioned previously occur here in low abundance. The rock outcrops and jumble of boulders provided habitat for one specimen of Asplenium adiantum-nigrum, a member of the bird's-nest fern family (Aspleniaceae). Among the boulders, small shaded pockets and crevices with ash supported moss clumps of silvery-gray to black colored Grimmia sp. and bright green Pohlia cruda. Other lichens observed among the boulders were Rhizocarpon geographicum, two species of Umbilicaria, and Lecanora murabilis.

Just south and outside of the selected site, at the base of the unnamed cinder cone, glacial till and andesitic lava boulders and knobs provide a more suitable habitat of small caves, crevices, and overhangs for the lichens and mosses mentioned above. The mosses form fist-sized clumps in small run-off channels among the rocks. Other lichens found here include the whitish, crust forming Lepraria sp. and Acarospora depressa. Lichen and moss colonies in this area were generally associated with north, northwest, and west facing rocks. Moisture from snow melt and even pockets of compacted snow were seen in some caves areas.

Construction of the proposed antenna facility on the selected site (or alternative site) and access road will have only a minor impact on the botanical resources as they are sparsely vegetated and the species occurring there are also found throughout the Mauna Kea summit area.

Of more concern, are the indirect impacts of the proposed project, some of which have been expressed in various biological surveys (Howarth and Stone 1982; Smith et al. 1982) conducted for the Environmental Impact Statement for the Mauna Kea Science Reserve Complex Development Plan.

Only NRAO or other astronomy personnel should have access to the proposed VLBA facility road. Off-road vehicle use should be prohibited as such use will disturb most of the geologic features --glaciated surface, glacial ground moraine of the late Makanaka ice cap, periglacial movement and sorting of rocks, etc. In addition, access onto the nearby cinder cones may disturb habitat for endemic arthropod fauna.

All construction activities should take place within the defined areas of the antenna facility site and access road alignment. Litter from construction material, packaging, etc., should be collected and removed from the area.

Management policies already established by the University of Hawaii for the preservation of biological and geological resources within the Science Reserve Complex should be followed and enforced.

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APPENDIX F

FAUNAL SURVEY FOR THE PROPOSED
VLBA ANTENNA FACILITY
MAUNA KEA, HAMAKUA, HAWAII

MAILE S. KJARGAARD

FAUNAL SURVEY FOR THE PROPOSED
VLBA ANTENNA FACILITY
MAUNA KEA, HAMAKUA, HAWAII

INTRODUCTION

The following report presents the results of a survey of the vertebrate fauna of two sites between 11,800 and 12,400 feet elevation of Mauna Kea. These sites are the selected and alternate locations of a Very Long Baseline Array (VLBA) antenna to be operated by the National Radio Astronomy Observatory; both are approximately one acre in extent, and the selected site requires an additional 2.5 acres for the construction of an access road.

The field survey of these areas was conducted on 10 April 1988. A supplemental nocturnal survey will be performed during May 1988 to determine whether Hawaiian Dark-rumped Petrel are present in the area.

LITERATURE REVIEW

The major species of concern when considering the two sites is the Dark-rumped Petrel (Pterodroma phaeopygia sandwichensis), an endangered pelagic seabird endemic to the Hawaiian islands. It returns to land only during an extended breeding season; at the present time the major breeding localities for this bird are at high elevation sites on Maui and Hawaii. A detailed study of the Dark-rumped Petrel in Hawaii was completed by Simons (1983, andSimons and Simons 1982) on the Haleakala population. Much of the following information is excerpted from these reports.

Dark-rumped Petrel were formerly abundant throughout the main Hawaiian chain (Olson and James 1982a, 1982b) but underwent a serious decline in numbers due to habitat disturbance, predation and hunting. On Hawaii, Dark-rumped Petrel were once abundant in the saddle area between Mauna Loa and Mauna Kea (Henshaw 1902). They may also have been present at elevations of up to 12,400 feet on Mauna Kea as indicated by skeletal material found in these areas.

After a hiatus of many years, Dark-rumped Petrel were rediscovered on Mauna Kea in 1954 by Richardson and Woodside (1954), who found five freshly dug burrows at Pu'u Kole, east of Hale Pohaku. Since then there have been sporadic observations of these birds from Pu'u Kole around the eastern flank of Mauna Kea as far as Pu'u Kanakaleonui (Banko 1982). In 1969 to 1970, Banko (1982) spent a fair amount of time surveying this area for Petrel but found them only in the vicinity of Pu'u Kanakaleonui.

The chronology of the breeding cycle of the Dark-rumped Petrel is summarized in Figure 1 (Simons 1983). Breeding activity begins when adults return to the breeding colony in February and March. At this time, for a period of one or two weeks, the birds re-establish territories, repair burrows and build nests, and perhaps mate. A period follows shortly thereafter (throughout much of April and into May) when the birds are absent from the colony. It is thought that at this time the animals are feeding at sea in order to increase their fat stores for the upcoming breeding activity. During the summer months, eggs are laid, the chicks hatch and undergo a growing period before finally leaving the colony in the fall.

Dark-rumped Petrel nest in burrows dug into cliff sides or talus slopes. In Haleakala most nest sites occur at the bases of rock outcroppings or in areas with considerable local relief. Ninety five percent of the Haleakala burrows were excavated out of soft substrate beneath boulders or rock ledges. Most burrows were one to 10 meters in length. Nests were built in burrows only in locations where suitable materials (i. e., grasses) were present in the immediate vicinity.

The breeding success and adult longevity of Dark-rumped Petrel are limited by a number of factors. The primary cause of breeding failure appears to be predation by alien mammal species such as mongooses, cats, and rats. While the adults are also susceptible to predation, their deaths more frequently result from collisions with obstacles such as wires, towers, or fences while in flight. This problem is compounded by the fact that Petrel are attracted to bright light sources and often crash to the ground as a result of disorientation or collisions with structures near the lights. In this state they are frequently unable to fly and are at increased risk from predation. Young birds leaving the breeding colony for the first time are especially prone to such accidents (Reed et al. 1985).

SURVEY METHODS AND RESULTS

An initial survey of the two antenna sites was made on 10 April 1988. At both locations I walked through the site in a systematic manner in an attempt to locate any bird or mammal remains. During this diurnal portion of the survey I concentrated my efforts on locating potential nesting habitat and searching in these areas for evidence of nesting activity. A nocturnal survey of both sites for active Dark-rumped Petrel will be performed in May when the birds are actively breeding.

No evidence of Petrel breeding was found at either site, although several areas appeared suitable for burrow construction. The best areas for burrow construction were on the northern slopes of

Figure 1. Dark-rumped Petrel breeding chronology (from Simons, 1983).

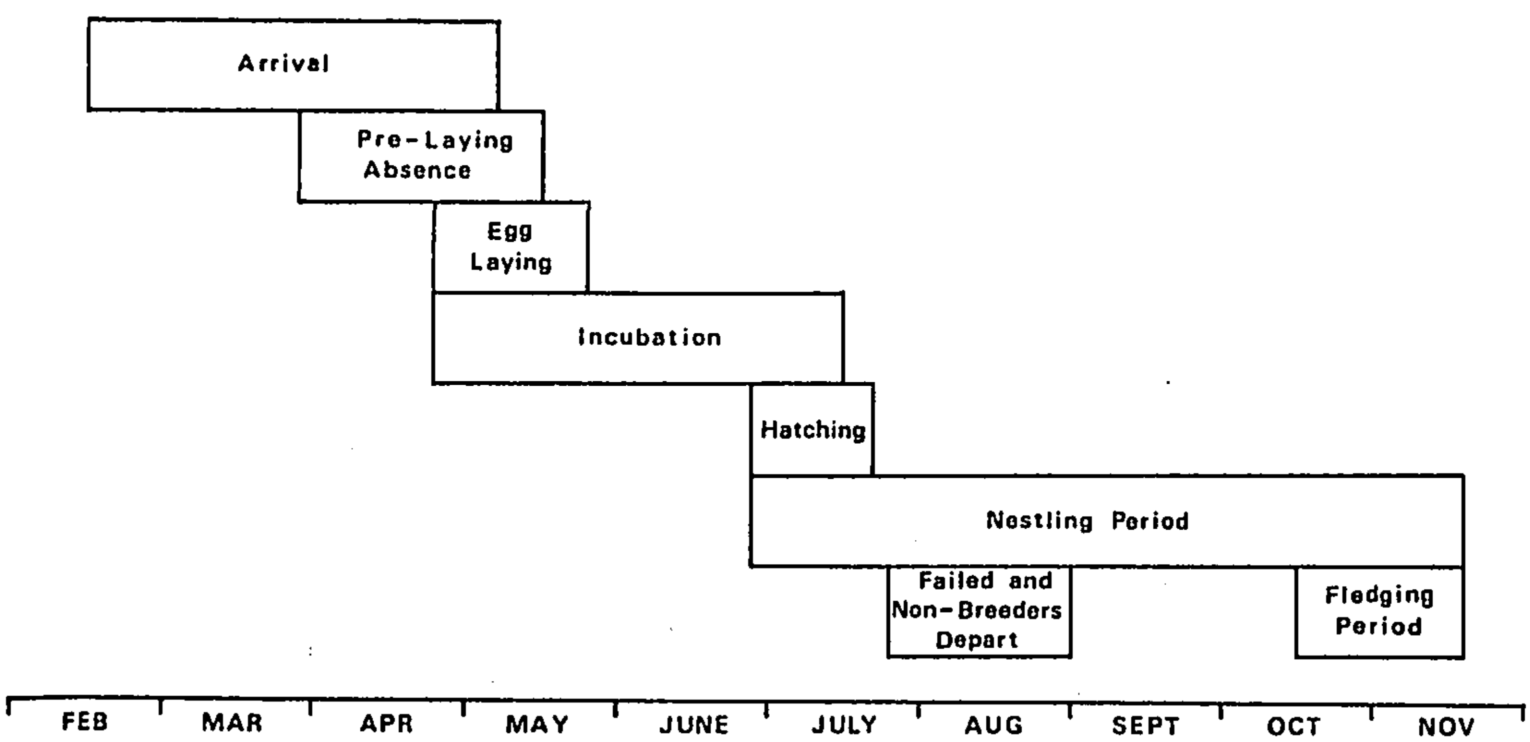
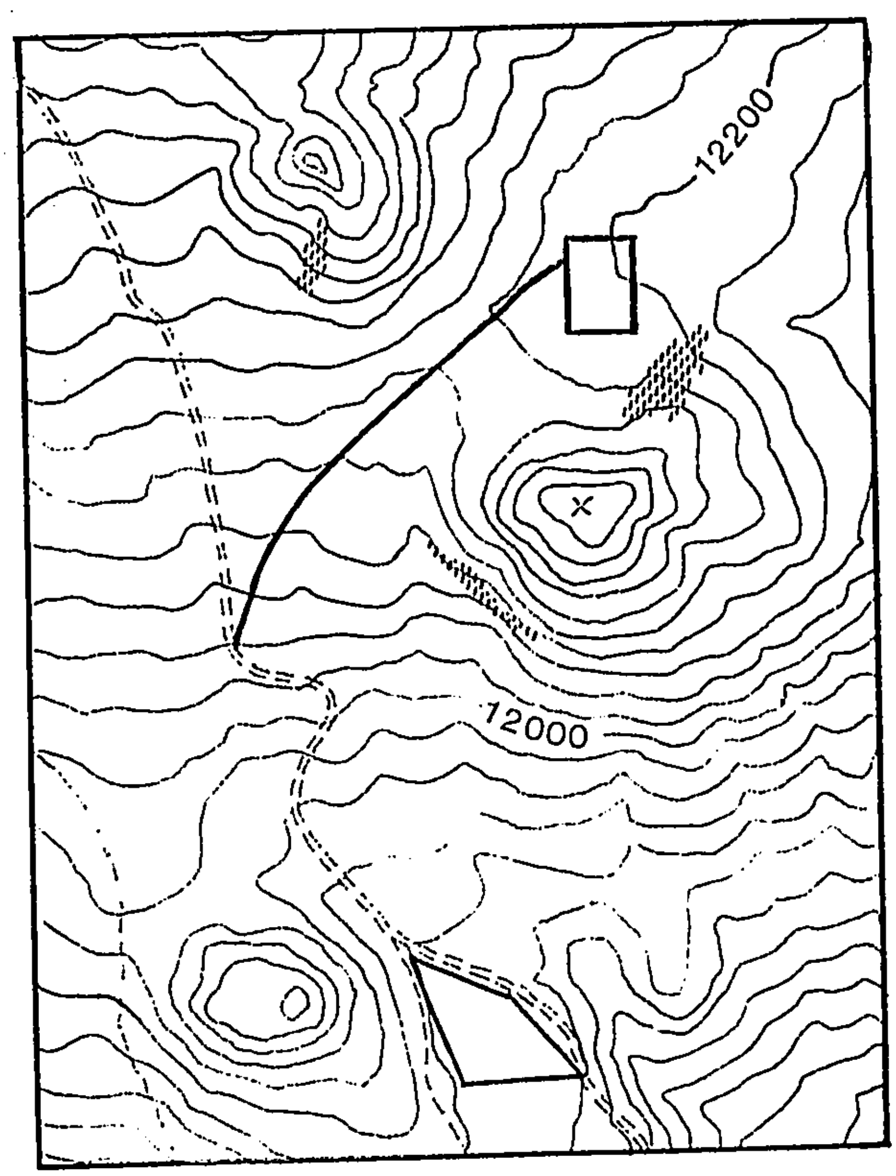


