SECTION 3

SETTING, IMPACTS, AND MITIGATION MEASURES

3.1 BIOTIC RESOURCES

Setting

Vegetation

Severe climatic conditions at the altitude of the project site limit the types of vegetation that can survive. Lichens and bryophytes are the principal components of the flora at the summit of Mauna Kea. A lichen is a dual organism formed by the close association of a fungus and an alga. Bryophytes are the group of nonvascular plants which includes mosses and liverworts. The two substrata present in the project area include cinder cones and essentially unweathered andesite lava flows. Cinder areas are an unstable substratum for most plants because of cinder instability and high porosity. Lava flows consist of dense rock with numerous pits.

In 1982, a botanical survey was conducted by the Bishop Museum as part of the Mauna Kea Science Reserve Complex Development Plan. Plant species identified as part of this survey included one alga, mosses, lichens, and vascular plants, as shown in Table 3.1-1. No officially designated endangered or threatened plant species were found in the surveyed project area which extended from approximately 13,000 feet above msl to the summit of Mauna Kea.

Of the 25 different lichen species found at the summit, approximately one-half are endemic (native to, and occurring only in the Hawaiian islands). Two lichens, *Pseudephebe pubescens* and *Umbilicaria pacifica*, are confined to Mauna Kea. Special interest areas of high lichen concentration identified in this survey are shown in Figure 3.1-1. Less than a quarter of the 12 species of mosses are endemic. Mosses are dispersed across the summit area. Of the six species of vascular plants identified in the survey, three are endemic to Hawaii: two grasses *(Agrostis sandwichensis* and *Trisetum glomeratum)* and a fern *(Cystopteris douglasii)*.

The project site itself is devoid of any kind of vegetation.

Fauna

Invertebrate Fauna. A survey of the arthropod fauna and aeolian ecosystem near the summit of Mauna Kea was conducted by F.G. Howarth and F.D. Stone in 1982. The aeolian zone lies above the limits of alpine habitats, and wind plays a major part in the

TABLE 3.1-1

VEGETATION OF THE MAUNA KEA SUMMIT

ALGA

Haematococcus sp.

LICHENS

Acarospora depressa
Acarospora pyrenuloides
Acarospora sp.
Bacidia sp.
Caloplaca lithopilia
Candelariella isidiata
Candelariella vitellina
Lecanora melaena
Lecanora muralis
Lecidea skottsbergii
Lecidea vulcanica
Lepraria spp.
Physcia dubia
Placopsis sp.?
Pseudephebe pubescens
Rhizocarpon geographicum var. *hawaiiensis*
Rinodina cf. *cacuminum*
Rinodina interrupta?

Umbilicaria hawaiiensis
Umbilicaria magnussonii
Umbilicaria pacifica

MOSSES

Andreaea acutifolia
Amphidium tortuosum
Bryum caespiticum
Grimmia spp.
Grimmia apocarpa var. *pulvinata*
Grimmia cf. *pilifera*
Pohlia cruda
Pohlia cf. *mauiensis*
Tortella humilis
Zygodon tetragonostomus

VASCULAR PLANTS

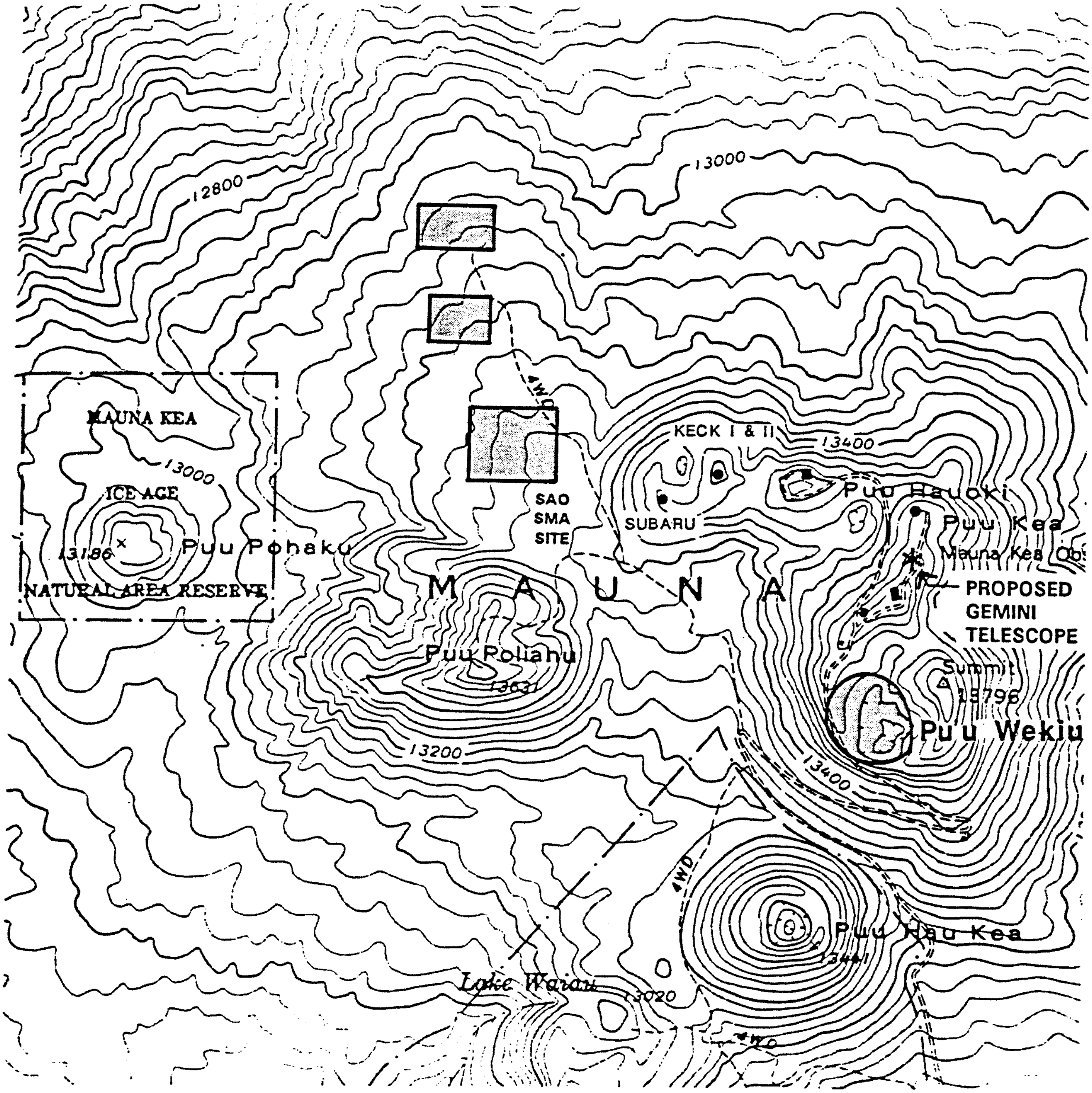
Pteridophyta (ferns)
Asplenium adiantum-nigrum
Cytopteris douglasii

Poaceae (grass family)
Agrostis sandwichensis
Trisetum glomeratum

Asteraceae (daisy family)
Hypochoeris radicata
Taraxacum officinale

Source: Smith et al. 1982

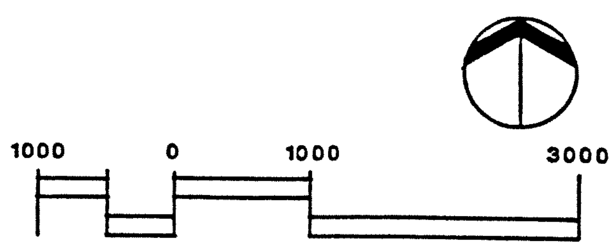
aeolian ecosystem. The major component of the fauna of the aeolian ecosystem on the summit is composed of arthropods such as spiders, moths, mites, springtails, centipedes, booklice, barklice, and true bugs. No officially designated endangered species of arthropod fauna were identified at the summit. Of the listed species, at least 11 are native to Hawaii. One notable species discovered at the summit is the Wekiu bug, a flightless species of the world-wide genus *Nysius*. This bug is commonly found under large boulders and among cinders at the summit. It preys on dying insects that have been carried upslope and deposited in crevasses in the lava. The bug was named after the summit cinder cone Puu Wekiu. Aeolian arthropods such as the Wekiu bug require undisturbed areas with large boulders which provide cover and trap windblown debris which serves as food.



Source: Smith et al., 1982.

LEGEND

Intensively studied areas



SPECIAL INTEREST AREAS OF HIGH LICHEN CONCENTRATION

FIGURE 3.1-1

Avifauna. An endangered bird species, the Hawaiian Dark-rumped Petrel or 'Ua'u (*Pteridroma phaeopygia sandwichensis*), is known to exist on the upper slopes of Mauna Kea. When a survey was conducted in 1988 for this species, no petrel were found. The Gemini site at the summit is well outside the designated critical habitat for the palila (*Loxiodes bailleui*), an endemic endangered species. Critical habitat area is shown in Figure 3.1-2.

Impacts

During removal of the existing 24-inch telescope and construction of the Gemini Northern 8-Meter Telescope, little biotic habitat disturbance is expected to occur. Construction activities could disturb boulders which provide habitat for aeolian invertebrates. However, this area has already been impacted from the construction and operation of the 24-inch telescope and other adjacent facilities. Concentrations of lichen would not be impacted by the proposed project, as shown in Figure 3.1-1. Relocation of the proposed access road could result in impacts to biotic habitat if substrate for invertebrates in adjacent undisturbed areas is disrupted during construction.

Mitigation Measures

The following mitigation measures should be implemented to reduce potential impacts to biotic resources:

- During construction, undisturbed areas should be protected by the establishment of specific areas for construction equipment and supplies. These areas should be limited to locations that have been previously disturbed.
- During relocation of the access road, care should be taken to protect existing habitat for invertebrates by preventing cinders from being pushed over the side of the road.

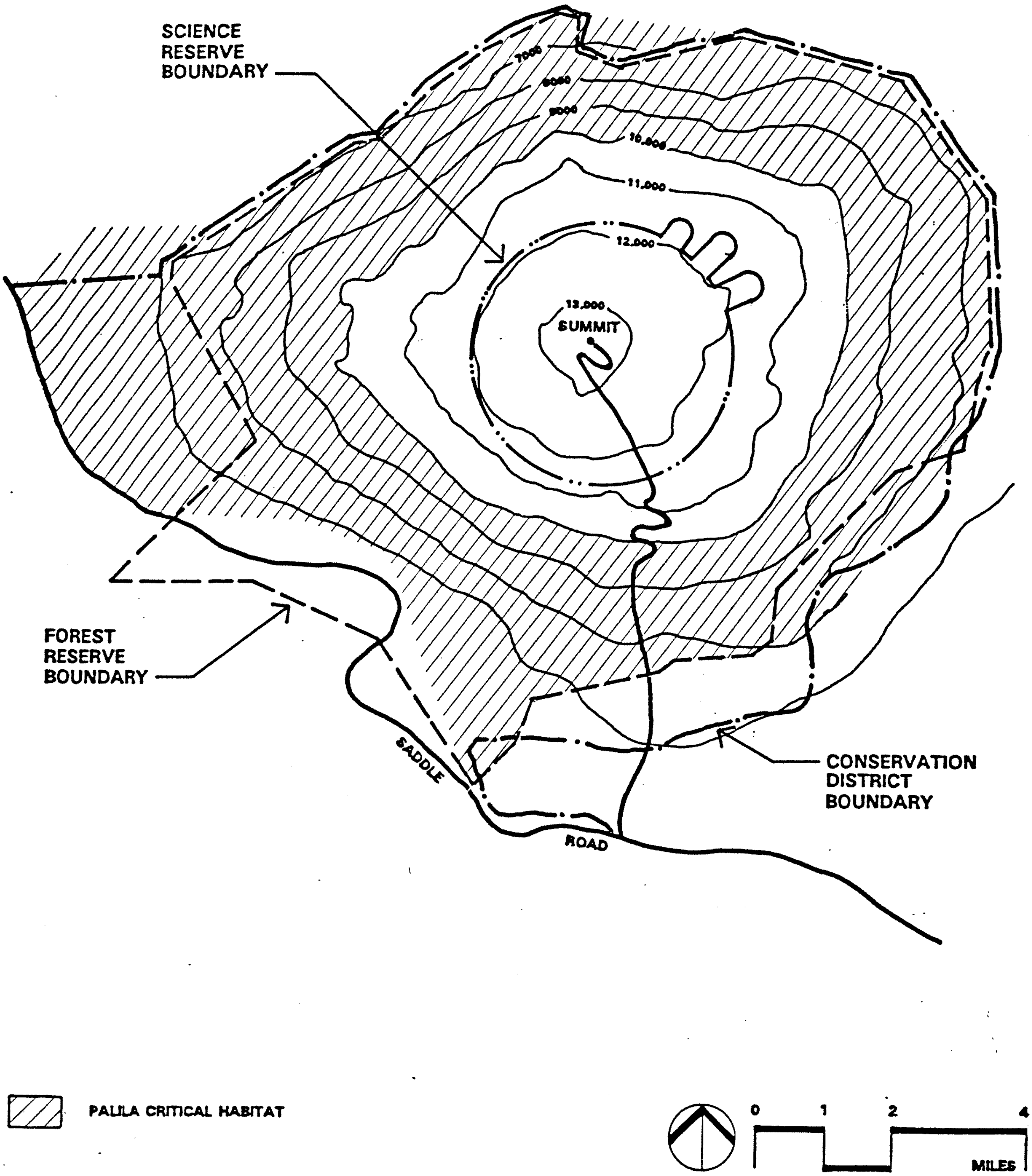
3.2 AIR QUALITY/CHEMICAL EMISSIONS

Setting

The potential for local air pollution is influenced by the location and size of air pollutant sources, and the dispersion of pollutants in the atmosphere. Dispersion of air pollutants is affected by atmospheric conditions such as wind speed, wind direction, and temperature inversions, as well as by topological features of the landscape.

The site of the Gemini Northern 8-Meter Telescope on the Mauna Kea summit ridge, at an elevation greater than 13,000 feet above msl, is well above the 7,000-foot altitude of temperature inversions for the area. Consequently, pollutants generated at the site would be free to mix vertically in the atmosphere, which aids their dispersion.

Winds at the project site also aid dispersion of air pollutants. Wind speed generally ranges from 10 to 30 miles per hour (mph), with typical speeds between 10 and 15 mph. High winds, with speeds occasionally exceeding 100 mph, can also arise during severe winter storms (RCUH 1983b). The steady winds and lack of surrounding features at the proposed site promote dispersion of air pollutants, although high winds can contribute to



PALILA CRITICAL HABITAT

FIGURE 3.1-2

increased concentrations of dust from wind erosion of exposed areas. Winds also contribute to unstable atmospheric conditions which foster turbulent mixing and dilution of air pollutants.

Precipitation can clear the atmosphere of air pollutants. At the summit, precipitation averages approximately 15 inches per year, mostly in the form of freezing fog or snow, and mostly during the cooler half of the year from October to April. Winter storms generally occur from December through March. Records of rainfall show that Hale Pohaku averages about 25 inches annually, with the wettest months being November through March. During most of the year, the mean temperature at the summit is a few degrees above freezing. The extremes in monthly average temperature range from 11 degrees centigrade maximum to -4 degrees centigrade minimum (RCUH 1983b).

Air quality has not been monitored at the Mauna Kea Science Reserve. However, Mauna Kea has the reputation of being among the finest astronomical sites in the world, which implies exceptional existing air quality.

Impacts

Air quality impacts of the project would primarily be those associated with project construction, which is of limited duration. Pollutants of concern during construction are fine dust particles, specifically respirable particles, which are those having an aerodynamic diameter less than 10 microns (PM_{10}). Regulated air pollutants emitted by heavy duty construction equipment are also potentially of concern during construction.

Construction Impacts

Construction equipment needed for Phases I and II would consist of bulldozers, backhoes, soil compactors, graders, rollers, drilling machines, water trucks, loaders, dump trucks, hoisting equipment, air compressors, welding machines, fork lifts, concrete trucks, and flatbed trucks. Excavating, grading, materials handling, and other construction operations would generate dust. Based on measurements of dust emissions at construction sites, total suspended particulate (TSP) emissions are about 1.2 tons per acre of worked area, per month of construction activity (EPA 1985). Although tephra at the project site may generate more dust than is generated by the project upon which this emission factor is based, it is nonetheless a reasonable estimate of the magnitude of dust emissions. Assuming 21 working days per month, about 114 pounds per day per acre (lbs/day-acre) of TSP emissions would be generated from construction activity. Consequently, for the approximately two acres of the project site, daily emissions of TSP would be about 228 lbs/day, for a total of about 48 tons emitted over the 20-month construction period. Emissions of PM_{10} are a fraction of TSP emissions, varying from about 30 percent at the source of emissions to as much as 80 percent well downwind where larger dust particles have been depleted. Dust would also be generated at the two-acre batch plant and staging area, especially from storage piles under windy conditions if they are not controlled. In addition to dust generated in earth-disturbing construction operations, fugitive dust emissions would occur from wind erosion of exposed soils.

Combustion emissions from the diesel emission of heavy construction equipment are estimated on the basis of a survey of construction projects in which it was found that approximately 0.27 gallons (gal) of diesel fuel were burned per cubic yard (yd^3) of earth excavated (BAAQMD 1985). Based on 11,500 yd^3 of material excavated, the total emissions from heavy duty construction equipment over the 20-month period are shown in Table 3.2-2.

TABLE 3.2-2

EMISSIONS FROM CONSTRUCTION EQUIPMENT

Pollutant	Emission Rate (1) (grams/cubic yard)	Emissions from Project(2) (pounds)
Carbon Monoxide	11.2	283
Total Hydrocarbons	6.1	154
Nitrogen Oxides	42.9	1,085
Sulfur Oxides	4.9	124
Total Particulates	2.6	66

(1) Source: BAAQMD, 1985

(2) Assumes 11,500 cubic yards of excavated material over a 20-month construction period.

In addition, there would be motor vehicle emissions from concrete trucks, trucks transporting precast structural elements to the site, and trucks transporting excavated material, fill, and construction materials to and from the site.

About 3,000 cubic yards of material would be temporarily stockpiled at the concrete batching plant site for construction of the relocated roadbed and backfill for concrete foundation walls. About 8,500 cubic yards of material would ultimately be taken off site. Although precast concrete would be widely used in the construction, about 2,500 cubic yards of cast-in-place concrete would be needed. This concrete casting would require about 313 truck loads of concrete mix from the batching plant, which is located at the site previously used and approved for staging construction operations for the Japanese National Large Telescope (Subaru) and Keck II Telescope.

Emissions would also be generated from automobiles used by construction personnel. Motor vehicle traffic would generate dust from travel over unpaved sections of the access road. The amount of truck traffic would depend on the construction schedule and the number of trucks available. Emissions would be generated over the length of the access roads as well as at the project site, and are expected to be dispersed by the prevailing winds and other favorable atmospheric conditions and topographic features of the area.

Due to atmospheric conditions at the summit, all emissions except particulate emissions are expected to be dispersed and to not result in significant air quality impacts. Dust emissions have the greatest potential for an adverse air quality impact, but they can be mitigated to a level of insignificance.