Figure 2. Overview of the study site, showing the proposed and alternate VLBA antenna locations, and potential Dark-rumped Petrel burrow locations (shaded areas).



the pu'u immediately south of the proposed antenna site, where there is a combination of steep slopes and rocky terrain.

Both sites had been used by feral sheep or sheep-mouflon hybrids. Old droppings were very common in both locations, particularly on the western side of the unnamed pu'u south of the selected antenna site. Much of the feral animal activity appeared centered in protected areas in the lee of rock outcroppings; such locations may have served as bedding sites. Confirmation of the use of the area by feral sheep comes from the discovery of partial remains of a sheep in the area of the proposed VLBA antenna. Because of the lack of forage in the area, it is unlikely that either site was much used by feral ungulates except as a refuge from intense hunting pressure at lower elevations.

There was no evidence of other vertebrates in the study area.

RECOMMENDATIONS

The recommendations regarding site selection and impact mitigation given here are provisional pending the completion of the breeding season survey of Dark-rumped Petrel.

Site selection

Antenna construction at the alternate site would be farthest from potential Petrel nesting habitat and would require the least land, thus reducing the overall impact of the project. In addition, since the area in the vicinity of the alternate site has already been disturbed by road construction, additional construction would cause a minimal amount of new impact.

Impacts and mitigation measures

No evidence of Petrel nesting was found during this study. However, should Petrel populations be located in the study area during the May survey, several kinds of impacts and mitigation will need to be addressed in the supplemental report. The most obvious of these is the direct disturbance of nest sites and breeding birds by construction and operation of the facility. Indirect impacts are potentially as damaging as direct disturbance. The primary indirect impacts include increasedmortality of birds in the area due to rodents and/or feral predators associated with the facility, as well as deaths by collision and as a result of light attraction.

The following recommendations are offered at present. If Petrels are found on or near the sites, then more detailed mitigation measures will be recommended in the supplemental report.

1. Trapping; use of mongoose-, rat- and cat-proof refuse containers; and frequent removal of refuse should be implemented as soon as construction begins and should be continued consistently as long as the facility is used. These mammals, while not in the area at present, may quickly become a problem once feeding opportunities become available.

2. Use of bright unshielded lights at the site should be prevented to reduce the potential for collisions, as light related mortality is one of the most frequent causes of mortality of Dark-rumped Petrel. Petrel are known to nest on the eastern flank of Mauna Kea.

3. Use of the area by irresponsible ORV users attracted to the area by the access roads should be prevented.

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SUPPLEMENTARY SURVEY FOR THE PROPOSED
VLBA ANTENNA FACILITY
MAUNA KEA, HAMAKUA, HAWAII

by

Maile S. Kjargaard

April 1988

This report presents the results of a nocturnal survey of the proposed VLBA antenna site performed on 28 May 1988; the intent of the survey was to determine whether breeding Hawaiian Dark-rumped Petrel were present in the vicinity of the antenna site.

The timing of the survey was planned so that the probability of detecting Petrel (should they occur in the area) was maximized. The survey was performed during the height of the breeding season, and at a period of the lunar cycle where calling is maximized.

An initial late-afternoon reconnaissance for burrow sites was performed in portions of the study area that I was able to explore during the April 1988 survey. As it became dark, I remained at the VLBA antenna site in order to detect any calling birds in the vicinity. I remained at the site until 8:15 PM, about 1.5 hours after sunset.

I detected no Petrel at the site during the survey, nor was there any evidence of burrow sites in suitable habitat nearby. Since the evaluation of the proposed antenna site is several thousand feet above that of the majority of Petrel breeding localities on both Maui and Hawaii, the lack of Petrel breeding in the project area is not anomalous. The proposed construction thus imposes minimal impact on Petrel populations on Mauna Kea.

APPENDIX G

A REPORT ON THE INVERTEBRATE FAUNA FOUND ON THE PROPOSED NRAO VLBA ANTENNA FACILITY SITE MAUNA KEA SCIENCE RESERVE MAUNA KEA, HAMAKUA, HAWAII

STEVEN L. MONTGOMERY, PH.D.

A REPORT ON THE INVERTEBRATE FAUNA

FOUND ON THE PROPOSED NRAO VLBA ANTENNA FACILITY SITE,

MAUNA KEA SCIENCE RESERVE, MAUNA KEA, HAMAKUA, HAWAII

INTRODUCTION

A report on the invertebrate fauna (Arthropoda) found on the selected NRAO VLBA facility site and access road follows. In addition, the report also includes findings from the alternative Mauna Kea site at the 11,800-foot elevation.

The survey work was conducted on April 10, 1988. A visual survey was conducted on foot covering the proposed facility site and access road, alternative site, and adjacent periphery areas. Notes on animals observed, substrate type, aeolian debris, etc., were recorded. The undersides of rocks and the area beneath the rocks were examined for animals and also to note presence of moisture and debris.

This survey was greatly aided by Masako Nakamura, Ph. D., an insect and annelid ecologist.

RESULTS AND DISCUSSION

The alpine zone on Mauna Kea is habitat for several remarkable invertebrates. Howarth and Stone (1982) found 11 native resident species unique to Hawaii. In the 2 sites surveyed on April 10, 1988, only 3 Hawaiian species were recorded (see Table 1). The only native herbivorous species seen was the lichen feeding,diurnal cutworm moth, Agrostis. One was recorded in rapid flight at the fork of the proposed access route. Because no sizeable patches of lichen were growing along the access route or on the facility site, the project is not expected to affect its habitat.

The most unusual predator is Nysius wekiuicola, the Wekiu bug, a lygaeid bug living off the fluids of insects carried to the summit by winds (Ashlock and Gagne 1983). None were found in the project area, probably due to the lack of moisture from snow in slow melting drifts. Two liters of snow found between large rocks yielded only alien flies, wasps and tiny spiders.

Endemic Lycosa wolf spider skins were frequent under large stones in the alternative site, but only one spider was sighted. The selected site, at about 12,250 ft., was more barren of life, probably because no peaks concentrated aerial waifs there.

Table 1. List of Invertebrates on Study Sites

	Selected site and access road	Alternative site
ARACHNIDA		
Araneae (spiders)		
Lycosidae: *Lycosa* species, *	-	+
Linyphiidae: *Erigone* species, *	+	+
INSECTA		
Collembola (springtails)		
Entomobryidae: Species undetermined	+	+
Diptera (flies)		
Ephydridae: *Hydrellia tritici*, X	+	+
Calliphoridae: *Pollenia rudis*, X (cluster fly)	+	+
Lepidoptera (moths)		
Noctuidae: *Agrostis* new species, * (Lichen cutworm)	+	-
Hymenoptera (sawflies, chalcids, ants, wasps, bees)		
Chalcidoidea: Species undetermined--transient, parasitoid, X	+	-

* = endemic species

X = introduced or exotic species

- = absent on site

+ = present on site

The exotic economic pests, Hydrellia and Pollenia, were by far the most prominent arthropods, likely due to their vast numbers at mid elevations.