Operational Emissions

The rotating portion of the telescope enclosure exterior would be finished with a diffuse metallic coating resembling oxidized aluminum. The exterior surface of the enclosure stationary base, the support facility roof, and exposed support facility walls would be finished with a white titanium dioxide paint. The purpose of these coatings is primarily for temperature control, which is essential to telescope operation. The coating on rotating portions is expected to be quite durable. The titanium dioxide coating can flake over time, but is expected to pose no problem to personnel at the site from paint pigments used in the coating because the amounts of substances that would be emitted are minute (Owen 1993).

Normal operations require the mirror surface coating to be stripped and recoated every 6 to 24 months, depending on the reflective coating material used and the cleaning method chosen. Coating would be done using a vacuum-plating technique to coat the mirror surface with a thin layer of highly-reflective metallic surface, such as aluminum. The mirror would be enclosed for this process, and tightly sealed to preserve the necessary vacuum. Some emissions would be generated from pumps, such as oil emissions from diffusion pumps needed to create and maintain the vacuum. The emissions from these plating operations, especially considering their frequency, would be insignificant (Cudaback 1993).

Stripping and cleaning operations would involve the use of solvents to clean the mirror surface and strip residual coating from its surface. The operation would involve the use of a few gallons of solvent every time stripping was to be performed, which would be from 6 to 24 months as noted above (Cudaback 1993). With adequate ventilation, this occasional use of solvents is not expected to pose any significant air quality impact to the area or to telescope personnel.

Staffing of the telescope facility would require a crew of up to six people during daytime hours to perform necessary maintenance. When the primary mirror is being recoated, up to ten people would be needed. Normal nighttime operations would require at least two astronomers or operators, depending on the nature of observations to be made. In addition, it is estimated that about 31 people would be located in the city of Hilo to support the Gemini operation. Motor vehicle use by project personnel would generate emissions. Other vehicle emissions would be associated with truck traffic. Trucks would be necessary to provide water to the project site and to remove septic tank wastewater from the facility. Due to air dispersion characteristics at the project site, motor vehicle emissions associated with project personnel and daily operations would not be significant.

Mitigation Measures

Construction

Mitigation measures to minimize combustion emissions include proper maintenance of construction equipment, and electrification of equipment when possible. Since dust emissions are a source of particulate air pollutants, feasible dust control mitigation measures are also included. The mitigation measures are as follows:

- Construction equipment should be maintained and tuned at the interval recommended by the manufacturers to minimize exhaust emissions.
- Equipment idling should be kept to a minimum when equipment is not in use. No piece of equipment should idle in one place for more than 30 minutes.

Normally, dust emissions are controlled by the application of water, or a chemical fixative mixed with water. However, water is in short supply at the summit, and must be trucked to the construction site from Hilo. As an alternative to frequent watering, which is judged to be infeasible, the following mitigation measures are suggested:

- Dust control during construction should be maintained by exposing the smallest area possible at any time, and by halting construction during high winds and storms. To a degree, water could be sprinkled on exposed surfaces to suppress dust; however, as water must be hauled from Hilo, it should be used sparingly.
- The contractor should comply with all State Department of Health rules and regulations as they pertain to dust emission and other emissions during construction.

Operations

No significant operation-related air quality impacts were identified. Consequently no mitigation measures are needed. However, it is recommended that adequate ventilation be maintained during the use of solvents for stripping and cleaning operations.

3.3 GEOLOGY/VOLCANOLOGY/SEISMOLOGY

Setting

The Gemini Northern 8-Meter Telescope site is located 800 feet northwest of the summit of Mauna Kea; elevations at the site are 40 feet below the summit at 13,760 feet above mean sea level. Soil at the site is classified as tephra, with gray cinders (including volcanic bombs) and coarse ash. Cobbles and boulders are common and are semirounded, porous and low density.

According to Porter (1973):

> *The tephra succession on Mauna Kea includes many distinct layers that were erupted over a considerable span of time from a large number of vents .... Exposed deposits are thickest and most widely distributed along the road to the Summit between the Humu'ula Sheep Station and Hale Pohaku, through a broad belt east and west of Hale Pohaku, and in a large Kipuka downslope from Puu Oo .... Puu Hawaihine is one of the most massive cinder cones on the south flank of Mauna Kea and produced a thick and extensive blanket of tephra that is distributed mainly east of the cone (towards Hale Pohaku). It underlies much of the ground surface between Puu Hawahine and the Hale Pohaku flow and is exposed in most roadcuts and natural outcrops within a 2-KM radius of Hale Pohaku.*

Below Hale Pohaku, between the mid-level facility and the Saddle Road, the lava flows are locally overlain by tephra. There are also postglacial stream sediments, largely gravelly sand or sandy gravel with a variable composition that reflects local bedrock.

Earthquakes

The Molokai fracture zone, major zone of structural weakness in the earth's crust, traverses the Hawaiian Islands. Occasional strong earthquakes are generated by the Molokai fracture zone. Some of these earthquakes were centered close enough to the islands to cause damage. This structural zone holds the potential for generating major, though infrequent, earthquakes in the future. The greatest number of earthquakes on the island of Hawaii originate beneath the summit areas and along or near the rift zones of Kilauea and Mauna Loa (Figure 3.3-1).

The two largest earthquakes in Hawaiian history, in 1868 and 1975, had magnitudes greater than 7 on the Richter Scale and probably were caused indirectly by movement of magma into rift zones of Mauna Loa and Kilauea, respectively.

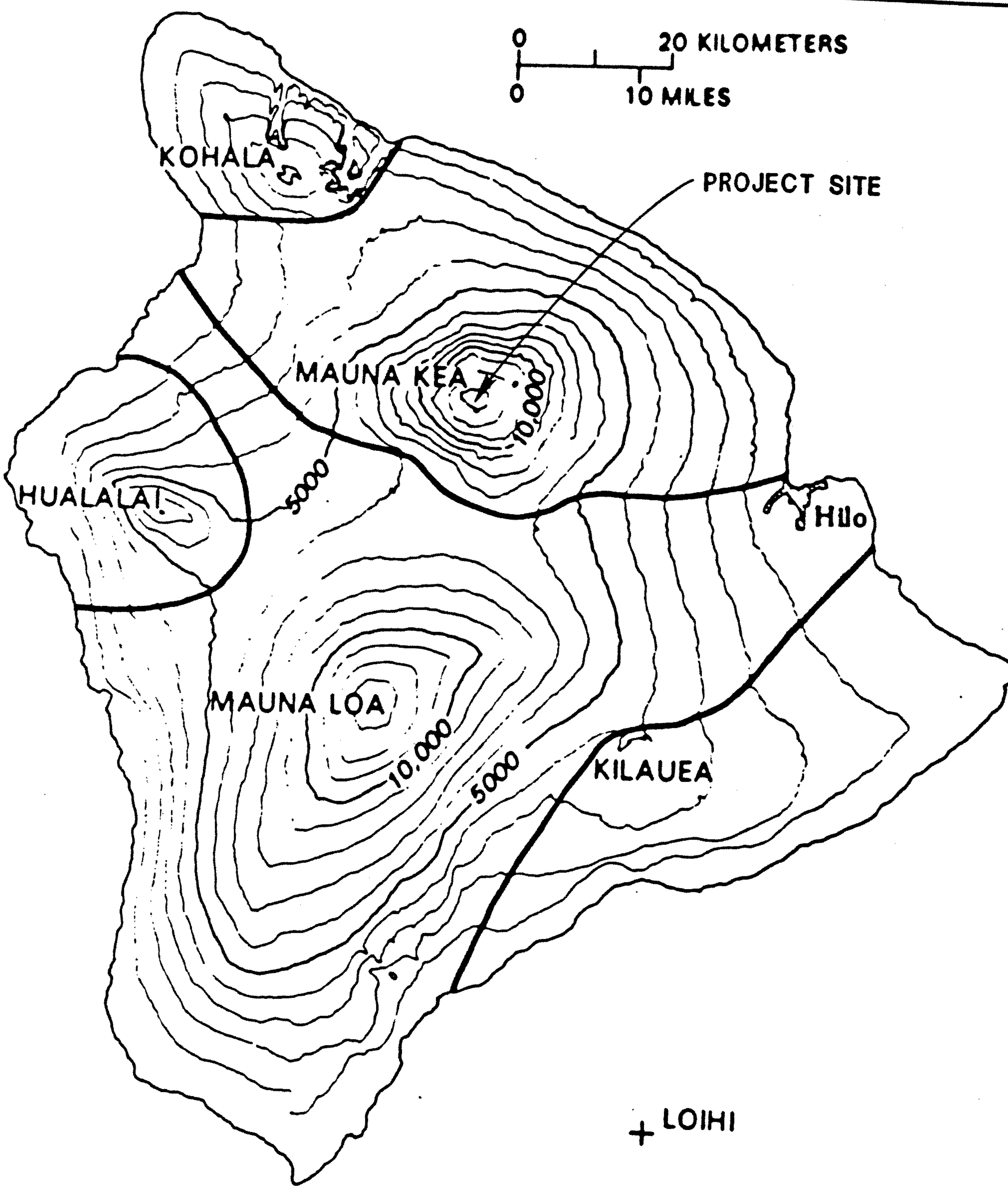
Several earthquakes of magnitude 7 have been reported historically. The Great Ka'u Earthquake (1868), magnitude 7.9, (Wyss 1992), was centered in the southern Ka'u district "where every stone building collapsed, and wood frame houses were thrown off their foundations" (Wyss 1988 and Wood 1914). Ground accelerations exceeded gravity in the epicentral region (boulders "thrown over undisturbed turf"). One major foreshock and one major aftershock occurred and were approximately magnitude 6.7. Major coastal subsidence (as much as 7 feet) occurred along most of the southern coast from Kapoho to Punaluu. This region was inundated by the resultant tsunami with run-up as high as 20 feet at Punaluu and in excess of 45 feet at Keauhou landing (Cox and Morgan 1977). The tsunami destroyed all of the coastal villages on the south flank of Hawaii, and killed 46 people. A large mudflow, triggered in the Wood Valley area near Pahala, killed 31 people (Tilling et al. 1976). Substantial ground cracking on the south and southwest flanks of Kilauea occurred.

The Kalapana Earthquake, magnitude 7.2, occurred on November 29, 1975. This earthquake was centered on the coast, south of the central East Rift Zone of Kilauea volcano on the island of Hawaii (Rojahn and Morrill 1977). Major ground displacement with coastal subsidence as great as 11.5 feet was observed on the south flank of Kilauea. Severe ground cracking and movement on faults of the Hilina and Koae fault systems occurred.

Impacts

Volcanic Hazards

Mauna Kea has been inactive during human occupation of Hawaii, but it probably will erupt again. Based on the infrequency of its eruptions in the recent past, the probability of Mauna Kea erupting in the next several decades is very low. Future eruptions of Mauna Kea would probably be accompanied by mild to moderate explosive activity, producing ash and cinder cones similar to those on its summit area and upper flanks, and ash deposits adjacent to the cones. If lava flows were erupted, they probably would be relatively



REFERENCE: U.S. Geological Survey Professional Paper 1350 "Volcanism in Hawaii", United States Government Printing Office, Washington : 1987; Figure 22.2 - Location and topography of the five volcanoes that form the Island of Hawaii. Contour interval 1,000 feet. Heavy solid lines mark boundaries of the five volcanoes. (Modified from Mullineaux, et.al., 1987.)

HLA **Harding Lawson Associates** Engineering and Environmental Services		**Location and Topography of the Five Volcanoes That Form the Island of Hawaii** Gemini Telescope Mauna Kea, Hawaii			FIGURE **3.3-1**
DRAWN kar/jcl	JOB NUMBER 26349.1	APPROVED	FILE 26349005 1.0 19931104.0933	DATE 10/93	REVISED DATE

viscous and would not travel more than a few miles from their sources. All of the most recent eruptions have occurred above elevations of 6,000 feet above msl, and future activity on Mauna Kea would most likely also originate at these higher elevations.

Relative volcanic hazards on Hawaii have been mapped by Mullineaux et. al. (1987). Although the last eruption on Mauna Kea occurred approximately 3,600 years ago (Porter 1979b), future eruptions are possible. The summit and upper flanks of Mauna Kea are mapped 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 volcanic eruption is judged to be very low. The project area is located in an area of moderate to low risk of impact from tephra (ash) falls, volcanic gases and earthquakes (Table 3-3.1).

Earthquake Hazards

Seismic risk is dependent on the recurrence interval between large earthquakes. Wyss and Koyanagi (1992) state that the historical record of earthquakes larger than magnitude 6.5 may be complete since 1833 in southern Hawaii, and that one has occurred about every 15 to 17 years on the average. They also state that the historic record is too short to define recurrence times for large earthquakes; i.e., recurrence times for the "same" earthquake in terms of size and location. The Uniform Building Code (UBC 1988) locates Mauna Kea in Seismic Hazard Zone 3. Zone 3 represents a moderate to high risk of seismic activity.

TABLE 3-3.1

RELATIVE VOLCANIC HAZARDS AT THE PROJECT SITE

Hazard Type	Zone	Potential Impacts
Lava flow	7	Eruptions have not occurred since about 3,500 years ago; low risk
Tephra Fall (ash fall)	3A	Low degree of hazard due to its distance from active vent areas and infrequency of southerly winds
Pyroclastic Surge	-	Does not affect the project site
Volcanic Gases	3A	Low degree of hazard due to its distance from active vent areas and infrequency of southerly winds
Ground Fracture	4	The project is in an area of least risk of ground fracture
Ground Subsidence	4	The project is in an area of least risk of ground fracture

Source: Mullineauz et.al., 1987

Mitigation Measures

Adherence to seismic standards for construction identified in the Uniform Building Code for Seismic Zone 3 should adequately mitigate potential seismic hazards.

3.4 GROUNDWATER RESOURCES

Setting

In Hawaii, groundwater occurs in either of two modes. The most important is fresh basal groundwater; fresh water floating on and displacing underground sea water. Less important is high-level groundwater; water either impounded within compartments formed by relatively impermeable dikes, or perched on low-permeability layers such as ash beds, buried soil horizons, and dense cores of lava flows. Examples of the various types of groundwater are shown in Figure 3.4-1.

On Mauna Kea, the basal groundwater would be 13,000 to 14,000 feet below ground surface, if present; however, perched and/or dike-confined water may be at much shallower depths. A shallow lake (Lake Waiau) is located 5,000 feet southwest of the project site, at the 13,020 foot elevation. The lake may have been formed either by water ponding above a deep layer of permafrost (a remnant of the Pleistocene era), or water perched above a hydroclastic tuff, which occurs near the base of the lake (RCUH 1983b). None of the geotechnical borings for existing telescopes encountered groundwater.

Impacts

Impermeable layers beneath the Gemini site, if present, probably slope toward the north flank of Mauna Kea, away from Lake Waiau (Dames & Moore 1982). Septic leachate generated at the site is not likely to reach the lake, which is located approximately one mile away. Natural biological oxidation would oxidize organic elements to undetectable levels rapidly after discharge in the permeable soil at the summit. Groundwater would not be negatively impacted by normal operations.

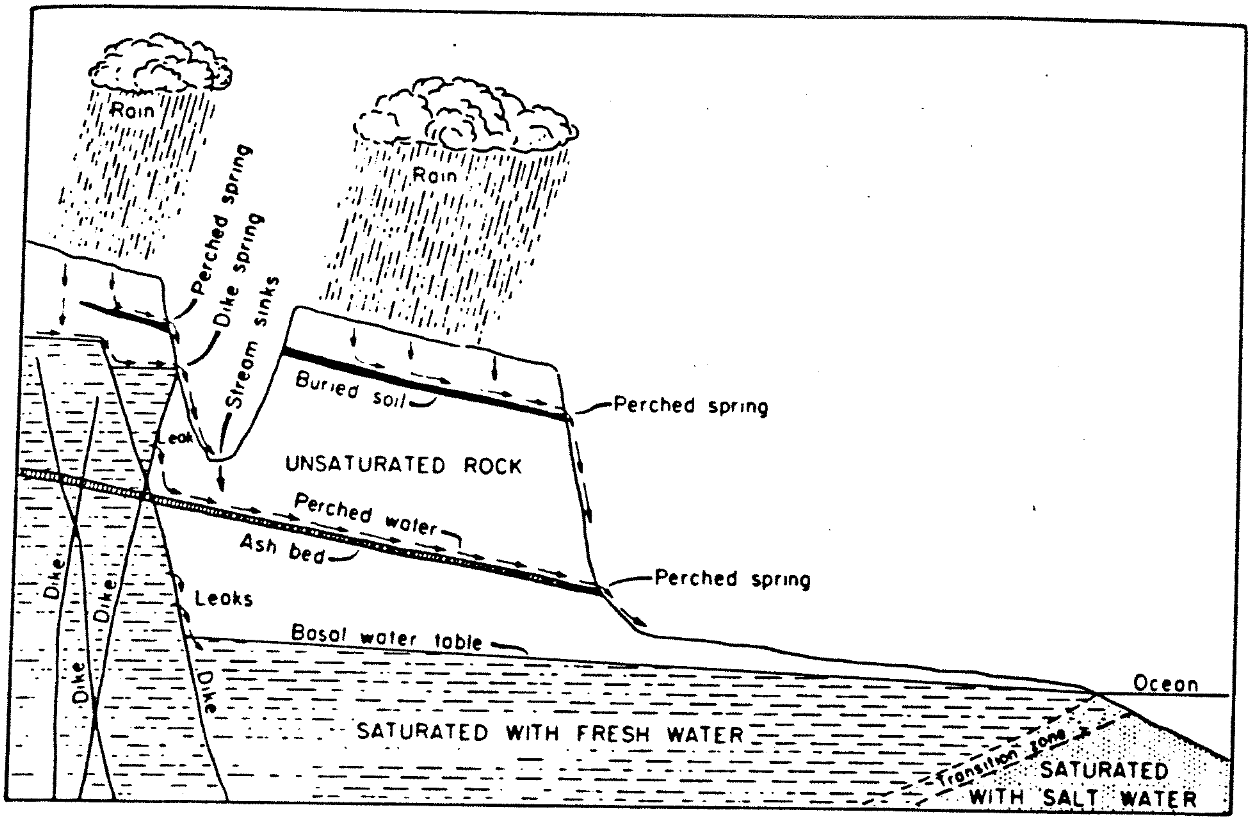
Mitigation Measures

To mitigate potential impacts of sewage disposal, an adequate treatment and disposal system should be designed. Fuel tanks, lubricants, and other chemicals should be placed above ground. They should be stored on cement slabs on site where they can be easily monitored.

3.5 SURFACE DRAINAGE/EROSION

Setting

Soils in the area have been studied in connection with the Gemini Northern 8-Meter Telescope and most other installations at the summit of Mauna Kea (HLA 1975, 1982, and 1990). Soils at existing telescope sites on Mauna Kea consist of loosely compacted volcanic cinders to the depths explored. During winter months, the upper layers of soil



REFERENCE: Macdonald, Gordon A.; Abbott, Agatin T.; and Peterson, Frank L.; "Volcanoes in the Sea", 1983, University of Hawaii Press, page 239, Figure 11.8. Diagram showing perched water, water confined between dikes, basal water, and perched springs (Modified after Stearns and Macdonald, 1946).