Because the sites are small, flat and uniformly bedded with fine ash and cinders, the biomass is much smaller than at higher elevations, thus the impacts on native invertebrates are projected to be extremely minor.

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APPENDIX H

VISIBILITY ANALYSIS OF
TWO ALTERNATIVE SITES
FOR THE VLBA ANTENNA FACILITY

MCM PLANNING

VISIBILITY ANALYSIS OF TWO ALTERNATIVE SITES
FOR THE VLBA ANTENNA FACILITY

I. METHODOLOGY

Two potential antenna sites within the Mauna Kea Science Reserve, one at the 12,200-foot elevation and one at the 11,800-foot elevation (Figure H-1), were evaluated for short-range (within the summit area) and long-range (island-wide) visual impact. The analysis was based on the following assumptions:

- The antenna is positioned towards the horizon, facing the viewer.
- At its highest point in this position the antenna is 95 feet above ground
- The viewer is standing at ground level, viewing height is five feet above ground.
- The viewer is standing on a flat area clear of vegetation; there are no natural or man-made obstructions nearby to block the view.
- The weather is clear; cloud levels are above 14,000 feet.

A detailed geometric analysis of potential view-planes, based on the hypothesis that "if I can see you - then you can see me", was undertaken. Figure H-2 illustrates the basic assumptions of the analysis.

Using data from photogrammetric maps of the project area and U.S.G.S. maps of Mauna Kea and Hawaii County, potential lines-of-site were interpolated from the top of the reflecting antenna to their intersection with points along the grade below. Calculations were made at 5^{o} intervals for rural areas; 1^{o} intervals for Hilo; and every 200 feet along the Mauna Kea Observatory (MKO) Access Road from the 11,600-foot elevation to the summit ridge. This resulted in the identification and delineation of areas where visibility of the antenna was not obstructed by natural terrain or other features.

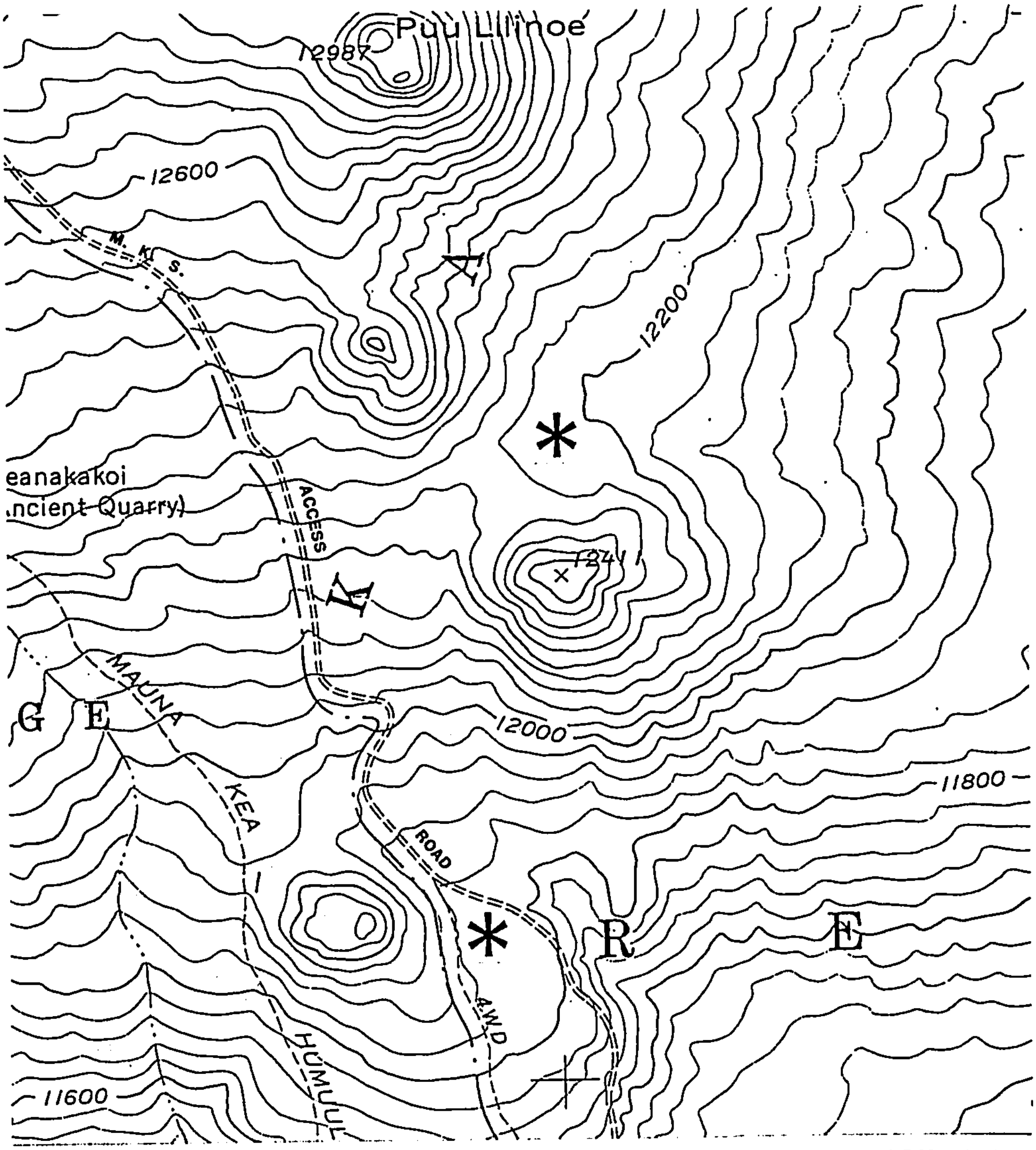


FIGURE H-1

LEGEND

SITE LOCATION MAP

* POTENTIAL SITES

0 1000 2000
SCALE IN FEET

LOCATION

NORTH

MCM PLANNING 6/88

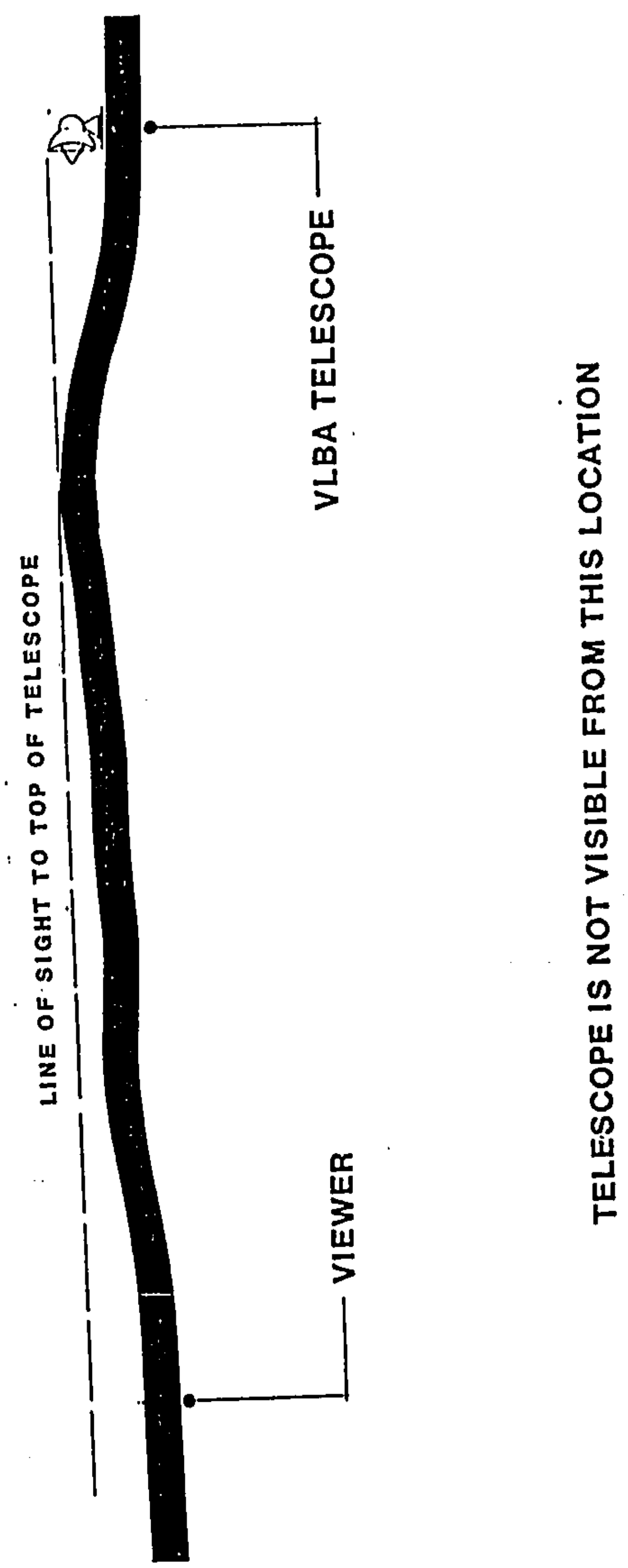


FIGURE H-2

METHODOLGY TO ASSESS VISUAL IMPACT

II. VISUAL IMPACT ANALYSIS

A. Potential Site at the 11,800-foot Elevation of Mauna Kea

The site is located just north of the southern boundary of the Mauna Kea Science Reserve, adjacent to the MKO Access Road. The area is flat and covered with ground moraine deposits; an unnamed cinder cone to the west of the siting area rises about 100 feet above ground level. There are no other landforms nearby that could significantly reduce visual impact.

As shown in Figure H-3, at short-range the antenna will be visible along about two miles of the MKO access road from about 500 feet below the site to a point near Puu Hau Kea. It will also be seen from a 2,500-foot stretch of the MKO Access Road at the 13,400-foot elevation near the summit. Because the terrain in the vicinity of the site is open and level, the entire complex (antenna and support facilities) will be visible from these points.