Harding Lawson Associates
Engineering and Environmental Services

Types of Groundwater Found in Hawaii
Gemini Telescope
Mauna Kea, Hawaii

FIGURE **3.4-1**

DRAWN	JOB NUMBER	APPROVED	FILE	DATE	REVISED DATE
kar/jcl	26349.1		26349001 1.0 19931104.0944	11/93	

may solidify due to ice formation. Runoff from uncompacted natural surfaces is rare; most can be attributed to snow melt while the ground surface is frozen. The erosion potential in undisturbed areas is slight; however, recently cut slopes and areas near impervious surfaces, such as parking lots, may experience some erosion from wind or water runoff.

Impacts

Construction at the project site is expected to require up to five years for completion. During this time, construction activities would have an impact on surface-water runoff and erosion. Relocation of the existing access road would be the first activity to be undertaken. Runoff from the site would be collected on the east side of the site in a drainage swale which parallels the relocated access road to an existing culvert on the north side of the site. The culvert connects to an existing stormwater drainage system which releases water downslope where it percolates into the soil. Construction activities would remove approximately 8,500 cubic yards of soil from the site. Excavation, temporary slopes, and artificial barriers to runoff are expected to increase erosion potential during the construction phase of the project.

Mitigation Measures

Stormwater runoff created by impervious surfaces would be directed to the existing drainage system which serves the UH 88-inch facility. Sufficient capacity exists in this drainage system without needing additional improvements.

To minimize potential erosion impacts, the following mitigation measures should be implemented:

- Major earthwork should not be scheduled during periods of high wind;
- Steep slopes, which would quickly erode during high winds or rain, should be minimized; and/or
- Temporary facilities should be installed to disperse runoff or shelter critical areas from wind. During the construction period, rapid surface water runoff and associated soil erosion may be prevented by installing drainage structures in conjunction with all impervious surfaces.
- Upon completion, final grades should be designed to have gentle slopes which are resistant to erosion.

3.6 CONSTRUCTION PHASES

Setting

Refer to the "Impacts" discussion regarding construction.

Impacts

Construction and installation of the Gemini Northern 8-Meter Telescope facilities would be performed in five phases over a period of approximately five years, as shown in

Table 2.2-1. Potable water would be carried in bottles by construction workers or obtained from other telescope facilities. On-site, portable toilets would be used.

Solid waste would be collected by Gemini telescope personnel and deposited at an appropriate site. Most impacts are limited to the duration of the construction period and are unavoidable during construction projects.

Two adjacent facilities, the Canada-France-Hawaii Telescope and the UH 88-inch telescope, would be affected by construction activities on the Pu'u Wekiu Ridge more than those located on nearby cinder cones. Impacts on all telescope facilities resulting from construction activities include:

- Temporary workers and increased traffic would impact transportation at the site.
- Heavy equipment operations would generate noise, exhaust emissions, fugitive dust, and vibrations during construction periods.
- Relocation of roads and electrical utilities would create power and access disturbances.
- Installation of the telescope's enclosure and support facility would alter the existing land form by leveling existing slopes and adding buildings. Approximately 8,500 cubic yards of soil would be removed from the site.
- Increased erosion from wind and runoff may occur during the construction phase.
- Generation of suspended particulates from machinery exhausts and fugitive dust may temporarily reduce the visual quality of the air for telescopes on the summit.

The project site is considered the most desirable location on Mauna Kea due to the air quality. The site has been previously disturbed by the construction of three large and two small telescopes. Construction-related impacts of the proposed project are less than would be expected in most other locations near the summit, due to the existing infrastructure which serves the existing telescopes.

Mitigation Measures

Mitigation of impacts associated with construction of the Gemini Northern 8-Meter Telescope should be implemented as necessary to protect the environment, and minimize disturbance of neighboring facilities. These measures may include:

- Personnel at neighboring facilities should be notified in advance of major excavations, concrete pours and utility disturbance. Fugitive dust is anticipated to be the major nuisance factor for operating telescopes. Complete mitigation of this impact is unlikely; however, scheduling and notification of dust-generating events may minimize disturbances.
- Earthwork should be restricted during periods of high wind to minimize production of fugitive dust. (Also, refer to the Air Quality section, Section 3.2, regarding other mitigation measures to reduce construction-related air quality impacts.)
- Activities should be planned to avoid exposure of highly erodible slopes.

- Equipment engines should be maintained in proper mechanical condition and tuned for high altitude operation.
- Transportation of construction personnel could be staged from Hale Pohaku to reduce traffic congestion.

3.7 AESTHETICS

Setting

The project site is currently used for the UH 24-inch Telescope, which would be removed from the project site. The site is visible from a wide area around Mauna Kea. In addition to existing telescopes, the landscape consists of unvegetated slopes.

Impacts

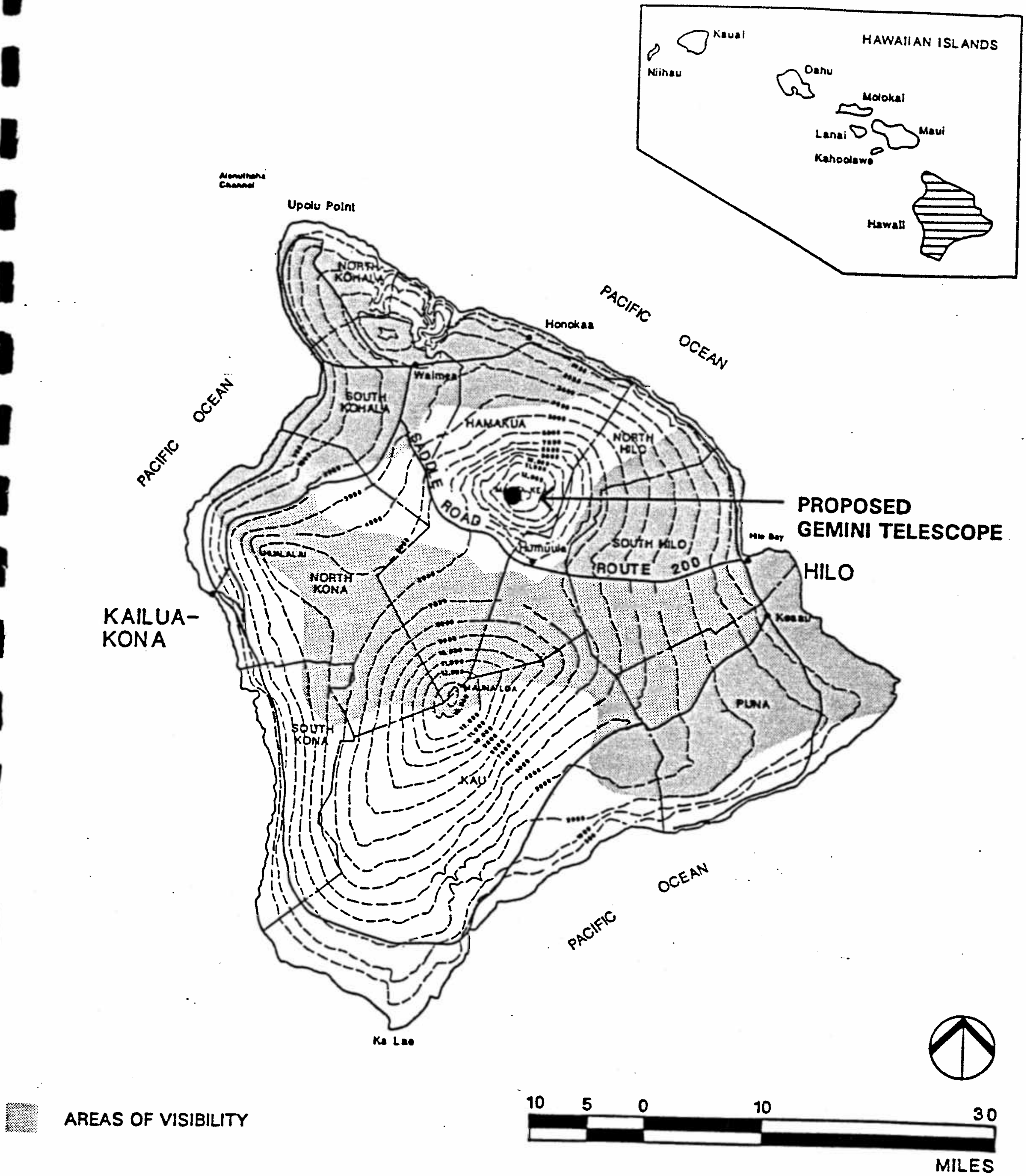
Construction equipment, construction materials and temporary structures would be present on the site during the construction period. The visual quality of the area would be affected during construction. However, the effects would be temporary, confined to the immediate summit area and would not be significant.

The Gemini Northern 8-meter Telescope is proposed to be located between the existing UH 88-inch and CFH telescopes (see Figures 2.2-5 and 2.2-6). It would replace an existing, smaller telescope. The proposed telescope dome enclosure would rise approximately 132 feet above the lower floor level. A geometric visibility analysis was undertaken to determine areas on the island of Hawaii where the Gemini telescope site could be seen. The analysis was based on the assumption that "if I can see you - then you can see me." The analysis, however, did not compensate for the curvature of the earth or the presence of vegetation which could obscure visibility from certain locations within certain areas. The results of the analysis of long-range visual impacts are shown in Figure 3.7-1. Due to the location of the telescope on the summit ridge, the Gemini Telescope would be visible from a wide area around Mauna Kea. Essentially, any location that has a view of the existing summit telescopes could also have a view of the project.

It should be emphasized that while the proposed Gemini telescope enclosure would be higher than the existing domes on the summit ridge, the distance from the viewer would make Gemini appear very small in relationship to the overwhelming mass of the mountain. In addition, since the project represents an expansion of an existing use, the existing relationships between the natural and man-made environments would be maintained.

Mitigation Measures

There are no viable measures that would completely mitigate the visual impact of the facility while still maintaining the operational integrity of the telescope. Visibility would be minimized by using a low emissivity coating called "Lo-Mit" to coat the rotating portion of the enclosure. This coating is an aluminum colored finish that tends to take on the color of the surrounding sky, so that the dome enclosure does not stand out.