Because the site is on the south face of the mountain, the antenna would not be seen from the northern section of the island. An unnamed cinder cone to the west would also obscure views of the antenna from the west and southwest. Because there are no minor topographic variations to the east and southeast that would obscure the lower portion of the antenna from the viewer, the entire telescope may be visible from much of the area shown on Figure H-4. This area includes: Leleiwi Point; portions of the Saddle Road; all of Waiakea Homesteads; all of Keeau, Puna; portions of Hawaii Volcanoes National Park; and, the north face of Mauna Loa.

B. Potential Site at the 12,200-foot Elevation on Mauna Kea

The proposed antenna facility site is in a low-lying saddle between between two cinder cones which rise from 230 to 380 feet above site elevation. These landforms are expected to block out the view of the antenna from most areas.

At short-range, the antenna will be partially visible from the MKO Access Road for about 150 feet from a point about 600 feet north of the entrance to the facility access road and again for about 250 feet from a point about 1,000 feet farther north. The antenna will be completely visible along a 2,500-foot stretch of the MKO Access Road at the 13,400-foot elevation. In

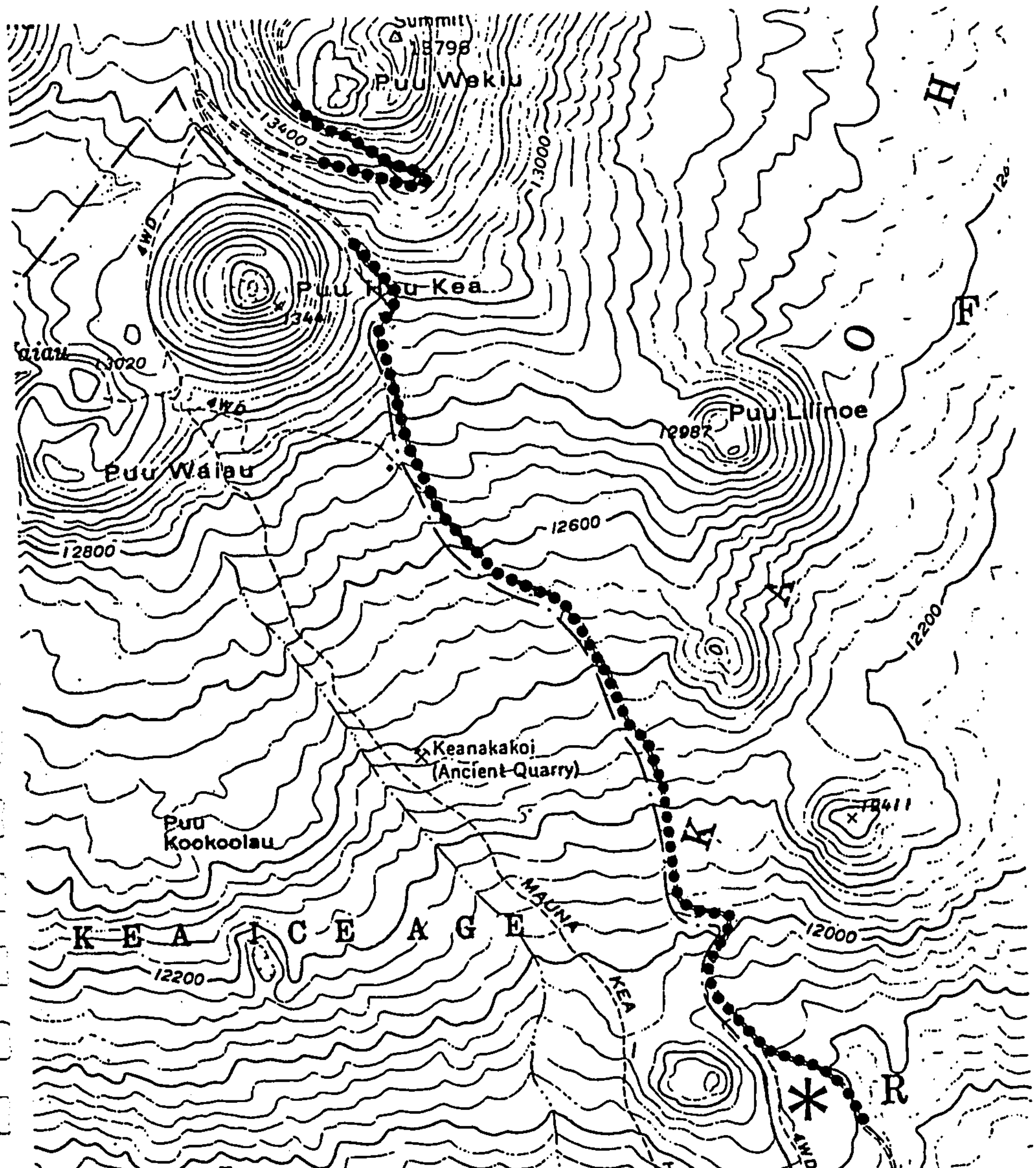


FIGURE H-3

LEGEND

* SITE LOCATION

●●● AREAS OF VISIBILITY

SHORT RANGE VISUAL IMPACT

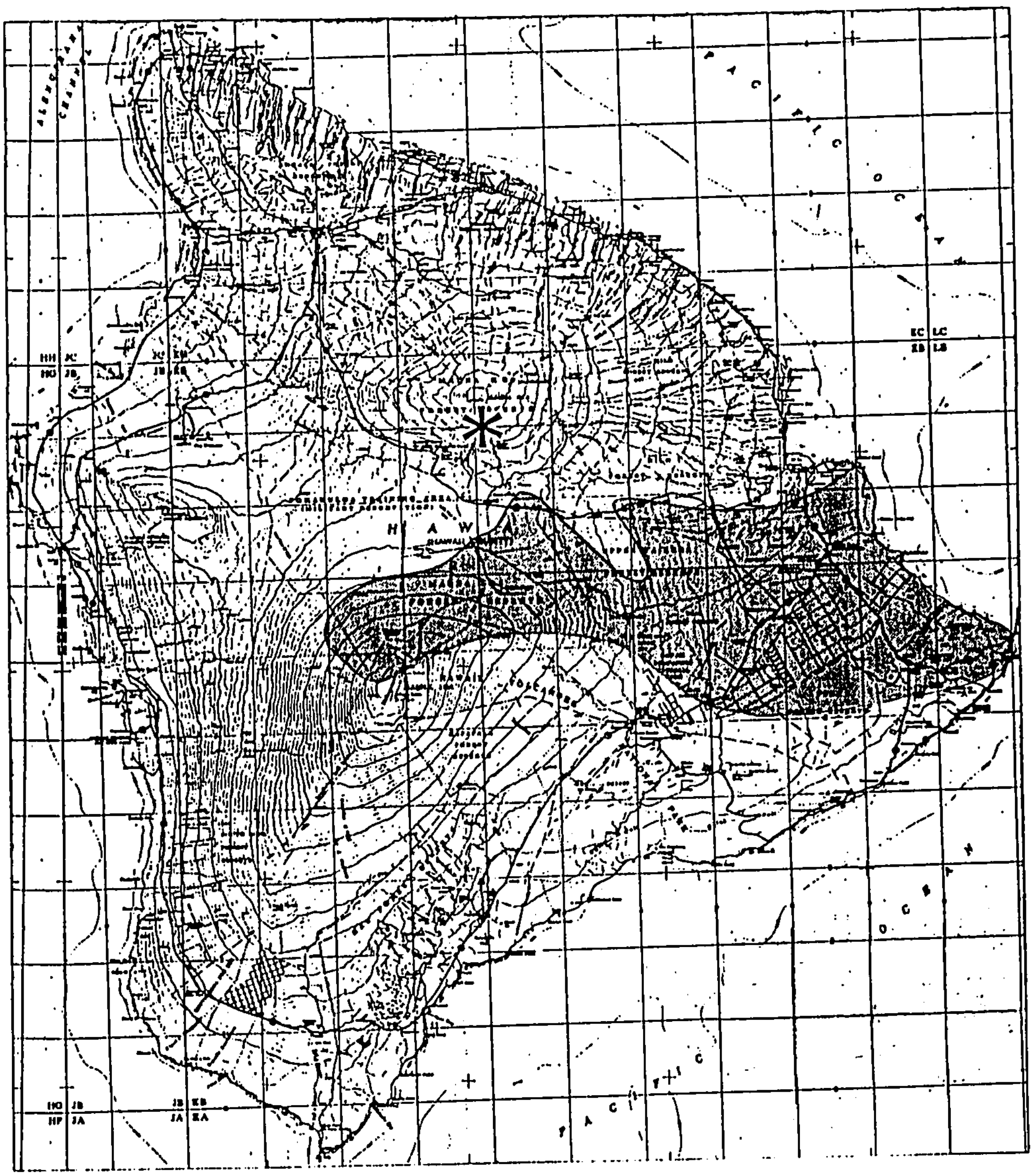
OF VLBA SITE AT 11,800' ELEVATION

0 1000 2000
SCALE IN FEET

HAWAII
LOCATION

NORTH

MCM PLANNING 6/88



LONG RANGE VISUAL IMPACT

FIGURE H–4

OF VLBA SITE
AT 11,800' ELEVATION

LEGEND

* SITE LOCATION

AREAS OF VISIBILITY

0 5 10 15
SCALE IN MILES

NORTH

MCM PLANNING 6/88

addition, several hundred feet of the facility access road will be visible from the MKO Access Road (Figure H-5).

Because the site is about 1,500 feet below the summit ridge on the southern face of the mountain, the facility would not be visible from the northern part of the island. As shown in Figure H-6, the antenna will not be visible from downtown Hilo. It may, however, be partially visible from Leleiwi Point, portions of Waiakea Homesteads, a two-mile stretch of the Saddle Road near Kaumana, portions of the Puna District from Keeau to Kapoho, one small area near Onomea and an area near Kipuka Alala in the Mauna Loa Forest and Game Reserve.

Visual impact of the antenna facility at the 12,200-foot elevation will be low.

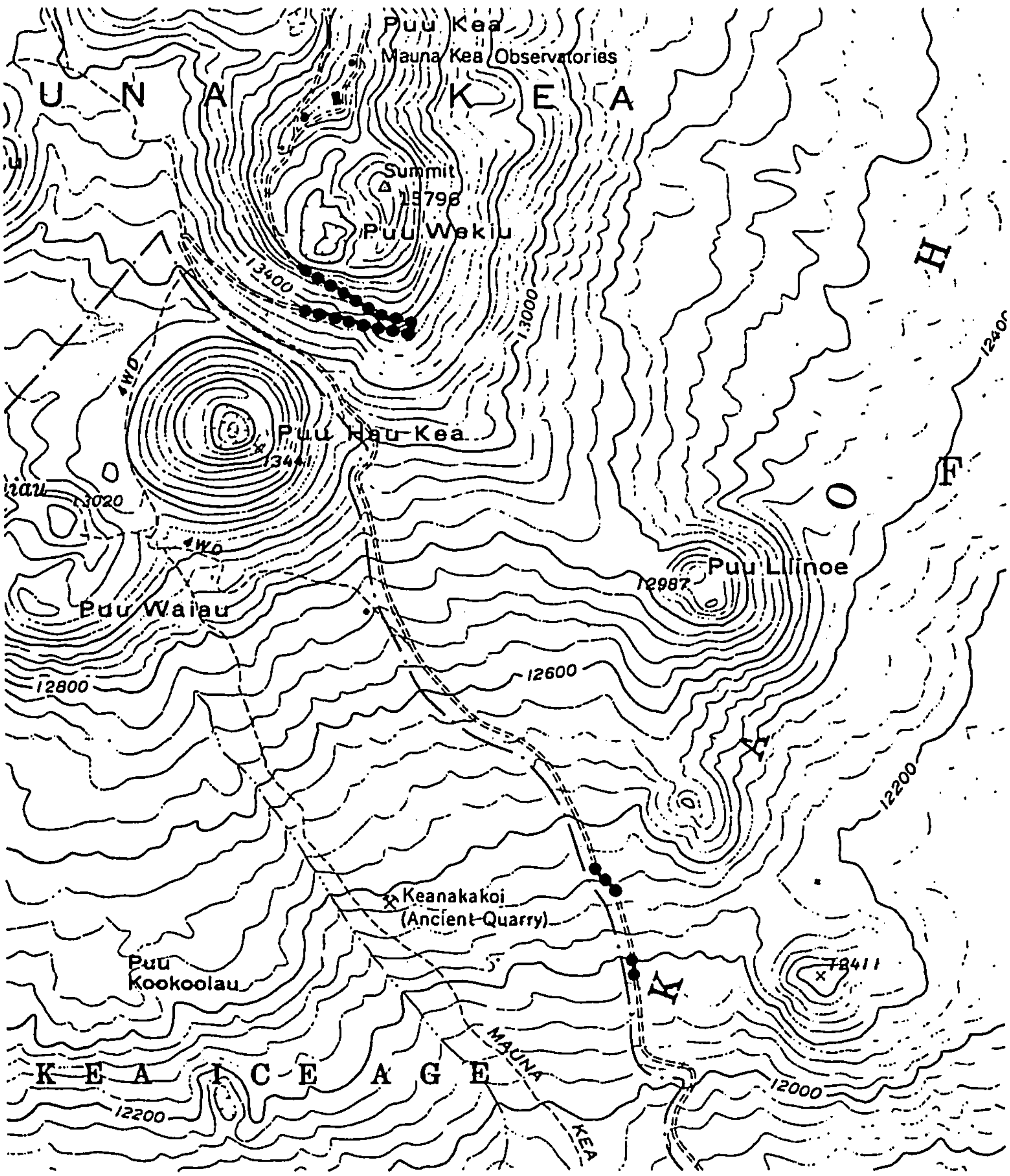


FIGURE H-5

SHORT RANGE VISUAL IMPACT

OF SELECTED VLBA SITE AT 12,200' ELEVATION

LEGEND

* SITE LOCATION

●●● AREAS OF VISIBILITY

0 1000 2000

SCALE IN FEET

HAWAII

LOCATION

NORTH

MCM PLANNING 6/88

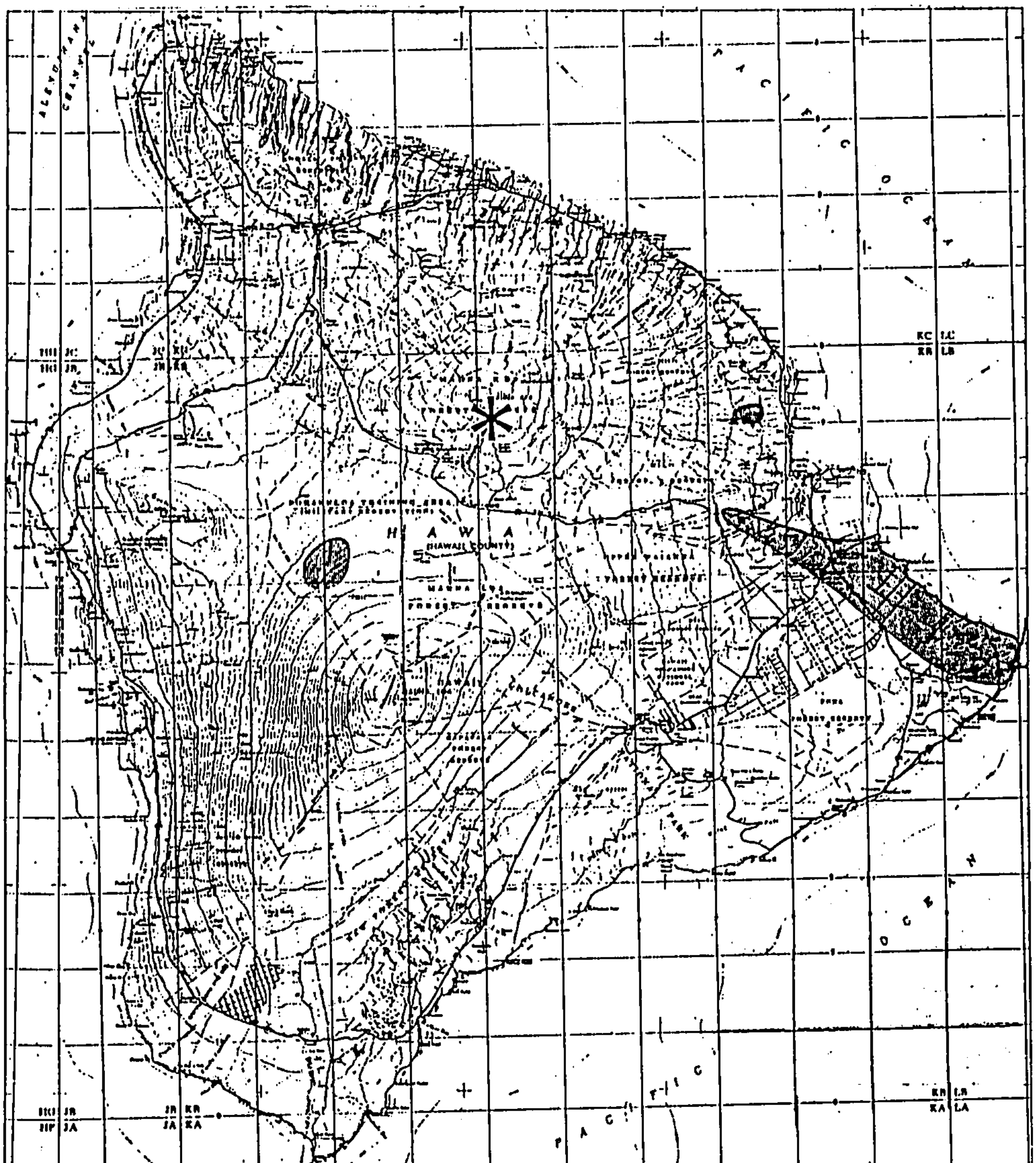


FIGURE H–6

LONG RANGE VISUAL IMPACT

OF SELECTED VLBA SITE AT 12,200' ELEVATION

LEGEND

* SITE LOCATION

AREAS OF VISIBILITY

0 5 10 15

SCALE IN MILES

NORTH

MCM PLANNING 6/88

APPENDIX I

ENVIRONMENTAL ASSESSMENT FOR THE
VLBA RADIO TELESCOPE
ON MAUNA LOA, HAWAII

FREDERICK R. WARSHAUER

ENVIRONMENTAL ASSESSMENT FOR VLBA RADIO TELESCOPE
ON MAUNA LOA, HAWAII

Frederick R. Warshauer

August 1987

Prime Contract No. NSF AST 84-03744
Consultant Subcontract VLBA-129

INTRODUCTION

This environmental assessment addresses the probable ecological impacts of the Very Long Baseline Array (VLBA) radio telescope proposed for construction at approximately the 2,740 m (8,990 ft) elevation on the north slope of the upper Northeast Rift Zone of Mauna Loa volcano. The VBLA site is planned to consist of a fenced facilities site and access road of total areal extent of about 0.6 ha (1.5 ac). This area would be cleared and grubbed, removing the native vegetation, and would be contained within a larger approximately 13 ha (32 ac) leased area immediately upslope of the Mauna Loa Observatory (MLO) access road. Operational activities at the facility would be limited to the fenced site and road, and no effluents or other farther-reaching impacts would be expected to be produced.

METHODS

This assessment's field work was a walk-through survey noting the character and composition of the limited on-site vegetation, and comparing it with that nearby. The area surveyed was a kipuka of older substrate from where the MLO road transected it at about 2,710 - 2,730 m (8,890 - 8,960 ft) elevation to its upslope end at 2,775 m (9,100 ft). Although the construction site is proposed to be in the lower portion of this area, this whole elevation range was traversed to better characterize the vegetation.

As the region's youthful geology dominates the landscape and the ecology of the region, use was made of recently processed unpublished findings of U. S. Geological Survey geologist John P. Lockwood, who has been involved in studying the eruptive behavior and surface geology of Mauna Loa for a number of years. This information includes areal determinations of surface lava flow segments, grouped into five age classes and sorted into elevation bands of 500 m altitude in width.