VISUAL IMPACT

FIGURE 3.7-1

3.8 LAND USE/PLANNING CONSIDERATIONS

Setting

Mauna Kea is among the very finest astronomical sites in the world and astronomical development on Mauna Kea has been ongoing since the late 1960s. A number of planning documents have been prepared in order to guide astronomy development on Mauna Kea including:

1. The Research Development Plan for the Mauna Kea Science Reserve and Related Facilities (UH RDP), adopted by the University of Hawaii Board of Regents in 1982, serves as the programmatic master plan for the continued development of the Science Reserve and related astronomy facilities on Mauna Kea. This Plan projected that there would be 13 telescopes in the Mauna Kea summit area by the year 2000.
2. The Mauna Kea Science Reserve Complex Development Plan (SRCDP) was adopted by the UH Board of Regents in 1983. The Plan incorporates the policies and criteria set forth in the UH RDP and provides the physical planning framework necessary to implement the RDP. The SRCDP also presents a management plan for public use of the resources within the UH-controlled areas on the mountain. In 1985, the SRCDP was amended to include a construction camp at Hale Pohaku for a maximum of 140 workers at one time.
3. The Final Environmental Impact Statement for the Mauna Kea Science Reserve (SRCDP FEIS) was accepted by the Governor of the State of Hawaii in 1983.

Impacts

The Gemini Northern 8-Meter Telescope would be compatible with the land use and planning policies of the Mauna Kea Science Reserve planning documents. It would be one of the last telescopes envisioned in the SRCDP. It is located in Telescope Siting Area VI (Figure 3.8-1) that was assessed during the SRCDP FEIS process.

The proposed project involves the use of state land and the expenditure of federal funds. Because of this, it must be consistent with the policies and objectives of the State of Hawaii's Coastal Zone Management Program. A Coastal Zone Management Program Consistency Certification will be filed; it will be accompanied by this environmental assessment.

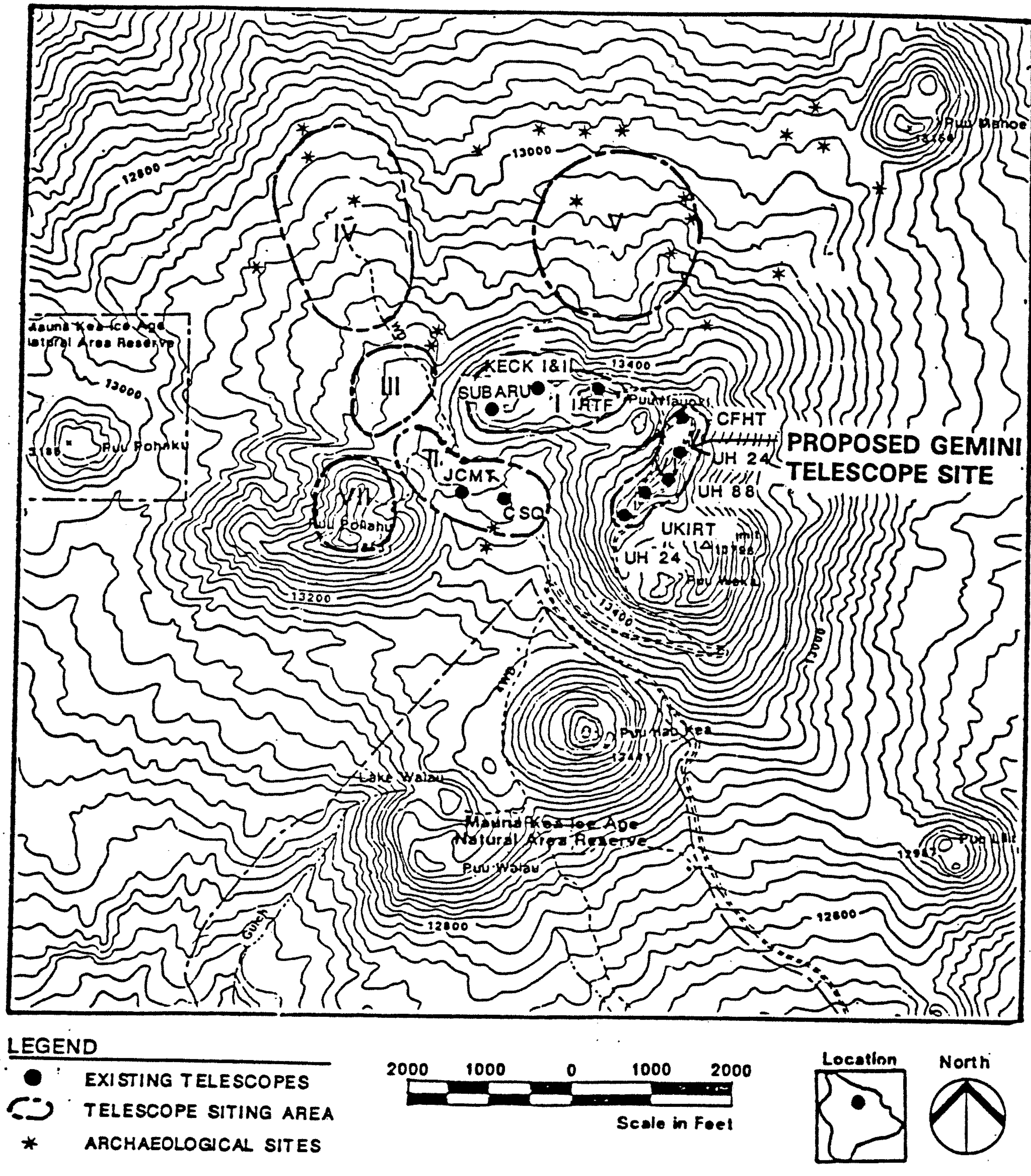
Mitigating Measures

None required.

3.9 HISTORIC/CULTURAL RESOURCES

Setting

The Mauna Kea Ice Age Natural Area Reserve is located between the 10,400-foot and 13,200-foot elevations on Mauna Kea (Figure 2.1-2), outside of the Mauna Kea Science Reserve. The main ice age features located in the Reserve are Pohakuloa Gulch (formed by glacial meltwater), glacial moraine and meltwater deposits of fine sediments, and the



SRCDP FEIS: TELESCOPE SITING AREAS

FIGURE 3.8-1

glacially-sculptured features of cinder cones and lava flows. Lake Waiau, one of the highest lakes in the United States, and the Keanakakoi Adze Quarry, an ancient Hawaiian Historic Place, are other features of the Reserve. The complex was placed on the National Register of Historic Places and designated a National Historic Landmark in 1962 (Site 50-10-23-4136). The quarry site is listed on the National Register of Historic Places (McCoy 1979).

Reconnaissance surveys of portions of the Science Reserve were conducted by Bishop Museum (McCoy 1982, McCoy 1984). The 40 sites located were collectively given the state site number 50-10-23 10228. No archaeological features were recorded within the present project area during these surveys. The sites within the telescope development area of the summit that were located in 1982 are shown on Figure 3.8-1.

An archaeological reconnaissance survey was conducted for the proposed Gemini Northern 8-Meter Telescope site in 1990 by Cultural Surveys Hawaii. The objective of the survey was to assess what impact, if any, further development of the summit ridge would have on archaeological resources. Findings of the 1990 survey indicate that the Gemini project area has been entirely graded, modified, and utilized for existing telescope facilities. The project area was the first area of the summit to be modified for telescope facilities with the construction of the UH 24-inch telescope in the mid to late 1960s (operational in 1968). Since then, major construction on this portion of the summit has included two 24-inch telescopes (1968 and 1969), the UH 88-inch (UH 2.2-m.) telescope (1970), the United Kingdom Infrared Telescope (1979), and the Canada-France-Hawaii Telescope (1979). One of the UH 24-inch telescopes is located on the proposed Gemini telescope site.

Impacts

No archaeological features were observed during the reconnaissance survey in areas specific to the proposed Gemini site or on the ridge that includes the existing telescopes.

Mitigation Measures

No further archaeological research is deemed necessary based on the lack of any features and the overall degree of constructed modification to this portion of the summit. Although no mitigation is required for the Gemini site, the University of Hawaii is working with the State Department of Land and Natural Resources (DLNR) Historic Preservation Division to implement an Historic Preservation Management Plan for the UH Management Area on Mauna Kea, in order to address potential cumulative impacts from overall development of the Science Reserve. The scope of work for this plan is currently being refined.

3.10 UTILITIES AND SERVICES

Setting

Potable water is trucked from Hilo to the Science Reserve in a 5,000-gallon water tanker. Each telescope has its own on-site water storage and distribution system and sewage disposal facility. Solid waste disposal is the responsibility of each telescope facility. Telescope personnel transport the waste from the summit to an appropriate disposal site near their base facilities.

Commercial electric power to the summit is provided by a 12.47-kV underground power and communications conduit that runs from a substation near Hale Pohaku to the summit area. The system is connected to the Hawaii Electric Light Company (HELCO) power grid. A fiber-optic cable for high-speed data transmission was installed in conduits running parallel to those for the power line. The cable runs from the summit telescopes to Hale Pohaku. Transmitters are no longer allowed at individual telescope sites.

Impacts

Cumulative impacts of telescope development on Mauna Kea to the year 2000 were assessed in the Final Environmental Impact Statement for the Mauna Kea Science Reserve Complex Development Plan (RCUH 1983b). Gemini would be the tenth major telescope identified in the Science Reserve Complex Development Plan (SRCDP).

Potable Water

The SRCDP predicted that water consumption at full development would be approximately 1,300 to 2,600 gallons per day. Water usage for the Gemini telescope would be less than 200 gallons per day; this would bring the total consumption for 10 major telescopes (including Gemini) and the antenna facility to 1,580 gallons per day, still well below the higher range of predicted consumption by the year 2000.