OBSERVATIONS AND INFORMATION

Rainfall.--On a median rainfall map of the island (Circular C88, Hawaii State Dept. of Land and Natural Resources, Honolulu, 1982), the project area falls along the 800 mm (31.5 in) isohyet.

Plants.--Vascular plants in the area of the proposed VLBA site are limited in occurrence to the oldest substrates, as plant colonization and succession proceed very slowly under local conditions. Eleven vascular plants, two lichens and two mosses were recorded (Table 1). None of these are officially listed endangered or threatened species nor candidates for such status. All of these species, plus others, were seen far more abundantly at slightly lower elevations on similarly aged and younger substrates.

Vegetation.--The vegetation can be categorized as a low, sparse micophyllous sclerophyll scrub. The vascular species were all shrubs and herbs, mostly perennial, below about 75 cm (2.5 ft) in height. They occurred both as scattered individuals or as small groupings of several species occupying up to 1-2 m^2 of area, usually much less. The clumped plants usually sheltered small amounts of soil. Total plant cover is very much less than 1 %, and the surface between is barren pahoehoe lava, somewhat oxidized to a gray-brown color. The much younger \`a\`a lava flows flanking the pahoehoe kipuka (remnant of older substrate) were not seen to support vascular plants near the kipuka boundary, only a small amount of lichen.

Wildlife.--No birds were observed at the site, but three native species might occasionally visit or fly over the site. The `oma`o (Phaeornis obscurus) is known to live in low numbers in this upper elevation vegetation, and I have seen them 6 km to the northeast of the site at approximately 2,300 m (7,550 ft) elevation. The nene (Nesochen sandvicensis), and endangered goose which ranges widely on Mauna Loa's middle and upper slopes, may utilize the age "II" vegetation from this elevation occasionally, but is not site specific to the area. The `ua`u or dark-rumped petrel (Pterodroma phaeopygia sandwichensis) is an endangered bird, and may possibly be affected by this project. It is a pelagic bird which nests in the upper mountainous parts of several islands, including Mauna Loa. From March through October it flies up and down the mountain slopes in the dark hours to breed, nest, and feed young. The fledging young, and to a lesser extent the adults, can be fatally disoriented by bright lights.

Several introduced mammals may be expected to occasionally pass through or utilize the area. These are feral goat (Capra hircus), feral cat (Felis catus), mongoose (Herpestes auropunctatus), black rat (Rattus rattus) and house mouse (Mus musculus).

Lava tube.--A lava tube was observed running down the western side of the pahoehoe kipuka, marked by several surface openings or "skylights". About 400 m of the tube's length was traversed just below the MLO road. No life of any sort was seen, and, importantly no plant roots penetrated into the tube from the sparsely vegetated surface above. As plant roots are the primary energy source for the Hawaiian lava tube ecosystem, the likelihood of this tube containing known native troglodytes is quite low.

DISCUSSION

In keeping with the site's desired design requirements, the location is usually above the penetration of moisture-laden tradewind air. Consequently, this dryness supplements the high elevation as limitations to the rate of succession and the species diversity. Little vegetation occurs above this elevation. The predominantly youthful nature of the lava flow surfaces further limits the total amount of vegetation at these higher elevations.

Accordingly, it is appropriate to consider how much of the total upper level vegetation would be removed by the project. The vegetated pahoehoe flow is considered by Lockwood to be in age class "II", about 1,500 - 4,000 years old. There are approximately 39,460 ha (97,506 ac) of total land surface in the 2,500 - 3,000 m (8,200-9845 ft) elevation band on Mauna Loa. Of this total, the age class "II" substrate occupies 5,240 ha (12,948 ac) or about 13.3 % (J. P. Lockwood, pers. comm.). The other two flows mentioned are age class "IV" (about 107-750 years old) and "Historic" (1843-1984; 1899 in this case).

If one assumes that 1) the vegetated portions of the 2,500 - 3,000 m elevation band extends only up to about 2,800 m (just above the top of the "II" pahoehoe kipuka), and 2) that all age class "II" flows support similar vegetation, one can get a very rough estimate of the total amount of this vegetation community on Mauna Loa, and the proportion of it which would be consumed by the construction of the 0.6 ha VLBA facilities, the project's main impact. Calculations indicate that this is about 0.02 %.

Total "II" vegetation: $\frac{2,800 - 2,500 \text{ m}}{500 \text{ m}} \times (5,240 \text{ ha}) = (0.6)(5,240 \text{ ha})$

$= \underline{3,144} \ \underline{\text{ha}}.$

Amount of "II" impacted: (0.6 ha) / (3,144 ha) = <u>0.02 %</u>

CONCLUSIONS AND RECOMMENDATIONS

It appears that the major impact of the proposed project would be the destruction of about 0.6 ha of the sparse, but relatively mature plant community (and any associated sessile arthropods) on the older pahoehoe flow during construction. Consisting of only about 0.02 % of this community type on Mauna Loa, this loss can be considered relatively insignificant, particularly in the context of natural losses due to lava flow inundation. The construction of the proposed lava diversion barrier upslope on the unvegetated young flows can also be considered insignificant biologically.

Two other sorts of potential impacts can be avoided if proper precautions are taken. Any construction activities will change the physical nature of the lava substrate and will likely bring introduced plant species into the disturbed site. It is recommended that a botanist be arranged to monitor the site for introduced plants at least twice following construction and to direct or effect their removal in order to prevent the spread of these weeds into adjoining native vegetation. Although the composition of the native vegetation is relatively simple at this upper elevation, it is unusual in Hawaii to find such a low presence of introduced plants and is valuable in that regard.

Lights on or next to VLBA facilities might disorient night-flying dark-rumped petrels. It is recommended that, other than an aircraft warning light, all exterior lighting be kept to a minimum and effectively shielded to prevent upward and outward escape of light.

Table 1. Plants observed in the survey area.

Species	Life form
Vascular plants	
<u>Asplenium adiantum-nigrum</u>	fern
<u>A. trichomanes</u>	fern
<u>Carex wahuensis</u>	sedge
<u>Coprosma ernodeoides</u>	shrub
<u>Gnaphalium sandwichensium</u>	herb
<u>Hypochaeris radicata</u>	herb-introduced
<u>Pellaea ternifolia</u>	fern
<u>Styphelia tameiameiae</u>	shrub
<u>Tetramolopium humile</u>	herb
<u>Trisetum glomeratum</u>	grass
<u>Vaccinium peleanum</u>	shrub
Non-vascular plants	
<u>Grimmea</u> sp.	moss
<u>Rhacometrium lanuginosum</u>	moss
<u>Stereocaulon vulcani</u>	lichen
<u>Usnea</u> sp.	lichen

APPENDIX J

COMMENTS AND RESPONSES ON THE DRAFT SEIS

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

AUG 23 1988

RECEIVED

AUG 29 1988

DIRECTOR
INSTITUTE FOR ASTRONOMY

Dr. Donald N. B. Hall
Director
Institute for Astronomy
University of Hawaii
2680 Woodlawn Drive
Honolulu, Hawaii 96822

Dear Dr. Hall:

In letters, dated July 5, 1988, I invited appropriate Federal agencies to submit comments to my office on the Draft Supplemental Impact Statement in the matter of constructing a Very Long Baseline Array antenna on Mauna Kea; copies of the Draft Statement were enclosed. The following agencies were contacted:

1. Environmental Protection Agency
   Region IX
   Office of Federal Activities
   Attention: Dr. Jacqueline Wyland
   215 Fremont Street
   San Francisco, CA 94105

2. Environmental Protection Agency
   Office of Federal Activities
   Mailstop A-104
   Attention Ken Mittelholt
   401 M Street, SW
   Washington, DC 20460

3. Department of the Army
   U.S. Army Engineering and Housing Support Center
   Attention CEHSC-EP
   Pulaski Building, Room 6123
   Washington, DC 20314-1000

4. USDA Forest Service
   12th and Independence SW
   Attention: Richard V. Smythe
   Director
   Forest Environment Research
   P.O. Box 96090
   Washington, DC 20090-6090

5. Department of the Interior
   Fish and Wildlife Service
   Attention: Frank Dunkle
   Director
   Washington, DC 20240

6. Advisory Council on Historic Preservation
   1100 Pennsylvania Avenue, NW, Suite 809
   Attention: Don Klima
   Washington, DC 20004

7. National Oceanic and Atmospheric Administration
   EC Room 6222 HCHB
   Attention: David Cottingham
   Washington, DC 20230

We received two replies, copies of which are enclosed for your records.

Sincerely,

Julian Shedlovsky

Julian Shedlovsky
Chairperson
NSF Committee on Environmental Matters
1800 G Street NW, Room 641
Washington, DC 20550

Enclosures

United States
Department of the Interior

Fish and Wildlife Service
Lloyd 500 Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

In Reply Refer To: Your Reference:

JUL 22 1988

Dr. Julian Shedlovsky, Chair
Committee on Environmental Matters
Directorate for Geosciences
National Science Foundation
1800 G Street, N.W., Room 641
Washington, DC 20550

Dear Dr. Shedlovsky:

We have reviewed the Amendment to the Environmental Impact Statement of the Mauna Kea Science Reserve Complex Development Plan for a Very Long Baseline Array Antenna Facility at Hamakua on the Island of Hawaii, State of Hawaii. We have no further comments to offer.

We appreciate the opportunity to comment.

Sincerely,

Larry Edwards

Acting
Regional Director

CC – Dr. Ludwig Oster/AST

United States Department of Agriculture
Forest Service
Washington Office
12th & Independence SW
P.O. Box 96090
Washington, DC 20090-6090

Reply To: 1950-4-2

Date: July 20, 1988

Dr. Julian Shedlovsky
Chair, Committee on Environmental Matters
Directorate for Geosciences, Rm 641
National Science Foundation
1800 G Street, N.W.
Washington, DC 20550

Dear Dr. Shedlovsky:

Thank you for providing us the opportunity to review the amendment to the Draft Supplemental Environmental Impact Statement (SEIS) entitled "Amendment to the Mauna Kea Science Reserve Complex Development Plan for a VLBA Antenna Facility at Mauna Kea, Hamakua, Hawaii." We have no comments on the amendment to the development plan.

Sincerely,

RICHARD V. SMYTHE
Director of
Forest Environment Research

cc: Ludwig Oster, Rm. 618

RECEIVED 7-25-88

JOHN WAIHEE
GOVERNOR

EDWARD Y. HIRATA
DIRECTOR

DEPUTY DIRECTORS
JOHN K. UCHIMA
RONALD N. HIRANO
DAN T. KOCHI
JEANNE K. SCHULTZ

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813

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'88 AUG -8 P4:17
OFC. OF ENVIRO... QUALITY CONTROL

IN REPLY REFER TO:
STP 8.3046

August 3, 1988

Dr. Marvin Miura, Director
Office of Environmental Quality Control
465 South King Street, Room 104
Honolulu, Hawaii 96813

Dear Dr. Miura:

Draft Environmental Impact Statement
Mauna Kea Science Reserve
Complex Development Plan

By letter dated June 14, 1988 (STP 8.2916), we submitted comments to Dr. Donald N.B. Hall, Director of the Institute for Astronomy, University of Hawaii. Since the comments are still valid, we are attaching a copy of the letter for your consideration.

Thank you for this opportunity to provide comments.

Very truly yours,

Edward Y. Hirata
Director of Transportation

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2489

SEP 8 1988

June 14, 1988

Dr. Donald N.B. Hall, Director
University of Hawaii
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, Hawaii 96822

Dear Dr. Hall:

Environmental Assessment and Supplemental
Environmental Impact Statement Preparation Notice
Antenna Facility Within the Mauna Kea Science Reserve

We are recommending that clearances be obtained from the Federal Aviation Administration (FAA). To assist you, we have enclosed FAA Form 7460-1 which should be completed and submitted to FAA.

Thank you for this opportunity to provide comments.

Very truly yours,

Edward Y. Hirata
Director of Transportation

DT:ko
Enclosure
cc: AIR, STP(dt)

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

August 30, 1988

Mr. Edward Y. Hirata, Director
Department of Transportation
State of Hawaii
869 Punchbowl Street
Honolulu, Hawaii 96813

Dear Mr. Hirata:

Subject: Draft Supplemental Environmental Impact Statement (DSEIS) - Amendment to the Mauna Kea Science Reserve Complex Development Plan for a VLBA Antenna Facility at Mauna Kea, Hamakua, Hawaii

Thank you for reviewing and commenting on the subject DSEIS. For your information, a Notice of Proposed Construction or Alteration was filed with the FAA on August 3, 1988. In addition, we sent a copy of the DSEIS to the FAA office in Honolulu; they did not comment.

Sincerely yours,

Donald N. B. Hall

Donald N. B. Hall
Director

DNBH:jec
cc: MCM Planning
National Radio Astronomy Observatory
Office of Environmental Quality Control

University of Hawaii at Manoa

Office of Campus Operations
1951 East West Road
Honolulu, Hawaii 96822

Office of the Director

RECEIVED

'88 JUL 28 A11:53

July 25, 1988

Dr. Marvin T. Miura
465 So. King Street, Room 104
Honolulu, Hawaii 96813

Dear Dr. Miura:

Subject: AMENDMENT TO THE MAUNA KEA SCIENCE RESERVE COMPLEX DEVELOPMENT PLAN FOR A VLBA ANTENNA FACILITY

After reviewing the draft of the Supplemental Environmental Impact Statement (EIS), the following comments were made by my staff on the subject matter.

1. Construction of the VLBA Antenna Facility will overlap with the Mauna Kea Observatory Access Road project, which is currently under construction and scheduled for completion on December 11, 1989. Access to the VLBA site will have to be coordinated with the road contractor.

2. The fifth sentence in the last paragraph on page II-8 mentions the possible use of the "skier's parking lot" as a concrete batching plant. This is a potential problem since the access road contractor is already using the area for his operations.

If you have any questions regarding the above comments, please call Mr. Clyde Akita at 948-7201.

Sincerely,

Allan Ah San
Director of Campus Operations

University of Hawaii at Manoa

Institute for Astronomy

MEMORANDUM

August 30, 1988

TO: Allan Ah San
Director of Campus Operations

FROM: Donald N. B. Hall
Director, Institute for Astronomy

SUBJECT: Draft Supplemental Environmental Impact Statement (DSEIS) - Amendment to the Mauna Kea Science Reserve Complex Development Plan for a VLBA Antenna Facility at Mauna Kea, Hamakua, Hawaii

Thank you for reviewing the subject DSEIS. Construction of the VLBA facility will be coordinated with your office and the road contractor. Because the concrete "pours" will be of short duratin (one to two days each), alternatives to use of the "skiers' parking lot," such as hauling already mixed concrete from the contractor's base of operations or batching on site, will be undertaken if the designated batch plant site is unavailable.

DNBH:jec

cc: MCM Planning
National Radio Astronomy Observatory
Office of Environmental Quality Control

-file

University of Hawaii at Manoa

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Environmental Center
Crawford 317 • 2550 Campus Road
'88 AUG -8 P4:06 Honolulu, Hawaii 96822
Telephone (808) 948-7361

OFC. OF ENVIR. QUALITY C...

August 5, 1988
RE:0503

Dr. Marvin T. Miura
Office of Environmental Quality Control
465 South King Street, Room 104
Honolulu, Hawaii 96813

Dear Dr. Miura:

Draft Supplemental Environmental Impact Statement
Mauna Kea Science Reserve Complex
(Development Plan for a VLBA Antenna Facility)
Mauna Kea, Hawaii

This document discusses the construction of a Very Long Baseline Array (VLBA) antenna facility on the slopes of Mauna Kea within the Mauna Kea Science Reserve Complex at an elevation between 12,200 and 12,400 feet. The Mauna Kea siting is the westernmost facility for the VLBA which includes similar antennas on the Virgin Islands, Puerto Rico and various states of the western United States. Construction activities will include road building, utility installation, fencing of archaeological sites, concrete foundation laying, and the final assembly of the antenna, which will be shipped to Hawaii from the continental United States. This review was conducted with the assistance of P. Bion Griffin, Anthropology; Edwin Murabayashi, Henry Gee and Yu-Si Fok, Water Resources Research Center; Roy Takekawa, Environmental Health and Safety; and Steven Armann, Environmental Center.

Specific Comments:

Drainage and Erosion Control. The discussion of drainage and erosion control would be improved by including more specific quantitative information on relevant climate conditions. Seasonal information on wind and rainfall at the site would appear to be important to assure that construction schedules can be adjusted to minimize erosion and fugitive dust impacts to other Mauna Kea science facilities.

Archaeology. The archaeological studies reflect a minimally acceptable level of study. Provisions are needed to assure that mitigation measures for both short and long term protection, such as fencing of the sites, are not overlooked when the construction begins. We strongly urge that a trained archaeologist be present when the fencing is erected and before any construction, including roads and utilities takes place.

Environmental Health. Since the antenna facility is "a receiving instrument only" and does not transmit or radiate any radio frequency energy, there should not be any harmful effects on humans.

EIS Organization. All four copies of our Draft EIS's were missing pages. In addition, one entire section (V) was duplicated. Such major obvious errors in collation of the document leads the reviewer to suspect the adequacy of the content of the document as well. Considerably greater effort should be given to the production of the Final Supplemental EIS to assure that an adequate and factually accurate document is produced.

In conclusion, compliance with all the recommendations and mitigative measures identified in the EIS should be made a part of any construction contract to assure that all parties are aware of their respective environmental responsibilities.

Thank you for the opportunity to review this document. We look forward to your response and the final statement.

Yours truly,

Jacquelin N. Miller

Jacquelin N. Miller
Associate Environmental Coordinator

cc: L. Stephen Lau
Donald N.B. Hall
Yu-Si Fok
Henry Gee
P. Bion Griffin
Edwin Murabayashi
Roy Takekawa
Steven Armann

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

August 30, 1988

Ms. Jacquelin N. Miller
Associate Environmental Coordinator
Environmental Center, Crawford 317B
2550 Campus Road
Honolulu, Hawaii 96822

Dear Ms. Miller:

Subject: Draft Supplemental Environmental Impact Statement (DSEIS) - Amendment to the Mauna Kea Science Reserve Complex Development Plan for a VLBA Antenna Facility at Mauna Kea, Hamakua, Hawaii

Thank you for reviewing and commenting on the subject DSEIS. First, we would like to apologize for your incomplete copies. We had some initial problems with the printer; however, we were able to replace most of the defective copies before they were distributed. Unfortunately, yours were not among those replaced. We wish that you had contacted us as we would have been more than happy to replace your copies. In response to your specific comments:

1. There are no site-specific meteorological data available for the VLBA site. Rainfall information for the Mauna Kea Science Reserve is presented on Page III-4 of the DSEIS; wind data for the summit is presented on that page and on Page V-13. Although it is assumed that wind velocities at the proposed VLBA site would be less than at the exposed summit, seasonality is expected to be similar. Because the location of the VLBA site is roughly 2.7 miles below the summit area (Page II-1), fugitive dust impacts to other Mauna Kea science facilities are not anticipated.

2. Archaeological mitigation will be coordinated with the State Historic Preservation Office; all of their recommendations will be followed.

Ms. Jacquelin N. Miller
August 30, 1988
Page 2

It is intended that compliance with the mitigation measures and recommendations identified in the SEIS will be made part of any construction contract.

Sincerely yours,

L. Cowie for D.N.B. Hall

Donald N. B. Hall
Director

DNBH:jec

cc: MCM Planning
National Radio Astronomy Observatory
Office of Environmental Quality Control

COPY

PLANNING DEPARTMENT 25 AUPUNI STREET
COUNTY OF HAWAII HILO, HAWAII 96720

August 22, 1988

Dr. Marvin T. Miura, Ph.D.
Office of Environmental Quality Control
465 So. King Street, Room 104
Honolulu, HI 96813

Dear Dr. Miura:

Draft EIS - Amendment to the Mauna Kea Science Reserve Complex Development Plan

We have no objections to the establishment of the VLBA facility itself at the summit area of Mauna Kea.