Water would be trucked from Hilo in conjunction with deliveries to other telescope facilities. It would be stored in a 6,000-gallon tank located on site (Figure 2.2-2). The current number of tanker trips (four times per week) should be adequate to service the Gemini facility. The additional amount of water needed to supply the Gemini facility would not affect the County of Hawaii water supply.

Sewerage

About 200 gallons per day of wastewater, consisting primarily of human washing and waste, would be disposed of by means of an on-site septic tank with leaching field (Figure 2.2-2). Wastewater treatment facilities must be approved by the State Department of Health.

Lake Waiau lies approximately 5,000 feet south of the site and at an elevation approximately 600 feet lower than the project site. The large distance separating the telescope site and Lake Waiau, combined with the low discharge rate of sewage effluent and the likely northerly flow direction, indicates that Lake Waiau would not be impacted. Also, surface drainage to the south from the site towards Lake Waiau is deflected westerly, so that should subsurface drainage follow the surface drainage pattern, it would bypass the lake (HLA 1991).

Electrical Power

Power usage is estimated at 2,000 kilowatt hours per day. As planned in the SRCDP (RCUH 1983a), there is sufficient capacity in the existing commercial electrical power system to accommodate the Gemini project.

A 100 kilovolt amps stand-by generator would be located on the site. It would be used during system-wide interruptions of HELCO power to close the dome and to keep sensitive instruments cold.

Communications

A fiber-optic cable for high-speed data transmission was installed in conduits running parallel to those for the power line. The cable runs from the summit telescopes to Hale Pohaku; this system would be extended to service the Gemini project as shown on Figure 2.2-7. Radio transmitters are no longer allowed at individual telescope sites.

Protective Services

There would be minimal impact on County of Hawaii protective services. Telescope personnel are responsible for both security and fire protection at their respective facilities. The closest medical facilities are located in Hilo, Waimea, and at the Pohakuloa Training Area. Because response time for these services is longer than one hour, observatory personnel render volunteer emergency service to both staff and visitors. Many observatory personnel are trained in advanced first aid and cardio-pulmonary resuscitation.

An emergency evacuation vehicle (EEV), equipped with a stretcher, first aid supplies and oxygen is based at the summit and is available in case of medical emergencies. A two-way radio in the EEV has direct communication with the County of Hawaii Fire & Rescue Service, the coordinating agency for medical emergencies. In case of an emergency, either an astronomer or a member of the support staff would drive the patient to Hale Pohaku; the Fire & Rescue Service would dispatch help to Hale Pohaku.

Mitigation

None required.

3.11 TRAFFIC

Setting

Access is via the Saddle Road (Route 200), to Pu`u Huluhulu and from there via a 6-mile-long, 20-foot-wide paved portion of the Mauna Kea Access Road to Hale Pohaku, at 9,200 feet above msl. From Hale Pohaku, the Mauna Kea Access Road continues 8.3 miles to the summit (Figure 2.1-1). It is a gravel road to approximately the 11,800-foot elevation and paved from this elevation to the summit. Traffic on this road is associated with telescope personnel as well as visitors.

Impacts

Construction of the Gemini telescope and appurtenant facilities would involve transferring about 300 truck loads of concrete mix from the batch plant site at the 12,700-foot elevation to the site. In addition, construction traffic would include heavy truck loads and flatbed trailer loads of dome segments and telescope components that would be trucked from the harbors at either Hilo or Kawaihae (Figure 2.1-1) for assembly on the Gemini site.

An increase in traffic would be unavoidable during construction. This traffic includes cement trucks, large construction equipment, trucks transporting construction materials and vehicles bringing workers to the site. Most heavy construction equipment would be stored on the site for the duration of the construction period. Some negative traffic impacts are unavoidable during construction of the project. These are normal for any large construction project and would diminish considerably after the first three years and terminate when telescope installation is complete. No adverse traffic effects are anticipated during telescope operations.

Mitigation Measures

In order to minimize negative construction-related effects, all trips of heavy trucks, such as those transporting dome and telescope components, should be scheduled during off-peak hours so as not to interfere with normal traffic flow in Hilo, Waimea or along the Saddle Road. Some roads may have to be closed for short periods of time when the 8-meter mirror is being transported to the summit. Such a closure would be coordinated with appropriate County of Hawaii agencies.

In order to minimize the number of vehicles going to the summit, the Gemini project would be connected via data communication lines with its base support facilities at Hilo. Day crews would transfer to one or two 4-wheel-drive vehicles at Hale Pohaku before proceeding to the summit. Visitor traffic would be subject to the controls adopted in the UH Management Plan (RCUH 1983a).

SECTION 4

ENVIRONMENTAL EVALUATION

ENVIRONMENTAL SIGNIFICANCE CHECKLIST

This checklist was used to identify physical, biological, social and economic factors which might be impacted by the proposed project. In many cases, the background studies performed in connection with this project clearly indicate the project will not affect a particular item. A "NO" answer in the first column documents this determination. Where there is a need for clarifying discussion, an asterisk is shown next to the answer. The discussion is in Section 3 of the Environmental Assessment.

Physical. Will the proposal either directly or indirectly:	Yes or No	If Yes, is it Significant? Yes or No
1. Appreciably change the topography or ground surface relief features?	No*	
2. Destroy, cover, or modify any unique geologic or physical features?	No	
3. Result in unstable earth surfaces or increase the exposure of people or property to geologic or seismic hazards?	No*	
4. Result in or be affected by soil erosion or siltation (whether by water or wind)?	Yes	No*
5. Result in the increased use of fuel or energy in large amounts or in a wasteful manner?	No	
6. Result in an increase in the rate of use of any natural resource?	No	
7. Result in the substantial depletion of any nonrenewable resource?	No	
8. Violate any published Federal, State, or local standards pertaining to hazardous waste, solid waste, or litter control?	No*	
9. Modify the channel of a river or stream or the bed of the ocean or any bay, inlet or lake?	No	

	Yes or No	If Yes, is it Significant? Yes or No
10. Encroach upon a floodplain or result in or be affected by floodwaters or tidal waves?	No	
11. Adversely affect the quantity or quality of surface water, groundwater, or public water supply?	No*	
12. Result in the use of water in large amounts or in a wasteful manner?	No	
13. Affect wetlands or riparian vegetation?	No	
14. Violate or be inconsistent with Federal, State, or local water quality standards?	No	
15. Result in changes in air movement, moisture, or temperature, or any climatic conditions?	No	
16. Result in an increase in air pollutant emissions, adverse effects on or deterioration of ambient air quality?	No*	
17. Result in the creation of objectionable odors?	No	
18. Violate or be inconsistent with Federal, State, or local air standards or control plans?	No	
19. Result in an increase in noise levels or vibration for adjoining areas?	No	
20. Result in any Federal, State, or local noise criteria being equal or exceeded?	No	
21. Produce new light, glare, or shadows?	No*	

Biological. Will the proposal result in (either directly or indirectly):

22. Change in the diversity of species or numbers of any species of plants (including trees, shrubs, grass, microflora, and aquatic plants)?	No*	
23. Reduction of the numbers of or encroachment upon the critical habitat of any unique, threatened or endangered species of plants?	No*	
24. Introduction of new species of plants into an area, or result in a barrier to the normal replenishment of existing species?	No	

	Yes or No	If Yes, is it Significant? Yes or No
25. Reduction in acreage of any agricultural crop or commercial timber stand, or affect prime, unique, or other farmland of State or local importance?	No	
26. Removal or deterioration of existing fish or wildlife habitat?	No*	
27. Change in the diversity of species, or numbers of any species of animals (birds, land animals including reptiles, fish and shellfish, benthic organisms, insects or microfauna)?	No*	
28. Reduction of the numbers of or encroachment upon the critical habitat of any unique, threatened or endangered species of animals?	No*	
29. Introduction of new species of animals into an area, or result in a barrier to the migration or movement of animals?	No	
Social and Economic. Will the proposal directly or indirectly:		
30. Cause disruption of orderly planned development?	No*	
31. Be inconsistent with any elements of adopted community plans, policies or goals?	No*	
32. Be inconsistent with a Coastal Zone Management Plan?	No*	
33. Affect the location, distribution, density, or growth rate of the human population of an area?	No	
34. Affect lifestyles or neighborhood character or stability?	No	
35. Affect minority, elderly, handicapped, transit-dependent, or other specific interest groups?	No	
36. Divide or disrupt an established community?	No	
37. Affect existing housing, require the acquisition of residential improvements or the displacement of people or create a demand for additional housing?	No	
38. Affect employment, industry or commerce, or require the displacement of businesses or farms?	No	
39. Affect property values or the local tax base?	No	

	Yes or No	If Yes, is it Significant? Yes or No
40. Affect any community facilities (including medical, educational, scientific, recreational, or religious institutions, ceremonial sites or sacred shrines)?	No	
41. Affect public utilities, or police, fire, emergency or other public services?	No*	
42. Have substantial impact on existing transportation systems or alter present patterns of circulation or movement of people and/or goods?	No*	
43. Generate additional traffic?	Yes	No*
44. Affect or be affected by existing parking facilities or result in demand for new parking?	No	
45. Involve a substantial risk of an explosion or the release of hazardous substances in the event of an accident or otherwise adversely affect overall public safety?	No	
46. Result in alterations to waterborne, rail or air traffic?	No	
47. Support large commercial or residential development?	No	
48. Affect a significant archaeologic or historic site, structure, object, or building?	No*	
49. Affect wild or scenic rivers or natural landmarks?	No	
50. Affect any scenic resources or result in the obstruction of any scenic vista or view open to the pubic, or creation of an aesthetically offensive site open to public view?	No*	
51. Result in substantial impacts associated with construction activities (e.g., noise, dust, temporary drainage, traffic detours and temporary access, etc.)?	No*	
52. Result in the use of any public-owned land from a park, recreation area, or wildlife and waterfowl refuge?	No	

Mandatory Findings of Significance.