However, the presence of transmitters already at the summit appears to be a separate issue needing to be resolved even through the proposed VLBA is not hampered by nor contributes to that problem.

Page S-9, paragraphs 3 and 4 state the Institute for Astronomy proposes an end to all transmitters at the summit. The Land Board Chairman in one of his letters on this subject matter (letter dated April 25, 1988, to Dr. Donald Hall, IAF Director) clearly states otherwise. We were not aware until reading this report that UHIFA was proposing the removal of all transmitters from the general area. The County of Hawaii Police Department expressed concern over future conflicts with their lower elevation based radio communications facilities.

As this application is an amendment to the Mauna Kea Science Reserve Complex Development Plan (SRCDP), we recall also that the original SRCDP made mention of a Management Committee in 1983 to include the County as well as other agencies. We have had no notice of the Committee's formulation to date.

Sincerely,

ALBERT LONO LYMAN
Planning Director

DT/ALL:lv

cc: Dr. Donald Hall

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

August 30, 1988

Mr. Albert Lono Lyman
Planning Director
County of Hawaii Planning
Department
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Lyman:

Subject: Draft Supplemental Environmental Impact Statement (DSEIS) - Amendment to the Mauna Kea Science Reserve Complex Development Plan for a VLBA Antenna Facility at Mauna Kea, Hamakua, Hawaii

Thank you for reviewing and commenting on the subject DSEIS. In response to your concerns about the removal of transmitters from the summit of Mauna Kea:

A meeting was held with the Deputy Director and staff of DLNR on June 2, 1988, to discuss their concerns about removal of transmitters from the Mauna Kea Science Reserve. At the conclusion of this meeting, it was our understanding that DLNR will support IFA's position on this matter. We, therefore, responded to their comments of April 25, 1988, as follows:

"Although the University recognizes that Mauna Kea is a premier site for telecommunications as well as astronomy, the two activities are not compatible. The University leased 13,000 acres from BLNR (S-4191) for the Mauna Kea Science Reserve so that there would be a buffer zone adequate to prevent intrusion of activities inimical to observatory operations at the summit. Activities defined in the lease as being 'inimical to the scientific complex' include light and dust interference to observatory operation and certain types of electric or electronic installations.

"The Institute for Astronomy (IFA) has received many proposals to install new or upgrade old transmitters at the summit; some of these requests have come from astronomy users themselves. It is the policy of IFA to reject all such proposals because they are inimical to the scientific complex within the Science Reserve.

"In the context of our mission to preserve the qualities of the Science Reserve, so that Mauna Kea remains the premier site for ground-based astronomy in this hemisphere, we have asked your Department to find an alternative location for the Forestry and Wildlife repeater on the summit. IFA promises to do everything possible to assist you in this endeavor so that an amicable solution to this potential problem can be found. We assure you that no new transmitters of any kind will be allowed in the Science Reserve."

As stated in the SEIS, UH IFA only intends to remove transmitters from the Mauna Kea Science Reserve; no others will be affected. A briefing on this matter and other Radio Frequency Interference concerns, at which County of Hawaii personnel (including two members of your staff) were present, was held in the County Council Chambers on June 3, 1988. At this meeting, as Director of IFA, I stated the intention of the University to eventually remove all transmitters from Mauna Kea Science Reserve. In addition, NRAO personnel assured members of the Police Department and others present that there should be no problem with their lower elevation based radio communication facilities.

The Management Plan aspects of the original SRCDP have not been completely implemented as yet. This will take place after the road has been completely paved. At that time, the Management Committee may be formed.

Sincerely yours,

/L. Lewis for D.N.B. Hall

Donald N. B. Hall
Director

DNBH:jec

cc: MCM Planning
National Radio Astronomical Observatory
Office of Environmental Quality Control

DEPARTMENT OF WATER SUPPLY • COUNTY OF HAWAII
25 AUPUNI STREET • HILO, HAWAII 96720

RECEIVED
JUL 6 1988
DIRECTOR

June 30, 1988

Marvin T. Miura, Ph.D.
465 South King Street, Room 104
Honolulu, HI 96813

DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT
AMENDMENT TO THE MAUNA KEA SCIENCE RESERVE COMPLEX DEVELOPMENT PLAN FOR A VLBA ANTENNA FACILITY, MAUNA KEA, HAMAKUA, ISLAND OF HAWAII-STATE OF HAWAII

Thank you for the opportunity to review the subject report.

Our comments are the same as those indicated in our letter of April 27, 1988 to Dr. Donald N. B. Hall, Director, Institute for Astronomy, University of Hawaii.

H. William Sewake
Manager

KO

cc - University of Hawaii - Institute for Astronomy
Mr. Guy Paul, Chief of Police

... Water brings progress ...

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Office of the Director

August 30, 1988

Mr. H. William Sewake, Manager
Department of Water Supply
County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Sewake:

Subject: Draft Supplemental Environmental Impact Statement (DSEIS) - Amendment to the Mauna Kea Science Reserve Complex Development Plan for a VLBA Antenna Facility at Mauna Kea, Hamakua, Hawaii

Thank you for commenting on the subject DSEIS. A new radio astronomical observing site and antenna must operate within the radio spectral environment existing at the time of construction. The radio enviroment includes all radio communication and broadcast emissions authorized by Federal Communications Commission (FCC) Regulations and by National Telecommunications and Information Adminstration (NTIA) Regulations. RFI from transmitters that comply with FCC and NTIA regulations (such as yours) are not expected to be a problem at the site.

NRAO has analyzed existing and proposed radio systems that might affect the VLBA. The facility site was selected because surrounding terrain will shield the antenna from harmful RFI sources. In addition, as shown in Figure IV-2 (Long Range Visual Impact), Page IV-16 of the DSEIS, because the antenna will not be visible from Hilo, it will also not be in direct line-of-sight of transmitters located there.

Sincerely yours,

Donald N. B. Hall
Director

DNBH:jec
cc: MCM Planning
National Radio Astronomy Observatory
Office of Environmental Quality Control

END

CERTIFICATION

I HEREBY CERTIFY THAT THE MICROPHOTOGRAPH APPEARING IN THIS REEL OF FILM ARE TRUE COPIES OF THE ORIGINAL DOCUMENTS.

2005

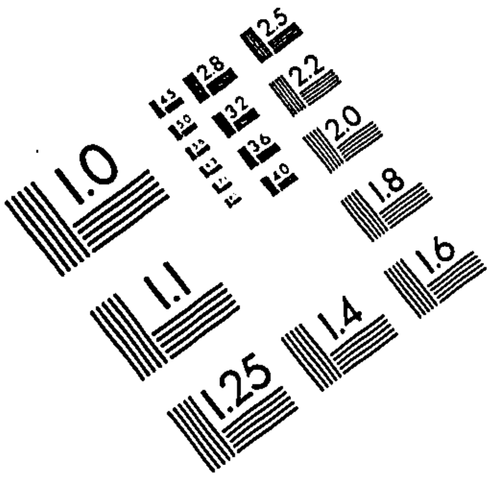
DATE

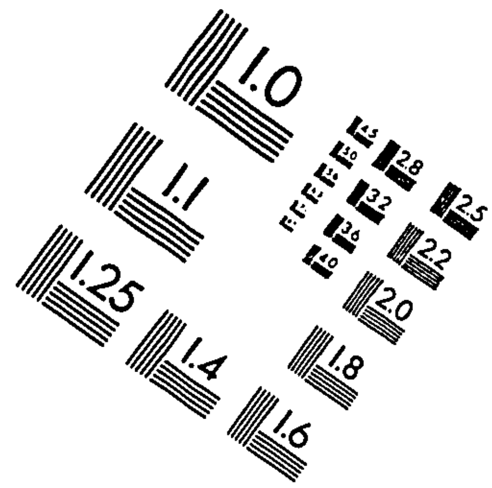
Lorraine Collops-Burke

SIGNATURE OF OPERATOR

TOP

Film Identification





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577 Locust Street • Prescott, WI 54021
Web Site http://www.zimc.com/apintl

PRECISION[SM] RESOLUTION TARGETS

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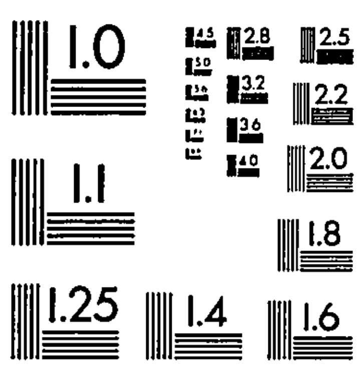

RIGHT

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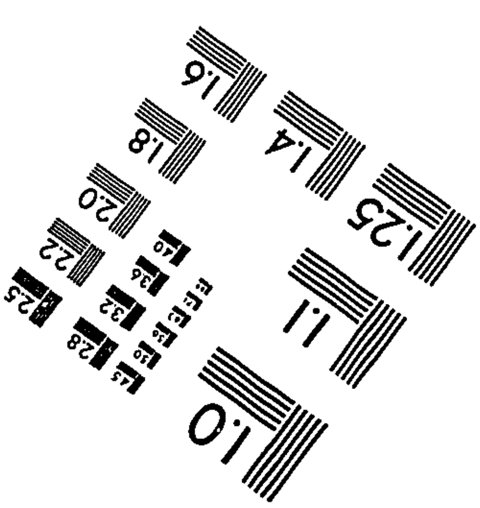

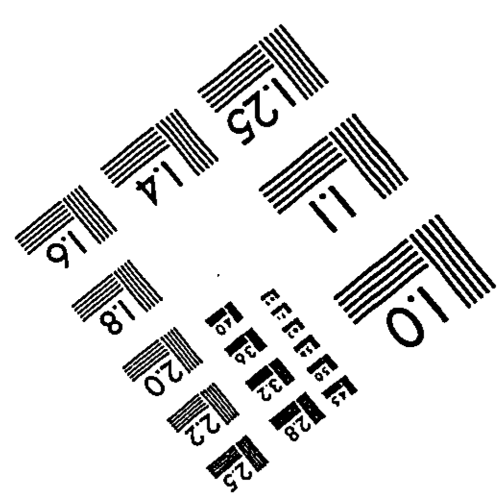

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