	Yes or No
53. Does the project have the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of Hawaiian history or prehistory?	No
54. Does the project have the potential to achieve short-term, to the disadvantage of long-term, environmental goals? (A short-term impact on the environment is one which occurs in a relatively brief, definitive period of time while long-term impacts will endure well into the future.)	No
55. Does the project have environmental effects which are individually limited, but cumulatively considerable? (Cumulatively considerable means that the incremental effects of an individual project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probably future projects. It includes the effects of other projects which interact with this project and, together, are considerable.)	No
56. Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?	No

SECTION 5

LIST OF PREPARERS

The following personnel prepared technical reports or major sections of the document:

Thomas Peters, Technical Director, Engineering-Science, Inc. Reviewed document for NEPA Compliance. Eighteen years experience in air quality analysis. M.S., San Jose State.

Robin Cort, Ph.D., Project Manager, Engineering-Science, Inc. Prepared biotics section and oversaw preparation of entire document. Fifteen years of experience in environmental documentation. Ph.D., State University of New York at Stoney Brook.

Claire Chapin, Ph.D., Engineering-Science, Inc. Prepared air quality analysis. Over 25 years of experience in air quality analysis. Ph.D., Purdue University.

Amy Skewes-Cox, Planner, Engineering-Science, Inc. Coordinated preparation of document. Thirteen years of environmental analysis experience. MLA, University of California at Berkeley.

Marilynn Metz, Planner, MCM Planning. Prepared land use, public utilities/services, construction transportation, aesthetics and historic/cultural resources analyses. Sixteen years of experience. Masters in Urban and Regional Planning, University of Hawaii.

David Robichaux, Project Engineer, Harding Lawson Associates. Prepared geology/seismicity, groundwater resources, and surface drainage/erosion sections of document. Fifteen years of experience. MS, University of Maryland and University of Hawaii.

SECTION 6

ENVIRONMENTAL DETERMINATION

On the basis of this environmental assessment, it is determined that the appropriate document for the proposal is a Finding of No Significant Impact. With the mitigation measures described in the environmental assessment, the proposed action is not a major Federal action significantly affecting the quality of the human environment.

H M Van Horn — 1/5/94

Hugh M. Van Horn, Director
Division of Astronomical Sciences

Date

SECTION 7

REFERENCES

Bay Area Air Quality Management District (BAAQMD) 1985, Air Quality and Urban Development Guidelines for Assessing Impacts of Projects and Plans.

Cox, D.C., and J. Morgan 1977, Local Tsunamis and Possible Local Tsunamis in Hawaii. HIG7714, Hawaii Institute of Geophysics, University of Hawaii

Cudaback, D. 1993, Professor of Astronomy, University of California, Berkeley California, personnel communication with Claire Chapin, Engineering Science, Inc. 26 October

Dames & Moore, Inc. 1982, Geotechnical Evaluation of Telescope Siting Areas. Mauna Kea Science Research, July

Department of Land and Natural Resources (DLNR) 1968, DLNR/UH Lease No. S-4191 dated 21 June 1968. Honolulu, Hawaii

Environmental Protection Agency (EPA) 1985, Compilation of Air Pollutant Emission Factors; Volume 1: Stationary and Area Sources, 4th Edition.

Hammatt & Borthwick 1988, Archaeological Reconnaissance of Two Proposed Antenna Sites, Mauna Kea, Hawaii.

Harding Lawson Associates 1975, Foundation Investigations for the UH Telescope Facility, Mauna Kea, Hawaii.

Harding Lawson Associates (HLA) 1991, Geotechnical Consultation of Proposed Japanese National Large Telescope, Mauna Kea, Island of Hawaii, Hawaii.

__________ 1982, Soils Report of the UK/NL MT Site.

__________ 1990, Geotechnical Investigation for the JNLT Site. Mauna Kea, Hawaii

Howarth, F. G. and Stone, F. D. 1982, An Assessment of the Arthropod Fauna and Aeolian Ecosystem Near the Summit of Mauna Kea, Hawaii. November

Macdonald, G. A. 1972, Volcanoes, Englewood Cliffs, New Jersey, Prentice-Hall.

McCoy, Patrick C. 1979, The Mauna Kea Adze Quarry Complex Hawaii: A First Analysis.

McCoy, Patrick C. 1982, Cultural Resource Reconnaissance of the Mauna Kea Summit Regional: Archaeological Reconnaissance Survey. B.P. Bishop Museum, Department of Anthropology, Honolulu, Hawaii

McCoy, Patrick C. 1984, Mauna Kea Summit Region Survey: A Summary of the 1984 Fieldwork. Bishop Museum Manuscript on File at the State Historic Preservation Office, Honolulu

McCoy, Patrick 1985, Preliminary Archaeological Survey of the Pu'u Kalepeamoa Site, Mauna Kea. Bishop Museum MS 080285

Mullineaux, D.R., D.W. Peterson, and D.R. Crandell 1987, Volcanic Hazards in the Hawaiian Islands. U.S. Geological Survey. Professional Paper 1350, pp. 599-621

Owen, S. 1993, Air Quality Engineer, Bay Area Air Quality Management District (BAAQMD), personal communication with Claire Chapin, Engineering-Science, Inc. October 27

Porter, S.C. 1973, Stratigraphy and Chronology of Late Quaternary Tephra Along the South Rift Zone of Mauna Kea Volcano, Hawaii. Geological Society of American Bulletin, v. 84, pp. 1923-1940

Rojahn, C., and B. Morrill 1977, The Island of Hawaii Earthquakes of November 29, 1995: Strong-motion Data and Damage Reconnaissance Report. Seismological Society of America Bulletin, v. 67, pp. 493-515

Research Corporation of the University of Hawaii (RCUH) 1983a, The Mauna Kea Science Reserve Complex Development Plan. Prepared by Group 70, Inc., Honolulu, Hawaii

Research Corporation of the University of Hawaii (RCUH) 1983b, Final Environmental Impact Statement for the Mauna Kea Science Reserve Complex Development Plan. Prepared by Group 70, Inc., Honolulu, Hawaii

Smith, C. W., Hoe, W. J., and O'Connor, P. J. 1982, Botanical Survey of the Mauna Kea Summit Above 13,00 Feet. October

Swanson, D.A., and R.L. Christiansen 1973, A Tragic Base Surge in 1790 at Kilauea Volcano: Geology, v. 1, no. 2, pp. 83-86.

Tilling, R.I., R.Y. Koyanagi, P.W. Lipman, J.P. Lockwood, J.G. Moore, and D.A. Swanson 1976, Earthquakes and Related Catastrophic Events, Island of Hawaii, November 29, 1975 - a Preliminary Report. U.S. Geological Survey Circular 740, 33.

University of Hawaii 1993, Conservation District Use Application, Prefinal #3/Gemini Draft #2.

University of Hawaii, Institute for Astronomy (UH IfA) 1982, Research Development Plan. Honolulu, Hawaii

Wood, H.O. 1914, On the Earthquakes of 1868 in Hawaii. Seismological Society of America Bulletin, v. 4, no. 4, pp. 169-203

Wyss, M. 1988, A Proposed Source Model for the Great Kau, Hawaii Earthquake of 1868. Bulletin of the Seismological Society of America, v. 78, no. 4, pp. 1450-1462

Wyss, M., and Koyanagi 1992, Seismic Gaps in Hawaii. Bulletin of the Seismological Society of America, v. 82, no. 3, pp. 1373-1387

APPENDIX A

PROCEDURES FOR MIRROR STRIPPING/CLEANING

TENTATIVE AMOUNTS FOR STRIP/CLEAN OF GEMINI MIRROR

Extrapolated from info from Don Kucera, NOAO Coating Engineer. Process listed is for aluminum and silver, with appended info for removing chromium underlayer for silver. Process will only remove said layers; appropriate additional chemicals will be required depending on protected overcoat.

Chemical "A":	13.6 kilos Hydrochloric Acid, (37%) reagent grade. 1.13 kilos of Cupric Sulfate, reagent grade. Place in appropriate container and add distilled water to make 50 liters. Agitate until dissolved.
Chemical "B":	.946 liters of Potassium Hydroxide, reagent grade. Place in appropriate container, and add distilled water to make 20 liters. Agitate until dissolved.
Chemical "C":	2.72 kilos of nitric acid, (70%) reagent grade. Place in appropriate container and add distilled water to make 10 liters.
Chemical "D":	For removing chromium underlayer. To 6 liters of distilled water, add 1.65 kilos of ceric ammonium nitrate, reagent grade, and 900 milliliters of nitric acid (70%). Mix, and add enough distilled water to make 10 liters.
Chemical "E":	Calcium carbonate, reagent grade. Enough for neutralizing several times over.
Chemical "F":	Distilled water.
Other chemicals:	Assorted solvents such as methanol, propanol, and acetone

Procedure: USE APPROPRIATE SAFETY GEAR FOR THIS! Standard procedure is to thoroughly rinse mirror with "D" before starting.

1. Use A and rub with Texwipe (or appropriate material)
2. Rinse well with D.
3. Repeat steps 1 and 2 until old coating is completely removed.
4. (Chromium removal) Use E and rub with Texwipe.
5. Rinse well with D.
6. Use B and E, rub with Texwipe.
7. Rinse well with D.
8. Repeat steps 6 and 7 three to four times.
9. Rinse mirror with C.
10. Rinse with D for 5-10 minutes (appropriate to area)
11. Dry thoroughly with Texwipes.
12. use filtered gaseous nitrogen to blow off lint, dust, etc. from mirror.
13. Inspect surface for soils, using appropriate equipment (high intensity light, magnifying glass, etc.)
14. Use solvents as necessary to remove fingerprints, smudges, etc.
15. If soil not removed, go back to Step 5 and repeat the process.